

EXPANSIVE AND COLLAPSING BEHAVIOUR OF VOLUME CHANGE SOILS

VOLUME TWO

A Thesis presented to the
DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF CAPE TOWN

In partial* fulfilment of the requirements for
the degree of Master of Science in Engineering

by

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* This candidate has successfully completed five postgraduate courses (30 credit points) in partial fulfilment of the requirements for the M.Sc.Eng. degree, and therefore this thesis should be less than one half of the value of an M.Sc. thesis submitted in complete fulfilment of the requirements for the degree. For details of courses taken, see page 1 in Appendix I.

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PREFACE

It was decided to include the test data used in this thesis as a separate volume.

This Volume Two includes the test procedures and results, in tabular and illustrative form, for the eight appendices.

The following are the appendices:

Appendix A: Soil sampling, indicator and classification test procedures and results.

Appendix B: Scanning electron microscopy and x-ray diffraction.

Appendix C: Free shrinkage and free swell.

Appendix D: Consolidometer and triaxial.

Appendix E: Consolidometer tests for expansive and collapsing soils.

Appendix F: Swell pressure tests for expansive soils.

Appendix G: Consolidometer tests with lateral pressure measurements.

Appendix H: Triaxial tests for expansive and collapsing soils.

EXPANSIVE AND COLLAPSING BEHAVIOUR OF VOLUME CHANGE SOILS

VOLUME TWO

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EXPERIMENTAL RESULTS USED FOR PUBLICATION

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POSTSCRIPT

The manuscript of this thesis was prepared in electronic form.

Text and graphics were processed and formatted using the following computer programs:

1. Microsoft Word (version 5.0) - word processing;
2. Microsoft Chart (ver. 3.0) - chart program;
3. Statgraphics (ver. 2.1) - statistical graphical system;
4. Perspective (ver. 1.2) - business & scientific graphics;
5. Pizazz Plus - screen capture and print facility;
6. Lotus 123 (ver. 2.01) - spreadsheet and graphics.

The operating system used was MS Dos 3.21.

The hardware consisted of the following: PC-XT IBM compatible, with 640 Kb Ram; Intel's 8088 processor, and 8087 numerical co-processor; 30 Mb hard disk.

FIGURES

APPENDIX A

Number Title

- A.01: Relative Specific Density of the Mercury Used
G_s·H_g: Varies between 13.63 at 16°C (used for the
'colder' months in Cape Town - May to October) and
13.62 at 20°C (used for the 'warmer' months of
November to April).
- A.02: Temperature Calibration of Hydrometer - (1)
distilled water without dispersing agents.
- A.03: Temperature Calibration of Hydrometer - (2)
distilled water plus 10 cc of each sodium silicate
and sodium oxalate.
- A.04: Temperature Calibration of Hydrometer - (3)
distilled water plus 20 cc of each sodium silicate
and sodium oxalate.
- A.05: Temperature Calibration of Hydrometer - (4)
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- A.06: Site, 11 Rosebank - [Liquid Limit] Number of Blows
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- A.45: Particle size distribution - Bentonite B.1 (3.5%), B.2 (7%), B.3 (11.5%), B.4 (15.5%), and B.5 (35%).
- A.46: Site 11, Rosebank - plot of water content versus dry (and wet) density, and curves for degree of saturation.

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- A.47: Site 36, Rondebosch - plot of water content versus dry (and wet) density, and curves for degree of saturation.
- A.48: Site 30, Hout Bay - plot of water content versus dry (and wet) density, and curves for degree of saturation.
- A.49: Site A, Berea Road - plot of water content versus dry (and wet) density, and curves for degree of saturation.
- A.46: Site 7, Mowbray - plot of water content versus dry (and wet) density, and curves for degree of saturation.

APPENDIX B

- B.01: Site 11, trace 1.A - 3° 30° 20 Mg-saturated (speed of 2° 20/minute).
- B.02: (i) Site 11, trace 1.B - 24° $25\frac{1}{2}^{\circ}$ 20 Mg-saturated ($\frac{1}{4}^{\circ}$ 20/min.); (ii) Site 11, trace 1.C - 3° 13° 20 Mg-saturated, Ethylene glycolated (2° 20/min.).
- B.03: Site 11, trace 8.D - 3° 30° 20 Mg-saturated (previously heated to 550°C for 1 hr, following which it was allowed to cool and then placed in a desiccator until testing).
- B.04: (i) Site 11, trace 15.E - 3° 30° 20 Mg-saturated, previously heated to 105°C overnight, allowed to cool and placed in desiccator until testing; (ii) Site 11, trace 15.C - 3° 13° 20 Mg-saturated, ethylene glycolated.
- B.05: Site 36, trace 2.A - 3° 30° 20 Mg-saturated at 2° 20/min.
- B.06: (i) Site 36, trace 2.B - 24° $25\frac{1}{2}^{\circ}$ 20 Mg-saturated ($\frac{1}{4}^{\circ}$ 20/min.); (ii) Site 36, trace 2.C - 3° 13° 20 Mg-saturated, Ethylene glycolated (2° 20/min.).
- B.07: Site 36, trace 9.D - 3° 30° 20 Mg-saturated (previously heated to 550°C for 1 hr, following which it was allowed to cool and then placed in a desiccator until testing).
- B.08: (i) Site 36, trace 16.E - 3° 30° 20 Mg-saturated, previously heated to 105°C overnight, allowed to cool and placed in desiccator until testing; (ii) Site 36, trace 16.C - 3° 13° 20 Mg-saturated, ethylene glycolated.
- B.09: Site 30, trace 3.A - 3° 30° 20 Mg-saturated at 2° 20/min.
- B.10: (i) Site 30, trace 3.B - 24° $25\frac{1}{2}^{\circ}$ 20 Mg-saturated ($\frac{1}{4}^{\circ}$ 20/min.); (ii) Site 30, trace 3.C - 3° 13° 20 Mg-saturated, Ethylene glycolated (2° 20/min.).

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- B.11: Site 30, trace 10.D - 3° 30° 2θ Mg-saturated (previously heated to 550°C for 1 hr, following which it was allowed to cool and then placed in a desiccator until testing).
- B.12: (i) Site 30, trace 17.E - 3° 30° 2θ Mg-saturated, previously heated to 105°C overnight, allowed to cool and placed in desiccator until testing; (ii) Site 30, trace 17.C - 3° 13° 2θ Mg-saturated, ethylene glycolated.
- B.13: Site A, trace 4.A - 3° 30° 2θ Mg-saturated at 2° 2θ/min.
- B.14: (i) Site A, trace 4.B - 24° 27° 2θ Mg-saturated (½° 2θ/min.); (ii) Site A, trace 4.C - 3° 13° 2θ Mg-saturated, Ethylene glycolated (2° 2θ/min.).
- B.15: Site A, trace 11.D - 3° 30° 2θ Mg-saturated (previously heated to 550°C for 1 hr, following which it was allowed to cool and then placed in a desiccator until testing).
- B.16: (i) Site A, trace 18.E - 3° 30° 2θ Mg-saturated, previously heated to 105°C overnight, allowed to cool and placed in desiccator until testing; (ii) Site A, trace 18.C - 3° 13° 2θ Mg-saturated, ethylene glycolated.
- B.17: Site 7, trace 5.A - 3° 30° 2θ Mg-saturated at 2° 2θ/min.
- B.18: (i) Site 7, trace 5.B - 24° 25½° 2θ Mg-saturated (½° 2θ/min.); (ii) Site 7, trace 5.C - 3° 13° 2θ Mg-saturated, Ethylene glycolated (2° 2θ/min.).
- B.19: Site 7, trace 12.D - 3° 13° 2θ Mg-saturated (previously heated to 550°C for 1 hr, following which it was allowed to cool and then placed in a desiccator until testing).
- B.20: (i) Site 7, trace 19.E - 3° 30° 2θ Mg-saturated, previously heated to 105°C overnight, allowed to cool and placed in desiccator until testing; (ii) Site 7, trace 19.C - 3° 13° 2θ Mg-saturated, Ethylene glycolated.
- B.21: Kaolin 'K', trace 6.A - 3° 30° 2θ Mg-saturated at 2° 2θ/min.
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- B.23: Kaolin 'K', trace 13.D - 3° 30° 2θ Mg-saturated (previously heated to 550°C for 1 hr, following which it was allowed to cool and then placed in a desiccator until testing).
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- B.25: Bentonite 'B', trace 7.A - 3° 30° 20 Mg-saturated at 2° 20/min.
- B.26: (i) Bentonite 'B', trace 7.B - 24° 25½° 20 Mg-saturated (½° 20/min.); (ii) Bentonite 'B', trace 7.C - 3° 13° 20 Mg-saturated, Ethylene glycolated (2° 20/min.).
- B.27: Bentonite 'B', trace 14.D - 3° 30° 20 Mg-saturated (previously heated to 550°C for 1 hr, following which it was allowed to cool and then placed in a desiccator until testing).
- B.28: (i) Bentonite 'B', trace 21.E - 3° 30° 20 Mg-saturated, previously heated to 105°C overnight, allowed to cool and placed in desiccator until testing; (ii) Bentonite 'B', trace 21.C - 3° 13° 20 Mg-saturated, Ethylene glycolated.

APPENDIX C

- C.01: Site 11, Rosebank [Remoulded, M≥LL] - Void Ratio 'e' versus Water Ratio 'wr'.
- C.02: Site 11, Rosebank [Remoulded, M<LL] - Void Ratio 'e' versus Water Ratio 'wr'.
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- C.16: Site 7, Mowbray [Undisturbed] - Void Ratio 'e' versus Water Ratio 'wr'.
- C.17: Site B, Francois Road [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.
- C.18: Site C, Margaret Mayton Avenue [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.
- C.19: Site D, Rose Hill [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.
- C.20: Kaolin, K.1 - Void Ratio 'e' versus Water Ratio 'wr'.
- C.21: Kaolin, K.2 - Void Ratio 'e' versus Water Ratio 'wr'.
- C.22: Kaolin, K.3 - Void Ratio 'e' versus Water Ratio 'wr'.
- C.23: Bentonite, B.1 [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.
- C.24: Bentonite, B.2 [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.
- C.25: Bentonite, B.3 [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.
- C.26: Bentonite, B.4 [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.
- C.27: Bentonite, B.5 [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.

APPENDIX D

- D.01: One-dimensional consolidation test - Calibration of equipment.
- D.02: Triaxial test - the de-airing system installed.
- D.03: Triaxial test - volume change indicator of the twin burette type with change over valves.
- D.04: Triaxial test - components assembled and ready for starting the test (refer to section 6).
- D.05: Triaxial test - Calibration of equipment - (ie. For use for Volume Change Device).
- D.06: Remoulded Natural Soils [Consolidometer tests] - Plot of Vertical Pressure 'peV' versus Void Ratio 'e'. [For results for undisturbed samples see Figures 5.12(i), 5.13 and Figure 5.14].
- D.07: Remoulded Natural Soils [Triaxial tests] - Plot of All Round Pressure 'peAR' versus Void Ratio 'e'. [For plot for undisturbed sample S11-T5 See Figure 5.12(ii)].
- D.08: Saturated Artificial Soils [Consolidometer tests] - Plot of Vertical Pressure 'peV' Void Ratio 'e'.
- D.09: Saturated Artificial Soils [Triaxial Tests] - Plot of All Round Pressure 'peAR' versus Void Ratio 'e'.

APPENDIX E

Number Title

- E.01: Consolidometer test for expansive and collapsing soil [1 Kpa] - Calibration of equipment.
- E.02: Consolidometer test for expansive and collapsing soil [50 Kpa] - Calibration of equipment.
- E.03: Consolidometer test for expansive and collapsing soil [100 Kpa] - Calibration of equipment.
- E.04: Consolidometer test for expansive and collapsing soil [400 Kpa] - Calibration of equipment.
- E.05: Site 11, Rosebank [Remoulded samples - 1 Kpa overnight vertical pressure and then water added at 1 Kpa without prop] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.06: Site 11, Rosebank [Remoulded samples - 1 Kpa overnight vertical pressure, and then water added at 1 Kpa without prop] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.07: Site 11, Rosebank [Remoulded samples - 50 Kpa overnight vertical pressure and then water added at 50 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.08: Site 11, Rosebank [Remoulded samples - 50 Kpa overnight vertical pressure and then water added at 50 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.09: Site 11, Rosebank [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.10: Site 11, Rosebank [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.11: Site 11, Rosebank [Remoulded samples - 400 Kpa overnight vertical pressure and then wetted at 400 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.12: Site 11, Rosebank [Remoulded samples - 400 Kpa overnight vertical pressure and then wetted at 400 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.13: Site 11, Rosebank [Compacted samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.14: Site 11, Rosebank [Compacted samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

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- E.15: Site 11, Rosebank [Undisturbed samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.16: Site 11, Rosebank [Undisturbed samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.17: Site 36, Rondebosch [Remoulded sample - 1 Kpa overnight vertical pressure and then wetted at 1 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.18: Site 36, Rondebosch [Remoulded sample - 1 Kpa overnight vertical pressure and then wetted at 1 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.19: Site 36, Rondebosch [Remoulded sample - 50 Kpa overnight vertical pressure and then wetted at 50 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.20: Site 36, Rondebosch [Remoulded sample - 50 Kpa overnight vertical pressure and then wetted at 50 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.21: Site 36, Rondebosch [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.22: Site 36, Rondebosch [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.23: Site 36, Rondebosch [Remoulded sample - 400 Kpa overnight vertical pressure and then wetted at 400 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.24: Site 36, Rondebosch [Remoulded sample - 400 Kpa overnight vertical pressure and then wetted at 400 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.25: Site 36, Rondebosch [Compacted sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.26: Site 36, Rondebosch [Compacted sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

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- E.27: Site 36, Rondebosch [Undisturbed sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.28: Site 36, Rondebosch [Undisturbed sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.29: Site 30, Hout Bay [Remoulded sample - 1 Kpa overnight vertical pressure and then wetted at 1 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.30: Site 30, Hout Bay [Remoulded sample - 1 Kpa overnight vertical pressure and then wetted at 1 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.31: Site 30, Hout Bay [Remoulded sample - 50 Kpa overnight vertical pressure and then wetted at 50 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.32: Site 30, Hout Bay [Remoulded sample - 50 Kpa overnight vertical pressure and then wetted at 50 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.33: Site 30, Hout Bay [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.34: Site 30, Hout Bay [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.35: Site 30, Hout Bay [Undisturbed sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.36: Site 30, Hout Bay [Undisturbed sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.37: Site A, Berea Road [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

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- E.38: Site A, Berea Road [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.39: Site A, Berea Road [Compacted samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.40: Site A, Berea Road [Compacted samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.41: Site A, Berea Road [Undisturbed samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.42: Site A, Berea Road [Undisturbed samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.43: Site 7, Mowbray [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.44: Site 7, Mowbray [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.45: Site 7, Mowbray [Compacted sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.46: Site 7, Mowbray [Compacted sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.47: Site 7, Mowbray [Undisturbed samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.48: Site 7, Mowbray [Undisturbed samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.49: Site B, Francois Road [Remoulded sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

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- E.50: Site B, Francois Road [Remoulded sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.51: Site C, Margaret Mayton Avenue [Remoulded sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.52: Site C, Margaret Mayton Avenue [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.53: Site D, Rose Hill [Remoulded sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.54: Site D, Rose Hill [Remoulded sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.55: Site 48, Lady Grey [Undisturbed sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.56: Site 48, Lady Grey [Undisturbed sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'. (Using Rubber membrane method - Ballantyne and Sparks 1978).
- E.57: Kaolin K.1 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.58: Kaolin K.1 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.59: Kaolin K.2 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.60: Kaolin K.2 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.61: Kaolin K.3 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

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- E.62: Kaolin K.3 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.63: Bentonite B.1 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.64: Bentonite B.1 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.65: Bentonite B.2 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.66: Bentonite B.2 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.67: Bentonite B.3 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.68: Bentonite B.3 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.69: Bentonite B.4 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.70: Bentonite B.4 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- E.71: Bentonite B.5 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- E.72: Bentonite B.5 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

APPENDIX F

Number Title

- F.01: Site 11, Rosebank [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path. Swelling at "constant void ratio" from "zero loading".
- F.02: Site 11, Rosebank [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).
- F.03: Site 11, Rosebank [Compacted Samples] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- F.04: Site 11, Rosebank [Compacted Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).
- F.05: Site 11, Rosebank [Undisturbed Samples] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- F.06: Site 11, Rosebank [Undisturbed Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).
- F.07: Site 36, Rondebosch [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- F.08: Site 36, Rondebosch [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).
- F.09: Site 36, Rondebosch [Compacted Sample] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path. (No air drying between compaction and start of wetting).
- F.10: Site 36, Rondebosch [Compacted Sample] - Void ratio 'e' versus Water ratio 'wr', for the controlled wetting path (includes swell pressures). (No air drying between compaction and wetting).
- F.11: Site 36, Rondebosch [Undisturbed Samples] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- F.12: Site 36, Rondebosch [Undisturbed Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).
- F.13: Site 30, Hout Bay [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- F.14: Site 30, Hout Bay [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).
- F.15: Site 30, Hout Bay [Undisturbed Sample] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- F.16: Site 30, Hout Bay [Undisturbed Sample] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).

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- F.17: Site A, Berea Road [Compacted Sample] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- F.18: Site A, Berea Road [Compacted Sample] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).
- F.19: Site 7, Mowbray [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- F.20: Site 7, Mowbray [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).
- F.21: Site 7, Mowbray [Undisturbed Sample] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.
- F.22: Site 7, Mowbray [Undisturbed Sample] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).

APPENDIX G

- G.01: Consolidometer tests with horizontal strain measurements - Calibration of equipment.
- G.02: Consolidometer tests with horizontal strain measurements - Correlation between strain measurement and pressure applied.
- G.03: Consolidometer tests with horizontal pressure measurements - Calibration of equipment.
- G.04: Site 11, Rosebank [Remoulded sample - one-dimensional consolidation] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- G.05: Site 11, Rosebank [Remoulded sample] - one-dimensional consolidation] - Void Ratio 'e' versus Effective Horizontal Pressure, or stress, 'peH'.
- G.06: Site 11, Rosebank [Remoulded sample - overnight vertical pressure of 50 Kpa, then wetted at 50 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.
- G.07: Site 11, Rosebank [Remoulded sample - overnight vertical pressure of 50 Kpa then wetted at 50 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- G.08: Site 11, Rosebank [Remoulded sample - overnight vertical pressure of 50 Kpa then wetted at 50 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.
- G.09: Site 11, Rosebank [Remoulded samples - overnight vertical pressure of 100 Kpa then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

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- G.10: Site 11, Rosebank [Remoulded samples - overnight vertical pressure of 100 Kpa then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- G.11: Site 11, Rosebank [Remoulded samples - overnight vertical pressure of 100 Kpa then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.
- G.12: Site 11, Rosebank [Compacted sample - overnight vertical pressure of 100 Kpa then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.
- G.13: Site 11, Rosebank [Compacted sample - overnight vertical pressure of 100 Kpa then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- G.14: Site 11, Rosebank [Compacted sample - overnight vertical pressure of 100 Kpa then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or stress, 'peH'.
- G.15: Site 11, Rosebank [Remoulded sample - wetted at vertical pressure of 400 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.
- G.16: Site 11, Rosebank [Remoulded sample - wetted at vertical pressure of 400 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or stress, 'peV'.
- G.17: Site 11, Rosebank [Remoulded sample - wetted at vertical pressure of 400 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.
- G.18: Site 11, Rosebank [Remoulded sample - swell pressure] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.
- G.19: Site 11, Rosebank [Remoulded sample - swell pressure] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- G.20: Site 11, Rosebank [Remoulded sample - swell pressure] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.
- G.21: Site 11, Rosebank [Compacted sample - swell pressure] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

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- G.22: Site 11, Rosebank [Compacted sample - swell pressure] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- G.23: Site 11, Rosebank [Compacted sample - swell pressure] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.
- G.24: Site 36, Rondebosch [Remoulded samples - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.
- G.25: Site 36, Rondebosch [Remoulded samples - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- G.26: Site 36, Rondebosch [Remoulded samples - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.
- G.27: Site A, Berea Road [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.
- G.28: Site A, Berea Road [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- G.29: Site A, Berea Road [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.
- G.30: Site 7, Mowbray [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.
- G.31: Site 7, Mowbray [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.
- G.32: Site 7, Mowbray [Undisturbed sample - wetted at vertical pressure of 50 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.
- G.33: Site 48, Lady Grey [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.
- G.34: Site 48, Lady Grey [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or stress, 'peV'.
- G.35: Site 48, Lady Grey [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.

APPENDIX H

Number Title

- H.01: Site 11, Rosebank - [Undisturbed sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and the Water Ratio 'wr'.
- H.02: Site 11, Rosebank - [Undisturbed sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and the Effective All Round Pressure 'peAr'.
- H.03: Site 11, Rosebank - [Compacted sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and the Water Ratio 'wr'.
- H.04: Site 11, Rosebank - [Compacted sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and the Effective All Round Pressure 'peAr'.
- H.05: Site A, Berea Road - [Undisturbed sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and the Water Ratio 'wr'.
- H.06: Site A, Berea Road - [Undisturbed sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and the Effective All Round Pressure 'peAr'.
- H.07: Site A, Berea Road - [Compacted sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and the Water Ratio 'wr'.
- H.08: Site A, Berea Road - [Compacted sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and the Effective All Round Pressure 'peAr'.

TABLES

APPENDIX A

Number Title

- A.01: Results used to determine the Specific Gravity of Mercury 'G_sHg'.
- A.02: Values of K for Use in Equation for Computing Diameter of Particle In Hydrometer Analysis.
- A.03: Values of effective depth 'L', based on the hydrometer and sedimentation cylinder of the specified size for Hydrometer 151.H.
- A.04: Relative density of water and conversion factor 'K' for various temperatures.
- A.05: Site 11, Rosebank - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-I.80; 2-I.36; 3-II.209).
- A.06: Site 36, Rondebosch - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.205; 2-II.209; 3-III.222; 4-A.49).
- A.07: Site 30, Hout Bay - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.205; 2-A.60; 3-A.49).
- A.08: Site A, Berea Road - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-I.119; 2-II.209; 3-II.222; 4-A.50).
- A.09: Site 7, Mowbray - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.209; 2-II.222; 3-I.105; 4-I.74).
- A.10: Site B, Francois Road - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-I.119; 2-II.121).
- A.11: Site C, Margaret Mayton Avenue - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-I.138; 2-II.97).
- A.12: Site D, Rose Hill - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-I.138; 2-II.145).

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- A.13: Kaolin K.1 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.209; 2-II.210).
- A.14: Kaolin K.2 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.209; 2-II.210).
- A.15: Kaolin K.3 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.210(LHS); 2-II.210(RHS)).
- A.16: Bentonite B.1 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.232(LHS); 2-II.232(RHS); 3-A.56).
- A.17: Bentonite B.2 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.232(LHS); 2-II.232(RHS); 3-A.56).
- A.18: Bentonite B.3 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.232; 2-II.233; 3-A.56).
- A.19: Bentonite B.4 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.232; 2-II.233).
- A.20: Bentonite B.5 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: NSI 6-6-79).
- A.21: Site 11, Rosebank - Shrinkage Limit test results.
- A.22: Site 36, Rondebosch - Shrinkage Limit test results.
- A.23: Site 30, Hout Bay - Shrinkage Limit test results.
- A.24: Site A, Berea Road - Shrinkage Limit test results.
- A.25: Site 7, Mowbray - Shrinkage Limit test results.
- A.26: Site B, Francois Road - Shrinkage Limit test results.
- A.27: Site C, Margaret Mayton Avenue - Shrinkage Limit test results.
- A.28: Site D, Rose Hill - Shrinkage Limit test results.
- A.29: Kaolin K.1 - Shrinkage Limit test results.
- A.30: Kaolin K.2 - Shrinkage Limit test results.
- A.31: Kaolin K.3 - Shrinkage Limit test results.
- A.32: Bentonite B.1 - Shrinkage Limit test results.
- A.33: Bentonite B.2 - Shrinkage Limit test results.
- A.34: Bentonite B.3 - Shrinkage Limit test results.
- A.35: Bentonite B.4 - Shrinkage Limit test results.
- A.36: Bentonite B.5 - Shrinkage Limit test results.

Number	Title

A.37:	Soil types - Summary of measured values for the specific gravity 'Gs', $T_x/20^{\circ}\text{C}$.
A.38:	Soil samples - pH values, as defined in chapter two (refer to 'Test Procedure'.)
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C.03:	Site 11, Rosebank [Remoulded, M_2] - Free Shrinkage and Free Swell test results.
C.04:	Site 11, Rosebank [Compacted] - Free Shrinkage and Free Swell test results.
C.05:	Site 11, Rosebank [Undisturbed] - Free Shrinkage and Free Swell test results.
C.06:	Site 36, Rondebosch [Remoulded] - Free Shrinkage and Free Swell test results.
C.07:	Site 36, Rondebosch [Compacted] - Free Shrinkage and Free Swell test results.
C.08:	Site 36, Rondebosch [Undisturbed] - Free Shrinkage and Free Swell test results.
C.09:	Site 30, Hout Bay [Remoulded] - Free Shrinkage and Free Swell test results.
C.10:	Site 30, Hout Bay [Undisturbed] - Free Shrinkage and Free Swell test results.
C.11:	Site A, Berea Road [Remoulded] - Free Shrinkage and Free Swell test results.

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- C.12: Site A, Berea Road [Compacted] - Free Shrinkage and Free Swell test results.
- C.13: Site A, Berea Road [Undisturbed] - Free Shrinkage and Free Swell test results.
- C.14: Site 7, Mowbray [Remoulded] - Free Shrinkage and Free Swell test results.
- C.15: Site 7, Mowbray [Compacted] - Free Shrinkage and Free Swell test results.
- C.16: Site 7, Mowbray [Undisturbed] - Free Shrinkage and Free Swell test results.
- C.17: Site B, Francois Road [Remoulded] - Free Shrinkage and Free Swell test results.
- C.18: Site C, Margaret Mayton Avenue [Remoulded] - Free Shrinkage and Free Swell test results.
- C.19: Site D, Rose Hill [Remoulded] - Free Shrinkage and Free Swell test results.
- C.20: Kaolin, K.1 - Free Shrinkage and Free Swell test results.
- C.21: Kaolin, K.2 - Free Shrinkage and Free Swell test results.
- C.22: Kaolin, K.3 - Free Shrinkage and Free Swell test results.
- C.23: Bentonite, B.1 [Remoulded] - Free Shrinkage and Free Swell test results.
- C.24: Bentonite, B.2 [Remoulded] - Free Shrinkage and Free Swell test results.
- C.25: Bentonite, B.3 [Remoulded] - Free Shrinkage and Free Swell test results.
- C.26: Bentonite, B.4 [Remoulded] - Free Shrinkage and Free Swell test results.
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- D.04: Natural Soils - One-dimensional (Consolidometer) Consolidation test results.
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Number Title

- E.01: Consolidometer test procedure for expansive and collapsing soils [Pressure = 1 Kpa] - Calibration of equipment.
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- E.06: Site 11, Rosebank [Remoulded samples - 50 Kpa vertical pressure overnight, and then water added at 50 Kpa without prop] - Expansive and/or Collapsing test results.
- E.07: Site 11, Rosebank [Remoulded samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.08: Site 11, Rosebank [Remoulded samples - 400 Kpa vertical pressure overnight, and then water added at 400 Kpa without prop] - Expansive and/or Collapsing test results.
- E.09: Site 11, Rosebank [Compacted samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.10: Site 11, Rosebank [Undisturbed samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.11: Site 36, Rondebosch [Remoulded sample - 1 Kpa vertical pressure overnight, and then water added at 1 Kpa without prop] - Expansive and/or Collapsing test results.
- E.12: Site 36, Rondebosch [Remoulded sample - 50 Kpa Vertical pressure overnight, and then water added at 50 Kpa without prop] - Expansive and/or Collapsing test results.
- E.13: Site 36, Rondebosch [Remoulded samples - 100 Kpa Vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

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- E.14: Site 36, Rondebosch [Remoulded sample - 400 Kpa
Vertical pressure overnight, and then water added at
400 Kpa without prop] - Expansive and/or Collapsing
test results.
- E.15: Site 36, Rondebosch [Compacted sample - 100 Kpa
Vertical pressure overnight, and then water added at
100 Kpa without prop] - Expansive and/or Collapsing
test results.
- E.16: Site 36, Rondebosch [Undisturbed sample - 100 Kpa
Vertical pressure overnight, and then water added at
100 Kpa without prop] - Expansive and/or Collapsing
test results.
- E.17: Site 30, Hout Bay [Remoulded sample - 1 Kpa
Vertical pressure overnight, and then water added at
1 Kpa without prop] - Expansive and/or Collapsing
test results.
- E.18: Site 30, Hout Bay [Remoulded sample - 50 Kpa
Vertical pressure overnight, and then water added at
50 Kpa without prop] - Expansive and/or Collapsing
test results.
- E.19: Site 30, Hout Bay [Remoulded samples - 100 Kpa
Vertical pressure] - Expansive and/or Collapsing
test results.
- E.20: Site 30, Hout Bay [Undisturbed sample - 100 Kpa
Vertical pressure overnight, and then water added at
100 Kpa without prop] - Expansive and/or Collapsing
test results.
- E.21: Site A, Berea Road [Remoulded samples - 100 Kpa
Vertical pressure overnight, and then water added at
100 Kpa without prop] - Expansive and/or Collapsing
test results.
- E.22: Site A, Berea Road [Compacted samples - 100 Kpa
Vertical pressure overnight, and then water added at
100 Kpa without prop] - Expansive and/or Collapsing
test results.
- E.23: Site A, Berea Road [Undisturbed samples - 100 Kpa
Vertical pressure overnight, and then water added at
100 Kpa without prop] - Expansive and/or Collapsing
test results.
- E.24: Site 7, Mowbray [Remoulded samples - 100 Kpa
Vertical pressure overnight, and then water added at
100 Kpa without prop] - Expansive and/or Collapsing
test results.
- E.25: Site 7, Mowbray [Compacted sample - 100 Kpa
Vertical pressure overnight, and then water added at
100 Kpa without prop] - Expansive and/or Collapsing
test results.
- E.26: Site 7, Mowbray [Undisturbed samples - 100 Kpa
Vertical pressure overnight, and then water added at
100 Kpa without prop] - Expansive and/or Collapsing
test results.

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- E.27: Site B, Francois Road [Remoulded sample - 100 Kpa Vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.28: Site C, Margaret Mayton Avenue [Remoulded sample - 100 Kpa Vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.29: Site D, Rose Hill [Remoulded sample - 100 Kpa Vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.30: Site 48, Lady Grey [Undisturbed sample - 100 Kpa Vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.31: Kaolin K.1 [Remoulded samples - 100 Kpa Vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.32: Kaolin K.2 [Remoulded samples - 100 Kpa Vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.33: Kaolin K.3 [Remoulded samples - 100 Kpa Vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.34: Bentonite B.1 [Remoulded samples - 100 Kpa Vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.35: Bentonite B.2 [Remoulded samples - 100 Kpa Vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.36: Bentonite B.3 [Remoulded samples - 100 Kpa Vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.37: Bentonite B.4 [Remoulded samples - 100 Kpa Vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.
- E.38: Bentonite B.5 [Remoulded samples - 100 Kpa Vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

APPENDIX F

Number Title

- F.01: Site 11, Rosebank [Remoulded Samples] - Swell Pressure test results.
- F.02: Site 11, Rosebank [Compacted Samples] - Swell Pressure test results.
- F.03: Site 11, Rosebank [Undisturbed Samples] - Swell Pressure test results.
- F.04: Site 36, Rondebosch [Remoulded Samples] - Swell Pressure test results.
- F.05: Site 36, Rondebosch [Compacted Samples] - Swell Pressure test results.
- F.06: Site 36, Rondebosch [Undisturbed Sample] - Swell Pressure test results.
- F.07: Site 30, Hout Bay [Remoulded Samples] - Swell Pressure test results.
- F.08: Site 30, Hout Bay [Undisturbed Sample] - Swell Pressure test results.
- F.09: Site A, Berea Road [Compacted Sample] - Swell Pressure test results.
- F.10: Site 7, Mowbray [Remoulded Samples] - Swell Pressure test results.
- F.11: Site 7, Mowbray [Undisturbed Sample] - Swell Pressure test results.

APPENDIX G

- G.01: Consolidometer tests with horizontal strain measurements - Calibration of equipment.
- G.02: Calibration of internal pressure and strain readings on the strain bridge.
- G.03: Consolidometer tests with horizontal pressure measurements - Calibration of equipment.
- G.04: Site 11, Rosebank [Remoulded sample - one-dimensional consolidation] - Consolidometer test with horizontal strain, or stress, measurements.
- G.05: Site 11, Rosebank [Remoulded sample - vertical pressure of 50 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.
- G.06: Site 11, Rosebank [Remoulded samples - vertical pressure of 100 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.
- G.07: Site 11, Rosebank [Compacted sample - vertical pressure of 100 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.
- G.08: Site 11, Rosebank [Remoulded sample - vertical pressure of 400 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.
- G.09: Site 11, Rosebank [Remoulded sample - swell pressure] - Consolidometer test with horizontal strain, or stress, measurements.

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- G.10: Site 11, Rosebank [Compacted sample - swell pressure] - Consolidometer test with horizontal strain, or stress, measurements.
- G.11: Site 36, Rondebosch [Remoulded samples - vertical pressure of 100 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.
- G.12: Site A, Berea Road [Undisturbed sample - vertical pressure of 100 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.
- G.13: Site 7, Mowbray [Undisturbed sample - vertical pressure of 100 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.
- G.14: Site 48, Lady Grey [Undisturbed sample - vertical pressure of 100 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.

APPENDIX H

- H.01: Site 11, Rosebank [Undisturbed sample - 100 Kpa] - Triaxial tests for expansive and collapsing soils.
- H.02: Site 11, Rosebank [Compacted sample - 100 Kpa] - Triaxial tests for expansive and collapsing soils.
- H.03: Site A, Berea Road [Undisturbed samples - 100 Kpa] - Triaxial tests for expansive and collapsing soils.
- H.04: Site A, Berea Road [Compacted sample - 100 Kpa] - Triaxial tests for expansive and collapsing soils.

APPENDIX A

SOIL SAMPLING, INDICATOR AND CLASSIFICATION TEST PROCEDURES AND RESULTS

A.1 INTRODUCTION

The standard soil sampling and testing methods were studied and made more functional. The aim was to obtain accurate and repeatable test results for the soil samples being investigated. The indicator test procedures were designed to optimize the usage of the equipment available in the Soils Laboratory at UCT. The procedures thus evolved provided a practical means of obtaining the required engineering properties for each soil sample.

The following points should be noted:

1. The test procedures were based on standard test method - a list of references is included at the end of the Appendix.
2. The procedures were adapted to suit the South African conditions and local availability of apparatus - the aim was to determine indicator soil properties which can also be obtained in a well equipped field laboratory.
3. The present writer's practical experience (obtained during actual soil sampling and testing) has been incorporated into these procedures.
4. These basic, or indicator, soil properties were the main factor in the choice of the soil samples. They played a fundamental role in the choice of the soil types used in this thesis.

The following Test Procedures are included:
Soil sampling - field investigations, soil profiles, and in situ sampling; Preparation of soil samples for testing - remoulded, compacted and undisturbed samples; and, the following indicator and classification test procedures - (1) Linear Shrinkage, (2) Liquid Limit, (3) Plastic Limit, (4) Plasticity Index, (5) Shrinkage Limit, (6) Particle Size Analysis, (7) pH value of soil suspension, (8) Specific Gravity, and (9) Compaction Tests.

Test data sheets were developed for the purpose of recording data and calculations obtained during the tests. The following data sheets are included in the Test Results: Consistency Limits (1) - Liquid Limit, Linear Shrinkage, Plastic Limit and Plasticity Index; Limits (2) - Shrinkage Limit; Particle Size Distribution; and, Specific Gravity. Test results are also included for the pH measurements, and Standard and Modified AASHTO compaction tests¹.

¹ - refer to Tables A.47 to A.52 of this appendix.

A.2 SOIL SAMPLING

Introduction to field investigations and soil sampling:-

An acceptable and consistent field investigation and sampling procedure will facilitate correlation of subsurface investigation data with such engineering properties of soil as plasticity, permeability, density, grading, compressibility and strength. Such procedure will also help to determine the influence of the geologic and geographic environment on soil and rock classifications.

Prior to starting the investigation of the site, the soil engineer should obtain information regarding the topography and geology of the site, and of any existing structures. This can be carried out by reviewing all the available reports for subsurface investigations of nearby projects, including a study of the topographic and geological maps, and making a reconnaissance survey of the site. Wherever available, aerial photographs of the site area can provide very useful information as well. Advice should also be sought from the local authorities, such as the National Building Research Institute 'NBRI' of the Council for Scientific and Industrial Research 'CSIR', and the Geological Survey.

It should be noted that this procedure was originally prepared in order to meet the soil sampling requirements for this thesis. Although the basic procedure was carried out in the field for that purpose, the procedure has been expanded so that it can be used as the basis for other field investigations with similar soil sampling requirements.

Requirements of the field survey:-

The field survey should attempt to identify and locate, both horizontally and vertically, major soil and rock types encountered within a given site. The soils investigation should provide sufficiently large soil samples of such quality as to allow adequate testing to determine the soil classification and/or mineralogic type, and the engineering properties required by the particular project.

Subsoil conditions can be explored by drilling and sampling, excavating test pits, and by further studying the existing data. Auger drilling through boulders and cobbles is difficult, and the cost of rotary drilling may not be warranted for small projects. Seismic Surveying methods may also be used to complement drilling - geophysical equipment can be used to determine bedrock, changes in subsoil conditions and groundwater depth.

Probably the most accurate subsoil investigation method is by opening a test or sampling pit. Another possible investigation method is to drill a large caisson hole to the required depth. One drawback for both test pit and caisson methods, is that the standard penetration tests cannot be performed.

The actual number of test holes required for a particular project depends upon the type of foundation, uniformity of subsoil conditions and the relative importance of the structure. In order to be able to predict volume changes in the field with a reasonable degree of accuracy, a program should include most of the following steps:

- (i) Determine the soil profile, and obtain representative samples, including undisturbed blocks of soil;
- (ii) Measure the basic engineering properties of the soil - enables a broad classification to be made in terms of those properties ;
- (iii) Subject the undisturbed soil samples to the same moisture conditions and loads that will occur in the field, and measure the resultant volume changes;
- (iv) Prepare disturbed samples at different conditions (varying the initial density and water content), and measure the volume changes that take place due to changes in water content and loading;
- (v) Extrapolate the time-volume relationship (obtained in the laboratory) to the field.

This particular soil sampling procedure deals with step (i) above. The basic engineering properties of the soil (that is, step (ii)), are determined by the Indicator test procedures of Appendix A. The other steps are dealt with in Appendices C, D, E, F, G and H. It should be noted that step (iv) is an optional one for many projects - it is used mainly for research purposes, and for situations which require the knowledge of volume changes in a soil layer previously compacted to a specified compaction standard.

Apparatus required:-

Engineering judgement usually determines the final selection of the equipment listed below. The equipment required for field investigation and sampling, depends upon the nature of the terrain and the requirements of the project. The following equipment was necessary for the field requirements of this thesis:

- (i) Small hand tools - spades, cutting tools, knives, wire saws, a brush, wax, a pot for heating the wax and a gas or parafin stove;

- (ii) Moisture-tight sample containers (capable of being sealed); a provision of good quality plastic bags (strong and of larger size); closely woven bags with capacity of at least 15 kg, or pockets made of sacking.
- (iii) Appropriate boxes for undisturbed samples (refer to section on in situ sampling).
- (iv) A sheet of canvas for in situ examination and processing of soil samples;
- (v) Accessories - shovels, geological pick, hand auger, hard hat, portable ladder, measuring tape, steel pegs, colour chart, handlevel, eye glass, notebook, camera, (etc).

Equipment necessary for other field investigations:-

Study of soil profiles by sinking shafts with diameter = ± 0.75 m, to depths of 25 m or more (refer to Code of Practice for working in small diameter shafts - see reference list) - safety harness, rope, winch, lamp, etc.

Geophysical apparatus used for subsurface investigation - seismic instruments (single or multi-geophone reception of signals originating from hammer blows, explosives or other energy sources), soil resistivity (measure resistance of soil to direct or alternating current), nuclear moisture and density measuring devices.

In situ tests and sampling - auger borings (disturbed soil samples), field vane shear test (measure in-situ unit shear resistance of cohesive soils), standard penetration test 'SPT' and Dutch Probes (resistance to penetration - measures shear strength), split-barrel and thin-walled tube sampling of soils (representative and undisturbed soil samples), and diamond core drilling (to recover intact samples of rock and hard soils).

Description of the soil profile:-

The depth of each layer should be measured from the surface and the following descriptions used:

- (i) Moisture condition - whether dry, slightly moist, moist, wet or standard;
- (ii) Colour - the colour of the wet soil after mixing should be given first (to allow standard comparisons), and the natural colour of the exposed profile should be noted;
- (iii) Consistency - whether granular soils (gravels and clean sands, usually free drainage - very loose, loose, medium density, dense or very dense), cohesive soils (silts, clays and combinations with sand, usually slow draining - very soft, soft, firm, stiff and very stiff), cemented materials (describe hardness - slightly cemented, well cemented, cement-bound, concrete), or rocks (describe hardness - very soft rock, soft rock, hard rock, very hard rock and extremely hard rock);

- (iv) Structure - whether intact, fissured, slickensided, shattered, laminated or jointed (state of weathering of rock should be noted - fresh, weathered or badly weathered);
- (v) Soil type (or rock type) - whether boulders, gravel, sand, silt, clay, fine sand, clayey sand, etc (rock types - sandstone, shale, ferricrete, etc), and describe the shape of the coarser sand and gravels (whether rounded, sub-angular, angular or pitted);
- (vi) Origin of soil - determine whether residual (may be recognized by the structure and mineralogical composition originating from the parent rock), or transported (that is, above a possible pebble marker - for example, windblown sand, transported clay residual from shale);
- (vii) Remarks and significant features to be recorded - water table (permanent and/or perched), roots, ant workings, presence of lime, iron concretions, salt crystals, etc.

In situ sampling:-

Obtain representative soil samples. The size and type of sample required is dependent upon the tests to be performed, and the percentage of coarse particles in the sample. The following quantities are suggested as suitable for most soil materials:

- * Visual classification - 0,1 to 0,5 kg;
- * Indicator tests¹, excluding soil compaction - between 2,0 and 5,0 kg;
- * All indicator tests¹ - more than 10,0 kg;
- * All laboratory tests² - more than 30,0 kg.

Accurately identify each sample with the sampling hole (test pit or boring), and the depth below reference ground surface from where it was taken. Soil samples should be taken out (as soon as possible after the hole has been opened) and placed inside the previously numbered bags, containers or boxes. Place an identification inside the container, securely close the container and mark it with paper identification on the outside. Keep samples for natural moisture determination in sealed containers to prevent moisture loss.

Guide for obtaining disturbed soil samples:-

- 1) Clean site - remove top soil and vegetation roots;
- 2) Use shovel to place soil into pockets made of sacking - if possible also include blocks of soil;
- 3) Write information required in the labels provided with the pockets, and stitch up the opening - make sure the stitching is strong;
- 4) Return the samples to laboratory.

¹ - Appendix A.

² - Appendices A, B, C, D, E, F, G, and H.

Guide for obtaining in situ undisturbed soil samples:

- (i) Remove top soil and vegetation roots - also remove first 100 mm of soil to be sampled;
- (ii) The paraffin wax is heated up (at a temperature of just over 60°C) until it becomes liquid;
- (iii) At the required position on the side or bottom of the sampling hole (previously excavated and profiled), use the spade to cut and remove (carefully) the soil from the top and sides - it is done in such a way as to leave behind a column of undisturbed in situ soil of the required size (of box - next step) with its bottom side still untouched and continuous with the in situ soil layer;
- (iv) The appropriate box for undisturbed samples (without its top and bottom sides) is fitted over the undisturbed column of soil, and the molten wax is poured into the gap between the soil sample and the box;
- (v) The top (of the soil column) is trimmed, from the sides towards its centre, to a level slightly below the top of the box;
- (vi) The molten wax is poured over the top of the sample, levelled with the top of the sides of the box, and the wax allowed to cool and harden;
- (vii) After the top of the box is screwed tightly into place, the bottom side (of the column) is cut off - use spade and insert it at a downwards angle from the side of the box, until it reaches past the centre of the soil column;
- (viii) The box (with the sample) is gently turned over and lifted out of the sampling hole - the remaining side is trimmed, waxed and sealed.
- (ix) The box with the undisturbed sample is carefully taken to the laboratory, where it is stored in a safe place.

A.3 PREPARATION OF SOIL SAMPLES FOR TESTING.

These methods for preparing soil samples will provide the background for the actual testing described in subsequent sections of this Appendix - they are the link with the field sampling¹.

Dry Preparation of Soil Samples:-

The initial preparation of the disturbed soil samples received from the field (for all the preliminary testing and the preparation of remoulded and compacted test samples) is as follows:

- (i) Spread soil over a clean surface and let air dry.
- (ii) Break up the aggregations by means of a rubber covered pestle.
- (iii) Obtain a representative sample by quartering, or using a sample/riffler, until the amount required to perform the desired test is available.
- (iv) The expansive and collapsing soil samples used were of fine size. Virtually no particles greater than 2,0 mm size were found. Therefore the 2,362 mm size sieve (mesh # 8) was used to remove foreign matter, such as impurities and any odd stone.

Remoulded Samples:-

Basically a remoulded test sample consists of soil mixed with water to form a wet paste which is then moulded into the required shape. A suitable mould of known dimensions, is used for the consolidometer test samples. Similarly, a cylindrical tube is used for the future triaxial test samples. If a sample with initial high void ratio is required, the dry soil is firstly mixed² with sodium carbonate and tartaric acid before adding water².

The test sample is firstly allowed to air dry while in the mould/tube until it reaches a state of nondeformability when handled with care. It is then removed from the mould/tube for controlled air drying. Measurements of mass are taken for the first part of the air drying period. Both mass and volume measurements are recorded for the controlled air drying period following removal from its container. Volume measurements are made with the mercury displacement equipment (refer to: (i) Shrinkage Limit Test - in this appendix; and, (ii) Free Shrinkage and Free Swell paths - appendix B). When the required moisture content for testing is reached, the sample is stored in a desiccator until needed for testing. Each experimental testing method includes a section dealing with cutting and trimming of the sample to the required size and shape.

¹ - refer to section A.2 "Soil Sampling".

² - subsequent Method 2.

Method 1:

- A) Known amounts of soil and water are mixed to form a wet paste. The water content at mixing should be in the Plasticity Index Range¹.
- B) The wet paste is moulded into a suitable container. A consolidometer ring is used for the standard one-dimensional consolidation test (refer to Appendix D); a perspex mould, of somewhat larger size than the consolidometer ring to allow for volume decrease, is used for other consolidometer tests (refer to Appendix E); a cylindrical tube is used for triaxial tests (refer to Appendix D), that is, the wet paste is packed into a 1½ in diameter tube against the end of a dolly being progressively moved down the tube. A portion of the wet soil paste is also moulded into a special glass "petri" dish for a free shrinkage and free swell test (refer to Appendix C). The water content is also determined.
- C) The mass of the test sample plus the consolidometer ring, is recorded, the equipment assembled and readied for the actual test (refer to Appendix D - The basic one-dimensional consolidation test); In the case of the triaxial test the sample inside the cylindrical tube mould is removed by means of the dolly, its mass recorded and the equipment is assembled for testing (refer to Appendix D - drained consolidation under an all around three dimensional pressure).
- D) The samples in the perspex consolidometer moulds (Appendix E other consolidometer tests), petri dishes (Appendix C - Free shrinkage and swell tests), and cylindrical triaxial tubes (Appendix H - Drained Ko/stress-strain), are firstly allowed to air dry within the moulds until they will not deform when handled. The samples are removed and further controlled air drying is permitted with masses and volume changes being measured and recorded for each stage. The volume changes are measured by means of the mercury displacement apparatus. In the particular case of the free shrinkage and swell sample, volume changes are recorded while the sample is firstly allowed to air dry completely, and then the sample is wetted up in stages (refer to Appendix C). When the Consolidometer and Triaxial test samples reach the required water content, they are stored in a dessicator or alternatively the sample is firstly allowed to air dry completely and then brought to the required water content by adding water gradually in stages. When the sample is required for testing, it is cut and trimmed to fit the consolidometer test ring or to the required size for the triaxial test. Cutting tools, a trimmer or a cylindrical cutter may be used. Obviously some of these samples have been precompressed by desiccation during the method of preparation. This fact must be noted and borne in mind during the testing of the samples (see Chapter 4).

¹ - that is, between the Liquid and Plastic Limits.

Method 1.A:

A) A custom made steel mould with a bottom plate that can be removed, is used. A releasing agent is applied to the inside surfaces to facilitate the removal of the sample. The mass of the mould is determined. Soil is added until the mould is full and its top surface levelled off. The mass of mould plus soil is recorded.

B) The mould (with soil) is placed on a platform which is suspended from the inside screwing cap of a watertight container. The water level in the container is below the bottom of the mould with soil. Thus the atmosphere inside the container is saturated. Allow time for water vapour to condensate on top of the sample and to infiltrate into it. Alternatively the water is sprinkled on top of the soil which then absorbs it. The operation is repeated until the soil stops absorbing water - usually takes a matter of days.

C) The platform is removed and the mass of the mould plus the moist soil is recorded. The sample is then allowed to air dry completely and the mass recorded. The bottom is detached, the sample removed and cut to fit the consolidometer ring.

Method 2: (To obtain higher initial void ratios)

The pH value of the soil suspension is determined¹. Sodium bicarbonate and tartaric acid (lime is also necessary) are added separately to the soil suspension such that the pH value will be the same afterwards. The intention is to increase the void ratio of the soil sample while keeping the pH the same.

The procedure is as follows:

A) Known amounts of soil, sodium bicarbonate, tartaric acid and if necessary also lime, are mixed together until an homogeneous mixture is obtained.

B) Add a known amount of water and quickly mix using a spatula and place into perspex mould. The time of mixing should not be more than 30 seconds in order to entrap as much of the gas being formed as possible. Samples are also taken for free shrinkage and free swell paths and water content determination.

C) Allow sample to air dry until it can be removed from the mould without any change in shape. Further air drying is carried out and volume and mass measurements are taken at various suitable intervals. After it is fully air dried the sample is cut and trimmed to fit the test ring.

Compacted Samples:-

Based upon the dry density vs. moisture content curve for the representative sample obtained from a particular site (refer to Standard and Modified A.A.S.H.T.O. Compaction Test, in this Appendix). Individual samples are compacted, each one aiming for a particular water content.

¹ - refer to section A.4.8 "pH Value of Soil Suspension".

The preparation of each compacted sample is as follows:

- (i) Mix the soil and water to the required water content. Compact the moist soil in the mould according to the Standard or Modified 'Mod' A.A.S.H.T.O. specifications.
- (ii) By means of an hydraulic jack remove the sample from the mould. From the compacted cylinder of soil carefully cut the test sample to the required size and shape. Store the test sample in an airtight vessel until it is required for testing. If the test sample is for the consolidometer, cut it to fit the Test Ring; if for a triaxial test then trim it to the required size and shape. At the same time specimens should be obtained for shrinkage/swell paths and water content determination.

Undisturbed Samples:-

A block of soil is originally cut and removed from the in situ condition¹. Apart from the physical disturbance caused by cutting and removing the block of soil from its natural state, and consequently affecting its outer moisture content condition as well as releasing the in situ stresses previously acting on it, the soil sample is otherwise undisturbed.

Later in the laboratory, a test sample is cut from the undisturbed block of soil. The step by step preparation of an undisturbed sample is as follows:

- (i) A test sample of somewhat larger size than required for the particular test, to allow for shrinkage, is carefully cut from the undisturbed block of soil. Samples for free shrinkage and free swell paths and water content determination, are also cut from the block. With exception of the soil for determining the water content, trimming to the required shapes is carried out. Spatulas, knives, wire saws, cutting tools, trimmer/cylindrical cutter, are all used for preparing the test samples. After the samples have been cut, wax is poured over the exposed surface left on the block of undisturbed soil in order to avoid further loss of water content, and thus preserve the soil for future usage. The mass of the test sample is recorded and its volume determined by means of the Mercury displacement equipment.
- (ii) Under close control the sample is allowed to air dry in stages to the required water content. Alternatively, it is wetted up if the initial water content for testing is higher. The volume and mass are recorded for each air drying and wetting up stage.
- (iii) When the required water content for testing is reached the sample is stored in a desiccator. When required for testing the sample is finally trimmed to the required size depending whether for a Consolidometer or Triaxial test (refer to Appendices D, E, F, G and H).

¹ - refer to section A.2 "Soil Sampling".

A.4 INDICATOR AND CLASSIFICATION TEST PROCEDURES

A.4.1 Linear Shrinkage

Linear Shrinkage is defined as the (one dimensional) decrease in length of a soil mass expressed as a percentage of its original length (moulded inside a trough), after the water content is reduced from the initial Liquid Limit¹ to an oven dried ($105 \pm 5^{\circ}\text{C}$) condition.

Apparatus required:-

- (i) to (viii): Refer to Liquid Limit - apparatus required.
- (ix) Standard Linear Shrinkage trough.
- (x) Soil releasing agent, such as silicone grease by Bayer.
- (xi) Vernier calipers accurate to 0,02 mm.

Procedure:-

A) Use a clean, dry shrinkage trough. The inside surface of the trough is covered completely with a thin layer of the releasing agent.

Note: The Silicone grease by Bayer proved to be the most effective soil releasing agent.

B) Follow steps A) to E) of the Liquid Limit procedure, as far as the water content determination for 25 blows - refer to Notes 1) and 2) at the end of that procedure.

Comment: This test is usually carried out at the same time as the Liquid Limit test.

C) The wet soil 'at 25 blows' is carefully placed inside the shrinkage trough, and its length measured. This operation should be carried out in three stages:

- (i) Fill the bottom half of the trough (diagonally across) starting from one end, to continue over the whole length, and use spatula to press small pieces of the wet soil against the inside of the trough.
- (ii) Turn the trough around and do the other side (this time only one quarter of its volume is filled).
- (iii) The hollow along the top is now filled - the excess wet soil is removed by levelling off the top surface; the length of wet soil is measured to nearest 0,1 mm.

D) Place the Shrinkage trough (overnight) inside the drying oven set to the temperature of $105 \pm 5^{\circ}\text{C}$. Remove the trough from the oven, allow to cool to room temperature, and then measure the length of the oven-dry soil (inside the trough) to nearest 0,1 mm.

¹ - refer to section A.4.2 "Liquid Limit".

Notes:

- 1) After testing, the oven dried soil bar should be examined to ensure that the corners of the trough were filled properly and no air pockets were present during step C).
- 2) It is usually found that the ends of the oven dry soil have a slight lip or projecting piece at the top: These must be carefully removed to ensure that the ends of the soil bar are parallel to the ends of the trough.
- 3) If the oven-dry soil bar is curved, it should be pressed back into the trough so as to make the top surface as level as possible. The soil bar should be tightly against the end (of the trough) at which there is a better fit, before measuring the distance to the other end.

Calculations and Report:-

1. Linear Shrinkage, " w_{LS} (%)" =

$$\frac{(\text{length, 'wet soil'}) - (\text{length, 'oven dry soil'})}{(\text{length, 'oven-dry soil'})} \times 100.$$

The Linear Shrinkage " w_{LS} " is calculated to the first decimal figure.

2. The Linear Shrinkage is usually reported to the nearest whole number.

A.4.2 Liquid Limit

It is defined as the water content expressed as a percentage of the mass of oven dried soil, at the boundary between the liquid and plastic states.

The water content at this boundary is arbitrarily defined as the water content at which two halves of a soil cake will flow together for a distance of 12 mm ($\frac{1}{2}$ in) along the bottom of the groove separating the two halves when the cup¹ is dropped 25 times for a distance of 10mm at the rate of 2 drops per second.

Apparatus required:-

- (i) Standard Liquid Limit Unit: The mechanical device itself which consists of a cup and a carriage, plus a combined grooving tool and gauge.
- (ii) A calibrating plate with a thickness of 10,0 mm for adjusting the height which the 'cup' will fall.
- (iii) A ground-glass plate measuring 200 mm x 300 mm, or other suitable working surface which does not absorb water.
- (iv) Supply of distilled water.
- (v) Spatula with slightly flexible blades.
- (vi) Suitable dishes for water content determination.
- (vii) A balance accurate to 0,01 grams.
- (viii) A drying oven, thermostatically controlled, and capable of maintaining a temperature of $105 \pm 5^{\circ}\text{C}$.

Procedure:-

A) Mix approximately 100 grams of soil (see procedure for 'Dry' preparation of soil samples) with water until a consistently uniform wet paste is formed - in order to facilitate the mixing, the water should be added in small increments. A mixing time of about 10 minutes or longer should be used, with the longer periods being used for the more plastic soils.

B) A representative sample of the wet soil is transferred to the cup of the Liquid Limit device, mixed slightly and its top surface made level. By means of the grooving tool, the soil in the cup is divided into two equal portions - the groove should fall along the centre-line drawn through the cam-follower attached to the cup.

C) The Liquid Limit device is then operated at a speed which results in two 'falls' (or blows) per second being applied to the soil - until the lower parts of the soil portions have flowed together and make contact over a distance of approximately 12 mm along the bottom of the groove.

¹ - which is part of the Liquid Limit device.

D) The first point should be obtained at about 35 blows - to obtain the required number of blows either allow the soil to air dry or add more water in small amounts. When that has been achieved, take a representative sample from the portion of the groove which has closed, and use it for the water content determination. Record the exact number of blows.

E) The procedure is repeated for two additional water content determinations at approximately 25 and 15 blows respectively. The test should always proceed from the dryer to the wetter condition of the soil.

Notes:

1) Water content determination: Soil sample is placed in a suitable container of known mass - record mass of 'Wet' soil plus container; Place container (overnight) inside drying oven set to temperature of $105 \pm 5^{\circ}\text{C}$; Remove the container from the oven, allow to cool to room temperature, and then record the mass of 'oven dry' soil plus container.

2) At the same time of the water content determination for 25 blows representative wet soil is transferred to the Linear Shrinkage trough for determination of the Linear Shrinkage¹.

Calculation and Report:-

1. Water content, "w"

$$= \frac{(\text{Mass of 'wet' soil}) - (\text{Mass of 'oven dry' soil})}{\text{Mass of 'oven dry' soil}}$$

$$= \frac{\text{Mass of water}}{\text{Mass of solids}}$$

2. Plot a 'flow curve' representing the relationship between water content (as abscissae on the arithmetic scale) and the corresponding number of blows (as ordinates on the logarithmic scale). The flow curve plots as a straight line. Obtain the water content corresponding to 25 blows - this is the Liquid Limit 'w_L' of the soil, which is determined to the first decimal figure.

3. To draw the best straight line on the graph:

- (i) Plot the centroid of all points (x' = mean of all x-coordinates 'No. Blows', and y' = mean of all y-coords. 'w');
- (ii) By visual inspection draw the best straight line through the centroid, call it 'Line A';
- (iii) Divide the plotted points into two equal groups A and B by a line perpendicular to line A (if there is an odd number of points, draw the dividing line through the middle one, and count it as a half point in each group);

¹ - see section A.4.1 'Linear Shrinkage'.

(iv) Find the centroid of groups A and B - hence, draw the best straight line through the two centroids.

4. The Liquid Limit is usually reported to the nearest whole number.

Notes:

$$\text{Water ratio, } 'w' = \frac{\text{Volume of water in soil, } 'V_w'}{\text{Volume of soil grains, } 'V_s'};$$

$$\text{Void ratio, } 'e' = \frac{\text{Volume of voids, } 'V_v'}{\text{Volume of solids, } 'V_s'};$$

$$\text{Degree of saturation, } 'S_r' = \frac{\text{Volume of water, } 'V_w'}{\text{Volume of voids, } 'V_v'};$$

Specific gravity, ' G_s '

$$= \frac{\text{Mass, soil in air (given volume and temperature)}}{\text{Mass, distilled water in air (for same vol. and temp.)}}.$$

Therefore, ' w ' = $S_r \times e = w \times G_s$.

A.4.3 Plastic Limit

It is defined as the water content expressed as a percentage of the mass of oven dried soil, at the boundary between the plastic and semi-solid states. The water content at this boundary is arbitrarily defined as the lowest water content at which the soil can be rolled into threads 3,2 mm (1/8 in) in diameter without the threads breaking into pieces, but at which water content the threads are just about to break.

Apparatus required:-

(i) to (vi): See Liquid Limit¹ - apparatus, steps (iii) to (viii).

Note: Provide and use covers with the containers for the water content determination.

Procedure:-

A) A small portion (about 20 g) of the moist soil set aside from the Liquid Limit determination (after air drying from its wet state) is mixed with the fingers to form the shape of a ball. When it feels like a stiff 'putty', break into two halves and leave one half aside for the moment (to be used in step C).

B) The other half of the moist soil is kneaded with the fingers to an ellipsoidal shape. It is then rolled into a thread of uniform diameter throughout its length. When the diameter of the thread is approximately 3 mm, the soil is again kneaded to an ellipsoidal shape and rolled out. This process is continued until the threads become brittle and start crumbling at the required diameter. These 'crumbled' threads are placed in a container, and kept there until a sufficient number of threads are obtained (usually about 10) using the procedure just described. Record the mass of covered container with soil, and place it in the drying oven for the water content determination - see Note 1 of the procedure for Liquid Limit.

C) A duplicate determination should be carried out in precisely the same manner - repeat step B) for the one half of the moist soil which was set aside at the beginning (see step A).

Notes:

1) The water content of the moist soil initially set aside from the Liquid Limit determination (step A), should not be reduced by the admixture of dry soil.

1 - refer to section A.4.2.

- 2) The operator should ensure that the thread is not broken up or crumbled by applying slightly excessive pressure, but crumbles on account of a lack of plasticity.
- 3) Duplicate determinations should not vary by more than 1,5 units.

Calculations and Report:-

1. Calculate the Plastic Limit, expressed as water content in percentage of the mass of the oven-dry soil, as follows:

Plastic Limit, 'w_p'

$$\text{Plastic Limit, 'w}_p\text{'} = \frac{(\text{Mass, 'Moist' soil}) - (\text{Mass, 'oven-dry' soil})}{\text{Mass of oven-dry soil}}$$

2. The calculation should be carried out to the first decimal figure, and the average (of the water content determinations) is recorded as the Plastic Limit.

3. The Plastic Limit is usually reported to the nearest whole number.

A.4.4 Plasticity Index

The Plasticity Index is the water content range over which the soil is in a plastic state. That is, the Plasticity Index is the numerical difference between the Liquid Limit¹ and the Plastic Limit² values.

Calculation and Report:-

1. Plasticity Index,

$$I_p = (\text{Liquid Limit, } 'w_L') - (\text{Plastic Limit } 'w_p')$$

2. The Plasticity Index is determined to the first decimal figure. It is reported to the nearest whole number.

3. The calculated difference (in 1. above) is reported as the Plasticity Index, except under the following conditions:

- (i) When the Liquid Limit or Plastic Limit cannot be determined, report the Plasticity Index as 'NP' (Non plastic).
- (ii) When the soil is extremely sandy, the plastic limit test shall be made before the Liquid Limit. If the plastic limit cannot be determined, report both the Liquid Limit and Plastic Limit as 'NP'.
- (iii) When the Plastic Limit is equal to, or greater than, the Liquid Limit, report the Plasticity Index as 'NP'.

Note: If the Liquid Limit cannot be determined 'but' there is slight Linear Shrinkage, ' w_{Ls} ' (see Linear Shrinkage test), both the Liquid Limit and the Plasticity Index are usually reported as 'SP' (slightly plastic). If there is no shrinkage at all, they are reported as 'NP' (as in 3 above).

¹ - refer to section A.4.2 "Liquid Limit".

² - refer to section A.4.3 "Plastic Limit".

A.4.5 Shrinkage Limit

It is defined as the water content below which the volume (of the soil sample) remains constant for further air drying - that is, further reduction in the water content will not cause a decrease in the volume of the soil mass. This Shrinkage Limit test procedure provides the initial Free Shrinkage path (used only for soil mixed with water at about the Liquid Limit value) of the main test procedure for 'Free Shrinkage and Free Swell'¹.

Apparatus required:-

- (i) The mercury displacement unit: The apparatus was designed and built to enable an accurate measurement to be made for the volume of the soil mass; Its components and operational details are shown in Photographic Plate 4.01, of the visual sequence included with the test method for 'free shrinkage and free swell', in Chapter Four of the Thesis².
 - (ii) A shrinkage dish (a special glass 'petri' dish).
 - (iii) Soil releasing agent, such as silicone grease by Bayer.
 - (iv) A container with an adjustable opening to permit control of the rate of air drying from the soil sample while being stored until the next volume and mass determination.
 - (v) A balance accurate to 0,1 g to measure the mass of mercury displaced.
 - (vi) Supply of mercury (its relative specific density is determined at the end of this procedure).
 - (vii) A steel straight edge.
 - (viii) 'G_s' bottles of small size, also known as pycnometers, to determine the specific gravity (ie, the relative specific density of the mercury) - refer to test procedure for specific gravity.
 - (ix) to (xiv) See Liquid Limit - apparatus required, steps (iii) to (viii).
- Note: The balance accurate to 0,01 g, step (xiii), is used to measure soil mass.

Procedure:-

A) Mix approximately 50 grams of soil (See procedure for 'Dry preparation of Soil Samples') with distilled water until a consistently uniform wet paste (at about the Liquid Limit value, or greater) is formed. In order to facilitate mixing, the water should be added in small increments - a mixing time of about 10 minutes or longer should be used; the longer periods being used for the more plastic soils. Note: The amount of water must be sufficient to fill the soil voids completely and to make the soil pasty enough to be readily worked into the shrinkage dish without the inclusion of air bubbles (a sample can also be taken for water content determination).

¹ - see Appendix C.

² - refer to Volume One of the Thesis.

B) Use a clean, dry shrinkage dish. The inside of the dish is completely covered with a thin layer of silicone grease to prevent the adhesion of the soil to the dish. Record the mass of the shrinkage dish with silicone grease.

C) Place an amount of wet soil in the centre of the shrinkage dish - use about one third of its total volume. Cause the wet soil to flow to the edges by tapping the dish on a firm surface which has been covered with a thick cloth or cardboard (to avoid breakage of the glass dish). Add another portion of wet soil (approximately equal to the first one) and again carefully tap the dish until the soil is thoroughly compacted and all the entrapped air has been brought to the surface. Add more wet soil and repeat the tapping procedure until the dish is slightly overfilled.

D) Level off the top of the shrinkage dish (use straight edge to remove the excess soil), and wipe off all the wet soil adhering to the outside. Record the mass of the wet soil plus shrinkage dish.

E) Allow the wet soil to air dry only until it becomes stiff enough to be handled without being deformed (by this time the soil has shrunk away from the sides of the shrinkage dish, thus facilitating its careful removal). The soil mass is at this stage in the plastic state, that is, its water content is between the plastic and liquid limit values. Record the mass of the moist soil sample, and measure its volume by means of the mercury displacement apparatus (also used to measure the internal volume of the shrinkage dish).

Brief description of how to use the mercury displacement apparatus (components and operational details are shown in Photographic Plate 4.01 which is included in 'Free Shrinkage and Free Swell Paths' - Chapter Four of the Thesis¹):

- (i) Fill up unit (to overflowing) with mercury;
- (ii) Clean both the top surface of the mercury and the glass beaker to be used for collecting the mercury;
- (iii) Remove the excess mercury by pressing the flat plate (with the three prongs) firmly into the mercury, until it reaches the top of the unit - wipe off any mercury that may be adhering to the unit, and the excess (which flowed into the glass beaker) is returned to the mercury bottle;
- (iv) Place the soil sample on top of the mercury and carefully force it under the mercury meniscus (by means of the flat plate with the three prongs) pressing the plate firmly to reach the top of the unit - ensure that no air is trapped under the soil sample;
- (v) The mercury overflow goes into the glass beaker (also ensure that all the bits of mercury are brushed into the beaker) - record the mass of the glass beaker (of known mass) plus mercury.

¹ - refer to Volume One of the Thesis.

F) The soil mass is placed in the container with the adjustable opening (to enable control of the rate of air drying). The soil mass is allowed to air dry in stages, its mass and volume being measured at the end of each stage - the shrinkage path (of the soil mass) is thus obtained, and the air drying stages are continued until there is no further decrease in its volume. The soil mass could still be allowed to air dry further (leave overnight, in open container), after which its mass and volume are measured.

G) Place the soil mass (overnight) inside the drying oven set to the temperature of $105 \pm 5^{\circ}\text{C}$. Remove from oven, allow to cool to room temperature, and then measure its mass and volume.

Calculations and Report:-

1. Total volume of soil mass (at each drying stage), ' V_T '
 Mass of mercury, ' H_g ' grams
 = $\frac{\text{Mass of mercury, 'H}_g\text{' grams}}{\text{Specific gravity of 'H}_g\text{' (13.6 approx See Fig A.01)}} \text{ (cm}^3\text{)}.$
2. Water content, ' w ' (%)
 (Mass, 'Moist/dry' soil) - (Mass, 'oven-dry' soil)
 = $\frac{\text{Mass, 'Moist/dry' soil} - \text{Mass, 'oven-dry' soil}}{\text{Mass, 'oven-dry' soil}} \times 100.$
3. Plot the volume of the soil mass (V_T) against the water content (w) for each drying stage: The Shrinkage Limit ' w_s ' is obtained by the intersection of the 'shrinkage path' line with the (horizontal) line resulting from the constant volume that has been reached; The point of intersection determines the water content below which there is no further decrease in the volume of the soil mass - that is, the Shrinkage Limit.

The Specific Gravity of the Mercury used, $G_{S\text{'H}_g\text{'}}$:-
 (That is, The Relative Specific density of mercury)

Procedure to determine the $G_{S\text{'H}_g\text{'}}$:

- (i) The mercury was cleaned in contact with damp filter paper in order to remove any dust/grit particles.
- (ii) ' G_S ' bottles were first filled with distilled water: The mass and temperature were recorded for each one.
- (iii) The ' G_S ' bottles were next 'carefully' filled with mercury: Again the mass and temperature were recorded for each one.
- (iv) The Specific gravity was calculated for each ' G_S ' bottle measured, by dividing the mass of mercury by the mass of distilled water - the $G_{S\text{'H}_g\text{'}}$ results are plotted for each temperature.

Table A.01: Results used to determine the Specific Gravity of Mercury 'Gs'Hg'.

'Gs' bottle	No.1	2	3	4	5	6	7	8
A= bottle gr	10,70	10,69	13,17	10,70	12,59	10,60	12,75	12,69
B= (A+H ₂ O)gr	62,05	62,0	36,9	62,0	36,5	62,0	36,50	36,6
C= (A+Hg) gr	710,4	710,4	336,6	710,3	338,5	710,0	336,3	338,8
Temp. °C	16,1	17,0	15,4	16,0	20,0	20,5	20,0	16,6
Density, Hg	13,63	13,63	13,63	13,64	13,63	13,61	13,62	13,64

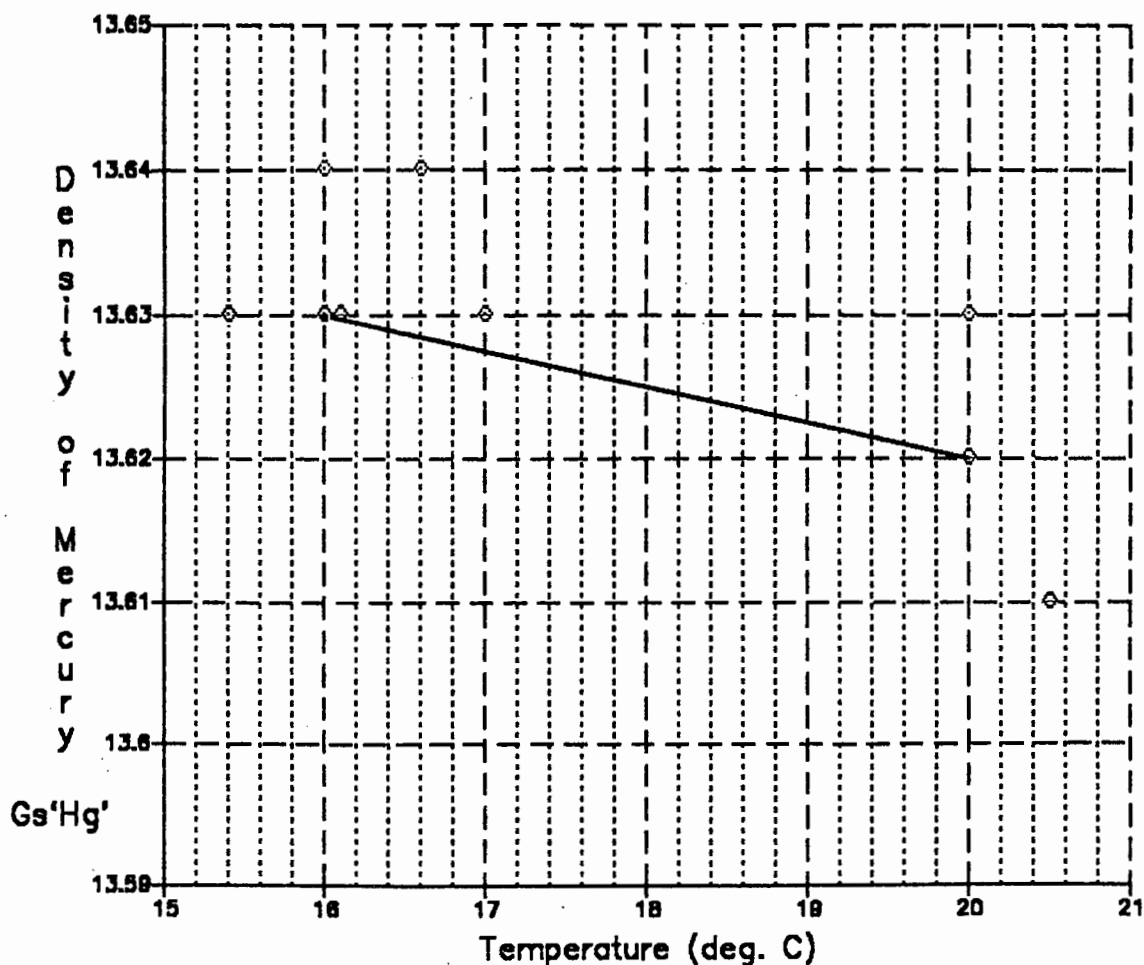


Figure A.01: Relative Specific Density of the Mercury Used, Gs'Hg': Varies between 13,63 at 16°C (used for the 'colder' months in Cape Town - May to October) and 13,62 at 20°C (used for the 'warmer' months of November to April).

A.4.6 Particle Size Analysis

Definition of Particle Size.

Particle Size: (mm)	Definition:
2 \	> Coarse Sand
0,6 <	> Medium Sand
0,02 <	> Fine Sand
0,06 <	> Coarse Silt
0,02 <	> Medium Silt
0,006 <	> Fine Silt
0,002 /	CLAY

The analysis of particle size larger than 0,074 mm¹ is determined by dry sieving, while the analysis of particle sizes smaller than 0,074 mm is determined by a sedimentation process using an hydrometer to secure the necessary data.

Apparatus required:-

- (i) A 250 ml glass beaker.
- (ii) A balance accurate to 0,01 grams.
- (iii) Suitable dishes/containers for 'hygroscopic' moisture and sieve analysis.
- (iv) A drying oven, thermostatically controlled, and capable of maintaining a temperature of $105 \pm 5^{\circ}\text{C}$.
- (v) One set of sieves with the following aperture sizes (mm): 2,362; 1,204; 0,589; 0,417; 0,295; 0,246; 0,147; 0,074; pan to collect the material passing the 0,074mm size.
- (vi) A mechanical sieve shaker.
- (vii) A standard ASTM Hydrometer².
- (viii) Several 1000 ml glass cylinders - one per sample, with an additional one being used to keep both the hydrometer and thermometer in between readings.
- (ix) A thermometer able to read to the nearest 0,1°C.
- (x) Electrical mixer capable of 1000 revolutions per minute.
- (xi) Supply of distilled water.
- (xii) A large container for oven drying, capable of carrying about 2 litres of the soil-water solution.
- (xiii) A stop clock capable of reading in seconds.
- (xiv) Dispersing agents: sodium silicate; sodium oxalate; sodium hexametaphosphate.
- (xv) A hose pipe to be connected to the water supply - it will enable the wet sieving of material through the 0,074 mm sieve.

¹ - the amount retained in the No. 200# sieve.

² - ASTM Designation: E 100.

Procedure:-

A) The composite correction for each 1000 ml cylinder is determined as follows: Fill up the cylinder to the 1000 ml mark with distilled water and the dispersing agent(s) to be used; Place the cylinder in a water bath at the lowest expected temperature, allow the temperature of the soil-water solution to become stable (usually takes several hours), and record both the hydrometer and temperature readings; repeat the procedure for a warmer water bath temperature - the intention is to cover the maximum possible temperature range that can occur during the actual test; Plot a graph of temperature versus correction to be applied, that is, the difference between 1,000 and the reading obtained above. (Note: Included with this procedure are calibration graphs for the hydrometers used, with the various dispersing agents).

B) The soil sample (refer to procedure for dry preparation of soil sample¹) is spread out over a clear surface where it is allowed to air dry completely. An amount of 50.00 grams is weighed out in the 250 ml glass beaker. A moisture content determination is also carried out in order to determine the Hygroscopic Moisture correction factor.

C) Add the required amount of dispersing agent to the soil sample inside the glass beaker. Top up to the 200 ml mark with distilled water, and leave overnight - the glass beaker should be covered in order to avoid evaporation and consequent exposure of the soil.

Note: In the search for the most effective standard solution various types and amounts of dispersing agents were tried. The mixtures which gave the most consistent results (that is, without flocculation of the soil particles) were: A combination of sodium silicate with sodium oxalate - the amounts used were 10 cc from each of the two previously prepared solutions: (The one solution consists of 36 grams of sodium silicate with 1000 ml of distilled water, and the other of sodium oxalate and distilled water is mixed in the same proportion); A solution consisting of 125 ml of sodium hexametaphosphate was made up to 1000 ml with distilled water. Graphs of percentage (%) passing versus size, using the various types/combinations of dispersing agents, are included for several of the soil samples tested.

D) Carefully transfer the contents of the beaker into the cup of the electrical mixer. Use distilled water from a plastic bottle to wash all the contents from the beaker into the cup, and to bring the water level in the cup to about one half of its capacity. Switch on the electrical mixer and allow mixing of the contents for about one minute. Use distilled water to carefully wash-transfer the contents into the 1000 ml cylinder, and top up to the 1000 ml mark.

¹ - see 'Dry Preparation of Soil Samples' in section A.3.

E) Place both the hydrometer and thermometer in a similar cylinder full of distilled water at the same temperature. Both cylinders should be placed on top of something solid, such as a concrete table in a safe place. The stop-clock¹ should be nearby, ready to be started.

F) Use the palm of one hand to cover the open end of the cylinder with soil-water, pressing down onto the cylinder until it feels watertight but still reasonably comfortable. (Note: The present author found that by placing a small amount of grease on the palm of the hand any possibility of leakage was entirely avoided). Hold the body of the cylinder (at the other end) with the other hand. Stand back from the concrete table - ensure that the cylinder is firmly held at both ends, and that there is ample room around the operator to enable shaking of the cylinder. The shaking of the cylinder plus contents is started one minute before the actual settlement of the particles begins and thus the start of the test or zero reading. Stretching both arms out while holding the ends of the cylinder, the shaking up of the contents is accomplished by turning the cylinder upside down and back the right way up again, in a rhythmic and systematic motion every 2 - 5 seconds. While the cylinder with contents is being held upside down, a small amount of vigorous sideways shaking will be needed if the contents are sticking to the bottom of the cylinder. Ensure that the last turning motion, that is as the settlement of the particles is about to begin, will be one of turning the cylinder back to its upright position.

G) Carefully place the cylinder on the table. Hydrometer and thermometer readings are to be taken at the following times (from the start of sedimentation to the taking of the reading): 1, 2, 5, 15, 30, 60, 250 and 1440 minutes. The hydrometer is immersed into the soil-water solution half a minute before each reading is due. Extreme care is taken when immersing the hydrometer: The stem of the hydrometer is held between the thumbs and indicator fingers of both hands, and slowly immersed into the liquid while the small fingers of both hands take a stand on top of the cylinder; the hydrometer is released when no more oscillating occurs and it remains floating in the middle of the cylinder. If at a particular time it is not possible to take the hydrometer reading, then as soon as it is possible to do so record the reading and the actual time it was taken.

H) Immediately after each reading the hydrometer is removed from the cylinder with the soil-water solution. It is then placed (with a spinning motion) back into the cylinder with distilled water. The thermometer is then slowly immersed into the soil-water solution and allowed to settle at the temperature of the contents for a few seconds. After the temperature is recorded the thermometer is placed back into the cylinder with distilled water.

¹ - or use a wrist watch with a large seconds' dial.

I) After the last reading is taken and recorded, the contents of the cylinder are carefully transferred into the 0,074 mm mesh sieve - a controlled jet of water from a small diameter (± 5 mm) plastic hose is used for this purpose. Once all the contents are inside the sieve, the washing continues until the water coming out through the sieve is clear. The material left inside the sieve is now carefully wash-transferred into a suitably large oven drying container, without losing any of it. The basin with contents are then placed inside the oven set at $105 \pm 5^{\circ}\text{C}$, for a period of time which depends on the amount and type of the soil but which is usually not less than 6 hours.

J) Remove the basin with contents from inside the oven and allow to cool down. The soil contents are first carefully brushed into a clean container and the mass is recorded. The contents are then transferred to the top of the previously assembled series of 'spotless clean' sieves plus pan. The set of sieves consist of the following (size in millimetres): 2,362; 1,204; 0,589; 0,417; 0,295; 0,246; 0,147; 0,074 and the pan to collect the material passing the 0,074 mm sieve. The set of sieves is firmly secured to the mechanical sieve shaker - allow shaking for a minimum of 10 minutes. At the end of the shaking, remove the sieves and carefully record the mass of material retained in each one of them, including the pan.

Note: The amount to be sieved at one time should not exceed about 100 grams.

Calculations and Report:-

1. Mass of Air Dried Soil sample, 'ADS' used = 50,00 g (unless otherwise specified).

2. Hygroscopic Moisture Correction factor, CM^1

Mass of oven dried 'hygroscopic' sample
 = -----
 Mass of air dried 'hygroscopic' sample before oven drying

3. Calculated mass of oven dried soil used in Hydrometer analysis, $W = \text{'ADS'} \times \text{CM}$.

¹ - refer to step B.

4. Hydrometer analysis:

(i) Time 'T'(min.)	(ii) Hydrometer Reading 'R'	(iii) Temp. (°C)	(iv) Composite Correction 'CR'	(v) Adjusted Reading [AR]=R+CR-G _{SL}
Step G)	Step G)	Step H)	(iii) into graph of Step A).	
(vi) Constant 10 ⁵ G _S C=---x----- W G _S -G _{SL}	(vii) Percentage, P=[AR]xC. (%)	(viii) K	(ix) L (cm)	(x) Diameter, D=Kx √L/T (mm)

Table A.02 Table A.03

Formulae used above:

For Hydrometer 151.H (Ref. A.S.T.M. Standards):

$$\text{Percentage, } P = \left| \frac{100000}{W} \times \frac{G_S}{G_S - G_{SL}} \right| \times (R - G_{SL}).$$

-----v-----
Constant C (see below)

According to Stoke's Law:

$$\text{Diameter, } D = \left| \left| \frac{30xn}{980} \times (G_S - G_{SL}) \right| \times \frac{L}{T} \right|^{\frac{1}{2}}$$

$$= K \times \sqrt{(L/T)}.$$

Where:

T = Interval of time from the start of sedimentation to the taking of the reading;

R = Corrected hydrometer reading.

CR = Composite correction for Hydrometer Reading.

AR = Adjusted Hydrometer Reading = [R + CR - G_{SL}];G_{SL} = Specific gravity (relative density) of suspending medium - May use 1,000 for the temperature range covered;

$$C = \text{Constant (see (vi) above)} = \left| \frac{10^5}{W} \times \frac{G_S}{G_S - G_{SL}} \right| ;$$

G_s = Specific gravity of soil particles;
 P = Percentage of soil remaining in suspension at the level at which the hydrometer measures the density of the suspension;
 K = Constant depending on the temperature of suspension and the Specific gravity ' G_s ' - see Table A.02 below;
 L = The effective depth or distance from the surface of the suspension to the level at which the density of the suspension is being measured - see Table A.03 below;
 D = Diameter of soil particle in millimeters.
 n = Coefficient of viscosity of the suspended medium 'water', in poises varies with temperature.
 (Note: 1 P, 'Poise' = 0,1 x Pa.s, 'Pascal second').

5. Composite correction, 'CR': To obtain 'CR', enter the temperature reading obtained in step H) into the relevant calibration graph from step A).

Table A.02: Values of K for Use in Equation for Computing Diameter of Particle In Hydrometer Analysis

Temp Specific Gravity of Soil Particles ' G_s '								
$^{\circ}\text{C}$		2.55	2.60	2.65	2.70	2.75	2.80	2.85
16		0.01481	0.01457	0.01435	0.01414	0.01394	0.01374	0.01356
17		0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18		0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19		0.01425	0.01403	0.01382	0.01361	0.01342	0.01323	0.01305
20		0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21		0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22		0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23		0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24		0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25		0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26		0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27		0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28		0.01283	0.01264	0.01244	0.01225	0.01208	0.01191	0.01175
29		0.01269	0.01249	0.01230	0.01212	0.01195	0.01178	0.01162
30		0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149

Table A.03: Values of effective depth 'L', based on the hydrometer and sedimentation cylinder of the specified size for Hydrometer 151.H.

Actual Hydrometer Reading	Effective Depth. L, cm	Actual Hydrometer Reading	Effective Depth. L, cm	Actual Hydrometer Reading	Effective Depth. L, cm
1.000	16.3	1.016	12.1	1.031	8.1
1.001	16.0	1.017	11.8	1.032	7.8
1.002	15.8	1.018	11.5	1.033	7.6
1.003	15.5	1.019	11.3	1.034	7.3
1.004	15.2	1.020	11.0	1.035	7.0
1.005	15.0			1.036	6.8
				1.037	6.5
1.006	14.7	1.021	10.7	1.038	6.2
1.007	14.4	1.022	10.5		
1.008	14.2	1.023	10.2		
1.009	13.9	1.024	10.0		
1.010	13.7	1.025	9.7		
1.011	13.4	1.026	9.4		
1.012	13.1	1.027	9.2		
1.013	12.9	1.028	8.9		
1.014	12.6	1.029	8.6		
1.015	13.3	1.030	8.4		

Specified size of hydrometer - the values of effective depth are calculated from the equation:

$$L = L_1 = \frac{1}{2} [L_2 - (V_B/A)].$$

Where:

L = effective depth, cm;

L₁ = distance along the stem of the hydrometer from the top of the bulb to the mark for a hydrometer reading, cm;

L₂ = overall length of the hydrometer bulb, cm;

V_B = volume of hydrometer bulb, cm³; and,

A = cross-sectional area of sedimentation cylinder, cm².

The values used were the following:

L₂ = 14,0 cm;

V_B = 67,0 cm³;

A = 27,8 cm²;

L₁ = 10.5 cm for a reading of 1.000; and

L₁ = 2.3 cm for a reading of 1.031.

6. Dry Sieve Analysis:

ODS = Mass of oven dried soil used in dry sieve analysis¹.

Mass of material passing sieve 0,074 mm during wet sieving²,
Ws = W - ODS.

Sieve Apertures (mm)	(Mesh)	Mass Retained (grams)	Percentage Retained (%)	Percentage Passing (%)
2,36	(8)			100,0
1,204	(14)			
0,589	(28)			
0,417	(35)			
0,295	(52)			
0,246	(60)			
0,147	(100)			
0,074	(200)			
PAN				
WS (wet sieving)				

Calibration of Hydrometer 151.H, No.9843, Test A.39:

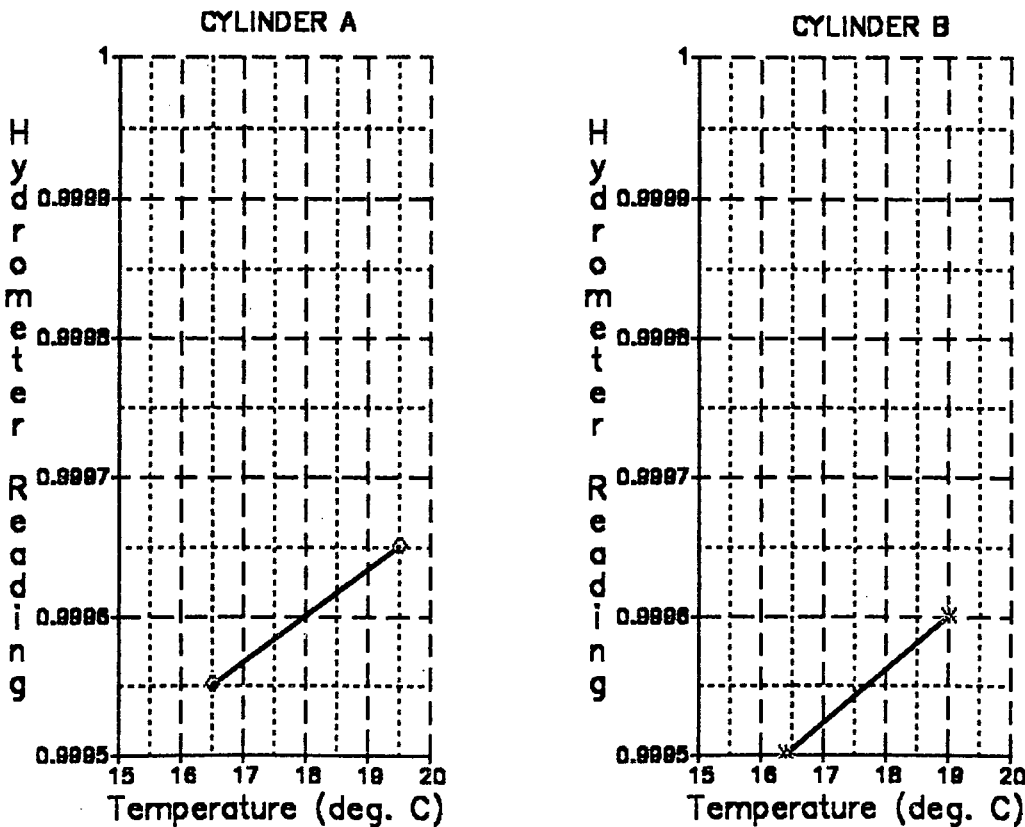


Figure A.02: Temperature Calibration of Hydrometer - (1) distilled water without dispersing agents.

¹ - refer to step J.
² - refer to step I.

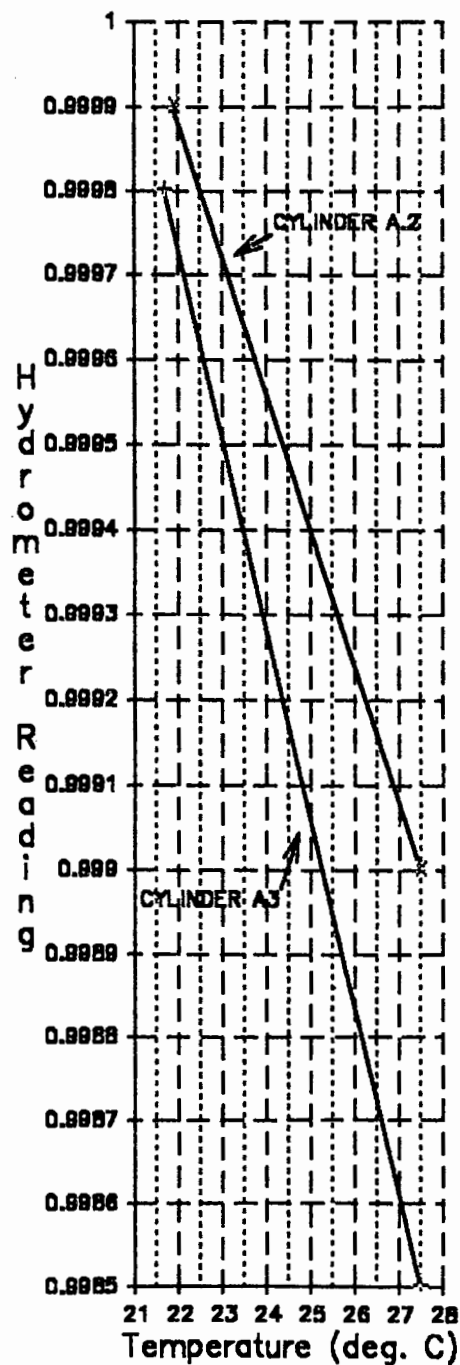
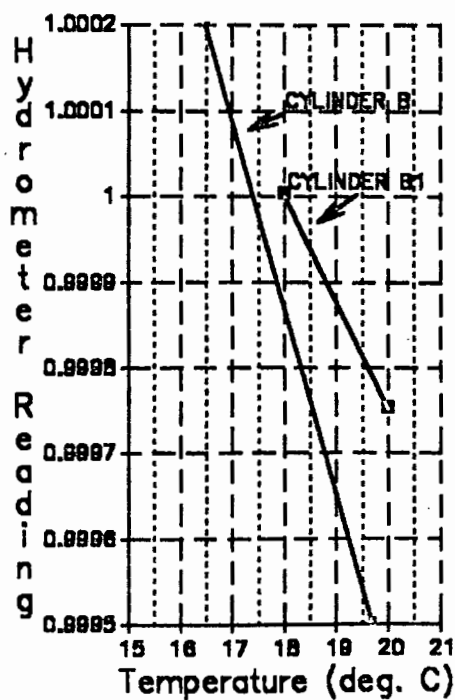
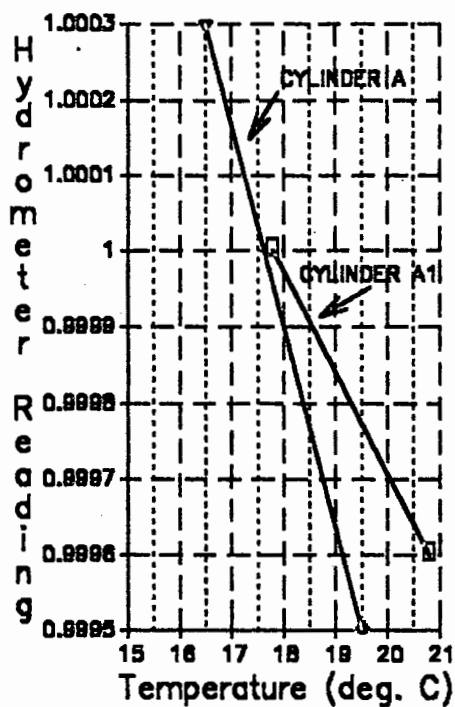


Figure A.03: Temperature Calibration of Hydrometer - (2) distilled water plus 10 cc of each sodium silicate and sodium oxalate.

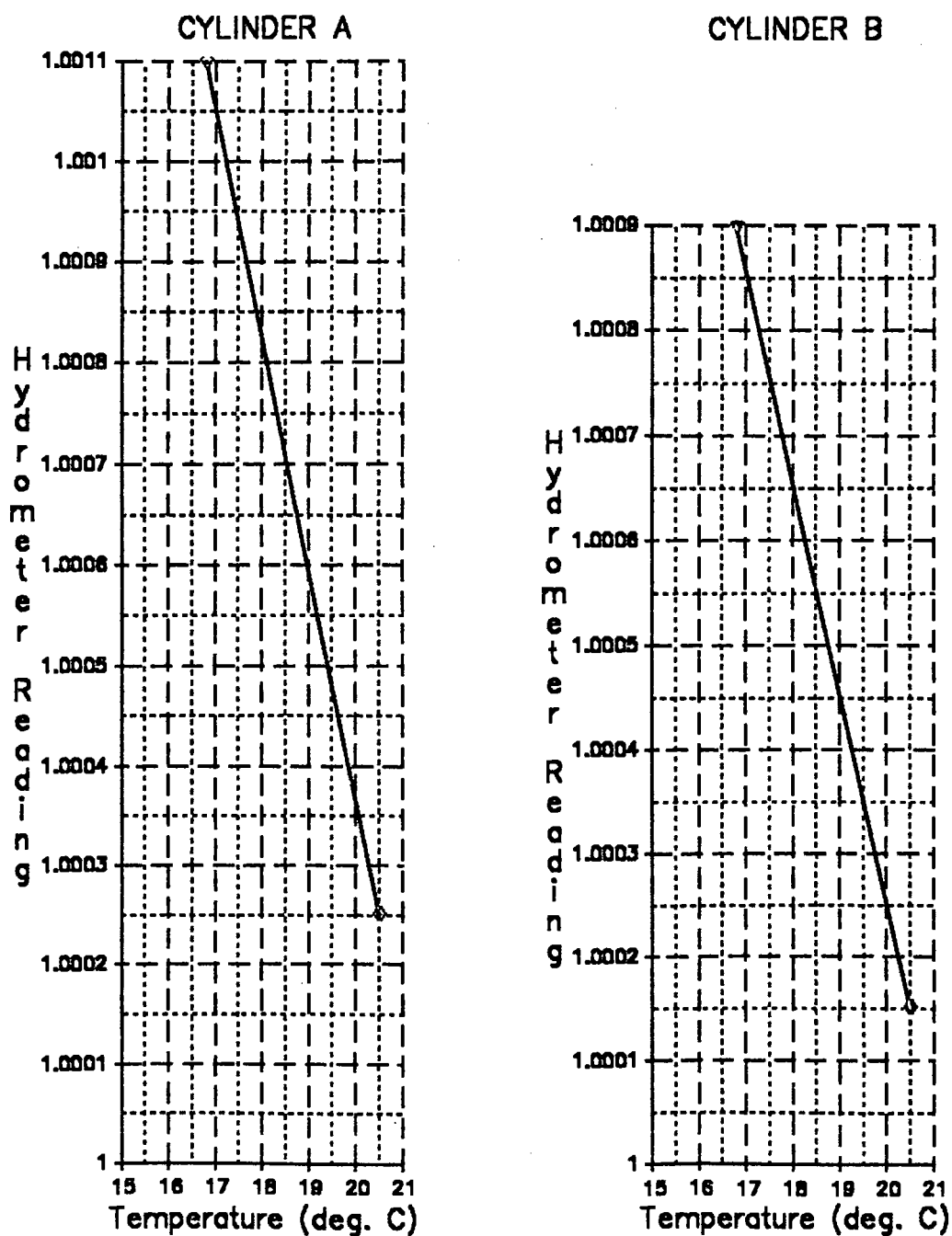


Figure A.04: Temperature Calibration of Hydrometer - (3) distilled water plus 20 cc of each sodium silicate and sodium oxalate.

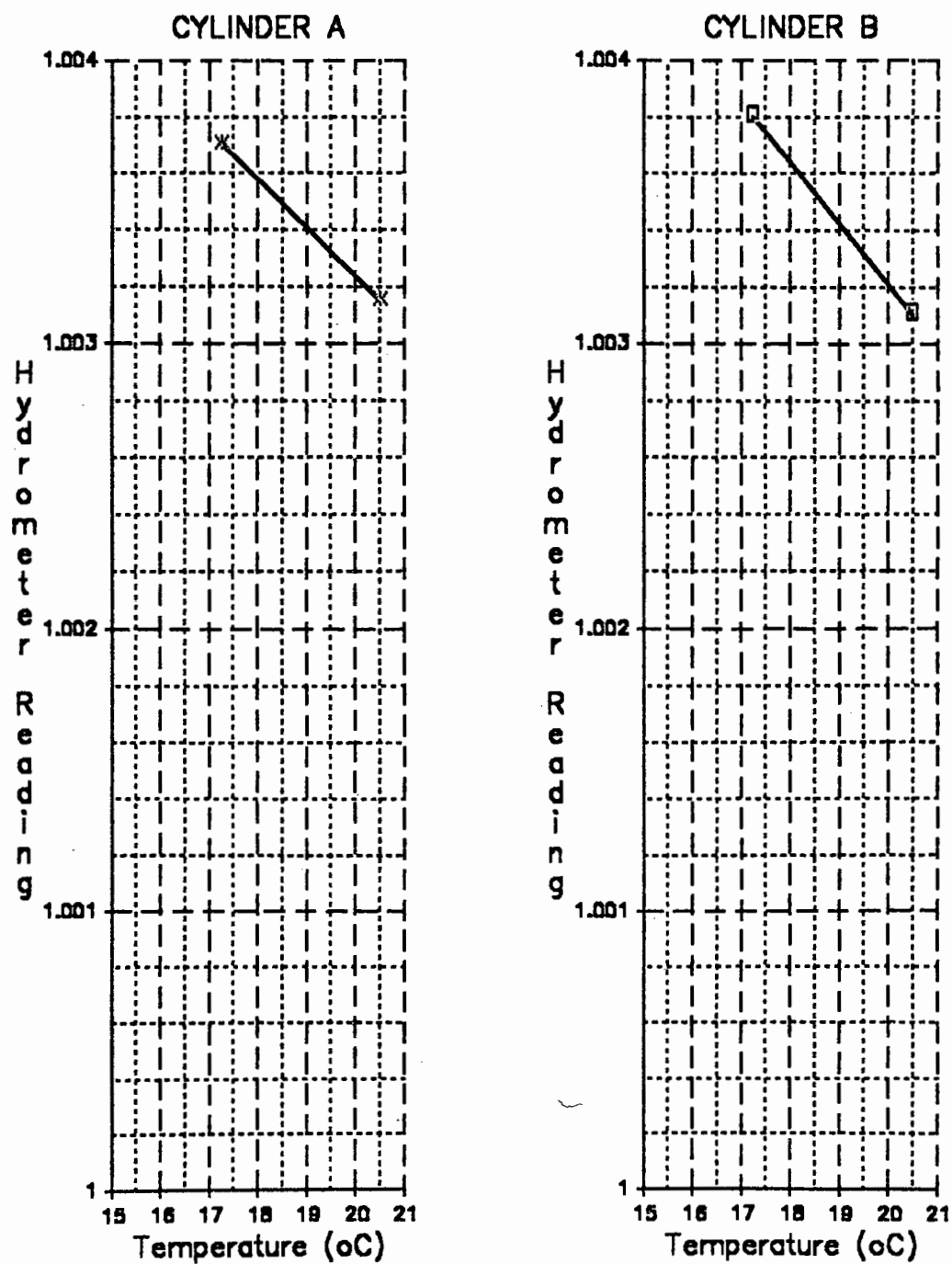


Figure A.05: Temperature Calibration of Hydrometer - (4) distilled water plus 125 cc of sodium hexametaphosphate.

A.4.7 Specific Gravity

Definition:-

(That is, the relative specific density of the soil particles).

"It is defined as the ratio of weight in air of a given volume of a material at a stated temperature, to the weight in air of an equal volume of distilled water at a stated temperature."

The Specific Gravity Test:-

This soil test procedure is used to determine the relative specific density of the soil particles by means of a specific gravity 'G_s' bottle.

Apparatus required:-

- (i) A 1000 ml specific gravity bottle, also known as a pycnometer, and a small flat piece of glass to enable the top to be closed without entrapping air.
- (ii) A 250 ml glass beaker.
- (iii) Supply of distilled water.
- (iv) Electric mixer capable of 1000 revolutions per minute.
- (v) De-airing equipment consisting of an air pump with connecting pipe and fittings.
- (vi) A balance capable of weighing 2000 grams, accurate to 0,1 g.
- (vii) A large container for oven drying, capable of carrying about 2 litres of the water-soil solution.
- (viii) A thermometer graduated to 0,5°C.
- (ix) A drying oven, thermostatically controlled, and capable of maintaining a temperature of 105 ± 5°C.

Procedure:-

A) Weigh approximately 150 grams of soil (See procedure for 'Dry preparation' of soil samples) in the 250 ml beaker. Add distilled water to cover the soil and leave overnight. Note: At this stage record the mass of the large 'oven drying' container to be used later.

B) Carefully wash, clean and dry the empty 1000 ml 'G_s' bottle plus piece of glass - record the mass [W_f].

C) Fill up the G_s bottle with de-aired distilled water. When full, use piece of glass to level off the excess water and remove all bubbles. Use cloth to dry the outside of the bottle. Record the mass of the bottle with water and the piece of glass [W_a]. Record the water temperature [T_i].

Note: To de-air the distilled water inside the 'G_s' bottle, full vacuum suction is applied in stages: usually the bottle is first filled to the half way mark and suction applied until no more air bubbles come out of solution; the procedure is repeated at the three quarter and full stages. Since suction causes the temperature to drop, allow the bottle with contents to warm up to room temperature before recording the mass.

D) Transfer the soil in the beaker to the electric mixer cup. Add water to bring to the half full mark. Switch on the mixer and allow to mix for about one minute.

E) Transfer the soil-water mix to the 'G_s' bottle - wash all the soil into the bottle using distilled water. The mixture in the bottle should be at about the half way mark. Apply suction to the bottle with contents, for as long as required - every now and then shake the bottle vigorously to help releasing the entrapped air. This operation is carried out for as long as it takes to remove all the entrapped air, that is, to de-aerate the mixture - usually the suction is kept on for at least half an hour. Use distilled water to fill the 'G_s' bottle to the three quarter mark - repeat the suction operation. And, again with the 'G_s' bottle full. Allow the bottle with contents to warm up to room temperature.

F) Top up to the brim and use the piece of glass to level off the excess distilled water in the 'G_s' bottle. Use a cloth to dry the outside of the bottle. Record the mass of the bottle with the soil-water solution and the piece of glass [Wb]. Record the soil-water temperature [Tx].

G) Very carefully transfer the contents of the 'G_s' bottle into the large 'oven drying' container. Use distilled water to ensure that all contents of the 'G_s' bottle are washed into the large 'oven drying' container. Carefully place the container into the oven set at $105 \pm 5^{\circ}\text{C}$, and leave overnight.

H) Remove the container from the oven and let it cool to room temperature. Note the mass of the container with the oven dry soil, and subtract the mass of the container. Record the mass of oven dry soil [Wo].

Calculation of the Specific Gravity 'G_s' :-

$$\text{The Specific Gravity 'G}_s\text{' , Tx/Tx}^{\circ}\text{C} = \frac{\text{Wo}}{\text{Wo} + (\text{Wa} - \text{Wb})}$$

Where:

Wo = Mass of oven dry soil (g)

Wa = Mass of the 'G_S' bottle with water at the desired temperature 'Tx'(g)

Wb = Mass of the 'G_S' bottle with soil-water at temperature 'Tx'(g).

Note: The required value of 'Wa' at temperature 'Tx'(g) is,

$$Wa \text{ (at 'Tx')} = \frac{\text{density, water at 'Tx'}}{\text{density, water at 'Ti'}} \times [Wa(\text{at 'Ti'}) - Wf] + Wf$$

Where:

Ti = Observed temperature of water (°C)

Wf = Mass of 'G_S' bottle (g)

The Specific Gravity values reported are normally based on water at the temperature of 20°C. Therefore,

The Specific Gravity 'G_S', $Tx/20^{\circ}C = K \times G_S, Tx/Tx^{\circ}C$

$$\text{Where: } K = \frac{\text{Relative density of water at 'Tx'}}{\text{Relative density of water at } 20^{\circ}C}$$

Table A.04: Relative density of water and conversion factor 'K' for various temperatures.

Temperature °C,	Relative density,	Water Correction factor 'K'
18	0,9986244	1,00039
19	84347	20
20	82343	1,00000
21	80233	0,99979
22	78019	957
23	75702	933
24	73286	909
25	70770	884
26	68156	858
27	65451	831
28	62652	803
29	59761	774
30	0,9956780	0,99744

Results:-

Two Specific Gravity tests are done for each soil sample - the two 'G_S' results should agree within 0,005. If they do not, a third 'G_S' determination is required.

A.4.8 pH Value of Soil Suspension

Introduction:-

The pH value of a soil suspension, as defined in chapter two (refer to macro studies - pH measurements) is determined by measuring the hydrogen ion concentration in the suspension with a calibrated pH meter. The pH test provides a measure of the acidity of the soil sample. It is determined by inserting a special probe into a mixture of soil and water that has been stirred gently.

Apparatus required:-

- (i) An electrically operated pH meter with temperature compensation, accurate to 0,02 pH units in the range pH = 0 to pH = 14;
 - (ii) Stirring device, with adjusting speed (preferably of the magnetic rotating type);
 - (iii) Glass beaker of 600 ml size (or greater);
 - (iv) Balance to weigh up to 100 g, accurate to 0,1 g.
 - (v) Thermometer to read from 0°C to 50°C;
- Other accessories (optional): A polythene wash bottle with distilled water; Glass beaker and stirring rod (or similar); Cover glasses for the beakers; Buffer solutions at pH 4 and pH 9; A combination glass/calomel reference electrode with a high strength bulb to fit the pH meter.

Method:-

Preparation of soil material: Prepare at least 50 grams of material finer than 0,425 mm as described in the preparation of soil samples for testing¹ - the same material used for the determination of the Consistency Limits may be tested; Weigh out 50 g of the prepared soil (accurate to 0,1 g), transfer to glass beaker and top up to 500 ml mark with distilled water; Cover the beaker and allow to stand for a few hours (preferably overnight).

Determination of pH: Start stirring the contents (soil suspension previously left standing for at least 2 hours), using the magnetic rotating device, for at least 30 minutes; Insert the pH probe and record the reading (Note: the salt bridge of the reference electrode, visible as a small spot, should be covered by the solution but without the electrode touching the bottom of the beaker); Repeat at 5 minute intervals until a constant pH reading is obtained. Remarks: For meters without automatic temperature compensation, the temperature of the suspension should be measured first and then set on the pH meter; Manufacturer's instructions should be followed in order to put the meter in operation; After removing the electrode rinse with distilled water (using wash bottle) and dry with tissue paper.

¹ - refer to section A.3.

Readings recorded:

- (i) Record the constant pH reading (to the nearest 0,02) as being the pH of the soil;
- (ii) The temperature (at which the pH reading was taken) should also be recorded.

Additional notes:

Set up and calibrate the pH meter according to the manufacturer's instructions with buffer solutions at pH 4 and 9 - should be done prior to the beginning of the testing;

The tip of the combination electrode should be kept immersed in distilled water for at least one hour prior to testing, in order to wet the salt bridge in the reference electrode - the meter should be kept immersed in distilled water between tests;

For field determinations use may be made of colorimetric methods, or pH paper, for less accurate determinations of pH.

A.5 COMPACTION TESTS*Introduction:-*

The main purpose of a laboratory compaction test is to determine the proper amount of mixing water to use when compacting the soil in the field and the resulting degree of denseness which can be expected from compaction at this optimum water content. In the compaction test, a Maximum Dry Density 'MD_p' (and a maximum wet density 'MW_p') is obtained at a certain Optimum Moisture Content 'OMC', from which the particular field requirements can be proposed.

The Standard AASHTO (American Association of State Highway and Transportation Officials) or Proctor, and the Modified¹ AASHTO compaction tests:-

Standard and Mod AASHTO were introduced in "Soil Density versus Water Content Relationship" of Chapter Two². A summary of the requirements for the two types of compaction tests (used in this thesis) is given below:

	Mould size (in)	Hammer weight (lbs)	Compact. layers	Hammer drop (in)	Blows/ layer	Energy a) ft.lb/ft ³ b) joules/m ³
Std. AASHTO	4,6x4	5,5	3	12	25	a) 12400 b) 593,7
Mod. AASHTO	4,6x4	10	5	18	25	a) 56300 b) 2695,6

Apparatus required:-

- (i) Steel mould of size 4,6 in height (116,8 mm) x 4 in diameter (101,6 mm), with matching base plate and collar;
- (ii) Hammers for compaction test - weight of 5,5 lbs for Std. AASHTO (2,49 kg), and 10 lb for Mod AASHTO (4,54 kg);
- (iii) Large tray for mixing the soil sample with water;
- (iv) Water spray bottle - (to assist in obtaining a more constant soil-water mixture);
- (v) Trowel and garden spade for mixing soil;
- (vi) Soil mortar and rubber covered pestel (for breaking up the soil aggregations);
- (vii) Spatula or straight edge, for levelling the top side;
- (viii) A one inch wide brush (25 mm);
- (ix) Balance capable of weighing 10 kg to the nearest 1 g;
- (x) Dishes for water content determination (to take between 50 and 100 g of soil);
- (xi) Balance capable of 150 - 200 g, accurate to 0,01 g;
- (xii) Oven capable of 105 ± 5°C.

¹ - usually referred to as "Mod AASHTO".

² - refer to section 2.2 "Macro Studies".

Procedure:-

- 1) An amount of about 3000 g of air dry soil is placed on the large tray as described in the preparation of soil samples for testing¹. Add approximately 3 % by mass of distilled water (use the spray bottle), and mix thoroughly with the soil using the trowel and spade.
- 2) Assemble the mould and base plate - record the mass. Also record the mass of the dish for water content determination.
- 3) Transfer enough soil to the mould for the compaction of one layer. Start compaction using the required hammer (Note: remember to place the base of the hammer squarely on top of the soil inside the mould - the hammer stands vertical) - lifting the hammer vertically to the end of its travel, let it drop freely and hit the soil below with one blow. Seven such blows are to be dealt with at constant intervals around the side plus one in the middle of the soil surface. The procedure is repeated twice more, with an extra blow in the middle at the end, for a total of 25 blows per layer.
- 4) Repeat the previous stage 3), until the required number of compacted layers is achieved. At the end, carefully remove the collar, and level the soil sticking out at the top (use spatular or straight edge). Use the brush to clean the mould and base plate - take care not to disturb the compacted soil.
- 5) Place the mould with soil (and base plate) on the balance - record the mass to the nearest 1 gram.
- 6) Remove the base plate - take out a representative moisture content soil sample using cuttings from the top, middle and bottom of the (compacted) soil sample. Place these in the moisture content dish (keep it covered in between the cuttings), and when the representative sample is obtained, place it on the balance and record its mass to the nearest 0,01 g. Place the dish inside oven ($105 \pm 5^{\circ}\text{C}$) for a few hours, preferably overnight - afterwards, record the oven dry mass of the sample.
- 7) Remove the remainder of the soil sample from the mould, and mix with previously left over soil from 3) and 4). Add another 3 % (by mass) of distilled water - this amount varies, depending whether the soil sample is mainly sand or clay. Repeat 1) to 6), that is, another full compaction cycle.

¹ - refer to section A.3 of this appendix.

8) Repeat 7) until such time as the 'MDD' and 'OMC' (stage) is reached. After that two more compaction cycles, on the wet side of OMC, should be carried out. Ideally one should obtain 2 points on the dry side of the 'OMC', and two more on the wet side. This way a truly representative compaction curve (that is, the density versus water content) for the particular soil samples should be obtained. It may be necessary to obtain more points in between the five points just mentioned in order to obtain a more accurate 'OMC' or 'MDD'.

Calculations:- (In Road Laboratories the units used are kg/m^3)

(i) Wet Density¹,

$$D_W = \frac{\text{weight of compacted soil 'M' x } 9.80665}{\text{volume of compaction mould 'VT'}} \quad (\text{KN/m}^3).$$

Notes: VT = Total volume of Sample x 'V_T'.
For units of kg/m^3 replace 9.80665 by 1000.

(ii) Water content of compacted sample,

$$w = \frac{\text{weight 'wt.' of water}}{\text{weight of oven-dry sample}},$$

Note: wt. of water = wt. moist sample - wt. oven-dry sample.

(iii) Dry Density,

$$D_D = \frac{D_W}{1 + w} \quad (\text{KN/m}^3).$$

Note: The following are relationships between dry density 'D_D', void ratio 'e', and degree of saturation 'S_r',

$$D_D = \frac{G_s}{1 + e} w_D \quad (\text{KN/m}^3), \text{ and}$$

$$e = \frac{w \times G_s}{S_r}$$

where:

G_s = specific gravity of soil²; and,
w_D = specific weight of water (9.80665 kn/m^3).

¹ - also known as "bulk, or moist specific weight".

² - refer to section A.4.7.

Presentation of results:-

The results of the compaction tests (for each soil type), are tabulated and presented in a plot of dry (or wet) density versus water content. The plots include the Maximum Dry Density 'MD_D' and the Optimum Moisture Content 'OMC' for each Standard or Modified AASHTO test carried out in each soil type¹. Curves for the percentage of saturation are also included.

Chapter two of this thesis includes scales of void ratio, porosity and degree of saturation, in addition to the dry density curves, for both the Standard and Modified AASHTO compaction tests.

¹ - refer to section A.7.6 "Standard and Modified AASHTO Compaction Tests".

A.6 REFERENCES FOR APPENDIX A

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A.7 TEST RESULTS

A.7.1 Consistency Limits (Part 1): Liquid Limit; Linear Shrinkage; Plastic Limit; and, Plasticity Index.

Site 11, Rosebank (Cape):-

Table A.05: Site 11, Rosebank - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-I.80; 2-I.36; 3-II.209).

Liquid Limit, 'LL':-

Water Content 'w' (%):

76.9 78.9 83.3 58.6 59.1 60.4 68.9 69.5 71.6 71.6

Number of 'Blows':

29 25 18 32 25 17 30 25 16 25

Linear Shrinkage, 'LS':-

Linear Shrinkage (%):

12.2 10.1 11.2 12.1

Mean of Result: Linear Shrinkage, 'LS' = 11.4%

Plastic Limit, 'PL':-

Water Content 'w' (%):

34.4 33.8 27.8 27.4 30.0 30.7

Mean of 'w' results: Plastic Limit, 'PL' = 30.7%

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL' - 'PL' = 38.

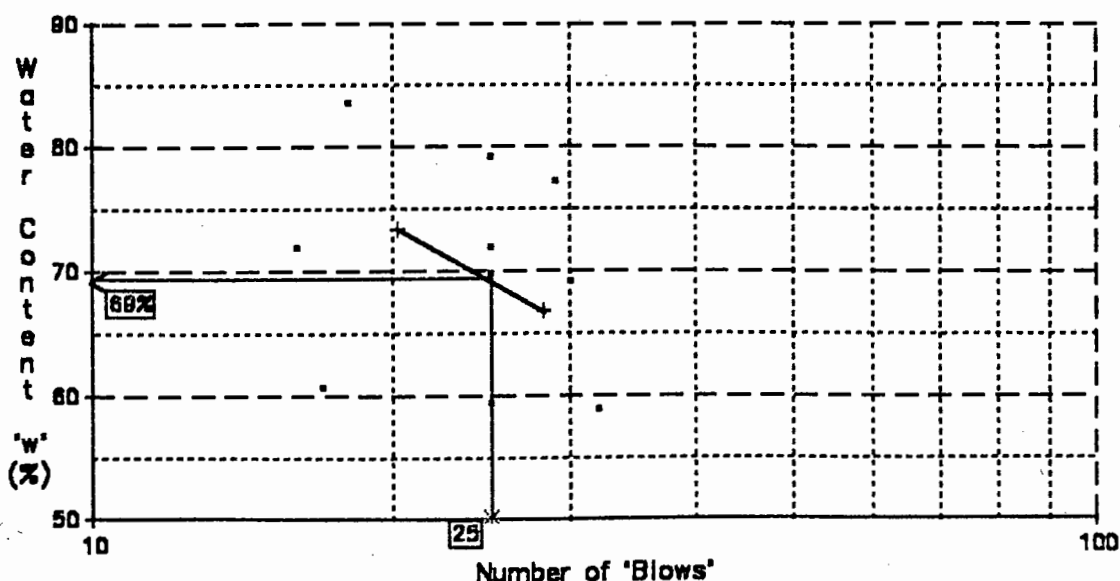


Figure A.06: Site 11, Rosebank - [Liquid Limit] Number of Blows versus Water Content 'w'.

Site 36, Rondebosch (Cape):-

Table A.06: Site 36, Rondebosch - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.205; 2-II.209; 3-II.222; 4-A.49).

Liquid Limit, 'LL':-

Water Content 'w' (%): 46.2 46.6 46.5 46.6 47.9 48.6 47.4
 Number of 'Blows': 30 25 22 30 25 19 25

Linear Shrinkage, 'LS':-

Linear Shrinkage (%): 8.3 8.4 8.3
 Mean of Result: Linear Shrinkage, 'LS' = 8.3%

Plastic Limit, 'PL':-

Water Content 'w' (%): 23.3 23.8 23.3 22.8
 Mean of 'w' results: Plastic Limit, 'PL' = 23.3%

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL' - 'PL' = 24.

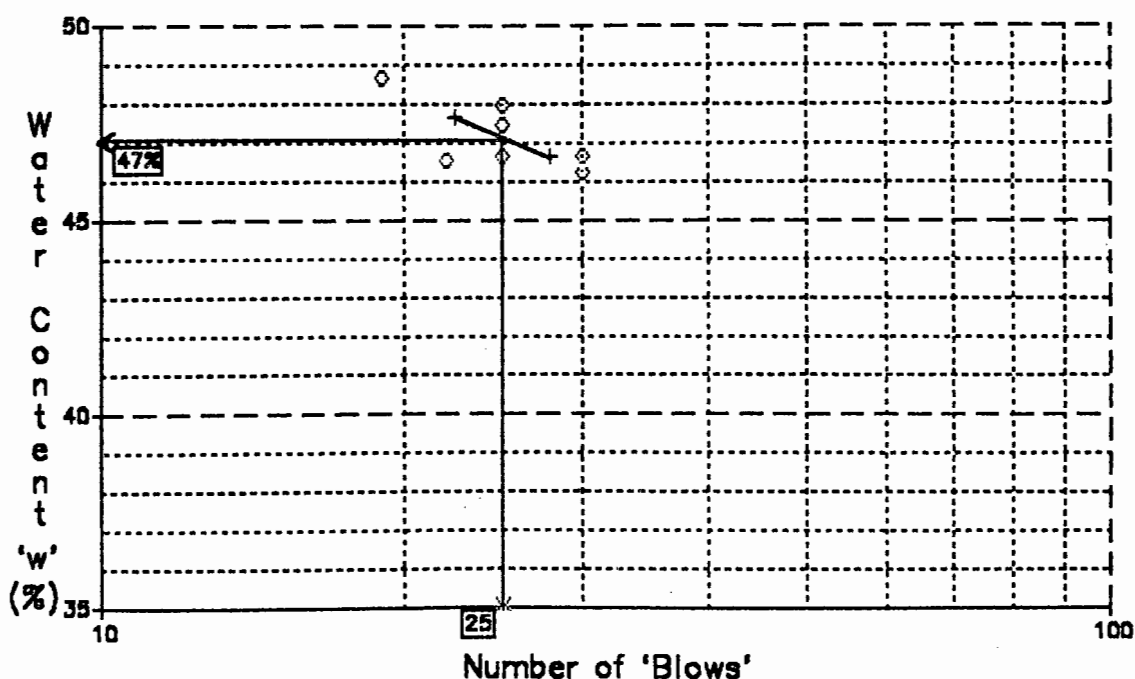


Figure A.07: Site 36, Rondebosch - [Liquid Limit] Number of Blows versus Water Content 'w'.

Site 30, Hout Bay (Cape):-

Table A.07: Site 30, Hout Bay - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.205; 2-A.60; 3-A.49).

Liquid Limit, 'LL':-

Water Content 'w' (%)	50.0	50.6	50.9	49.4	44.7	46.8	49.2
Number of 'Blows'	32	25	21	25	33	25	20

Linear Shrinkage, 'LS':-

Linear Shrinkage (%): 6.1 6.5 6.5
 Mean of Result: Linear Shrinkage, 'LS' = 6.4%

Plastic Limit, 'PL':-

Water Content 'w' (%): 31.1 30.6 26.7 27.5
 Mean of 'w' results: Plastic Limit, 'PL' = 29.0%

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL' - 'PL' = 20.

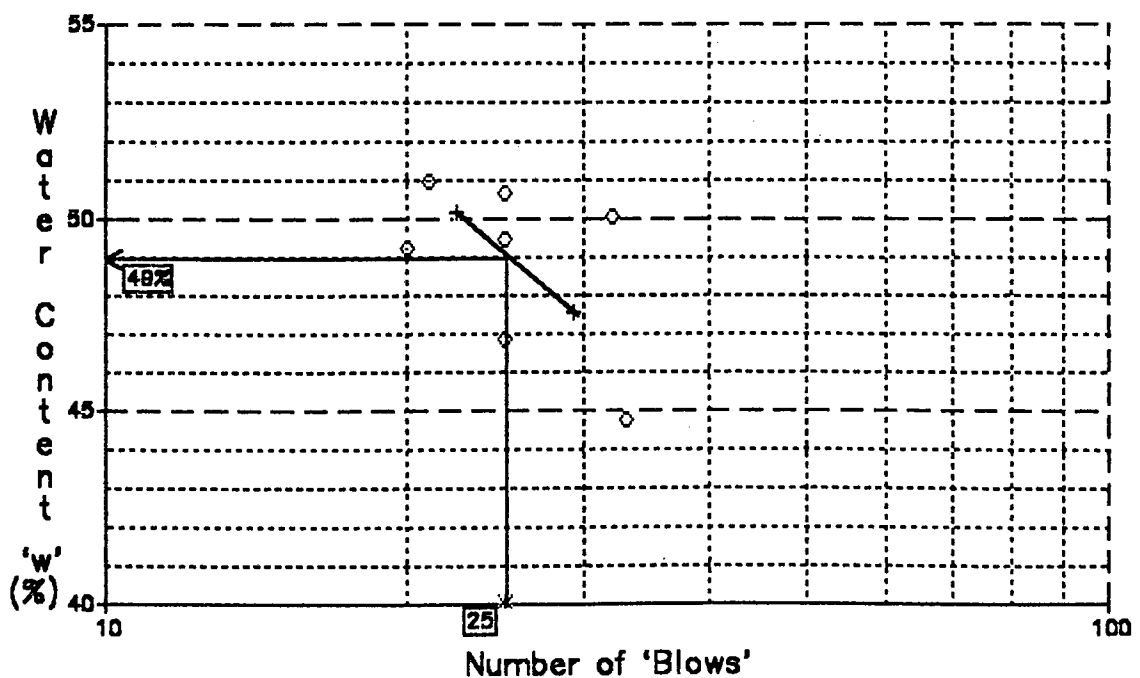


Figure A.08: Site 30, Hout Bay - [Liquid Limit] Number of Blows versus Water Content 'w'.

Site A, Berea Road (Durban):-

Table A.08: Site A, Berea Road - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-I.119; 2-II.209; 3-II.222; 4-A.50).

Liquid Limit, 'LL':

Water Content 'w' (%)									
23.4	23.4	23.6	26.8	27.4	27.1	27.7	22.9	22.5	24.7
Number of 'Blows'									
30	25	20	35	25	21	25	32	25	14

Linear Shrinkage, 'LS':

Linear Shrinkage (%)				3.7	4.0	3.8	3.2
Mean of Result: Linear Shrinkage, 'LS' =				3.7%			

Plastic Limit, 'PL':

Water Content 'w' (%)	12.7	12.2	13.7	13.6	13.1
Mean of 'w' results: Plastic Limit, 'PL' =	13.1%				

Plasticity Index, 'PI':

Plasticity Index of the Soil, 'PI' = 'LL' - 'PL' = 12.

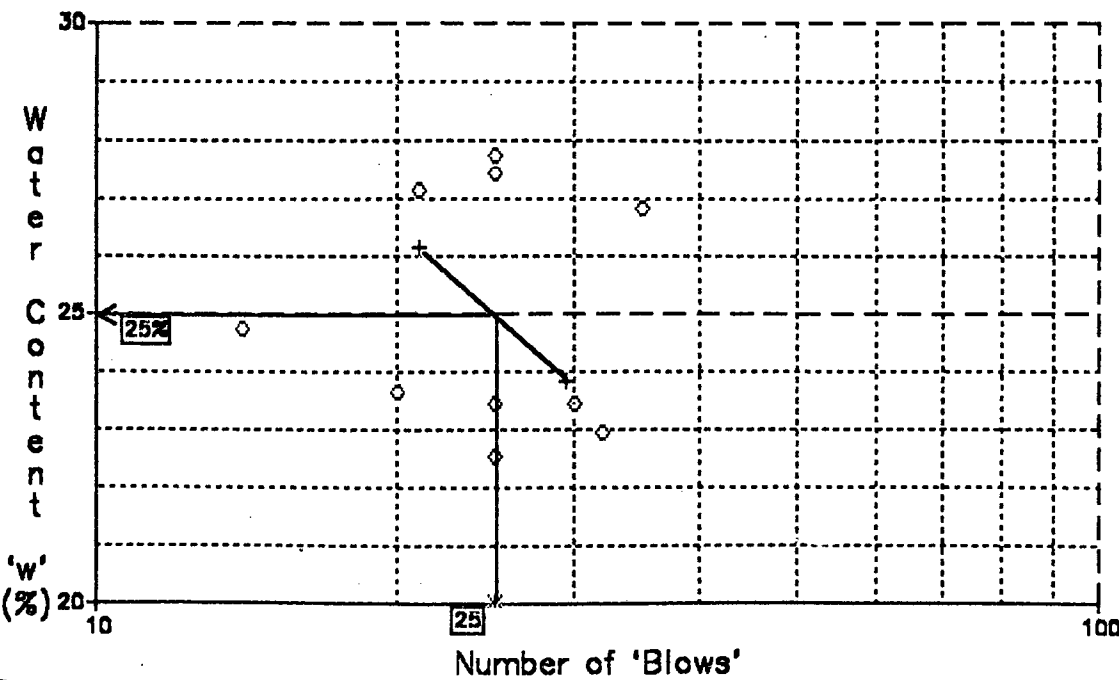


Figure A.09: Site A, Berea Road - [Liquid Limit] Number of Blows versus Water Content 'w'.

Site 7, Mowbray (Cape):-

Table A.09: Site 7, Mowbray - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.209; 2-II.222; 3-I.105; 4-I.74).

Liquid Limit, 'LL':-

Water Content 'w' (%): 45.7 47.0 48.3 46.7 45.6 47.3 47.9
 Number of 'Blows': 29 25 20 25 31 25 22

Linear Shrinkage, 'LS':-

Linear Shrinkage (%): 10.4 11.2 10.5 10.0
 Mean of Result: Linear Shrinkage, 'LS' = 10.5%

Plastic Limit, 'PL':-

Water Content 'w' (%): 22.9 22.7 25.0 24.2 18.6 18.8
 Mean of 'w' results: Plastic Limit, 'PL' = 22.0%

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL - PL' = 25.

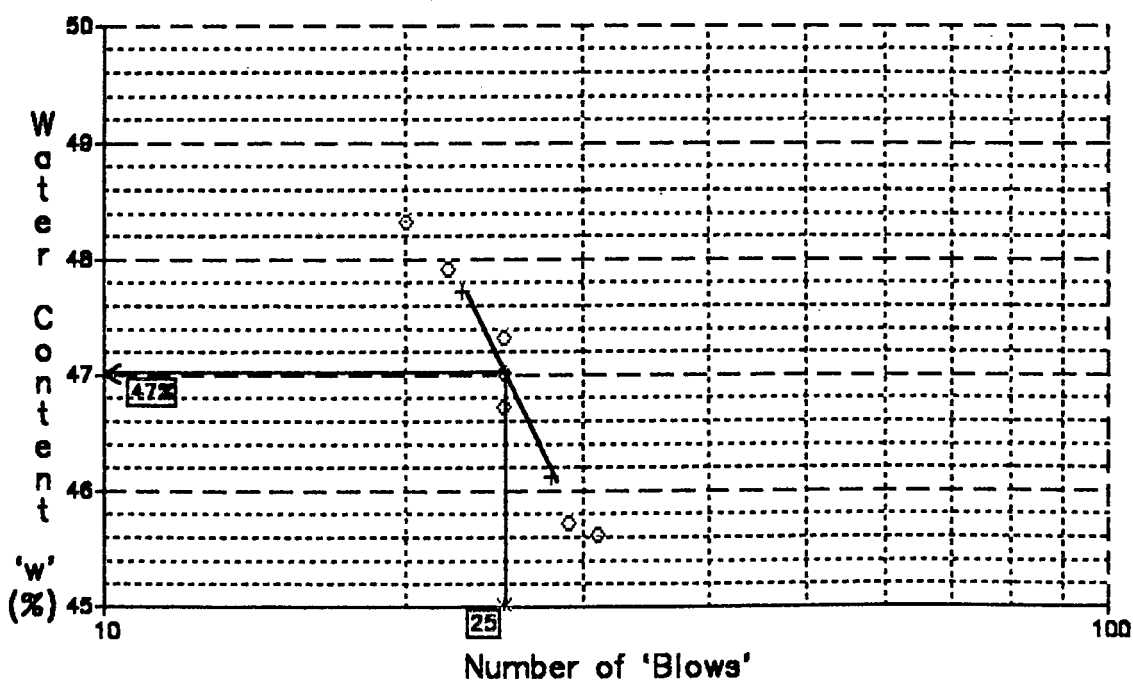


Figure A.10: Site 7, Mowbray - [Liquid Limit] Number of Blows versus Water Content 'w'.

Site B, Francois Road (Durban):-

Table A.10: Site B, Francois Road - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-I.119; 2-II.121).

Liquid Limit, 'LL':-

Water Content 'w' (%)	15.1	15.1	15.2	14.5	14.9	15.1
Number of 'Blows'	34	25	19	29	23	16

Linear Shrinkage, 'LS':-

Linear Shrinkage (%): 0.5
 Mean of Result: Linear Shrinkage, 'LS' = 0.5%

Plastic Limit, 'PL':-

Water Content 'w' (%)	12.9	13.6	12.6	12.4
Mean of 'w' results: Plastic Limit, 'PL'	= 12.9%			

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL' - 'PL' = 2.

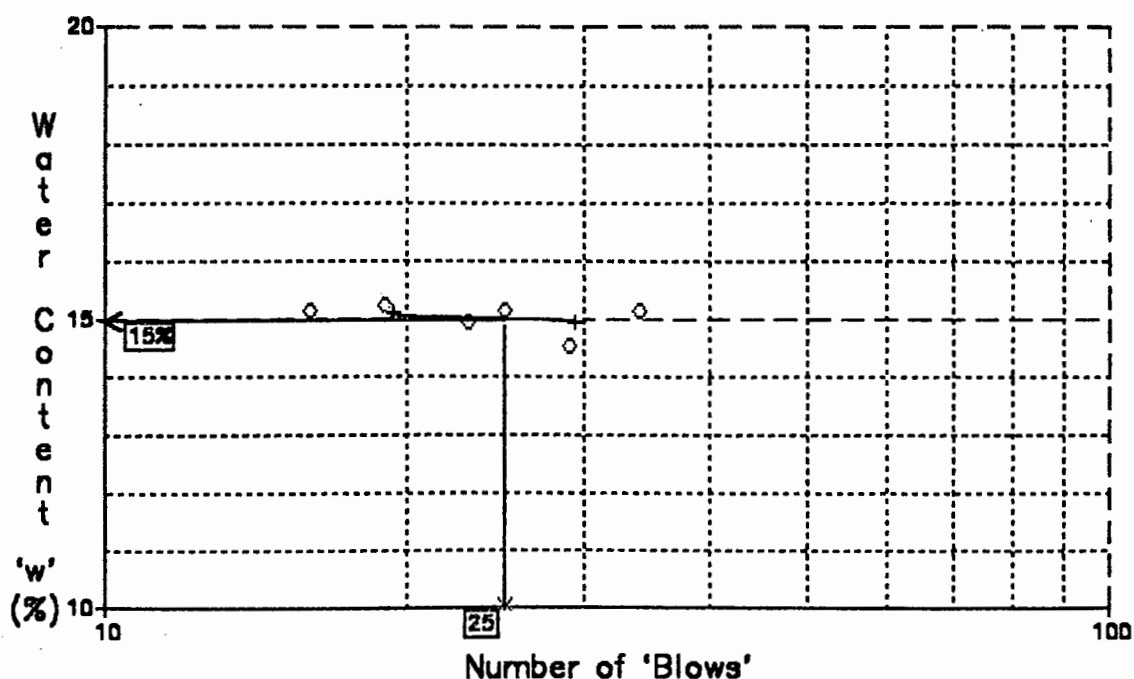


Figure A.11: Site B, Francois Road - [Liquid Limit] Number of Blows versus Water Content 'w'.

Site C, Margaret Mayton Avenue (Durban):-

Table A.11: Site C, Margaret Mayton Avenue - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-I.138; 2-II.97).

Liquid Limit, 'LL':-

Water Content 'w' (%)	20.3	20.5	20.5	19.1	18.8	18.8
Number of 'Blows'	33	25	21	31	28	17

Linear Shrinkage, 'LS':-

Linear Shrinkage (%): 1.8
 Mean of Result: Linear Shrinkage, 'LS' = 1.8%

Plastic Limit, 'PL':-

Water Content 'w' (%)	16.6	16.6	15.2	15.0
Mean of 'w' results: Plastic Limit, 'PL'	= 15.9%			

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL' - 'PL' = 4.

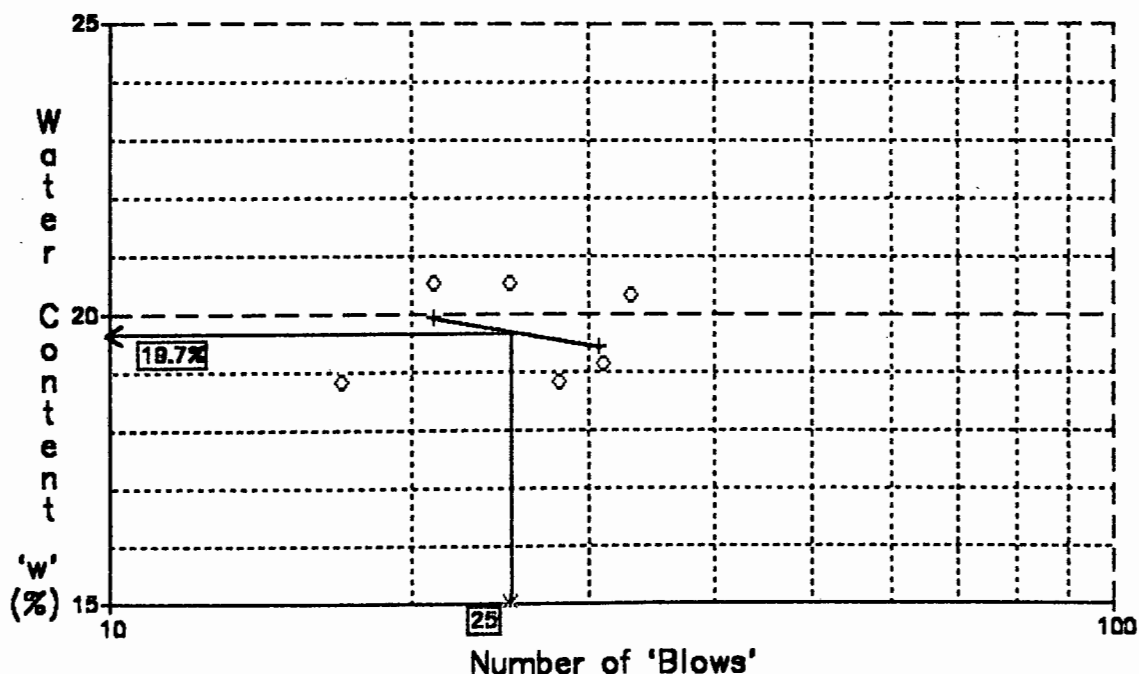


Figure A.12: Site B, Margaret Mayton Avenue - [Liquid Limit] Number of Blows versus Water Content 'w'.

Site D, Rose Hill (Durban):-

Table A.12: Site D, Rose Hill - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-I.138; 2-II.145).

Liquid Limit, 'LL':-

Water Content 'w' (%)	20.2	21.6	22.1	18.3	19.1	20.8
Number of 'Blows'	36	25	19	34	26	20

Linear Shrinkage, 'LS':-

Linear Shrinkage (%): 2.2
Mean of Result: Linear Shrinkage, 'LS' = 2.2%

Plastic Limit, 'PL':-

Water Content 'w' (%):15.3 15.7 14.2 14.3
Mean of 'w' results: Plastic Limit, 'PL' = 14.9%

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL' - 'PL' = 6.

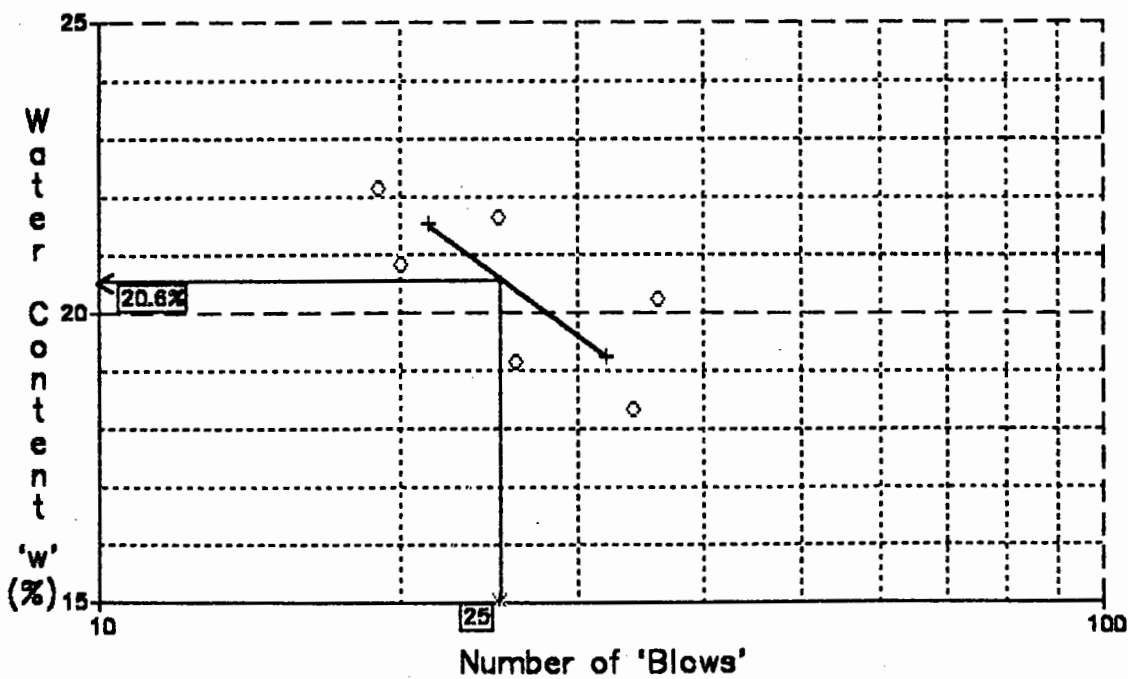


Figure A.13: Site D, Rose Hill - [Liquid Limit] Number of Blows versus Water Content 'w'.

Kaolin K.1 (13% clay size):-

Table A.13: Kaolin K.1 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.209; 2-II.210).

Liquid Limit, 'LL':-

Water Content 'w' (%): 11.8 12.1 12.7 12.3
 Number of 'Blows': 32 25 21 25

Linear Shrinkage, 'LS':-

Linear Shrinkage (%): 0.5 0.3
 Mean of Result: Linear Shrinkage, 'LS' = 0.4%

Plastic Limit, 'PL':-

Water Content 'w' (%): 11.7 11.9
 Mean of 'w' results: Plastic Limit, 'PL' = 11.8%

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL' - 'PL' = 1.

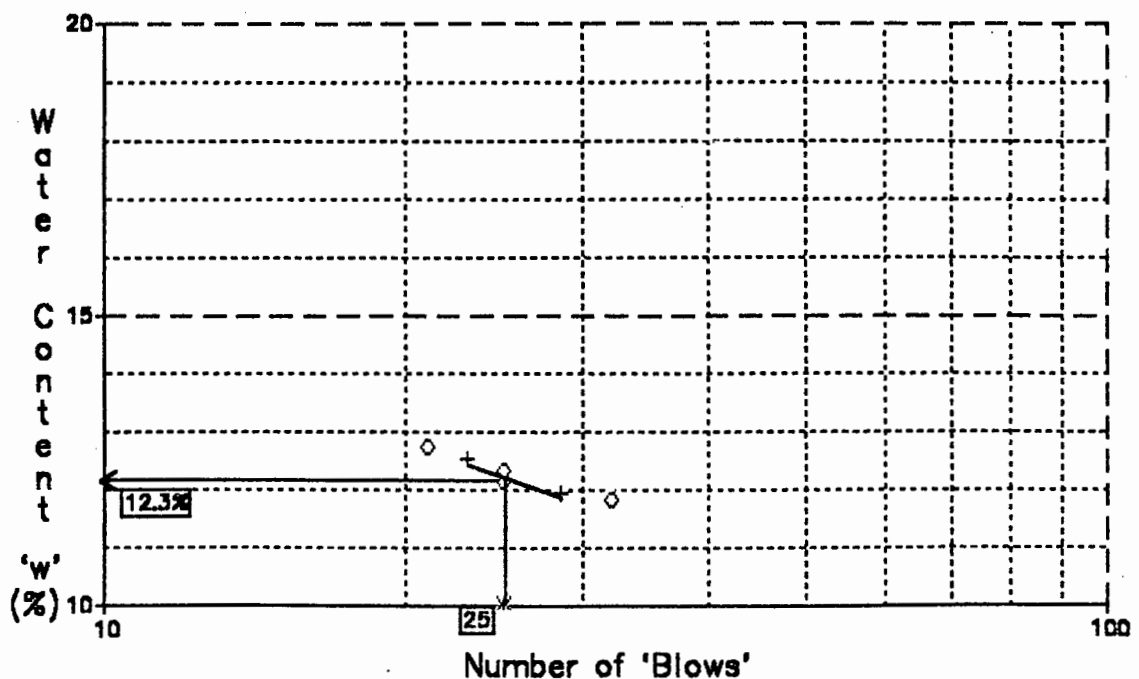


Figure A.14: Kaolin K.1 - [Liquid Limit] Number of Blows versus Water Content 'w'.

Kaolin K.2 (20% clay size):-

Table A.14: Kaolin K.2 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.209; 2-II.210).

Liquid Limit, 'LL':-

Water Content 'w' (%)	13.3	13.4	14.3	14.3
Number of 'Blows'	30	25	22	25

Linear Shrinkage, 'LS':-

Linear Shrinkage (%)	1.4	1.6
Mean of Result: Linear Shrinkage, 'LS'	= 1.5%	

Plastic Limit, 'PL':-

Water Content 'w' (%)	10.1	10.6
Mean of 'w' results: Plastic Limit, 'PL'	= 10.4%	

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL - PL' = 4.

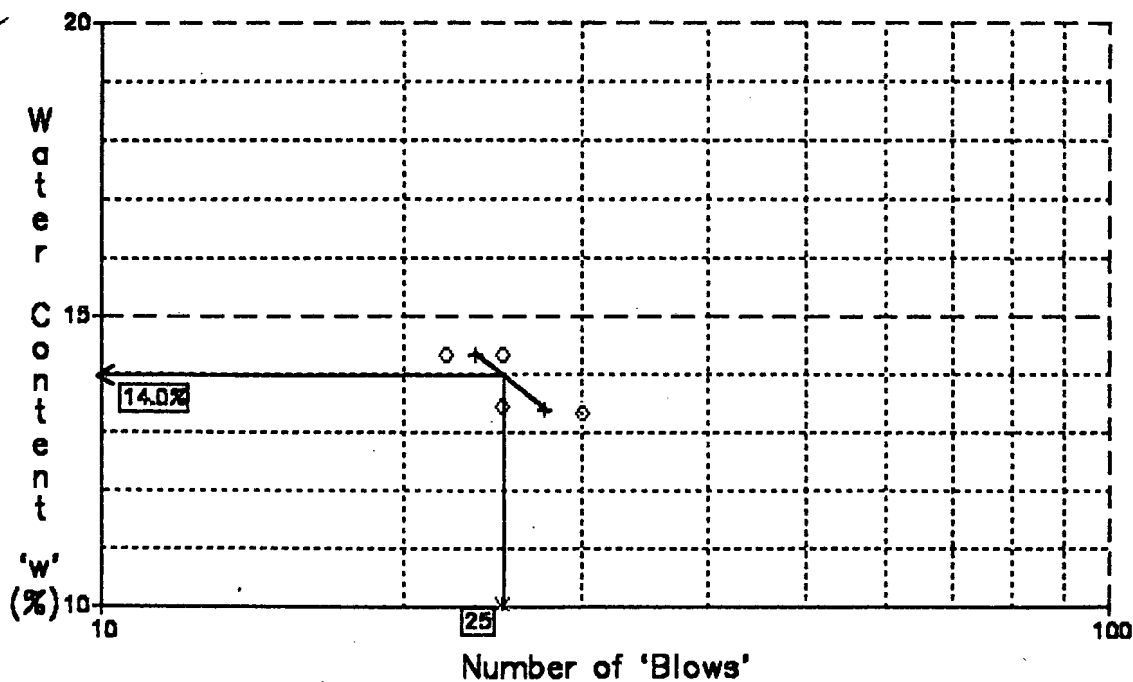


Figure A.15: Kaolin K.2 - [Liquid Limit] Number of Blows versus Water Content 'w'.

Kaolin K.3 (10% clay size):-

Table A.15: Kaolin K.3 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.210 (LHS); 2-II.210 (RHS)).

Liquid Limit, 'LL':-

Water Content 'w' (%):- - -
Number of 'Blows': - - -

Linear Shrinkage, 'LS':-

Linear Shrinkage (%): 0.04
Mean of Result: Linear Shrinkage, 'LS' = 0.0%

Plastic Limit, 'PL':-

Water Content 'w' (%):- -
Mean of 'w' results: Plastic Limit, 'PL' = NP%

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL - PL' = NP.

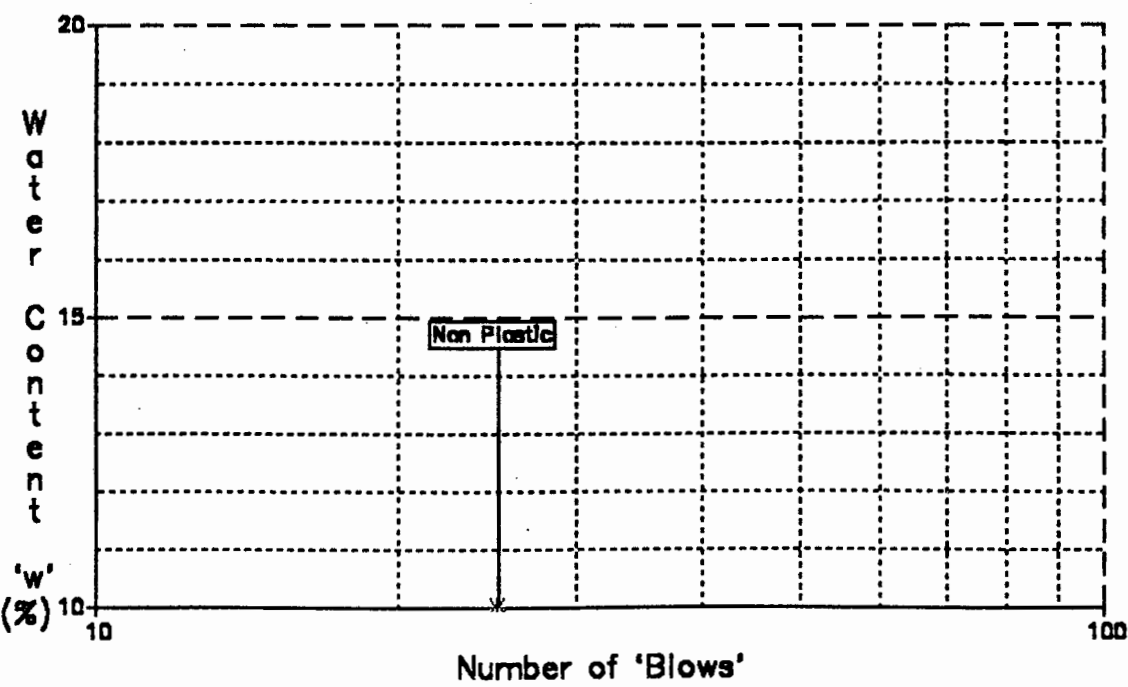


Figure A.16: Kaolin K.3 - [Liquid Limit] Number of Blows versus Water Content 'w'.

Bentonite B.1 (3.5% clay size):-

Table A.16: Bentonite B.1 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Ref: 1-II.232 (LHS); 2-II.232 (RHS); 3-A.56).

Liquid Limit, 'LL':-

Water Content 'w' (%): 21.2 21.0
 Number of 'Blows': 23 25

Linear Shrinkage, 'LS':-

Linear Shrinkage (%): 0.05
 Mean of Result: Linear Shrinkage, 'LS' = 0.1%

Plastic Limit, 'PL':-

Water Content 'w' (%): 20.6 19.5
 Mean of 'w' results: Plastic Limit, 'PL' = 20%

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL - PL' = 1.

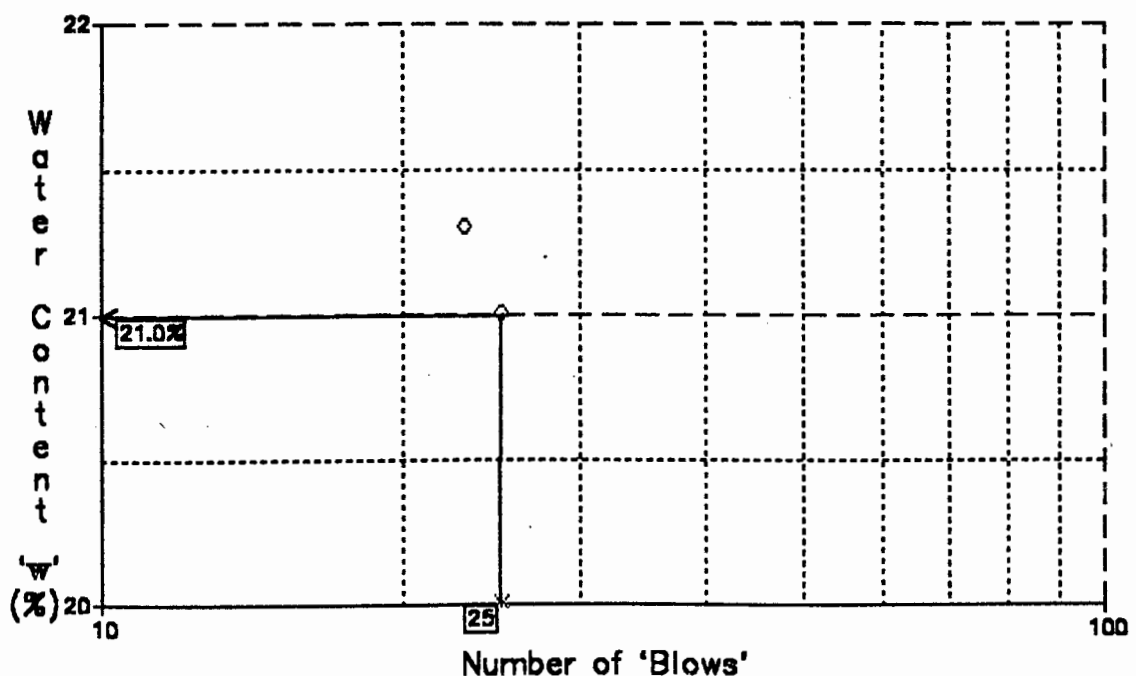


Figure A.17: Bentonite B.1 - [Liquid Limit] Number of Blows versus Water Content 'w'.

Bentonite B.2 (7% clay size):-

Table A.17: Bentonite B.2 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Ref: 1-II.232 (LHS); 2-II.232 (RHS); 3-A.56).

Liquid Limit, 'LL':-

Water Content 'w' (%): 32.2 32.1
 Number of 'Blows': 22 23

Linear Shrinkage, 'LS':-

Linear Shrinkage (%): 0.65
 Mean of Result: Linear Shrinkage, 'LS' = 0.5%

Plastic Limit, 'PL':-

Water Content 'w' (%): 21.3 21.3
 Mean of 'w' results: Plastic Limit, 'PL' = 21.0%

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL' - 'PL' = 11.

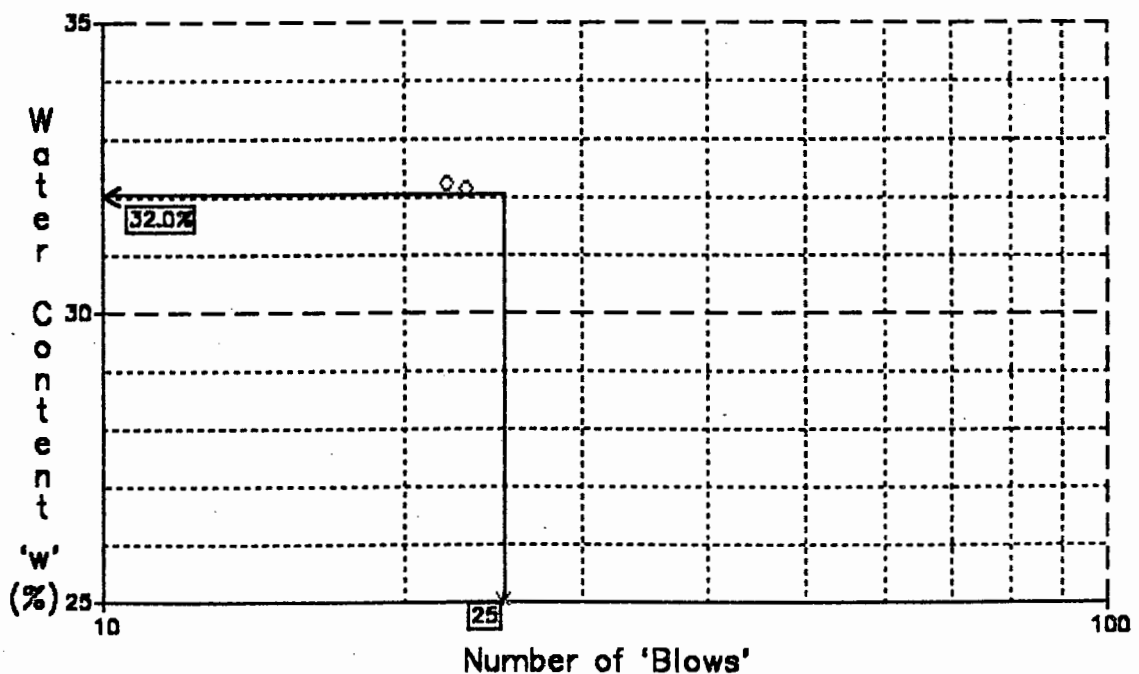


Figure A.18: Bentonite B.2 - [Liquid Limit] Number of Blows versus Water Content 'w'.

Bentonite B.3 (11.5% clay size):-

Table A.18: Bentonite B.3 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.232; 2-II.233; 3-A.56).

Liquid Limit, 'LL':-

Water Content 'w' (%): 46.8 46.0

Number of 'Blows': 20 25

Linear Shrinkage, 'LS':-

Linear Shrinkage (%): 0.08

Mean of Result: Linear Shrinkage, 'LS' = 1.0%

Plastic Limit, 'PL':-

Water Content 'w' (%): 20.6 19.8

Mean of 'w' results: Plastic Limit, 'PL' = 20.0%

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL' - 'PL' = 26.

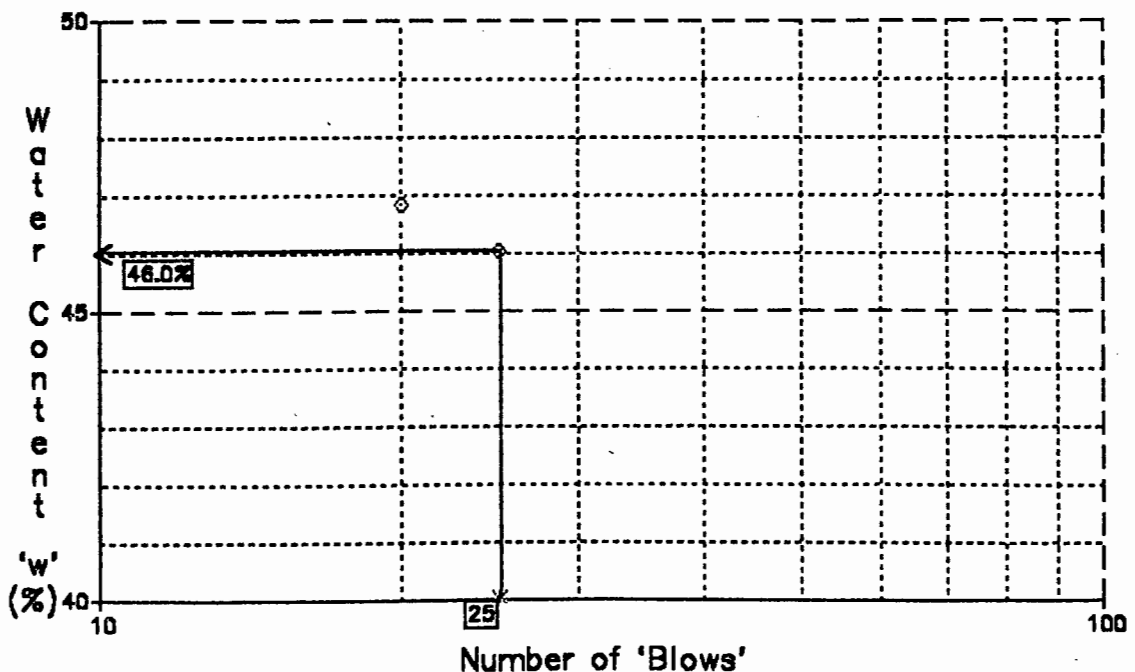


Figure A.19: Bentonite B.3 - [Liquid Limit] Number of Blows versus Water Content 'w'.

Bentonite B.4 (15.5% clay size):-

Table A.19: Bentonite B.4 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: 1-II.232; 2-II.233).

Liquid Limit, 'LL':-

Water Content 'w' (%): 59.1 58.9
 Number of 'Blows': 27 28

Linear Shrinkage, 'LS':-

Linear Shrinkage (%): 1.59
 Mean of Result: Linear Shrinkage, 'LS' = 1.5%

Plastic Limit, 'PL':-

Water Content 'w' (%): 18.5 19.0
 Mean of 'w' results: Plastic Limit, 'PL' = 19.0%

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL' - 'PL' = 40.

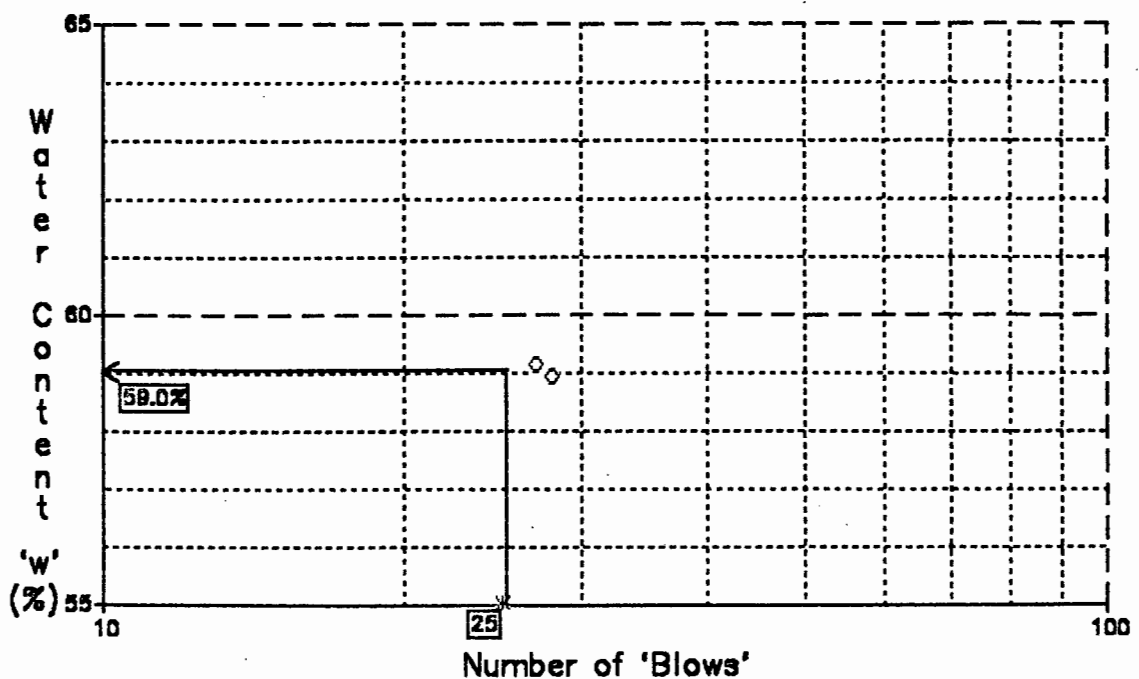


Figure A.20: Bentonite B.4 - [Liquid Limit] Number of Blows versus Water Content 'w'.

Bentonite B.5 (35% clay size):-

Table A.20: Bentonite B.5 - Liquid Limit 'LL', Linear Shrinkage 'LS', Plastic Limit 'PL', and Plasticity Index 'PI' (Test Reference: NSI 6-6-79).

Liquid Limit, 'LL':-

Water Content 'w' (%): 136.8 128.5
 Number of 'Blows': 28 28

Linear Shrinkage, 'LS':-

Linear Shrinkage (%): 6.69
 Mean of Result: Linear Shrinkage, 'LS' = 6.5%

Plastic Limit, 'PL':-

Water Content 'w' (%): 20.6 20.4
 Mean of 'w' results: Plastic Limit, 'PL' = 21.0%

Plasticity Index, 'PI':-

Plasticity Index of the Soil, 'PI' = 'LL' - 'PL' = 112.

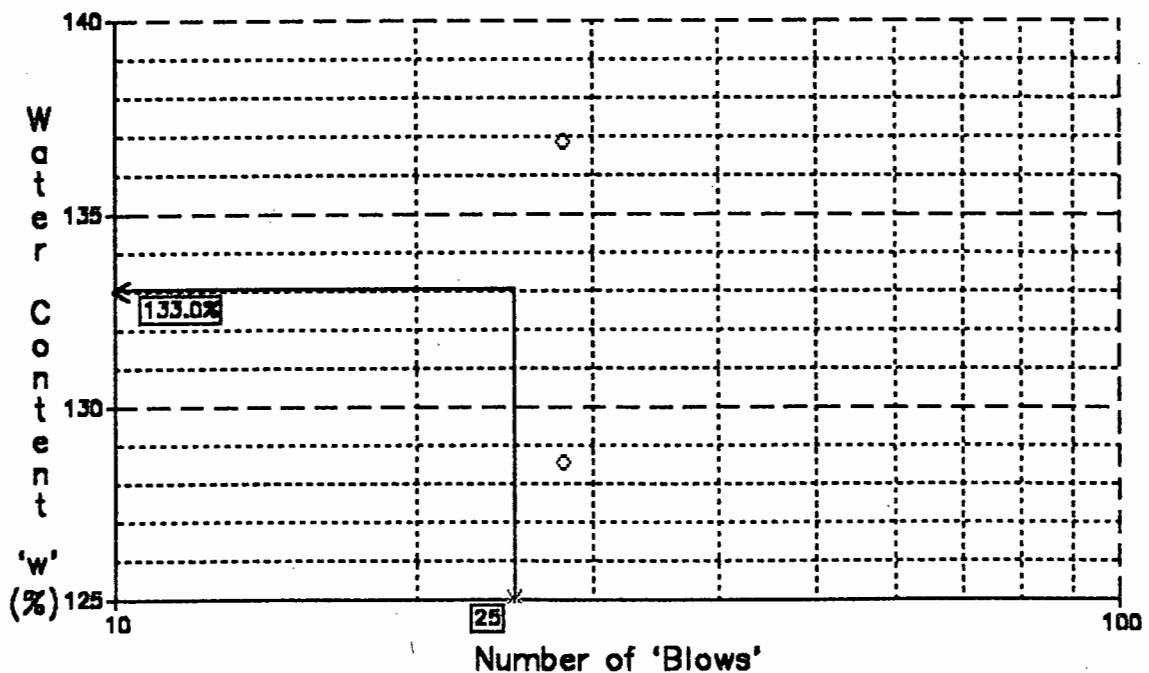


Figure A.21: Bentonite B.5 - [Liquid Limit] Number of Blows versus Water Content 'w'.

A.7.2 Consistency Limits (Part 2): Shrinkage LimitSite 11 - Rosebank, Cape*Table A.21: Site 11, Rosebank - Shrinkage Limit test results.*

Sample number/ref.	Volume Vt, cm ³	Water w, %	Sample number/ref	Volume Vt, cm ³	Water w, %
S.11-42/III.282	27.98	75.9	S.11-49/IV.305	27.98	45.5
	20.37	43.1		23.90	35.0
	17.92	32.8		21.47	27.4
	16.65	27.3		20.40	23.2
	16.05	22.3		19.73	18.4
	15.73	15.4		19.53	10.3
	15.68	8.7		19.42	5.6
	15.61	5.2			
S.11-41/III.278	29.57	74.5	S.11-64/IV.451	29.38	72.7
	22.21	44.6		21.15	42.5
	19.68	35.3		16.16	17.7
	18.23	29.8		15.98	8.1
	17.24	24.5		16.08	5.8
	16.76	17.6			
	16.57	9.6			
	16.72	5.0			
S.11-23/II.253	29.38	70.5	S.11-46/III.290	29.59	71.4
	20.75	39.3		19.76	34.2
	17.40	26.4		17.10	20.8
	16.16	18.4		16.79	13.1
	15.93	9.7		16.67	5.4
S.11-33/II.250	29.81	75.4	S.11-60/III.384	29.57	68.9
	19.99	39.3		21.57	41.3
	16.06	22.7		20.87	38.9
	15.75	18.9		19.30	32.9
	15.67	15.4		18.70	30.6
	15.61	7.8		16.53	21.3
	15.55	6.0		16.17	16.3
	15.52	5.0		16.19	11.0
				16.24	3.6
S.11-59/III.394	29.38	70.8	S.11-40/III.276	29.38	74.6
	22.85	46.6		21.56	43.8
	20.44	37.5		19.05	34.2
	16.63	17.2		17.62	28.6
	16.52	12.0		16.63	21.5
	16.41	6.6		16.30	15.1
				16.22	8.5
				16.19	5.1

Sample number/ref.	Volume ₃ Vt, cm ³	Water w, %	Sample number/ref	Volume ₃ Vt, cm ³	Water w, %
S.11-65/IV.65	29.57	75.2	S.11-16/II.23	27.98	73.4
	22.06	45.7		16.52	29.0
	16.17	17.6		15.58	25.1
	15.94	8.1		14.72	18.5
	16.12	5.4		14.58	14.0
				14.53	8.7
				14.40	6.2
				14.43	5.7
S.11-34/II.34	29.57	75.9	S.11-24/II.253	29.57	68.6
	20.21	41.1		21.15	38.6
	16.68	26.5		17.95	27.4
	15.90	22.2		16.51	19.3
	15.72	18.4		16.32	11.2
	15.50	9.6			
	15.47	6.6			
	15.45	5.3			
S.11-45/III.288	29.81	75.6	S.11-63/IV.421	29.38	75.7
	19.24	36.3		22.17	48.3
	16.27	20.7		18.83	35.3
	16.04	12.5		15.63	16.7
	15.91	5.5		15.45	10.4
				15.41	6.3

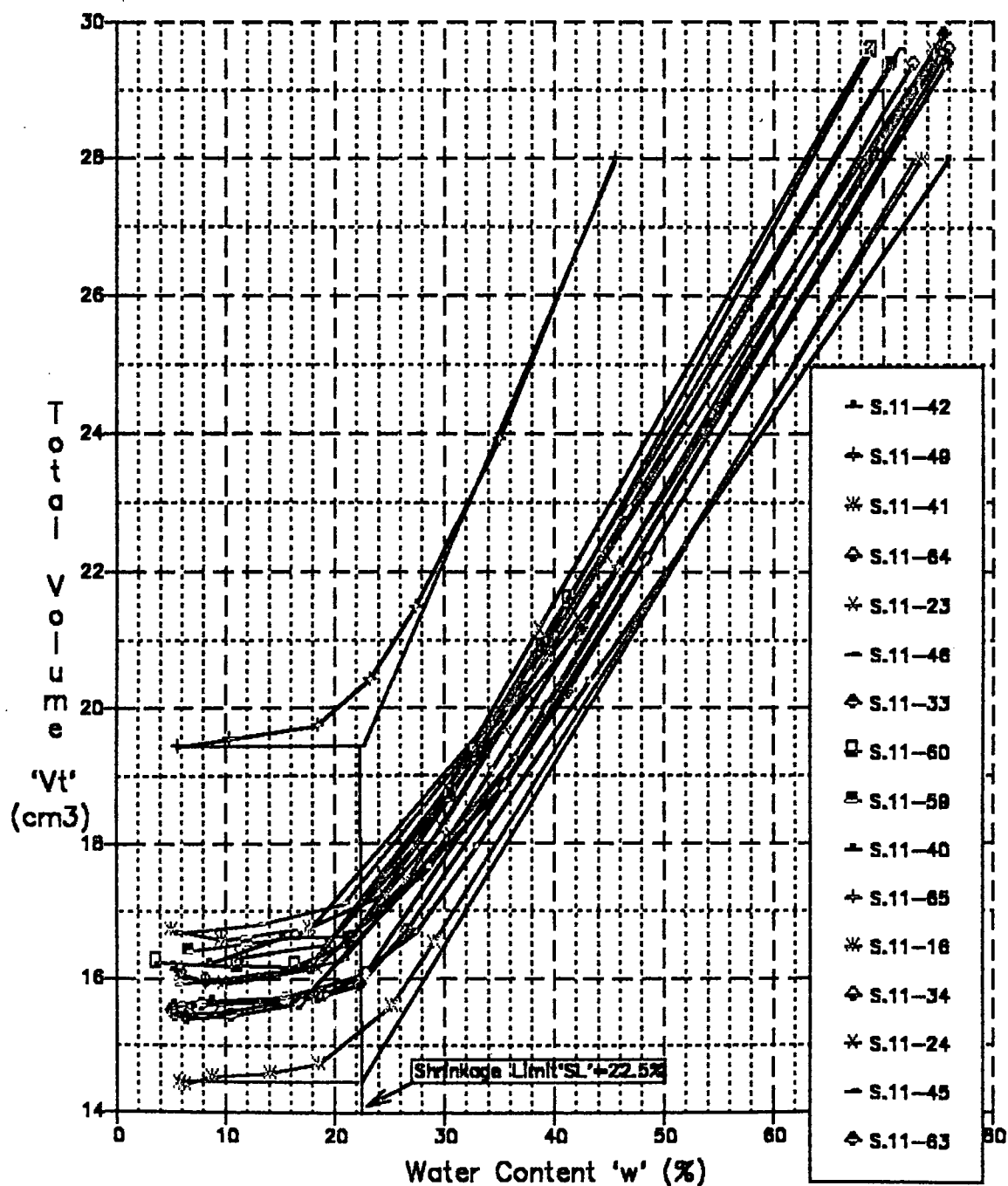


Figure A.22: Site 11, Rosebank - [Shrinkage Limit] total volume V_t versus water content w ¹.

¹ - for void ratio values see Appendix C.

Sample number/ref.	Volume Vt, cm ³	Water w, %	Sample number/ref	Volume Vt, cm ³	Water w, %
S.36-7-III.360	29.57	39.2	S.36-6/III.358	29.38	36.8
	22.12	24.6		20.94	21.6
	20.40	12.2		19.57	6.8
	20.32	3.1		19.41	1.2

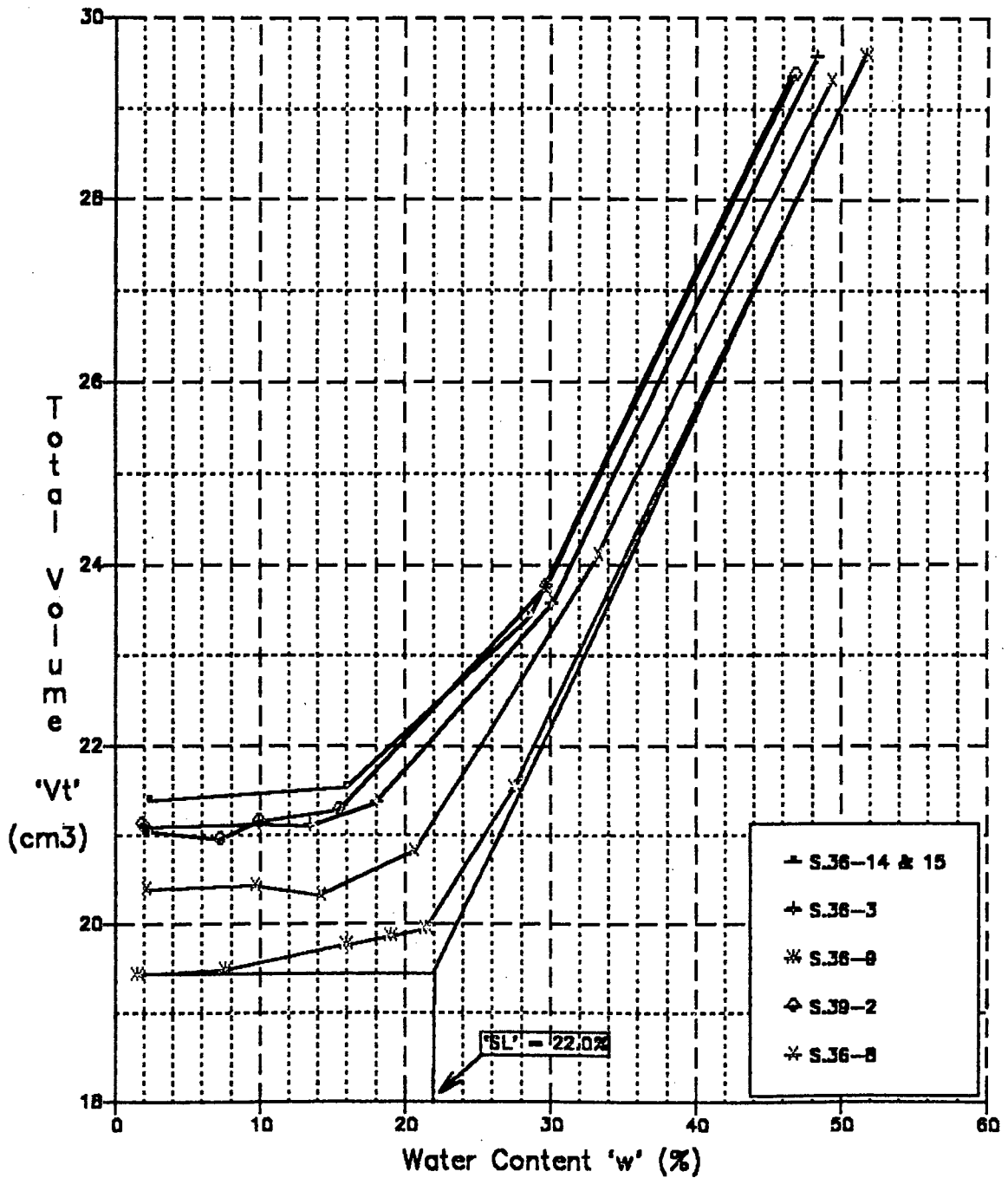


Figure A.23: Site 36, Rondebosch - [Shrinkage Limit] total volume V_t versus water content w ¹.

¹ - for void ratio values see Appendix C.

Site 30 - Hout Bay, Cape*Table A.23: Site 30, Hout Bay - Shrinkage Limit test results.*

Sample number/ref.	Volume Vt, cm ³	Water w, %	Sample number/ref	Volume Vt, cm ³	Water w, %
S.30-10 & 11/ IV.465	29.31	47.2	S.30-3/III.336	29.31	49.8
	22.93	28.5		24.16	33.4
	20.75	19.2		21.37	22.3
	20.05	5.0		20.81	17.5
	20.06	2.1		20.85	13.0
				20.74	2.4
S.30-9/III.388	29.31	50.8	S.30-2/III.333	27.98	52.7
	24.06	33.9		22.01	32.8
	23.47	32.1		19.21	20.1
	22.15	27.3		19.04	13.7
	21.62	24.8		18.99	2.2
	20.83	18.8			
	20.54	15.6			
	20.51	1.9			
S.30-8/III.386	27.98	49.9			
	22.43	33.8			
	21.86	31.7			
	20.43	26.2			
	20.17	24.2			
	19.22	14.4			
	19.21	1.8			

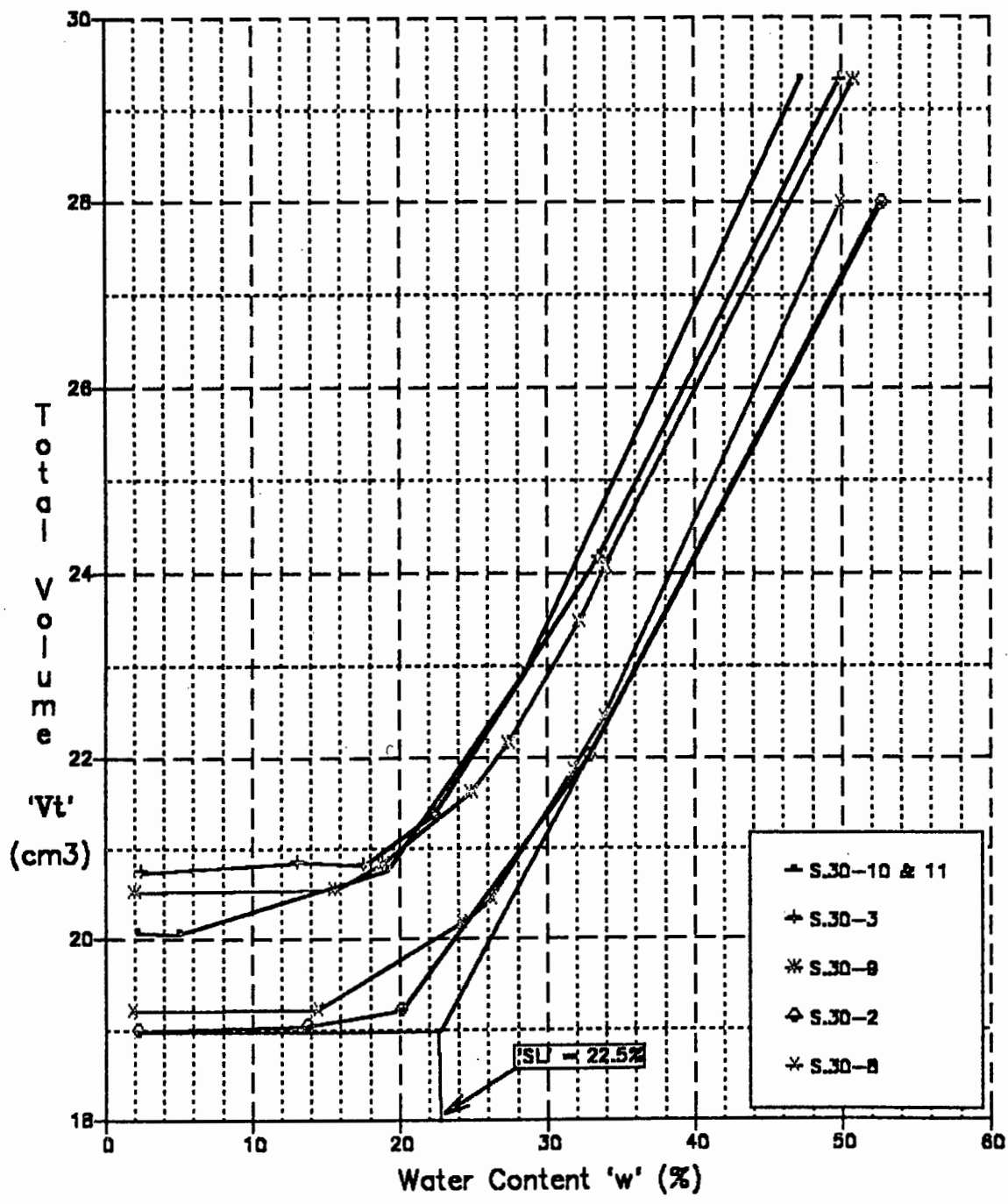


Figure A.24: Site 30, Hout Bay - [Shrinkage Limit] total volume V_t versus water content w ¹.

¹ - for void ratio values see Appendix C.

Site A, Berea Road, Durban

Table A.24: Site A, Berea Road - Shrinkage Limit test results.

Sample number/ref.	Volume Vt, cm ³	Water w, %	Sample number/ref	Volume Vt, cm ³	Water w, %
S.A-T.1/V.9	29.59	18.8	S.A-1.A/II.139	29.38	23.0
	27.93	16.1		25.93	14.4
	27.51	15.5		25.68	10.8
	27.38	14.9		25.51	9.1
	26.49	7.9		25.27	4.4
	26.46	6.7		25.31	1.0

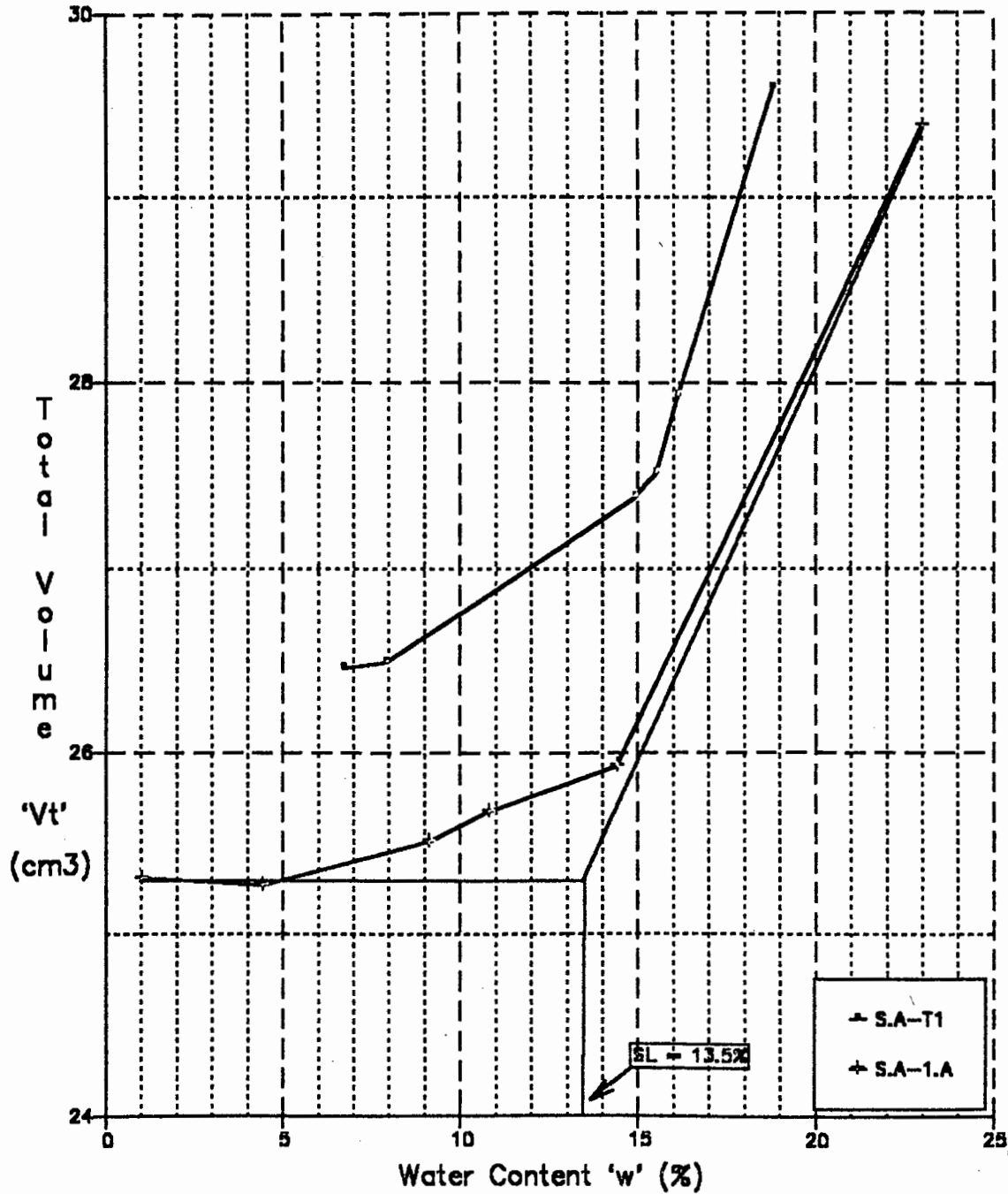


Figure A.25: Site A, Berea Road- [Shrinkage Limit] total volume V_t versus water content w .

¹ - for void ratio values see Appendix C.

Site 7 - Mowbray, Cape*Table A.25: Site 7, Mowbray - Shrinkage Limit test results.*

Sample number/ref.	Volume Vt, cm ³	Water w, %	Sample number/ref	Volume Vt, cm ³	Water w, %
S.7-2/I.91	27.58	59.0	S.7-1/I.90	28.68	65.2
	18.27	26.8		18.86	30.3
	15.98	17.6		16.23	20.8
	15.75	11.6		15.71	14.4
	15.76	5.6		15.62	7.0
	15.73	2.4		15.59	3.9
				15.56	2.0

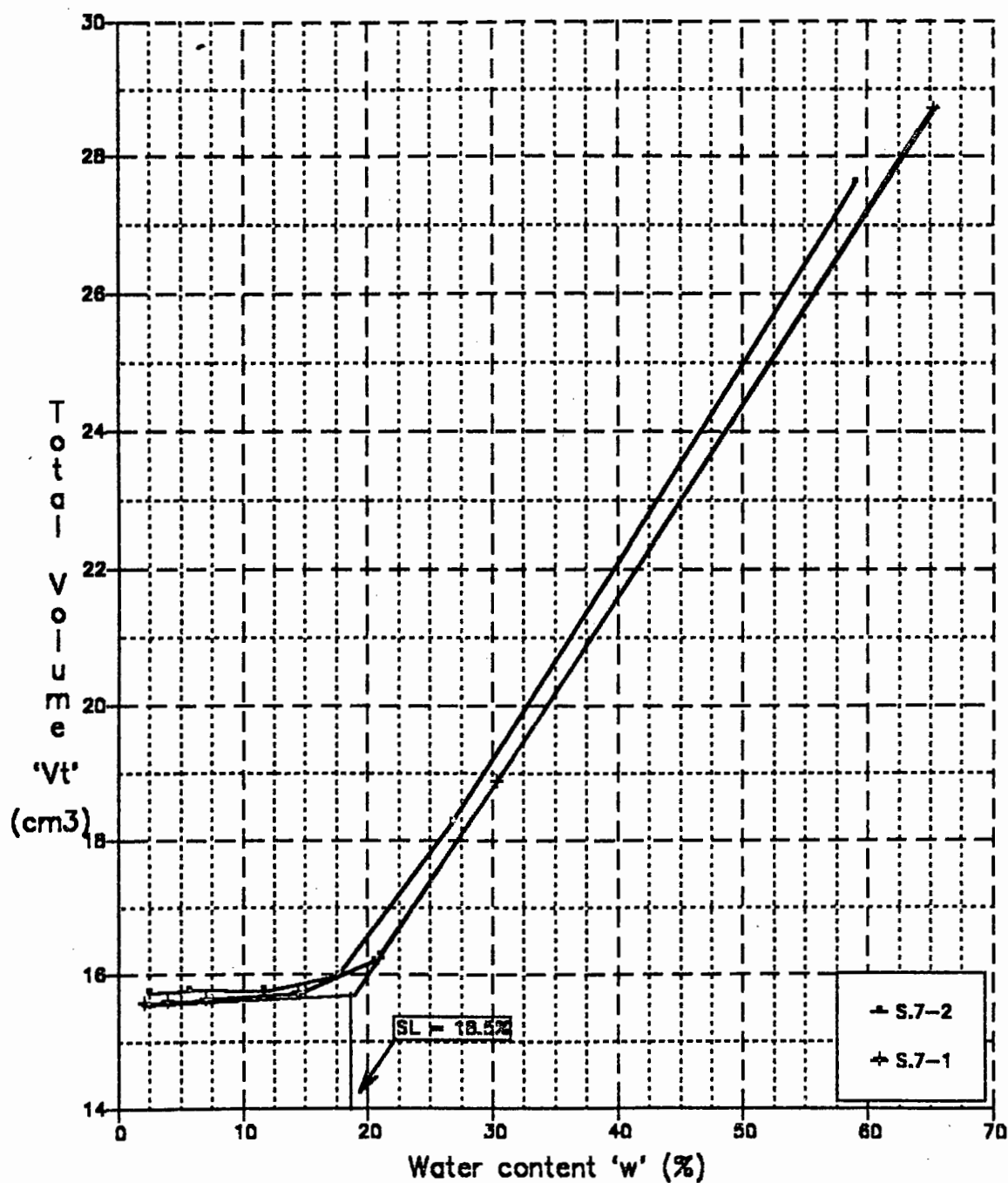


Figure A.26: Site 7, Mowbray - [Shrinkage Limit] total volume V_t versus water content w ¹.

¹ - for void ratio values see Appendix C.

Site B - Francois Road, Durban

Table A.26: Site B, Francois Road - Shrinkage Limit test results.

Sample	Volume	Water
number/ref.	Vt, cm ³	w, %
S.B-1A/III139	29.57	23.2
	26.06	12.6
	25.91	11.3
	25.84	8.2
	25.59	1.0

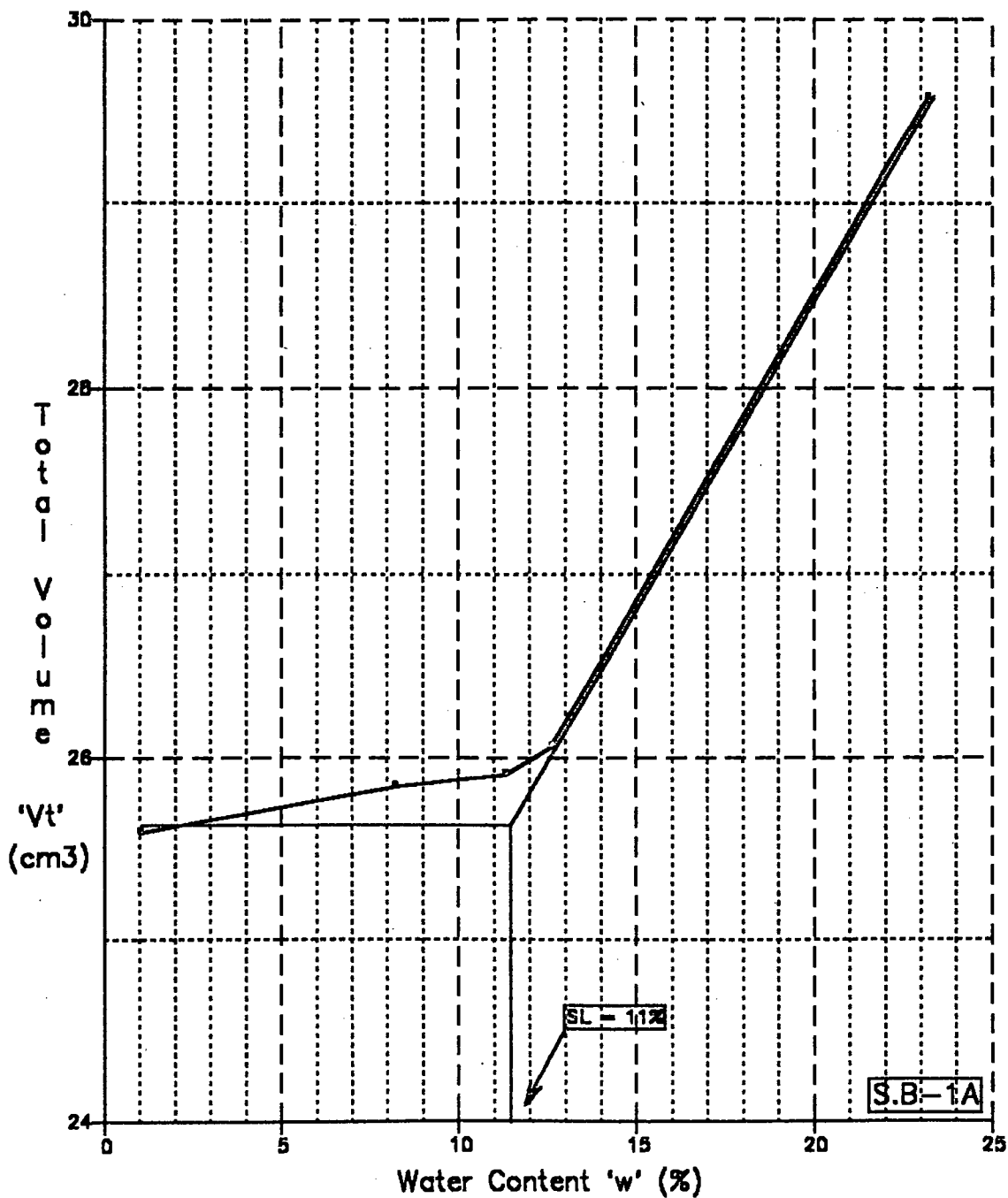


Figure A.27: Site B, Francois Road - [Shrinkage Limit] total volume V_t versus water content w ¹.

¹ - for void ratio see Appendix C.

Site C - Margaret Mayton Avenue, Durban

Table A.27: Site C, Margaret Mayton Avenue - Shrinkage Limit test results.

Sample number/ref.	Volume Vt, cm ³	Water w, %
S.C-1A/II.140	27.98	18.6
	26.17	10.4
	26.04	7.6
	25.86	5.6
	25.82	2.2

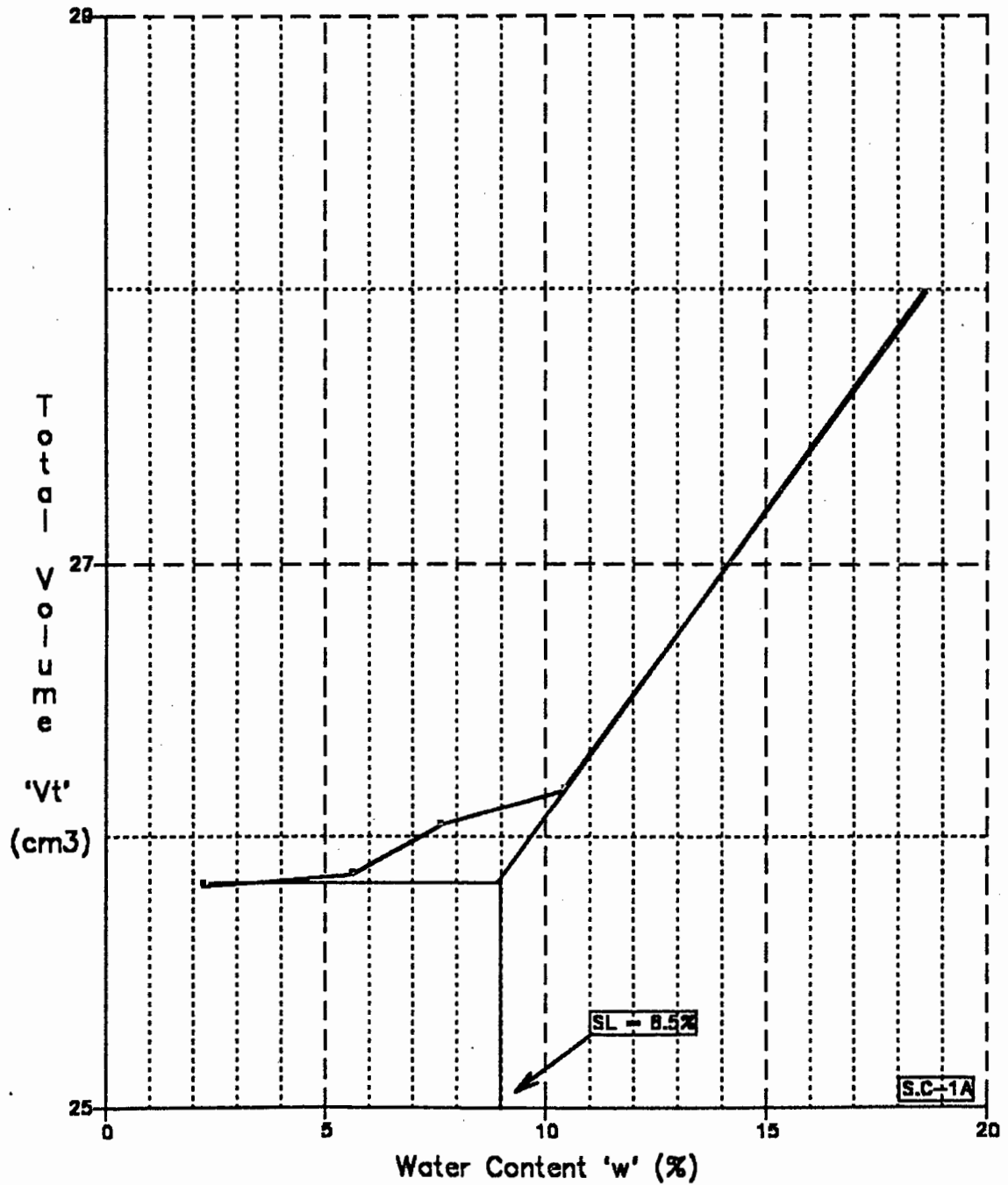


Figure A.28: Site C, Margaret Mayton Avenue - [Shrinkage Limit] total volume V_t versus water content w ¹.

¹ - for void ratio values see Appendix C.

Site D - Rose Hill, Durban

Table A.28: Site D, Rose Hill - Shrinkage Limit test results.

Sample number/ref.	Volume Vt, cm ³	Water w, %
S.D-1A/II.140	29.81	23.2
	26.67	13.6
	26.46	10.5
	26.23	8.6
	26.15	1.6

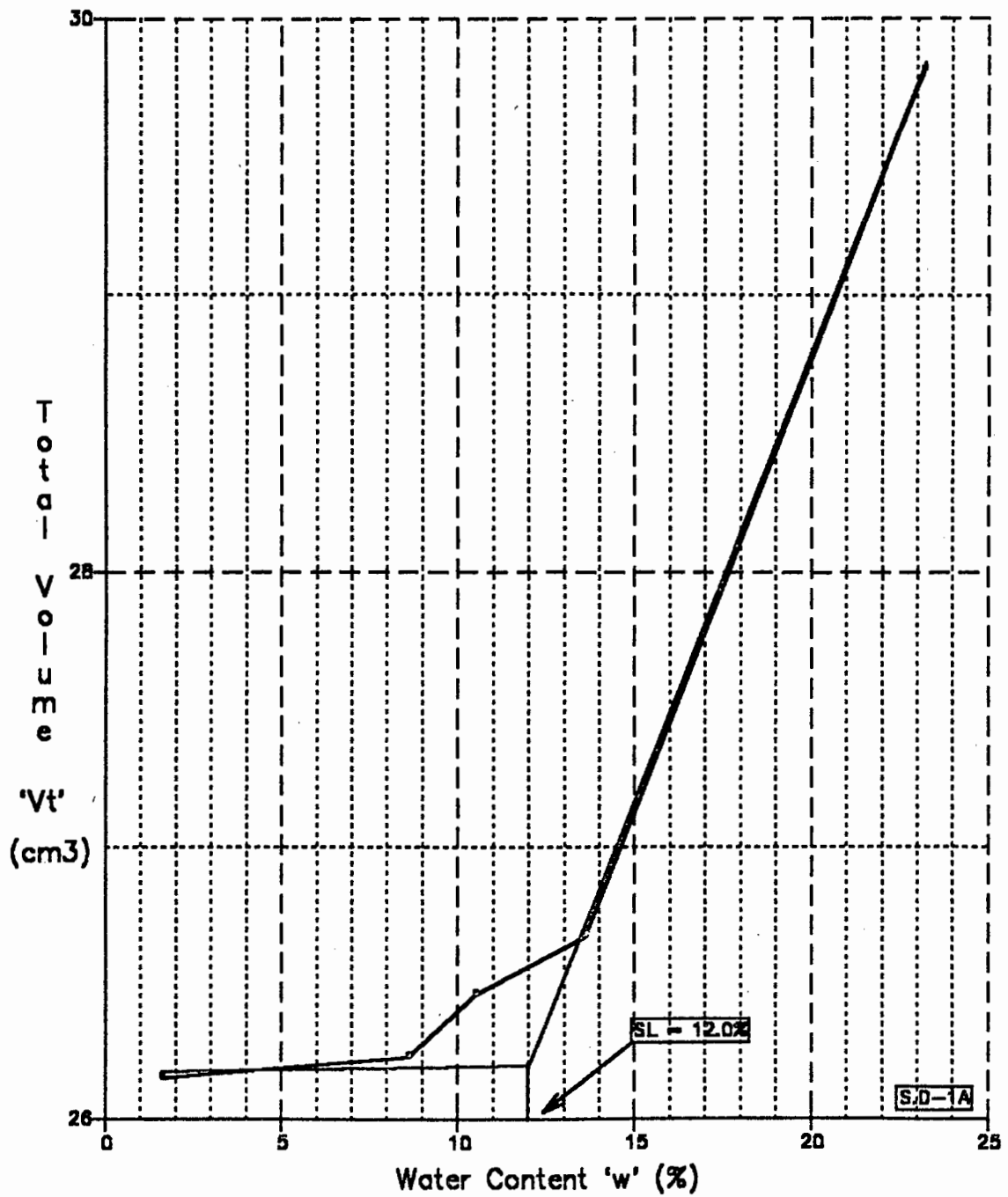


Figure A.29: Site D, Rose Hill - [Shrinkage Limit] total volume V_t versus water content w ¹.

¹ - for void ratio values see Appendix C.

Kaolin - K.1 (13% Clay Size)

Table A.29: Kaolin K.1 - Shrinkage Limit test results.

Sample number/ref.	Volume Vt, cm ³	Water w, %	Sample number/ref	Volume Vt, cm ³	Water w, %
K.1-2/II.215	29.38	21.5	K.1-3/II.215	29.57	18.5
	26.43	6.5		27.30	6.6
	26.24	1.0		27.28	4.1

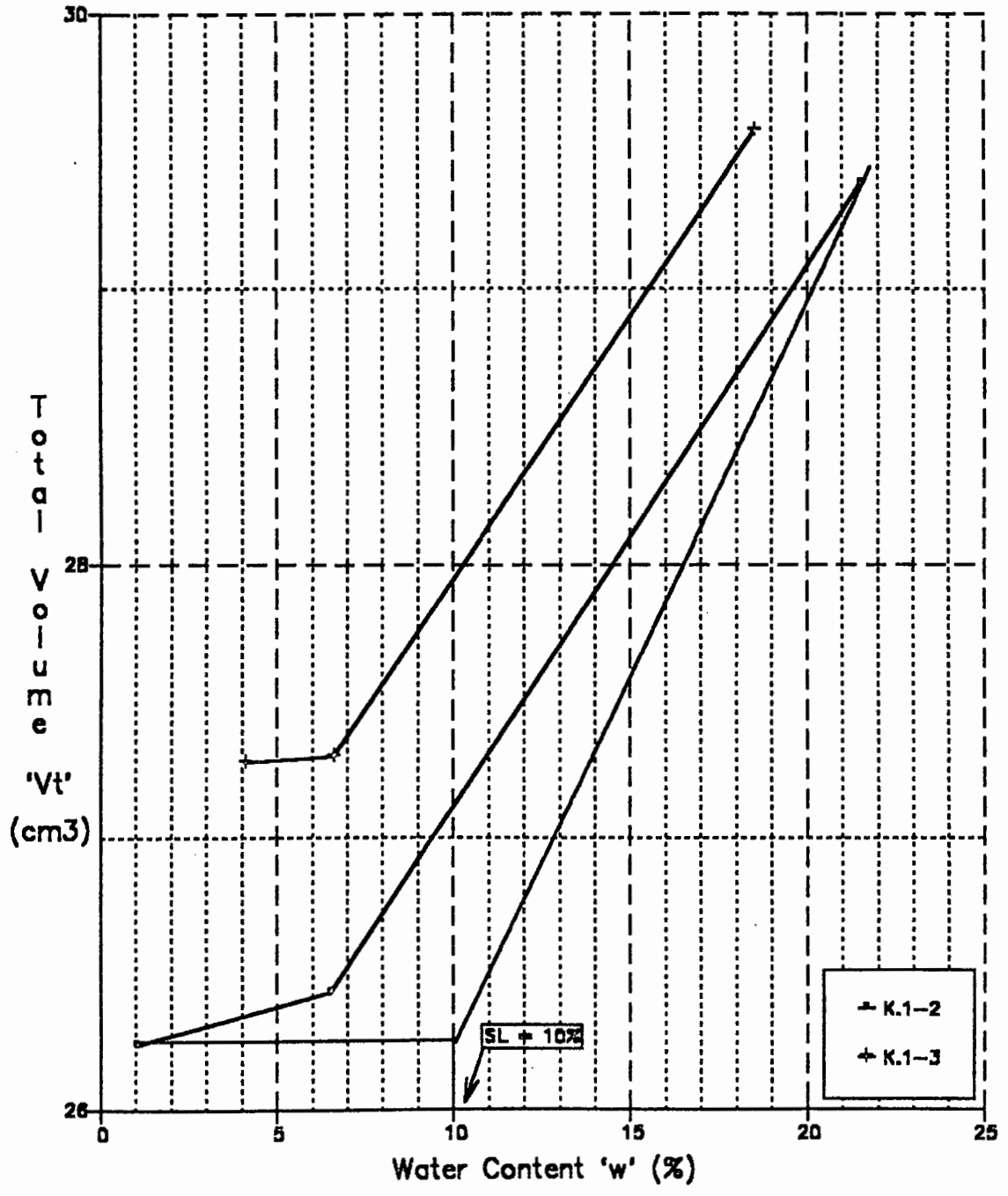


Figure A.30: Kaolin K.1 - [Shrinkage Limit] total volume ' V_t ' versus water content ' w '¹.

¹ - for void ratio values see Appendix C.

Kaolin - K.2 (20% Clay Size)

Table A.30: Kaolin K.2 - Shrinkage Limit test results.

Sample number/ref.	Volume Vt, cm ³	Water w, %	Sample number/ref	Volume Vt, cm ³	Water w, %
K.2-2/II.219	29.81	23.0	K.2-3/II.219	29.59	18.6
	25.80	13.3		26.61	10.1
	25.57	11.0		26.46	7.7
	25.36	8.1		26.40	5.2
	25.17	0.8			
K.2-T.1/V.13	29.59	15.0			
	29.21	13.1			
	28.48	9.8			
	28.33	3.0			

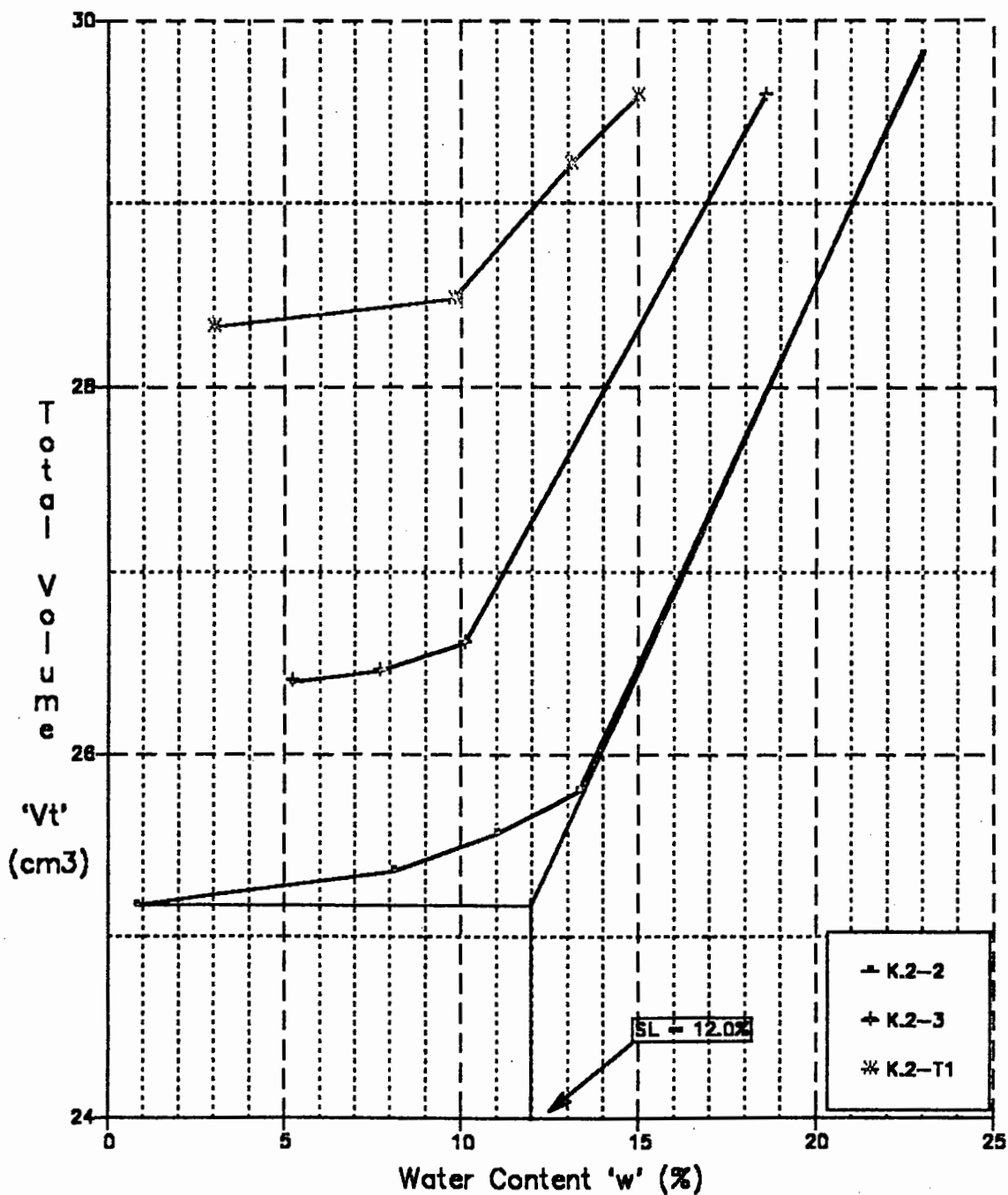


Figure A.31: Kaolin K.2 - [Shrinkage Limit] total volume V_t versus water content w ¹.

¹ - for void ratio values see Appendix C.

Kaolin - K.3 (10% Clay Size)

Table A.31: Kaolin K.3 - Shrinkage Limit test results.

Sample number/ref.	Volume Vt, cm ³	Water w, %	Sample number/ref	Volume Vt, cm ³	Water w, %
K.3-2/II.265	27.98	23.1	K.3-3/II.265	29.81	19.2
	26.04	1.0		28.55	0.4
	25.94	0.8		28.52	0.3
K.3-T.1/V.15	29.59	10.5			
	28.33	9.3			
	28.00	2.8			
	27.86	0.4			

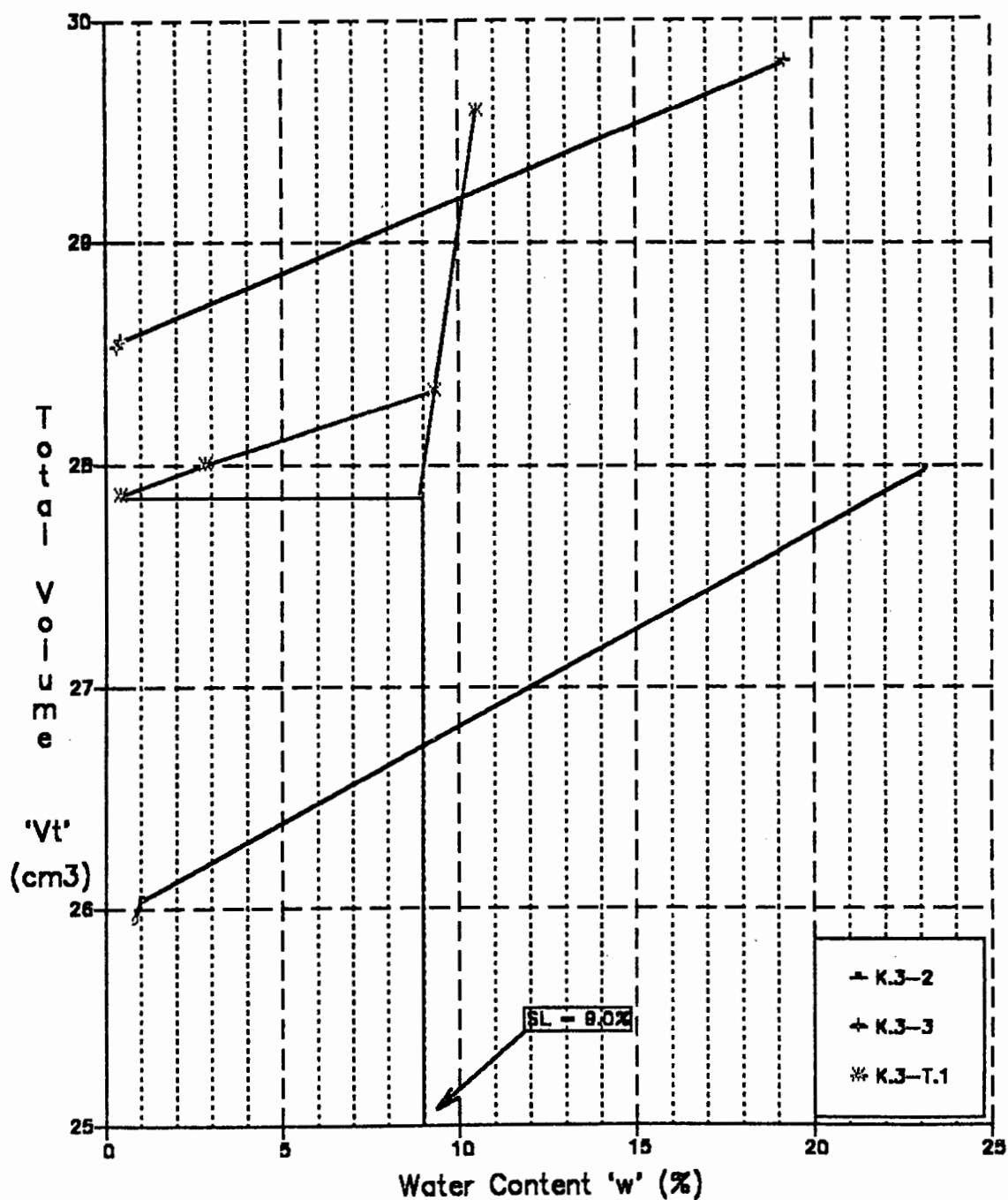


Figure A.32: Kaolin K.3 - [Shrinkage Limit] total volume V_t versus water content w .

1 - for void ratio values see Appendix C.

Bentonite, B.1 (3.5% Clay Size)

Table A.32: Bentonite, B.1 - Shrinkage Limit test results.

Sample number/ref.	Volume Vt, cm ³	Water w, %
B.1-2/III.338	29.31	21.4
	28.35	16.8
	28.22	8.9
	27.95	1.9
	27.84	0.9

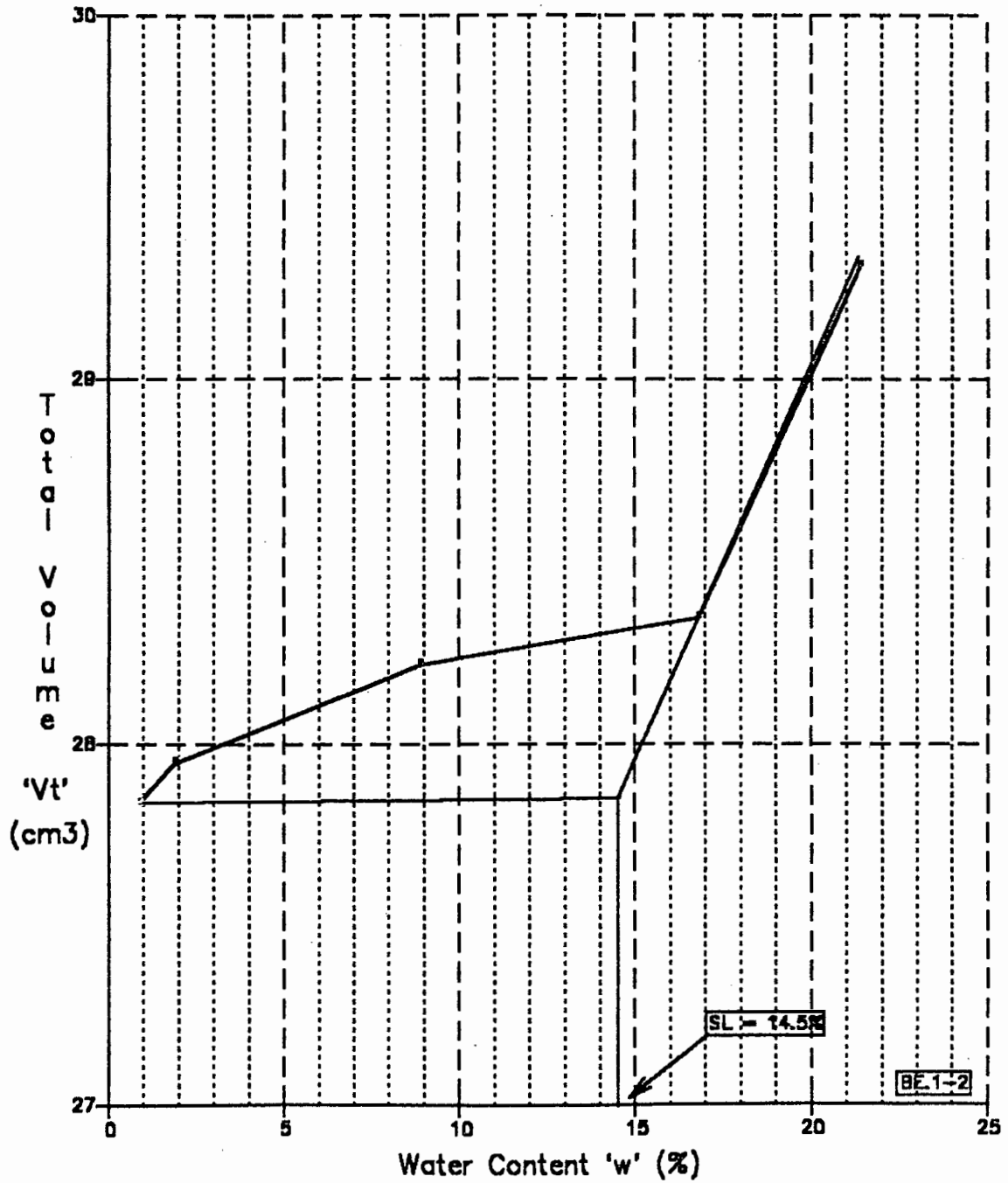


Figure A.33: Bentonite, B.1 - [Shrinkage Limit] total volume V_t versus water content w ¹.

¹ - for void ratio values see Appendix C.

Bentonite, B.2 (7% Clay Size)

Table A.33: Bentonite, B.2 - Shrinkage Limit test results.

Sample number/ref.	Volume Vt, cm ³	Water w, %
B.2-T.1/V.17	29.59	35.8
	28.32	32.5
	26.85	26.5
	26.33	22.9
	26.13	4.2

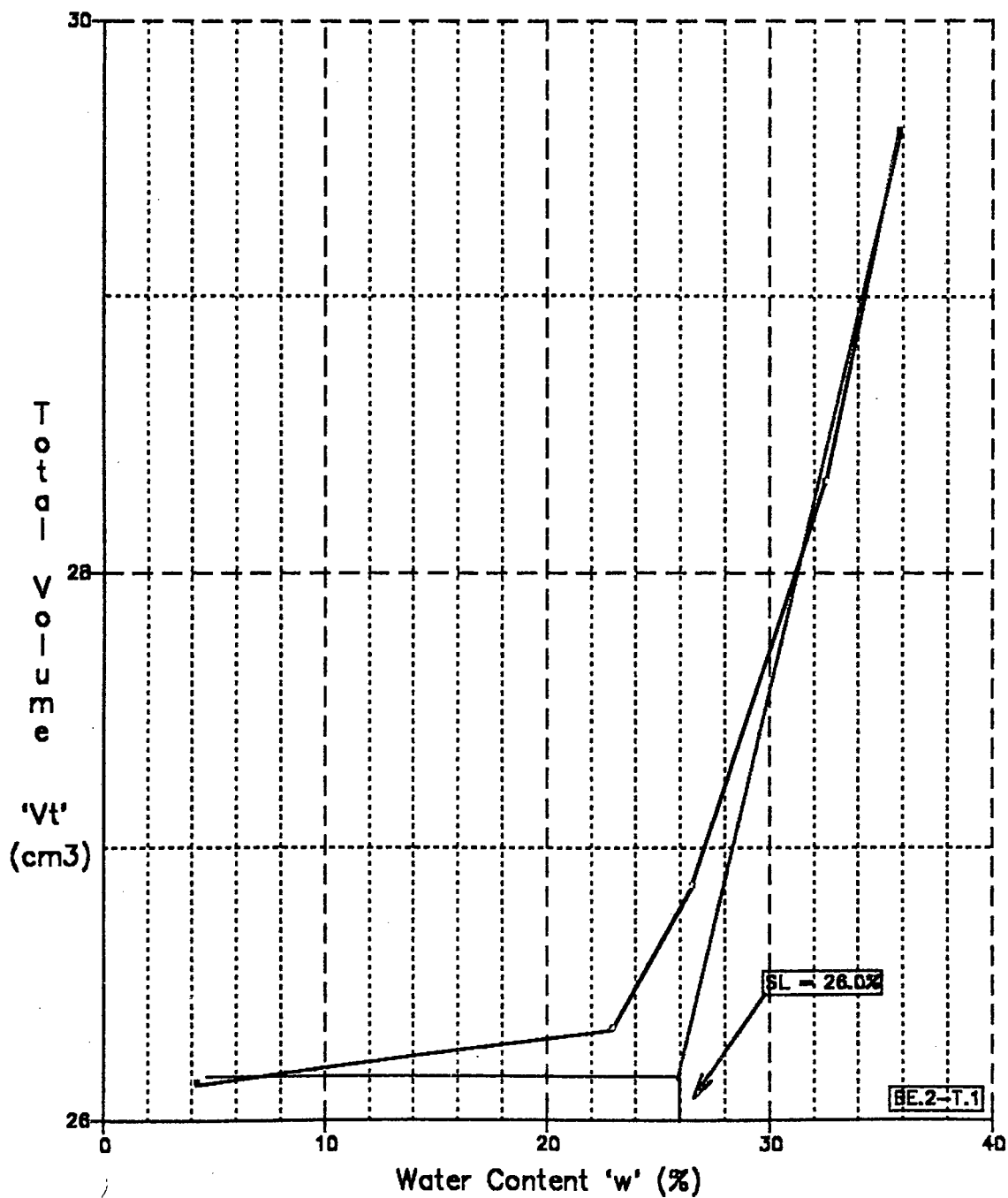


Figure A.34: Bentonite, B.2 - [Shrinkage Limit] total volume V_t versus water content w ¹.

¹ - for void ratio values see Appendix C.

Bentonite, B.3 (11.5% Clay Size)

Table A.34: Bentonite, B.3 - Shrinkage Limit test results.

Sample number/ref.	Volume Vt, cm ³	Water w, %
B.3-2/IV.482	27.98	33.9
	26.63	29.6
	26.49	23.2
	26.22	18.3
	26.10	13.0

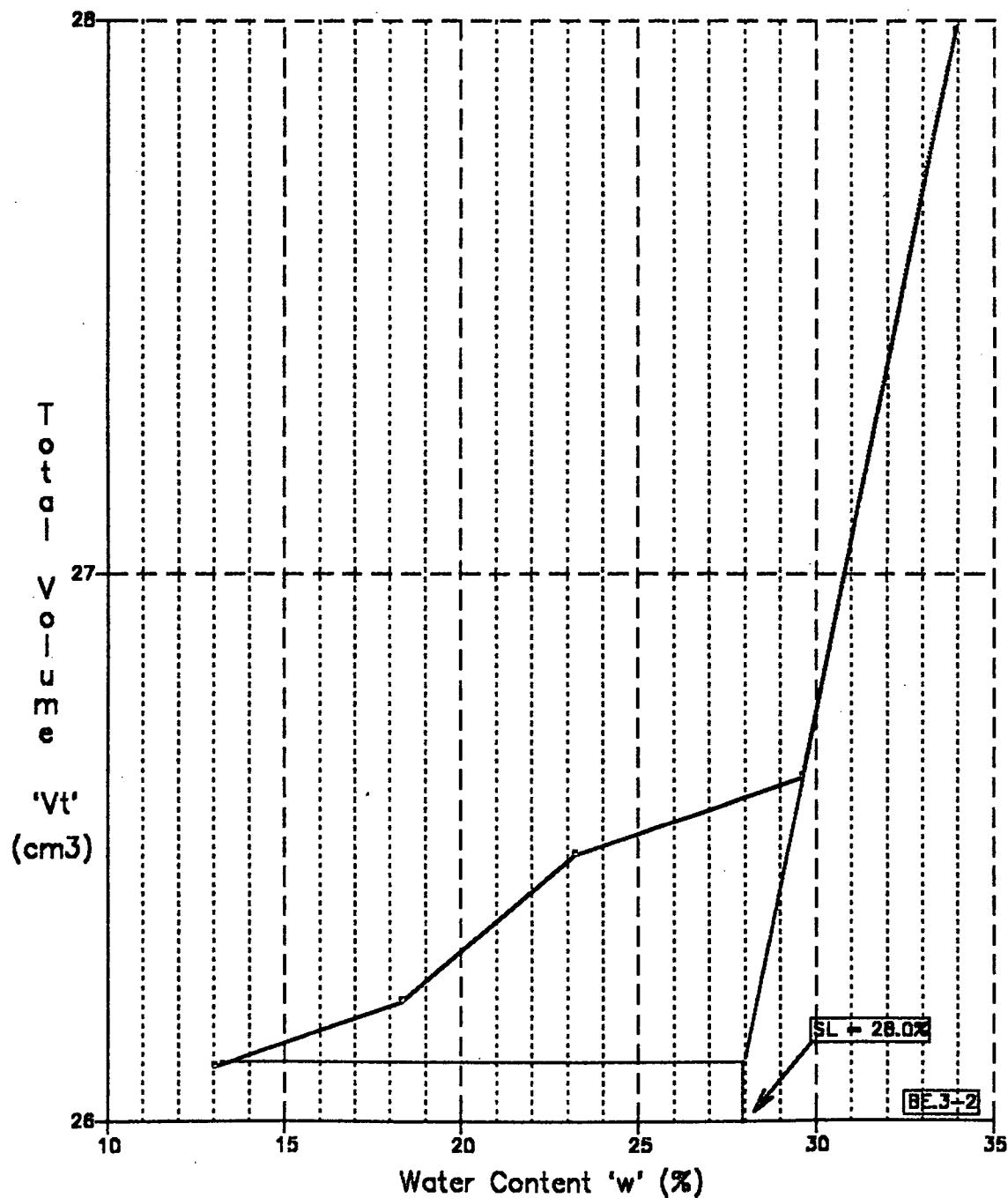


Figure A.35: Bentonite, B.3 - [Shrinkage Limit] total volume V_t versus water content w ¹.

¹ - for void ratio values see Appendix C.

Bentonite, B.4 (15.5% Clay Size)

Table A.35: Bentonite, B.4 - Shrinkage Limit test results.

Sample number/ref.	Volume ₃ Vt, cm ³	Water w, %
B.4-T.1/V.19	29.59	58.7
	26.40	50.0
	24.32	42.7
	22.13	30.0
	21.14	13.0
	20.75	6.4

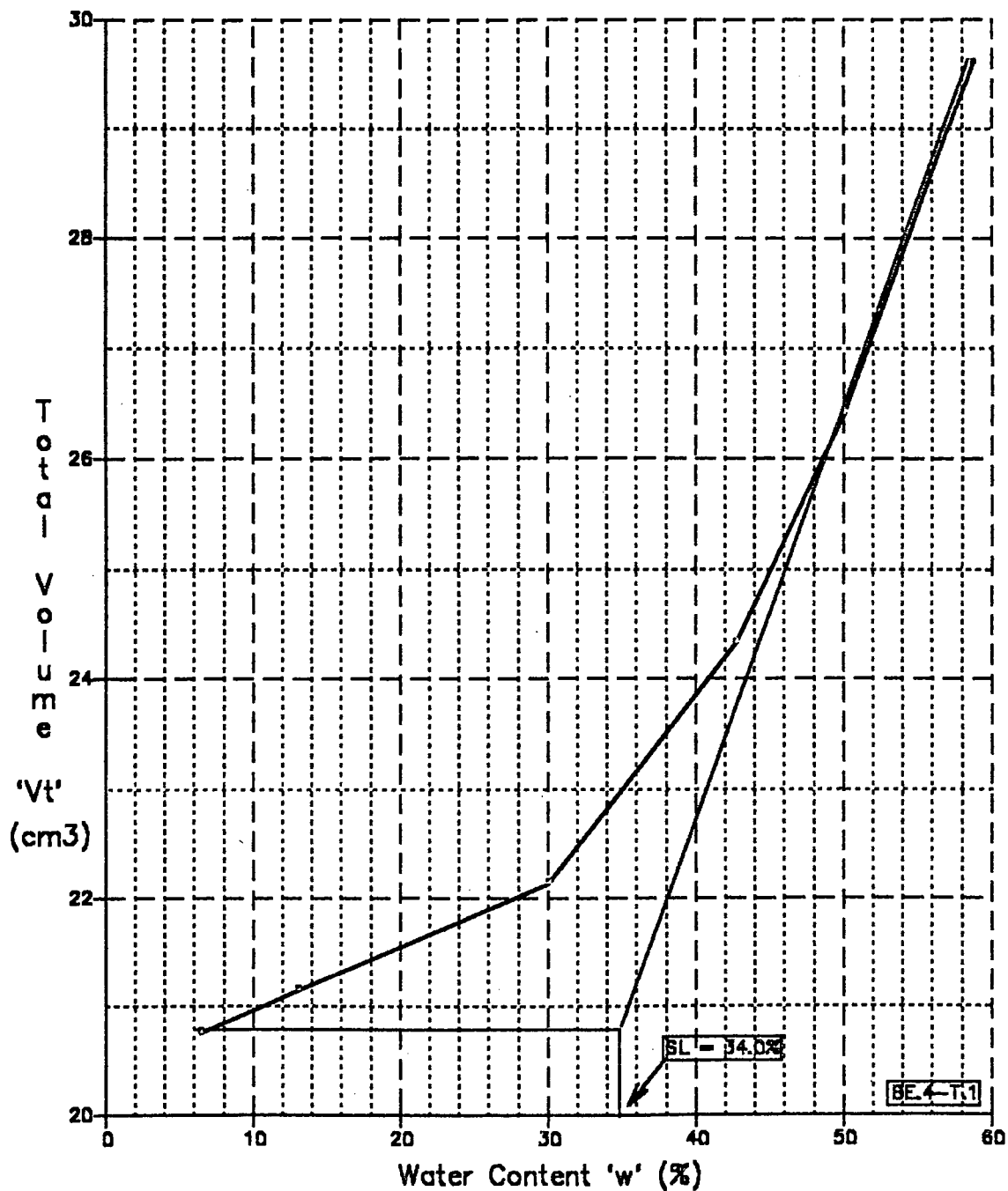


Figure A.36: Bentonite, B.4 - [Shrinkage Limit] total volume ' V_t ' versus water content ' w '¹.

¹ - for void ratio values see Appendix C.

Bentonite, B.5 (35% Clay Size)

Table A.36: Bentonite, B.5 - Shrinkage Limit test results.

Sample number/ref.	Volume Vt, cm ³	Water w, %	Sample number/ref	Volume Vt, cm ³	Water w, %
B.5-T.1/V.21	29.59	95.6			
	26.39	84.8			
	20.63	58.2			
	17.75	43.9			
	14.58	26.5			
	12.99	13.7			

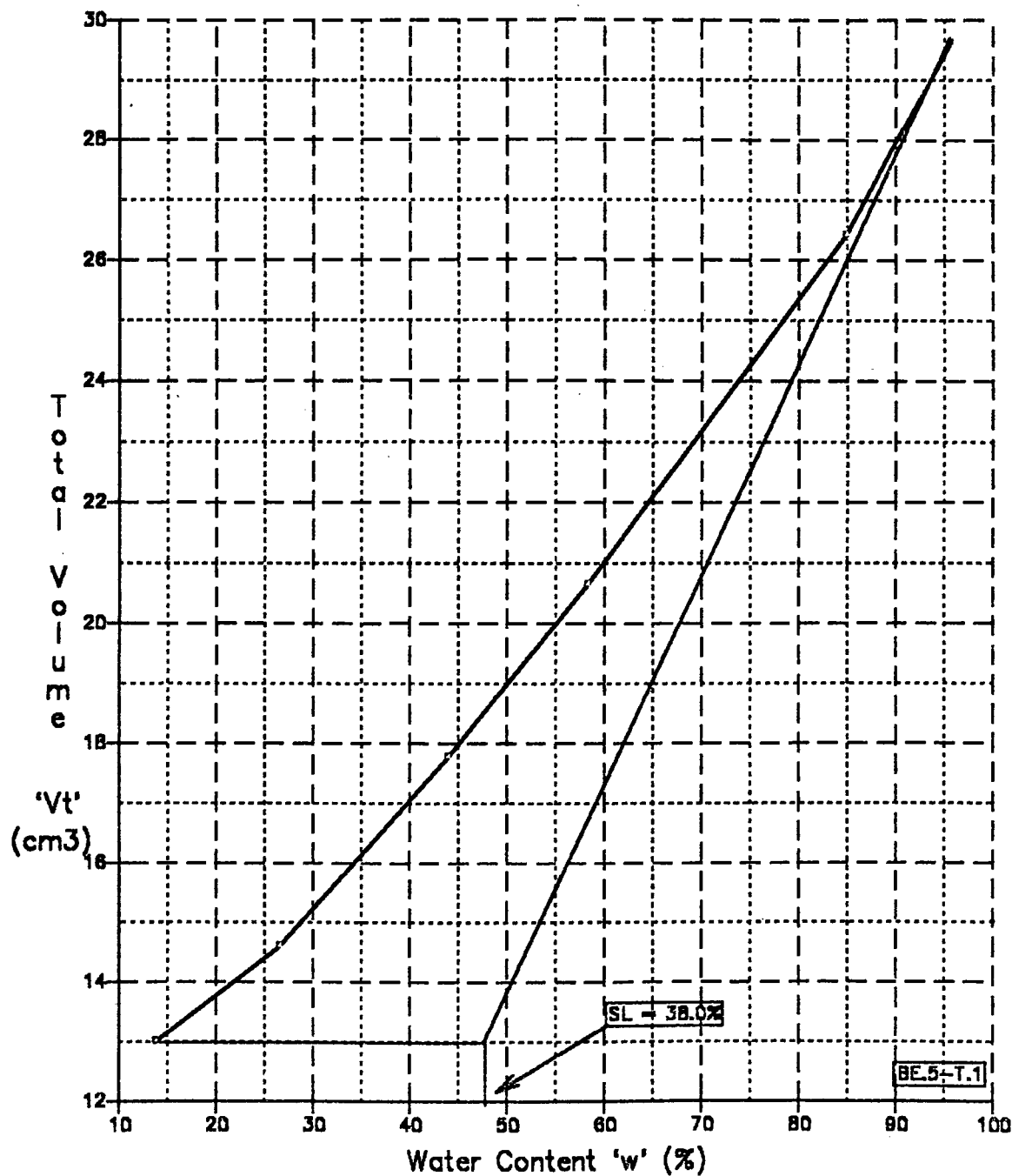


Figure A.37: Bentonite B.5 - [Shrinkage Limit] total volume ' V_t ' versus water content ' w '.

¹ - for void ratio values see Appendix C.

A.7.3 Particle Size Distribution

Site 11, Rosebank

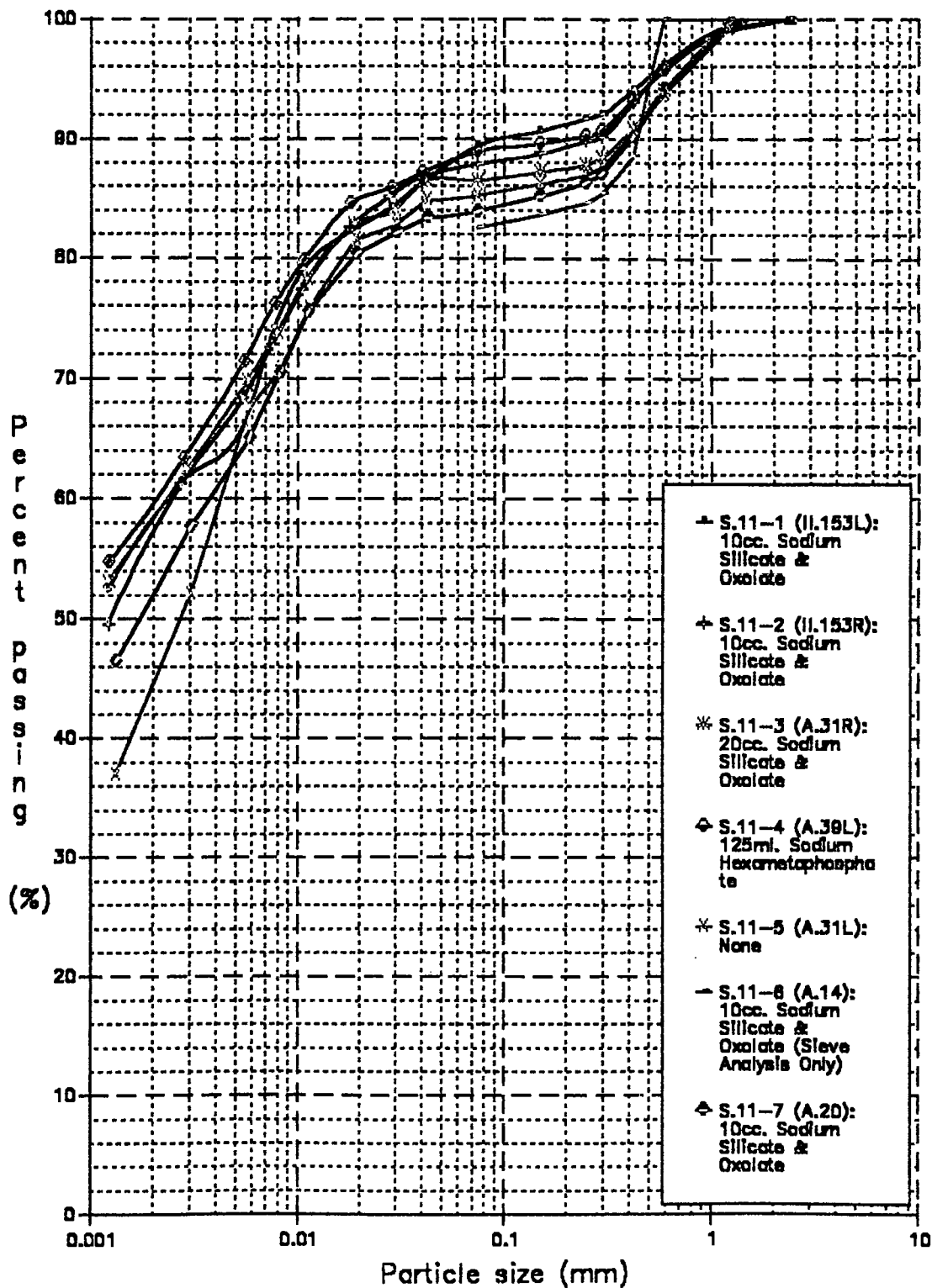


Figure A.38: Particle size distribution - Site 11, Rosebank.

Site 36, Rondebosch

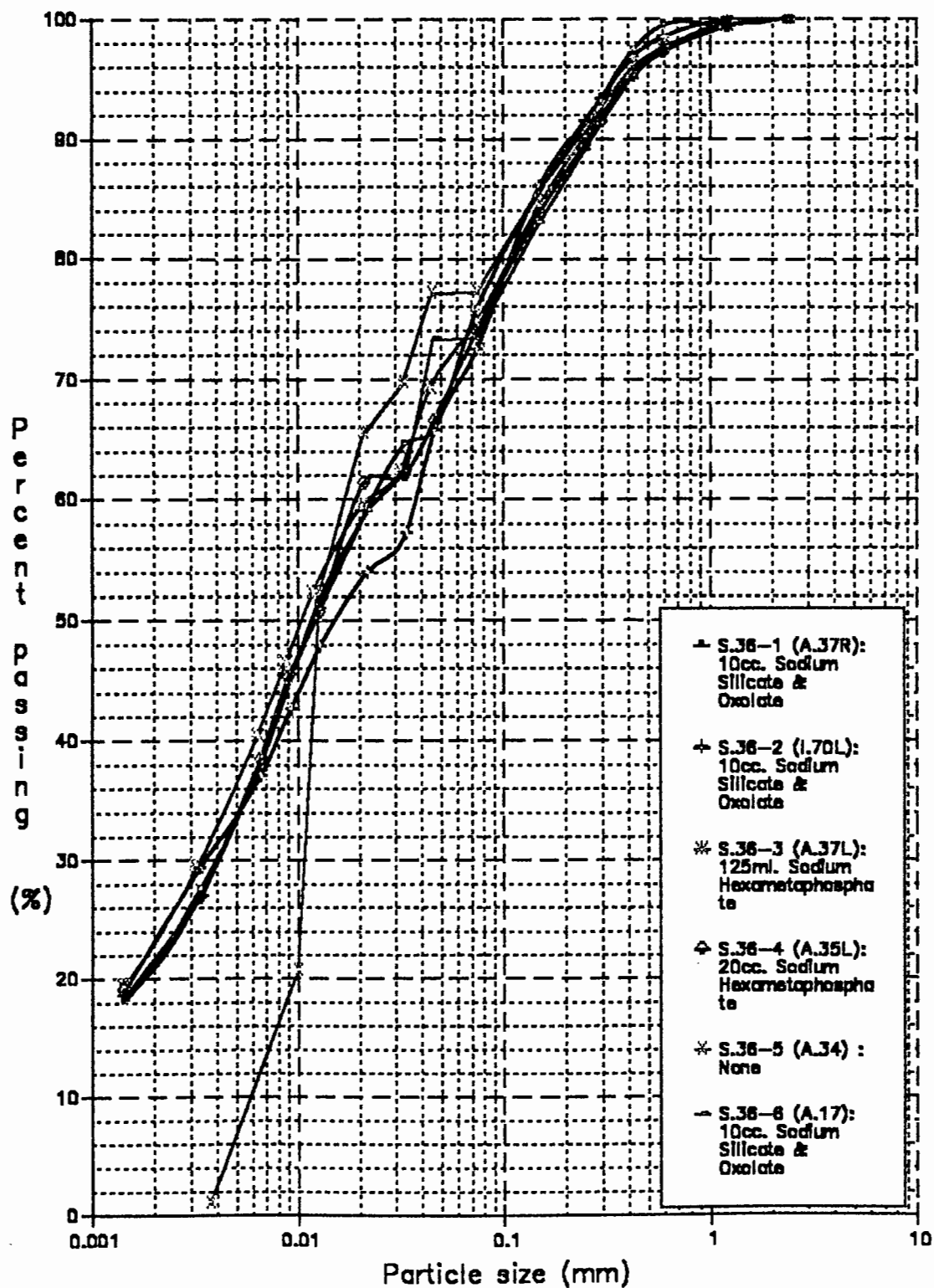


Figure A.39: Particle size distribution - Site 36, Rondebosch.

Site 30, Hout Bay

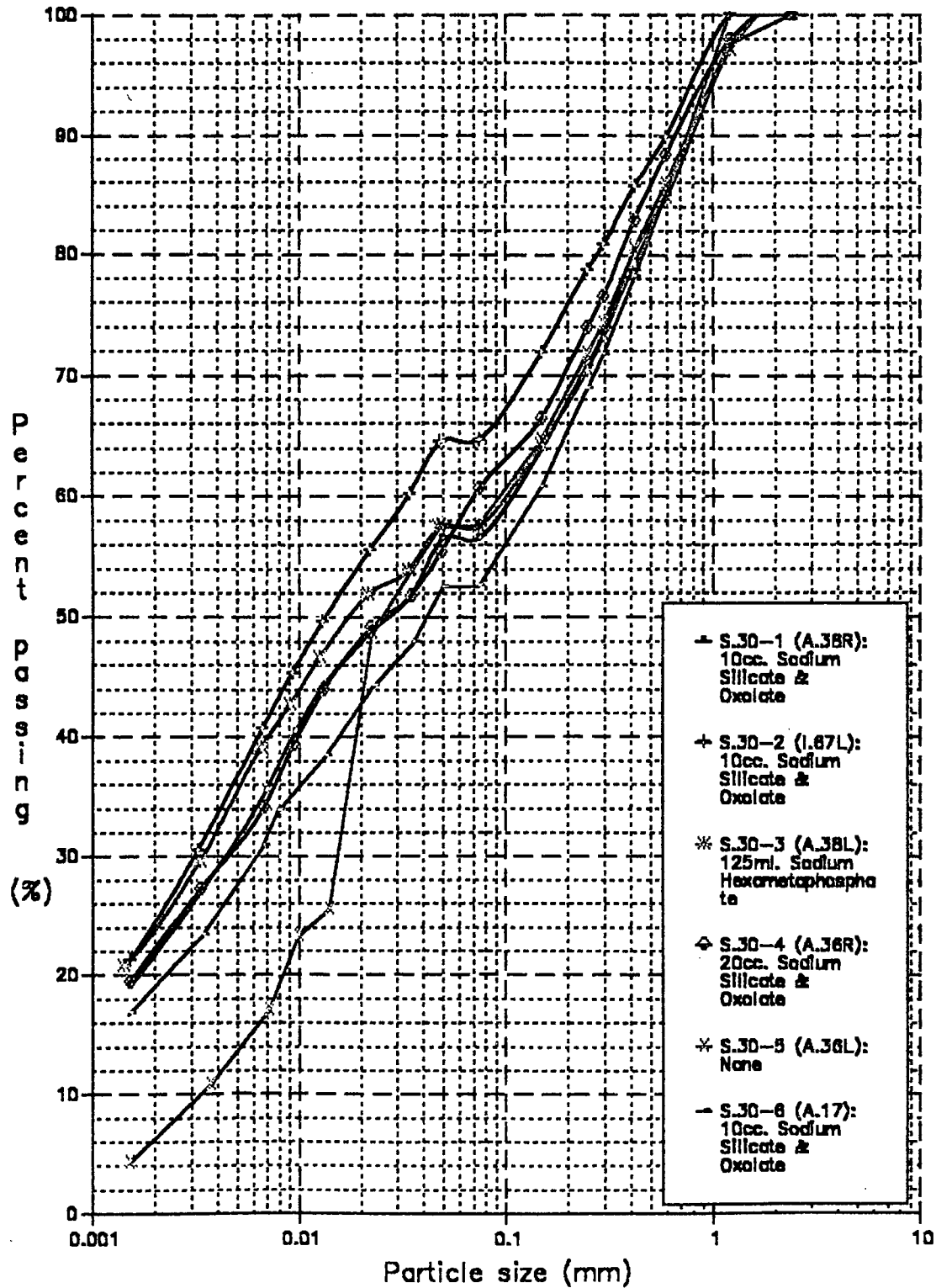


Figure A.40: Particle size distribution - Site 30, Hout Bay.

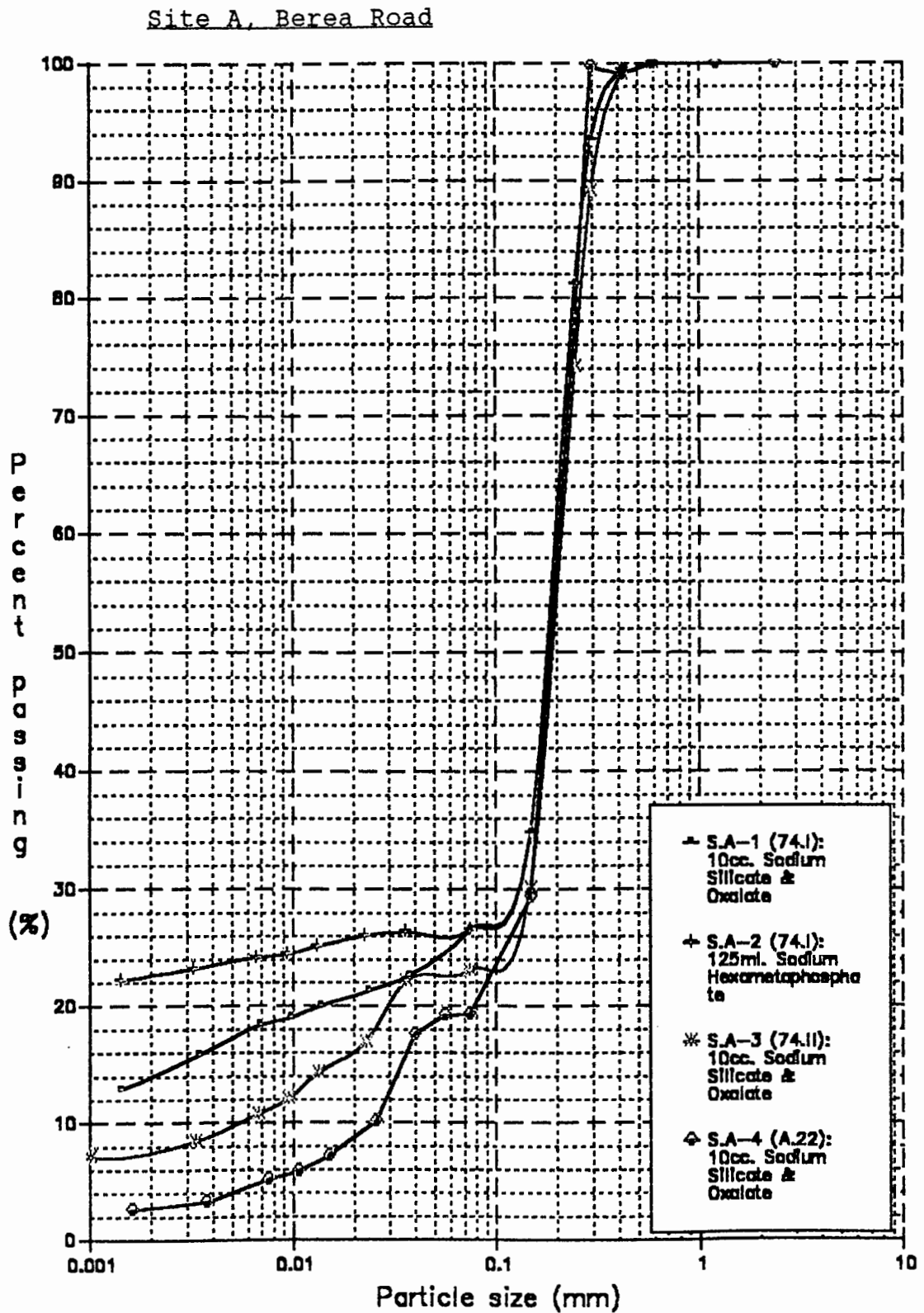


Figure A.41: Particle size distribution - Site A, Berea Road.

Site 7, Mowbray

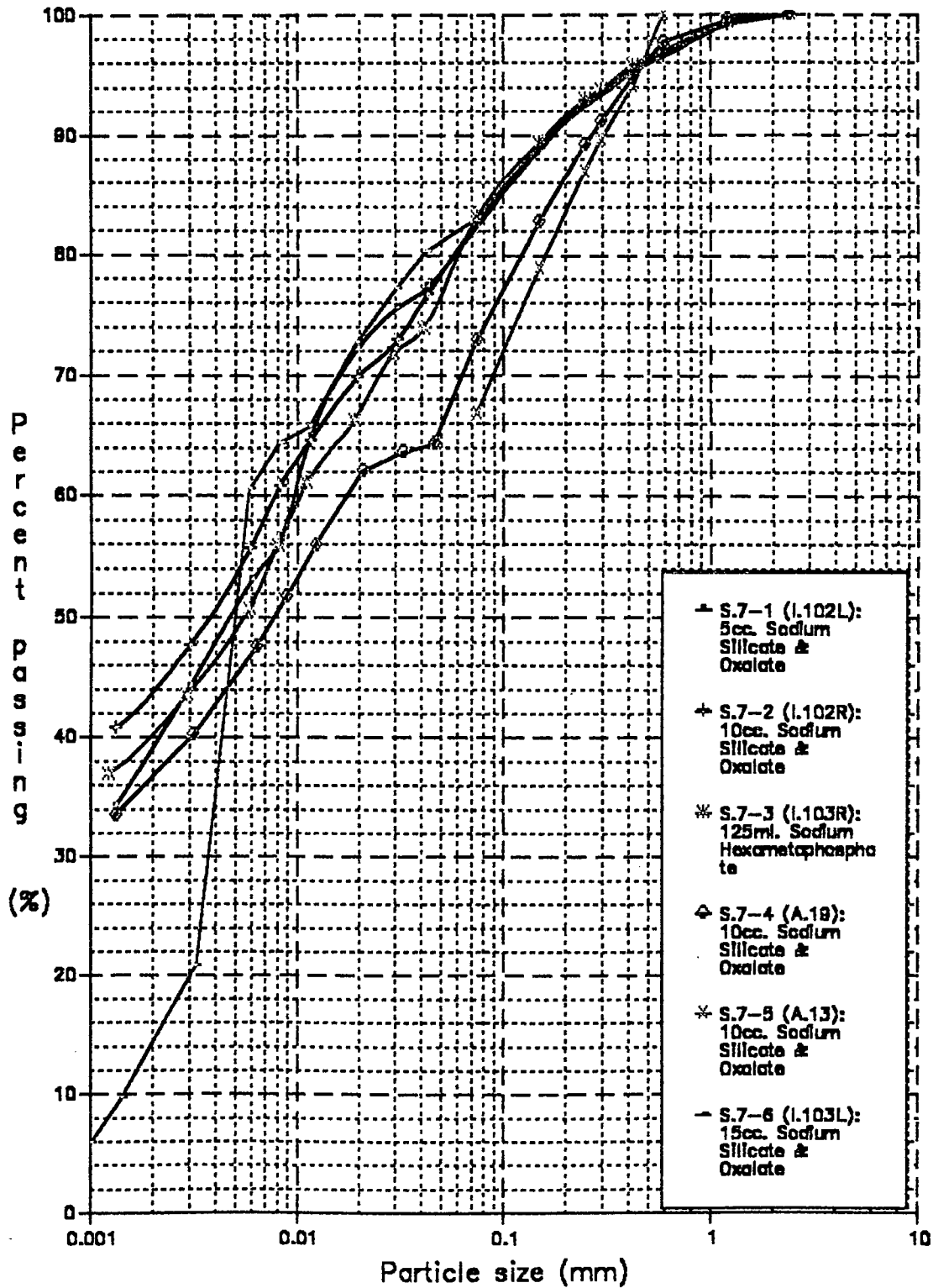


Figure A.42: Particle size distribution - Site 7, Mowbray.

Site 'B' Francois Road, 'C' Margaret Mayton Avenue,
and, Site 'D' Rose Hill

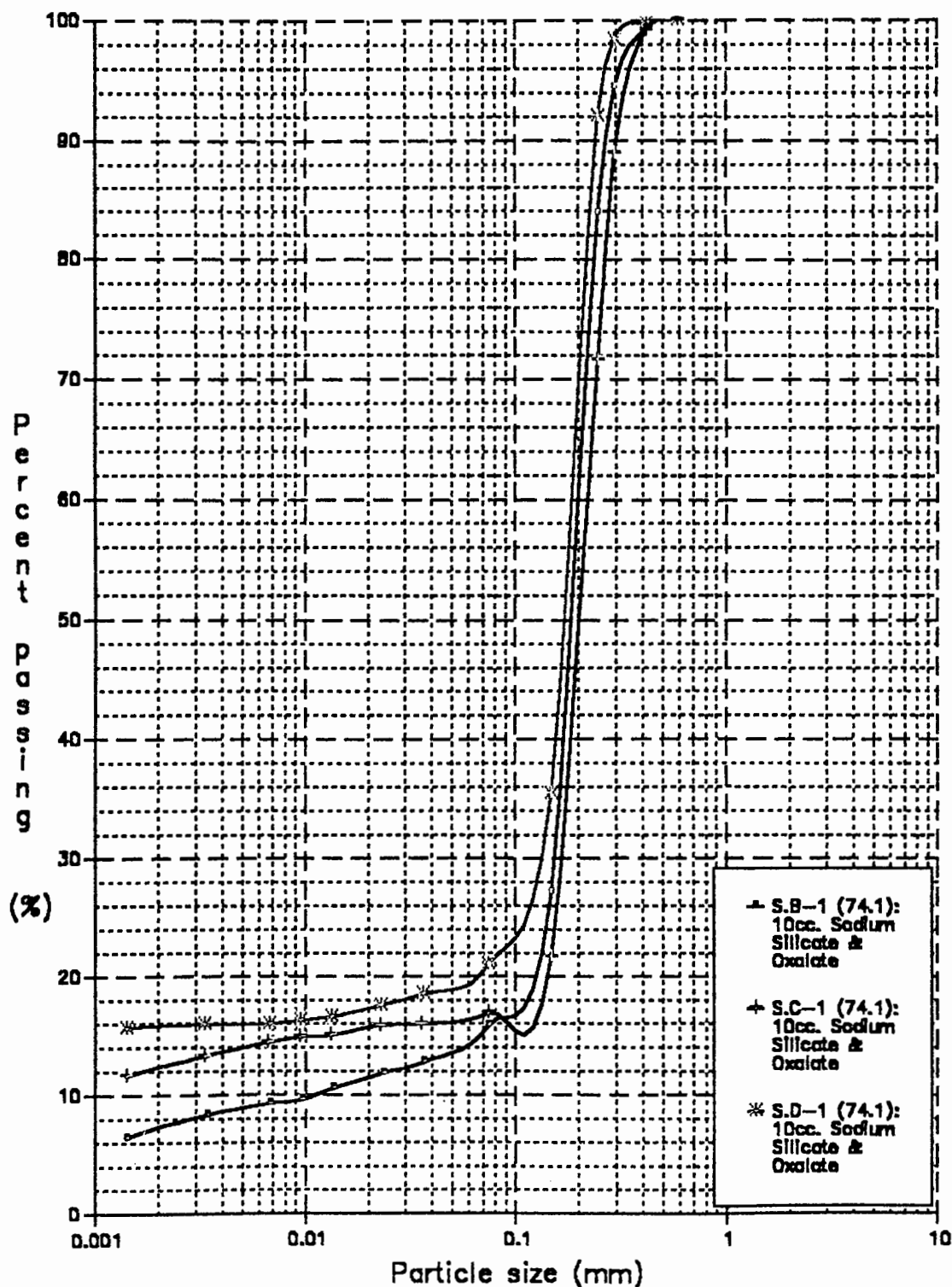


Figure A.43: Particle size distribution - (i) Site B, Francois Road, (ii) Site C, Margaret Mayton Avenue, and (iii) Site D, Rose Hill.

Kaolin K.1 (13%), K.2 (20%), and Kaolin K.3 (10%)

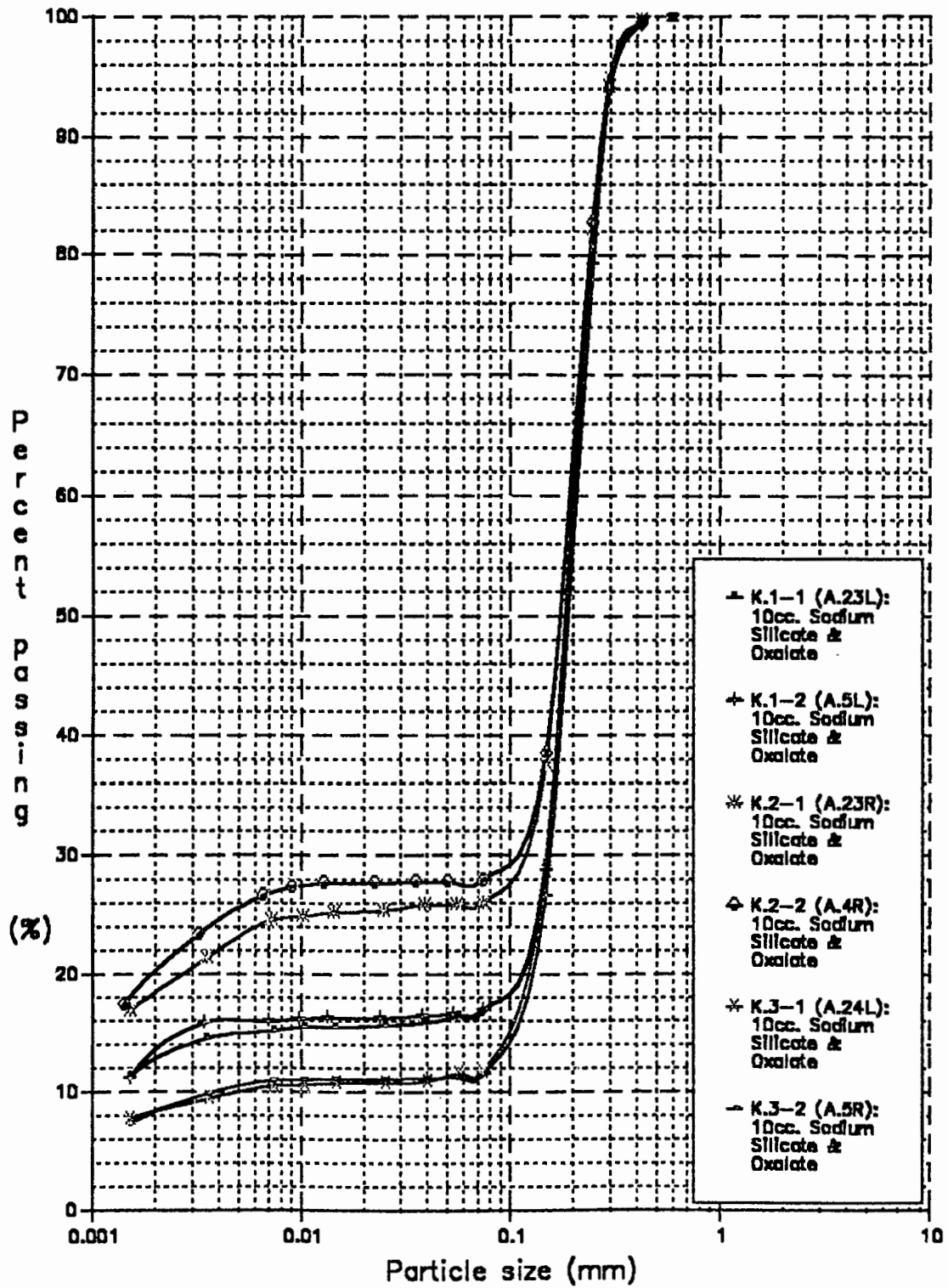


Figure A.44: Particle size distribution - Kaolin K.1 (13%), K.2 (20%), and K.3 (10%).

Bentonite B.1 (3.5%), B.2 (7%), B.3 (11.5%),
B.4 (15.5%), and Bentonite B.5 (35%)

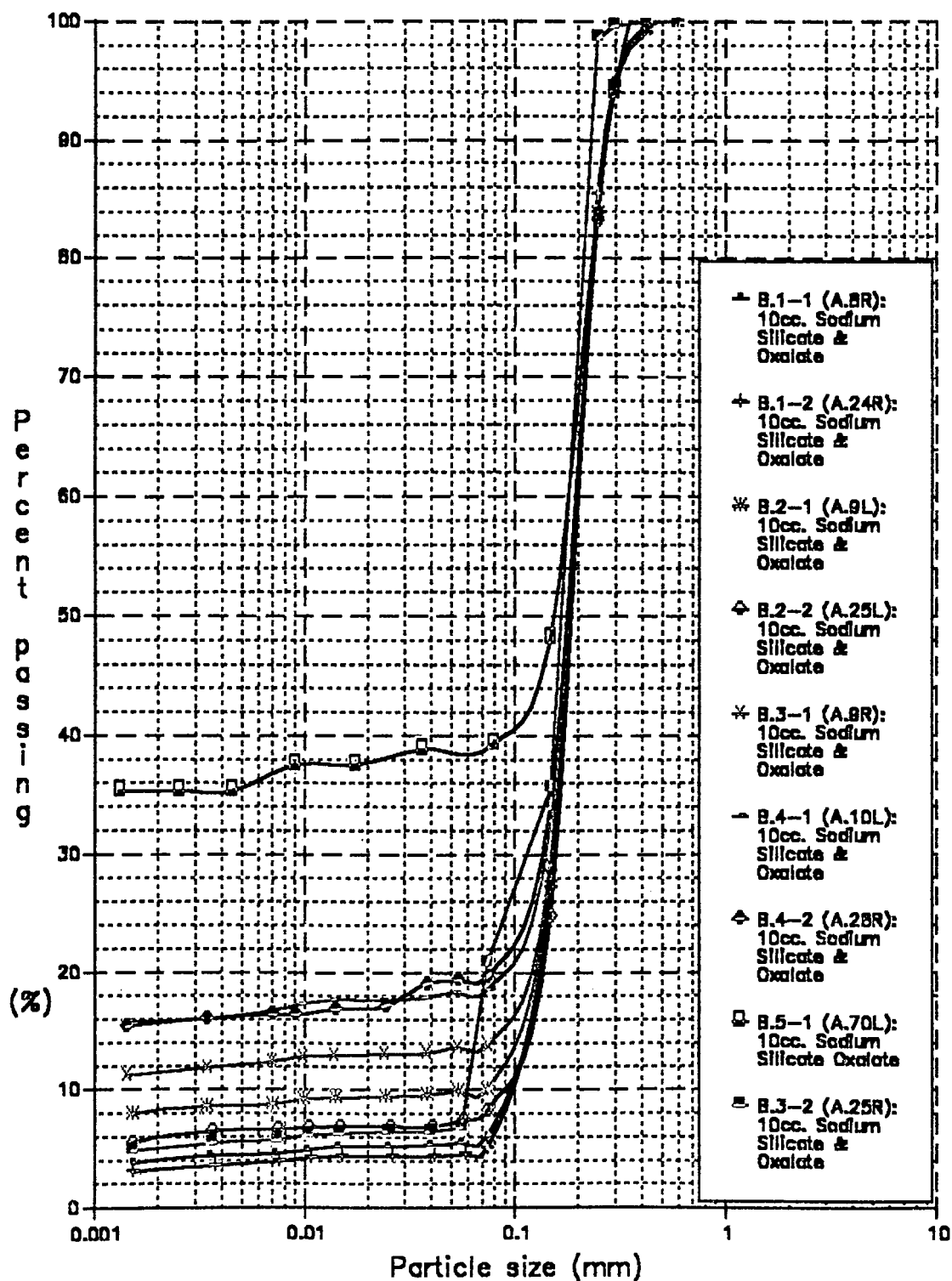


Figure A.45: Particle size distribution - Bentonite B.1 (3.5%), B.2 (7%), B.3 (11.5%), B.4 (15.5%), and B.5 (35%).

A.7.4 Specific Gravity

Table A.37: Soil types - Summary of measured values for the specific gravity 'Gs', Tx/20°C.

Site Number, name (reference)	Specific Gravity [Gs, Tx/20°C]		
	Test 1	Test 2	'Gs'

Natural Soils Types - Cape area

11, Rosebank	(A.68)	2.7580	2.7526	2.755
36, Rondebosch	(A.68)	2.6913	2.6840	2.688
30, Hout Bay	(A.68)	2.6324	2.6421	2.637
7, Mowbray	(A.68)	2.7449	2.7722	2.759
45, Bellville	(A.59)	2.746		2.746
48, Lady Grey	(A.61)	2.750		2.750

Natural Soil Types - Durban area

A, Berea Road	(A.68)	2.6607	2.6693	2.665
B, Francois Road	(74)	2.704		2.704
C, Margaret Mayton Ave	(74)	2.645		2.645
D, Rose Hill	(74)	2.702		2.702

Artificial Soil Types - Kaolin

K 1	(13% - A.68)	2.6671		2.667
K 2	(20% - A.68)	2.6419		2.642
K 3	(10% - A.68)	2.6679		2.668

Artificial Soil Types - Bentonite

B 1	(3.5% - A.68)	2.6399		2.640
B 2	(7% - A.68)	2.6439		2.644
B 3	(11.5% - A.68)	2.6596		2.660
B 4	(15.5% - A.68)	2.6824		2.682
B 5	(35% - A.68)	2.6448	2.6476	2.646

A.7.5 pH MeasurementsTable A.38: Soil samples - pH values, as defined in chapter two (refer to test procedure¹).

Site, Locality 'pH' Site, Locality 'pH' Site, Locality 'pH'

Natural Soil Types[Cape Area]

1	Blackheath	7.7	24	Durbanville	6.0	47	Bellville	9.0
2	"	8.1	25	Kenridge	7.3	48	Lady Grey	6.8
3	Durbanville	9.0	26	"	7.2	49	Epping	9.0
4	Kenridge	6.8	27	Kenridge	5.0	50	Wynberg	6.0
5	Mowbray	5.0	28	Wynberg	6.8			
6	"	6.8	29	"	5.9	[Berea Red, Durban]		
7	"	4.5	30	Hout Bay	8.5			
8	Mowbray	6.0	31	"	5.7	A	Berea Road	6.0
9	Somerset W	7.5	32	Kommetjie	6.8	B	Francois rd	6.2
10	Pinelands	9.2	33	Fish Hoek	5.2	C	Margaret M.av	5.2
11	Rosebank	6.0	34	"	4.7	D	Rose Hill	4.6
12	Durbanville	6.6	35	Fish Hoek	6.1	E	Yellow Wood	5.5
13	Kenridge	7.3	36	Rondebosch	5.3	F	Woodlands	5.9
14	Mowbray	6.9	37	"	4.8	G	Glenhills	6.7
15	Durbanville	6.1	38	"	6.4	H	Glenwood	4.9
16	"	9.1	39	"	6.4			
17	Tygerberg	6.9	40	Rondebosch	7.0			
18	Bergvliet	5.7	41	Sishen	7.2			
19	Mowbray	7.3	42	Parow	9.9			
20	"	7.1	43	Bellville	6.3			
21	Rondebosch	7.8	44	"	6.9			
22	Tygerberg	6.5	45	"	6.5			
23	Durbanville	7.2	46	Bellville	9.4			

Artificial Soil Types

K1	Kaolin, 13%	9.3
K2	Kaolin, 20%	9.4
K3	Kaolin, 10%	9.5
B1	Bentonite, 3.5%	9.8
B2	Bentonite, 7%	9.7
B3	Bentonite, 11.5%	9.8
B4	Bentonite, 15.5%	9.8
B5	Bentonite, 35%	9.9

1 - section A.4.8 "pH Value of Soil Suspension".

A.7.6 Standard and Modified AASHTO Compaction TestsSite 11 - Rosebank, Cape

Table A.39: Site 11, Rosebank - Compaction test results.

Standard AASHTO

Volume of mould used 'VT' = 943,7 cm³; G_S = 2,755.

Determination No.	1	2	3	S11/70	S11/71
Compacted soil 'M'(g)	1606	1720	1726	1709	1721
Wet density 'Dw'(KN/m ³)	16,69	17,87	17,94	17,76	17,88
(Water content)					
Wt. moist sample (g)	62,93	58,69	56,86	157,5	153,9
Wt. oven-dry sample (g)	53,30	46,06	42,82	128,1	120,6
Wt. water (g)	9,63	12,63	14,04	29,4	33,3
Water content (%)	18,07	27,42	32,79	23,0	27,6
Dry density 'Do'(KN/m ³)	14,13	14,03	13,51	14,44	14,02
Degree of saturation 'Sr'	0,546	0,816	0,903	0,727	0,820

Modified AASHTO

No.	1	2	3	4	5	6	7
'M', g	1548	1675	1804	1888	1903	1859	1816
'Dw', KN/m ³	16,09	17,41	18,75	19,62	19,78	19,32	18,87
(w)							
moist, g	67,16	53,04	53,62	55,28	56,24	56,6	60,18
dry, g	63,24	47,92	46,87	47,07	45,71	44,79	46,95
water, g	3,92	5,12	6,75	8,21	10,53	11,81	13,23
w, %	6,20	10,68	14,40	17,44	23,04	26,37	28,18
'D _p '	15,15	15,73	16,39	16,71	16,07	15,29	14,72
'Sr'	0,218	0,410	0,612	0,778	0,932	0,947	0,930

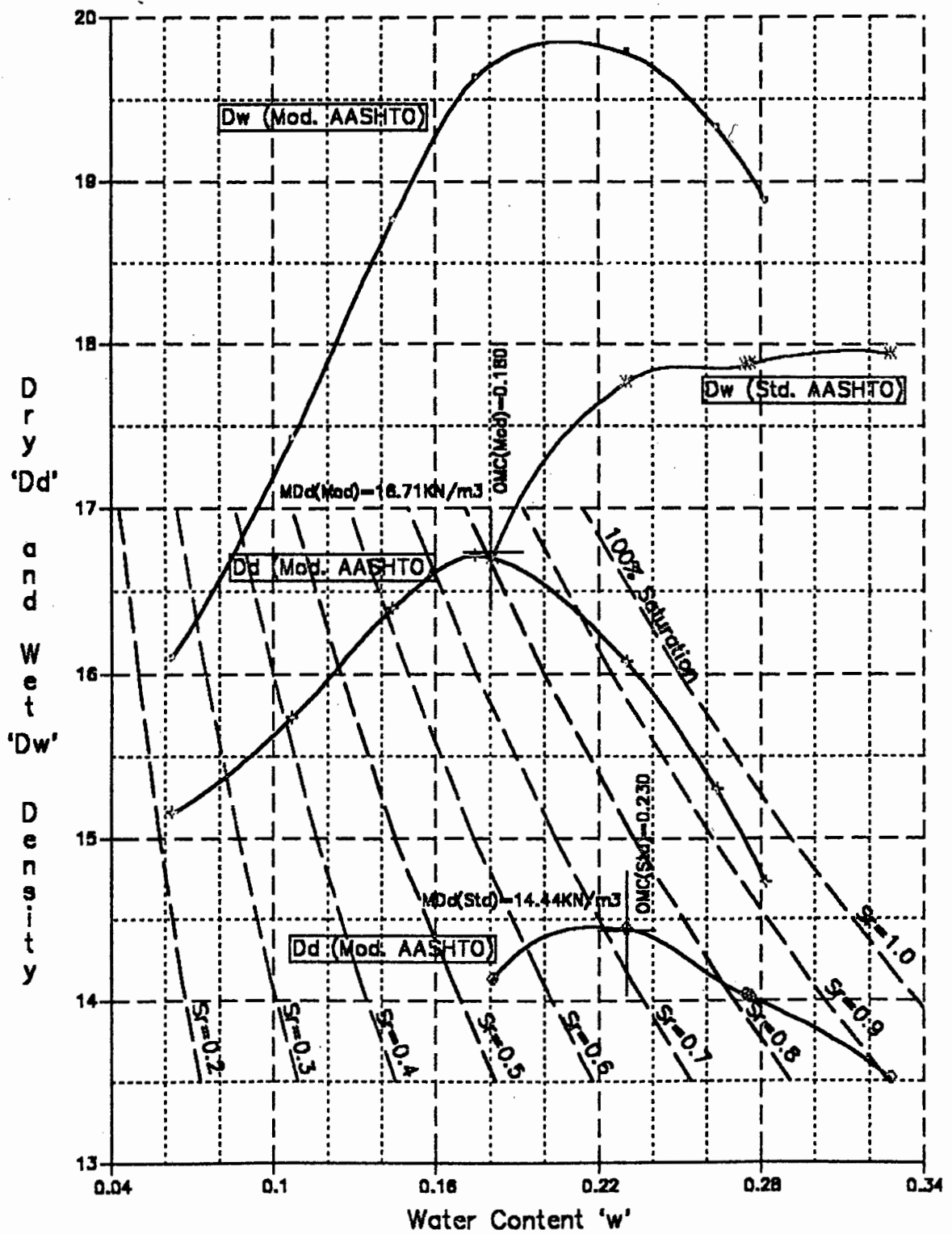


Figure A.46: Site 11, Rosebank - plot of water content versus dry (and wet) density, and curves for degree of saturation.

Site 36, RondeboschTable A.40: Site 36, Rondebosch - Compaction test results.Standard AASHTO

Volume of mould used 'VT' = 943,7 cm³; G_s = 2,688.

Determination No.	1	2	3	4	5
Compacted soil 'M'(g)	1757	1849	1923	1895	1844
Wet density 'D _w '(KN/m ³)	18,26	19,21	19,98	19,69	19,16
(water content)					
Wt. moist sample (g)	-	-	-	-	-
Wt. oven-dry sample (g)	-	-	-	-	-
Wt. water (g)	-	-	-	-	-
Water content (%)	13,2	15,1	16,7	18,6	19,1
Dry density 'D _d '(KN/m ³)	16,13	16,69	17,12	16,60	16,09
Degree of saturation 'Sr'	0,559	0,701	0,832	0,851	0,804

Modified AASHTO

No.	1	2	3	4	5	6	7
'M', g	1585	1635	1840	1956	2015	1963	1880
'D _w ', KN/m ³	16,47	16,99	19,12	20,33	20,94	20,40	19,54
(w)							
moist, g	35,2	54,18	28,77	35,56	53,61	54,37	63,08
dry, g	34,66	51,78	26,67	31,66	46,12	45,30	50,89
water, g	0,54	2,40	2,10	3,90	7,49	9,07	12,19
w, %	1,56	4,63	7,87	12,32	16,24	20,02	23,95
'D _d '	16,22	16,24	17,73	18,10	18,01	17,00	15,76
'Sr'	0,067	0,200	0,434	0,725	0,942	0,977	0,957

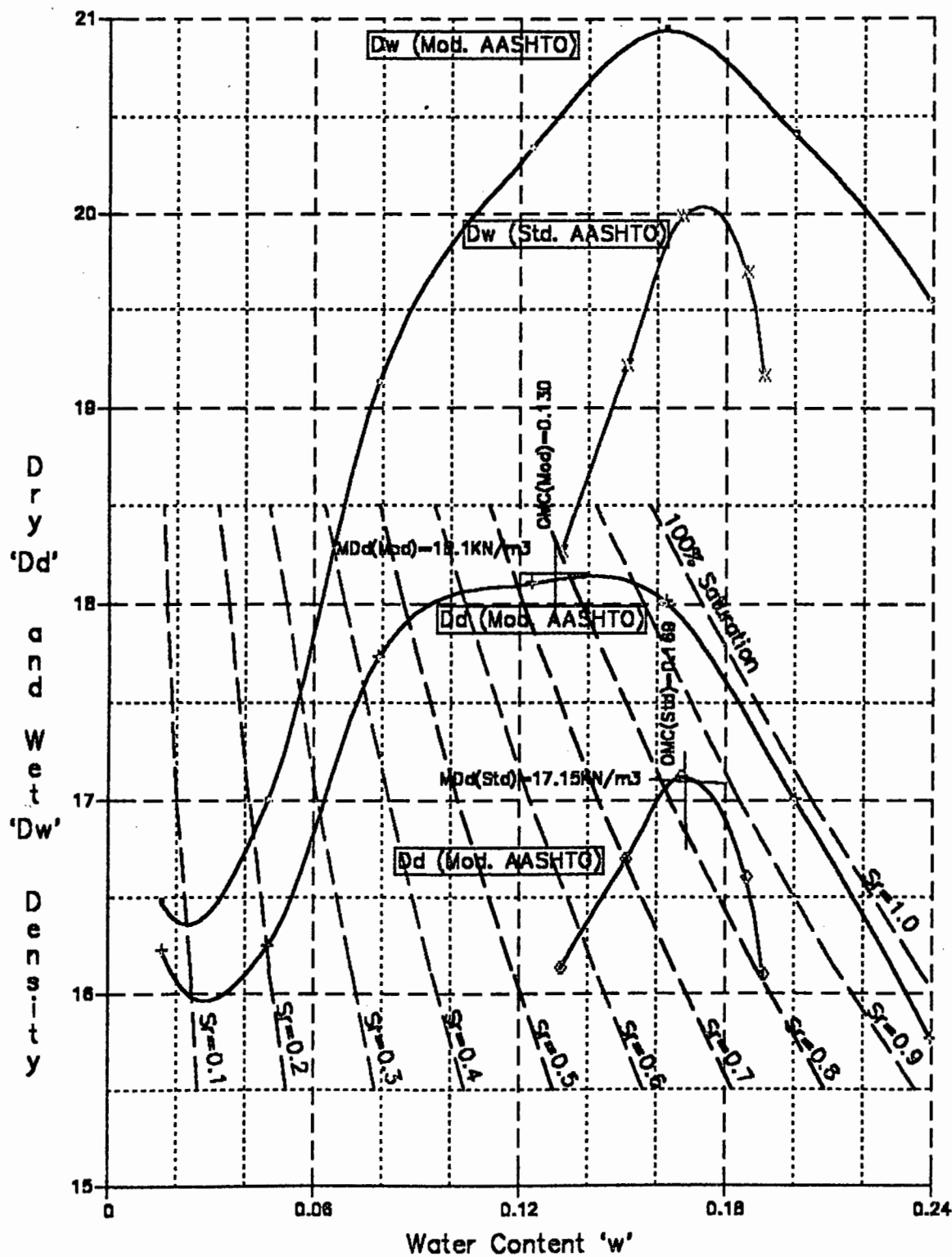


Figure A.47: Site 36, Rondebosch - plot of water content versus dry (and wet) density, and curves for degree of saturation.

Site 30, Hout BayTable A.41: Site 30, Hout Bay - Compaction test results.Standard AASHTO

Volume of mould used 'VT' = 943,7 cm³; G_s = 2,637.

Determination No.	1	2	3
Compacted soil 'M' (g)	1731	1754	1685
Wet density 'D _w ' (KN/m ³)	17,99	18,23	17,51
(water content)			
Wt. moist sample (g)	61,00	58,98	61,05
Wt. oven-dry sample (g)	50,34	45,73	45,75
Wt. water (g)	10,66	13,25	15,30
Water content (%)	21,18	28,97	33,44
Dry density 'D _p ' (KN/m ³)	14,84	14,13	13,12
Degree of saturation 'Sr'	0,753	0,921	0,908

Modified AASHTO

No.	1	2	3	4	5	6	7
'M', g	1575	1655	1741	1885	1915	1815	1770
'D _w ', KN/m ³	16,37	17,20	18,09	19,59	19,90	18,86	18,39
(w)							
moist, g	36,03	33,15	38,19	43,46	42,68	54,39	47,28
dry, g	35,43	31,25	34,66	38,27	35,70	43,21	36,65
water, g	0,60	1,90	3,53	5,19	6,98	11,18	10,63
w, %	1,69	6,08	10,18	13,56	19,55	25,87	29,00
'D _p '	16,09	16,21	16,42	17,25	16,65	14,98	14,26
'Sr'	0,073	0,269	0,467	0,716	0,931	0,940	0,940

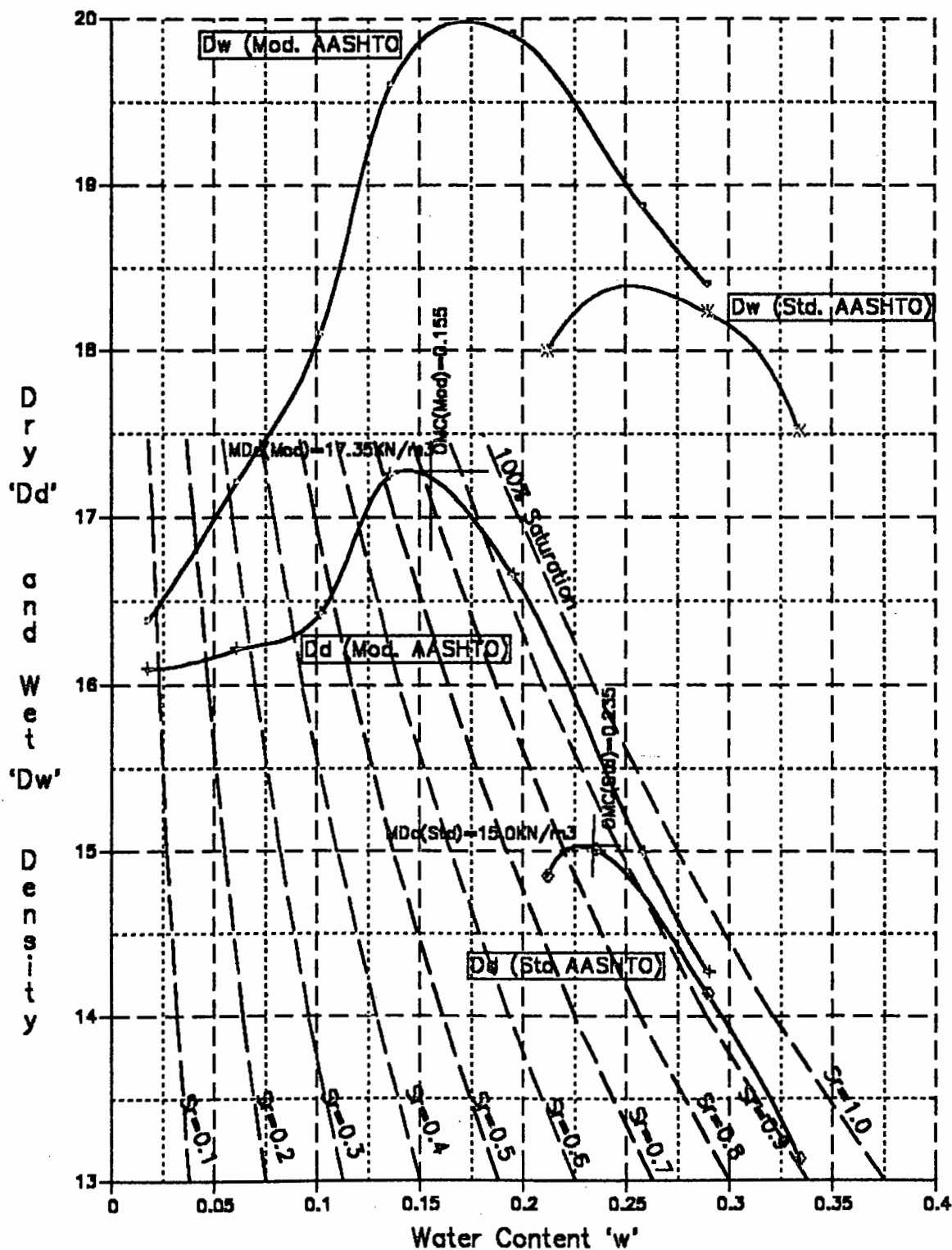


Figure A.48: Site 30, Hout Bay - plot of water content versus dry (and wet) density, and curves for degree of saturation.

Site A, Berea Road

Table A.42: Site A, Berea Road - Compaction test results.

Standard AASHTO

Volume of mould used ' V_T ' = 943,7 cm³; G_S = 2,665.

Determination No.	1	2	3
Compacted soil ' M '(g)	1947	2041	1964
Wet density ' D_W '(KN/m ³)	20,23	21,21	20,41
(water content)			
Wt. moist sample (g)	60,90	58,69	60,83
Wt. oven-dry sample (g)	55,76	52,30	52,35
Wt. water (g)	5,14	6,39	8,48
Water content (%)	9,22	12,22	16,20
Dry density ' D_D '(KN/m ³)	18,52	18,90	17,56
Degree of saturation ' S_r '	0,598	0,851	0,885

Modified AASHTO

No.	1	2	3	4	5	6	SA/9
' M ', g	1661	1676	1984	2146	2089	2018	1839
' D_W ', KN/m ³	17,26	17,42	20,62	22,30	21,71	20,97	19,11
(w)							
moist, g	63,24	59,46	50,39	58,46	54,39	57,26	171,05
dry, g	62,87	57,45	47,40	53,66	48,76	50,60	162,14
water, g	0,37	2,01	2,99	4,80	5,63	6,66	8,91
w, %	0,59	3,50	6,31	8,95	11,55	13,16	5,50
' D_D '	17,16	16,83	19,39	20,47	19,46	18,53	18,11
' S_r '	0,030	0,169	0,484	0,862	0,898	0,855	0,331

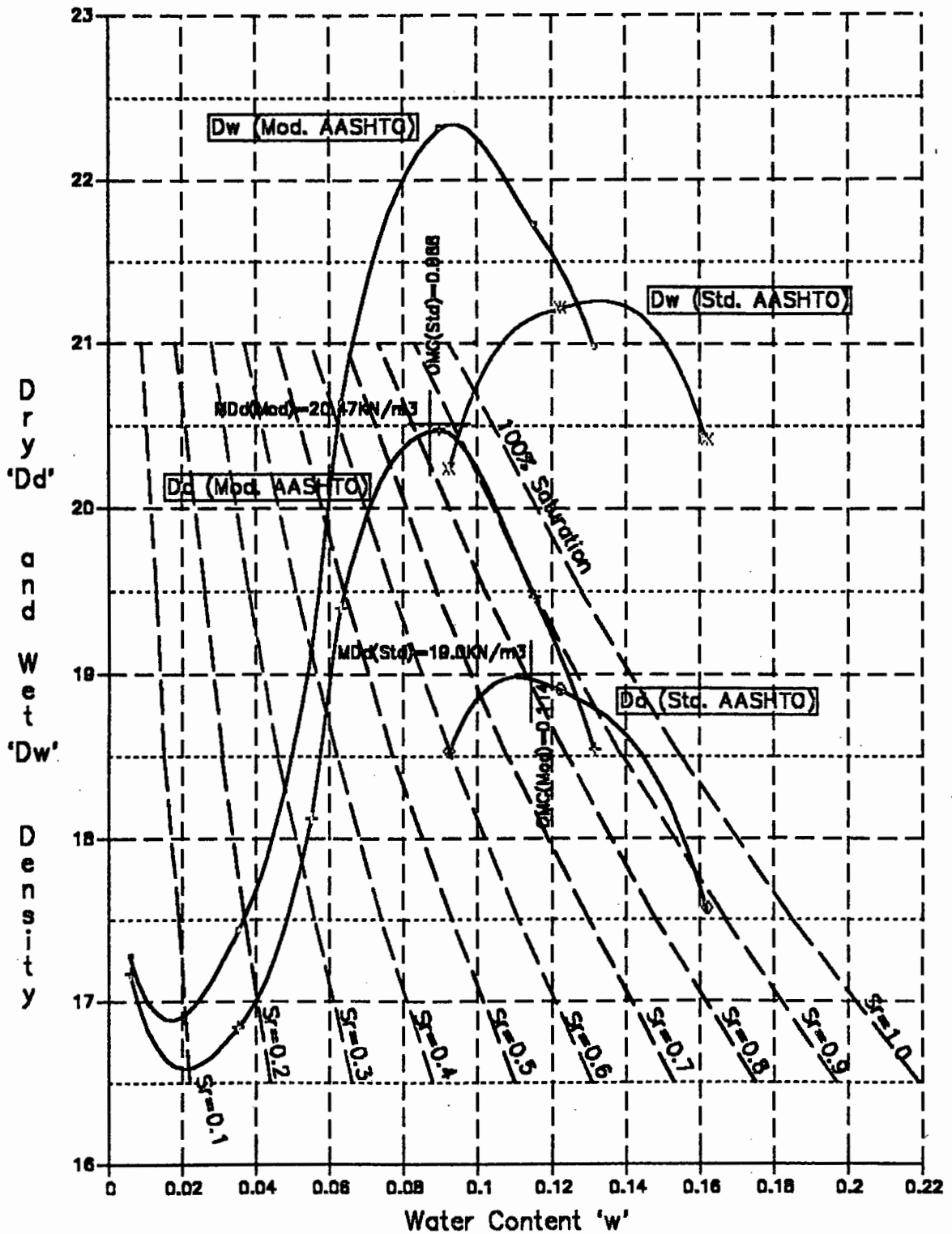


Figure A.49: Site A, Berea Road - plot of water content versus dry (and wet) density, and curves of saturation.

Site 7, MowbrayTable A.43: Site 7, Mowbray - Compaction test results.Standard AASHTO

Volume of mould used 'VT' = 943,7 cm³; G_S = 2,759.

Determination No.	1	2
Compacted soil 'M'(g)	1895	1880
Wet density 'D _W '(KN/m ³)	19,69	19,54
(water content)		
Wt. moist sample (g)	63,11	60,14
Wt. oven-dry sample (g)	53,12	49,20
Wt. water (g)	9,99	10,94
Water content (%)	18,81	22,24
Dry density 'D _D '(KN/m ³)	16,57	15,98
Degree of saturation 'Sr'	0,821	0,886

Modified AASHTO

No.	1	2	3	4	5	S7/13
'M', g	1739	1907	2045	2002	1896	1864
'D _W ', KN/m ³	18,07	19,82	21,25	20,80	19,70	19,37
(w)						
moist, g	50,52	31,06	29,72	40,39	51,29	177,78
dry, g	48,05	28,68	26,35	34,56	41,96	164,87
water, g	2,47	2,38	3,37	5,83	9,33	12,91
w, %	5,14	8,30	12,79	16,87	22,24	7,83
'D _D '	17,19	18,30	18,84	17,80	16,12	17,96
'Sr'	0,247	0,478	0,809	0,895	0,904	0,427

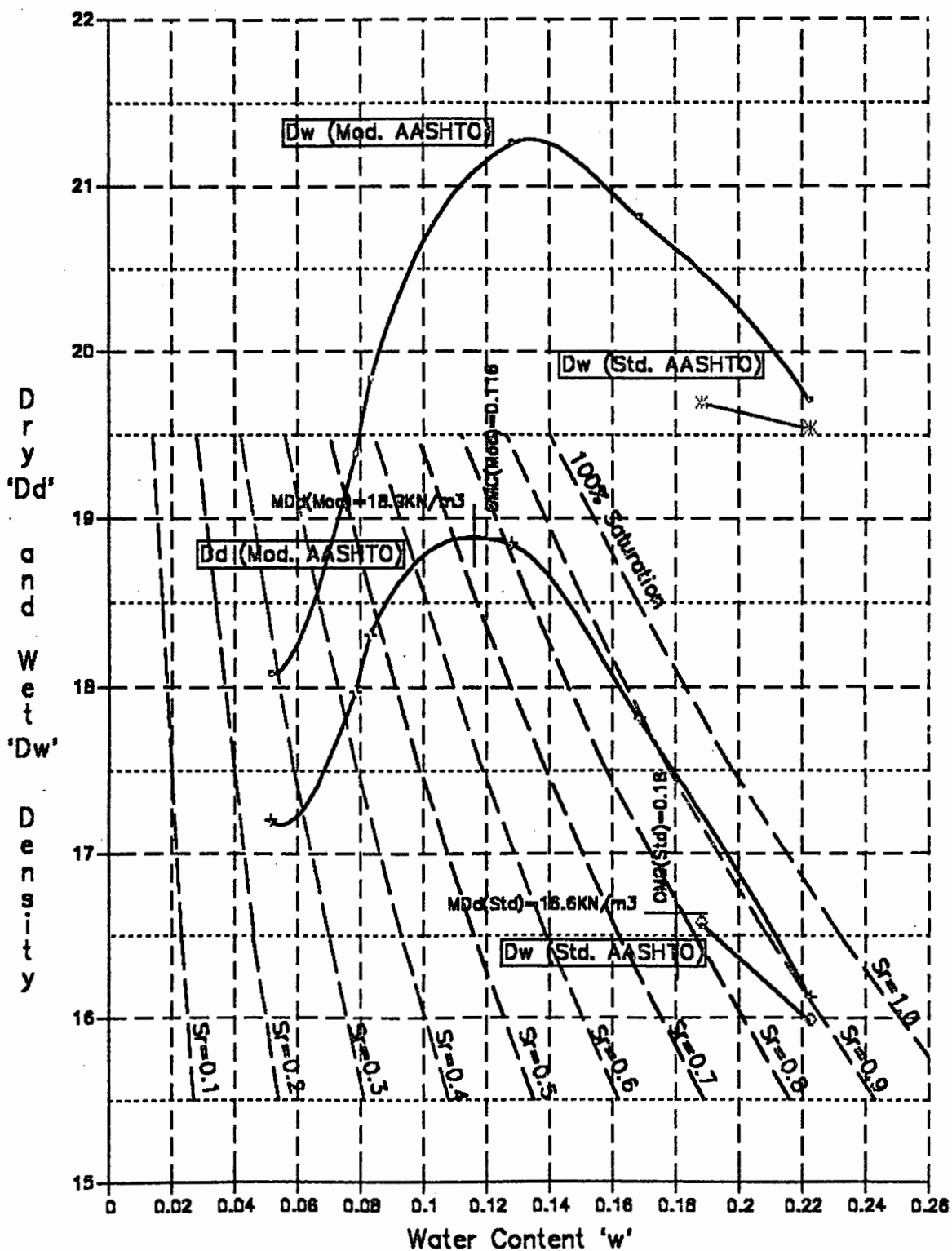


Figure A.50: Site 7, Mowbray - plot of water content versus dry (and wet) density, and curves for degree of saturation.

CONSISTENCY LIMITS. (Part I)
SOIL SAMPLE: _____

TEST REFERENCE NOS.: _____

LIQUID LIMIT, 'LL':

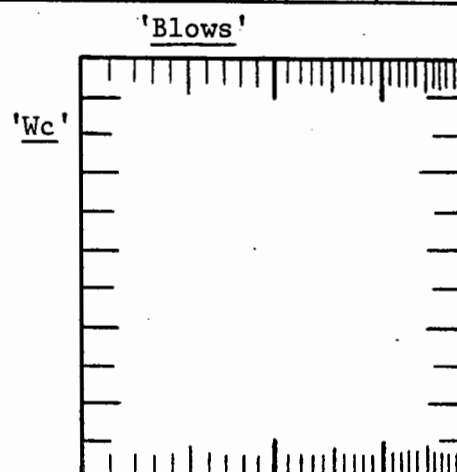
Test reference number.										
Moist soil + Tare (g).										
Oven-dry soil + Tare (g).										
Mass of water (g).										
Tare (g).										
Mass of oven-dry soil (g).										
Water content 'Wc' (%).										
Number of 'Blows'.										

Plot " 'Blows' vs. 'Wc' ": LIQUID LIMIT, 'LL' = ____%.

LINEAR SHRINKAGE, 'LS':

Test reference number.				
At 'LL': Initial length (mm).				
Oven-dry: Final length (mm).				
Linear Shrinkage (%).				

Mean of 'LS' results: LINEAR SHRINKAGE, 'LS' = ____%.


PLASTIC LIMIT, 'PL':

Test reference number.							
Moist soil + Tare (g).							
Oven-dry soil + Tare (g).							
Mass of water (g).							
Tare (g).							
Mass of oven-dry soil (g).							
Water content 'Wc' (%).							

Mean of the 'Wc' results: PLASTIC LIMIT, 'PL' = ____%.

PLASTICITY INDEX, 'PI':

PLASTICITY INDEX OF THE SOIL, 'PI' = 'LL' - 'PL' = _____.

REMARKS:

TEST REFERENCE NO.: _____

Soil sample at each drying stage: Recorded masses of soil and mercury; Calculated volume of the soil mass 'Vt', and its water content 'Wc'.

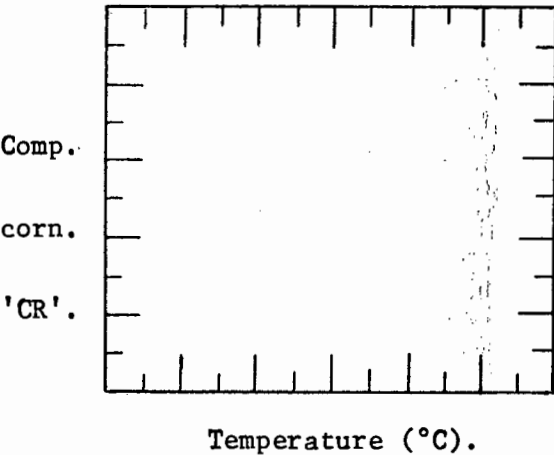
SHRINKAGE LIMIT, 'SL' = ____ %.

PARTICLE SIZE ANALYSIS.

SOIL SAMPLE: _____ TEST REFERENCE NO.: _____

Mass of air dried soil used = (ADS) = ____ g.
Hygroscopic moisture correction factor = (CM) = ____ = ____.
Calculated mass of oven dried soil in Hydrometer Analysis = (W) = ADS x CM = ____ g.

Composite correction, 'CR': _____ DRY SIEVE ANALYSIS:
Dispersing agent used: _____ Mass of oven-dry soil = (ODS) = ____ g.
_____ 'Wet sieving' soil = (WS) = W - ODS = ____ g.



PERCENTAGE PASSING.	Percent retain.	Mass retain.	Sieve size.	PARTICLE DIAMETER.
(%)	(%)	(g)	(Mesh#)	(mm)
			(8)	2,362
			(14)	1,204
			(28)	0,589
			(35)	0,417
			(52)	0,295
			(60)	0,246
			(100)	0,147
			(200)	0,074.
			PAN	
			WS.	

HYDROMETER ANALYSIS:

Time	Hydro- meter	Temp.	Comp. corn.	Adjusted reading,	SUSPENSION: PERCENTAGE,	Table I:	Table 2:	PARTICLE DIAMETER,
'T'. (min)	Reading. 'R'	(°C)	'CR'.	'AR' =R+CR-G _{SL} .	P=(AR)x C. (%)	'K'.	'L'. (cm)	D=K x $\sqrt{\frac{L}{T}}$. (mm)
I								
2								
5								
15								
30								
60								
250								
I440								

Notes: (i) Specific Gravity of suspending medium, G_{SL} = 1,000.
(ii) Specific Gravity of soil particles, G_S = ____.
(iii) Constant, C = $\frac{100\ 000}{W} \times \frac{G_S}{G_S - G_{SL}} =$ ____.

REMARKS:

SPECIFIC GRAVITY, 'GS'.

The relative specific density of the soil particles.

SOIL SAMPLE: _____ TEST REFERENCE NO.: _____

Calibration of the 'GS' bottle:

Mass of 'GS' bottle = (Wf) = _____ g.

Mass of 'GS' bottle + distilled water = (Wa) = _____ g.; Temp.(Ti)= _____ °C.

Calculated "Wa"(for Temp."Tx") = $\frac{\text{density of water at "Tx"}}{\text{density of water at "Ti"}} \times [Wa(\text{at "Ti"}) - Wf] + Wf$.

= _____ g.

Calculation of the Specific Gravity, 'GS':

Mass of 'GS' bottle + soil + distilled water = (Wb) = _____ g.; Temp.(Tx)= _____ °C.

Mass of oven-dry soil = (Wo) = _____ g.

Therefore, 'GS', Tx / Tx °C. = $\frac{Wo}{Wo + ("Wa" - Wb)}$ = _____.

Hence, 'GS', Tx / 20°C = "k" x 'GS', Tx / Tx °C. = _____.

<u>Table:</u>	<u>Temp. °C. ;</u>	<u>Relative density of water ;</u>	<u>Correction factor "k".</u>
	I4	0,99 927	I,00 I04
	I5	9I3	090
	I6	897	074
	I7	880	057
	I8	862	039
	I9	843	020
	20	823	I,00 000
	2I	802	0,99 979
	22	780	957
	23	756	933
	24	732	909
	25	707	884
	26	68I	858
	27	654	83I
	28.	0,99 626.	0,99 803.

REMARKS:

APPENDIX B

SCANNING ELECTRON MICROSCOPY AND X-RAY DIFFRACTION - PREPARATION OF CLAY SAMPLES AND TEST DATA

B.1 INTRODUCTION

This appendix includes the required step-by-step preparation of the clay samples used for Scanning Electron Microscopy 'SEM' testing and X-Ray Diffraction 'X-ray D' analysis. Also included are detailed test procedures for SEM testing and X-ray D analysis.

The appendix is divided in four parts, as follows:

- Part 1 - Clay separation of samples for Scanning Electron Microscopy and X-ray Diffraction;
- Part 2 - Preparation of clay samples and SEM testing;
- Part 3 - X-ray Diffraction: preparation and testing of samples; and,
- Part 4 - X-ray diffraction test traces.

B.2 CLAY SEPARATION OF SAMPLES FOR SCANNING ELECTRON MICROSCOPY AND X-RAY DIFFRACTION.

This part describes the initial preparation of the samples for scanning electron microscopy and x-ray diffraction - that is, the clay separation of a sample representative from each soil type.

Initial preparation of samples for SEM and X-ray D:-

Representative soil samples were originally obtained for each soil type selected for this thesis (refer to Appendix A¹). The following soil types were previously selected: sites 11, 36, 30, A and 7 (natural soils); and, K and B (artificial soils).

This section describes the initial preparation of soil samples for the purposes of both scanning electron microscopy and x-ray diffraction. After this initial sample preparation stage, the next stage in the preparation differs between the SEM and X-ray D. The next section of this Appendix (refer to section B.3, "Preparation of Clay Samples and SEM Testing") deals with the preparation of clay samples for SEM purposes only.

Concerning the X-ray D, the next stage of sample preparation will be dealt with in a subsequent section of this Appendix² - "X-Ray Diffraction: Preparation and Testing of Samples".

¹ - section A.3 "Preparation of Soil Samples for Testing".

² - refer to section B.4 of this Appendix.

Clay separation of soil samples:-

The procedure adopted¹ can be summarized in the following steps:

1. Place approximately 50 grams of soil sample into a tub, and fill it about 1/3 of the way with distilled water;
2. Siphon off the clay (up to six times) using the values, for depth of pipetting versus time at different temperatures for the $< 2 \mu\text{m}$ material, included in Table B.01. Allow the clay to settle for 2 - 3 weeks. Discard, the material left in the tub².
3. Decant or siphon off the supernatant water of each sample (alternatively, centrifuge the water off). Homogenize clay by shaking, split each sample into two portions, and store them in bottles. Therefore there will be two representative clay samples, stored in separate bottles, for each soil sample. One of the clay samples will be used for X-ray D - refer to section B.4 of Appendix B).
4. Draw off a small quantity of clay from the other clay sample, and store in a vial for electron microscope examination - refer to section B.3 of this Appendix.

Sediment laboratory procedure:-

The pipetting table presented as table B.01 (Ref. 39) is based on particle size. Depending on the temperature of the day, coarse silt is pipetted at a depth of 15 - 22 cm, and clay at 4 - 6 cm. It should be noted that the table ranges from $63 \mu\text{m}$ to $1 \mu\text{m}$. The particle sizes have also been given in phi values, that is, the negative logarithm to the base 2 of the size in millimetres - according to the size frequency distribution of sediments originally proposed by Krumbein (Ref. 40).

Siphon off the clay fraction using the pipetting table after recording the temperature of the soil-water mix - use Table B.01 (below) to determine depth of pipetting for $2 \mu\text{m}$ particle size (that is, at time of pipetting = 4 hr).

The above procedure was used for all the soil types - refer to Tables B.02 to B.08 below. It should be noted that Tables B.07 and B.08 provide a check for clay separation of the two artificial soil types. That is, the artificial soil types consisted of Bentonite and Kaolin clay (commercial grade) mixed with sand. Only the clay size was mixed with distilled water for the purpose of sample preparation for SEM and X-ray D (concerning artificial soils, refer to Chapters 1 and Appendix A).

¹ - originally presented by Rodgers (Ref. 38).

² - ie, the 'gravel + sand + silt + little clay'.

*Table B.01: Pipetting table for particle size.
[Depth of Pipetting = Settling Velocity x Time of Pipetting]*

Time of pipetting and corresponding particle size:						
3 1/3min.	15 min.	20 min.	1 hr.	4 hr.	12 hr.	
31 μm	16 μm	8 μm	4 μm	2 μm	1 μm	
(5 phi)	(6 phi)	(7 phi)	(8 phi)	(9 phi)	(10 phi)	
Temp. ($^{\circ}\text{C}$)	Depth of pipetting (cm):					
15	16.1	18.4	6.1	4.6	4.6	3.5
15.5	16.3	18.7	6.2	4.7	4.7	3.5
16	16.5	18.9	6.3	4.7	4.7	3.5
16.5	16.7	19.2	6.4	4.8	4.8	3.6
17	16.9	19.4	6.5	4.9	4.9	3.7
17.5	17.1	19.7	6.5	4.9	4.9	3.7
18	17.3	19.9	6.7	5.0	5.0	3.8
18.5	17.6	20.2	6.7	5.1	5.1	3.8
19	17.8	20.4	6.8	5.1	5.1	3.8
19.5	18.0	20.7	6.9	5.2	5.2	3.9
20	18.2	20.9	7.0	5.2	5.2	3.9

Natural Soil Types:

Table B.02: Site 11, Rosebank - clay separation.

Date/Time of mixing	Time of pipetting	Temperature ($^{\circ}\text{C}$)	Depth of pipetting (cm)
19-9/13:08-09	17:09	16.5	4.8
20-9/08:15-16	12:16	16.0	4.7
20-9/12:43-44	16:45	16.5	4.8
21-9/09:10-11	13:13	16.5	4.8
21-9/13:32-33	17:33	17.0	4.9
22-9/08:36-37	12:41	17.5	4.9
22-9/13:10-11	17:52	17.5	4.9

Table B.03: Site 36, Rondebosch - clay separation.

Date/Time of mixing	Time of pipetting	Temperature ($^{\circ}\text{C}$)	Depth of pipetting (cm)
19-9/13:10-11	17:11	16.5	4.8
20-9/08:18-19	12:24	16.0	4.7
20-9/12:58-59	16:48	16.5	4.8
21-9/09:22-23	13:19	16.5	4.8
21-9/13:35-36	17:36	17.0	4.9
22-9/08:39-40	12:47	17.5	4.9
22-9/13:26-27	17:27	17.5	4.9

Table B.04: Site 30, Hout Bay - clay separation.

Date/Time of mixing	Time of pipetting	Temperature (°C)	Depth of pipetting (cm)
19-9/13:14-15	17:15	16.5	4.8
20-9/08:21-22	12:27	16.0	4.7
20-9/12:49-50	16:51	16.5	4.8
21-9/09:14-15	13:21	16.6	4.8
21-9/13:38-39	17:39	17.0	4.9
22-9/08:42-43	12:49	17.5	4.9

Table B.05: Site A, Berea Road - clay separation.

Date/Time of mixing	Time of pipetting	Temperature (°C)	Depth of pipetting (cm)
19-9/13:16-17	17:17	16.5	4.8
20-9/08:24-25	12:29	16.0	4.7
20-9/12:52-53	16:55	16.5	4.8
21-9/09:17-18	13:24	17.0	4.6
21-9/13:41-42	17:52	17.0	4.9
22-9/08:45-46	12:58	17.5	4.9
22-9/13:16-17	17:17	17.5	4.9

Table B.06: Site 7, Mowbray - clay separation.

Date/Time of mixing	Time of pipetting	Temperature (°C)	Depth of pipetting (cm)
19-9/13:18-19	17:19	16.5	4.8
20-9/08:27-28	12:32	16.0	4.7
20-9/12:56-57	16:59	16.5	4.8
21-9/09:20-21	13:29	17.0	4.6
21-9/13:44-45	17:45	17.0	4.9
22-9/08:48-49	13:01	17.5	4.9

Artificial Soil Types:*Table B.07: Kaolin - check for clay separation.*

Date/Time of mixing	Time of pipetting	Temperature (°C)	Depth of pipetting (cm)
22-9/13:45-46	17:46	17.5	4.9
23-9/08:30-31	12:31	18.0	5.0
23-9/12:37-38	16:38	18.0	5.0
24-9/08:35-36	13:04	18.5	5.1

Table B.08: Bentonite - check for clay separation.

Date/Time of mixing	Time of pipetting	Temperature (°C)	Depth of pipetting (cm)
23-9/08:23-24	12:24	18.0	5.0
23-9/12:29-30	16:30	17.5	4.9
24-9/08:27-28	12:37	18.0	5.0

B.3 PREPARATION OF CLAY SAMPLES AND SEM TESTING

This part deals with the preparation of clay samples for scanning electron microscopy, and the testing of the natural (sites 11, 36, 30, A, and 7), and artificial (kaolin and bentonite) soil types.

Test procedure using the emissive mode:-

Before instrument or sample are touched, the results expected should be carefully considered, the most interesting magnification range decided upon and other points of interest, such as depth of focus required and the type of sample being used, noted. The sample should be prepared with this information in mind, and placed on the stage of the SEM.

Conditions for optimum topographical detail:

If low magnifications are required and the specimen has a rough surface, the smallest final aperture should be used along with the largest working distance since, with a rough surface, we are interested in having as much depth of focus as possible. At low magnifications the spot size does not have to be at its smallest diameter and, therefore, the lens currents can be reduced so that there is an increase in signal and the noise (resulting from using a small aperture) is removed from the image.

The beam voltage chosen will depend mainly on the type of specimen used and, to a lesser extent, on the magnification required. High beam voltage may be chosen where very high magnification is required and the specimen is not easily penetrated by the beam. In general beam voltages of about 10 kV are a safer alternative since at high beam penetration one may receive a picture of a sub-surface layer which may be substantially different in topographical detail from the surface layer.

The tilt of the specimen to the beam at which the best electron emission is given varies with the make of instrument but for most of them it is 45° . However, this gives a foreshortened image unless a tilt correction unit is used, and 30° has been found a useful compromise. The choice of line and frame speed on the visual display raster depends entirely on the individual operator. The faster the frame speed the easier it is to judge the focusing and movement of the specimen, however, the picture becomes less clear as the frame speed increases.

Operational sequence:

With the specimen in place and imaged on the screen, the magnification should be set low and the image coarsely focused. The magnification should then always be turned up in stages, to a final high value, so that the focus point is quite obvious. Intermediate focusing takes place at about 1000x, and fine focusing somewhere above that value.

At each magnification range the signal amplification should be set below the flattering level as seen on the Y-modulated oscilloscope. The visual screen has contrast and brightness controls, which do not affect the Y-modulated oscilloscope or the record screen, and are set for the operator's own convenience. If the contrast is not suitable, one should consider using the black level or gamma controls; however, they affect the image on the visual and record screens and, in a sense, give an artificial picture, so the fact that they have been used should always be noted and remembered.

For magnifications above 2000x, precautions should be taken against astigmatism (that is, if the picture appears to have smear marks which lie at an angle to the scanning axes on one side of the focus point, and at the opposite angle on the other side of it). Focusing and astigmatic adjustments should be checked at the highest possible magnifications, or at least one step higher magnification than is to be recorded. If at any stage the beam voltage, aperture or lens currents are altered, the image must be refocused and the astigmatic corrections reapplied.

Photography:

When the image on the visual display screen is satisfactory it may be decided to take a photomicrograph. The line and frame speed of the record raster will depend upon the type of image displayed. The signal is integrated over time for each picture element so that less noise appears on a micrograph taken at a slow frame speed than one taken at a fast frame speed.

Summary of procedure:

1. The following should be noted: Type of sample and preparation; Magnification range expected to be most interesting; Depth of focus needed.
2. Choose the following: Aperture size; Lens currents; Beam voltage; Tilt of specimen.
3. Shut the isolation valve between column and chamber and let air into the specimen chamber; Position the specimen on the stage; Shut the stage and pump down; Check that magnification is at lowest, and collector voltage is at maximum positive value; When the vacuum ready light is on, open the isolation valve.
4. On the visual display screen, adjust line speed to fastest and frame speed to suit operator: Focus starting with coarse focusing at the lowest magnification; Check signal amplification is just below flattening level on Y-modulated oscilloscope; Set brightness and contrast levels on visual display to suit operator; check for and reduce astigmatism.
5. Alter beam voltage and lens currents to give maximum detail with tolerable noise, refocus and reset the astigmatic controls.
6. When a photomicrograph is wanted: Choose line and frame speed for record raster to suit image displayed; Set brightness and contrast controls on record screen, and take the photograph. It should be pointed out that several micrographs, at various rotations and tilts relative to the collector, often yield information unsuspected at first viewing.

*Final preparation and testing of
clay samples at UCT:-*

A summary is provided for the final stage of preparation and SEM testing of the clay samples obtained (refer to previous section) from each soil type used in this thesis.

Preparation of samples for SEM - the final stage comprised the following steps:

- (i) The clay samples were dispersed ultrasonically in acetone;
- (ii) Each sample was in turn pipetted out and two drops were carefully placed on an aluminium stud; and,
- (iii) The samples were coated with carbon and gold palladium.

Highlights of SEM testing (for general description, refer to previous section 'Test procedure using the emissive mode') - the adjustments and recordings performed:

(i) Focus - coarse (x10 to x30), intermediate (x300 to x1000), and fine (x3000);

(ii) Reduce raster, and check astigmatism (at higher magnification than that for recording);

(iii) Wave form monitor - camera set for response to full signal variation;

(iv) Record 1600 lines/frames (800 is acceptable), and recording time (60 s, 125 s or longer depending on noise).

It should be added that the following factors affect the quality of SEM image: Operator; Spot size and penetration; Spherical aberration coefficient of the final lens; Distortion; Astigmatism; Noise; Vibration; Specimen damage; Focus; and, incorrect instrumental parameters.

B.4 X-RAY DIFFRACTION: PREPARATION AND TESTING OF SAMPLES

This section comprises two parts:

1. Preparation of samples for X-ray diffraction analysis. The first stage of sample preparation was carried out at the same time, and using the same procedure, as the samples for the scanning electron microscope. This part takes up from the end of the sample preparation stage previously reached - refer to previous section B.2, "Clay Separation of Samples for Scanning Electron Microscopy and X-Ray Diffraction".

2. The x-ray diffraction test method adopted, the equipment used, and all the traces (or plots) obtained for each soil sample tested.

Preparation of clay samples for X-ray diffraction:-

Representative samples were previously obtained for each soil type selected for the thesis (refer to Appendix A¹ and to Chapter One²).

The natural soil types originate from the following localities: Cape Peninsula - Sites 11, 36, 30 and 7; and Durban, Natal - Site A. The Artificial soils used consist of Kaolin and Bentonite mixed with sand.

¹ - section A.3 "Preparation of Soil Samples for Testing".

² - see section 1.6 "Selection of Soil Types".

The purpose of this section is to describe the second stage parts 2.A and 2.B, of sample preparation for the purpose of X-ray diffraction.

Stage 2.A of sample preparation - the chemical side of the preparation. The following steps summarize the procedure adopted:

1. One of the two representative clay samples previously prepared for each soil sample, is used for X-ray diffraction 'X-ray D'. Transfer all 'X-ray D' samples to 250 ml beakers.

2. Add 50 ml of 25% acetic acid (*) to each beaker. Leave overnight, and in most cases the reaction will have ceased (all carbonate removed). Centrifuge the acid off, and then centrifuge twice again with distilled water.

3. Return the samples to original glass beakers. Make the clay suspensions up to 100 ml with tap water, and then add 25 ml 30% H_2O_2 (*) to each beaker using the dropper bottle. Heat carefully with swirling, and add octanol when frothing becomes vigorous. When the reaction ceases, add another 25 ml H_2O_2 and observe if it starts again. When the sample acquires a "bleached" appearance, all the organic matter has been oxidized¹. Centrifuge, and then twice again with tap water.

Note: It may be necessary to flocculate the clay with only 4 drops diluted HCL.

4. Transfer the samples to 250 ml conical flasks, and make the suspensions up to 150 ml with tap water. Now check its pH with MERCK litmus paper, and adjust by adding drop by drop diluted HCL until the pH reads between 3.5 and 4.0. Then, add 50 ml 3N $MgCl_2$ (*) solution to the suspension (this reduces it to 1N). Use rubber stoppers lined with thin plastic to cap 12 flasks, and then agitate them on the shaker for 4 hours. Centrifuge off the $MgCl_2$ solution, and then twice again with distilled water.

5. Store the clay in small vials for X-ray diffraction.

(*) Solution preparation: - Into a 1000 ml beaker add 400 ml tap water and 200 ml acetic acid (commercial grade is $\approx 90\%$) - this weakens the acid strength to 30% and makes sufficient available to treat 12 samples; Hydrogen Peroxide ' H_2O_2 ' (commercial grade $\approx 50\%$) - the strength is weakened to 25% by adding to the suspension; Magnesium Chloride (commercial salt is $MgCl_2 \cdot 6H_2O$, molecular weight 'MW' = 203.32 - a 1N solution is equal to $\frac{1}{6}$ MW) - weight out 304.98 gm salt and dissolve in 1 litre of distilled water (ie, 3N solution is diluted to 1N when added to suspension), and prepare 3 weighings to give ≈ 3 litres of solution.

¹ - here experience counts.

Stage 2.B - preparation of slides for X-ray diffraction 'X-ray D' tests, as follows:

6. Remove the supernatant¹ water from the vials which were previously prepared¹.
7. Prepare slides from ground glass - cut glass and use yellow pen to draw line to separate the sample number, written at one end of slide, from the sample itself.
8. Place 3 to 4 drops of sample on the glass slide and spread over the whole 2/3 of glass surface (other 1/3 is used for sample number).
9. Place the slide in the oven to dry (previously set at $50 \pm 5^{\circ}\text{C}$), following which it is placed in a desiccator until the start of the 'X-ray D' test.

X-ray diffraction test method:-

When the instrument is at zero position, the X-ray beam is parallel to the slide and passes directly into the X-ray detector. The slide mount and counter are driven by a motor through separate gear trains so that, while the slide and specimen rotate through the angle θ , the detector rotates 2θ .

As the X-ray detector scans, the strip chart records 'peaks' for the diffraction maxima from the specimen. The angle 2θ , at which diffraction occurred, may be read directly from the position of the peak on the chart. The heights of the peaks are directly proportional to the intensities of the diffraction effects.

The chart is divided into tenths of inches and moves at a constant speed (for example, 0.5 inches per minute). At this chart speed and a scanning speed for the X-ray detector of 1° per minute, 0.5 inches on the chart is equivalent to a 2θ of 1° . The positions of peaks on the chart can be read directly and the interplanar spacing causing them can be determined using the equation, $n\lambda = 2d \sin\theta$.

X-ray diffraction equipment:-

All the main X-ray D equipment available (at the X-ray diffraction unit) was manufactured by Phillips in Holland. The main components of the X-ray D analytical equipment were:

- (i) X-ray generator - PW 1130/00/60;
- (ii) X-ray diffraction tubes - WA6-E10;
- (iii) High voltage supply - PW 1375;
- (iv) Goniometer - PW 1050/25;
- (v) Goniometer supply - PW 1361;

¹ - refer to step 5 of stage 2.A.

- (vi) Flat rotating specimen holder - PW 1064 (accessory for PW 1050/25);
- (vii) Flat-bed recorder - PW 8000 (electronic counting and measuring equipment);
- (viii) Debye Scherrer Powder Cameras - PW 1024 and PW 1026 and their accessories;
- (ix) Others - ratemeter, X-ray focussing monochromator, propagation detector probe, switches, etc.

B.5 X-RAY DIFFRACTION TRACES

A total of 21 slides were prepared for testing in the X-ray diffractometer using 'Cu K α ' radiation - ie, 3 slides for each soil type to be tested (the soil types are listed at the beginning of this section).

Traces (or plots) carried out for each soil type:-

Five main traces were performed in the three slides. The traces were run at the speed of 2° 2 θ /min. Details for the final stages of preparation and testing:

- (i) Slide one - trace A, 3° - 30° 2 θ Mg-saturated;
- (ii) Slide one - trace C, 3° - 13° 2 θ Mg-saturated, Ethylene glycolated;
- (iii) Slide two - trace D, 3° - 30° 2 θ Mg-saturated, previously heated to 550°C for 1 hour;
- (iv) Slide three - trace E, 3° - 30° 2 θ Mg-saturated, previously heated to 105°C overnight;
- (v) Slide three - trace C, 3° - 13° 2 θ Mg-saturated, Ethylene glycolated.

An additional trace was performed in slide one, in between traces A and C, at the speed of $\frac{1}{4}$ ° 2 θ /minute to distinguish between kaolinite and chlorite:

- (vi) Slide one - trace B, 24° - 25 $\frac{1}{2}$ ° 2 θ Mg-saturated.

The basic test descriptions, for all traces (or plots) obtained, are included in Table B.09.

Table B.09: All the X-ray diffraction traces obtained for each soil type.

Soil Trace Description
type no.

[Slide One]

S.11	1.	A.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	at 2°	2 θ /minute.
		B.	$24^{\circ} - 25\frac{1}{2}^{\circ}$	2 θ	Mg-sat	at $\frac{1}{4}^{\circ}$	2 θ /min.
		C.	$3^{\circ} - 13^{\circ}$	2 θ	Mg-sat	ethyl. glycol. @ 2°	2 θ /min.
S.36	2.	A.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	at 2°	2 θ /min.
		B.	$24^{\circ} - 25\frac{1}{2}^{\circ}$	2 θ	Mg-sat	at $\frac{1}{4}^{\circ}$	2 θ /min.
		C.	$3^{\circ} - 13^{\circ}$	2 θ	Mg-sat	ethyl. glycol. @ 2°	2 θ /min.
S.30	3.	A.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	at 2°	2 θ /min.
		B.	$24^{\circ} - 25\frac{1}{2}^{\circ}$	2 θ	Mg-sat	at $\frac{1}{4}^{\circ}$	2 θ /min.
		C.	$3^{\circ} - 13^{\circ}$	2 θ	Mg-sat	ethyl. glycol. @ 2°	2 θ /min.
S.A	4.	A.	(repeated)				
		A.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	at 2°	2 θ /min.
		B.	$24^{\circ} - 27^{\circ}$	2 θ	Mg-sat	at $\frac{1}{4}^{\circ}$	2 θ /min.
		C.	$3^{\circ} - 13^{\circ}$	2 θ	Mg-sat	ethyl. glycol. at 2°	2 θ /min.
S.7	5.	A.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	at 2°	2 θ /min.
		B.	$24^{\circ} - 25\frac{1}{2}^{\circ}$	2 θ	Mg-sat	at $\frac{1}{4}^{\circ}$	2 θ /min.
		C.	$3^{\circ} - 13^{\circ}$	2 θ	Mg-sat	ethyl. glycol. @ 2°	2 θ /min.
K	6.	A.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	at 2°	2 θ /min.
		B.	$24^{\circ} - 25\frac{1}{2}^{\circ}$	2 θ	Mg-sat	at $4^{\circ} \times 10^3$	2 θ /min.
		C.	$3^{\circ} - 13^{\circ}$	2 θ	Mg-sat	ethyl. glycol. @ 2°	2 θ /min.
BE	7.	A.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	at 2°	2 θ /min.
		B.	$24^{\circ} - 25\frac{1}{2}^{\circ}$	2 θ	Mg-sat	at $\frac{1}{4}^{\circ}$	2 θ /min.
		C.	$3^{\circ} - 13^{\circ}$	2 θ	Mg-sat	ethyl. glycol. @ 2°	2 θ /min.

[Slide Two]

S.11	8.	D.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	(prev. heated to 550°C).
S.36	9.	D.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	(" " " 550°C).
S.30	10.	D.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	(" " " 550°C).
S.A	11.	D.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	(" " " 550°C).
S.7	12.	D.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	(" " " 550°C).
K	13.	D.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	(" " " 550°C).
BE	14.	D.	$3^{\circ} - 30^{\circ}$	2 θ	Mg-sat	(prev. heated to 550°C).

[Slide Three]

S.11	15.	E. 3° - 30° 2 θ Mg-sat (prev. heated to 105°C).
		C. 3° - 13° 2 θ Mg-sat, E. ethyl glyc @ 2° 2 θ /min.
S.36	16.	E. 3° - 30° 2 θ Mg-sat (prev. heated to 105°C).
		C. 3° - 13° 2 θ Mg-sat, E. ethyl glyc @ 2° 2 θ /min.
S.30	17.	E. 3° - 30° 2 θ Mg-sat (prev. heated to 105°C).
		C. 3° - 13° 2 θ Mg-sat, E. ethyl glyc @ 2° 2 θ /min.
S.A	18.	E. 3° - 30° 2 θ Mg-sat (prev. heated to 105°C).
		C. 3° - 13° 2 θ Mg-sat, E. ethyl glyc @ 2° 2 θ /min.
S.7	19.	E. 3° - 30° 2 θ Mg-sat (prev. heated to 105°C).
		C. 3° - 13° 2 θ Mg-sat, E. ethyl glyc @ 2° 2 θ /min.
K	20.	E. 3° - 30° 2 θ Mg-sat (prev. heated to 105°C).
		C. 3° - 13° 2 θ Mg-sat, E. ethyl glyc @ 2° 2 θ /min.
BE	21.	E. 3° - 30° 2 θ Mg-sat (prev. heated to 105°C).
		C. 3° - 13° 2 θ Mg-sat, E. ethyl glyc @ 2° 2 θ /min.

X-ray diffraction data output:-

A total of 42 traces (or plots) were obtained. The basic test description/sequence, for each one, are included in Table B.09.

There are six traces per sample.

The X-ray diffractometer traces are included below as Figure B.01 through to Figure B.28. For each trace, the position of the peaks on the chart have been identified, and the interplanar spacings giving rise to them have been determined.

The equation ' $n\lambda = 2d \sin \theta$ ' was used to determine interplanar spacing.

B.5.1 Natural Soil Types

Site 11, Rosebank - 'X-ray D' trace 1.A:-

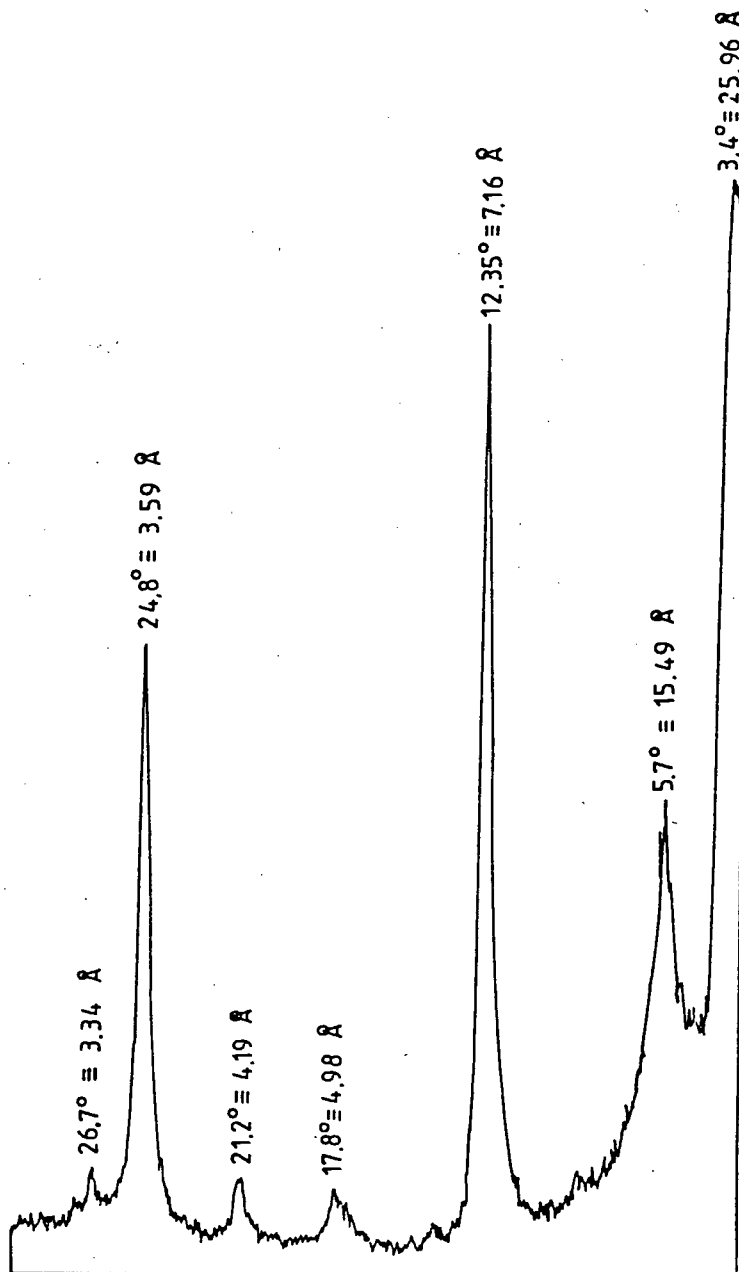


Figure B.01: Site 11, trace 1.A - 3° 30° 2θ Mg-saturated (speed of 2° 2θ /minute).

Site 11, Rosebank - 'X-ray D' traces 1.B and C:-

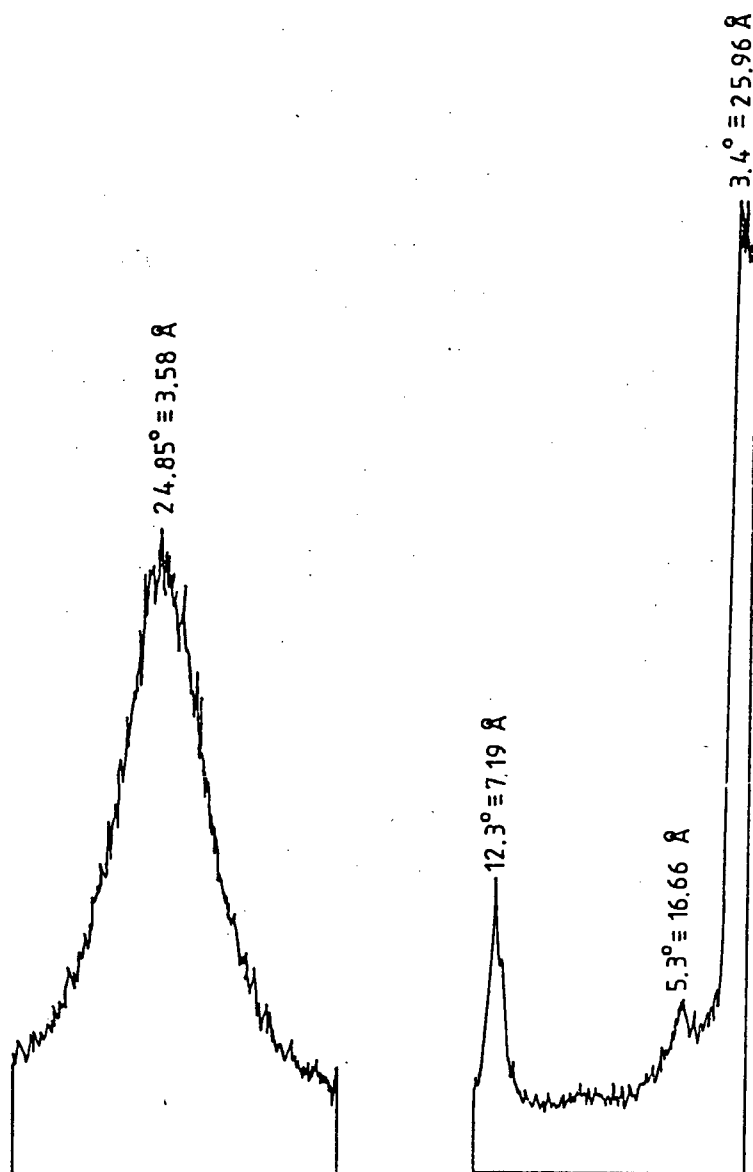


Figure B.02: (i) Site 11, trace 1.B - 24° $25\frac{1}{2}^\circ$ 2θ Mg-saturated ($\frac{1}{4}^\circ$ $2\theta/\text{min.}$); (ii) Site 11, trace 1C - 3° 13° 2θ Mg-saturated, Ethylene glycolated (2° $2\theta/\text{min.}$).

Site 11, Rosebank - 'X-ray D' trace 8.D:-

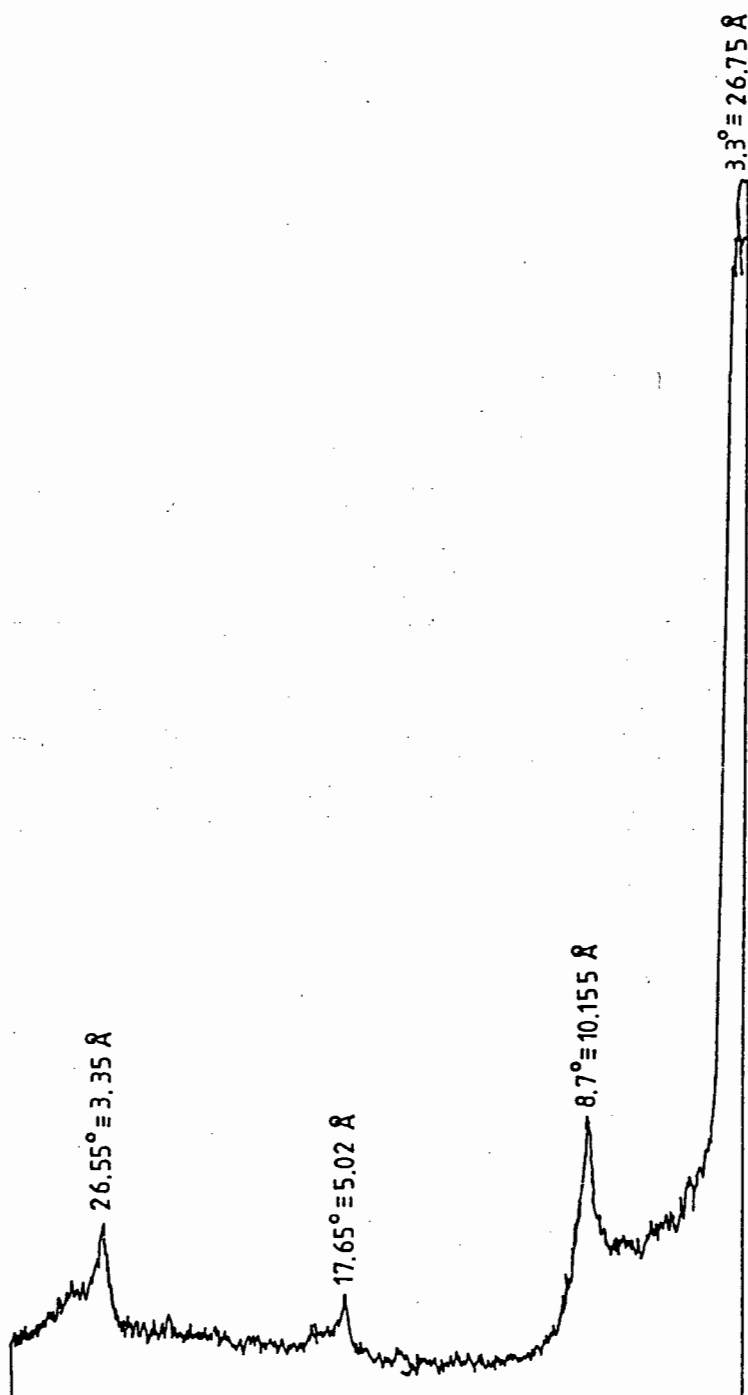


Figure B.03: Site 11, trace 8.D - 3° 30° 2θ Mg-saturated (previously heated to 550°C for 1 hr, following which it was allowed to cool and placed in a desiccator until testing).

Site 11, Rosebank - 'X-ray D' traces 15.E and 15.C:-

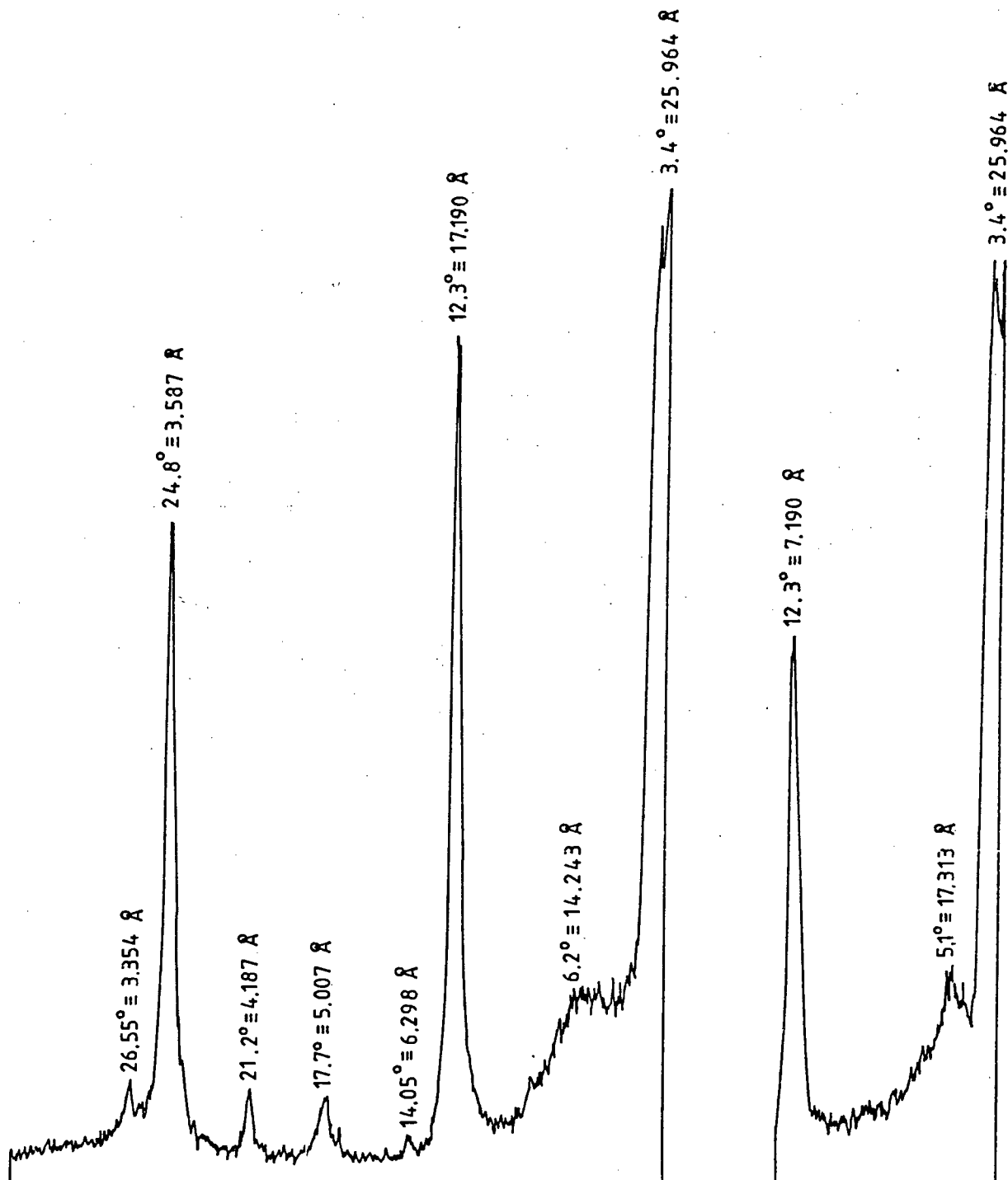


Figure B.04: (i) Site 11, trace 15.E - 3° 30° 2θ Mg-saturated, previously heated to 105°C overnight, allowed to cool and placed in desiccator until testing; (ii) Site 11, trace 15.C - 3° 13° 2θ Mg-saturated, ethylene glycolated.

Site 36, Rondebosch - 'X-ray D' trace 2.A:-

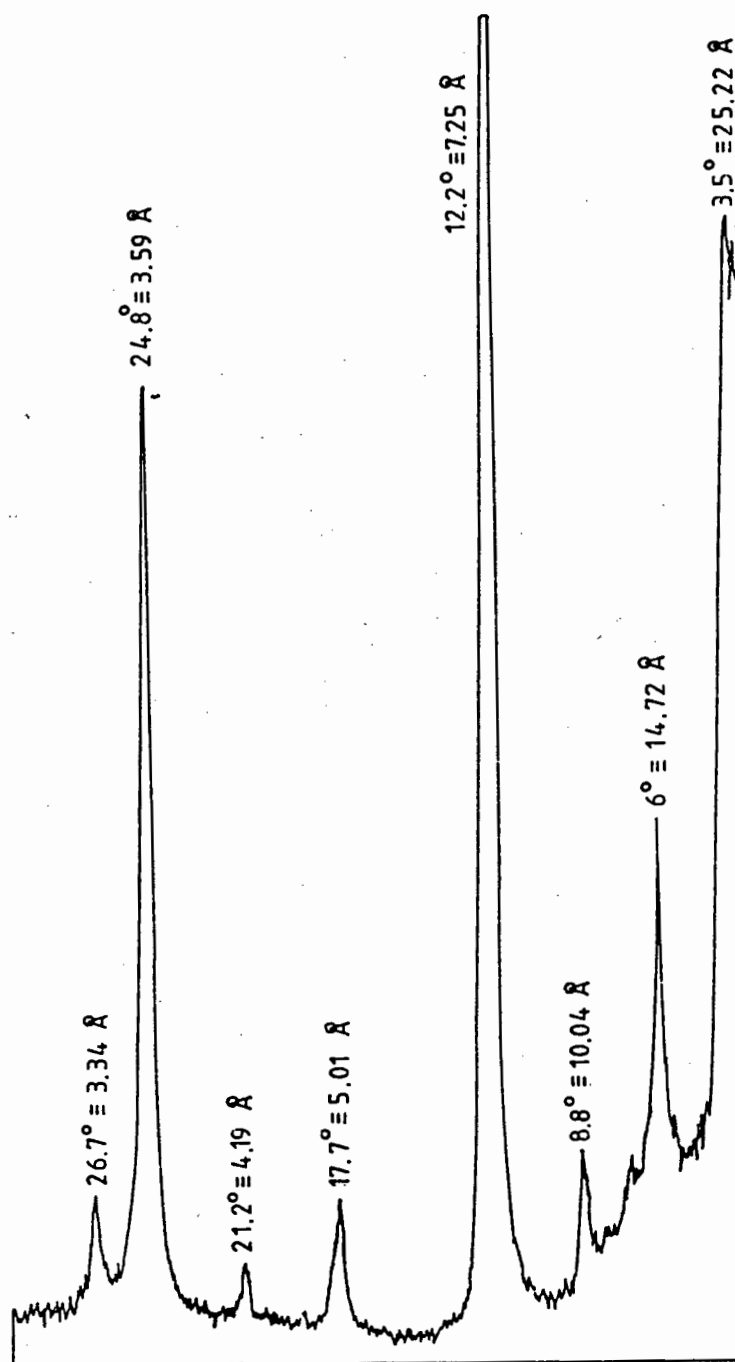


Figure B.05: Site 36, trace 2.A - 3° 30° 2θ Mg-saturated at 2° $2\theta/\text{min}$.

Site 36, Rondebosch - 'X-ray D' traces 2.B and 2.C:-

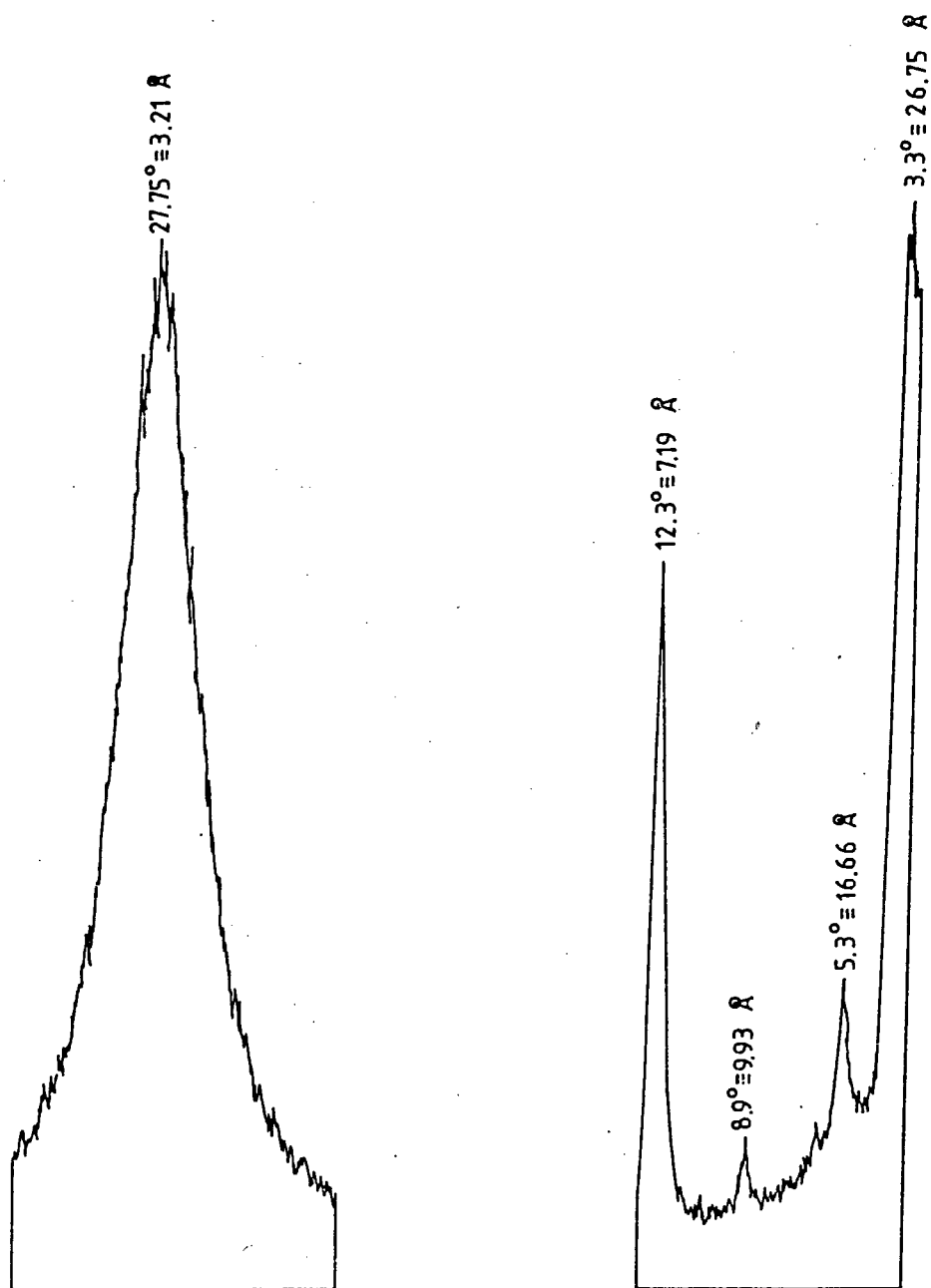


Figure B.06: (i) Site 36, trace 2.B - 24° $25\frac{1}{2}^\circ$ 2θ Mg-saturated ($\frac{1}{4}^\circ$ $2\theta/\text{min.}$); (ii) Site 36, trace 2.C - 3° 13° 2θ Mg-saturated, Ethylene glycolated (2° $2\theta/\text{min.}$).

Site 36, Rondebosch - 'X-ray D' trace 9.D:-

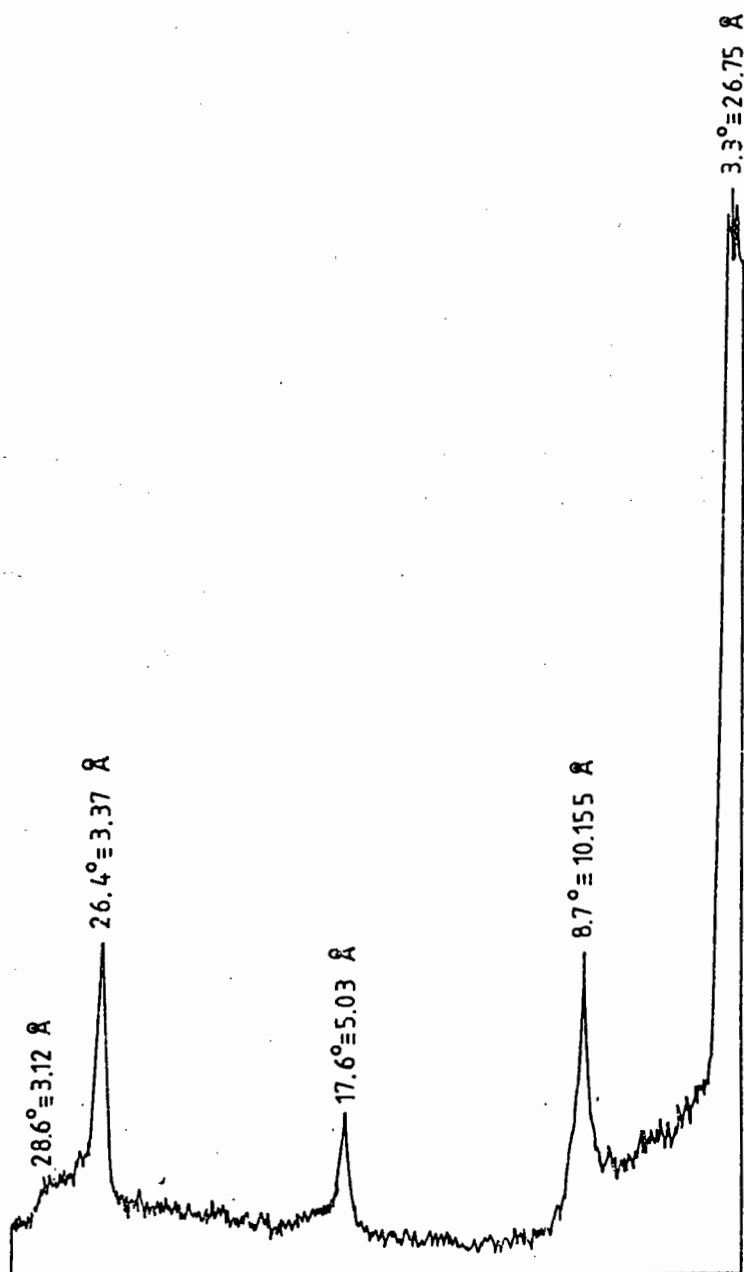


Figure B.07: Site 36, trace 9.D - 3° 30° 2θ Mg-saturated (previously heated to 550°C for 1 hr, following which it was allowed to cool and placed in a desiccator until testing).

Site 36, Rondebosch - 'X-ray D' traces 16.E and 16.C:-

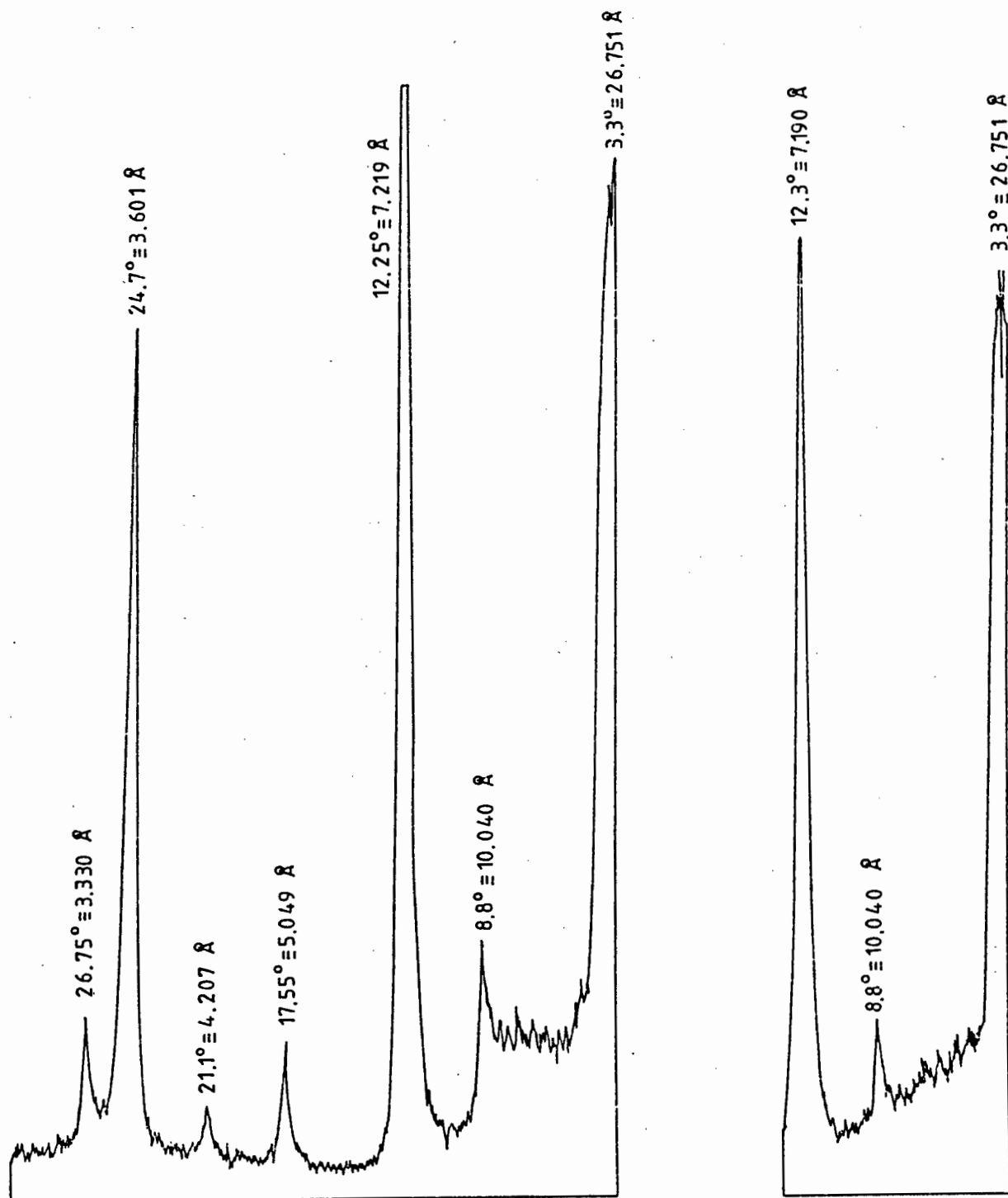


Figure B.08: (i) Site 36, trace 16.E - $3^\circ 30^\circ 2\theta$ Mg-saturated, previously heated to 105°C overnight, allowed to cool and placed in desiccator until testing; (ii) Site 36, trace 16.C - $3^\circ 13^\circ 2\theta$ Mg-saturated, ethylene glycolated.

Site 30, Hout Bay - 'X-ray D' trace 3.A:-

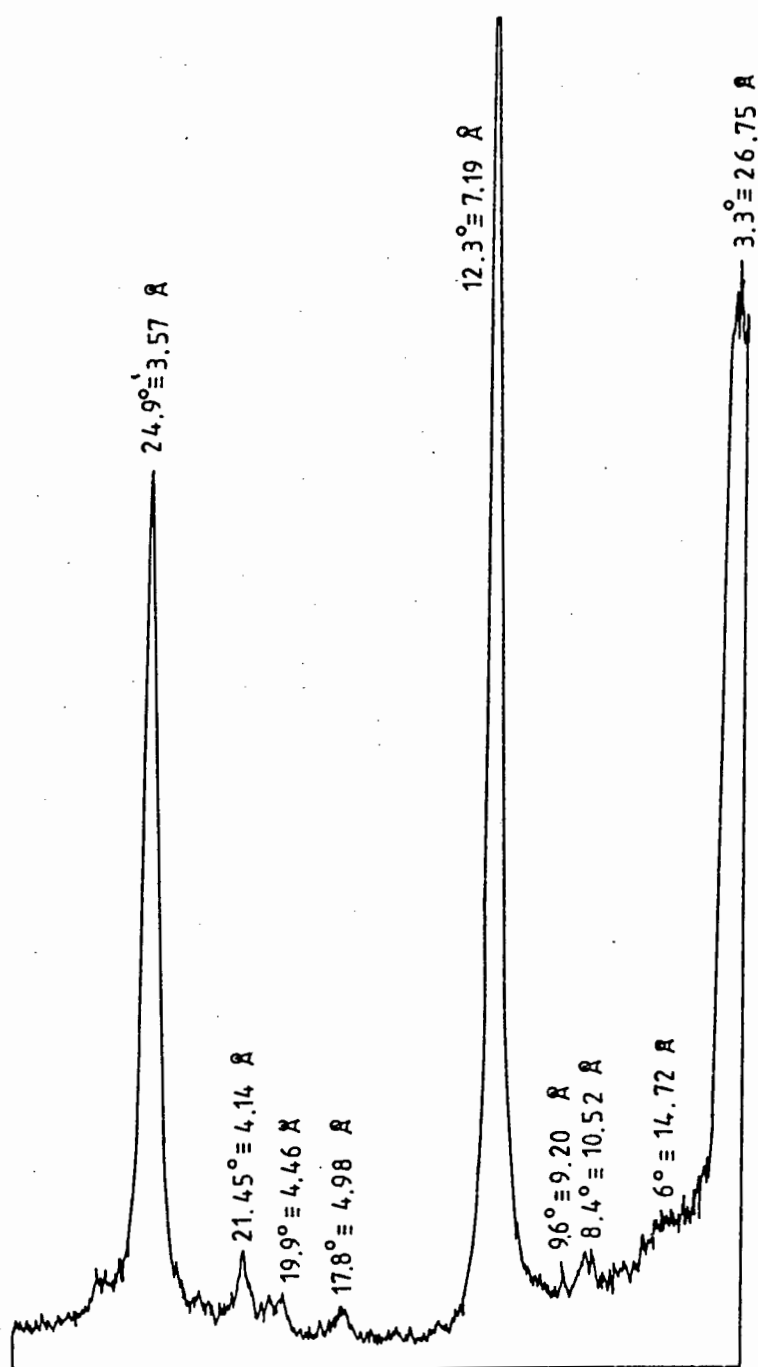


Figure B.09: Site 30, trace 3.A - 3° 30° 2θ Mg saturated at 2° $2\theta/\text{min}$.

Site 30, Hout Bay - 'X-ray D' traces 3.B and 3.C:-

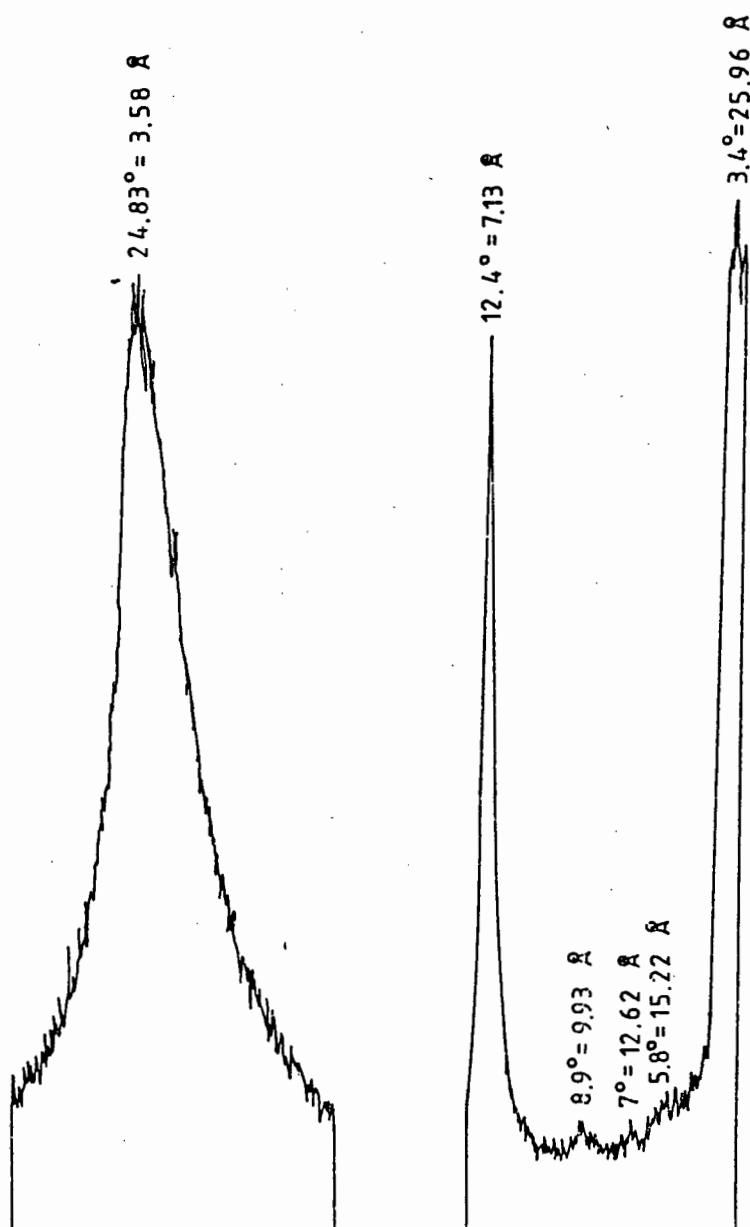


Figure B.10: (i) Site 30, trace 3.B - $24^\circ 25\frac{1}{2}^\circ 2\theta$ Mg-saturated ($\frac{1}{4}^\circ 2\theta/\text{min.}$); (ii) Site 30, trace 3.C - $3^\circ 13^\circ 2\theta$ Mg-saturated, Ethylene glycolated ($2^\circ 2\theta/\text{min.}$).

Site 30, Hout Bay - 'X-ray D' trace 10.D:-

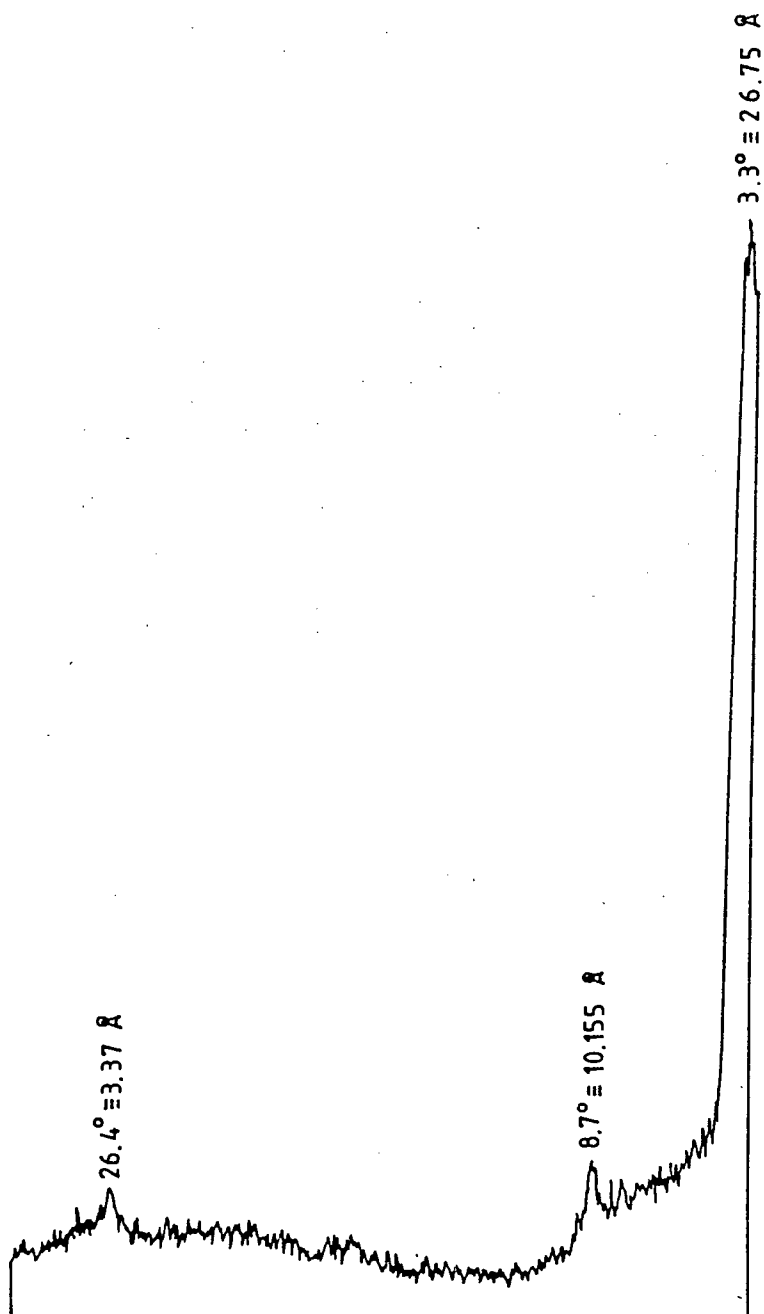


Figure B.11: Site 30, trace 10.D - 3° 30° 2θ Mg-saturated (previously heated to 550°C for 1 hr, following which it was allowed to cool and placed in a desiccator until testing).

Site 30, Hout Bay - 'X-ray D' traces 17.E and 17.C:-

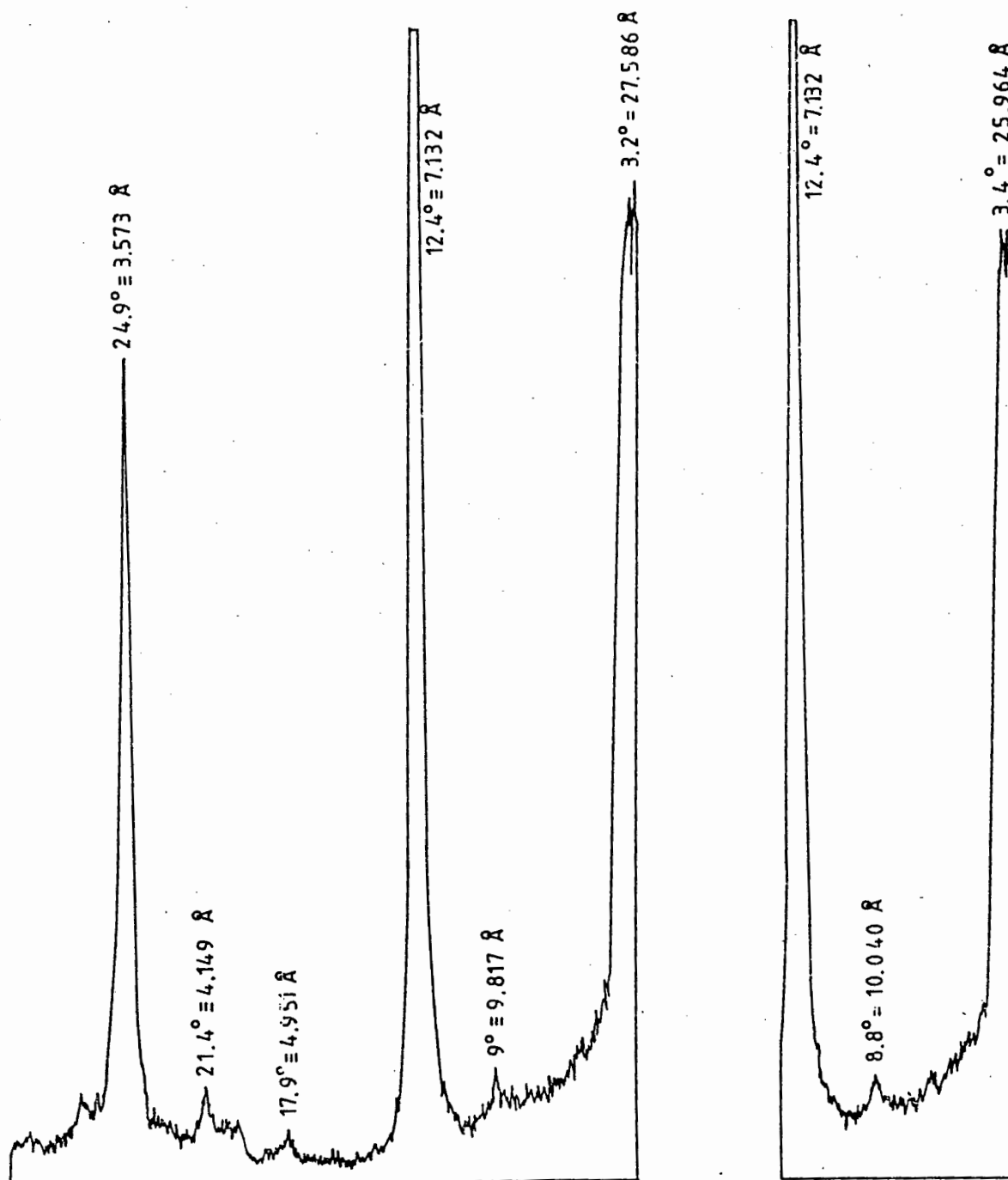


Figure B.12: (i) Site 30, trace 17.E - 3° 30° 2θ Mg-saturated, previously heated to 105°C overnight, allowed to cool and placed in desiccator until testing; (ii) Site 30, trace 17.C - 3° 13° 2θ Mg-saturated, Ethylene glycolated.

Site A, Berea Road (Durban) - 'X-ray D' trace 4.A:-

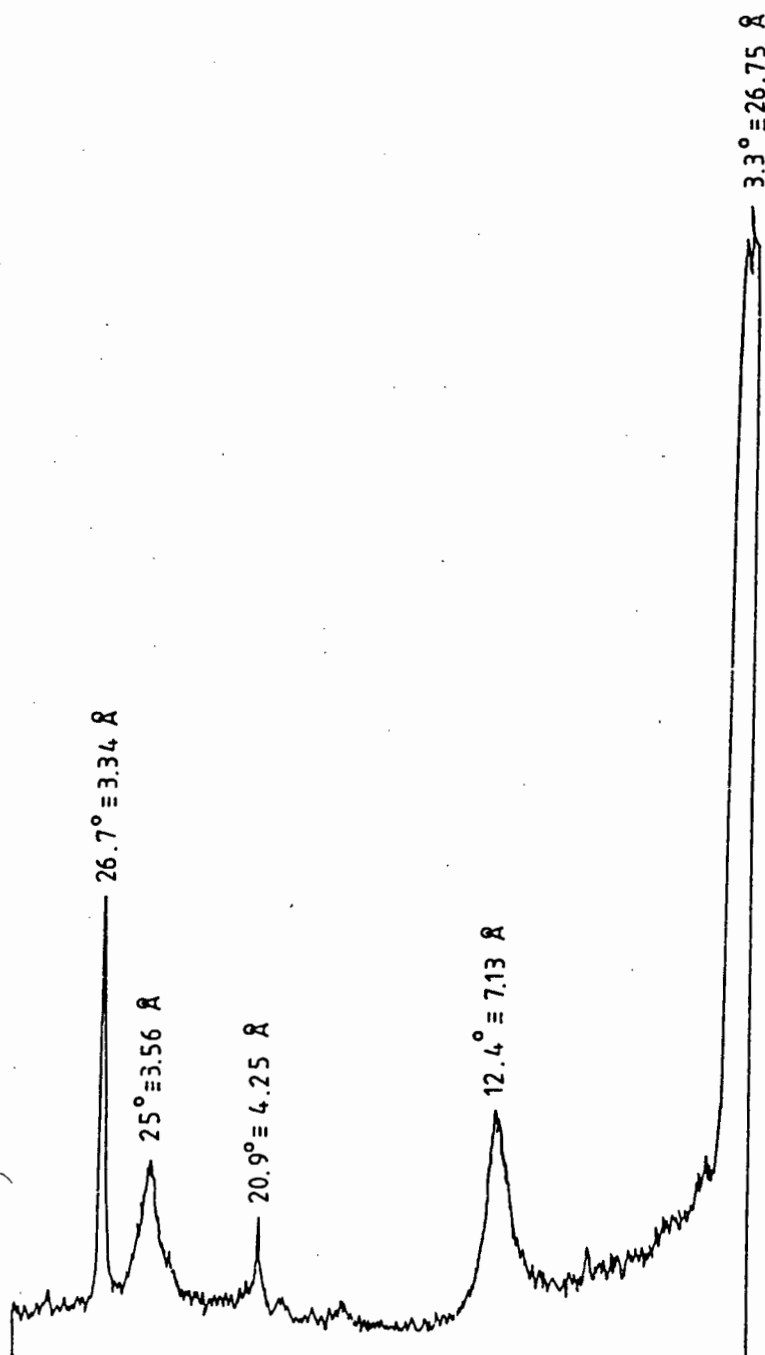


Figure B.13: Site A, trace 4.A - 3° 30° 2θ Mg-saturated at 2° $2\theta/\text{min}$.

Site A, Berea Road (Durban) - 'X-ray D' traces 4B and 4.C:-

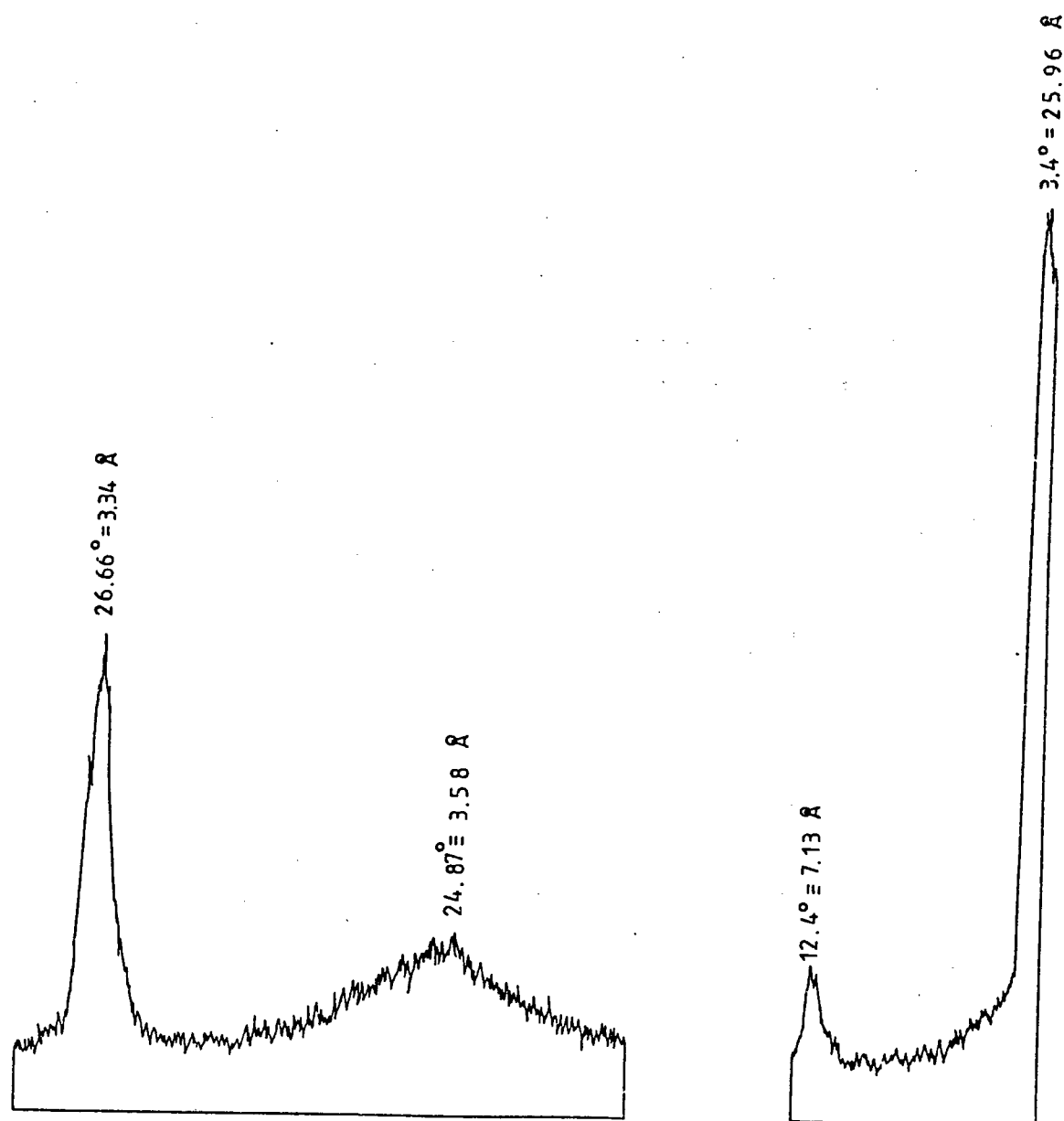


Figure B.14: (i) Site A, trace 4.B - 24° 27° 2θ Mg-saturated ($\frac{1}{4}^\circ$ $2\theta/\text{min.}$); (ii) Site A, trace 4.C - 3° 13° 2θ Mg-saturated, Ethylene glycolated (2° $2\theta/\text{min.}$).

Site A, Berea Road (Durban) - 'X-ray D' trace 11.D:-

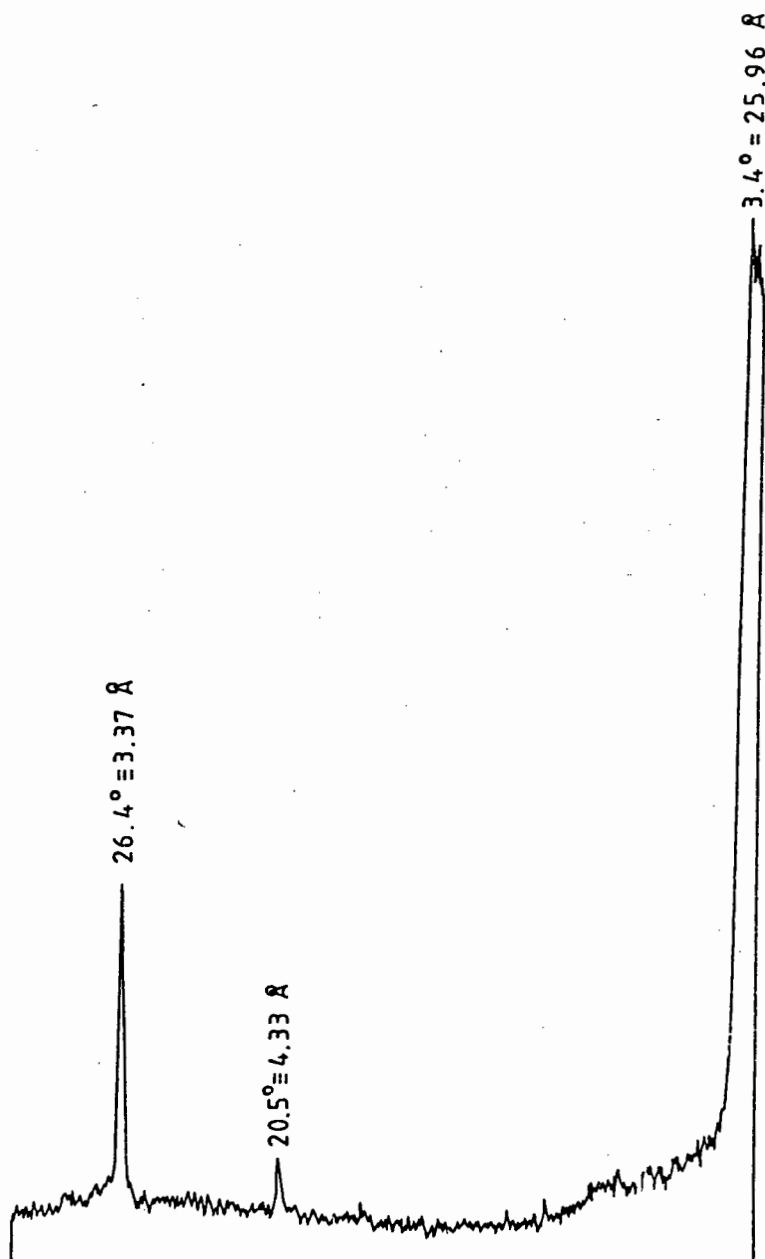


Figure B.15: Site A, trace 11.D - 3° 30° 2θ Mg-saturated (previously heated to 550°C for 1 hr, following which it was allowed to cool and placed in a desiccator until testing).

Site A, Berea Road (Durban) - 'X-ray D' traces 18.E and 18.C:-

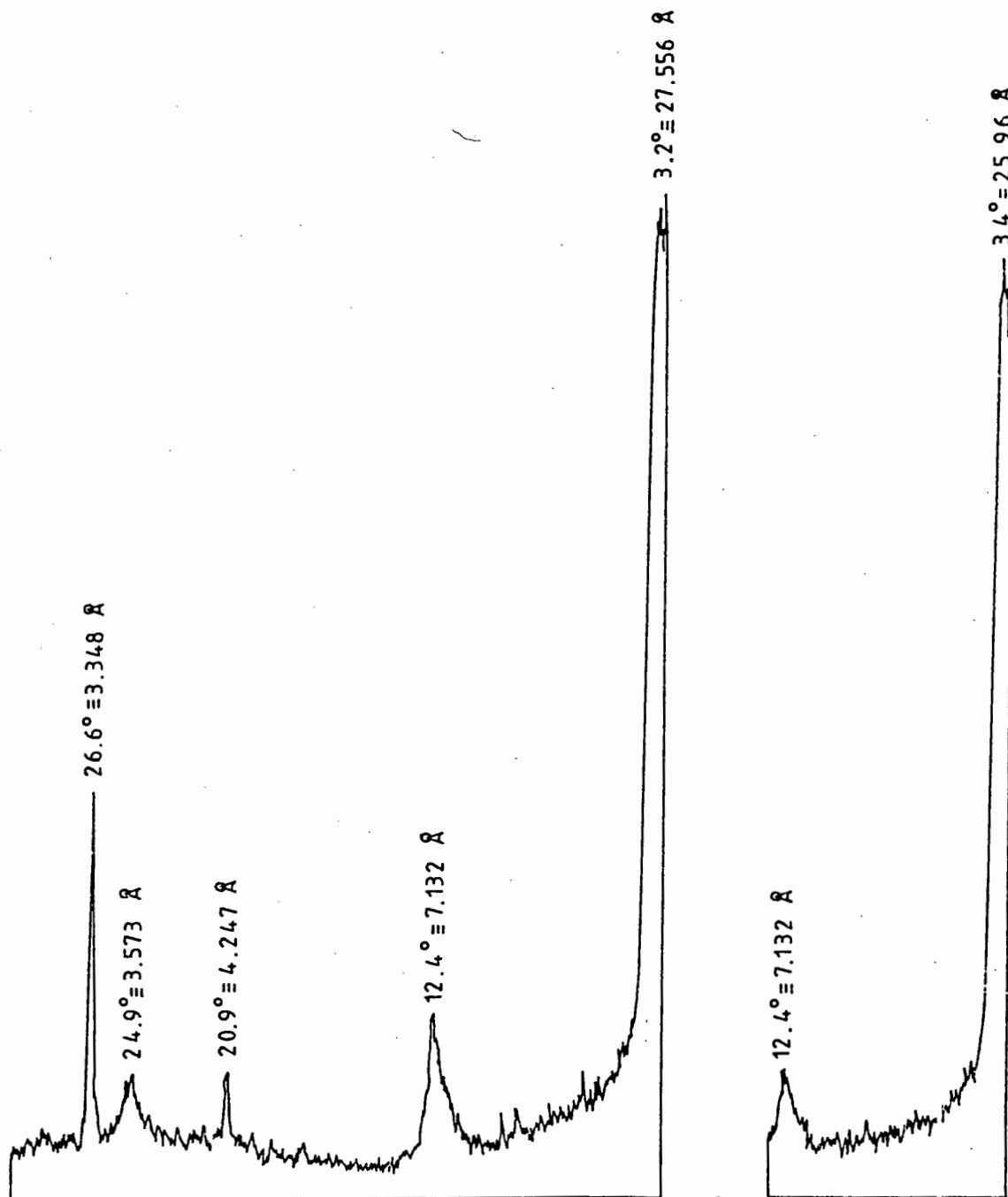


Figure B.16: (i) Site A, trace 18.E - $3^{\circ} 30'$ 2θ Mg-saturator, previously heated to 105°C overnight, allowed to cool and placed in a desiccator until testing; (ii) Site A, trace 18.C - $3^{\circ} 13'$ 2θ Mg-saturated, Ethylene glycolated.

Site 7, Mowbray - 'X-ray D' trace 5.A:-

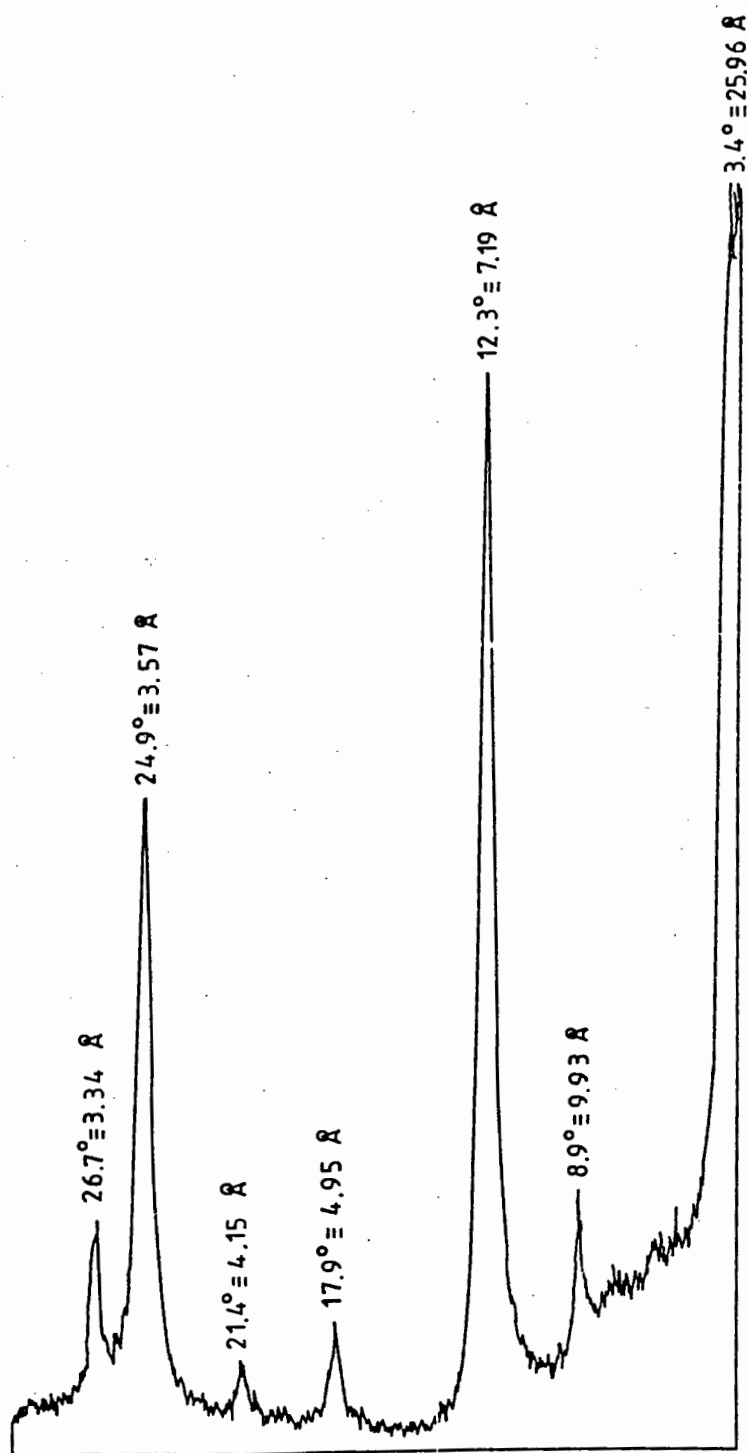


Figure B.17: Site 7, trace 5.A - 3° 30° 2θ Mg-saturated at $2\theta/\text{min}$.

Site 7, Mowbray - 'X-ray D' traces 5.B and 5.C:-

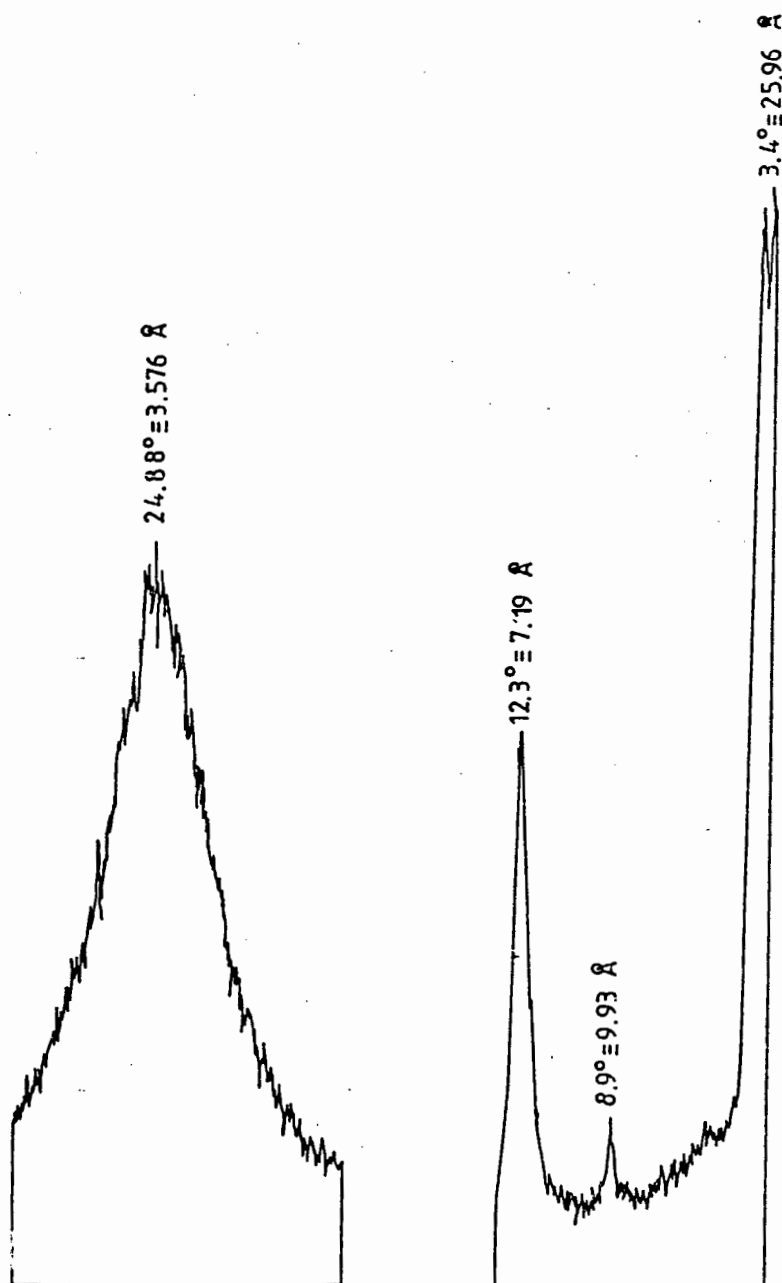


Figure B.18: (i) Site 7, trace 5.B - $24^\circ 25\frac{1}{2}^\circ 2\theta$ Mg saturated ($\frac{1}{4}^\circ 2\theta/\text{min}$); (ii) Site 7, trace 5.C - $3^\circ 13^\circ 2\theta$ Mg-saturated, Ethylene glycolated ($2^\circ 2\theta/\text{min}$).

Site 7, Mowbray - 'X-ray D' trace 12.D:-

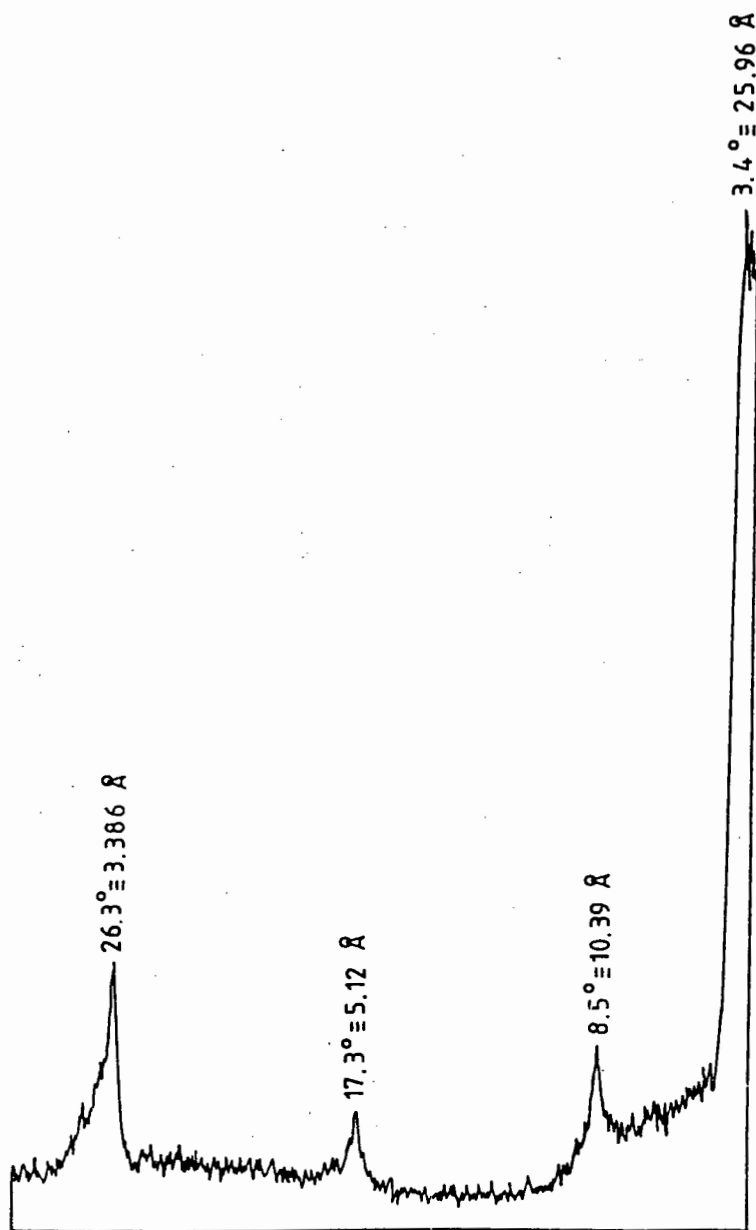


Figure B.19: Site 7, trace 12.D - 3° 13° 2θ Mg-saturated (previously heated to 550°C for 1 hr, following which it was allowed to cool and placed in a desiccator until testing).

Site 7, Mowbray - 'X-ray D' traces 19.E and 19.C:-

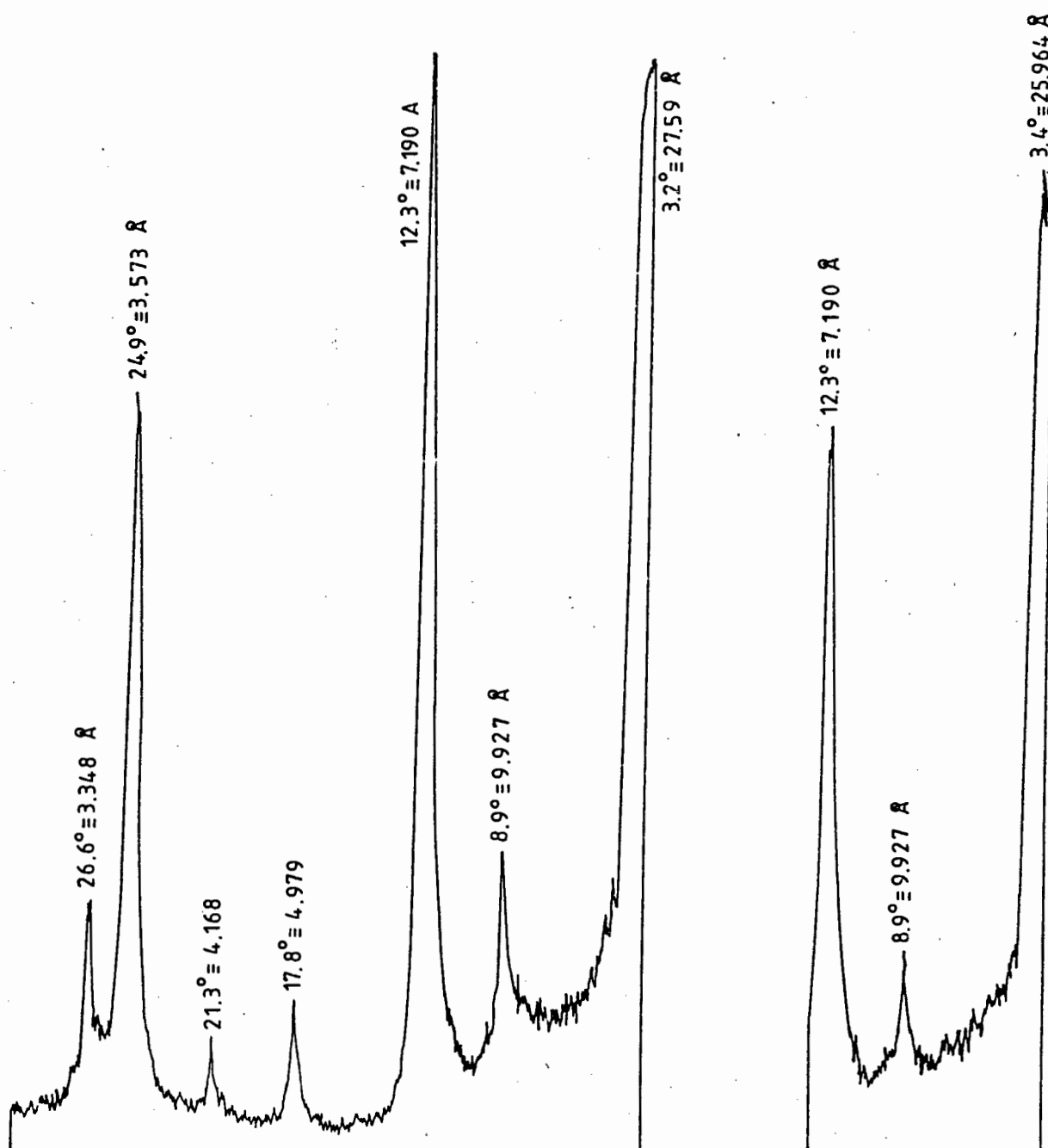


Figure B.20: (i) Site 7, trace 19.E - 3° 30° Mg-saturated, previously heated to 105°C overnight, allowed to cool and placed in desiccator until testing; (ii) Site 7, trace 19.C - 3° 13° 2θ Mg-saturated, Ethylene glycolated.

B.5.2 Artificial Soil Types

Kaolin 'K' - 'X-ray D' trace 6.A:-

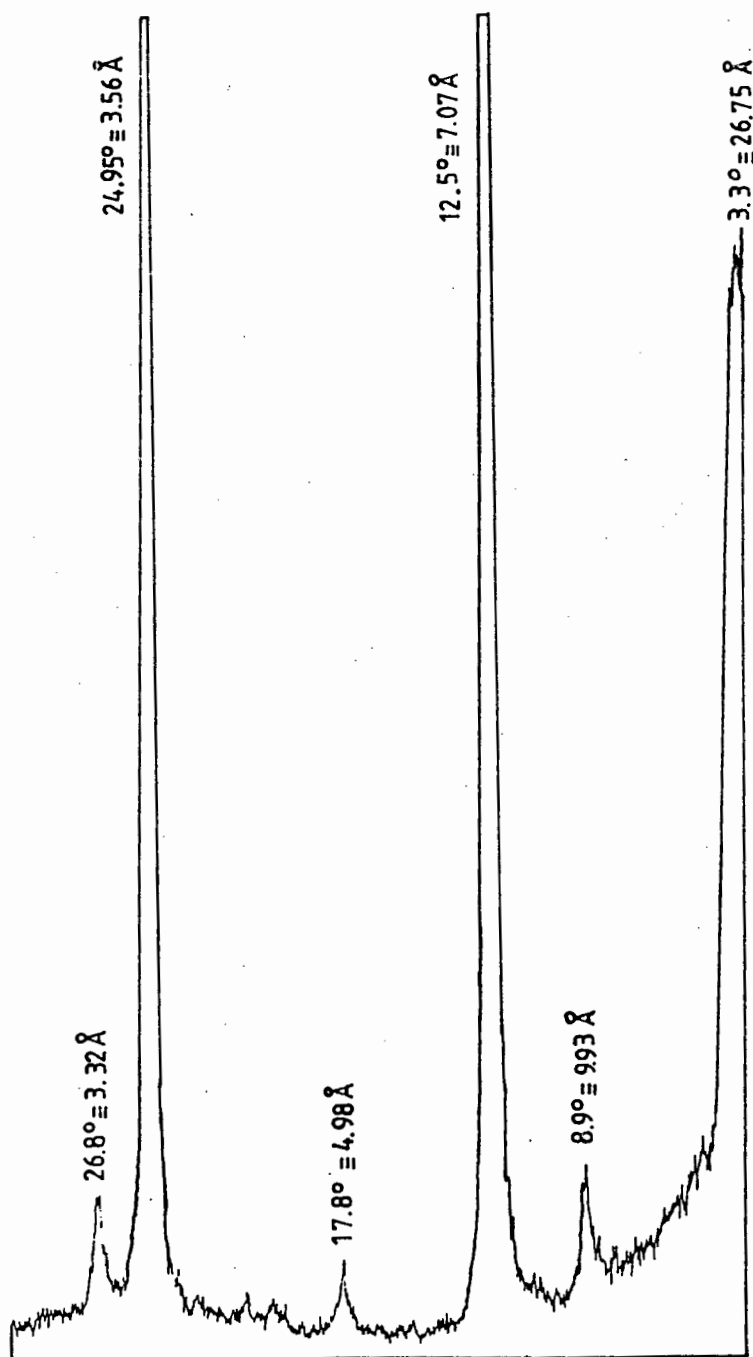


Figure B.21: Kaolin 'K', trace 6.A - 3° 30' 2θ Mg-saturated at 2° 2θ/min.

Kaolin 'K' - 'X-ray D' traces 6.B and 6.C:-

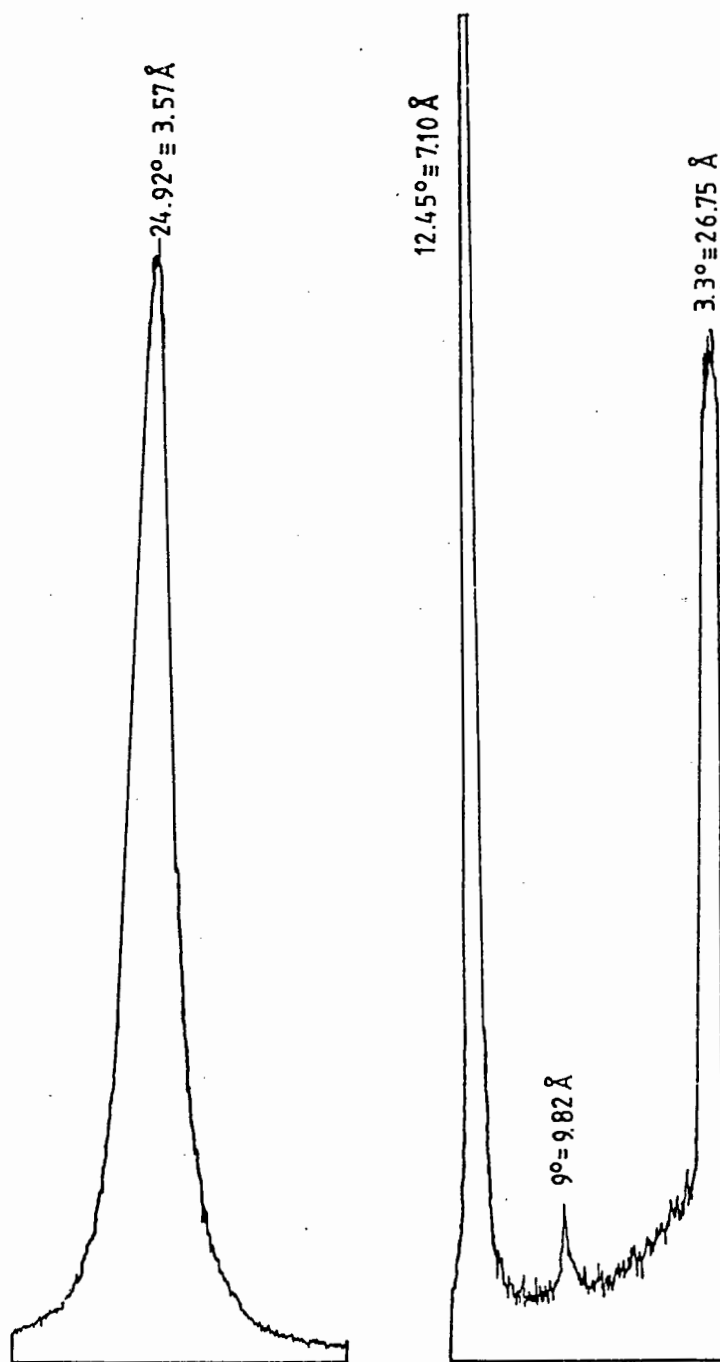


Figure B.22: (i) Kaolin 'K', trace 6.B - $24^\circ 25\frac{1}{2}^\circ$ 2θ Mg-saturated ($\frac{1}{4}^\circ$ $2\theta/\text{min}$); (ii) Kaolin 'K', trace 6.C - $3^\circ 13^\circ$ 2θ Mg-saturated, Ethylene glycolated (2° $2\theta/\text{min}$).

Kaolin 'K' - 'X-ray D' trace 13.D:-

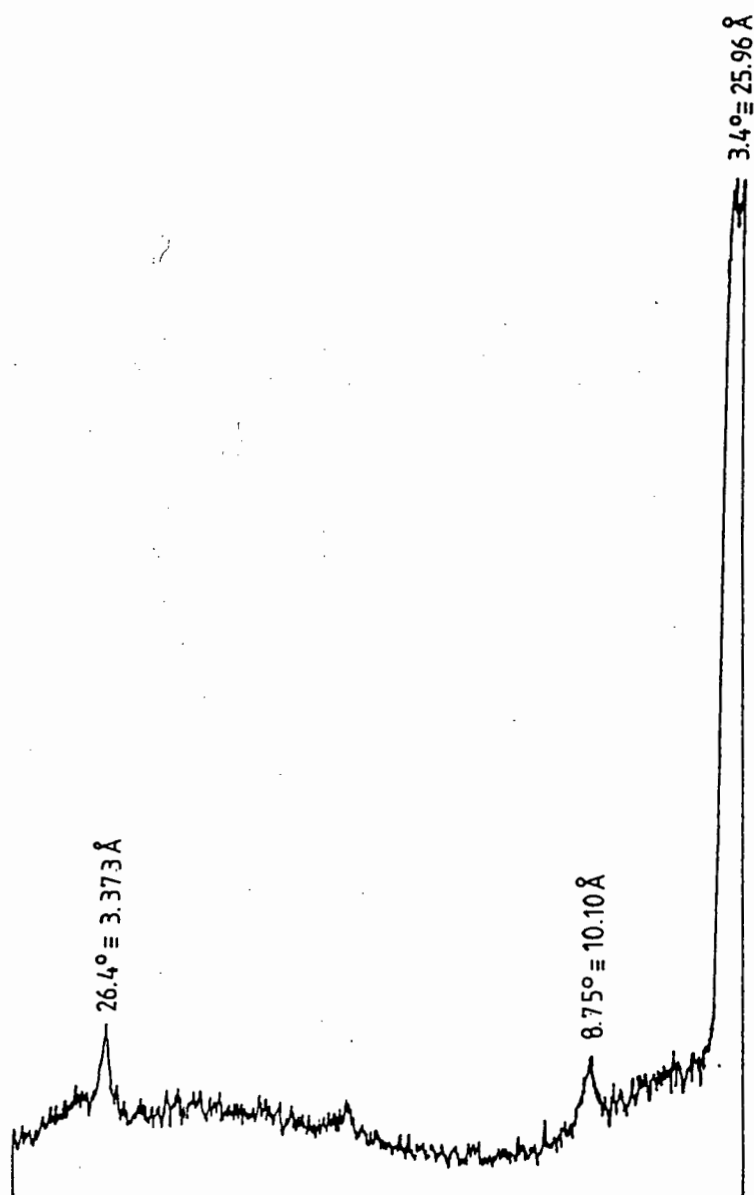


Figure B.23: Kaolin 'K', trace 13.D - 3° 30° 2θ Mg-saturated (previously heated to 550° for 1 hr, following which it was allowed to cool and placed in a desiccator until testing).

Kaolin 'K' - 'X-ray D' traces 20.E and 20.C:-

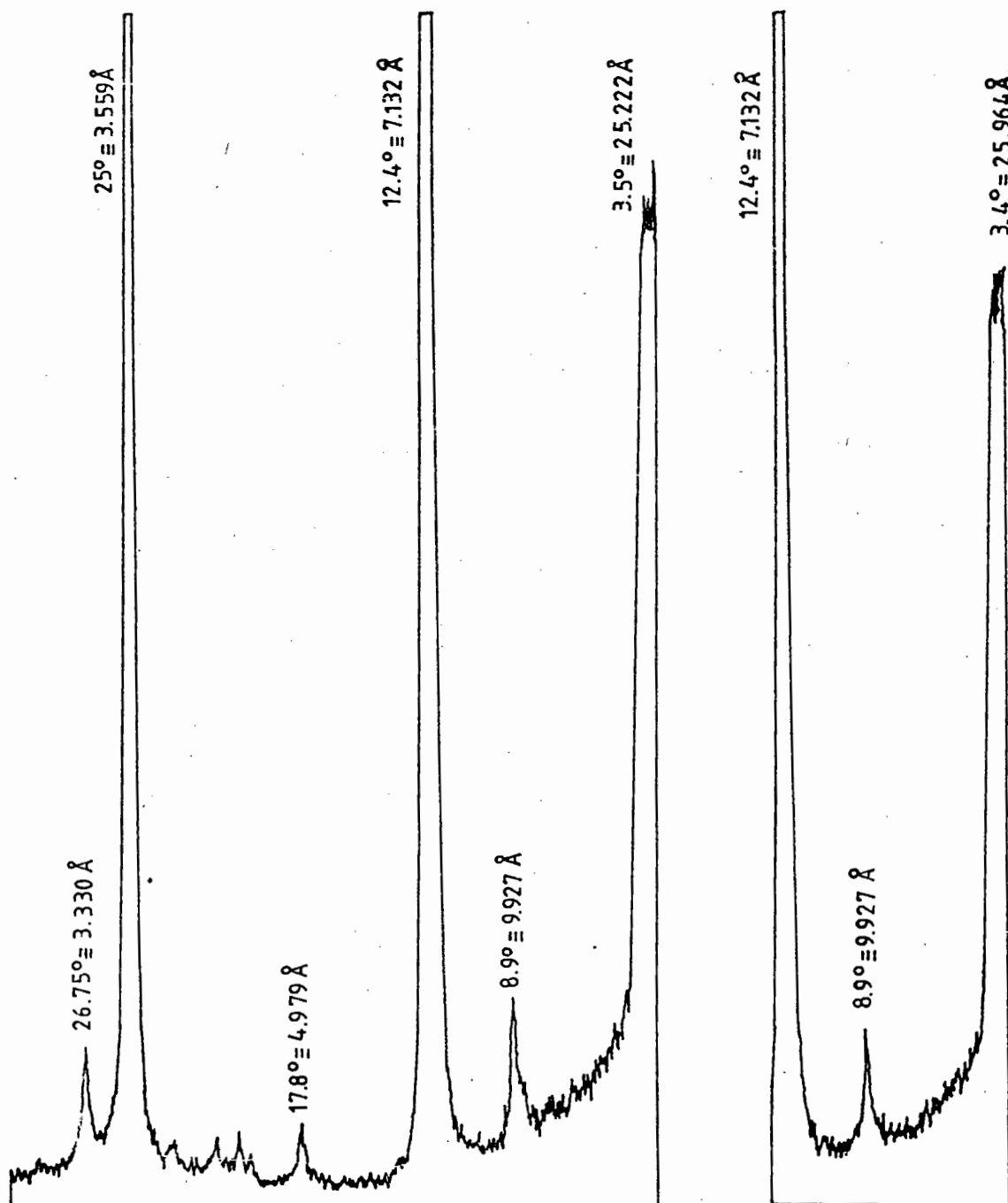


Figure B.24: (i) Kaolin 'K', trace 20.E - 3° 30° Mg-saturated, previously heated to 105°C overnight, allowed to cool and placed in desiccator until testing; (ii) Kaolin 'K' trace 20.C - 3° 13° 2θ Mg-saturated, Ethylene glycolated.

Bentonite 'B' - 'X-ray D' trace 7.A:-

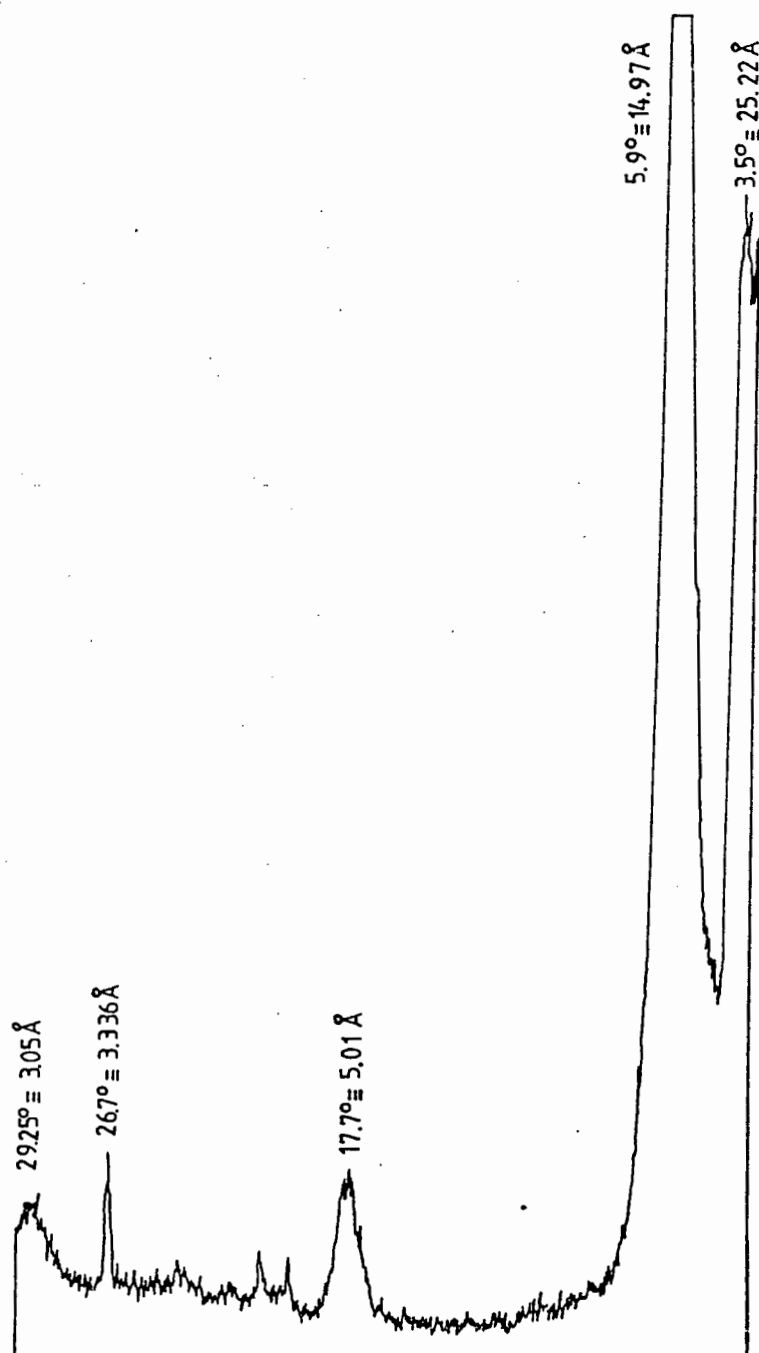


Figure B.25: Bentonite 'B', trace 7.A - 3° 30° 2θ Mg-saturated at 2° $2\theta/\text{min}$.

Bentonite 'B' - 'X-ray D' traces 7.B and 7.C:-

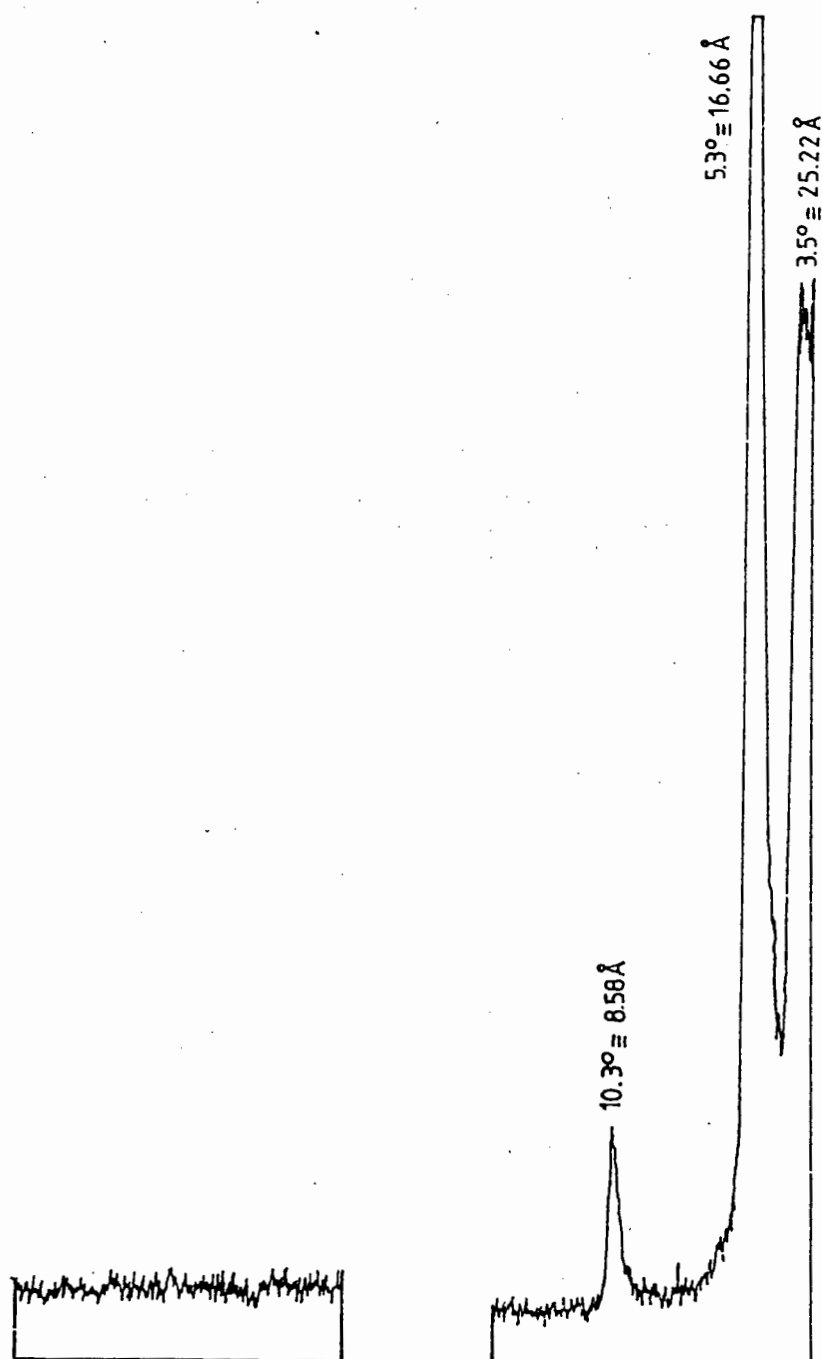


Figure B.26: (i) Bentonite 'B', trace 7.B - 24° $25\frac{1}{2}^\circ$ 2θ Mg-saturated ($\frac{1}{4}^\circ$ 2θ /min.); (ii) Bentonite 'B', trace 7.C - 3° 13° 2θ Mg-saturated, Ethylene glycoated (2° 2θ /min.).

Bentonite 'B' - 'X-ray D' trace 14.D:-

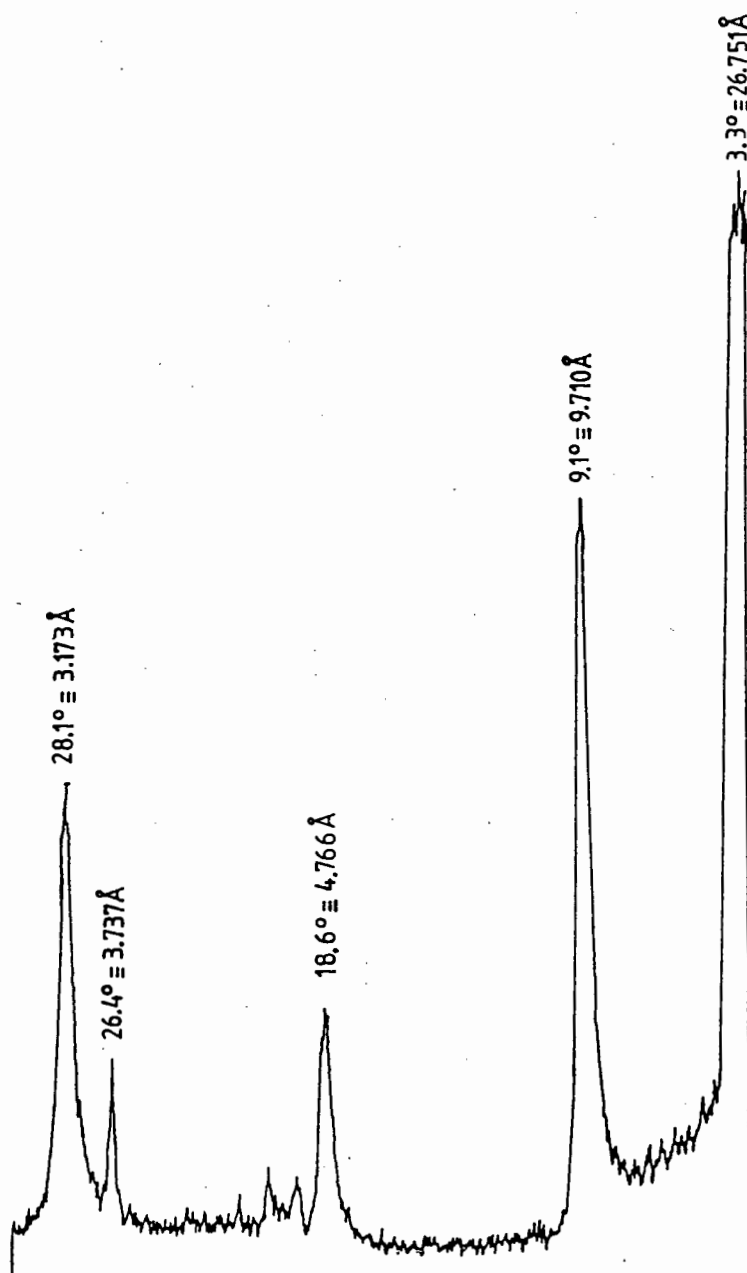


Figure B.27: Bentonite 'B', trace 14.D - 3° 30° 2θ Mg-saturated (previously heated to 550°C for 1 hr, following which it was allowed to cool and then placed in a desiccator until testing).

Bentonite 'B' - 'X-ray D' traces 21.E and 21.C:-

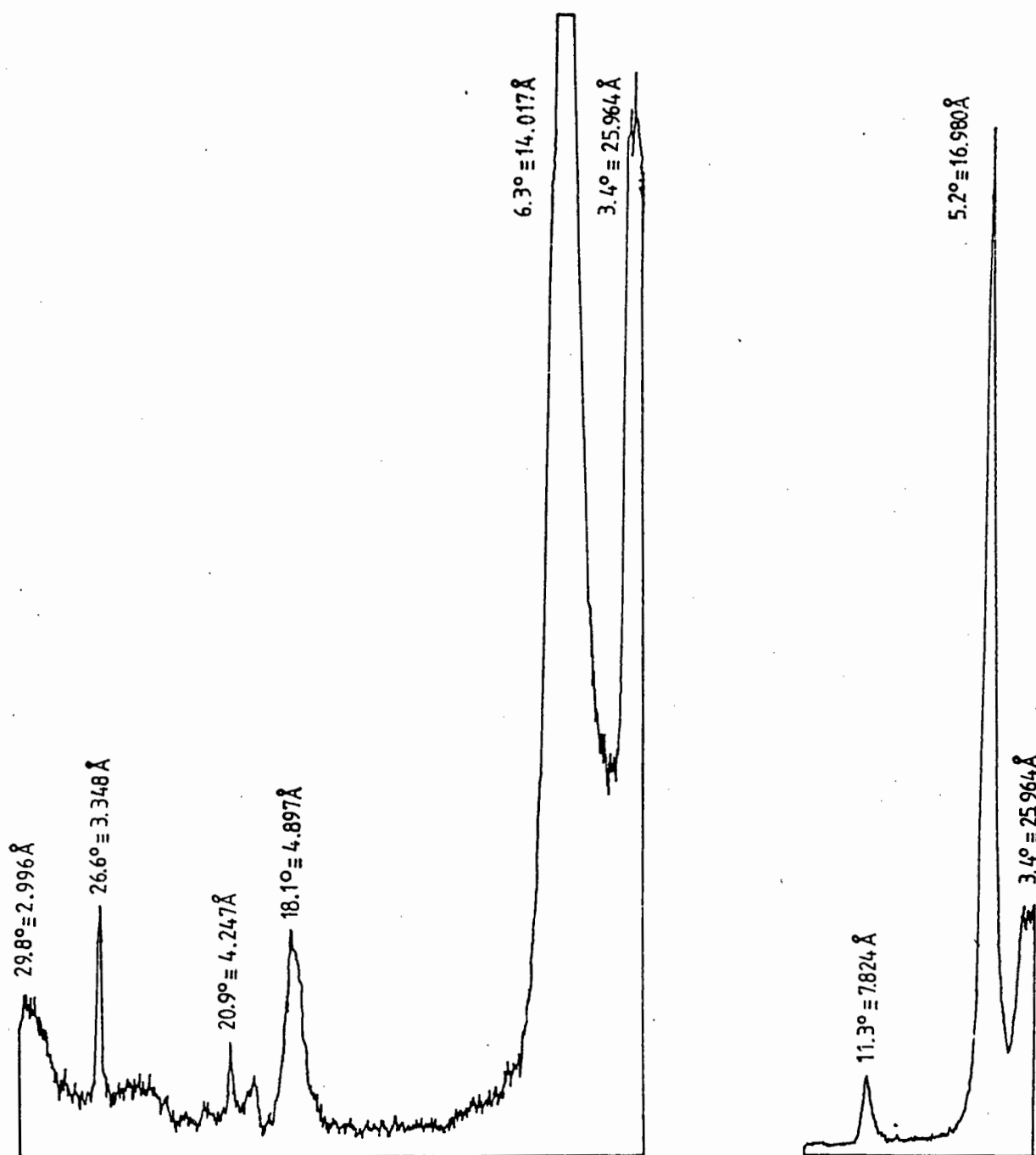


Figure B.28: (i) Bentonite 'B', trace 21.E - 3° 30° Mg-saturated, previously heated to 105°C overnight, allowed to cool and placed in a desiccator until testing; (ii) Bentonite 'B', trace 21.C - 3° 13° 2θ Mg-saturated, Ethylene glycolated.

B.6 REFERENCES FOR APPENDIX B

16. DE S. VINAGRE, T.J.V. (1976/77): Masters Thesis - Diaries One, Two, Three, Four, Five and Six.
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APPENDIX C

FREE SHRINKAGE AND FREE SWELL - TEST PROCEDURE AND RESULTS

C.1 INTRODUCTION

The main test procedures which were developed, or adapted for this thesis, are included from this Appendix C onwards. The aim was to be able to measure the behaviour of the soils types selected.

This Appendix presents the detailed 'Free Shrinkage and Free Swell' test procedure and results. The test method and results are summarized in Chapter Four. Chapter Four also includes a series of photographic plates presenting a visual sequence of the test procedure detailed below.

C.2 TEST PROCEDURE

Preparation of test samples:-

Test samples are prepared from either remoulded, compacted or undisturbed soil. The 'step by step' detailed procedure for the preparation of soil samples for testing is included in Appendix A¹.

Remoulded test samples:-

Method 1:

The basic remoulded test sample consists of soil mixed with water to form a wet paste, which is subsequently moulded into a suitable container. The water content varies from about the plastic limit to a value equal to or greater than the liquid limit - this latter condition is also a requirement for the determination of the Shrinkage Limit (refer to the procedure for the Shrinkage Limit²). It should be noted that the initial water content has a direct influence upon the void ratio of the test sample.

Method 2:

Test samples with higher void ratios can be obtained by the addition of a chemical elements. Known amounts of soil, Tartaric acid and Sodium bicarbonate (and if necessary also Calcium hydroxide - that is, 'Lime') are dry mixed together to form an homogeneous mixture¹. Add a known amount of water, mix quickly using the spatula, and place into a suitable container (shrinkage dish) - this operation should be carried out quickly, in order to entrap as much of the gas (being formed) as possible.

¹ - refer to section A.3 of Appendix A.

² - refer to Appendix A, section A.4.5 "Shrinkage Limit".

Note: The 'pH' value of the soil suspension is determined beforehand according to the test procedure included in Appendix A¹; While the soil suspension is being stirred, add tartaric acid and measure the pH value; Bring the pH value back to its original value (of the soil suspension) by the addition of small amounts of sodium bicarbonate (and if necessary also Calcium hydroxide). The intention is to keep the pH value of the test sample unchanged from that of the original soil sample.

Compacted samples:-

Starting with the 'Dry density versus Water content' compaction curve for the soil sample²: Select points along this curve for the required test samples; Mix the soil with the necessary amount of water in order to obtain the water content for the selected point along the curve - Compact the moist soil in the mould according to either the Standard or Modified AASHTO specifications (whichever one is required); By means of an hydraulic jack remove the compacted sample from the mould, and 'carefully' cut the test sample (to the required size and shape) from the compacted block.

Undisturbed samples:-

The test sample is cut from the undisturbed block of soil, as described in the preparation of soil samples for testing - refer to Appendix A.

Note: Immediately after the test sample has been cut, molten wax is poured over the exposed cut (in order to avoid any loss of water content from beneath the surface of the cut).

Apparatus required:-

(i) The mercury displacement unit: This apparatus was designed and built to enable an accurate measurement to be made of the (bulk) volume for the soil mass - all the components plus operational details are shown in the photographic plates of Chapter Four.

(ii) - (xiv) Refer to test procedure for 'Shrinkage Limit', Appendix A - apparatus required, steps (ii) to (xiv).

(xv) Hypodermic syringe to increase water content of soil by small amounts.

¹ - refer to section A.4.8 of Appendix A.

² - as described in section A.5 of Appendix A.

Procedure:-

A) The test sample (prepared according to 'Preparation of Test Samples' of Appendix A) is allowed to air dry (and consequently to shrink and reduce its overall volume) under controlled conditions - the mass and volume of the sample are measured at regular intervals of time (thus obtaining the shrinkage path of the soil).

Note: Use of the mercury displacement apparatus to measure the volume of the soil mass¹:

- (i) Set up the unit and all its components.
- (ii) Fill up unit with 'clean' mercury until it overflows slightly.
- (iii) Remove the excess mercury by pressing the flat plate (with the three prongs) firmly into the mercury in such a way that the plate is flush with the top of the unit and no air is entrapped - wipe off any mercury that may be sticking to the sides of the unit, and return the excess mercury (which flowed into the glass beaker) to the mercury bottle.
- (iv) Place the test sample on top of the mercury - press it firmly under the mercury (by means of the flat plate with the three prongs), until it is level with the top of the unit (ensure that no air is entrapped under the soil sample).
- (v) The mercury 'overflow' goes into the glass beaker (ensure that all the small bits of mercury are brushed into the glass beaker) - record the mass of the glass beaker (of known mass) plus mercury.

B) When the measured 'total Volume' of the Sample remains constant for further air drying, a small amount of distilled water is added to the underside of the soil. The test sample is left for a few hours (usually overnight) inside a closed container to allow the soil to absorb the water and to expand. The mass and volume (of the test sample) are then measured, after which another wetting stage is carried out (that is, wetting followed by swelling of the soil). The wetting/swelling will be repeated until the soil becomes soft and difficult to handle, that is, the water content is near the free expansion limit (by which time the soil is hardly absorbing any water).

C) When this stage is reached, either carry out another cycle of air drying/wetting, or place the test sample inside the drying oven (set to the temperature of $105 \pm 5^{\circ}\text{C}$) for a few hours (preferably overnight). Remove the container from the oven, allow to cool to room temperature, and then record the mass of the 'oven-dry' soil.

¹ - this section should be read together with the photographic plates included with Chapter Four of Thesis.

Calculations and Report:-

1. Void Ratio,

$$e = \frac{\text{Volume of voids 'Vv'} \quad (\text{Total volume}) - (\text{Volume of solids})}{\text{Volume of solids 'Vs'}} = \frac{\text{Volume of voids}}{\text{Volume of solids}}$$

$$= \left| \frac{\text{Mass 'Hg'} \quad \text{'M}_D'}{G_S \text{'Hg'} \quad \text{'G}_S'} \right| / \left| \frac{\text{'M}_D'}{\text{'G}_S'} \right|$$

Where:

Mass 'Hg' = mass of mercury;
 $G_S \text{'Hg'}$ = specific gravity of mercury;
 'M_D = mass of oven-dry soil;
 'G_S = specific gravity of soil particles.

2. Water Content,

$$w = \frac{\text{Mass of water} \quad M - M_D}{\text{Mass of solids} \quad M_D} = \frac{M - M_D}{M_D}$$

Where:

M = mass of moist/air dry soil.

Note:

$$\text{Water ratio '}\Omega\text{' = } \frac{\text{Volume of water in soil 'Vw'}}{\text{Volume of soil grains 'Vs'}}$$

$$\text{Degree of saturation 'Sr' = } \frac{\text{Volume of water 'Vw'}}{\text{Volume of voids 'Vv'}}$$

Specific gravity,

$$G_S = \frac{\text{Mass of soil in air (for given volume and temperature)}}{\text{Mass of distilled water in air (same volume and temp.)}}$$

Therefore: $\Omega = S_r \times e$;also, $\Omega = w \times G_S$.

3. Use graph paper to plot the void ratio 'e' (or volume) against the water content 'w' for each point of the drying/wetting cycle: The shrinkage path is obtained from the points for the air drying portion of the cycle, and the Free swelling path from the 'wetting' part.

C.3 REFERENCES FOR APPENDIX C

16. DE S. VINAGRE, T.J.V. (1976/77): Masters Thesis - Diaries One, Two, Three, Four, Five, and Six.

C.4 TEST RESULTSC.4.1 Natural SoilsSite 11 - Rosebank, Cape

Table C.01: Site 11, Rosebank [Remoulded, $M \geq LL$] -Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.11-42/III.282	2.105	2.090	S.11-49/III.305	1.391	1.253
	1.260	1.186		1.043	0.963
	0.988	0.903		0.834	0.754
	0.847	0.751		0.744	0.640
	0.781	0.614		0.686	0.506
	0.745	0.425		0.669	0.285
	0.740	0.239		0.660	0.153
	0.730	0.143		0.685	0.354
	0.748	0.371		0.754	0.581
	0.833	0.644		0.893	0.713
	0.979	0.851		1.077	0.974
	1.233	1.123		1.243	1.179
	1.432	1.341		1.321	1.269
	1.528	1.463		1.347	1.301
	1.544	1.491			
S.11-41/III.278	2.115	2.051	S.11-64/IV.451	2.088	2.003
	1.340	1.228		1.223	1.172
	1.074	0.972		0.698	0.489
	0.921	0.821		0.680	0.222
	0.816	0.675		0.690	0.161
	0.766	0.486		0.704	0.479
	0.746	0.265		0.849	0.803
	0.762	0.139		1.258	1.196
	0.754	0.358		1.435	1.390
	0.813	0.602		1.108	1.042
	0.924	0.772		0.652	0.488
	1.048	0.913		0.629	0.167
	1.262	1.150		0.632	0.102
	1.449	1.369		0.629	0.323
	1.500	1.444		0.706	0.552
				1.072	0.992
				1.332	1.265
				1.398	1.342
				1.400	1.357

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.11-23/II.253L	2.069	1.941	S.11-46/III.290	2.034	1.968
	1.168	1.083		1.026	0.943
	0.818	0.727		0.753	0.574
	0.689	0.506		0.721	0.362
	0.664	0.269		0.709	0.149
	0.697	0.439		0.729	0.356
	0.787	0.647		0.792	0.603
	0.942	0.847		0.953	0.812
	1.124	1.025		1.205	1.078
	1.272	1.199		1.437	1.335
	1.348	1.295		1.533	1.469
	1.378	1.344		1.570	1.520
S.11-33/II.250	2.186	2.077	S.11-60/III.384	1.985	1.898
	1.137	1.083		1.178	1.139
	0.716	0.626		1.107	1.071
	0.683	0.520		0.948	0.907
	0.675	0.425		0.888	0.844
	0.668	0.214		0.669	0.587
	0.661	0.166		0.632	0.448
	0.658	0.139		0.635	0.303
	0.674	0.338		0.639	0.098
	0.715	0.555		0.640	0.258
	0.886	0.791		0.681	0.506
	1.122	1.030		0.804	0.722
	1.326	1.252		0.942	0.863
	1.404	1.347		1.051	0.998
	1.447	1.389		1.258	1.229
				1.286	1.256
S.11-59/III.394	2.000	1.951	S.11-40/III.276	2.156	2.055
	1.334	1.285		1.315	1.207
	1.087	1.034		1.046	0.942
	0.698	0.473		0.893	0.787
	0.686	0.330		0.786	0.592
	0.676	0.182		0.751	0.416
	0.683	0.352		0.742	0.234
	0.732	0.580		0.739	0.140
	1.017	0.939		0.755	0.360
	1.337	1.272		0.823	0.634
	1.429	1.396		0.949	0.811
	1.458	1.432		1.094	0.958
	1.490	1.458		1.328	1.220
				1.519	1.448
				1.541	1.478

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.11-65/IV.451	2.092	2.071	S.11-16/II.231	2.146	2.023
	1.307	1.258		0.857	0.798
	0.691	0.486		0.752	0.690
	0.666	0.223		0.656	0.509
	0.685	0.148		0.639	0.387
	0.722	0.533		0.634	0.241
	0.897	0.860		0.619	0.170
	1.334	1.267		0.623	0.156
	1.433	1.383		0.635	0.282
	0.897	0.831		0.654	0.445
	0.642	0.373		0.713	0.598
	0.620	0.137		0.833	0.752
	0.625	0.094		0.860	0.798
	0.642	0.339		1.011	0.954
	0.776	0.634		1.218	1.189
	1.148	1.065		1.339	1.325
	1.295	1.232			
	1.349	1.307			
	1.363	1.328			
S.11-34/II.252	2.191	2.090	S.11-24/II.253	2.012	1.890
	1.179	1.131		1.154	1.062
	0.799	0.730		0.828	0.756
	0.714	0.612		0.681	0.533
	0.695	0.506		0.663	0.308
	0.672	0.264		0.692	0.460
	0.688	0.182		0.766	0.646
	0.666	0.146		0.941	0.845
	0.680	0.341		1.121	1.017
	0.729	0.554		1.264	1.189
	0.857	0.721		1.361	1.317
	0.979	0.898		1.405	1.371
	1.347	1.273			
	1.420	1.372			
	1.456	1.418			
S.11-45/III.45	2.206	2.084	S.11-63/IV.421	2.136	2.086
	1.069	1.000		1.367	1.331
	0.749	0.571		1.010	0.971
	0.725	0.343		0.668	0.459
	0.711	0.151		0.649	0.287
	0.719	0.370		0.645	0.173
	0.792	0.627		0.663	0.447
	0.985	0.863		0.779	0.647
	1.237	1.118		0.983	0.917
	1.439	1.353		1.367	1.307
	1.530	1.480		1.377	1.334
	1.551	1.516			

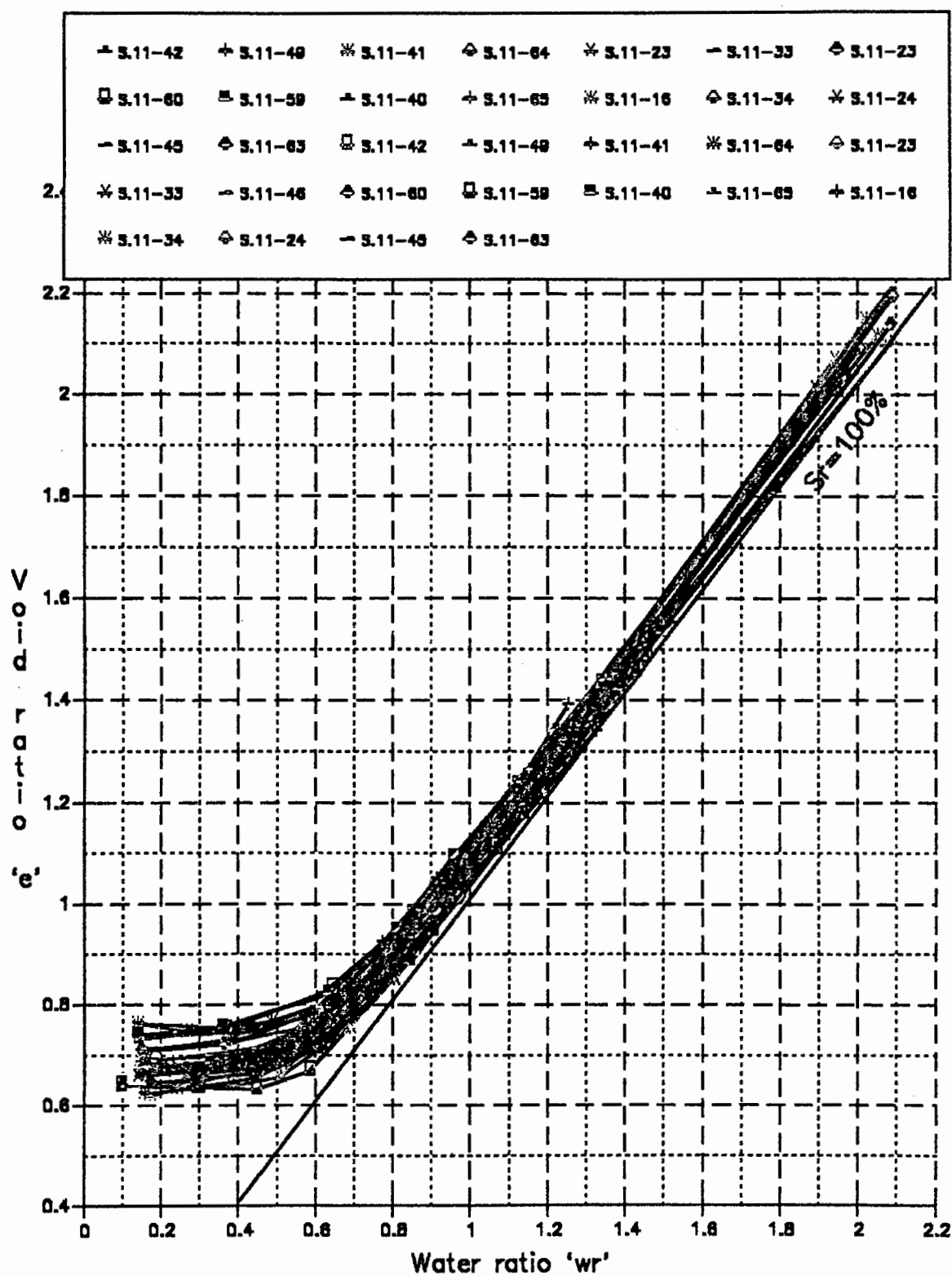


Figure C.01: Site 11, Rosebank [Remoulded, $M1 \geq LL$] - Void Ratio 'e' versus Water Ratio 'wr'.

Table C.02: Site 11, Rosebank [Remoulded, $M_1 < LL$] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.11-T.2/V.11	1.639	1.547	S.11-50/III.308	1.345	1.241
	1.339	1.266		1.058	0.974
	1.158	1.086		0.862	0.774
	0.934	0.857		0.782	0.673
	0.771	0.675		0.710	0.553
	0.701	0.507		0.680	0.312
	0.697	0.423		0.684	0.161
	0.710	0.376		0.698	0.302
	0.722	0.118		0.741	0.493
	0.720	0.307		0.831	0.679
	0.756	0.502		0.989	0.873
	0.899	0.787		1.163	1.058
	1.224	1.122		1.285	1.214
	1.356	1.266		1.347	1.293
	1.435	1.369			
S.11-43/III.284	1.445	1.295	S.11-11/II.216	1.862	1.739
	0.874	0.780		1.001	0.930
	0.719	0.556		0.859	0.776
	0.704	0.440		0.685	0.571
	0.696	0.338		0.657	0.498
	0.695	0.251		0.635	0.355
	0.711	0.411		0.626	0.295
	0.776	0.603		0.626	0.185
	0.920	0.795		0.645	0.315
	1.050	0.936		0.653	0.465
	1.239	1.145		0.731	0.608
	1.348	1.263		0.843	0.747
	1.423	1.343		0.988	0.894
				1.111	1.046
				1.183	1.138
				1.257	1.236

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.11-25/II.256L	1.595	1.429	S.11.48/III.303	1.319	1.198
	0.958	0.861		0.837	0.715
	0.730	0.607		0.678	0.450
	0.684	0.393		0.661	0.329
	0.670	0.236		0.663	0.220
	0.691	0.384		0.699	0.410
	0.732	0.559		0.753	0.583
	0.846	0.724		0.888	0.757
	0.989	0.882		1.023	0.920
	1.096	0.997		1.190	1.120
	1.214	1.138		1.258	1.201
	1.292	1.239			
	1.330	1.292			
S.11-62/III.396	1.357	1.252	S.11-61/IV.416	1.291	1.226
	1.193	1.101		1.118	1.050
	0.922	0.852		0.881	0.841
	0.680	0.448		0.766	0.686
	0.704	0.358		0.683	0.453
	0.707	0.511		0.676	0.197
	0.790	0.674		0.689	0.185
	0.953	0.869		0.689	0.385
	1.174	1.093		0.792	0.617
	1.352	1.286		0.967	0.864
	1.406	1.361		1.208	1.148
	1.436	1.397		1.384	1.329
	1.463	1.422		1.217	1.168
				0.673	0.411
S.11-51/III.311	1.377	1.231		0.667	0.249
	1.047	0.965		0.655	0.132
	0.823	0.743		0.700	0.372
	0.739	0.634		0.819	0.676
	0.694	0.516		1.057	0.992
	0.662	0.304		1.276	1.222
	0.669	0.159		1.344	1.290
	0.675	0.306		1.174	1.126
	0.728	0.506		0.839	0.769
	0.827	0.692		0.622	0.275
	0.996	0.892		0.625	0.163
	1.161	1.082		0.680	0.405
	1.284	1.226		0.905	0.752
	1.324	1.280		1.189	1.104
				1.324	1.250

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.11-26/II.256	1.642	1.502	S.11-44/III.286	1.349	1.289
	1.050	0.948		0.842	0.754
	0.766	0.651		0.721	0.571
	0.699	0.449		0.702	0.486
	0.686	0.263		0.690	0.378
	0.706	0.402		0.689	0.279
	0.750	0.574		0.711	0.432
	0.865	0.745		0.778	0.622
	0.989	0.877		0.904	0.793
	1.111	1.015		1.089	0.985
	1.222	1.144		1.267	1.181
	1.331	1.282		1.373	1.308
	1.366	1.331		1.445	1.389
S.11-47/III.301	1.337	1.238			
	0.813	0.726			
	0.679	0.501			
	0.664	0.371			
	0.662	0.245			
	0.676	0.395			
	0.732	0.570			
	0.844	0.722			
	0.983	0.873			
	1.140	1.056			
	1.224	1.142			

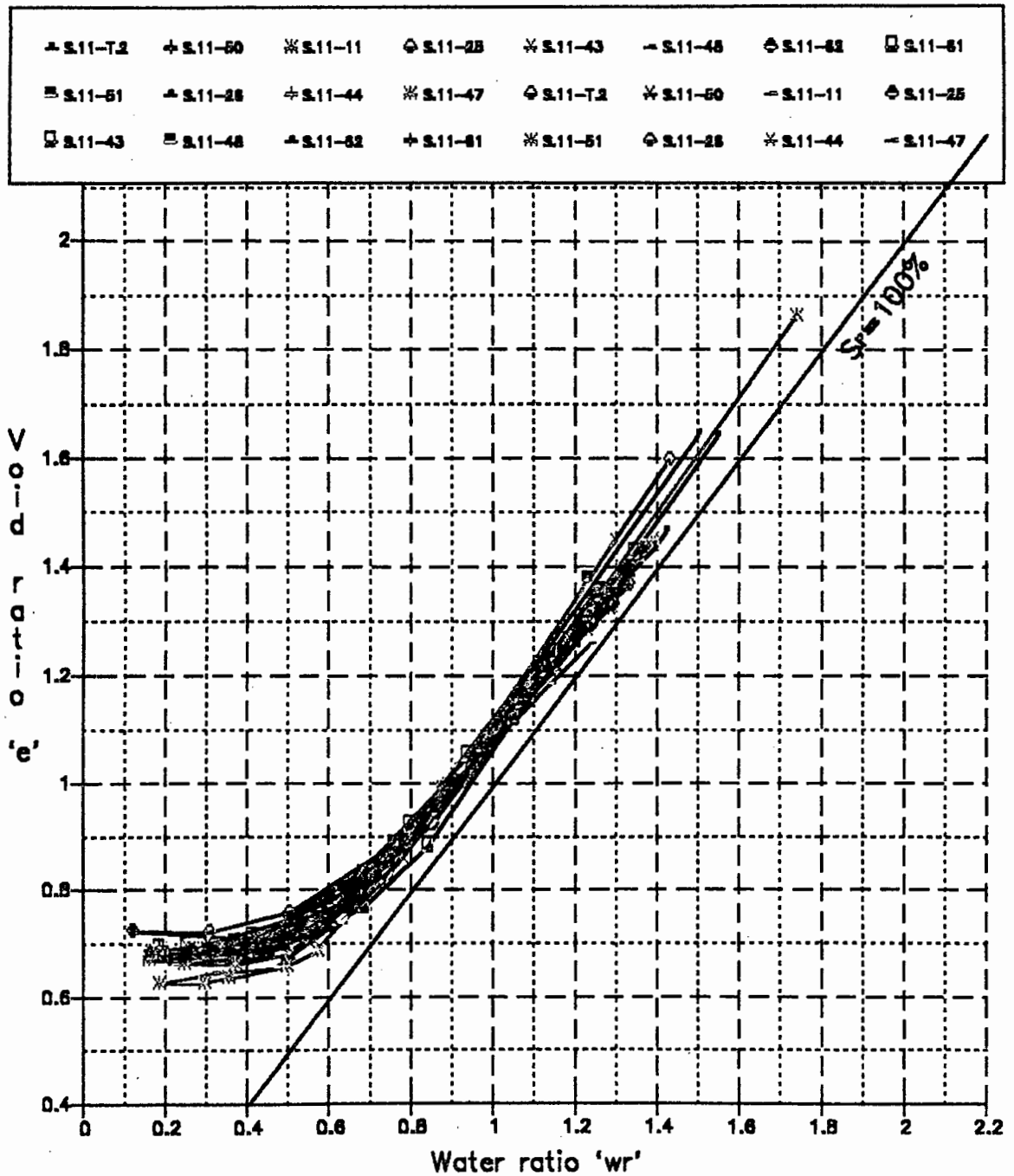


Figure C.02: Site 11, Rosebank [Remoulded, $M1 < LL$] - Void Ratio 'e' versus Water Ratio 'wr'.

Table C.03: Site 11, Rosebank [Remoulded, M2] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.11-35/II.270	2.043	1.630	S.11-36/II.272	2.481	1.547
	1.210	1.069		1.364	0.875
	0.894	0.758		1.016	0.580
	0.733	0.551		0.942	0.401
	0.674	0.386		0.898	0.273
	0.666	0.244		0.897	0.223
	0.677	0.433		0.904	0.186
	0.795	0.642		0.920	0.409
	1.008	0.868		1.071	0.686
	1.144	1.040		1.290	0.941
	1.245	1.159		1.462	1.210
	1.343	1.284		1.513	1.320
	1.416	1.362		1.550	1.386
				1.572	1.448
S.11-52/III.317	2.199	1.389	S.11-1/I.130	2.182	1.605
	1.490	1.126		1.397	1.147
	0.916	0.623		1.144	0.913
	0.798	0.446		0.970	0.753
	0.769	0.272		0.860	0.639
	0.775	0.186		0.772	0.466
	0.762	0.147		0.749	0.287
	0.763	0.131		0.741	0.094
	0.773	0.310		0.751	0.221
	0.833	0.495		0.771	0.420
	1.060	0.774		0.891	0.689
	1.227	0.987		1.094	0.895
	1.346	1.172		1.202	1.071
	1.432	1.297		1.326	1.278
				1.418	1.394

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.11-54/III.321	2.093	1.532	S.11-4/I.133	2.276	1.826
	1.383	1.152		1.529	1.373
	0.990	0.781		1.409	1.255
	0.898	0.690		1.267	1.121
	0.755	0.495		1.071	0.929
	0.737	0.432		0.866	0.720
	0.712	0.279		0.747	0.562
	0.721	0.151		0.723	0.472
	0.732	0.346		0.713	0.418
	0.812	0.570		0.702	0.175
	1.031	0.819		0.694	0.116
	1.238	1.037		0.707	0.177
	1.311	1.201		0.717	0.233
	1.400	1.304		0.731	0.430
				0.768	0.556
S.11-38/II.233	2.292	1.501		0.860	0.708
	1.378	0.973		1.073	0.928
	0.960	0.594		1.184	1.115
	0.820	0.377		1.267	1.227
	0.794	0.262		1.330	1.310
	0.802	0.186		1.441	1.431
	0.820	0.403			
	0.973	0.675			
	1.144	0.871			
	1.259	1.031			
	1.370	1.194			
	1.426	1.288			
	1.469	1.353			
S.11-57/III.354	2.006	1.374	S.11-37/II.274	2.146	1.616
	1.116	0.794		1.200	0.987
	0.928	0.531		0.881	0.690
	0.881	0.324		0.748	0.495
	0.884	0.148		0.714	0.340
	0.903	0.347		0.705	0.216
	0.928	0.552		0.724	0.419
	1.046	0.722		0.870	0.656
	1.214	0.903		1.112	0.921
	1.367	1.108		1.257	1.136
	1.414	1.221		1.403	1.306
	1.489	1.361		1.509	1.406
	1.563	1.467			

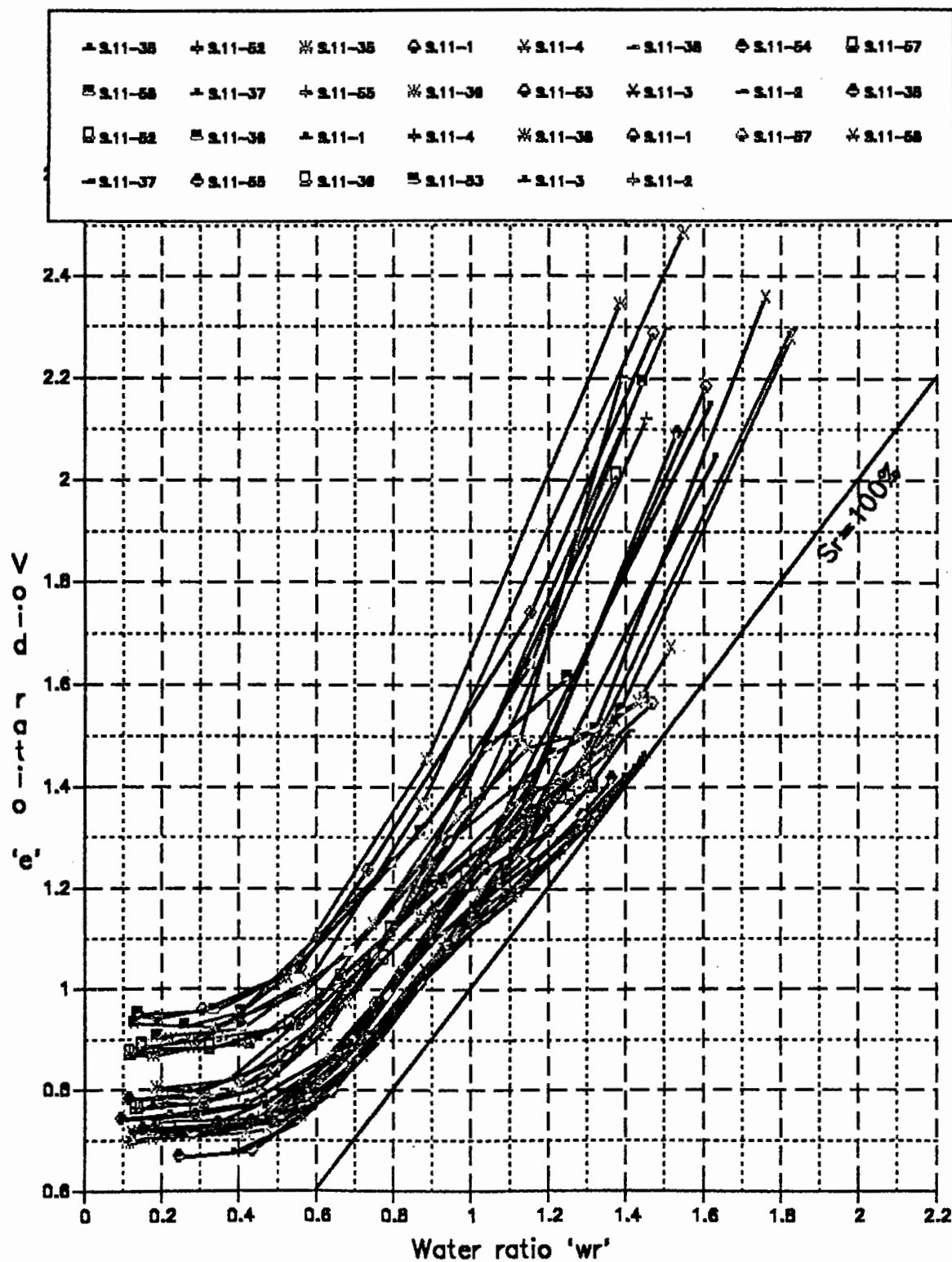


Figure C.03: Site 11, Rosebank [Remoulded, M2] - Void Ratio 'e' versus Water Ratio 'wr'.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.11-10/II.241	0.568	0.464	S.11-71 & T4/ IV.459	1.016	0.910
	0.538	0.405		0.630	0.326
	0.510	0.257		0.632	0.158
	0.506	0.216		0.658	0.423
	0.503	0.143		0.813	0.689
	0.520	0.247		1.090	1.013
	0.541	0.344		1.331	1.291
	0.661	0.547		0.941	0.880
	0.821	0.726		0.681	0.596
	1.025	0.956		0.600	0.324
	1.251	1.214		0.584	0.208
	1.323	1.306		0.644	0.505
	1.400	1.379		0.853	0.747
				1.089	1.010
S.11-28/II.260	0.897	0.769		1.313	1.252
	0.607	0.256		1.336	1.283
	0.576	0.106			
	0.622	0.365			
	0.893	0.705			
	1.072	0.930			
	1.368	1.297			

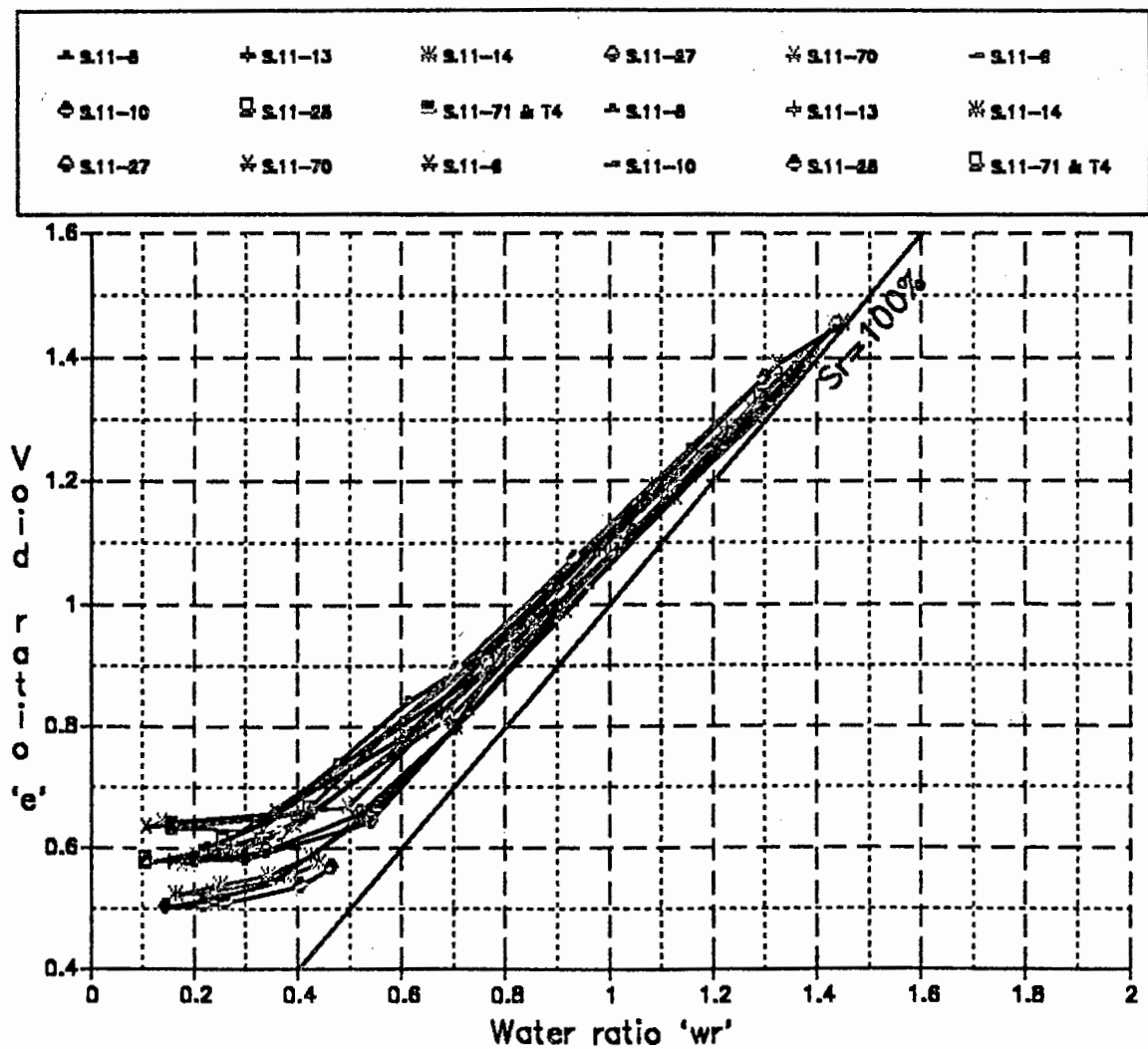


Figure C.04: Site 11, Rosebank [Compacted] - Void ratio 'e' versus Water Ratio 'wr'.

Table C.05: Site 11, Rosebank [Undisturbed] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.11-6/II.166L	0.907	0.797	S.11-12/II.216	0.892	0.775
	0.854	0.738		0.734	0.604
	0.731	0.580		0.656	0.395
	0.695	0.491		0.649	0.242
	0.675	0.368		0.661	0.356
	0.668	0.156		0.696	0.502
	0.671	0.239		0.933	0.794
	0.687	0.399		1.153	1.065
	0.719	0.511		1.288	1.237
	0.867	0.728			
	1.054	0.946			
	1.114	1.047			
S.11-15/II.221	1.025	0.891	S.11-17/II.244L	1.106	1.037
	0.953	0.745		0.894	0.806
	0.739	0.385		0.702	0.518
	0.746	0.156		0.674	0.125
	0.782	0.462		0.683	0.334
	1.025	0.871		0.748	0.551
	1.346	1.227		0.910	0.788
	1.418	1.334		1.100	1.015
				1.237	1.146
S.11-19/II.245L	1.079	1.017	S.11-22/II.246R	1.168	1.095
	0.905	0.821		0.839	0.751
	0.694	0.519		0.732	0.464
	0.671	0.108		0.716	0.122
	0.677	0.301		0.722	0.317
	0.759	0.560		0.770	0.560
	0.907	0.760		1.093	0.990
	1.075	0.965		1.374	1.296
	1.214	1.140		1.460	1.404
	1.283	1.211			
S.11-7/II.166L	1.016	0.892	S.11-18/II.244R	1.062	1.017
	0.787	0.647		0.788	0.711
	0.725	0.534		0.664	0.410
	0.694	0.355		0.650	0.098
	0.686	0.138		0.659	0.302
	0.689	0.230		0.705	0.548
	0.702	0.357		0.890	0.771
	0.795	0.604		1.091	1.015
	1.026	0.872		1.221	1.131
	1.146	1.017			
	1.227	1.131			

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.11-20/II.245R	1.123	1.071	S.11-21/II.246L	1.012	0.935
	0.893	0.835		0.705	0.576
	0.675	0.498		0.655	0.292
	0.654	0.117		0.655	0.114
	0.663	0.364		0.671	0.335
	0.764	0.655		0.763	0.597
	0.978	0.894		0.965	0.838
	1.213	1.157		1.186	1.067
	1.314	1.256		1.297	1.201
S.11-31/II.264	1.210	1.099	S.11-29/II.266L	1.086	1.044
	1.023	0.900		0.765	0.695
	0.795	0.655		0.671	0.394
	0.726	0.408		0.660	0.172
	0.712	0.172		0.680	0.394
	0.718	0.373		0.740	0.586
	0.816	0.636		0.910	0.827
	1.081	0.930		1.126	1.058
	1.293	1.190		1.330	1.278
	1.369	1.261		1.428	1.379
S.11-30/II.266R	1.026	0.928	S.11-T3/V.28	0.769	0.658
	0.743	0.559		0.711	0.420
	0.698	0.287		0.698	0.210
	0.705	0.147		0.706	0.173
	0.741	0.445		0.746	0.397
	0.851	0.698		0.873	0.776
	1.120	1.019		1.145	1.087
	1.324	1.236		1.346	1.325
				1.401	1.396
S.11-T.5/V.35	1.732	1.700		0.802	0.735
	0.820	0.768		0.645	0.221
	0.598	0.287		0.650	0.128
	0.621	0.168		0.674	0.357
	0.704	0.406		0.792	0.671
	0.811	0.686		1.156	1.091
	0.933	0.906		1.297	1.277
	1.117	1.068		1.417	1.386
	1.247	1.208			
	1.384	1.323			

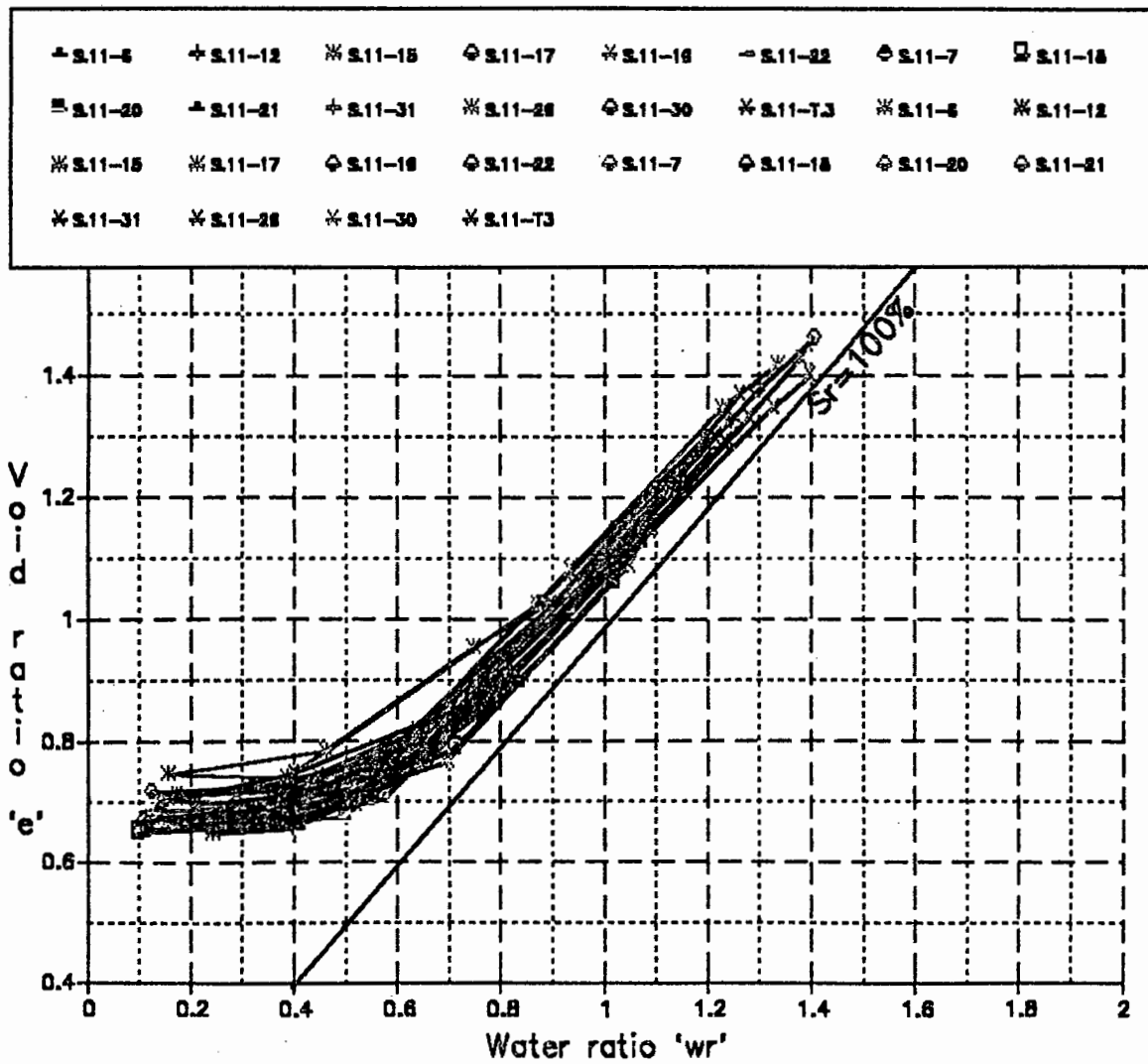


Figure C.05: Site 11, Rosebank [Undisturbed] - Void Ratio 'e' versus Water Ratio 'wr'.

Site 36 - Rondebosch, Cape*Table C.06: Site 36, Rondebosch [Remoulded] - Free Shrinkage and Free Swell test results.*

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.36-14 & 15 IV.452	1.303	1.249	S.36-3/III.331	1.313	1.299
	0.841	0.770		0.843	0.810
	0.691	0.427		0.671	0.483
	0.681	0.062		0.651	0.360
	0.687	0.198		0.652	0.266
	0.716	0.441		0.650	0.052
	0.824	0.699		0.652	0.164
	0.982	0.877		0.660	0.293
	0.818	0.706		0.674	0.433
	0.717	0.535		0.715	0.582
	0.685	0.377		0.798	0.706
	0.682	0.062		1.003	0.925
	0.690	0.179		1.020	0.940
	0.687	0.404			
	0.755	0.585	S.36-2/III.329	1.261	1.257
	0.920	0.783		0.828	0.797
	0.989	0.862		0.637	0.413
				0.627	0.266
S.36-9/III.376	1.455	1.389		0.612	0.192
	0.787	0.738		0.619	0.057
	0.654	0.575		0.625	0.049
	0.648	0.510		0.608	0.142
	0.639	0.427		0.627	0.295
	0.616	0.204		0.635	0.406
	0.612	0.039		0.685	0.554
	0.621	0.210		0.827	0.720
	0.633	0.401		0.976	0.880
	0.703	0.581		1.027	0.931
	0.859	0.772			
	0.956	0.878			
S.36-8/III.374	1.405	1.325			
	0.978	0.895			
	0.707	0.555			
	0.667	0.382			
	0.676	0.257			
	0.673	0.057			
	0.681	0.241			
	0.692	0.435			
	0.754	0.617			
	0.923	0.805			

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.36-T.1/V.5	1.110	1.020	S.36-13/IV.452	1.187	1.139
	0.909	0.861		0.873	0.811
	0.862	0.804		0.665	0.416
	0.689	0.629		0.639	0.048
	0.642	0.506		0.651	0.231
	0.625	0.335		0.682	0.462
	0.624	0.038		0.840	0.708
	0.629	0.200		1.054	0.914
	0.626	0.320			
	0.671	0.515	S.36-5/III.384	0.825	0.741
	0.862	0.748		0.609	0.521
	1.056	0.958		0.577	0.339
				0.569	0.035
S.36-12/III.382	0.834	0.727		0.568	0.151
	0.639	0.563		0.582	0.273
	0.616	0.529		0.596	0.390
	0.585	0.271		0.641	0.534
	0.582	0.232		0.766	0.670
	0.608	0.343		0.836	0.770
	0.643	0.528		0.884	0.821
	0.787	0.692			
	0.901	0.832	S.36-10/III.378	0.824	0.767
	0.965	0.909		0.748	0.678
				0.674	0.620
S.36-4/III.346	0.806	0.727		0.612	0.540
	0.573	0.494		0.580	0.332
	0.549	0.328		0.573	0.248
	0.539	0.173		0.573	0.073
	0.546	0.039		0.575	0.178
	0.553	0.032		0.583	0.286
	0.552	0.148		0.601	0.413
	0.563	0.269		0.650	0.543
	0.579	0.387		0.662	0.578
	0.606	0.502		0.785	0.721
	0.732	0.644		0.869	0.803
	0.812	0.747			
	0.856	0.796			

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.36-7/III.360	2.012	1.054	S.36-11/III.380	0.845	0.743
	1.253	0.661		0.711	0.654
	1.078	0.329		0.647	0.602
	1.069	0.083		0.620	0.546
	1.078	0.361		0.578	0.390
	1.098	0.625		0.577	0.281
	1.072	0.733		0.587	0.084
	1.226	0.885		0.582	0.196
S.36-6/III.358				0.591	0.309
	2.082	0.988		0.604	0.404
	1.197	0.580		0.671	0.587
	1.053	0.183		0.715	0.652
	1.053	0.043		0.840	0.669
	1.037	0.031		0.893	0.854
	1.051	0.188			
	1.057	0.527			
	1.098	0.726			
	1.233	0.922			

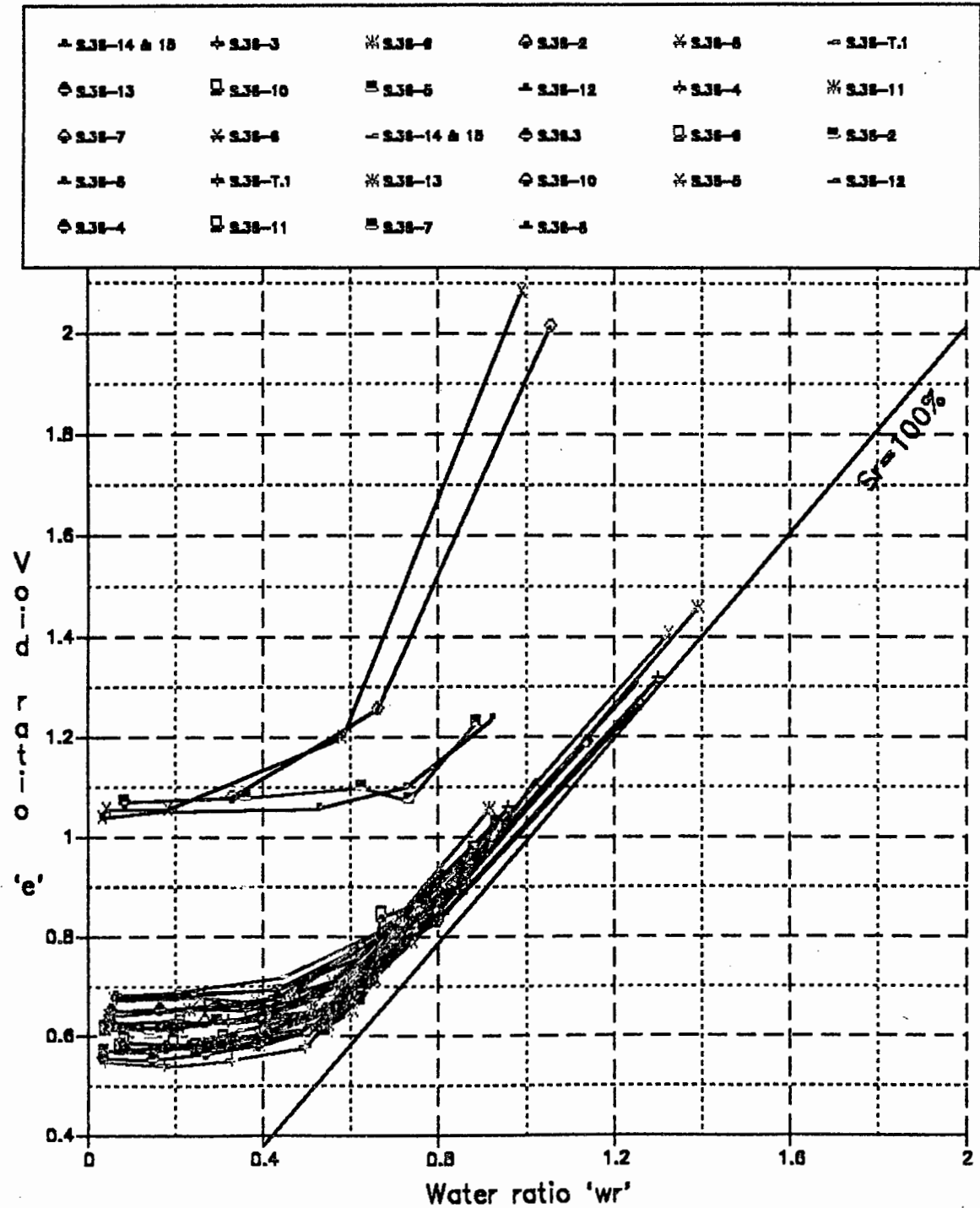


Figure C.06: Site 36, Rondebosch [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.

Table C.07: Site 36, Rondebosch [Compacted] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.36-18 & 19/ IV.453	0.491	0.448
	0.422	0.045
	0.427	0.044
	0.422	0.220
	0.528	0.490
	0.809	0.771
	0.947	0.921

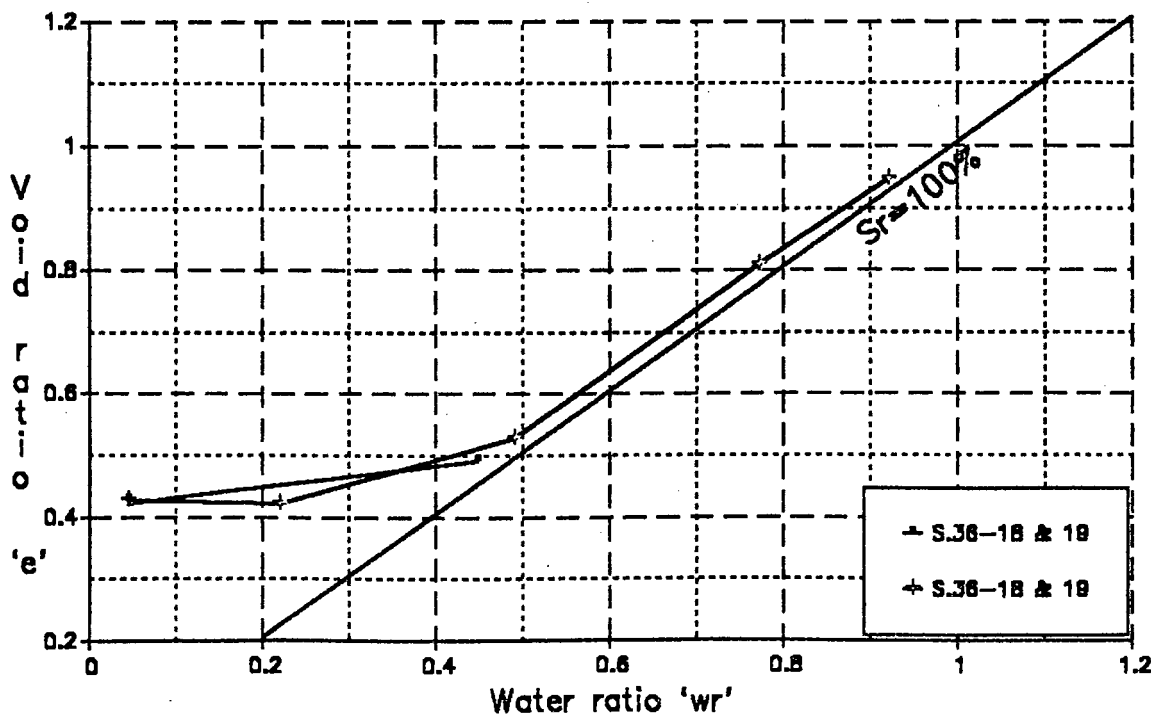


Figure C.07: Site 36, Rondebosch [Compacted] - Void Ratio 'e' versus Water Ratio 'wr'.

Table C.08: Site 36, Rondebosch [Undisturbed] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.36-16/III.390	0.564	0.416	S.36-17/III.392	0.536	0.392
	0.545	0.357		0.521	0.325
	0.525	0.212		0.505	0.131
	0.537	0.079		0.504	0.052
	0.533	0.212		0.508	0.192
	0.574	0.396		0.551	0.391
	0.679	0.587		0.678	0.589
	0.821	0.753		0.859	0.784
	0.917	0.841			
S.36-20/IV.407	0.612	0.415			
	0.598	0.343			
	0.597	0.059			
	0.598	0.258			
	0.636	0.440			
	0.782	0.690			
	0.993	0.902			

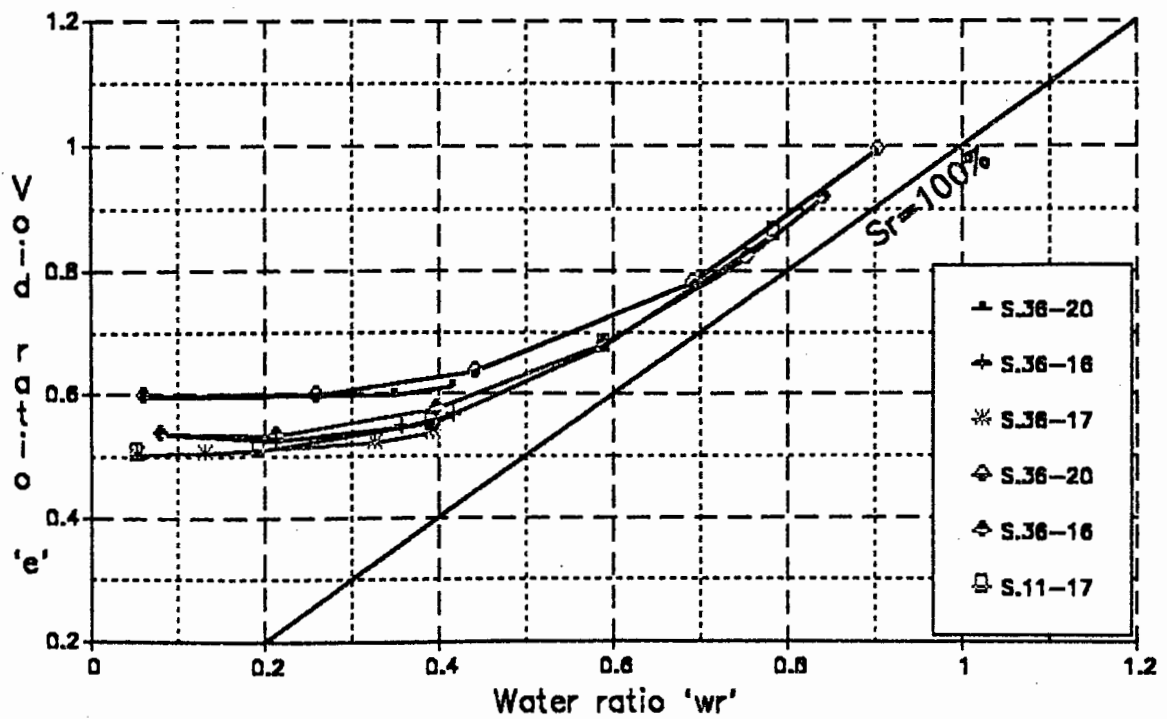


Figure C.08: Site 36, Rondebosch [Undisturbed] - Void Ratio 'e' versus Water Ratio 'wr'.

Site 30 - Hout Bay, Cape*Table C.09: Site 30, Hout Bay [Remoulded] - Free Shrinkage and Free Swell test results.*

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.30-10 & 11/ IV.465L	1.318	1.244	S.30-3/III.336	1.346	1.313
	0.813	0.767		0.933	0.880
	0.641	0.505		0.710	0.587
	0.585	0.131		0.665	0.460
	0.586	0.055		0.669	0.342
	0.589	0.244		0.660	0.062
	0.627	0.434		0.675	0.157
	0.757	0.640		0.667	0.299
S.30-9/III.388	0.954	0.863	S.30-2/III.333	0.683	0.414
				0.749	0.585
	1.386	1.340		0.861	0.736
	0.958	0.893		0.984	0.864
	0.910	0.846		1.077	0.962
	0.803	0.720			
	0.759	0.655		1.459	1.389
	0.695	0.496		0.935	0.864
S.30-8/III.386	0.672	0.413		0.689	0.530
	0.670	0.051		0.673	0.362
	0.680	0.223		0.670	0.059
	0.672	0.348		0.679	0.171
	0.737	0.533		0.688	0.338
	0.928	0.781		0.708	0.476
	1.089	0.974		0.809	0.633
				0.919	0.794
	1.446	1.315		1.050	0.945
	0.961	0.890		1.110	1.013
	0.911	0.836			
	0.787	0.691			
	0.763	0.638			
	0.681	0.379			
	0.680	0.046			
	0.686	0.191			
	0.718	0.477			
	0.879	0.728			
	1.093	0.978			

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.30-T.1/V.7	1.231	1.122	S.30-5/III.352	0.942	0.877
	0.937	0.874		0.736	0.657
	0.818	0.740		0.618	0.365
	0.657	0.352		0.614	0.043
	0.652	0.090		0.619	0.148
	0.655	0.280		0.640	0.410
	0.685	0.470		0.685	0.533
	0.793	0.667		0.772	0.670
	0.996	0.906		0.882	0.791
	1.090	1.030		0.967	0.903
S.30-4/III.350	0.983	0.891	S.30-7/III.366	1.614	0.979
	0.770	0.687		1.103	0.801
	0.633	0.480		0.933	0.652
	0.625	0.316		0.817	0.333
	0.615	0.066		0.799	0.200
	0.606	0.040		0.796	0.073
	0.623	0.167		0.796	0.057
	0.637	0.389		0.815	0.227
	0.660	0.491		0.845	0.483
	0.768	0.639		0.932	0.666
S.30-6/III.364	0.845	0.744		0.997	0.795
	0.957	0.870		1.086	0.967
	1.588	1.135			
	1.149	0.905			
	0.958	0.713			
	0.818	0.506			
	0.783	0.337			
	0.799	0.071			
	0.794	0.246			
	0.831	0.484			
	0.923	0.659			
	0.989	0.822			
	1.068	0.929			

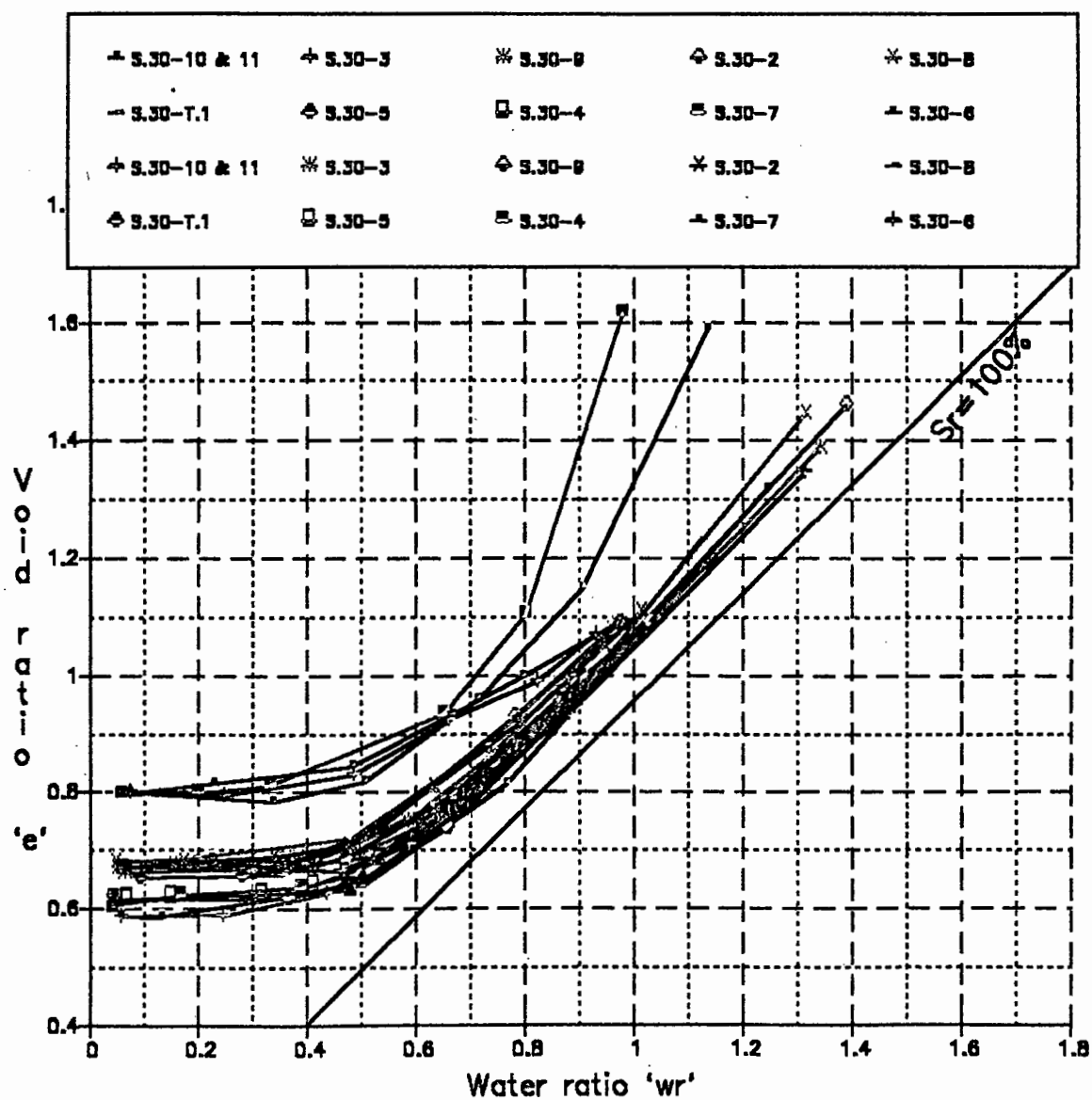


Figure C.09: Site 30, Hout Bay [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.

Table C.10: Site 30, Hout Bay [Undisturbed] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.30-17 & 13/ IV.438	0.545	0.355	S.30-14/IV.433	0.594	0.369
	0.541	0.133		0.580	0.204
	0.543	0.091		0.589	0.074
	0.543	0.290		0.588	0.213
	0.630	0.573		0.608	0.362
	0.891	0.841		0.671	0.588
	0.930	0.882		0.857	0.813

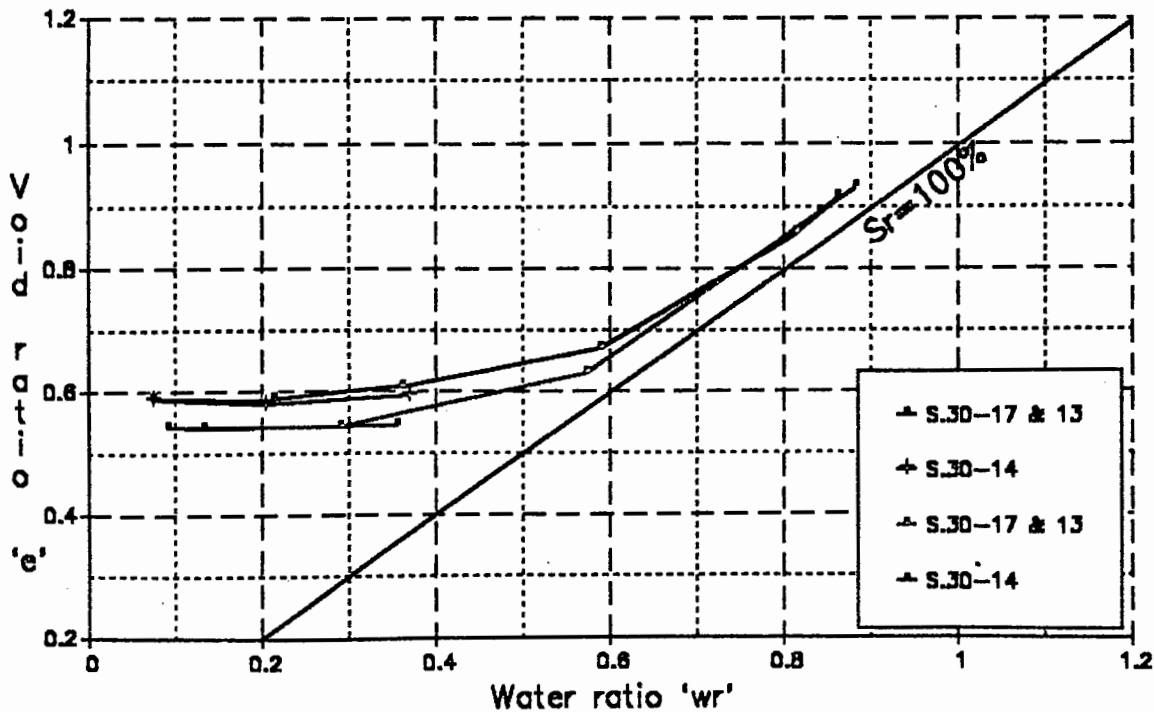


Figure C.10: Site 30, Hout Bay [Undisturbed] - Void Ratio 'e' versus Water Ratio 'wr'.

Site A - Berea Road, Durban

Table C.11: Site A, Berea Road [Remoulded] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.A-T.1/V.9	0.609	0.501	S.A-1.A/II.139	0.668	0.613
	0.519	0.430		0.473	0.384
	0.496	0.412		0.458	0.287
	0.489	0.397		0.449	0.241
	0.440	0.211		0.435	0.116
	0.439	0.178		0.437	0.028
	0.477	0.276		0.439	0.064
	0.516	0.363		0.446	0.175
	0.573	0.431		0.475	0.274
				0.500	0.330
				0.532	0.379
				0.556	0.417
S.A-2/I.113	0.789	0.640	S.A-3/I.114	0.991	0.696
	0.493	0.192		0.575	0.131
	0.488	0.097		0.561	0.071
	0.468	0.061		0.544	0.037
	0.469	0.052		0.528	0.030
	0.463	0.083		0.537	0.050
	0.475	0.178		0.544	0.117
	0.515	0.244		0.557	0.257
	0.537	0.308		0.587	0.325
	0.542	0.365		0.580	0.384
	0.562	0.425		0.591	0.439
	0.592	0.464		0.584	0.571
S.A-4/I.115	0.859	0.690	S.A-6/II.158	0.838	0.579
	0.495	0.177		0.439	0.349
	0.485	0.106		0.427	0.302
	0.480	0.059		0.407	0.188
	0.477	0.026		0.400	0.081
	0.480	0.059		0.395	0.175
	0.479	0.131		0.418	0.245
	0.516	0.238		0.448	0.315
	0.527	0.313		0.468	0.373
	0.538	0.423		0.470	0.417
	0.537	0.484			

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.A-7/II.159	0.788	0.447	S.A-8/II.160	0.830	0.590
	0.480	0.159		0.497	0.093
	0.467	0.152		0.487	0.042
	0.462	0.134		0.483	0.012
	0.459	0.008		0.482	0.102
	0.446	0.077		0.513	0.194
	0.470	0.163		0.525	0.261
	0.497	0.256		0.528	0.428
	0.507	0.298			
	0.516	0.418			

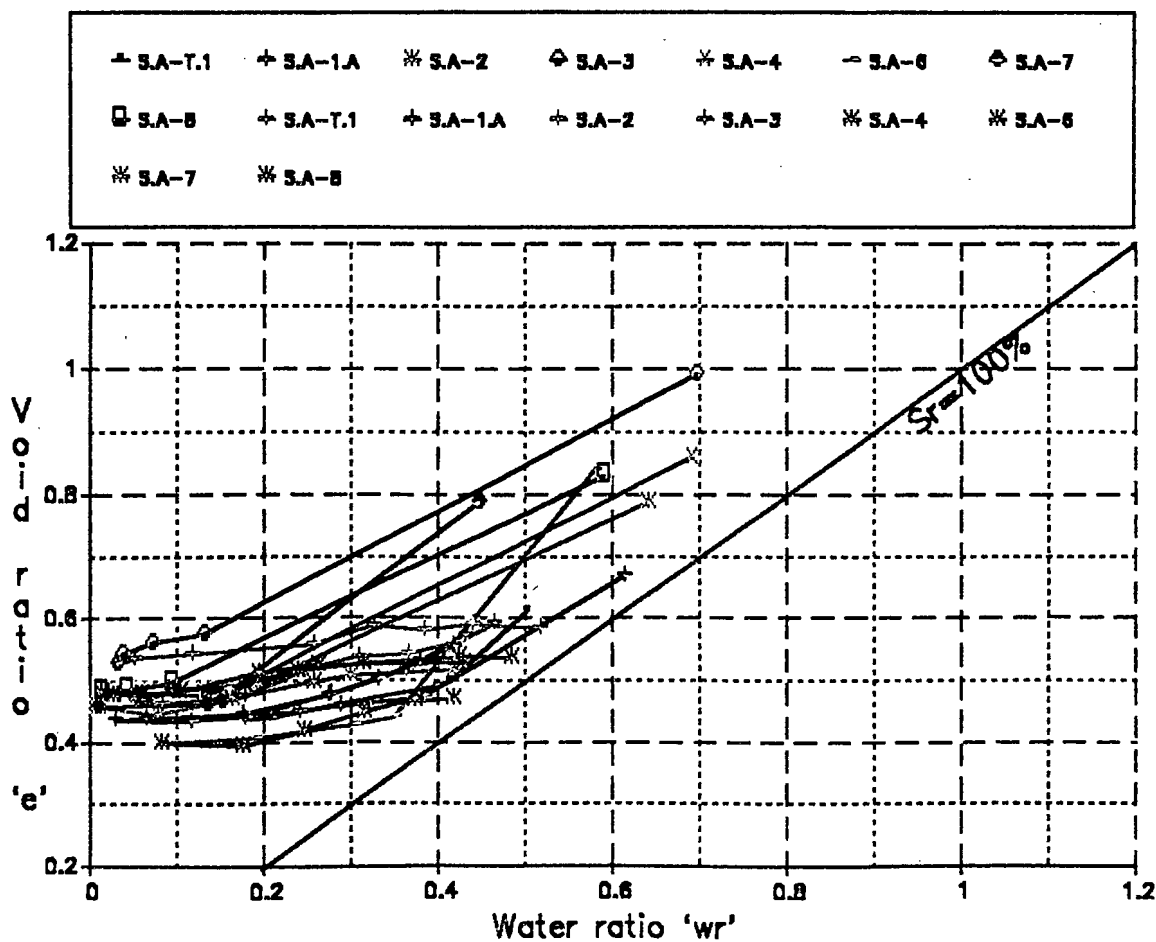


Figure C.11: Site A, Berea Road [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.

Table C.12: Site A, Berea Road [Compacted] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.A-9/II.9	0.395	0.148	S.A-10/II.178	0.581	0.086
	0.430	0.211		0.571	0.410
	0.440	0.291		0.606	0.497
	0.448	0.354		0.633	0.542
	0.504	0.422			
S.A-12/II.12	0.317	0.210	S.A-31 & T.2	0.445	0.290
	0.306	0.139	V.33	0.434	0.255
	0.303	0.045		0.427	0.166
	0.308	0.133		0.420	0.076
	0.350	0.256		0.413	0.062
	0.411	0.337		0.446	0.230
				0.468	0.388
				0.552	0.512
				0.487	0.382
				0.471	0.307
				0.443	0.127
				0.433	0.042
				0.454	0.192
				0.516	0.369

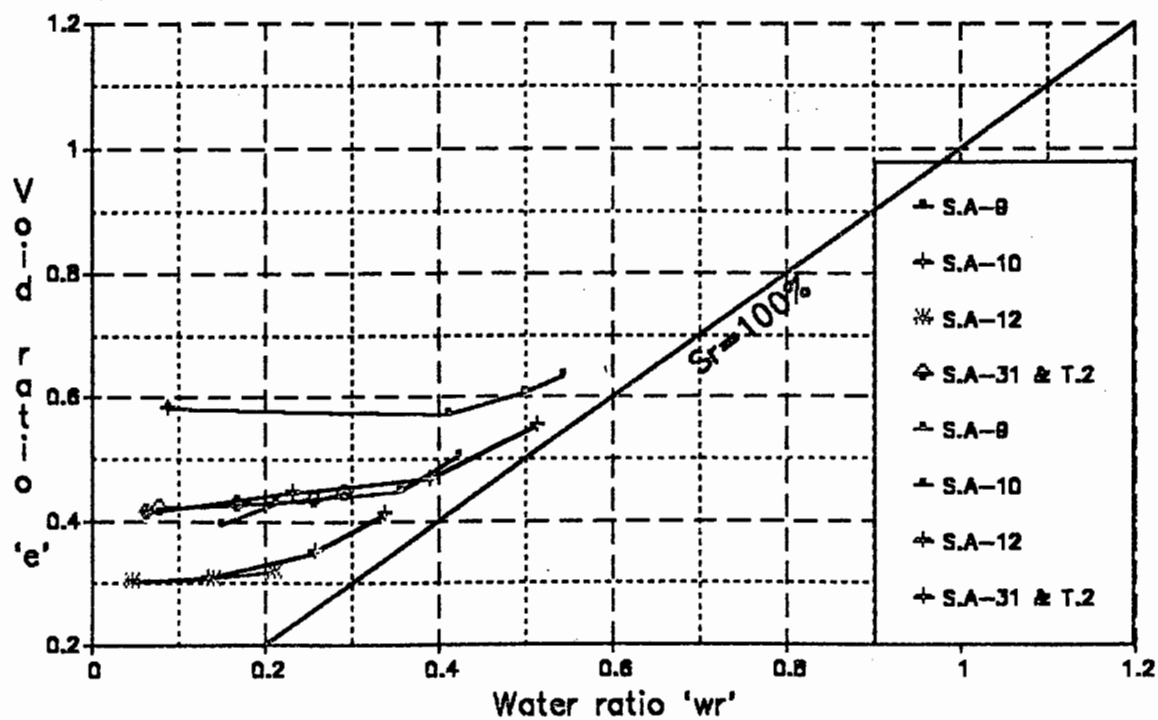


Figure C.12: Site A, Berea Road [Compacted] - Void Ratio 'e' versus Water Ratio 'wr'.

Table C.13: Site A, Berea Road [Undisturbed] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.A-11/II.180	0.500	0.053	S.A-T.3/V.25	0.432	0.046
	0.517	0.196		0.426	0.049
	0.551	0.356		0.085	0.225
	0.619	0.460		0.516	0.386
				0.653	0.504
S.A-T4 & T5/V26	0.508	0.064			
	0.507	0.061			
	0.521	0.161			
	0.558	0.268			
	0.600	0.417			
	0.712	0.530			
	0.621	0.382			
	0.566	0.173			
	0.539	0.028			
	0.567	0.181			
	0.613	0.358			
	0.663	0.470			

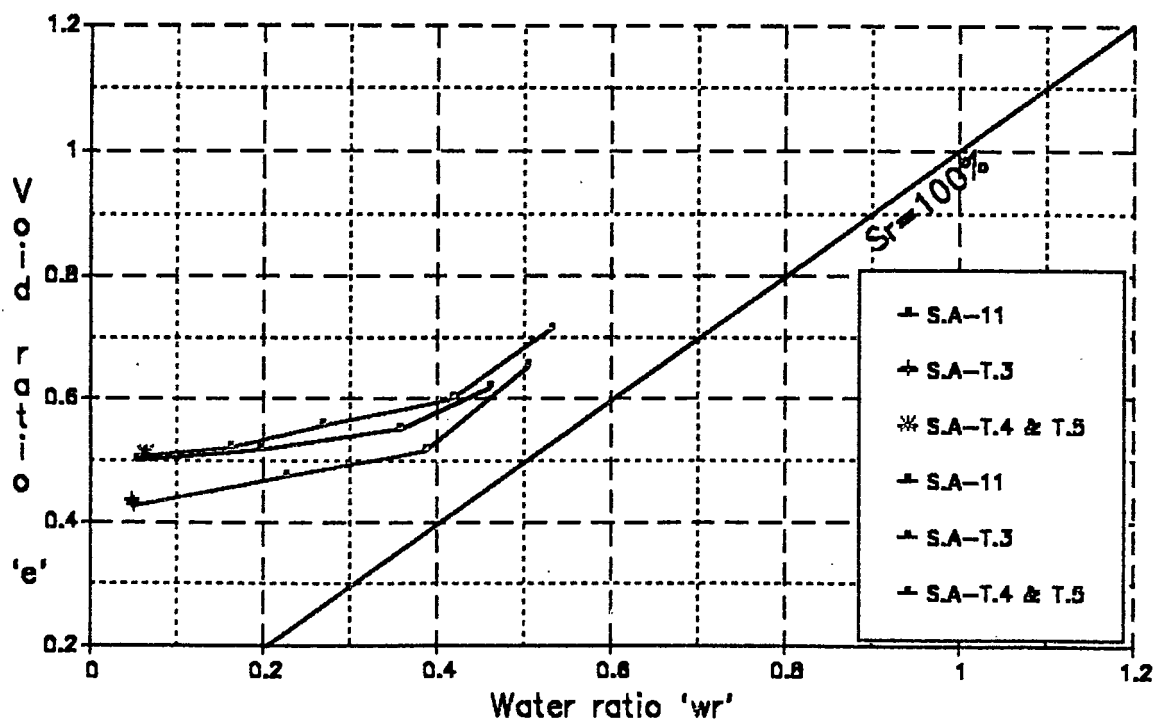


Figure C.13: Site A, Berea Road [Undisturbed] - Void Ratio 'e' versus Water Ratio 'wr'.

Site 7 - Mowbray, Cape*Table C.14: Site 7, Mowbray [Remoulded] - Free Shrinkage and Free Swell test results.*

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.7-2/I.91	1.668	1.627	S.7-1/I.90	1.826	1.799
	0.767	0.738		0.859	0.836
	0.546	0.486		0.600	0.573
	0.524	0.319		0.548	0.396
	0.524	0.154		0.539	0.194
	0.521	0.067		0.536	0.106
	0.526	0.150		0.533	0.054
	0.537	0.305		0.535	0.149
	0.577	0.469		0.547	0.307
	0.641	0.582		0.596	0.501
	0.749	0.704		0.689	0.638
	0.847	0.820		0.819	0.753
	0.891	0.854		0.885	0.863
				0.898	0.871
S.7-T.1/V.23	1.106	1.020	S.7-7/I.116	2.456	1.748
	0.855	0.809		1.009	0.986
	0.521	0.438		0.807	0.705
	0.514	0.095		0.639	0.537
	0.510	0.257		0.630	0.401
	0.575	0.422		0.585	0.114
	0.861	0.790		0.588	0.233
	0.957	0.889		0.645	0.474
	0.687	0.605		0.711	0.569
	0.509	0.386		0.778	0.730
	0.489	0.156		0.835	0.793
	0.482	0.075		0.878	0.914
	0.490	0.240		0.916	0.977
	0.613	0.527			
	0.816	0.743			
	0.839	0.769			
S.7-10/II.184	2.217	1.525	S.7-9/II.183	1.879	1.122
	1.017	0.857		0.765	0.518
	0.718	0.596		0.578	0.342
	0.593	0.441		0.520	0.279
	0.566	0.345		0.476	0.153
	0.566	0.240		0.461	0.083
	0.580	0.409		0.478	0.244
	0.589	0.587		0.530	0.402
	0.818	0.756		0.648	0.537
	0.898	0.864		0.794	0.681

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.7-5/I.96	1.028	0.971	S.7-3/I.92	1.699	1.681
	0.442	0.402		0.918	0.936
	0.434	0.248		0.686	0.676
	0.434	0.149		0.482	0.442
	0.431	0.077		0.469	0.309
	0.428	0.061		0.468	0.089
	0.434	0.115		0.470	0.193
	0.441	0.178		0.484	0.311
	0.448	0.262		0.523	0.454
	0.486	0.393		0.615	0.589
	0.555	0.502		0.723	0.705
	0.645	0.606		0.847	0.832
	0.765	0.728		0.902	0.888
	0.828	0.790			
S.7-4/I.93	1.700	1.700	S.7-8/I.117	1.537	1.192
	0.951	0.964		0.465	0.315
	0.713	0.696		0.438	0.121
	0.492	0.449		0.393	0.050
	0.462	0.176		0.407	0.107
	0.457	0.076		0.463	0.241
	0.467	0.163		0.528	0.384
	0.492	0.332		0.549	0.560
	0.557	0.501		0.585	0.632
	0.608	0.670			
	0.847	0.828			
	0.911	0.889			

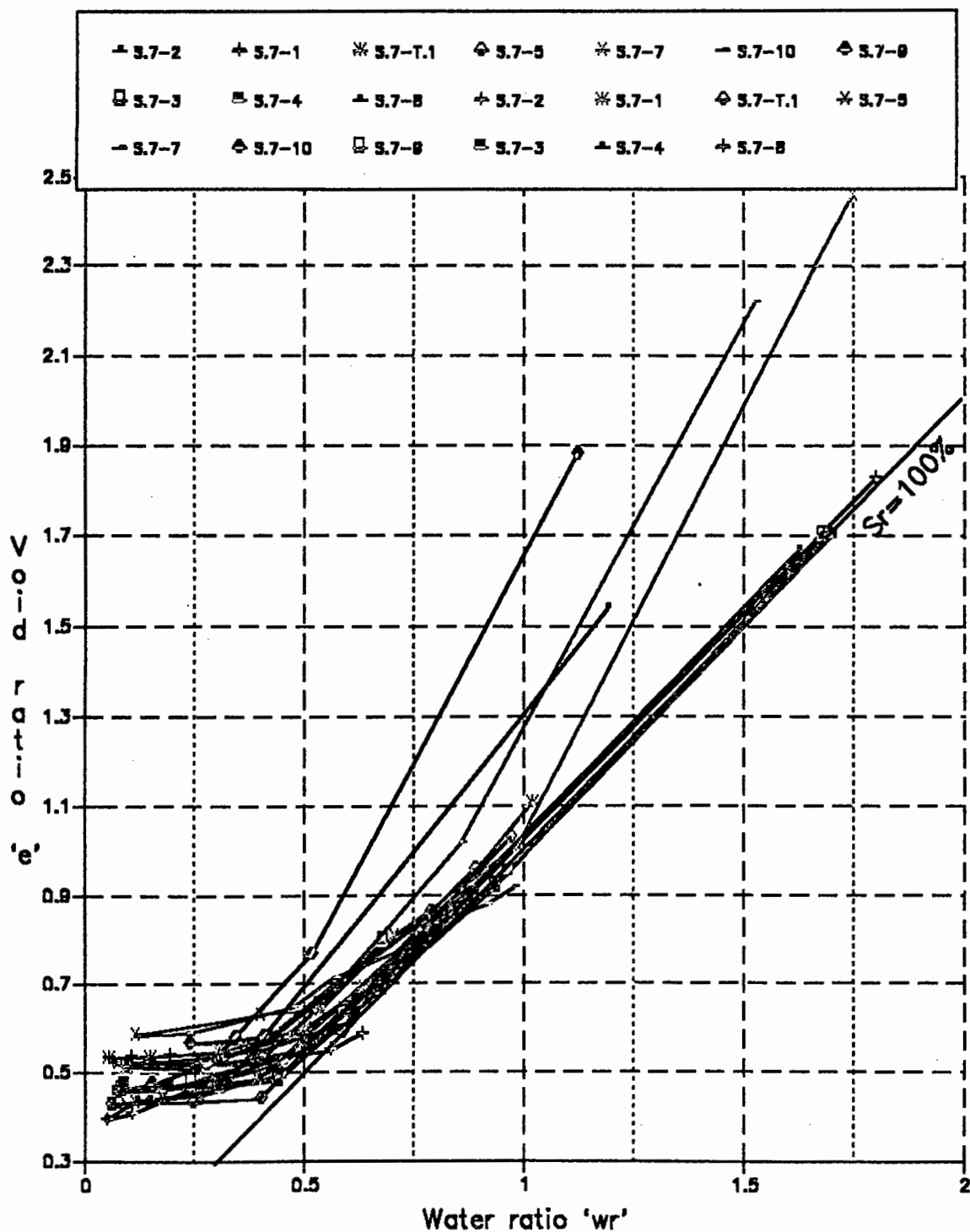


Figure C.14: Site 7, Mowbray [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.

Table C.15: Site 7, Mowbray [Compacted] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.7-13/II.203	0.424	0.194
	0.414	0.149
	0.444	0.259
	0.517	0.362
	0.580	0.447
	0.657	0.554
	0.737	0.618

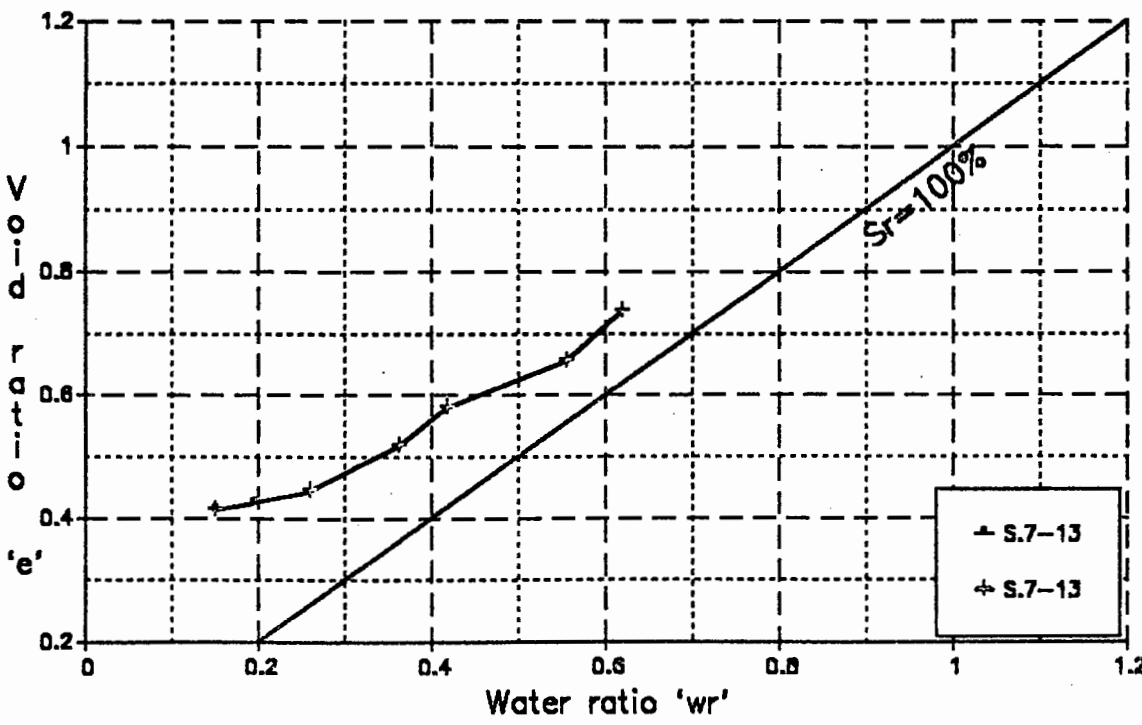


Figure C.15: Site 7, Mowbray [Compacted] - Void Ratio 'e' versus Water Ratio 'wr'.

Table C.16: Site 7, Mowbray [Undisturbed] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.7-12/II.185	0.624	0.595	S.7-11/II.185	0.579	0.550
	0.521	0.414		0.459	0.368
	0.506	0.257		0.455	0.215
	0.530	0.372		0.473	0.347
	0.569	0.496		0.533	0.479
	0.663	0.615		0.663	0.614
	0.746	0.727			

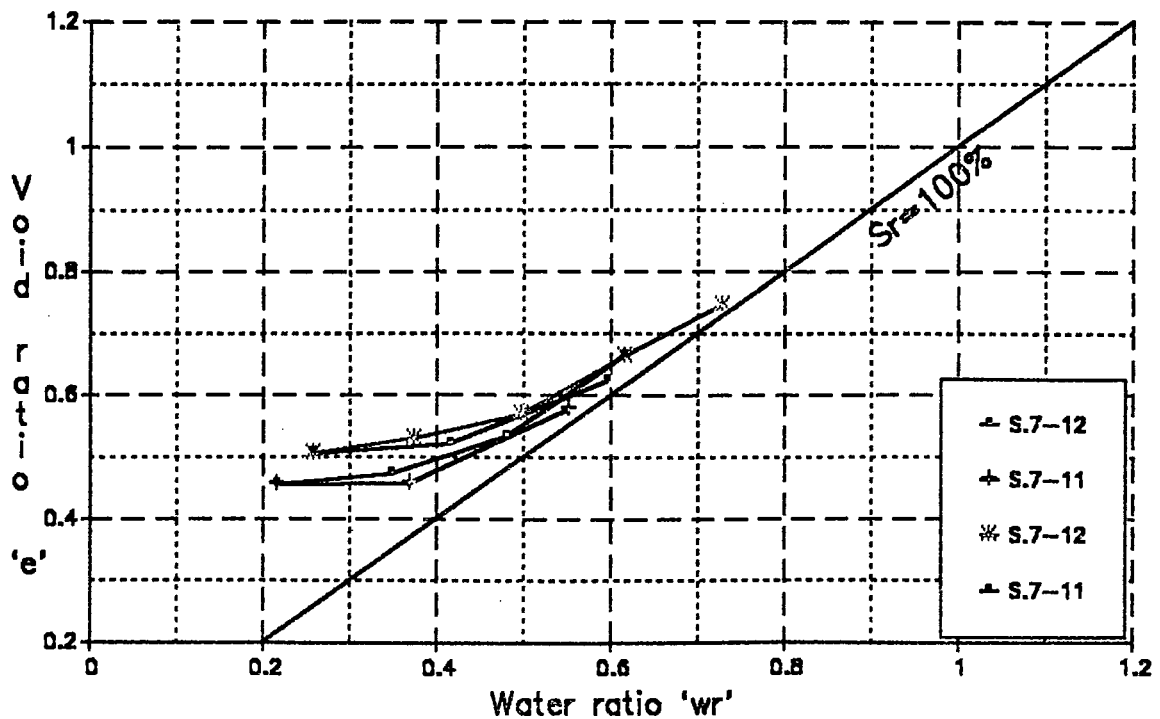


Figure C.16: Site 7, Mowbray [Undisturbed] - Void Ratio 'e' versus Water Ratio 'wr'.

Site B - Francois Road, Durban

Table C.17: Site B, Francois Road [Remoulded] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.B-1A/II.139	0.747	0.627
	0.540	0.340
	0.531	0.307
	0.526	0.223
	0.512	0.027
	0.523	0.127
	0.536	0.238
	0.551	0.319

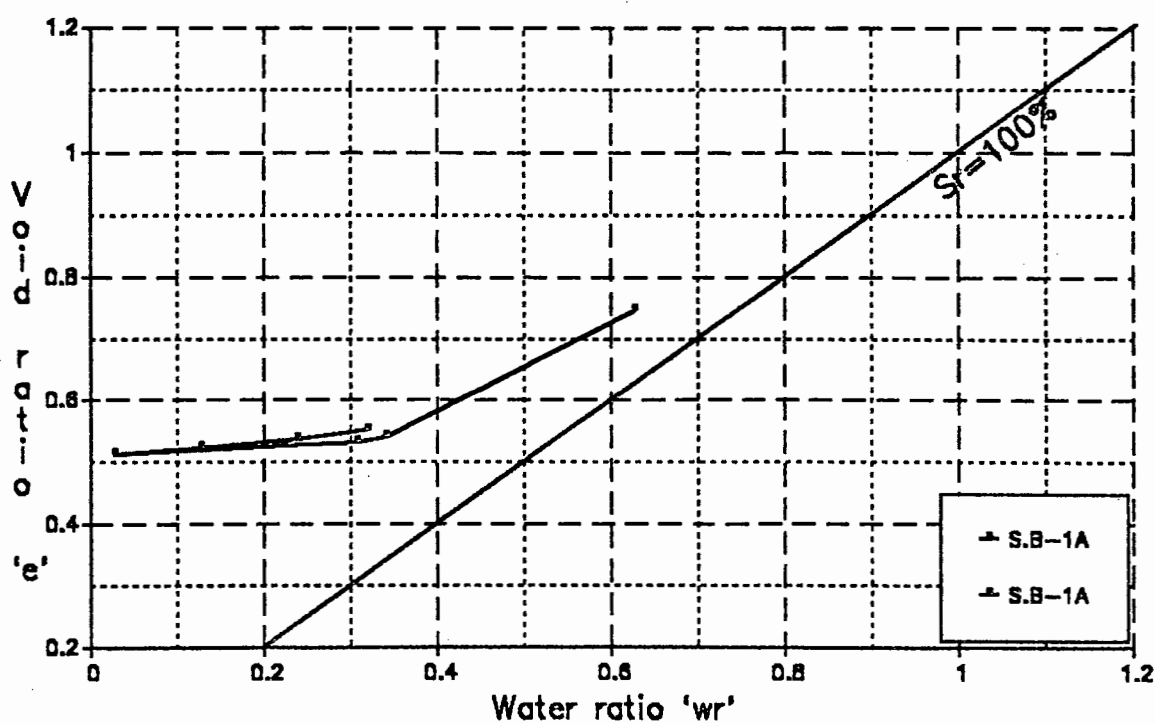


Figure C.17: Site B, Francois Road [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.

Site C - Margaret Mayton Avenue, Durban

Table C.18: Site C, Margaret Mayton Avenue [Remoulded] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.C-1A/II.140	0.613	0.491
	0.509	0.276
	0.502	0.202
	0.491	0.147
	0.488	0.059
	0.498	0.111
	0.511	0.165
	0.531	0.266
	0.568	0.371
	0.585	0.408

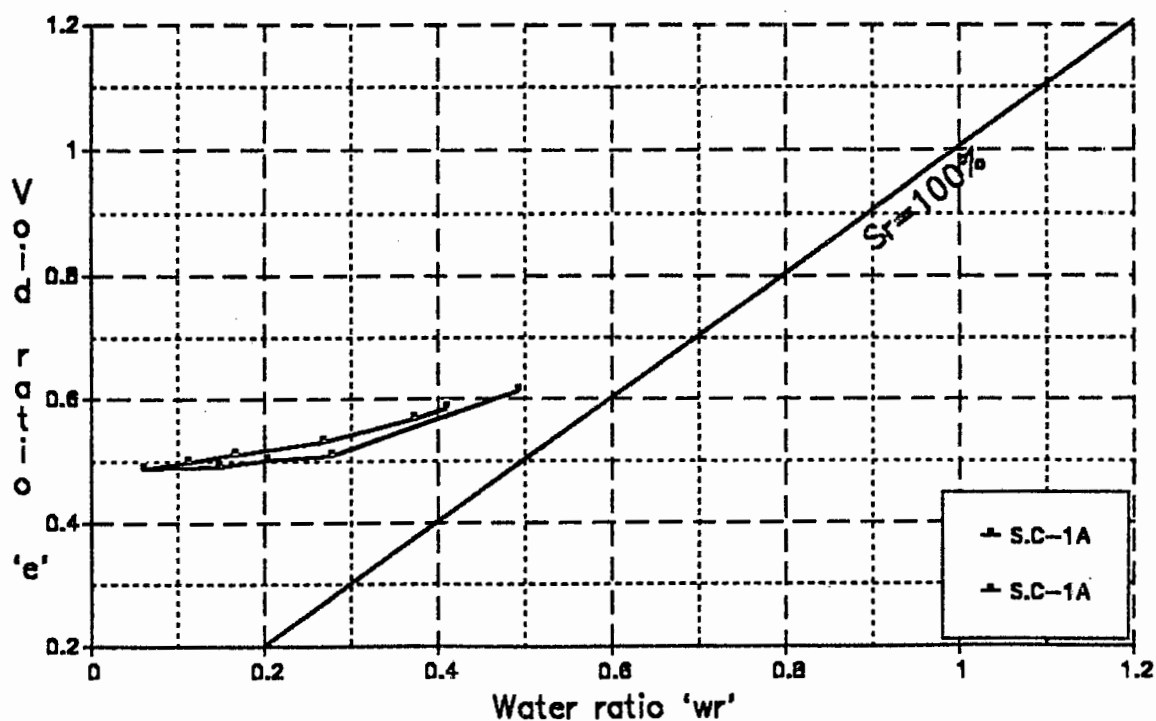


Figure C.18: Margaret Mayton Avenue [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.

Site D - Rose Hill, Durban

Table C.19: Site D, Rose Hill [Remoulded] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
S.D-1A/II.140	0.699	0.627
	0.520	0.368
	0.508	0.283
	0.495	0.234
	0.491	0.044
	0.503	0.163
	0.511	0.254
	0.524	0.309
	0.527	0.329

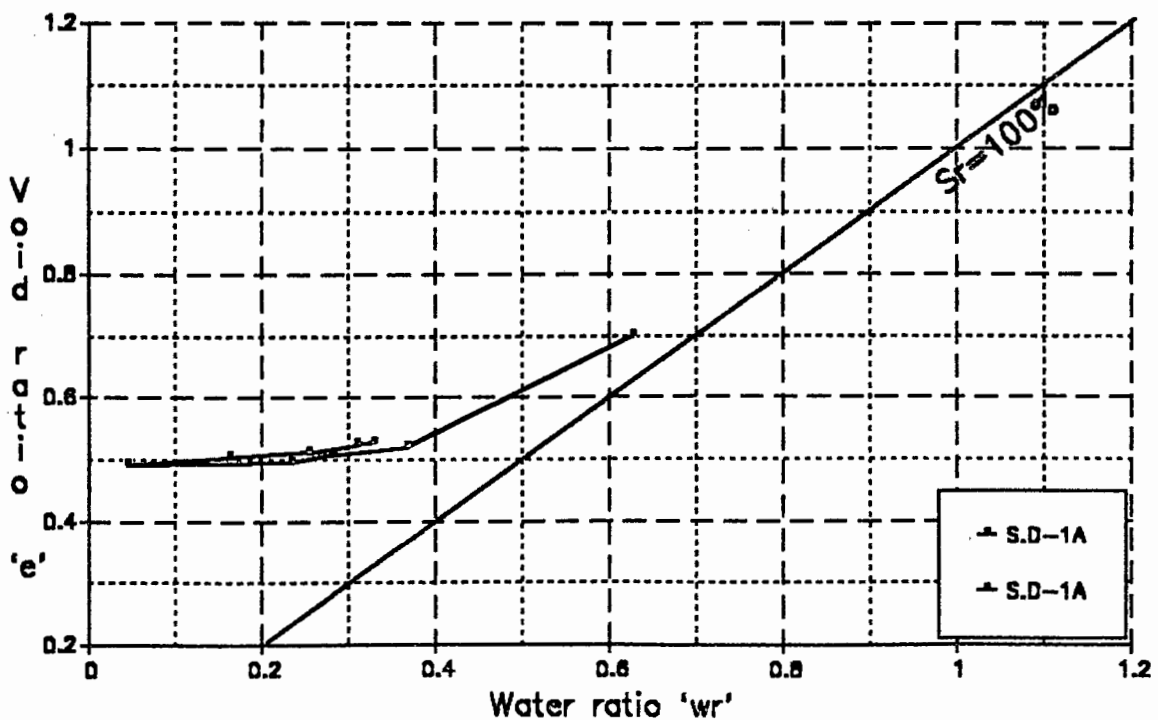


Figure C.19: Site D, Rose Hill [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.

C.4.2 Artificial Soils

Kaolin K.1 - (13% clay size)

Table C.20: Kaolin K.1 - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
K.1-2/II.215	0.700	0.573	K.1-3/II.215	0.644	0.492
	0.529	0.173		0.517	0.175
	0.518	0.028		0.516	0.108
	0.519	0.084		0.521	0.159
	0.531	0.170		0.530	0.213
	0.556	0.252		0.568	0.276
	0.603	0.329		0.599	0.329

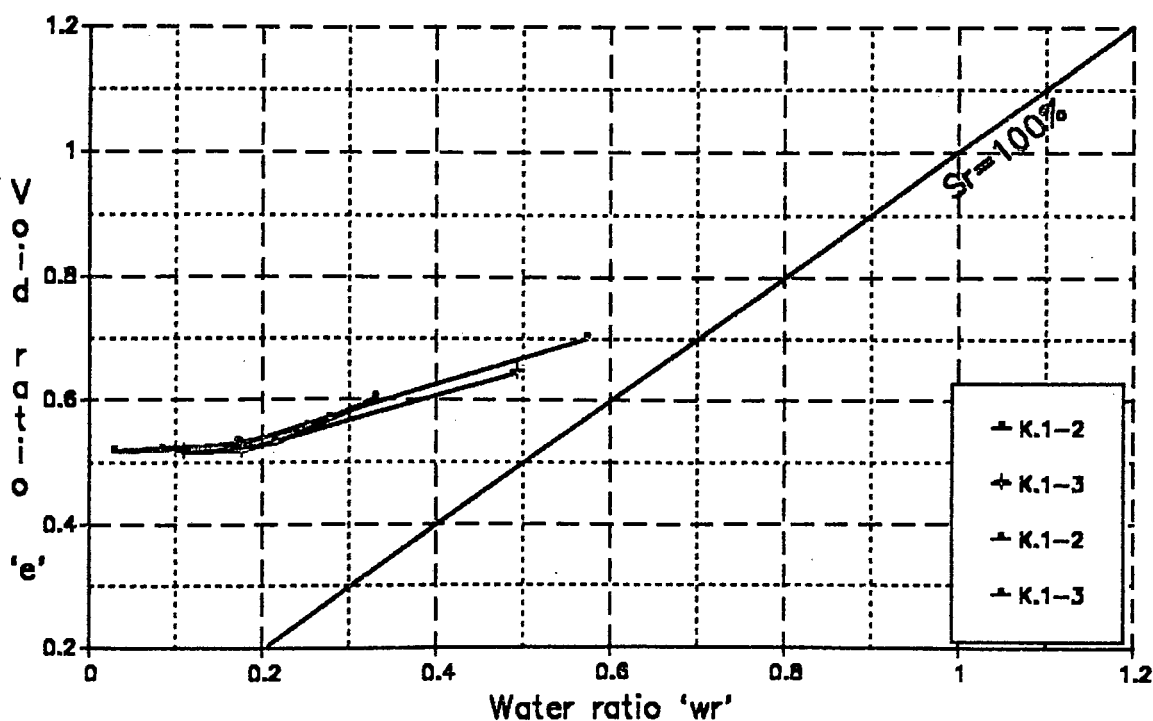


Figure C.20: Kaolin, K.1 - Void Ratio 'e' versus Water Ratio 'wr'.

Kaolin K.2 - (20% Clay Size)*Table C.21: Kaolin, K.2 - Free Shrinkage and Free Swell test results.*

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
K.2-T.1/V.13	0.451	0.397	K.2-2/II.219	0.706	0.607
	0.433	0.346		0.477	0.351
	0.397	0.258		0.463	0.291
	0.390	0.080		0.452	0.215
	0.393	0.157		0.440	0.022
	0.404	0.238		0.454	0.105
	0.427	0.307		0.460	0.268
	0.467	0.318		0.478	0.307
K.2-3/II.219	0.618	0.492			
	0.455	0.266			
	0.446	0.203			
	0.443	0.137			
	0.449	0.201			
	0.453	0.264			
	0.486	0.324			

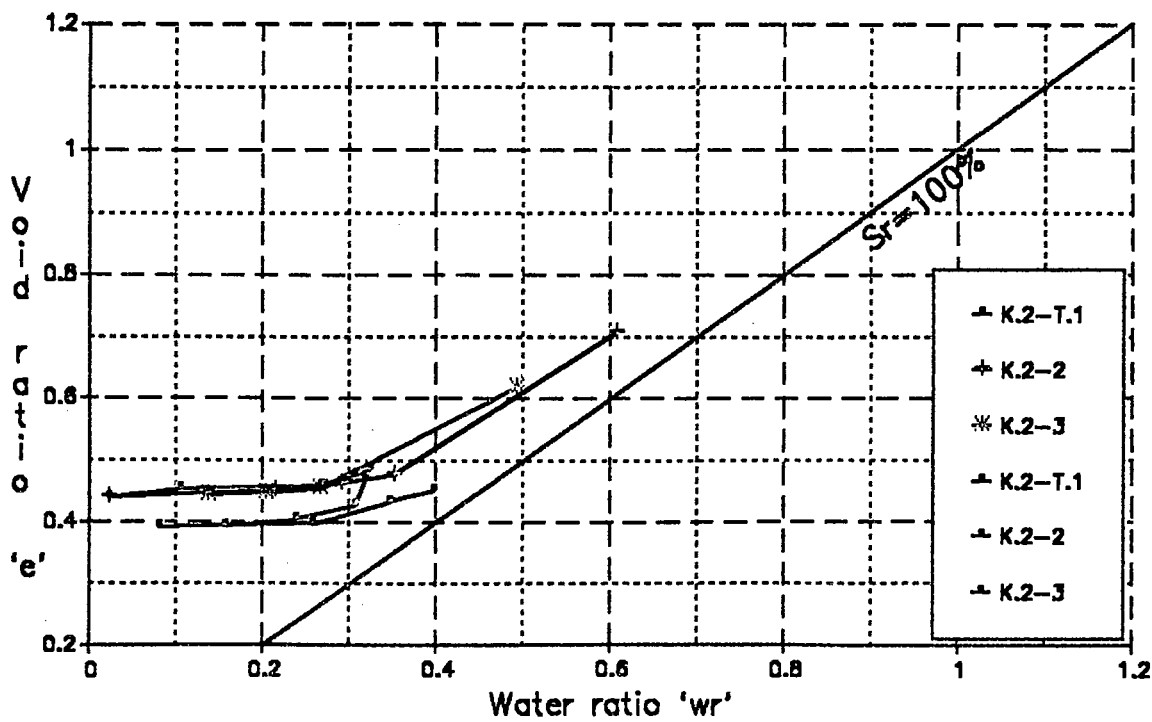


Figure C.21: Kaolin, K.2 - Void Ratio 'e' versus Water Ratio 'wr'.

Kaolin, K.3 - (10% Clay Size)

Table C.22: Kaolin, K.3 - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
K.3-T.1/V.15	0.649	0.280	K.3-2/II.265	0.689	0.616
	0.579	0.247		0.572	0.026
	0.561	0.074		0.566	0.021
	0.553	0.011		0.572	0.121
	0.562	0.119		0.586	0.221
	0.578	0.235		0.604	0.288
	0.595	0.333			
K.3-3/II.265	0.695	0.511			
	0.624	0.011			
	0.622	0.007			
	0.623	0.105			
	0.641	0.206			
	0.648	0.259			

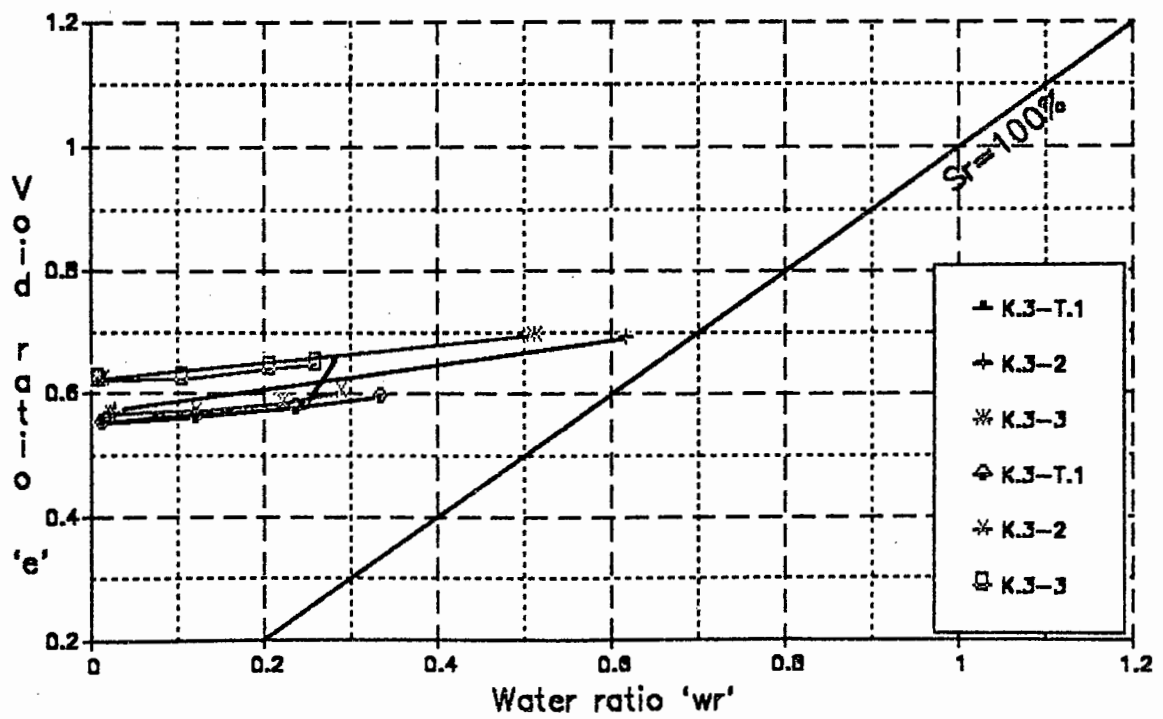


Figure C.22: Kaolin, K.3 - Void Ratio 'e' versus Water Ratio 'wr'.

Bentonite, B.1 - (3.5% Clay Size)

Table C.23: Bentonite, B.1 [Remoulded] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
B.1-2/III.338	0.707	0.565	B.1-3/III.340	0.818	0.742
	0.651	0.443		0.668	0.458
	0.643	0.236		0.646	0.323
	0.628	0.049		0.645	0.020
	0.621	0.023		0.681	0.135
	0.671	0.085		0.682	0.328
	0.707	0.169		0.697	0.463
	0.760	0.312		0.722	0.521
	0.788	0.420		0.794	0.599
	0.799	0.487			
	0.846	0.558			
B.1-5/III.362	0.840	0.750			
	0.749	0.324			
	0.722	0.222			

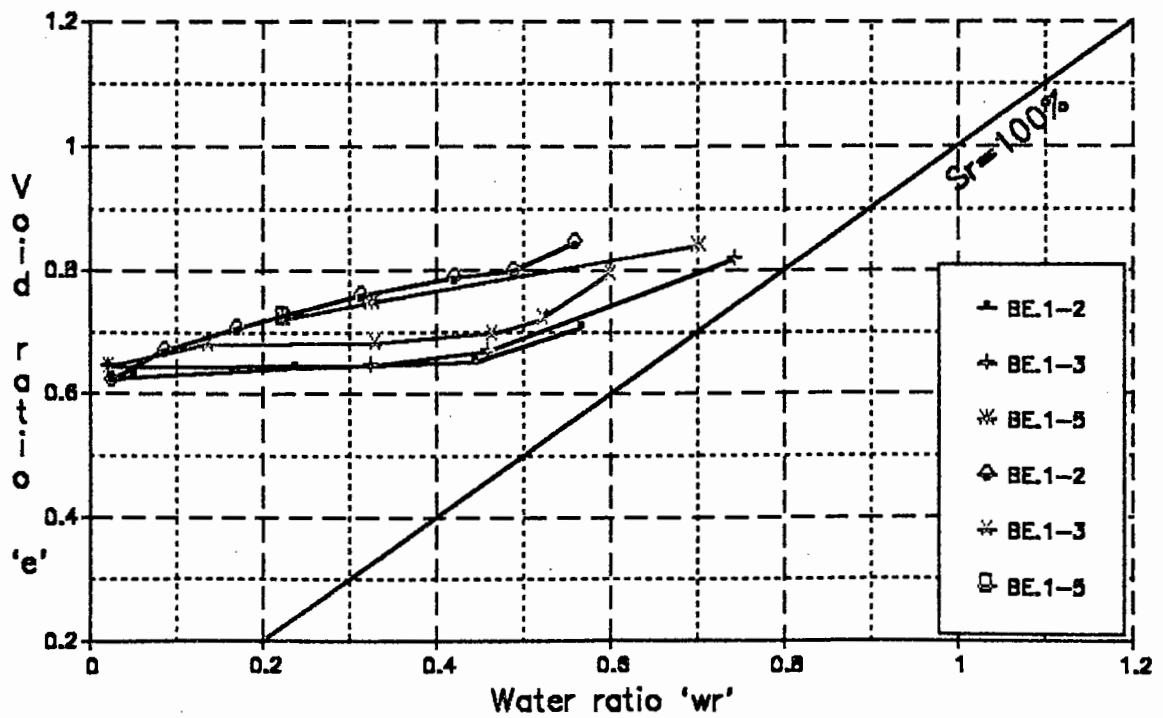


Figure C.23: Bentonite, B.1 [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.

Bentonite, B.2 - (7% Clay Size)*Table C.24: Bentonite, B.2 [Remoulded] - Free Shrinkage and Free Swell test results.*

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
B.2-T.1/V.17	1.033	0.948	B.2-2/III.368	0.787	0.654
	0.946	0.860		0.708	0.524
	0.845	0.701		0.697	0.443
	0.809	0.607		0.684	0.291
	0.795	0.110		0.681	0.122
	0.874	0.252		0.736	0.233
	1.033	0.523		0.805	0.423
	1.174	0.805		0.927	0.577
	1.267	0.932		1.034	0.721
	0.997	0.561		1.184	0.969
	0.849	0.156	B.2-3/III.370	1.761	0.832
	0.804	0.061		1.129	0.488
	0.969	0.336		1.111	0.246
	1.162	0.612		1.149	0.087
	1.293	0.768		1.125	0.230
				1.115	0.488
				1.114	0.625

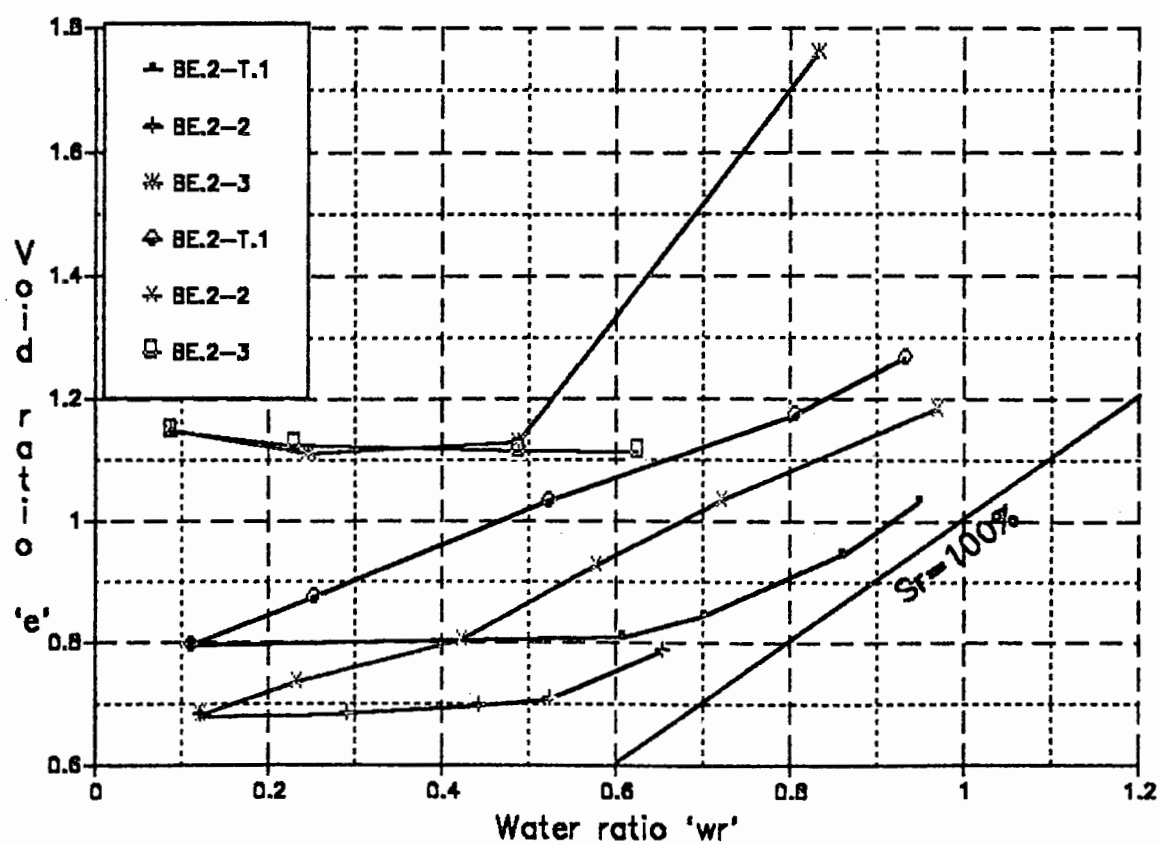


Figure C.24: Bentonite, B.2 [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.

Bentonite, B.3 - (11.5% Clay Size)

Table C.25: Bentonite, B.3 [Remoulded] - Free Shrinkage and Free Swell test results.

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
B.3-2/IV.432L	0.934	0.902	B.3-3/IV.432	1.445	0.845
	0.841	0.788		1.064	0.547
	0.831	0.617		1.040	0.376
	0.813	0.486		1.029	0.146
	0.804	0.346		1.035	0.349
	0.907	0.559		1.057	0.541
	1.042	0.789		1.034	0.764
	1.275	1.085			
	1.456	1.354			
	1.747	1.689			

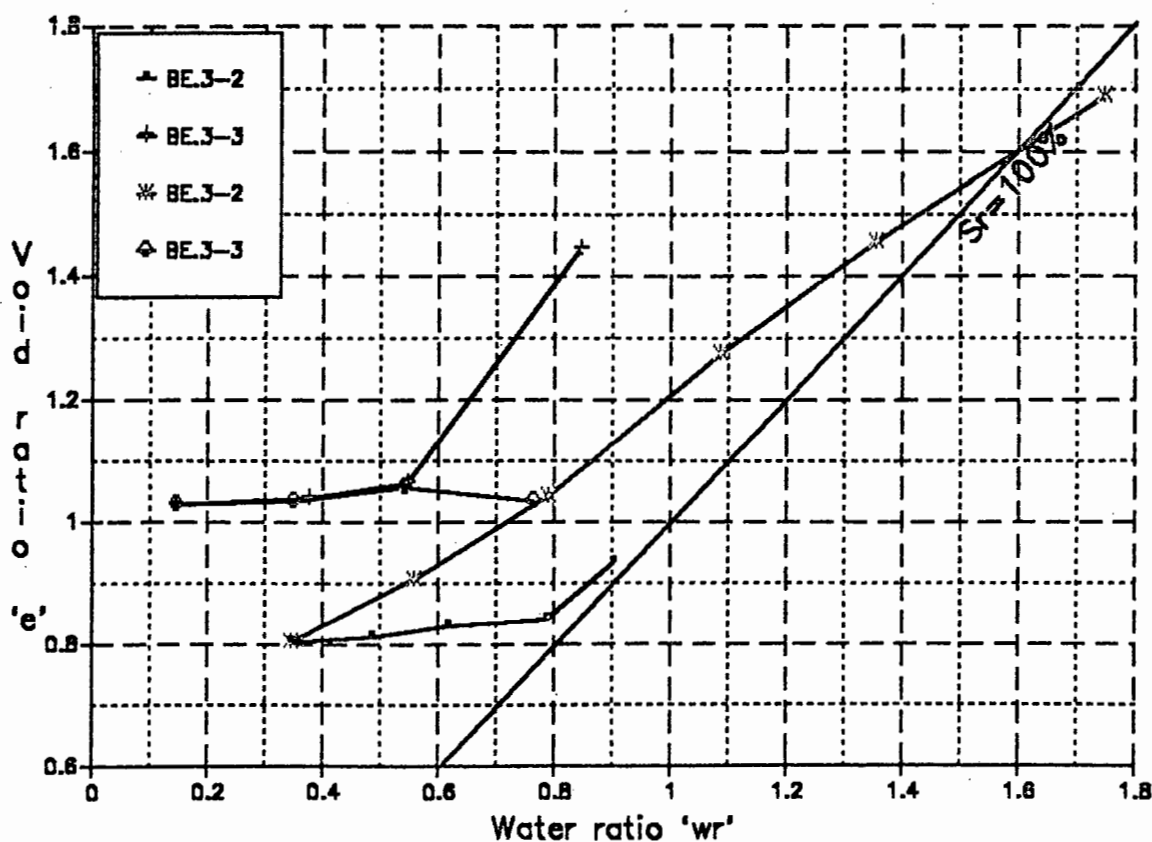


Figure C.25: Bentonite, B.3 [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.

Bentonite, B.4 - (15.5% Clay Size)*Table C.26: Bentonite B.4 [Remoulded] - Free Shrinkage and Free Swell test results.*

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
B.4-T.1/V.19	1.671	1.575	B.4-2/III.398	0.988	0.881
	1.383	1.341		0.908	0.833
	1.196	1.146		0.803	0.598
	0.998	0.804		0.772	0.433
	0.909	0.348		0.728	0.175
	0.873	0.171		0.819	0.282
	0.993	0.321		0.899	0.429
	1.204	0.646		1.031	0.631
	1.537	1.026		1.216	0.854
	1.729	1.283		1.412	1.113
	1.985	1.657	B.4-3/III.400	1.703	1.447
	1.551	1.211		1.977	1.747
	1.273	0.902		2.560	1.307
	1.107	0.617		1.300	0.868
	0.935	0.314		1.155	0.587
	0.901	0.154		1.101	0.347
	0.886	0.122		1.171	0.447
	1.039	0.401		1.199	0.590
	1.256	0.662		1.277	0.838
	1.476	0.948		1.350	0.975
	1.617	1.174			
	1.874	1.450			
	2.026	1.648			
	2.253	1.889			

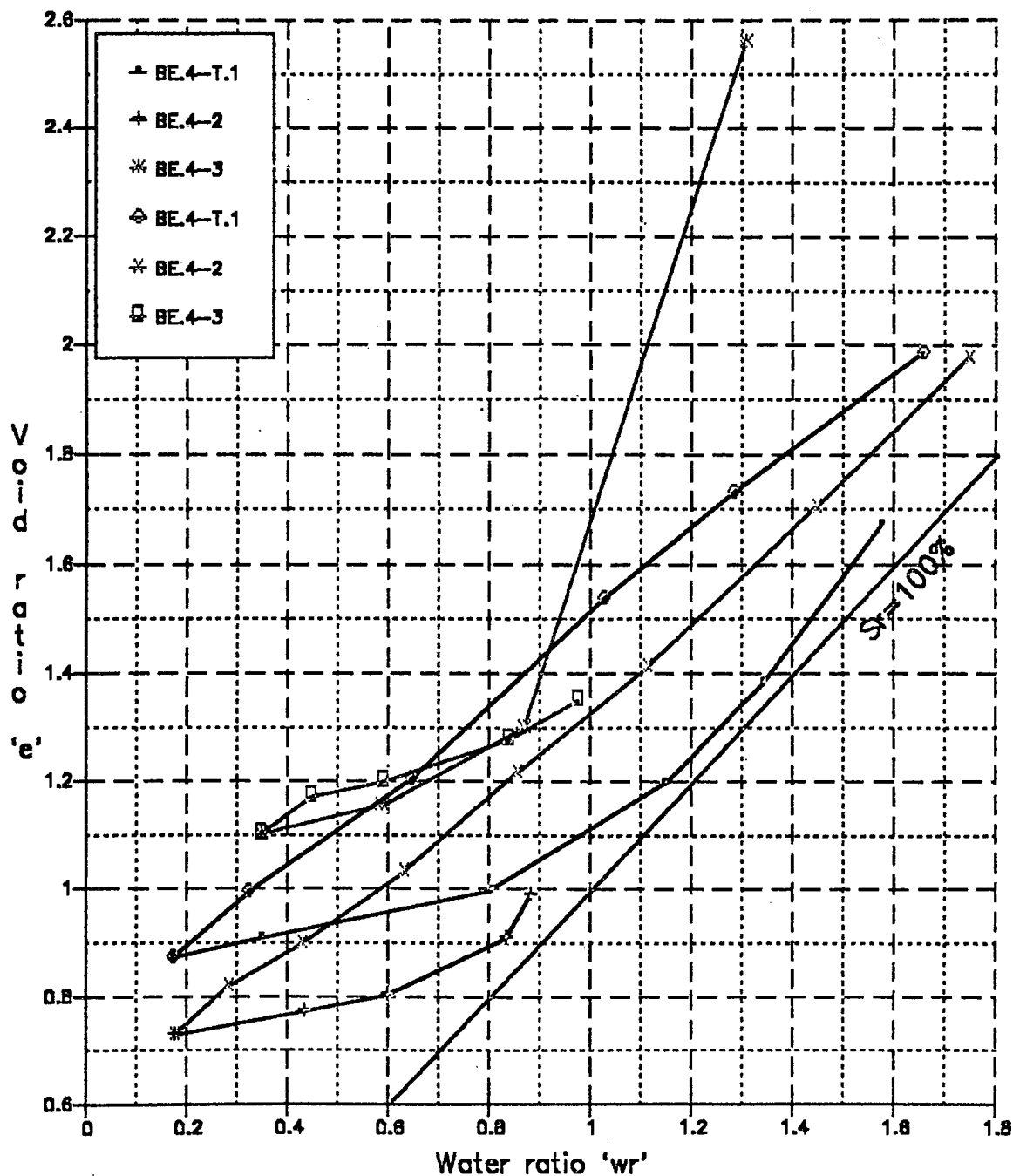


Figure C.26: Bentonite, B.4 [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.

Bentonite B.5, (35% Clay Size)*Table C.27: Bentonite, B.5 [Remoulded] - Free Shrinkage and Free Swell test results.*

Sample number/ref.	Void ratio 'e'	Water ratio 'wr'	Sample number/ref.	Void ratio 'e'	Water ratio 'wr'
B.5-T.1/V.21	2.654	2.530	B.5-2/IV.446	1.185	1.053
	2.258	2.243		0.960	0.882
	1.547	1.541		0.790	0.631
	1.192	1.162		0.692	0.468
	0.801	0.700		0.637	0.330
	0.603	0.363		0.604	0.237
	0.949	0.696		0.595	0.215
	1.364	1.067		0.675	0.322
	1.765	1.466		0.863	0.568
	2.172	1.924		1.165	0.897
	2.524	2.279	B.5-3/IV.446	1.802	1.562
	2.933	2.678		2.517	2.323
	2.334	2.083		2.828	2.648
	1.498	1.282		3.223	3.043
	1.228	1.008			
	0.733	0.395		1.799	1.131
	0.638	0.194		1.442	0.942
	0.844	0.437		1.168	0.636
	1.209	0.891		1.032	0.443
	1.517	1.193		0.988	0.362
	1.955	1.631		0.976	0.339
	2.553	2.200		1.087	0.503
	3.003	2.646		1.196	0.780
	3.356	2.995		1.300	0.975
				1.593	1.320
				2.121	1.912

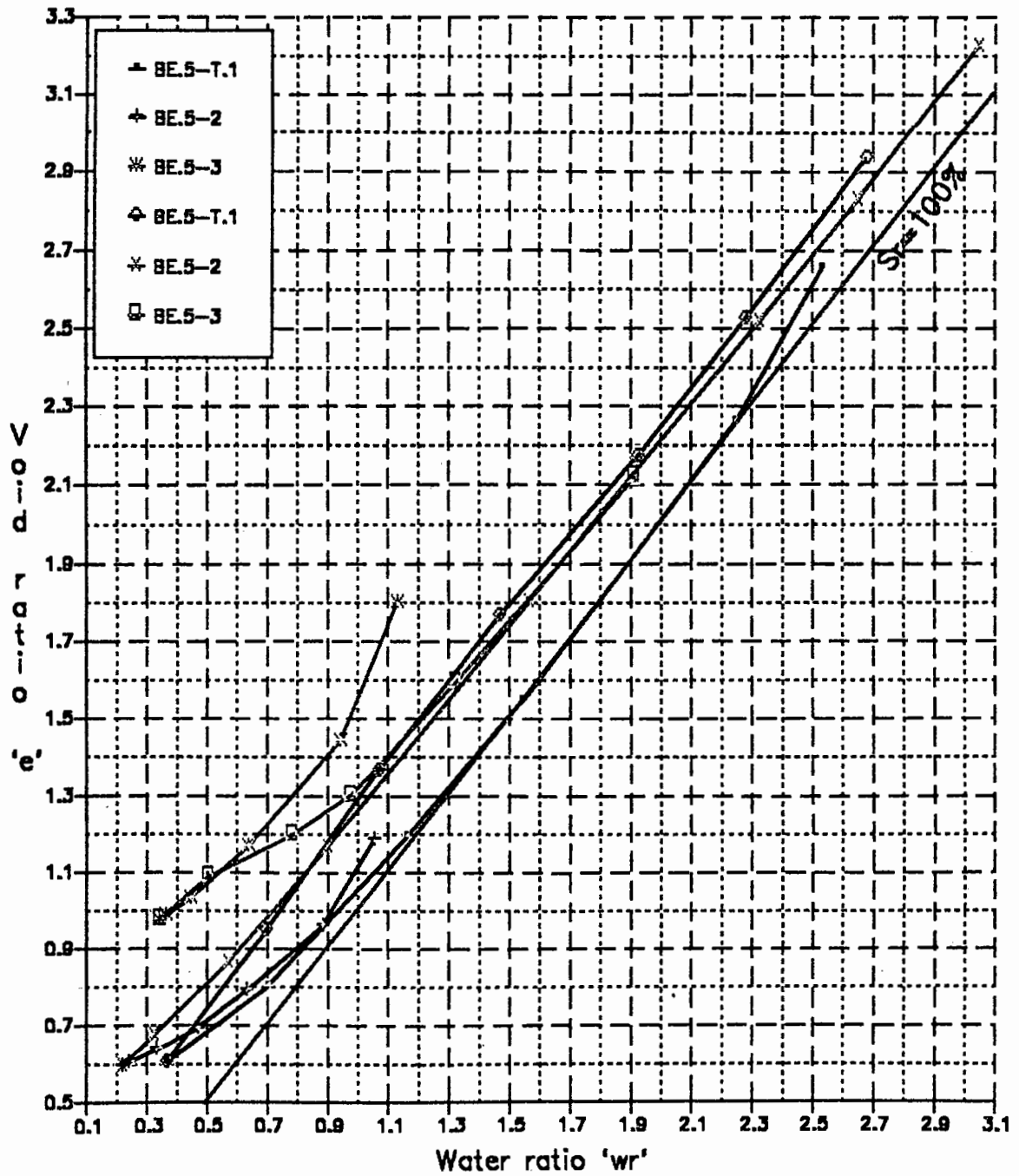


Figure C.27: Bentonite, B.5 [Remoulded] - Void Ratio 'e' versus Water Ratio 'wr'.

FREE SHRINKAGE AND FREE SWELL.

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SOIL SAMPLE: _____

TEST REFERENCE NO. _____

Method of preparation:

SOIL SAMPLE AT EACH DRYING / SWELLING STAGE: Recorded masses of soil and mercury;
Calculated void ratio 'e', and water content 'Wc'.

Time/date.	Mass of moist/dry soil plus Tare 1. (g)	Mass of mercury 'Hg' plus Tare 2. (g)	Void ratio 'e'.	Water content 'Wc'. (%)	Remarks.

Notes: (i) Shrinkage dish (Tare 1): Mass/capacity = ____ g./ ____ cm³.

(ii) Glass beaker (Tare 2) = ____ g.

(iii) Void ratio, 'e' =
$$\frac{\text{Mass 'Hg' - Mass of oven-dry soil}}{\text{Mass of oven-dry soil}}$$

(iv) Water content, 'Wc' =
$$\frac{(\text{Mass of moist/dry soil}) - (\text{Mass of oven-dry soil})}{\text{Mass of oven-dry soil}}$$

(v) Relative specific densities: Mercury used, $G_{S'Hg}$ = ____;
Soil particles, G_S = ____.

APPENDIX D

CONSOLIDOMETER AND TRIAXIAL - TEST PROCEDURES AND RESULTS

Appendix D presents the detailed Consolidometer and Triaxial test procedures for Chapter Five. These test procedures also provide the main reference, or basis, for Appendices E to H. This Appendix also includes all the test results used for Chapter Five. The test method and results are summarized in Chapter Five, 'Fitting stress scales to observed data'. Additional details, including selected photographic plates of the equipment used, are included with some of the chapters of the thesis¹.

D.1 CONSOLIDOMETER: ONE-DIMENSIONAL CONSOLIDATION TEST PROCEDURE

Introduction:-

A soil sample is either carefully moulded, or trimmed, to fit into a standard consolidometer steel ring of 70 mm diameter and 19 mm height - refer to Appendix A². After the equipment is assembled, the soil sample is loaded in stages, and settlement as a function of time is recorded. Consolidation of the soil can be defined as a void ratio reduction which takes place as a function of time. The rate and magnitude of consolidation (when it is restrained laterally and loaded and drained axially) are measured for the tested sample in the laboratory, and the results applied to engineering problems using basic theory of consolidation. Similarly, the soil sample is unloaded in stages, and soil recovery as a function of time is recorded. At the end of the consolidation test the sample is placed in the oven, and its oven dried mass recorded.

Apparatus required:-

(i) A consolidometer loading device, including the following necessary standard fittings - a standard consolidometer usually comes equipped with all the necessary fittings for this type of test: The change in soil sample thickness is measured by means of a dial micrometer gauge which is fitted to the front of the Consolidometer and connected to the top loading plate; A loading platform suitable for applying vertical loads, including all the necessary weights, and an additional frame to facilitate the load/unloading of these weights.

¹ - refer to Chapters Four, Five and Eight of Volume One.
² - section A.3 "Preparation of Soil Samples for Testing".

Note: Knowing the weights placed on the loading platform, the lever arm ratio of the consolidometer (11 to 1 for the consolidometers used), and the area of the soil sample (the internal diameter of the steel ring - refer to step (ii)), the pressures being applied are thus known.

(ii) A stainless steel ring 70 mm internal diameter, and 19 mm height.

(iii) A fixed (to the base) or floating consolidation pot or container - it holds the soil sample (within the stainless steel ring) with the filter papers and porous plates on either end of the sample (refer to (iv) and (v)), all the parts held in place using a collar which is securely held against the container by means of nuts (tightened against the bolts built into the container). This set up provides the means of wetting the soil sample and applying vertical loads to it.

(iv) Two filter papers (Whatmans No.1), the top one to be of the same diameter as the top porous plate (refer to (v)), and the bottom one about 20 mm larger than the steel ring.

Note: A plastic sheet (of diameter slightly larger than the bottom filter paper) was used for the special consolidometer tests described in Appendices E, F and G. Its purpose was to assist with the adding of water to the bottom of the soil sample, and to minimize water losses and thus improve the accuracy of the controlled increments of water content.

(v) Two porous stones or plates - can be made of silicon carbide, aluminium oxide (or metal), or alternatively of perspex. The top loading plate should be 0.2mm to 0.5mm less than the initial diameter of the steel ring, and should have a built-in (machined) 'seating' for applying the load.

(vi) Plastic cover with elastic bands to prevent moisture loss from the soil sample.

(vii) Hypodermic syringe calibrated to 0.1 ml, to increase the water content (of soil sample) by small amounts.

(viii) Stop clock (or wrist watch with a seconds' pointer).

(ix) Balance capable of 1000 ± 0.1 g.

(x) A desiccator complete with silica gel granules.

(xi) Suitable dishes for water content determination.

(xii) A drying oven, thermostatically controlled, and capable of maintaining a temperature of 105 ± 5 °C.

Procedure:-

A) Calibration of equipment: Assemble all the consolidometer parts as for an actual test (refer to step 'D' below) - a metal spacer is used (copper disc or other metal, with a smaller diameter than the internal diameter of the stainless steel ring, in order to avoid contact) in place of the soil sample; Ensure that all the parts are properly positioned and that the dial gauges are set (refer to steps D and E below) - load and unload the consolidometer as in the actual test (step F onwards); For each (load and unload) stage, measure the vertical deformation that takes place due to 'bedding in' of the consolidometer parts; Tabulate the corrections to be applied to the amount of total vertical movement (that is, after the soil sample consolidates) for each vertical pressure increase or decrease.

Note: Refer to Table D.01 and Figure D.01¹ for the corrections to be applied to each reading.

B) The internal diameter and height of the steel ring should be checked before each test or at regular intervals. Air dry masses should be recorded for the following items: Stainless steel ring; Top and bottom loading plates; Top and bottom filter papers. A record should also be kept for the masses of the other items (container, collar plus screws, plastic sheet and elastic bands).

Note: For saturated samples the porous plates should be dampened before the test; for other samples, the internal surfaces of the consolidometer pot (not in direct contact with the sample) should be moistened - wetting of apparatus in direct contact with soil should be avoided when dealing with expansive soils.

C) The soil sample is removed from the desiccator, where it has air dried to the required initial water content. With saturated remoulded samples the soil is moulded directly into the ring, and for natural undisturbed, compacted or remoulded samples (allowed to air dry first), the soil is trimmed to size until the ring just slides over it. The top and bottom surfaces of the sample are made level - full details are included in the preparation of soil samples for testing².

The mass of the soil sample is recorded - it is obtained by subtracting the tare from the weight of sample plus tare.

Note: For the purpose of chapter five of this thesis, the majority of the soil samples were at a saturated condition.

D) The parts (that make up the consolidometer container) are assembled in the following order:

(i) The bottom filter paper and the ring (containing the soil sample) are positioned on the bottom porous plate - they are centered inside the consolidometer pot;

¹ - see end of this test procedure.

² - refer to section A.3 of Appendix A.

- (ii) The top filter paper and the loading plate, are then placed on top of the sample - care should be taken when positioning the top filter paper in order to avoid it getting stuck between the top plate and the steel ring during the loading stages;
- (iii) This is followed by the guide collar - the nuts are used to tighten the collar firmly against the built-in bolts of the consolidometer pot;
- (iv) Enclose the assembled parts with a loose fitting plastic cover - rubber bands are used to keep it in place, and thus prevent sudden movement of air around the sample which could cause an increase in the evaporation rate.

E) Position the consolidometer container in the loading device, and adjust the following:

- (i) The counterweight alongside the lever arm until it balances - there should be a slight but firm pressure against the sample, which should not be compressed;
- (ii) The micrometer dial gauge (measures vertical movement) for the initial or zero reading - it should preferably be set to near the beginning of its travel because there will be a considerable 'downwards' movement due to settlement, caused by loading the sample, to be followed by 'an' upward movement when the sample recovers during unloading.

F) Give a final check over the equipment (to ensure that it is all in order), and record the initial or zero reading of the deflection gauge. Place the necessary weights onto the loading platform in order to apply (to the soil sample) the following sequence of pressure increments - 5 kpa, 10 kpa, 25 kpa, 50 kpa, 100 kpa, 200 kpa, 400 kpa, 800 kpa, and 1600 kpa. The use of the custom made loading frame, used for swell pressure and expansion or collapse consolidometer tests, greatly facilitates this operation¹. Record the readings on the vertical deflection dial gauge (to enable the calculation of thickness or changes in thickness of the sample to be - refer to the next section), before each pressure increment is applied and at the following time intervals after each of these increments starts acting on the soil - 0.25 minutes, 0.5 min, 1 min, 2.25 min, 4 min, 9 min, 16 min, 30 min, 60 min, 120 min, and so on. Readings should continue at least until the slope of the characteristic linear secondary settlement becomes apparent.

¹ - refer to Appendices E, F and G.

Note: For each pressure increment, the actual deflection movement (settlement in this case) should be plotted against log time (or square root of time) to determine when primary consolidation has been completed - this happens when the secondary portion of the settlement versus log time plot becomes linear (for soils which have slow primary consolidation, for example clays, pressures should act for at least 24 hours or longer); With the remoulded saturated samples in particular, the water can be observed being squeezed out of the sample - by means of the syringe the amount of water squeezed out (after each loading) can be measured approximately, and a more accurate determination of the water content (in the soil sample) can be made.

G) The recovery or unloading characteristics of the soil are recorded next. The external vertical pressure being applied to the sample is decreased in stages from 1600 kpa, to 1 kpa, and finally to 0 kpa. The following is the normal sequence of successive pressure decreases - 1600 kpa, 800 kpa, 200 kpa, 50 kpa, 10 kpa, and 1 kpa. For each pressure decrease, record the vertical deflection readings (to obtain the increase in sample thickness) at the same time intervals after each decrease as for the previous step (that is, 0.25 minutes, 0.5 min, 1.0 min, 2.25 min, etc). The readings should continue until no more expansion is observed.

H) At the completion of the unloading sequence, a final vertical deflection reading is taken. The consolidation container is removed from the consolidometer, and its parts are carefully taken out. The following masses are recorded - soil sample plus steel ring, top loading plate (or the porous plates, if they were used), and filter papers. The soil sample is carefully extracted from the steel ring and placed inside the oven, to dry at the temperature of 105 ± 5 °C for a few hours (preferably overnight). After that, the sample is removed from the oven, and allowed to cool down to room temperature, and its oven dry mass recorded.

Notes:

- 1) For the other consolidometer tests described in Appendices E, F and G, the masses of the following parts are recorded - collar and nuts, plastic cover with rubber bands, and container.
- 2) If necessary, the bedding in of the equipment is again checked by repeating step A.

Calculations:-

1) The following information should be recorded for each test:

- a) Before starting the loading stage - the initial reading for vertical deflection¹;
- b) For each loading stage - total load placed on the loading platform, time and vertical deflection readings¹;
- c) Each unloading stage - as for the loading stage;
- d) The moisture content at the start and end of the test,

$$\text{Mass of wet soil sample} - \text{Mass of oven-dry soil sample} \\ = \frac{\text{Mass of oven-dry soil sample}}{\text{Mass of oven-dry soil sample}}$$

Note: Intermediate water contents can be estimated as mentioned in the note of step F - for more details refer to the consolidometer tests described in Appendices E, F and G. e) The diameter, height and mass of the soil sample (before and after the test) were obtained in steps C to H.

2) To determine the void ratio at the initial, final and intermediate stages:

a) The initial void ratio 'e' of the soil sample:

$$'e' = \frac{\text{Volume of voids } 'V_V'}{\text{Volume of solids } 'V_S'} = \frac{\text{Total volume } 'V_T' - V_S}{V_S}$$

Where:

$$V_T = \frac{\pi \times D^2}{4} \times [\text{original height of soil sample } 'ht'];$$

$$\text{and, } V_S = \frac{\text{Mass of oven-dry soil } 'M_D'}{\text{Specific Gravity of soil particles } 'G_S'}$$

Notes:

- (i) For 'G_S' refer to the test procedure in Appendix A.
- (ii) D = diameter of soil sample (inside the steel ring).

b) Intermediate and final void ratios are obtained by using the corrected vertical deflection 'hi'², and then calculating the 'e' value as follows:

$$e = \frac{\pi \times D^2/4 (ht - hi) - V_S}{V_S}$$

¹ - refer to step F in Procedure.

² - refer to step A and Figure D.01.

3) The information obtained for each test will enable the following graphs to be plotted:

a) Vertical deformation (settlement or expansion) versus time (square root or log) for each applied pressure increase or decrease - the coefficient of consolidation ' c_v ' can be determined by measuring the time rate of consolidation (the initial and secondary compressions must be separated from primary consolidation by one of the following curve fitting methods: (i) Casagrande "Logarithm of Time"; (ii) Taylor "Square Root of Time"; or (iii) Naylor-Doran "Successive Approximations"): and entering that value, together with the layer of thickness and a time factor, into the equation for the ' c_v '¹,

$$c_v = \frac{T_v \times H^2}{t}$$

Where:

T_v = time factor (dimensionless quality) - Table D.02 includes values for various values of percentage saturation.
 H = average thickness of compressible layer (for the load increment) or distance to a drainage surface
 t = time (minutes) for a percentage of the consolidation process to take place.

b) Void ratio versus the effective pressure applied (log scale), from which the following can be determined:

(i) Slope of the void ratio vs. log effective pressure - that is, the coefficient of compressibility ' a_v '

$$a_v = \frac{\text{Change in void ratio } \delta e}{\text{Change in effective pressure } \delta p'}$$

(ii) The coefficient of permeability ' k '

$$k = \frac{c_v \times a_v \times j_w}{1 + e}$$

Where:

j_w = unit mass of water (g/cm^3); and,
 e = void ratio at middle of stage (that is, ' e_{av} ').

¹ - based on Terzaghi's Consolidation Theory.

Calibration test:-

The bedding in that takes place due to the equipment adjusting itself to the strains caused by the particular loading/unloading sequence used.

Table D.01: One-dimensional consolidation test procedure - Calibration of equipment.

Load ->		Vertical strain		Correction to be applied	
(lbs)	Kpa	Reading (0.0001")	Difference (0.0001")	Accumulative difference (0.0001")	-> cm
	1	1160.0	0	0	0
	4.1	1128.8	-31.2	-31.2	-0.0079
	8.3	1087.2	-41.6	-72.8	-0.0185
5	53.6	1029.0	-58.2	-131.0	-0.0333
10	107.3	986.2	-42.8	-173.8	-0.0441
20	214.6	968.5	-17.7	-191.5	-0.0486
40	429.2	934.1	-34.4	-225.9	-0.0574
80	858.4	888.7	-45.4	-271.3	-0.0689
160	1716.7	841.3	-47.4	-318.7	-0.0809
220	2360.5	822.6	-18.7	-337.4	-0.0857
40	429.2	864.4	41.8	-295.6	-0.0751
5	53.6	895.5	31.1	-264.5	-0.0672
	8.3	909.8	14.3	-250.2	-0.0636
	1	927.4	17.6	-232.6	-0.0591

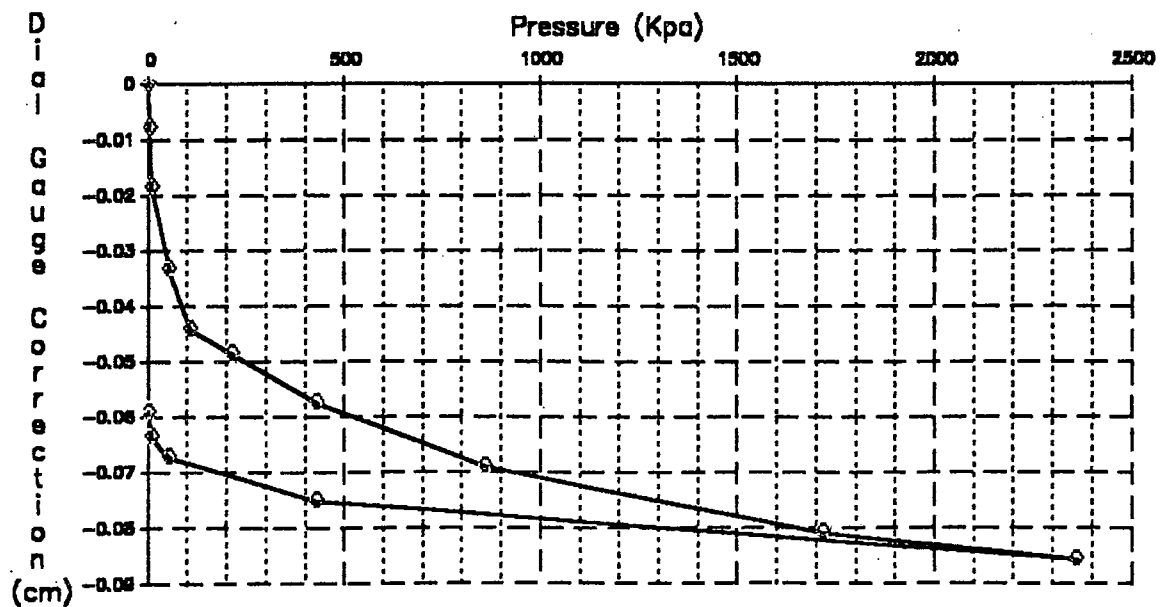


Figure D.01: One-dimensional consolidometer test - Calibration of equipment.

Percentage of consolidation:-

Table D.02 includes four cases of initial excess pore pressure distribution with double drainage:
Case 1 - constant or linear variation; Case 2 - half sine curve; Case 3 - full sine curve; and, Case 4 - triangular increase or decrease.

Table D.02: Values of time factor 'Tv' for various values of degree of consolidation 'U'.

U % (% consolidation)	Tv (time factor)			
	Case 1	Case 2	Case 3	Case 4
0	0	0	0	0
5	0.0017	0.0021	0.0208	0.0247
10	0.0077	0.0114	0.0427	0.0500
15	0.0177	0.0238	0.0659	0.0750
20	0.0314	0.0403	0.0904	0.102
25	0.0491	0.0608	0.117	0.128
30	0.0707	0.0845	0.145	0.157
35	0.0962	0.112	0.175	0.188
40	0.126	0.143	0.207	0.221
45	0.159	0.177	0.242	0.257
50	0.196	0.215	0.281	0.294
55	0.238	0.257	0.324	0.336
60	0.286	0.304	0.371	0.384
65	0.342	0.358	0.425	0.438
70	0.403	0.421	0.488	0.501
75	0.477	0.494	0.562	0.575
80	0.567	0.586	0.652	0.665
85	0.684	0.700	0.769	0.782
90	0.848	0.862	0.933	0.946
95	1.129	1.163	1.214	1.227
100	∞	∞	∞	∞

D.2 TRIAXIAL:
ISOTROPIC CONSOLIDATION TEST PROCEDURE

Introduction:-

The all round (or three dimensional) drained consolidation test is one in which drainage is permitted throughout the test so that isotropic consolidation of the soil sample occurs under an all round stress. The strength envelope in terms of effective stress is obtained directly from the stress circles at failure. The drained test provides information on the volume changes which accompany the application of the all around pressure and on the stress-volumetric strain characteristics of the soil. Deformation and volume-change characteristics in drained tests are largely controlled by the sequence and sign of the stress changes.

Drained tests are carried out on soil samples of all types - either undisturbed, remoulded, compacted or redeposited. The samples may be either fully or partly saturated. It is very time consuming (it can take several days) but probably is the most accurate, specially for soils in which the degree of saturation is less than 100 percent.

1. Apparatus Required:-

- (i) Triaxial cell for the 38 mm ($1\frac{1}{2}$ in) diameter sample - principle features: Base and porous disc; upper part (including ram); perspex top loading cap and porous disc; filter papers; side drains; rubber membranes; O-rings.
- (ii) The pedestal fitted to the base and the perspex loading cap both have grooves to provide a snug fitting to the "O" rings that fit around them to avoid leaks. The base of the cell has also been widened to provide the seating for a larger "O" ring and thus avoid any leaks.
- (iii) Apparatus for controlling the cell pressure - the self compensating mercury control: The pressure of water in the triaxial cell results from the difference in level between the mercury surfaces in two sets of small cylinders. Each set is connected by a thin flexible pressure tube, which form in effect the two limbs of a manometer. The two sets are connected in series in order to increase twofold the available cell pressure.
- (iv) Apparatus for measuring volume change - three principal methods were used:
 - (1) Volume Change Indicator - twin burette type with change over valve using coloured paraffin: Measures the volume of fluid entering the cell to compensate for the total change in the volume of the sample.
 - (2) 10 cc Burette: Measures the volume of fluid expelled from the pore spaces in the soil.

(3) Vernier telescope on a graduated sliding scale:

Direct measurement of change in length of sample by keeping the vernier sights on the metal ball (top cap) on the sample and reading off directly from the graduated sliding scale.

Note: Under an equal all around pressure the three principal strains are equal if the soil is isotropic, and volume changes can therefore be obtained directly (as a check) from the measurement of the axial strain alone.

2. Getting organized:-

What to do before starting the test:

(i) If necessary remove and clean the mercury; By means of an aspirator attached to a water faucet apply vacuum to the sytem in order to clean it; If the whole system is really dirty, slowly suck detergent through the apparatus letting it bubble through the mercury, and finally flush it all with clean water.

(ii) Setting up the de-airing system shown in Figure D.02.

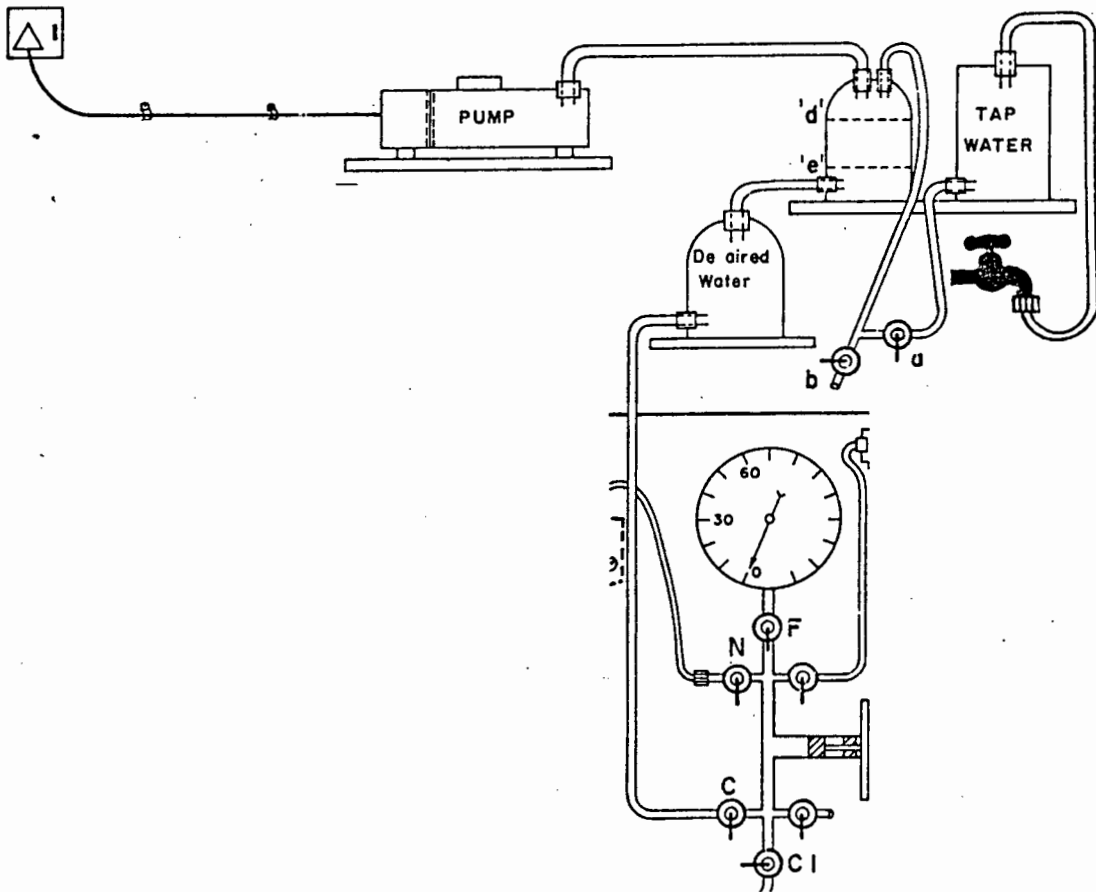


Figure D.02: Triaxial test - the de-airing system installed.

Operational procedure for setting up the de-airing system¹:

- (1) Keep the big plastic can topped up with tap water.
- (2) To obtain fresh de-aired water: Close valves *a*, *b* and *c*; switch on pump until the water is de-aired - no more bubbles are visible coming out of solution in glass bottle (A).
- (3) To use de-aired water at the board: Open valves *b* and *c* (keep valve *a* closed) let gravity feed the board but do not allow the level in the bottle (A) get below level 'e'.
- (4) To refill glass bottle (A): Close valves *c* and *b*; Open valve *a*; switch on the pump until water reaches level 'd'; Close valve *a* and start de-airing the water - that is, step number (2) above.

(iii) Volume Change Indicator - the twin burette type shown in Figure D.03 below.

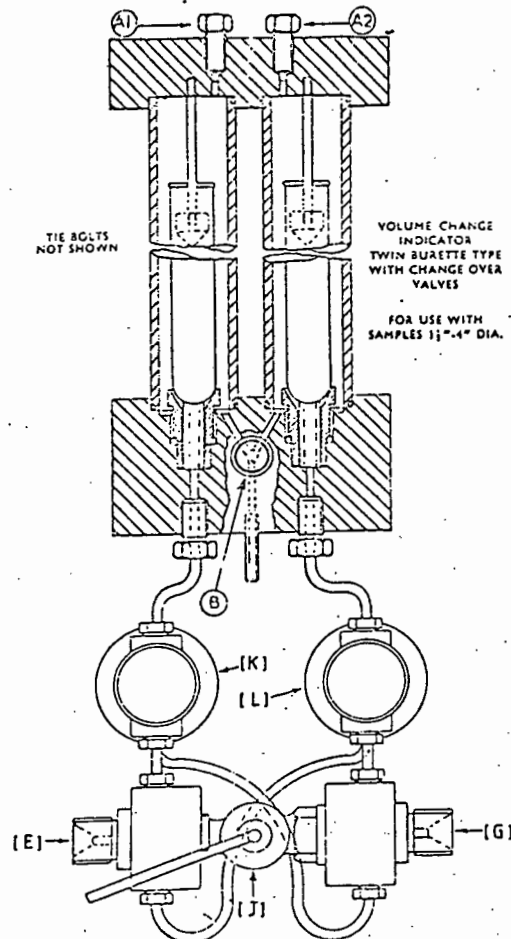


Figure D.03: Triaxial test - volume change indicator of the twin burette type with change over valves.

¹ - refer to figure D.02 on previous page.

Operation procedure (refer to Figure D.03):

- (1) Connect port [G] to the cell. With [K] and [L] in the "centre" closed position and valve [J] open, water will pass directly to the cell.
- (2) Close valve [J] and with valves [K] and [L] in the "out" position, the volume change is indicated by the fall of paraffin in the burette. When the paraffin is at the bottom of the burette, change valves [K] and [L] to the "in" position and the movement of the paraffin is reversed.
- (3) It may be necessary to dismantle the apparatus for cleaning the tubes. To fill the apparatus and have it ready for use, the procedure described by the manufacturer¹ should be followed.

3. Calibration of Equipment:-

Using a metal spacer instead of the soil sample, assemble all the parts and set the equipment for the start of a test². Load and unload the triaxial machine as in the actual test. Record the Volume Change Indicator Readings for each increase/decrease in the cell pressure as well as the zero cell pressure readings. Tabulate the corrections to be applied to the volume change readings at full consolidation versus cell pressure.

Note: Refer to Table D.03 and Figure D.05 (section 8) for the corrections to be applied to each load/unload stage.

4. Measurement of masses and dimensions, and positioning of the soil sample:-

- (i) The following parts are required. Their masses should be recorded if necessary: 38 mm (1½ in) diameter tube and dolly; Membrane stretcher; Two rubber membranes; Four "O" rings; Two porous discs; Two filter papers; Loading cap; Filter paper drains.
- (ii) The diameter and length of the sample are measured, and its mass is recorded.
In the case of remoulded samples, the soil is moulded with the fingers and compacted in the 1½ in diameter tube against the end of the dolly, which is progressively moved back down the tube. The ends of the sample are trimmed and the weight, diameter and length of the sample are recorded. Some samples tend to deform with handling - the dimensions are only measured after placing the sample on the pedestal. For details of sample preparation and requirements, refer to the preparation of soil samples for testing in Appendix A.
- (iii) The 10 cc burette is connected to drainage outlet [A], as shown in Figure D.04 (refer to the next section), at the base of the cell. This system is then filled with de-aired distilled water.

¹ - Wykeham Farrance Engineering Ltd.

² - refer to subsequent sections 5 and 6.

A small amount of water is allowed to flow back from the burette to cover the pedestal. A saturated porous disc is weighed and then slid on to the pedestal and is followed by a wet filter paper.

The sample is carefully placed on top of the filter paper. In order to accelerate consolidation, filter drains¹, which were saturated with water, are fitted around the specimen. The upper filter paper, porous plate (both wet and saturated) and perspex loading cap, are then positioned in that order on top of the sample.

(iv) A rubber membrane is placed inside a 100 mm length of twin-walled brass tubing of about 45 mm internal diameter, and is turned back over the ends. Suction is applied to the space between the membrane and the brass tube (either with the mouth or the vacuum line) expanding the membrane to a convenient size to slip over the sample without touching it. The suction is released so that the membrane contracts on to the sample and its ends are slipped off the membrane stretcher. In order to avoid any leaks, a second rubber membrane is used, following the above procedure.

(v) Two rubber "O" rings are then stretched over each end of the brass tube. The tube is held over the sample while one "O" ring at a time is rolled off with the fingers. Use two "O" rings to grip the membrane against the pedestal, upon which grooves have been made in order to provide a snug fitting and to prevent water leaks.

In order to remove as much air as possible (from between the rubber membranes and the specimen) the rubber membranes are gently stroked in an upward direction.

Two more "O" rings are used to grip the membrane against the top perspex loading cap, which has also been grooved, and thus seal the top part - its axial alignment is checked.

(vi) At this stage all the main valves in the triaxial equipment should be closed, and remain so until otherwise instructed during the course of the sections that follow.

5. Assembly of triaxial components - refer to Figure D.04:-

(i) The ram is lifted to the upper limit of its travel and held in place by a clamp on the adjustable arm which is used for strain measurement, whenever required. The upper part of the cell is carefully placed over the sample. The three wing nuts are tightened evenly with the fingers. Care should be taken with the alignment of the top of the cell. Check that valves [A] and [A1] are closed. Open valve [A2] and leave it opened throughout the test.

(ii) De-aired water is run into the cell from the main supply with the air release valve [I] open until the cell is nearly full - that is, with the mercury pressure supply connected to the cell and valves [B], [J], [B1], [D], [C3], [C2], [C1], c and b opened, valves [K] and [L] to remain closed (that is in the natural position), water is run into the cell from the de-aired water supply.

¹ - for example, Whatman's No. 54.

While the cell is filling up, the initial (or zero) reading in the Volume Change Indicator can be adjusted by closing valve [J] and using valves [K] and [L] to change direction of flow, and consequently change the initial reading. Once that reading is set, close valves [K] and [L] and open valve [J], and we are now back to just filling up the cell with de-aired water.

The rate of filling should be reduced when the cell is almost full. The remaining air is expelled through the air valve [I] by admitting more water. Valve c should be shut when water begins to flow from [I]. Valves [B] and [B1] are then closed (valve c is closed first to avoid any head pressure from the de-airing system coming into the tubing). Close air valve [I] and check that the oil plug [H] is also closed.

(iii) The pressure supply is now adjusted to the required cell pressure. The most reliable method is to first open valves [E], [G] and [G2] (valve [D] is already opened, and valve [G1] is to remain closed).

Note: Most of the mercury should be in the upper cylinders. This adjustment may be made just before raising the pressure by running in additional water at valve c .

Set the upper cylinders to give the required cell pressure on the gauge fitted to the pressure supply board - a check can be made to this cell pressure by opening valve [F] and reading the gauge fitted to the Volume Change Indicator board. Valve [G] is now closed.

(iv) Valves [K] and [L] are opened, both "in" for flow in one direction and both "out" for flow in the other direction. Valve [J] is closed. The volume change indicator measuring device is now connected with the pressure supply and ready for operation. A provisional zero reading is noted.

Ensure that valve c is closed, and as a precaution also close valve [C1].

(v) The water level in the 10 cc burette is adjusted to a suitable height, to allow for decrease in the volume of the sample and record that reading as its initial (zero) reading. The burette (itself) is raised until its water level is in line with the bottom of the sample. To minimize evaporation, a temporary (loose fitting) cover is placed over the top of the burette.

(vi) Open valves [G] and [B1] and note the correct initial or (zero) reading on the Volume Change Indicator.

(vii) Use the vernier telescope (mounted on the graduated column) to sight a convenient reference point of the sample inside the cell. The top of the metal ball on the top cap (or the cap itself) is quite convenient.

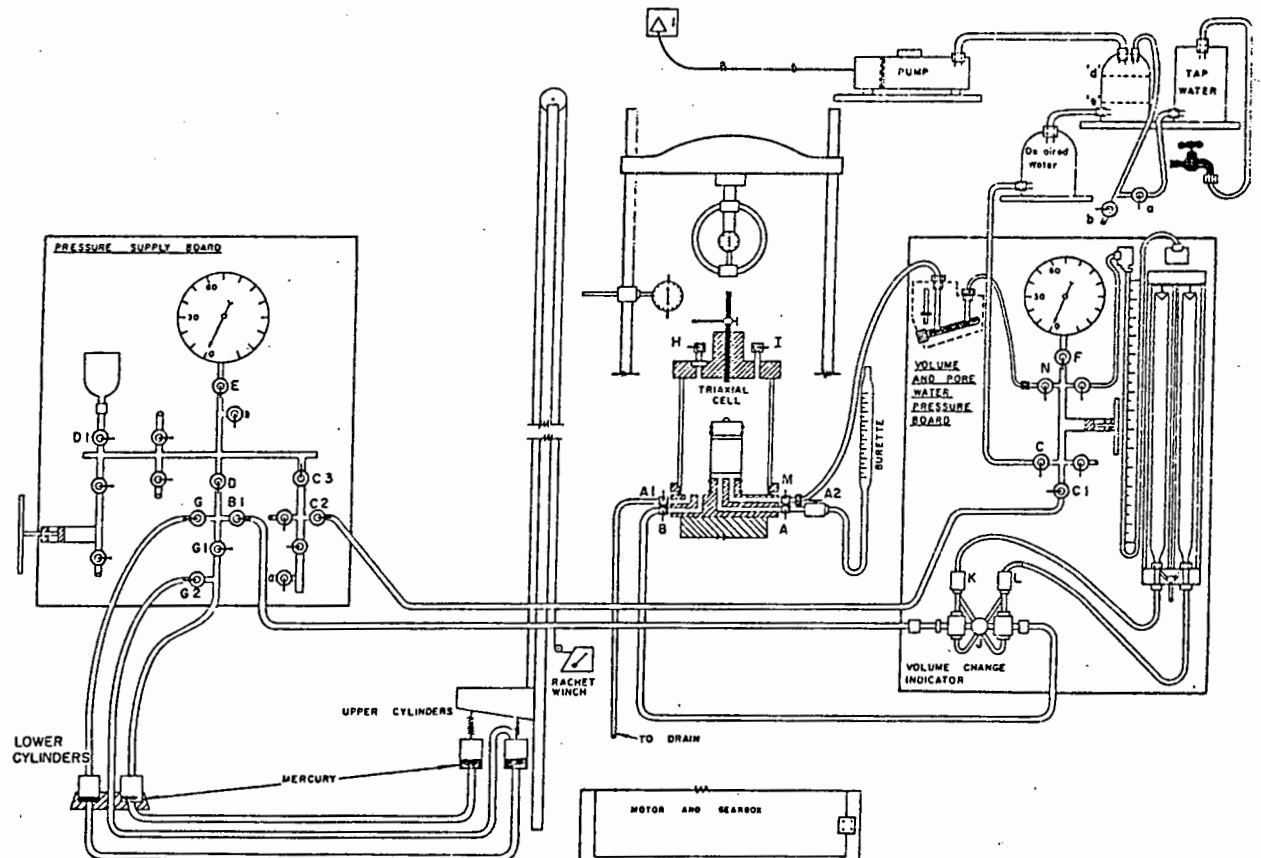


Figure D.04: Triaxial test - components assembled and ready for starting the test (refer to section 6).

6. Testing:-

- (i) Valves [A] and [B] are both opened at the same time. At suitable time intervals the volume change in the sample is measured on the Volume Change Indicator. Readings are also noted of the water level in the burette which is kept in line with the bottom of the sample. Consolidation is completed when no noticeable movement occurs of the water level in the volume change indicator (and burette), over a period of time. The change in water level occurs very slowly towards the end. The specimen should be allowed to consolidate for a few hours, preferably overnight or even longer depending on the type of soil used. The final water levels in the volume change indicator and in the burette are then recorded. The change in the height of the specimen is also noted using the vernier telescope.
- (ii) Valves [A], [B] and [B1] are closed. The upper "mercury" cylinders are raised high enough to provide the required new cell pressure on the gauge fitted to the pressure supply board. Open valve [B1]. Record the new reading in the volume change indicator (usually there is a slight change in the reading due to increasing the cell pressure, which causes the equipment to expand slightly).
- (iii) Adjust the water level in the burette to allow for a further decrease in the volume of the sample and record that reading. The burette itself should be moved up or down until the water level is again in line with the bottom of the sample being tested.
- (iv) The above steps (i) to (iii) are repeated until the maximum required (or available) cell pressure is reached. The range of effective stress employed is limited only by the capacity of the testing machine. The sequence of cell pressure increments are as follows: 10.3 kpa, 51.7 kpa, 103.4 kpa, 206.8 kpa, 413.7 kpa, 620.5 kpa, and 827.4 kpa. Ensure that valves [A], [B] and [B1] are then closed.
- (v) The unloading stage is carried out by reducing the cell pressure in steps. Record the changes in Volume¹ and axial strain for each cell pressure. To reduce the cell pressure, valves [A], [B] and [B1] are closed. The mercury control is adjusted down to provide the required cell pressure on the gauge fitted to the pressure supply board. Valve [B1] is then opened. Record the volume change indicator reading. Adjust the water level in the burette to allow for the expected increase (ie, soil recovery) in the volume of the sample and record that reading. The burette itself is moved up or down until the water level is in line with the bottom of the sample.

¹ - in the volume change indicator and burette.

Valves [A] and [B] are both opened at the same time. At suitable time intervals the volume change in the sample is measured on the volume change indicator. Readings are also recorded for the water level in the burette. Soil recovery is assumed to be complete when no noticeable movement of level occurs in the burette and indicator over a period of time. The final water levels (volume change indicator and burette) are recorded. The height of the specimen is also noted.

The procedure is repeated until the unloading is completed. The sequence of cell pressure decrements are as follows: 827.4 kpa, 206.8 kpa, 51.7 kpa, 10.3 kpa, and zero.

(vi) The volume and pressure supply systems are isolated by closing down valves [A] [G] [K] and [L] and opening [J]. By opening valve [D1] the cell pressure becomes atmospheric. With valves [E] and [F] shut to protect the pressure gauges, close valve [B] and [D1]. Open valve [I] and [A1]. Most of the water from the cell is allowed to drain from the base of the cell, through valve [A1].

(vii) The top of the cell is carefully removed and the surplus water is wiped from the loading cap. The rubber membranes are cut (right around) between the top cap and the porous plate. The top "O" rings, cap and porous plate are removed. The rubber membranes are gently pulled down and the filter paper drains removed. The filter papers are removed from the ends of the sample. Any relevant details should be noted, such as general appearance of the soil sample, inclination of any slip planes, (etc), and the mode of failure (if any) should also be sketched.

The sample is weighed, measured and placed in an oven set at $105 \pm 5^{\circ}\text{C}$ for a few hours, preferably overnight. It is then removed, allowed to cool down and its oven dried mass is recorded.

7. Test sheet and Calculations:-

(i) Introduction.

TRIAXIAL TEST: 3-Dimensional (all round) Consolidated Drained Test.

Sample No.: Method: Date: Remarks:

(ii) Preparation.

a) Parts used:

* Tube and dolly	* Porous discs (two)
* Membrane stretcher	* Filter papers (two)
* Rubber membranes (two)	* Loading cap
* "O" Rings (four)	* Filter paper drains

b) Estimation of Initial Water Content using cuttings¹:

Moist soil	+	Tare =	Water content =
Oven Dry soil	+	Tare =	
		Tare =	

c) Free Shrinkage and Free Swell test²:

Time/ date	Soil (g)	w (%)	Mercury + Tare (g)	Void ratio 'e'	Remarks

d) Mass of soil sample (moist) for triaxial test =
 Diameter of sample =
 Length of sample =

(iii) Readings:

(Date) Time	Cell Pressure (lbs/in ²)	Volume Change Volume Change Indicator	Readings Burette	Ht. of Sample	Remarks

(iv) At end of test.

1) Remarks concerning sample tested:

2) Mass of sample (moist)=	Diameter of sample = Height of sample =
3) Oven dry mass of sample =	

¹ - see previous section 4.

² - refer to Appendices A and C.

(v) Calculations.

1) Before/After test:

Initial water content = Final water content =
 Initial void ratio = Final void ratio =

2) Intermediate values: Use information from (iii) and find the intermediate values for Void Ratio and Water Content.

(vi) Remarks:

a) The change in water content during the test ($w_{ci} - w_{cf}$), provides an independent measure of the total volume change in a fully saturated soil. Thus,

$$-\frac{\delta v}{V_i} = \frac{w_{ci} - w_{cf}}{w_{ci} + 1/G_s}$$

Where:

δv = Change in volume;
 V_i = Initial volume;
 w_{ci} = Initial water content;
 w_{cf} = Final water content; and
 G_s = Specific gravity of soil grains.

b) Using the difference between initial and final masses, as well as water contents, the volume and cross-sectional area of the sample after consolidation can be determined. This is done by using either the assumption of isotropic strain or the axial strain obtained by the optical measurement.

The changes in cross-section during the test are calculated from:

$$a = a_o \cdot \frac{1 + \delta v/V_o}{1 - \epsilon}$$

Where:

a = average x-sectional area after change δl in length;
 a_o = initial cross sectional area;
 δv = change in volume;
 V_o = Initial volume;
 $\epsilon = \frac{\delta l}{L_o}$, where L_o = initial length.

8. Calibration test:-

The bedding in that takes place due to the equipment adjusting itself to the strains caused by the particular loading/unloading sequence used.

Table D.03: All round consolidation test procedure - Calibration of equipment (for volume change device).

Load (lbs/in ²)	All round (average) pressure 'peAR' Log ₁₀ p (Kpa)		Volume change		
			Reading (cm ³)	Difference (cm ³)	Accumulative Difference 'correction' (cu. cm)
0	0	-	38.0		0
1.5	10.3	1.01	38.2	0.2	0.2
1.5	10.3		38.2		
7.5	51.7	1.71	39.3	1.1	1.3
7.5	51.7		39.4		
15.0	103.4	2.01	40.4	1.0	2.3
15.0	103.4		40.45		
30.0	206.8	2.32	42.5	2.05	4.35
30.0	206.8		42.6		
60.0	413.7	2.62	45.3	2.7	7.05
60.0	413.7		45.4		
90.0	620.5	2.79	48.45	3.05	10.1
90.0	620.5		48.6		
120.0	827.4	2.92	52.4	3.8	13.9
120.0	827.4		54.2		
30.0	206.8	2.32	61.45	-7.25	6.65
30.0	206.8		61.8		
7.5	51.7	1.71	64.85	-3.05	3.6
7.5	51.7		65.0		
1.5	10.3	1.01	65.7	-0.7	2.9
1.5	10.3		65.7		
0	0	-	65.9	-0.2	2.7

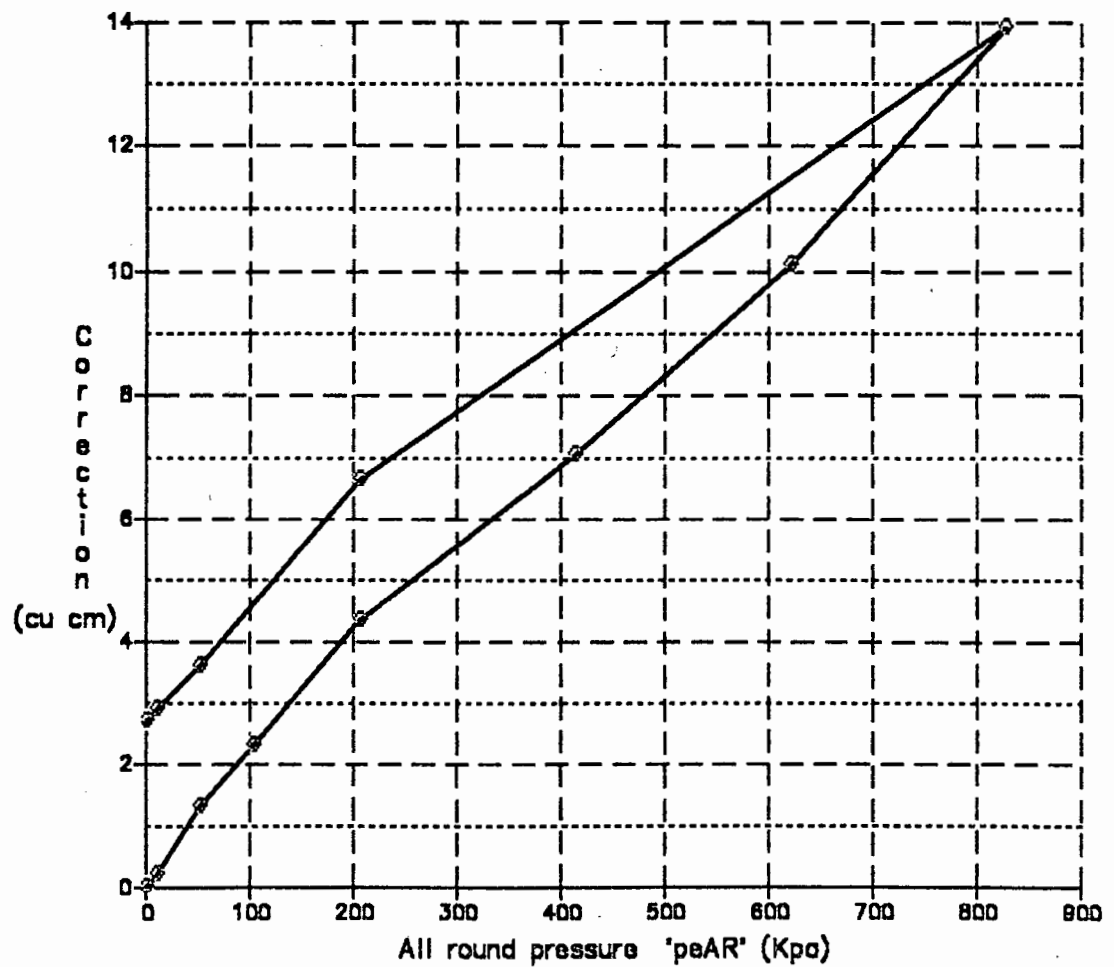


Figure D.05: Triaxial test - Calibration of equipment.
(ie. For use for Volume Change Device).

D.3 REFERENCES FOR APPENDIX D

16. DE S. VINAGRE, T.J.V. (1976/77): Masters Thesis - Diaries One, Two, Three, Four, Five, and Six.
88. BISHOP, A.W. and HENKEL, D.J. (1962): The measurement of soil properties in the triaxial test - Second Edition. Edward Arnold (Publishers) Ltd., London.

D.4 TEST RESULTSD.4.1. Natural Soils

Table D.04: Natural Soils - One-dimensional (Consolidometer) Consolidation test results.

Sample Number/Ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Sample Number/Ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'

Site 11 - Rosebank, Cape

[Remoulded samples]

S11-32/II.267	1	2.286	S.11-66/IV455	1	1.68
	4.1	2.159		8.3	1.62
	8.3	2.041		53.6	1.50
	53.6	1.654		107.3	1.36
	107.3	1.487		214.6	1.24
	214.6	1.317		429.2	1.09
	429.2	1.165		850.4	0.98
	858.4	1.014		214.6	1.03
	1716.7	0.872		53.6	1.10
	2360.5	0.815		8.3	1.17
	429.2	0.891			
	53.6	1.033			
	8.3	1.132			
	1	1.223			

[Undisturbed sample]

			('wr')
S.11-56/III.355	1	1.050	(0.931)
	1	1.047	(0.931)
	1	1.136	(1.088)
	4.1	1.135	(1.088)
	8.3	1.133	(1.088)
	53.6	1.096	(1.087)
	107.3	1.068	(1.086)
	214.6	1.032	(1.083)
	429.2	0.977	(1.079)
	858.4	0.906	(1.069)
	1716.7	0.832	(1.050)
	2360.5	0.792	(1.036)
	429.2	0.836	(1.053)
	53.6	0.928	(1.056)
	8.3	0.995	(1.057)
	1	1.045	(1.057)

Sample Number/Ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'

Site 36 - Rondebosch, Cape

[Remoulded sample]

S.36-1/III.277	1	1.178
	4.1	1.107
	8.3	1.079
	53.6	0.944
	107.3	0.882
	214.6	0.812
	429.2	0.733
	858.4	0.657
	1716.7	0.579
	2360.5	0.545
	429.5	0.571
	53.6	0.635
	8.3	0.704
	1	0.736

[Undisturbed sample]

			('wr')
S.36-20/III.407	1	0.610	(0.393)
	1	0.609	(0.393)
	1	0.615	(0.417)
	1	0.626	(0.511)
	1	0.641	(0.564)
	1	0.646	(0.589)
	9.8	0.644	(0.589)
	49.0	0.629	(0.586)
	98.1	0.620	(0.582)
	147.1	0.612	(0.579)
	196.1	0.607	(0.575)
	392.3	0.589	(0.564)
	784.5	0.560	(0.540)
	392.3	0.568	(0.562)
	196.1	0.575	(0.573)
	98.1	0.583	(0.578)
	49.0	0.589	(0.581)
	9.8	0.609	(0.583)
	1	0.619	(0.583)

Sample Number/Ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'

Site 30 - Hout Bay, Cape

[Remoulded sample]

S.30-1/III.283	1	1.271
	4.1	1.185
	8.3	1.150
	53.6	0.987
	107.3	0.919
	214.6	0.844
	429.2	0.762
	858.4	0.687
	1716.7	0.606
	2360.5	0.571
	429.5	0.606
	53.6	0.675
	8.3	0.732
	1	0.787

[Undisturbed sample]

			('wr')
S.30-17/VI.438	1	0.663	(0.325)
	1	0.662	(0.325)
	1	0.668	(0.356)
	1	0.676	(0.435)
	1	0.693	(0.527)
	1	0.713	(0.607)
	1	0.719	(0.612)
	9.8	0.712	(0.612)
	49.0	0.684	(0.684)
	98.1	0.666	(0.608)
	147.1	0.654	(0.606)
	196.1	0.645	(0.604)
	392.3	0.612	(0.595)
	784.5	0.570	(0.578)
	392.3	0.580	(0.599)
	196.1	0.590	(0.610)
	98.1	0.604	(0.615)
	49.0	0.614	(0.617)
	9.8	0.640	(0.619)
	1	0.653	(0.620)

Sample Number/Ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'

Site A - Berea Road, Durban

[Remoulded sample]

S.A-5/I.136	1	0.687
	4.1	0.684
	8.3	0.673
	26.8	0.637
	53.6	0.618
	107.3	0.596
	214.6	0.577
	429.2	0.558
	858.4	0.540
	1716.7	0.501
	2897.0	0.505
	858.4	0.507
	214.6	0.511
	53.6	0.516
	1	0.516

Site 7 - Mowbray, Cape

[Remoulded sample]

S.7-6/I.94	1	1.753
	4.9	1.587
	9.8	1.540
	24.5	1.428
	49.0	1.322
	98.1	1.214
	196.1	1.092
	392.3	0.978
	784.5	0.865
	1569.1	0.755
	3138.1	0.650
	784.5	0.742
	196.1	0.805
	49.0	0.902
	1	0.902

Sample Number/Ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'

Site 45 - Bellville, Cape

[Remoulded sample]

S.45-1/III.312	1	1.611
	4.1	1.546
	8.3	1.490
	53.6	1.259
	107.3	1.147
	214.6	1.042
	429.2	0.929
	858.4	0.824
	1716.7	0.718
	429.6	0.759
	53.6	0.865
	8.3	0.968
	1	1.035

Site B - Francois Road, Durban

[Remoulded sample]

SB-2/II.141	1	0.676
	4.1	0.673
	8.3	0.668
	26.8	0.656
	53.6	0.648
	107.3	0.635
	214.6	0.625
	429.2	0.611
	858.4	0.601
	1716.7	0.587
	2897.0	0.571
	858.4	0.601
	214.6	0.576
	53.6	0.580
	1	0.584

Sample Number/Ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'

Site C - Margaret Mayton Avenue, Durban

[Remoulded sample]

S.C-2/II.145	1	0.629
	4.1	0.622
	8.3	0.619
	26.8	0.607
	53.7	0.599
	107.3	0.591
	214.6	0.581
	429.3	0.571
	858.6	0.560
	1717.2	0.545
	2897.8	0.531
	858.6	0.534
	214.6	0.537
	53.7	0.540
	1	0.545

Site D - Rose Hill, Durban

[Remoulded sample]

S.D-2/II.147	1	0.625
	4.1	0.620
	8.3	0.616
	26.8	0.595
	53.6	0.581
	107.3	0.564
	214.6	0.552
	429.2	0.537
	858.4	0.521
	1716.7	0.505
	2897.0	0.488
	858.4	0.493
	214.6	0.496
	53.6	0.499
	1	0.505

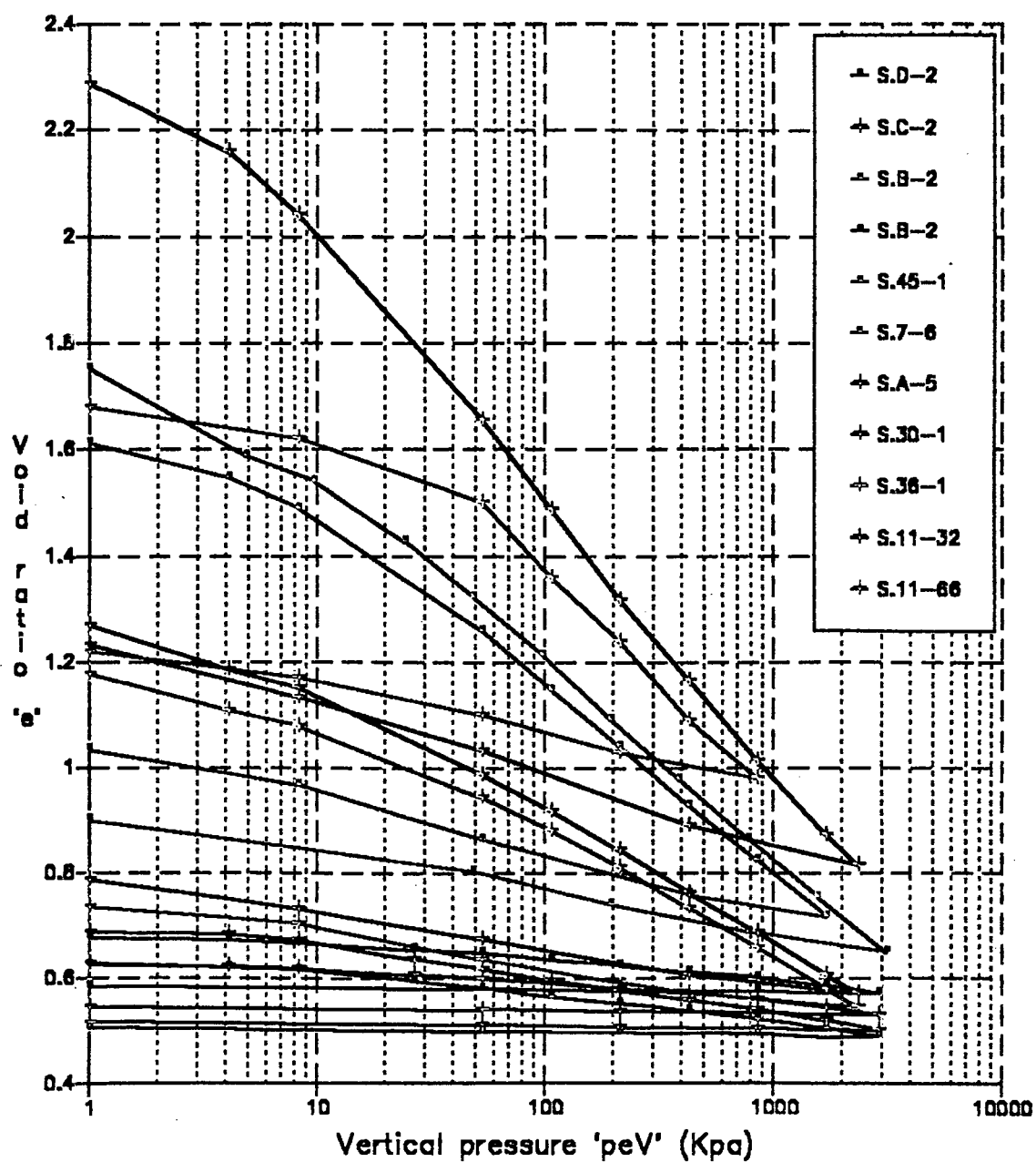


Figure D.06: Remoulded Natural Soils [Consolidometer tests]
 - Plot of Vertical Pressure 'peV' versus Void Ratio 'e'.
 [For results for undisturbed samples see Figures 5.12(i),
 5.13, and Figure 5.14].

*Table D.05: Natural Soils - Isotropic (Triaxial)
Consolidation test results.*

Sample Number/Ref.	All Round pressure 'peAr'	Void Ratio 'e'	Sample Number/Ref.	All Round pressure 'peAR'	Void Ratio 'e'

Site 11 - Rosebank, Cape

[Remoulded sample]			[Undisturbed sample]		
S.11-T.2/V.11	1	1.654	S.11-T.5/V.35	1	1.563
	10.3	1.497		10.3	1.508
	51.7	1.296		51.7	1.426
	103.4	1.206		103.4	1.097
	206.8	1.094		206.8	1.054
	413.7	0.975		413.7	0.961
	620.5	0.914		620.5	0.843
	827.4	0.891		827.4	0.840
	206.8	0.944		206.8	0.869
	51.7	0.993		51.7	0.960
	10.3	1.135		10.3	0.961
	1	1.190		1	0.963

Site 36 - Rondebosch, Cape

[Remoulded sample]		
S.36-T.1/V.5	1	1.026
	10.3	0.888
	51.7	0.690
	103.4	0.603
	206.8	0.494
	413.7	0.369
	620.5	0.303
	827.4	0.230
	206.8	0.237
	51.7	0.252
	10.3	0.321
	1	0.369

Sample Number/Ref.	All Round pressure 'peAr'	Void Ratio 'e'	Sample Number/Ref.	All Round pressure 'peAR'	Void Ratio 'e'

Site 30 - Hout Bay, Cape

[Remoulded sample]

S.30-T.1/V.7	1	1.188
	10.3	1.025
	51.7	0.862
	103.4	0.778
	206.8	0.700
	413.7	0.601
	620.5	0.529
	827.4	0.510
	206.8	0.553
	51.7	0.583
	10.3	0.667
	1	0.711

Site A - Berea Road, Durban

[Remoulded sample]

S.A-T.1/V.9	1	0.564
	10.3	0.425
	51.7	0.382
	103.4	0.360
	206.8	0.346
	413.7	0.317
	620.5	0.316
	827.4	0.316
	206.8	0.319
	51.7	0.323
	10.3	0.325
	1	0.334

Site 7 - Mowbray, Cape

[Remoulded sample]

S.7-T.1/V.23	1	1.042
	10.3	0.905
	51.7	0.778
	103.4	0.707
	206.8	0.651
	413.7	0.571
	620.5	0.538
	827.4	0.523
	206.8	0.546
	51.7	0.560
	10.3	0.616
	1	0.662

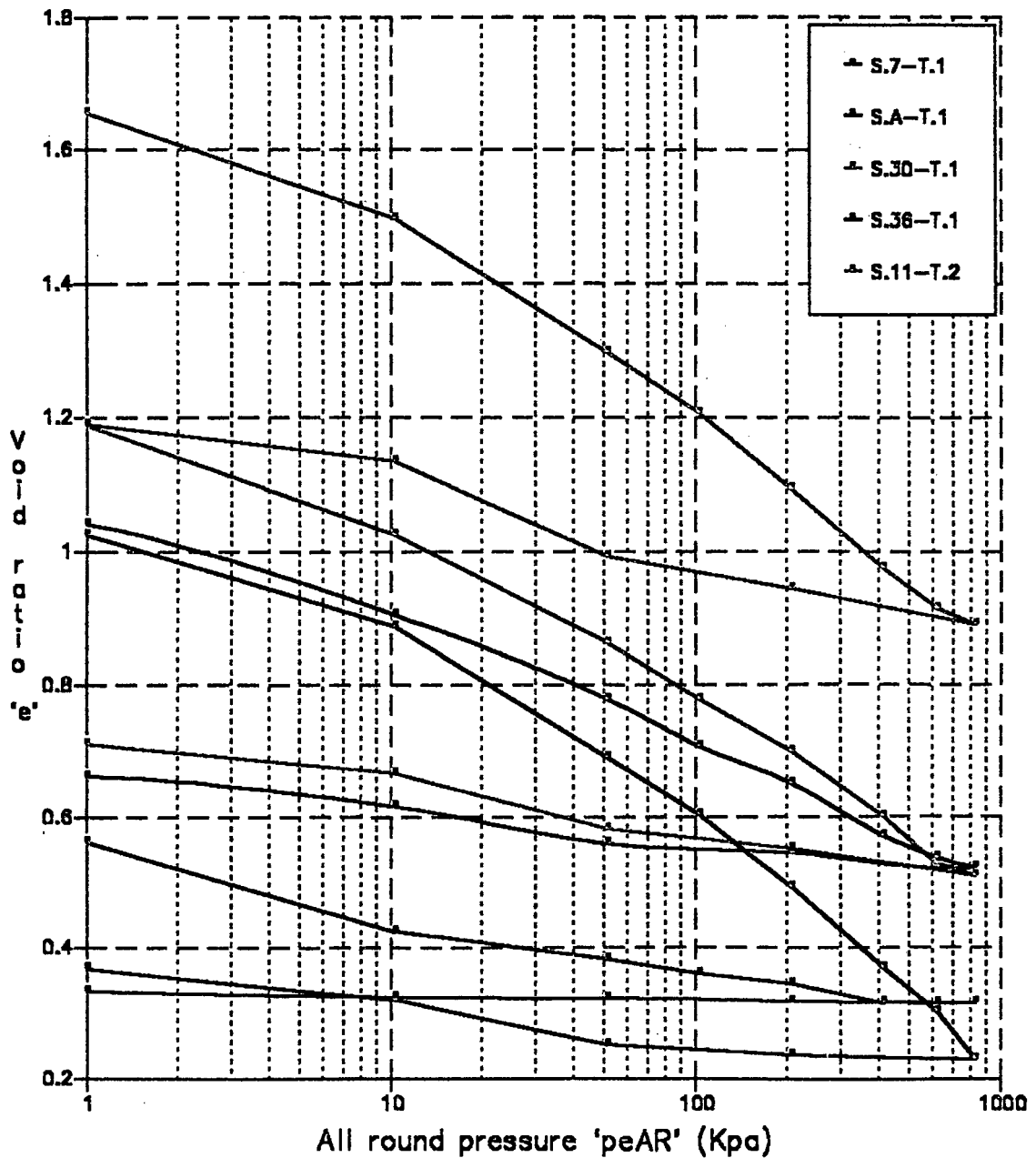


Figure D.07: Remoulded Natural Soils [Triaxial tests] - Plot of All Round Pressure 'peAR' versus Void Ratio 'e'. [For plot for undisturbed sample S11-T5 See Fig. 5.12(ii)].

D.4.2 Artificial Soils(Cape Flats Sand + Clay Fraction)¹.

*Table D.06: Artificial Soils - One-dimensional
(Consolidometer) Consolidation test results.*

Sample Number/Ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Sample Number/Ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'
<u>K.1 (13% Kaolin)</u>			<u>K.2 (20% Kaolin)</u>		
K.1-4/II.242	1	0.635	K.2-4/II.254	1	0.595
	4.1	0.606		4.1	0.514
	8.3	0.600		8.3	0.500
	53.6	0.569		53.6	0.438
	107.3	0.559		107.3	0.423
	214.6	0.550		214.6	0.404
	429.2	0.537		429.2	0.390
	858.4	0.528		858.4	0.375
	1716.7	0.514		1716.7	0.357
	2360.5	0.507		2360.5	0.349
	429.2	0.511		429.2	0.354
	53.6	0.514		53.6	0.360
	8.3	0.519		8.3	0.364
	1	0.521		1	0.372
<u>K.3 (10% Kaolin)</u>					
K.3-4/II.263	1	0.683			
	4.1	0.678			
	8.3	0.674			
	53.6	0.659			
	107.3	0.654			
	214.6	0.648			
	429.2	0.640			
	858.4	0.631			
	1716.7	0.621			
	2360.5	0.614			
	429.2	0.620			
	53.6	0.625			
	8.3	0.629			
	1	0.631			

¹ - See section 1.6 of Chapter One, Figures 2.04, 2.08, 2.09, and Figure 10.04.

Sample Number/Ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Sample Number/Ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'
<u>B.1 (3.5% Bentonite)</u>			<u>B.2 (7% Bentonite)</u>		
B.1-1/III.381	1	0.951	B.2-1/III.387	1	1.346
	8.3	0.893		8.3	1.204
	53.6	0.831		53.6	0.990
	107.3	0.812		107.3	0.915
	214.6	0.796		214.6	0.854
	429.2	0.779		429.2	0.803
	858.4	0.764		858.4	0.771
	1716.7	0.746		1716.7	0.736
	429.2	0.750		429.2	0.741
	53.6	0.754		53.6	0.748
	8.3	0.758		8.3	0.764
	1	0.762		1	0.805
<u>B.3 (11.5% Bentonite)</u>			<u>B.4 (15.5% Bentonite)</u>		
B.3-1/III.391	1	1.841	B.4-1/III.397	1	2.023
	8.3	1.662		8.3	1.890
	53.6	1.290		53.6	1.493
	107.3	1.071		107.3	1.180
	214.6	0.927		214.6	0.973
	429.2	0.824		429.2	0.824
	858.4	0.754		858.4	0.724
	1716.7	0.699		1716.7	0.653
	429.2	0.704		429.2	0.661
	53.6	0.731		53.6	0.756
	8.3	0.871		8.3	0.971
	1	0.948		1	1.111
<u>B.5 (35% Bentonite)</u>					
B.5-1/IV.439	1	2.726			
	9.8	2.649			
	49.0	2.245			
	98.1	1.772			
	196.1	1.404			
	392.3	1.103			
	588.4	0.903			
	784.5	0.744			
	196.1	0.809			
	49.0	0.817			
	9.8	0.821			
	1	0.819			

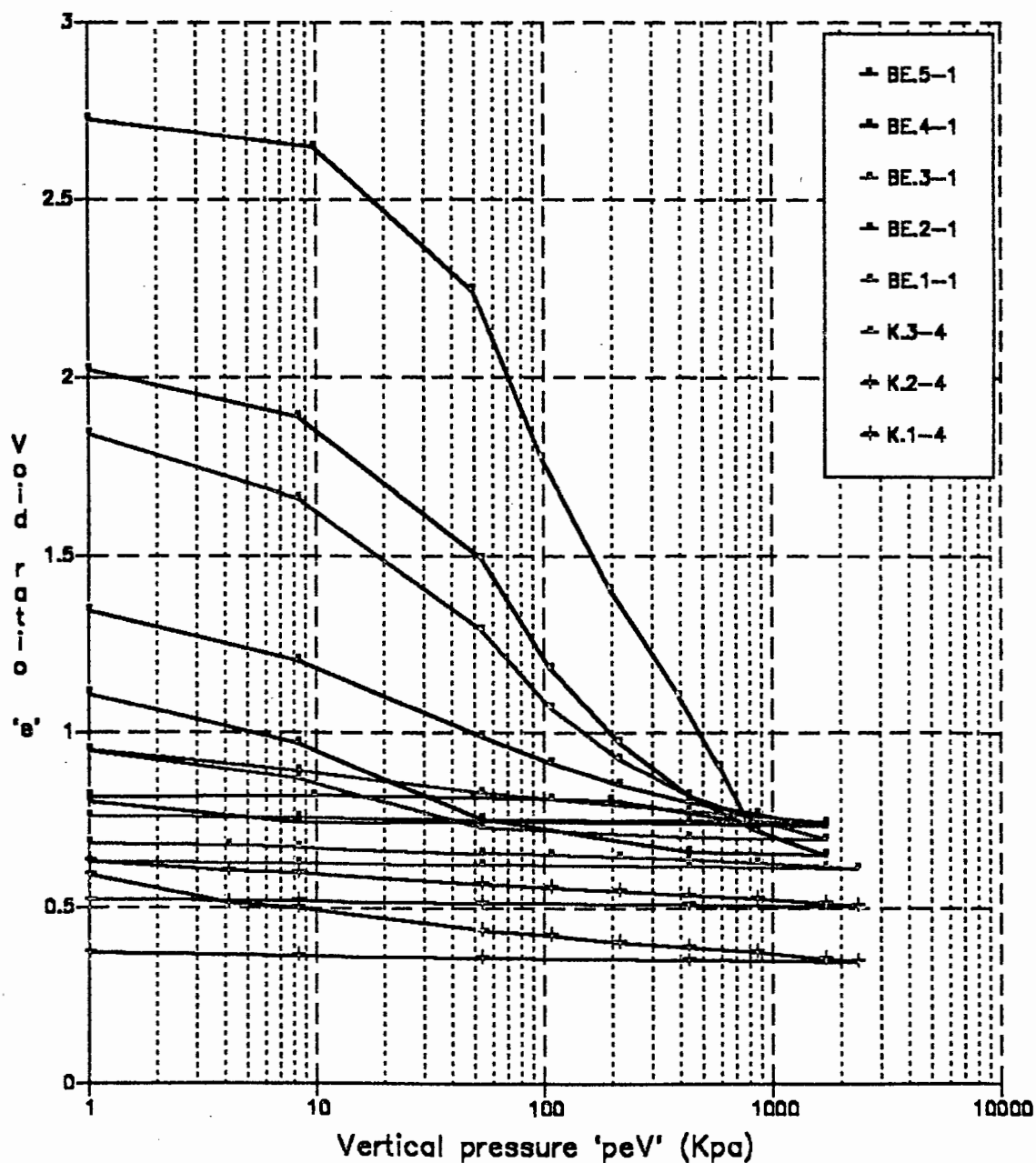


Figure D.08: Saturated Artificial Soils [Consolidometer tests] - Plot of Vertical Pressure 'peV' versus Void Ratio 'e'.

**Table D.07: Artificial Soil - Isotropic (Triaxial)
Consolidation test results.**

Sample Number/Ref.	All Round pressure 'peAr'	Void Ratio 'e'	Sample Number/Ref.	All Round pressure 'peAr'	Void Ratio 'e'
<u>K.2 (20% Kaolin)</u>			<u>K.3 (10% Kaolin)</u>		
K.2-T.1/V.13	1	0.413	K.3-T.1/V.15	1	0.586
	10.3	0.298		10.3	0.529
	51.7	0.259		51.7	0.513
	103.4	0.246		103.4	0.499
	206.8	0.242		206.8	0.498
	413.7	0.223		413.7	0.488
	620.5	0.219		620.5	0.485
	827.4	0.218		827.4	0.484
	206.8	0.226		206.8	0.494
	51.7	0.229		51.7	0.495
	10.3	0.253		10.3	0.501
	1	0.260		1	0.511
<u>B.2 (7% Bentonite)</u>			<u>B.4 (15.5% Bentonite)</u>		
B.2-T.1/V.17	1	0.968	B.4-T.1/V.19	1	1.531
	10.3	0.862		10.3	1.367
	51.7	0.767		51.7	1.153
	103.4	0.721		103.4	0.871
	206.8	0.696		206.8	0.724
	413.7	0.665		413.7	0.647
	620.5	0.661		620.5	0.596
	827.4	0.652		827.4	0.584
	206.8	0.653		206.8	0.579
	51.7	0.661		51.7	0.581
	10.3	0.692		10.3	0.808
	1	0.758		1	0.934
<u>B.5 (35% Bentonite)</u>					
B.5-T.1/V.21	1	2.449			
	10.3	2.248			
	51.7	1.849			
	103.4	1.580			
	206.8	1.386			
	413.7	1.143			
	620.5	1.022			
	827.4	0.980			
	206.8	0.926			
	51.7	0.998			
	10.3	1.273			
	1	1.604			

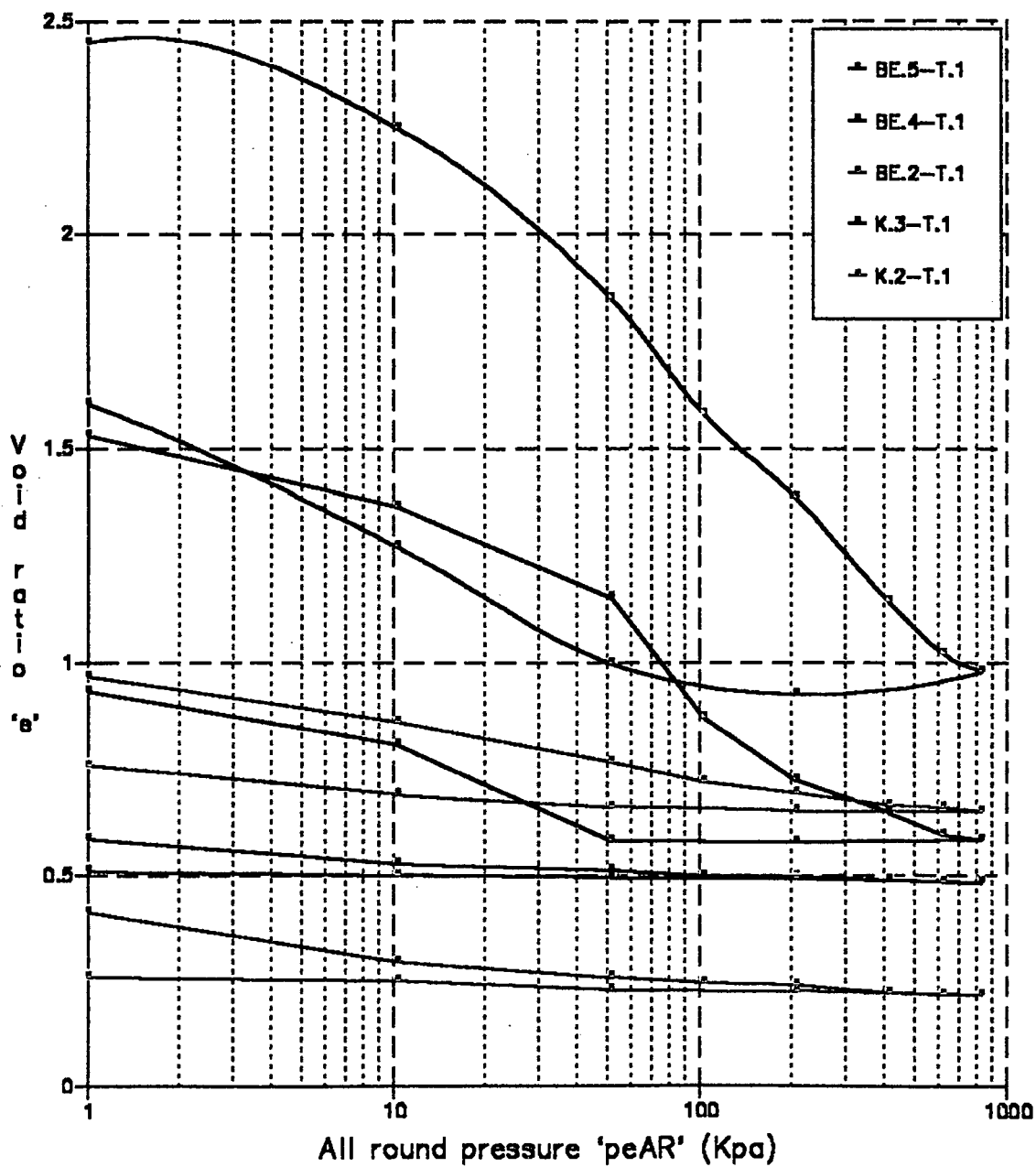


Figure D.09: Saturated Artificial Soils [Triaxial Tests] - Plot of All Round Pressure 'peAR' versus Void Ratio 'e'.

APPENDIX E

CONSOLIDOMETER TESTS FOR EXPANSIVE AND COLLAPSING SOILS - TEST PROCEDURES AND RESULTS

E.1 INTRODUCTION

This Appendix E presents the detailed consolidometer test procedures for Chapter Six. These detailed test procedures enable observations to be made of one-dimensional increase (expansion) or decrease (collapse) in volume of a soil sample, while supporting a known load, as the result of the addition of a measured volume of water. This Appendix also includes all the test results used for Chapter Six. The test method and results are summarized in Chapter Six "One-dimensional Expansion or Collapse". The basic consolidometer test procedure is detailed in Appendix D. Additional details, including selected photographic plates, are included with Chapters Five and Eight in Volume One of the Thesis.

E.2 TEST PROCEDURE

Preparation of test samples:-

Test samples are prepared from either remoulded, compacted or undisturbed soil samples. The 'step by step' detailed procedure for sample preparation is included in the preparation of soil samples for testing¹.

Remoulded samples.

Method 1:

The basic remoulded test sample consists of soil mixed with water to form a wet paste which is subsequently moulded into a suitable container. The water content of the mixture varies from about the Plastic Limit to a value equal to, or greater than, the Liquid Limit. This latter condition is also a requirement for the determination of the Shrinkage Limit - refer to section A.4.5 of Appendix A.

Method 2:

Test samples with higher void ratios can also be obtained by the addition of suitable chemical substances. An homogeneous dry mixture is prepared by mixing known amounts of soil, Tartaric Acid and Sodium Bicarbonate. Water is added to the mixture, quickly mixed and placed in a suitable container. The pH value is monitored and kept unchanged from the original sample².

¹ - refer to section A.3 of Appendix A.

² - by using Calcium Hydroxide.

Compacted Samples.

Based on the 'Dry Density versus Water Content' curve for the soil type being used as obtained in the compaction tests¹: Select points on the curve and obtain the corresponding values for water contents; Compact the soil to either Standard or Modified AASHTO specifications, as per requirements, aiming for one of the previously selected water contents; Remove the compacted sample from the mould and cut the required test sample from it.

Undisturbed samples.

The test sample is cut from the undisturbed block of soil - refer to section on 'Soil Sampling' in Appendix A.

Apparatus Required:-

(i) - (xii) Refer to "Consolidometer: One-dimensional consolidation test procedure" section D.1 of Appendix D².

Procedure:-

A) Calibration of equipment: Assemble all the consolidometer parts as for an actual test (refer to subsequent steps), except that a metal spacer is used in place of the test sample; All parts should be properly positioned and the dial gauges of the proving rings properly set to a 'zero' reading - load and unload the consolidometer as in the actual test; At the end of each stage of loading and unloading, measure the vertical deformation that took place as the result of 'bedding in' of the consolidometer parts as the result of the applied load; Tabulate the corrections to be applied to the recorded total vertical movement (ie, after consolidation of the sample) for each vertical pressure increase or decrease.

Note: Refer to Tables E.01 - E.04 and Figures E.01 - E.04 (end of test procedure) for the corrections to be applied to the recorded reading at the end of each load/unload stage.

B) Select a suitable consolidometer steel ring and record its mass, internal diameter and height.

C) After drying to the required initial water content, the soil sample is removed from the desiccator. The sample is cut and trimmed to size until the consolidometer steel ring just slides over the sample. The top and bottom surfaces of the sample are made level.

The mass of the test sample (soil plus steel ring) is recorded. Air dry masses should also be recorded from time to time, for the following items: Top and bottom loading plates; Filter papers; Plastic disc; Container plus collar and tightening screws; Plastic cover and elastic bands.

¹ - refer to section A.5 of Appendix A.

² - see "Apparatus Required", steps (i) to (xii).

D) The parts for the consolidometer container are assembled in the following order:

- (i) The bottom plate is centered in the consolidation pot, or container, followed by the plastic disc and the bottom filter paper;
- (ii) The steel ring, with the soil sample, is then positioned in the center of the bottom filter paper;
- (iii) The top filter paper is carefully placed over the soil sample, in such a way as to avoid getting caught during testing between the top plate and the steel ring;
- (iv) The top collar is fitted over the steel ring and tightened firmly, using its screws, against the consolidometer container;
- (v) The internal surfaces of the consolidometer container should be moistened before being enclosed with a loose plastic cover, or membrane, in order to minimize evaporation and to prevent movement of air around the sample;

Notes: (1) When dealing with expansive soils, great care should be exercised with wetting the container; (2) The sample must remain covered throughout the entire test.

E) Place the consolidometer container in the loading device and carry out adjustments to the following: Counterweight alongside the level arm of the consolidometer, until it balances firmly (ie, with a small pressure being exerted against the soil sample); Micrometer dial gauge for the initial, or "zero", reading.

Note: The lever arm ratio for the consolidometer is 11 to 1.

F) Place the necessary weights onto the loading platform in order to apply to the soil sample the required sequence of pressure increments, for each of the four external stresses applied, as follows:

(i) 1 Kpa test - one single load increment from "zero" pressure;

(ii) 50 Kpa test - as for (i);

(iii) 100 Kpa test - 0 -> 50 -> 100 Kpa; and

(iv) 400 Kpa test - 0 -> 50 -> 100 -> 400 Kpa.

Record the readings on the vertical deflection dial gauge before each pressure increment is applied, and at the following time intervals after each of these increments starts acting on the soil - 0.25 minutes, 0.5 min, 1.0 min, 2.25 min, 4 min, 16 min, 30 min, 60 min, 120 min, and so on, until no further settlement takes place. The readings should continue at least until the slope of the characteristic linear secondary settlement is apparent - that is, when the settlement versus square root of time, or log of time, becomes a straight line. For the last loading stage the sample should be allowed to consolidate overnight.

Notes: (1) The vertical deflections enable the calculation of thickness, or change in thickness, in the soil sample; (2) Use of the consolidometer loading frame facilitates the application of loads and load increments to the sample.

G) By means of an hypodermic syringe add a known amount of water to the sample, through the bottom filter paper. Allow the soil sample to expand, or to settle further, while being subjected to the same external vertical pressure. Record the vertical deflection reading at the same time intervals, from start of wetting, as given above¹.

H) Repeat the procedure until no further noticeable vertical movement, increase or decrease, occurs. Remove and measure any excess of water. Record the amount of water added at each stage, and also take note of the total water added for the whole wetting stage.

I) Support the lever arm of the consolidometer and use weights on the loading platform in order to measure the loading characteristics of the soil - apply further pressure increments of 50 Kpa, until a maximum of 300 Kpa is reached (in all cases except the 400 Kpa test). For each pressure increment, record the change in thickness at the same time intervals as those given above (refer to step F).

Notes: Observe if any water is being squeezed out of the soil at the end of each loading stage and, if so, remove the water by means of a syringe, and record the amount; A custom made bracket was incorporated onto the standard consolidometer in order to prevent the loading arm from settling (if required).

J) The unloading characteristics, of the soil sample, are also recorded. The sequence of pressure decrease should be as follows: 300 (or 400) Kpa → 50 → 10 → 1 Kpa. Record the readings for vertical deflection before each applied pressure decrease and, upon the application of the pressure, at the same time intervals as before - that is, $\frac{1}{4}$ minute, $\frac{1}{2}$ min, 1 min, etc. Readings should be continued at least until the slope of the characteristic expansion versus square root of time becomes a straight line.

K) At the completion of the unloading sequence, remove the consolidometer container from the loading device and record the mass of the steel ring with the soil sample. Thus, the mass of the sample (at the end of the test) is obtained. The soil sample is carefully extracted from the steel ring and placed inside the oven, previously set $105 \pm 5^{\circ}\text{C}$, for a few hours, preferably overnight. When removed from the oven the sample is allowed to cool down to room temperature, and its oven dry mass recorded.

Notes: (1) The following masses should also be recorded (at the end of unloading) - top plate, bottom plate with plastic sheet, filter papers, top collar and screws, plastic cover and elastic band; (2) If necessary the bedding in, or calibration, of the equipment is repeated².

¹ - refer to previous step F.

² - refer to step A.

Calculations and Report:-

1) Information to be recorded for each test:

- a) Before starting the initial loading stage - the initial, or "zero", reading for vertical deflection (refer to step F above).
- b) For each step of loading, during the initial loading stage - total load placed on the loading platform, time and vertical deflection readings (refer to step F);
- c) Before adding the first amount of water to the sample - the initial reading of the vertical deflection (step G);
- d) Each amount of water added to the bottom of the sample and, for each such stage of controlled wetting, the corresponding readings of the vertical deflection (steps G and H);
- e) The next loading stage - (for each load increase) total load placed on the loading platform, the time and vertical deflection readings (refer to step I above);
- f) The unloading stage - (for each step of unloading) the load placed on the loading platform, time, and vertical deflection readings (refer to step J above);
- g) The moisture content of the soil sample at the start, as well as after each step of water increment,

$$\begin{aligned} & (\text{Mass of moist soil} + \text{water added}) - \text{Mass of oven-dry soil} \\ & = \frac{\text{Mass of oven-dry soil sample}}{\text{Mass of oven-dry soil sample}} \end{aligned}$$

- h) The diameter, height and mass of the soil sample were obtained in stages B to K.

2) To determine the void ratio at the initial, final and intermediate stages:

- a) The initial void ratio 'e' of the soil sample,

$$e = \frac{\text{Volume of voids 'Vv'}}{\text{Volume of solids 'Vs'}} = \frac{\text{Total volume 'Vt'} - \text{'Vs'}}{\text{'Vs'}}$$

Where:

$$V_t = \frac{\pi \times D^2}{4} \times \text{original height of soil sample 'ht'};$$

and,

$$V_s = \frac{\text{Mass of oven-dry soil 'M}_D\text{'}}{\text{Specific Gravity of Soil particles 'G}_s\text{'}}$$

b) Intermediate and final void ratios are obtained by using the corrected vertical deflection 'hi' (refer to Calibration of equipment - step A above), and then by calculating the 'e' value as follows:

$$e = \frac{\pi \times D^2/4 (ht - hi) - V_s}{V_s}$$

3) The information obtained for each test will enable the following relationships to be plotted:

- a) Vertical deformation, either settlement or expansion, and time (square root or log) for each applied pressure increase or decrease - for more details refer to Appendix D;
- b) Void ratio 'e' and Water ratio 'wr';
- c) Void ratio 'e' and effective vertical pressure 'peV'.

Note: All the preliminary test procedures and definitions are included in Appendix A.

Calibration Tests:-

The bedding in that takes place due to the equipment adjusting itself to the load sequence used. Loading arm is supported prior to each increment in load, then released under the new loading and the difference in the deflection is noted.

Table E.01: Consolidometer test procedure for expansive and collapsing soils [Pressure = 1 Kpa] - Calibration of equipment.

Original pressure Kpa	Final Kpa	Original reading 0.0001"	Final reading 0.0001"	Difference 0.0001"	Correction to be applied cm.
0	to 1(*)	2820.0	2820.0	0	0
1	to 53.6	2820.0	2775.3	-44.7	-0.011
53.6	to 107.3	2775.3	2754.7	-20.6	-0.016
107.3	to 160.9	2754.7	2739.2	-15.5	-0.020
160.9	to 214.6	2739.2	2723.0	-16.2	-0.024
214.6	to 268.2	2723.0	2714.0	-9.0	-0.026
268.2	to 321.9	2714.0	2704.3	-9.7	-0.029
321.9	to 53.6	2704.3	2753.3	49.0	-0.016
53.6	to 8.3	2753.3	2774.0	20.7	-0.011
8.3	to 1	2774.0	2786.0	12.0	-0.008

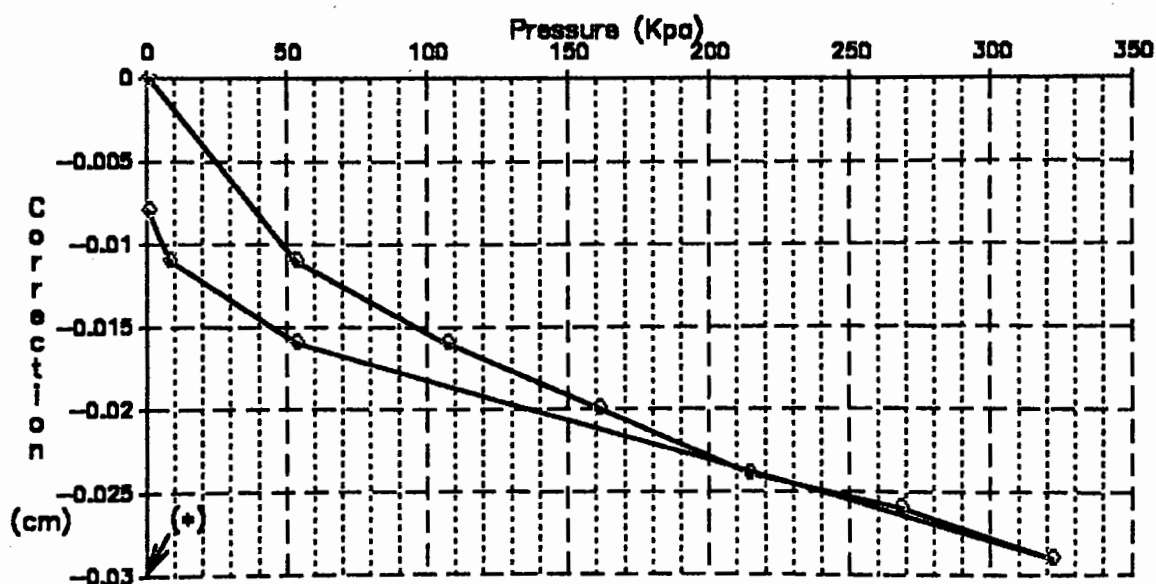


Figure E.01: Consolidometer test for expansive and collapsing soil [1Kpa] - Calibration of equipment.

(*) - 1 Kpa load kept on free of prop for 12 hours, (other loads kept on for about 5 minutes).

Table E.02: Consolidometer test procedure for expansive and collapsing soils [Pressure = 50 Kpa] - Calibration of equipment.

Original pressure Kpa	Final Kpa	Original reading 0.0001"	Final reading 0.0001"	Difference 0.0001"	Correction to be applied cm.
0	to 1	2611.0	2611.0	0	0
1	to 53.6 (*)	2611.0	2567.5	-43.5	-0.011
53.6	to 107.3	2567.5	2556.7	-10.8	-0.014
107.3	to 160.9	2556.7	2545.6	-11.1	-0.017
160.9	to 214.6	2545.6	2533.6	-12.0	-0.020
214.6	to 286.2	2533.6	2523.5	-10.1	-0.023
286.2	to 321.9	2523.5	2513.5	-10.0	-0.025
321.9	to 53.6	2513.5	2559.4	45.9	-0.013
53.6	to 8.3	2559.4	2580.0	20.6	-0.008
8.3	to 1	2580.0	2587.0	7.0	-0.006

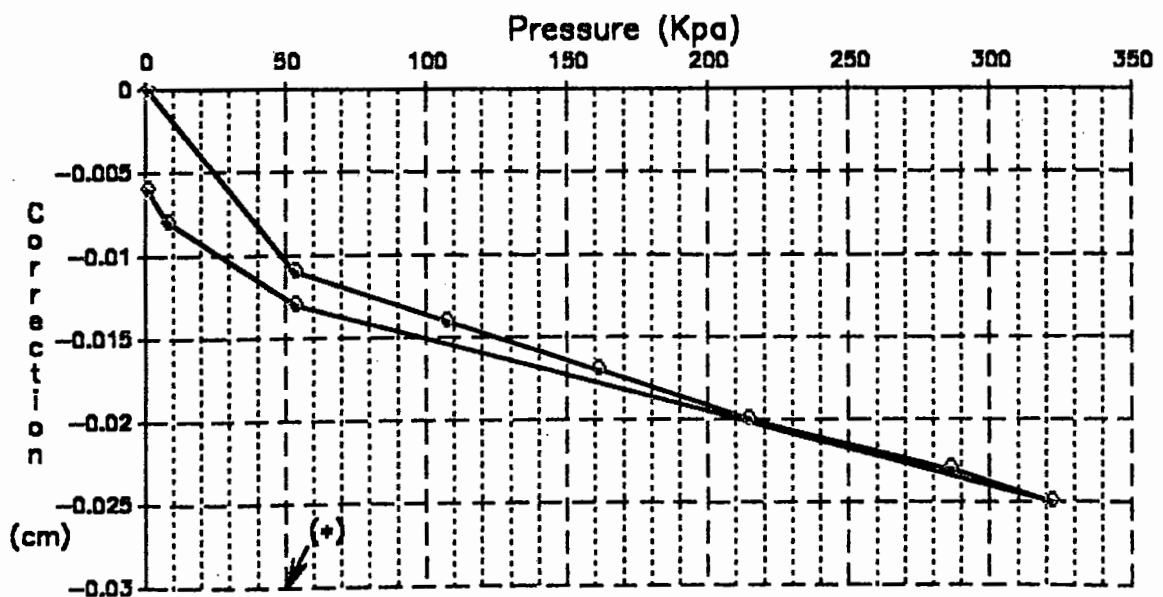


Figure E.02: Consolidometer test for expansive and collapsing soils [50 Kpa] - Calibration of equipment.

(*) - 53.6 Kpa load kept on free of prop for 12 hours, (other loads kept on for about 5 minutes).

Table E.03: Consolidometer test for expansive and collapsing soils [Pressure 100 Kpa] - Calibration of equipment.

Original pressure Kpa	Final Kpa	Original reading 0.0001"	Final reading 0.0001"	Difference 0.0001"	Correction to be applied cm.
0	to 1	2391.0	2391.0	0	0
1	to 53.6	2391.0	2358.0	-33.0	-0.009
53.6	to 107.3 (*)	2358.0	2337.0	-21.0	-0.014
107.3	to 160.9	2337.0	2328.5	-8.5	-0.016
160.9	to 214.6	2328.5	2319.8	-8.7	-0.018
214.6	to 286.2	2319.8	2310.8	-9.0	-0.020
286.2	to 321.9	2310.8	2301.5	-9.3	-0.023
321.9	to 53.6	2301.5	2344.5	43.0	-0.012
53.6	to 8.3	2344.5	2363.5	19.0	-0.007
8.3	to 1	2363.5	2374.5	11.0	-0.004

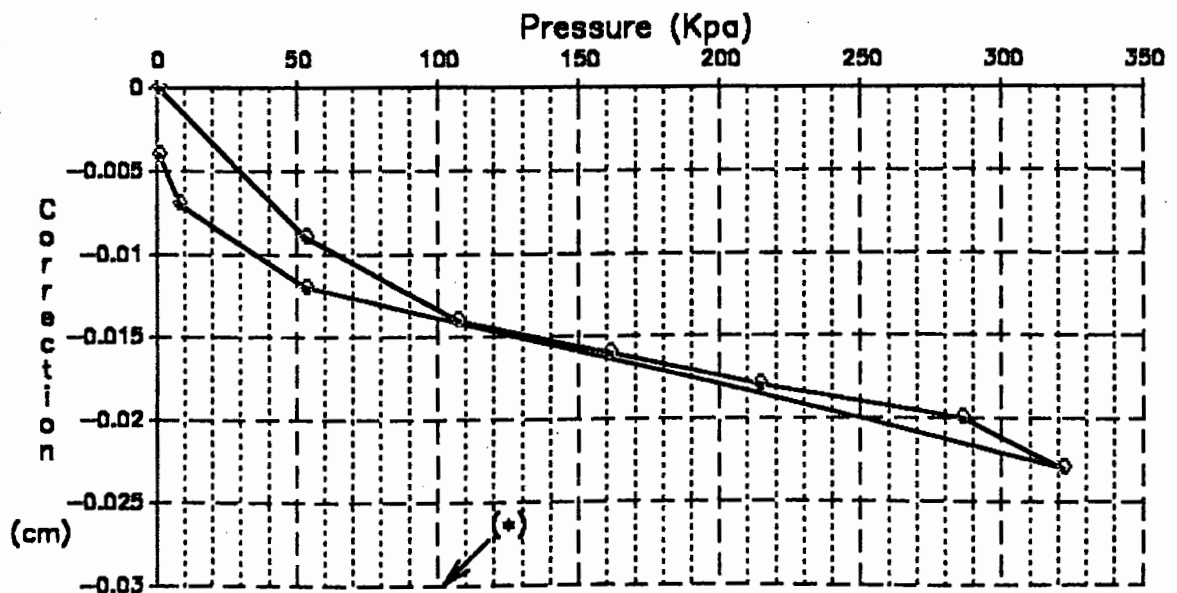


Figure E.03: Consolidometer test for expansive and collapsing soils [100 Kpa] - Calibration of equipment.

(*) - 107.3 Kpa load kept on free of prop for 12 hours, (other loads kept on for about 5 minutes).

Table E.04: Consolidometer test procedure for expansive and collapsing soils [Pressure 400 Kpa] - Calibration of equipment.

Original pressure Kpa	Final Kpa	Original reading 0.0001"	Final reading 0.0001"	Difference 0.0001"	Correction to be applied cm.
0	to 1	2535.0	2535.0	0	0
1	to 53.6	2535.0	2506.0	-29.0	-0.007
53.6	to 107.3	2506.9	2490.9	-15.1	-0.011
107.3	to 214.6	2490.9	2469.0	-21.9	-0.016
214.6	to 429.2 (*)	2469.0	2413.6	-55.4	-0.030
429.2	to 53.6	2413.6	2477.0	63.4	-0.014
53.6	to 8.3	2477.0	2497.0	20.0	-0.009
8.3	to 1	2497.0	2506.0	9.0	-0.007

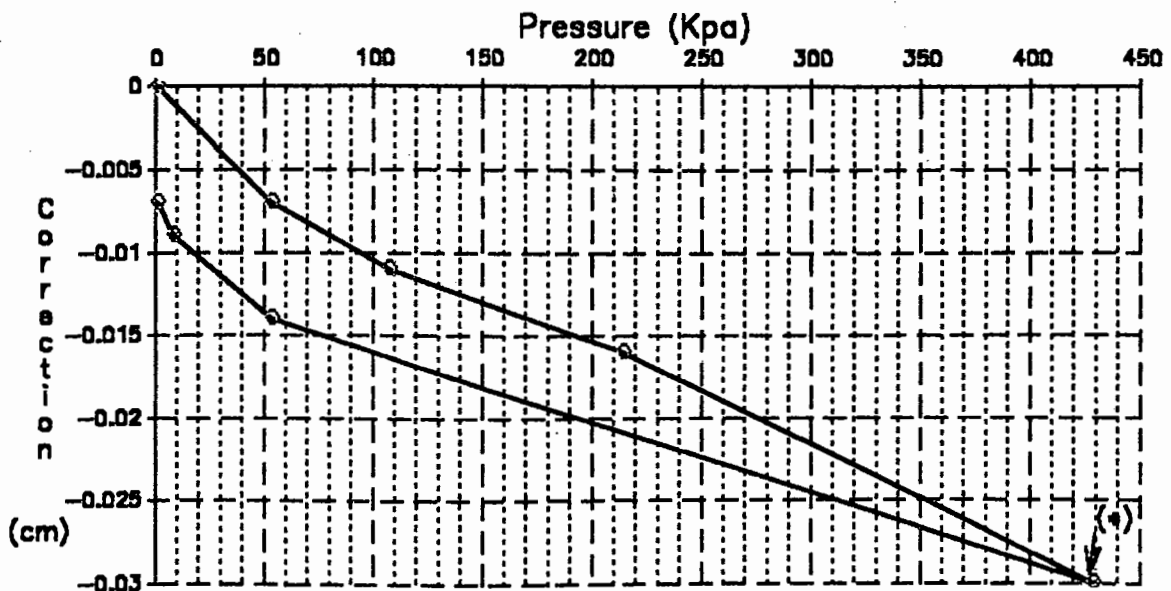


Figure E.04: Consolidometer test for expansive and collapsing soils [400 Kpa] - Calibration of equipment.

(*) - 429.2 Kpa load kept on free of prop for 12 hours, (other loads kept on for 5 minutes).

E.3 REFERENCES FOR APPENDIX E

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10. DE S. VINAGRE, T.J.V. (1978): Postgraduate course project for Advanced Soil Mechanics, C.E 500 " Expansive Soils: Review of the main aspects including their identification; An experimental study of potential expansive soils from the Cape Peninsula". Department of Civil Engineering, University of Cape Town.
16. DE S. VINAGRE, T.J.V. (1976/77): Master Thesis - Diaries One, Two, Three, Four, Five and Six.

E.4 TEST RESULTS FOR NATURAL SOILS (Remoulded and Undisturbed samples)

E.4.1 Site 11 - Rosebank, Cape

Table E.05: Site 11, Rosebank [Remoulded samples - 1 Kpa vertical pressure, and then water added at 1 Kpa without prop] - Expansive and/or Collapsing Test Results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.11-35/	0	2.413	1.417	S.11-42/	0	2.146	2.090
III.270&	0	1.429	1.111	III.282&	0	1.273	1.181
III.310	0	1.242	0.915	IV. 328	0	1.038	0.952
	0	1.110	0.829		0	0.974	0.885
	0	0.962	0.719		0	0.913	0.821
	0	0.841	0.601		0.8	0.912	0.821
	0	0.752	0.452		0.8	0.948	0.854
	0	0.731	0.347		0.8	1.018	0.909
	1.0	0.730	0.352		0.8	1.065	0.937
	1.0	0.738	0.358		0.8	1.150	1.019
	1.0	0.755	0.413		0.8	1.188	1.047
	1.0	0.795	0.496		0.8	1.251	1.102
	1.0	0.817	0.523		0.8	1.273	1.130
	1.0	0.877	0.606		0.8	1.318	1.185
	1.0	0.914	0.634		0.8	1.333	1.194
	1.0	0.953	0.689		0.8	1.337	1.203
	1.0	0.995	0.744		0.8	1.338	1.212
	1.0	1.054	0.827		53.6	1.214	1.203
	1.0	1.081	0.840		107.2	1.143	1.194
	1.0	1.143	0.854		160.7	1.105	1.185
	49.0	1.007	0.844		214.3	1.076	1.176
	98.1	0.921	0.835		267.9	1.051	1.167
	147.1	0.891	0.826		321.5	1.024	1.157
	196.1	0.864	0.817		53.6	1.073	1.240
	245.2	0.838	0.808		8.3	1.156	1.244
	294.2	0.815	0.799		0.8	1.135	1.245
	49.0	0.863	0.882				
	9.8	0.905	0.892				
	1.0	0.929	0.895				

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.11-49/	0	1.391	1.232	S.11-52/	0	2.466	1.539
III.305&	0	1.184	1.062	III.317&	0	1.458	0.981
III.330	0	1.162	1.043	III.347	0	1.216	0.775
	0	1.114	1.000		0	1.100	0.670
	1.0	1.112	1.000		0	1.022	0.591
	1.0	1.150	1.033		0	0.958	0.478
	1.0	1.173	1.061		0.8	0.956	0.478
	1.0	1.203	1.088		0.8	0.969	0.496
	1.0	1.205	1.022		0.8	0.991	0.537
	49.0	1.162	1.026		0.8	1.020	0.579
	98.1	1.117	1.030		0.8	1.078	0.634
	147.1	1.094	1.035		0.8	1.126	0.661
	196.1	1.067	1.039		0.8	1.200	0.716
	245.2	1.046	1.043		0.8	1.244	0.744
	294.2	1.027	1.047		0.8	1.286	0.771
	49.0	1.063	1.102		0.8	1.306	0.813
	9.8	1.102	1.106		0.8	1.318	0.840
	1.0	1.133	1.108		0.8	1.334	0.854
					0.8	1.350	0.863
					0.8	1.374	0.873
					0.8	1.383	0.882
					53.6	1.193	0.872
					107.3	1.054	0.863
					160.9	1.012	0.854
					214.6	0.976	0.845
					268.2	0.947	0.836
					321.9	0.921	0.827
					53.6	0.971	0.909
					8.3	1.002	0.915
					0.8	1.015	0.917

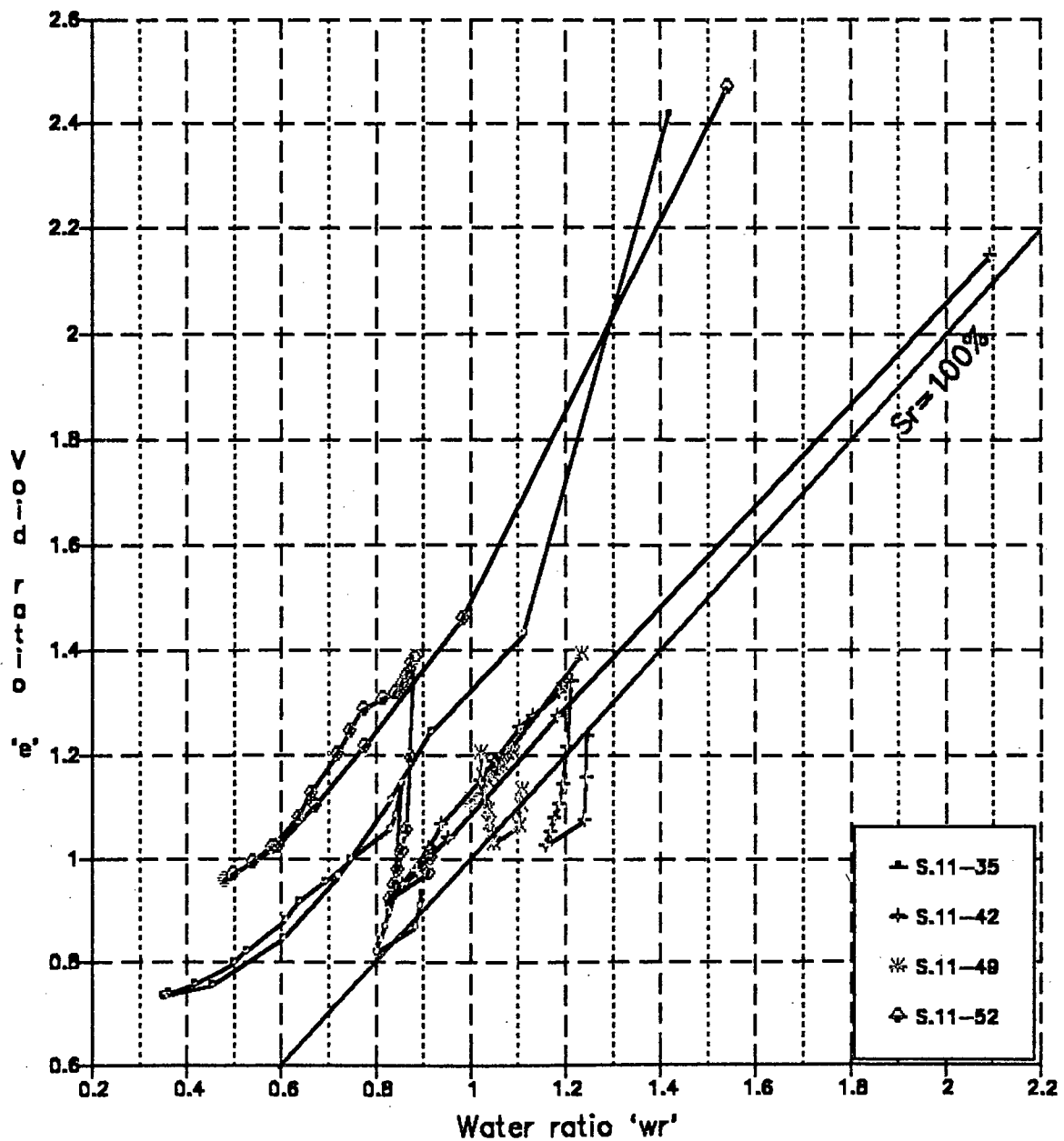


Figure E.05: Site 11, Rosebank [Remoulded samples - 1 Kpa overnight vertical pressure, and then water added at 1 Kpa without prop] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

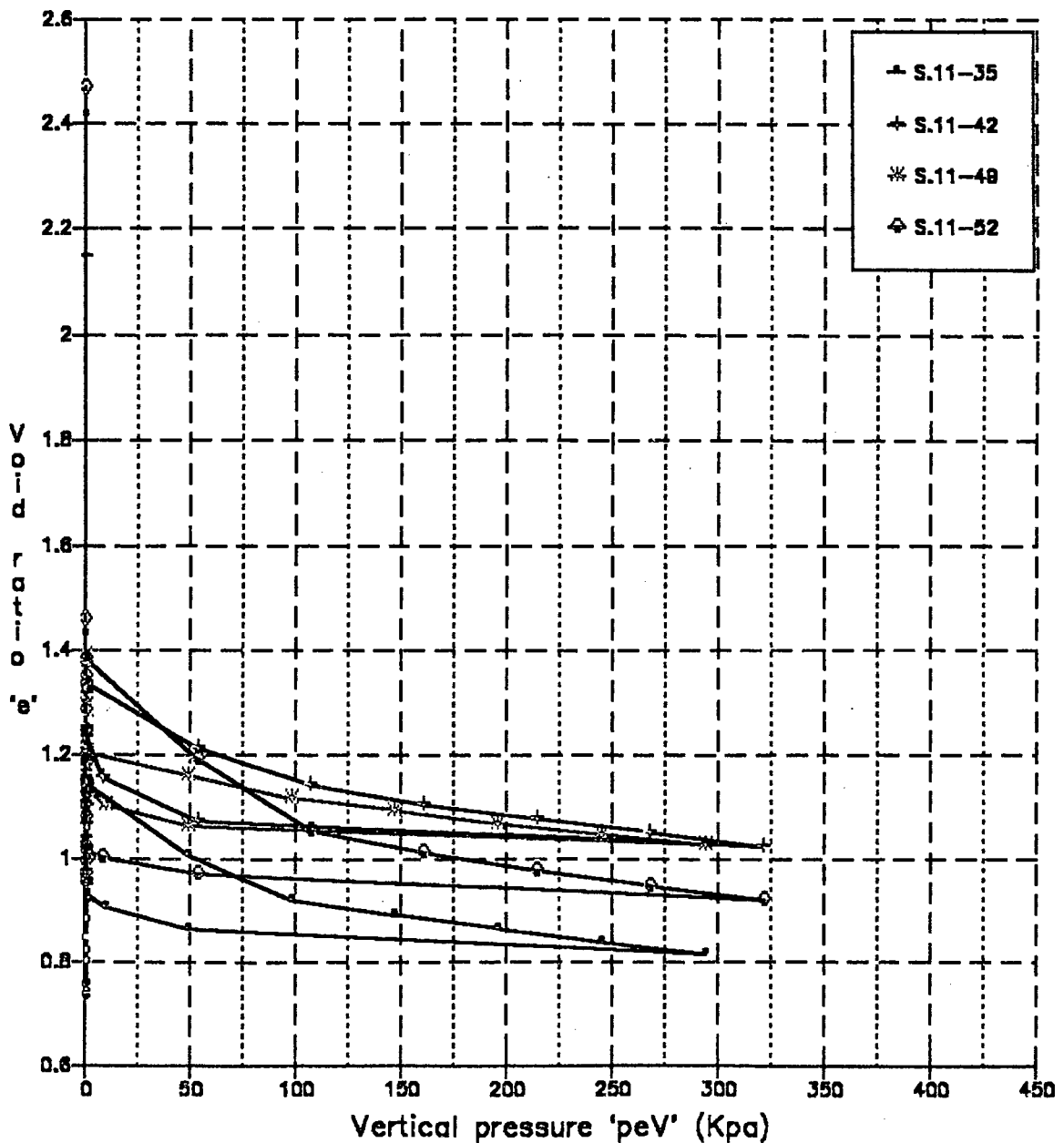


Figure E.06: Site 11, Rosebank [Remoulded samples - 1 Kpa overnight vertical pressure, and then water added at 1 Kpa without prop] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.06: Site 11, Rosebank [Remoulded samples - 50 Kpa vertical pressure overnight, and then water added at 50 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.11-36/	0	2.601	1.506	S.11-41/	0	2.142	2.041
II. 272&	0	1.612	1.130	III.278&	0	1.169	1.061
III.307	0	1.419	0.966	III.322	0	0.955	0.855
	0	1.280	0.867		0	0.864	0.752
	0	1.116	0.737		53.6	0.864	0.752
	0	0.971	0.609		53.6	0.885	0.771
	0	0.869	0.463		53.6	0.957	0.854
	0	0.853	0.416		53.6	0.990	0.895
	49.0	0.854	0.416		53.6	1.017	0.964
	49.0	0.867	0.455		53.6	1.027	1.006
	49.0	0.898	0.551		53.6	1.029	1.019
	49.0	0.918	0.592		53.6	1.043	1.047
	49.0	0.958	0.703		107.3	1.036	1.030
	49.0	0.974	0.744		160.9	1.019	1.014
	49.0	0.982	0.827		214.6	1.001	0.997
	49.0	0.985	0.854		268.2	0.986	0.981
	49.0	0.986	0.882		321.9	0.972	0.964
	98.1	0.959	0.865		53.6	1.025	1.047
	147.1	0.926	0.849		8.3	1.072	1.055
	196.1	0.895	0.832		0.8	1.117	1.058
	245.2	0.869	0.816				
	294.2	0.846	0.799				
	49.0	0.902	0.895				
	9.8	0.983	0.909				
	1.0	1.035	0.917				

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.11-50/	0	1.386	1.233	S.11-64/	0	2.17	1.962
III.308&	0	1.193	1.073	IV.451&	0	1.36	1.237
III.332	0	1.165	1.051	IV.464	0	0.87	0.752
	0	1.096	0.989		0	0.79	0.623
	53.6	1.093	0.989		0	0.767	0.557
	53.6	1.107	1.019		1.0	0.767	0.557
	53.6	1.109	1.061		54.6	0.758	0.551
	53.6	1.110	1.074		54.6	0.764	0.579
	107.3	1.102	1.058		54.6	0.781	0.634
	160.9	1.089	1.041		54.6	0.816	0.716
	214.6	1.067	1.025		54.6	0.903	0.827
	268.2	1.050	1.008		54.6	0.906	0.854
	321.9	1.031	0.992		109.3	0.900	0.850
	53.6	1.071	1.074		163.9	0.886	0.847
	8.3	1.112	1.085		218.6	0.870	0.843
	0.8	1.149	1.088		437.2	0.810	0.827
					874.4	0.753	0.799
					437.2	0.765	0.964
					218.6	0.789	0.975
					109.3	0.827	0.980
					54.6	0.842	0.983
					8.4	0.944	0.986
					0.8	0.973	0.986

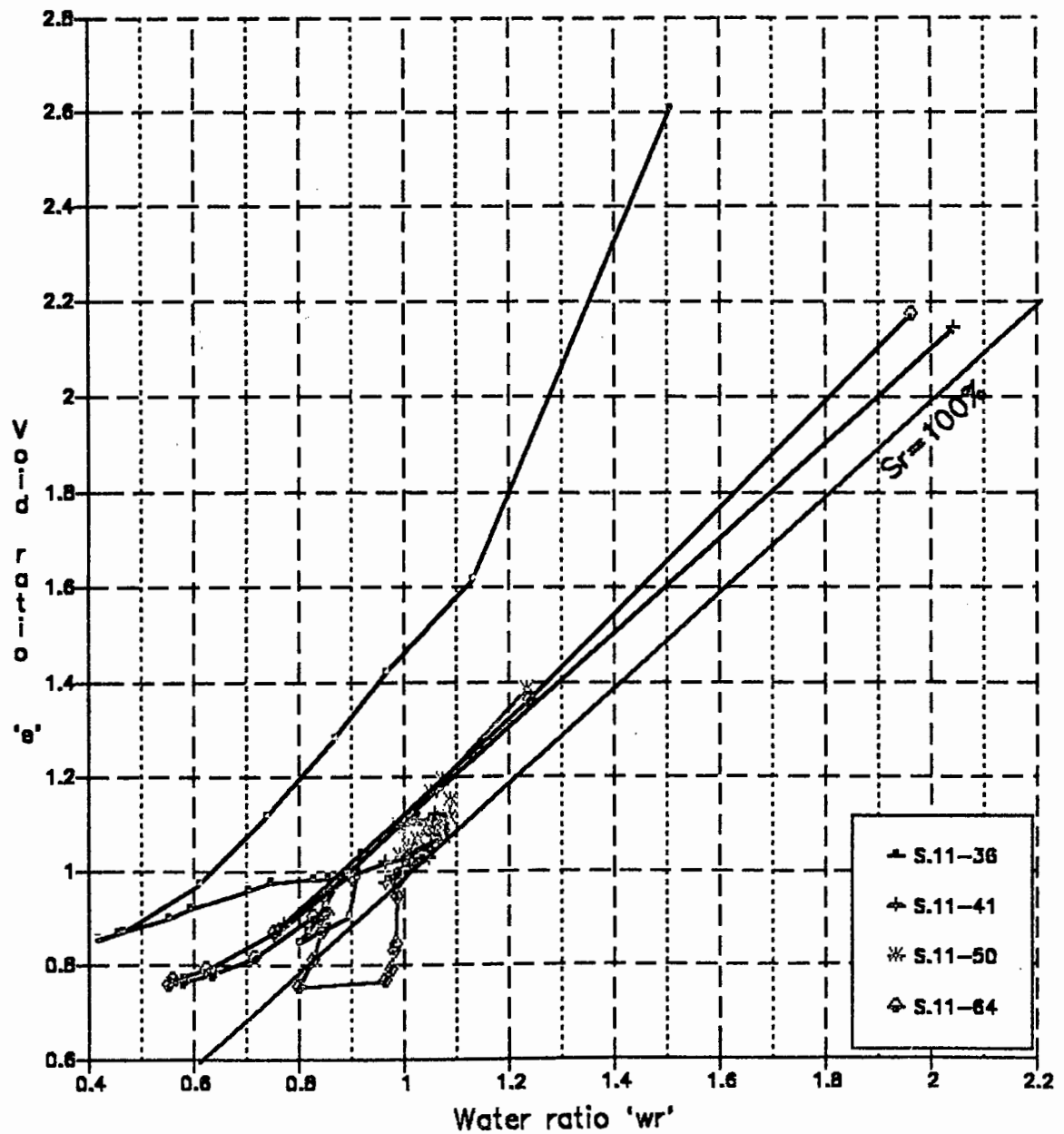


Figure E.07: Site 11, Rosebank [Remoulded samples - 50 Kpa overnight vertical pressure and then water added at 50 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

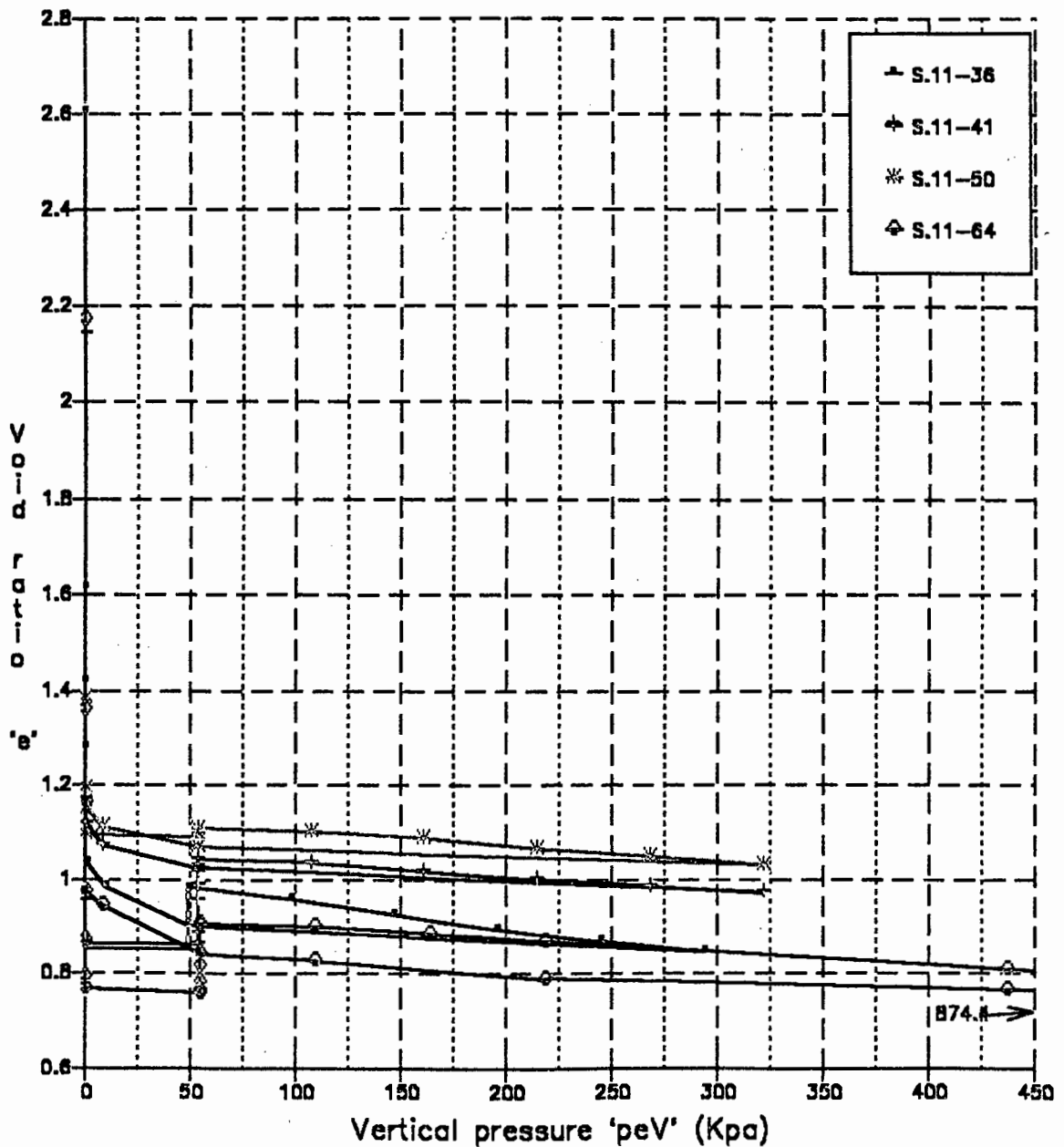


Figure E.08: Site 11, Rosebank [Remoulded Samples - 50 Kpa overnight vertical pressure and then water added at 50 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
✓S.11-11/ II.216& II.236	0 0 0 0 0 0 49.0 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 49.0 9.8 1.0	1.925 1.067 1.000 0.829 0.717 0.695 0.697 0.691 0.688 0.693 0.705 0.717 0.763 0.814 0.822 0.824 0.823 0.818 0.813 0.807 0.830 0.861 0.925	1.777 0.982 0.915 0.739 0.582 0.486 0.468 0.468 0.468 0.496 0.565 0.606 0.689 0.785 0.854 0.868 0.851 0.833 0.816 0.799 0.873 0.887 0.890	✓S.11-23/ II.253& III.287	0 0 0 0 0 0 0 0 0 49.0 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 49.0 9.8 1.0	2.142 1.427 1.219 1.136 1.003 0.854 0.732 0.720 0.715 0.715 0.715 0.717 0.722 0.723 0.734 0.758 0.822 0.836 0.857 0.856 0.851 0.845 0.840 0.896 0.971 0.993	1.992 1.332 1.134 1.054 0.919 0.766 0.561 0.477 0.317 0.317 0.317 0.331 0.413 0.441 0.537 0.634 0.785 0.827 0.882 0.882 0.882 0.882 0.840 0.923 0.937 0.865

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
✓ S.11-25/ II.256& III.289	0 0 0 0 0 0 53.6 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 160.9 214.6 268.2 321.9 53.6 8.3 0.8	1.628 1.056 0.888 0.830 0.765 0.739 0.737 0.733 0.731 0.734 0.746 0.770 0.789 0.835 0.850 0.872 0.874 0.872 0.865 0.857 0.850 0.905 0.953 0.981	1.471 0.944 0.778 0.716 0.614 0.525 0.488 0.488 0.488 0.496 0.551 0.647 0.675 0.758 0.785 0.854 0.882 0.868 0.855 0.855 0.841 0.827 0.909 0.920	✓ S.11-33/ II.250& III.295	0 0 0 0 0 0 0 53.6 107.3 107.3 107.3 107.3 107.3 107.3 160.9 214.6 268.2 321.9 53.6 8.3 0.8	2.281 1.341 1.081 0.983 0.973 0.895 0.923 0.922 0.919 0.945 0.993 0.998 1.005 1.004 0.998 0.991 0.985 1.043 1.116 1.132	2.159 1.261 1.014 0.916 0.906 0.822 0.849 0.849 0.849 0.854 0.923 0.964 1.047 1.033 1.020 1.006 0.992 1.061 1.072 1.074
✓ S.11-38/ II.233& III.304	0 0 0 0 0 0 53.6 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 160.9 214.6 268.2 321.9 53.6 8.3 0.8	2.468 1.425 1.278 1.124 0.987 0.836 0.758 0.756 0.754 0.763 0.787 0.800 0.823 0.842 0.868 0.873 0.865 0.851 0.836 0.824 0.885 0.920 0.938	1.614 1.181 1.040 0.900 0.770 0.621 0.477 0.477 0.477 0.496 0.565 0.606 0.689 0.730 0.813 0.827 0.813 0.799 0.785 0.771 0.827 0.843 0.849	✓ S.11-43/ III.284& III.316	0 0 0 0 0 0 53.6 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 160.9 214.6 268.2 321.9 53.6 8.3 0.8	1.425 0.978 0.898 0.827 0.729 0.717 0.713 0.711 0.718 0.735 0.747 0.785 0.828 0.831 0.837 0.839 0.837 0.832 0.825 0.818 0.866 0.907 0.934	1.268 0.853 0.772 0.694 0.519 0.463 0.463 0.463 0.482 0.551 0.592 0.675 0.744 0.785 0.813 0.827 0.813 0.799 0.785 0.771 0.854 0.865 0.871

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
× S.11-46/ III.290& III.339	0 0 0 0 53.6 107.3 107.3 107.3 107.3 160.9 214.6 268.2 321.9 53.6 8.3 0.8	2.123 1.528 1.418 1.339 1.269 1.255 1.248 1.251 1.251 1.252 1.244 1.221 1.190 1.158 1.205 1.258 1.261	1.989 1.408 1.299 1.225 1.157 1.157 1.157 1.168 1.174 1.185 1.171 1.158 1.130 1.168 1.168 1.168	S.11-48/ III.303& III.335	0 0 0 0 53.6 107.3 107.3 107.3 107.3 160.9 214.6 268.2 321.9 53.6 8.3 0.8	1.395 1.237 1.196 1.096 1.090 1.084 1.089 1.089 1.089 1.084 1.069 1.050 1.033 1.070 1.116 1.139	1.256 1.122 1.081 0.989 0.989 0.989 1.019 1.047 1.061 1.047 1.034 1.020 1.006 1.061 1.066 1.069
✓ S.11-54/ III.321& III.351	0 0 0 0 0 49.0 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 49.0 9.8 1.0	2.405 1.436 1.294 1.147 0.965 0.827 0.828 0.826 0.835 0.850 0.870 0.899 0.913 0.922 0.931 0.934 0.926 0.909 0.892 0.875 0.929 0.948 0.958	1.530 1.094 0.965 0.832 0.667 0.488 0.488 0.488 0.496 0.537 0.592 0.661 0.703 0.744 0.758 0.771 0.754 0.737 0.720 0.703 0.785 0.799 0.804	× S.11-57/ III.354	0 0 0 0 0 49.0 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 49.0 9.8 1.0	2.363 1.652 1.492 1.374 1.201 1.200 1.194 1.200 1.202 1.194 1.154 1.134 1.107 1.103 1.099 1.098 1.061 1.027 0.996 0.973 1.028 1.053 1.053	1.412 1.066 0.955 0.864 0.716 0.716 0.716 0.730 0.771 0.799 0.827 0.854 0.882 0.887 0.893 0.895 0.895 0.868 0.854 0.840 0.923 0.931 0.931

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.11-62/	0	1.462	1.248	S.11-61/	0	1.380	1.190
III.396&	0	1.184	1.028	IV.416&	0	0.996	0.873
IV.430	0	1.095	0.950	IV.437	0	1.140	1.017
	0	0.996	0.854		0	1.319	1.287
	0	0.783	0.612		1.0	1.319	1.287
	0	0.741	0.482		54.9	1.153	1.267
	0	0.735	0.518		109.9	1.090	1.240
	1.0	0.735	0.518		109.9	1.088	1.267
	54.2	0.721	0.496		109.9	1.087	1.212
	108.4	0.718	0.496		164.8	1.051	1.196
	108.4	0.720	0.523		219.8	1.012	1.181
	108.4	0.726	0.579		439.5	0.915	1.118
	108.4	0.736	0.606		879.0	0.816	0.992
	108.4	0.748	0.634		439.5	0.829	1.033
	108.4	0.763	0.661		219.8	0.856	1.054
	108.4	0.803	0.744		109.9	0.883	1.064
	108.4	0.819	0.827		54.9	0.913	1.069
	108.4	0.827	0.854		8.5	0.976	1.073
	108.4	0.829	0.882		0.8	1.008	1.074
	162.6	0.827	0.882				
	216.9	0.821	0.882				
	433.7	0.784	0.882				
	867.5	0.736	0.854				
	433.7	0.746	0.854				
	216.9	0.767	0.882				
	108.4	0.790	0.882				
	54.2	0.819	0.882				
	8.4	0.878	0.882				
	0.8	0.937	0.956				

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
✓S.11-60/	0	2.016	1.865	✓S.11-59/	0	2.07	1.898
III.384&	0	1.486	1.375	III.394&	0	1.60	1.471
IV.420	0	1.394	1.287	IV.442	0	1.46	1.342
	0	1.345	1.243		0	1.28	1.168
	0	1.271	1.165		0	1.12	1.006
	0	1.013	0.917		0	0.93	0.815
	0	0.919	0.821		0	0.82	0.689
	0	0.835	0.730		0	0.79	0.656
	1.0	0.835	0.730		0	0.738	0.501
	54.4	0.819	0.723		1.0	0.738	0.501
	108.7	0.812	0.716		54.2	0.737	0.498
	108.7	0.820	0.744		108.4	0.735	0.496
	108.7	0.833	0.771		108.4	0.738	0.523
	108.7	0.819	0.799		108.4	0.755	0.579
	108.7	0.899	0.882		108.4	0.785	0.661
	108.7	0.908	0.964		108.4	0.829	0.744
	108.7	0.909	0.964		108.4	0.859	0.827
	163.1	0.906	0.960		108.4	0.865	0.854
	217.4	0.900	0.956		162.6	0.863	0.850
	434.9	0.863	0.940		216.9	0.857	0.846
	869.8	0.814	0.909		433.7	0.817	0.830
	434.9	0.825	0.993		867.5	0.766	0.799
	108.7	0.881	1.055		433.7	0.778	0.964
	54.4	0.918	1.066		216.9	0.804	0.969
	8.4	1.014	1.074		108.4	0.838	0.971
	0.8	1.118	1.165		54.2	0.872	0.972
					8.4	0.954	0.973
					0.8	0.987	0.973

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
✓ S.11-58/	0	2.76	1.554
III.356&	0	1.80	1.099
IV.413	0	1.63	0.964
	0	1.43	0.799
	0	1.29	0.667
	0	1.19	0.559
	0	1.15	0.482
	0	1.135	0.444
	1.0	1.135	0.444
	54.5	1.135	0.442
	109.0	1.129	0.441
	109.0	1.130	0.468
	109.0	1.131	0.496
	109.0	1.134	0.523
	109.0	1.140	0.579
	109.0	1.152	0.634
	109.0	1.163	0.716
	109.0	1.140	0.771
	109.0	1.106	0.827
	109.0	1.055	0.882
	109.0	1.050	0.937
	163.5	1.006	0.928
	218.0	0.971	0.919
	436.0	0.863	0.882
	872.1	0.765	0.854
	436.0	0.778	0.937
	218.0	0.806	1.002
	109.0	0.842	1.034
	54.5	0.875	1.050
	8.4	0.977	1.065
	0.8	1.047	1.066

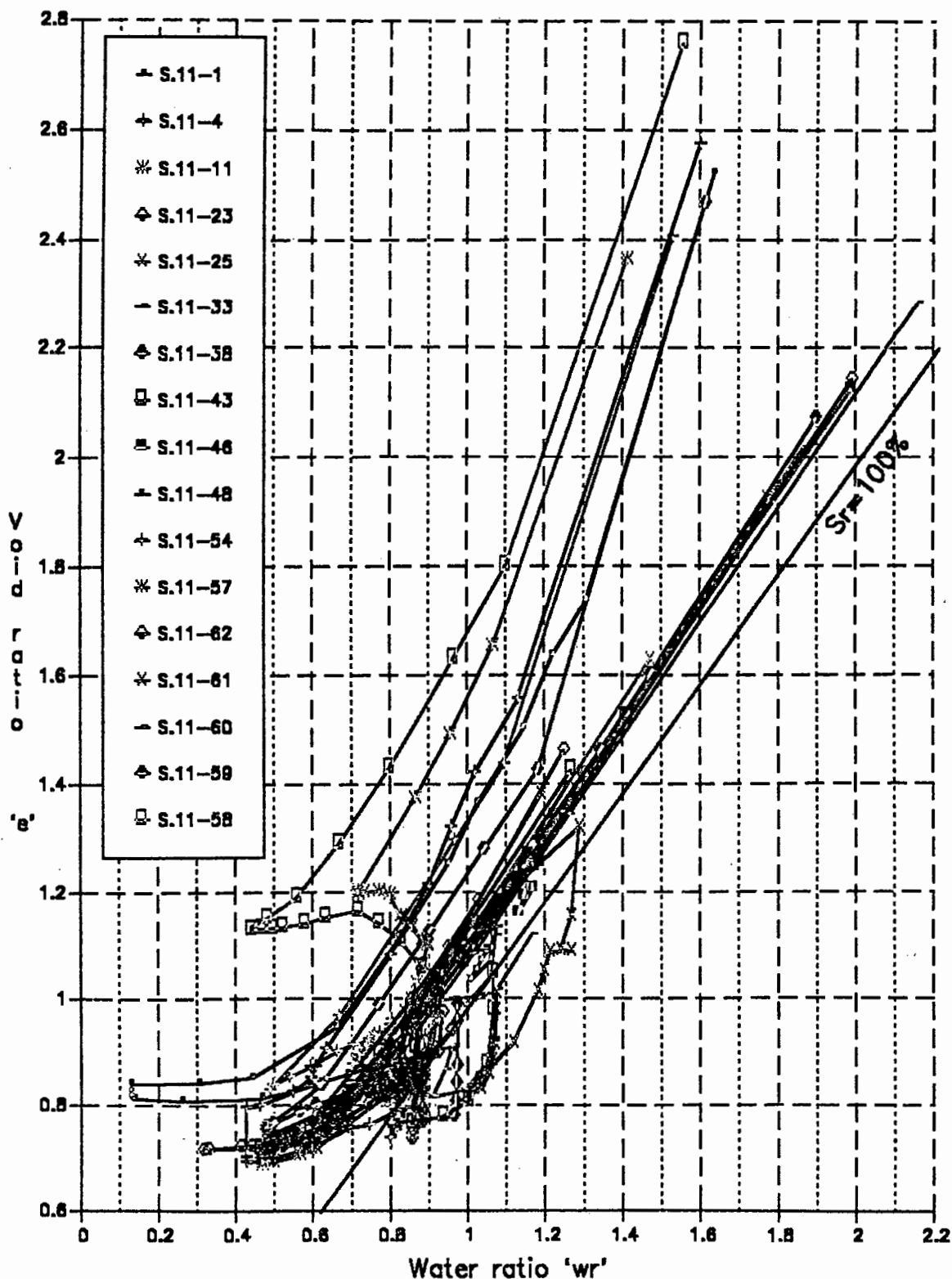


Figure E.09: Site 11, Rosebank [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

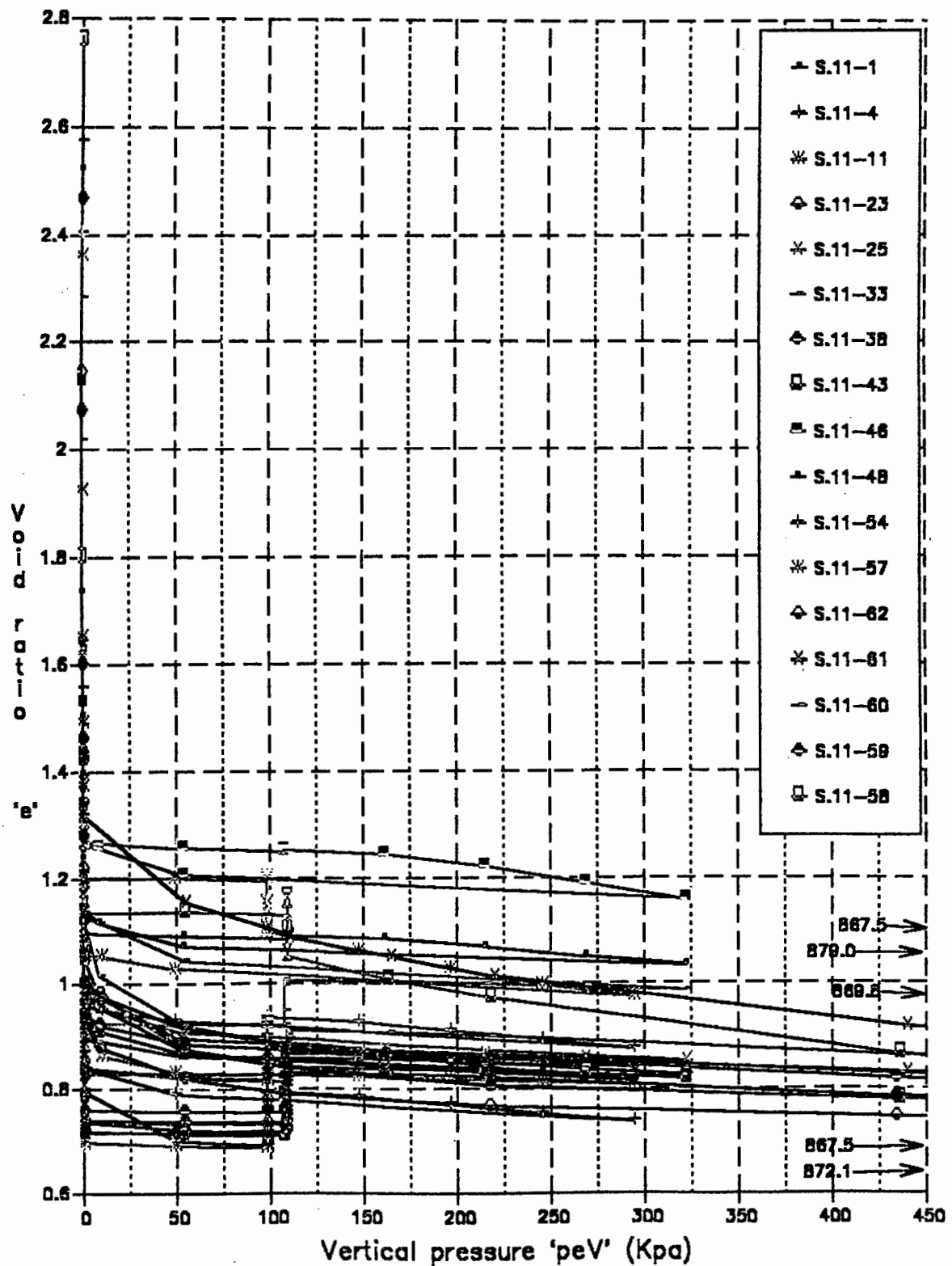


Figure E.10: Site 11, Rosebank [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.08: Site 11, Rosebank [Remoulded samples - 400 Kpa vertical pressure overnight, and then water added at 400 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
✓S.11-37/ II.274& III.302	0 0 0 0 0 0 0 49.0 98.1 196.1 392.3 392.3 392.3 392.3 392.3 49.0 9.8 1.0	2.661 1.486 1.279 1.152 1.001 0.878 0.777 0.760 0.758 0.757 0.754 0.752 0.757 0.766 0.774 0.773 0.774 0.858 0.900 0.903	1.596 1.206 1.017 0.908 0.770 0.658 0.520 0.471 0.471 0.471 0.470 0.468 0.482 0.551 0.620 0.716 0.730 0.813 0.818 0.818	✓S.11-40/ III.276& III.324	0 0 0 0 49.0 98.1 196.1 392.3 392.3 392.3 392.3 49.0 9.8 1.0	2.242 1.226 0.989 0.953 0.946 0.945 0.942 0.941 0.960 0.961 0.961 1.074 1.146 1.150	2.085 1.116 0.884 0.846 0.846 0.846 0.840 0.827 0.854 0.950 0.978 1.061 1.069 1.069
×S.11-51/ III.311& III.326	0 0 0 49.0 98.1 196.1 392.3 392.3 392.3 49.0 9.8 1.0	1.394 1.217 1.139 1.132 1.123 1.087 0.997 0.994 0.992 1.035 1.098 1.120	1.224 1.084 1.014 1.014 1.014 1.006 0.992 1.019 1.033 1.088 1.088 1.091	×S.11-55/ III.323& III.349	0 0 0 0 0 0 0 53.6 107.3 214.6 429.2 429.2 429.2 429.2 429.2 429.2 429.2 429.2 429.2 53.6 8.3 0.8	2.416 1.616 1.444 1.288 1.096 1.049 1.041 1.023 1.017 1.006 0.980 0.983 0.985 0.962 0.931 0.807 0.711 0.675 0.652 0.774 0.938 0.994	1.464 1.044 0.899 0.772 0.602 0.539 0.499 0.499 0.499 0.498 0.496 0.510 0.565 0.606 0.634 0.675 0.716 0.758 0.771 0.854 0.865 0.868

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
✓S.11-65/	0.	2.133	1.915
IV.451&	0.	1.320	1.171
IV.468	0	1.194	1.050
	0	0.958	0.821
	0	0.826	0.683
	0	0.765	0.543
	1.0	0.765	0.543
	54.2	0.763	0.540
	108.4	0.760	0.538
	216.9	0.756	0.533
	433.7	0.746	0.523
	433.7	0.747	0.579
	433.7	0.759	0.634
	433.7	0.774	0.716
	433.7	0.782	0.771
	433.7	0.782	0.799
	867.5	0.759	0.799
	433.7	0.771	0.882
	216.9	0.790	0.896
	108.4	0.846	0.902
	54.2	0.887	0.906
	8.4	0.903	0.909
	0.8	0.939	0.915

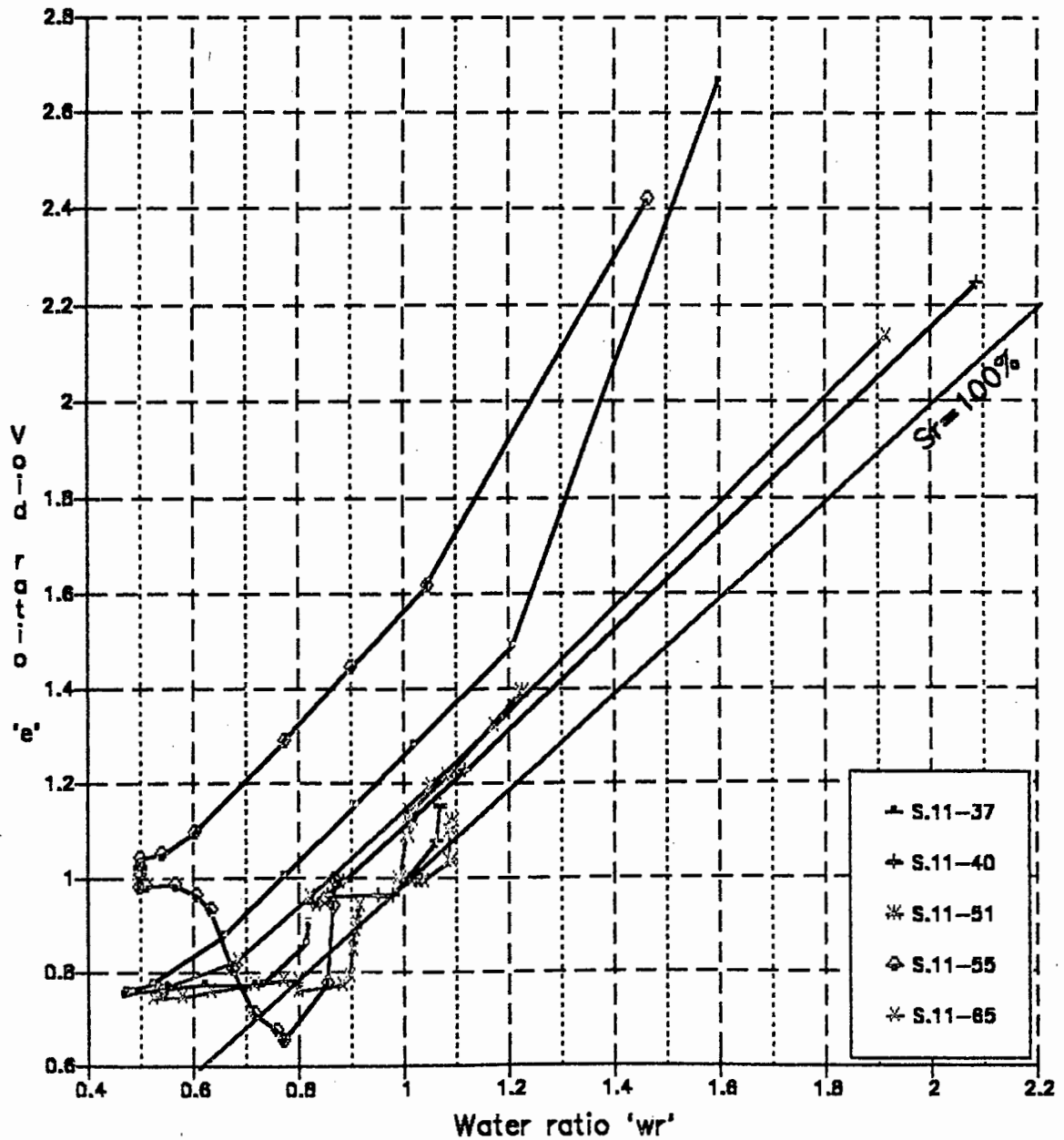


Figure E.11: Site 11, Rosebank [Remoulded samples - 400 Kpa overnight vertical pressure and wetted at 400 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

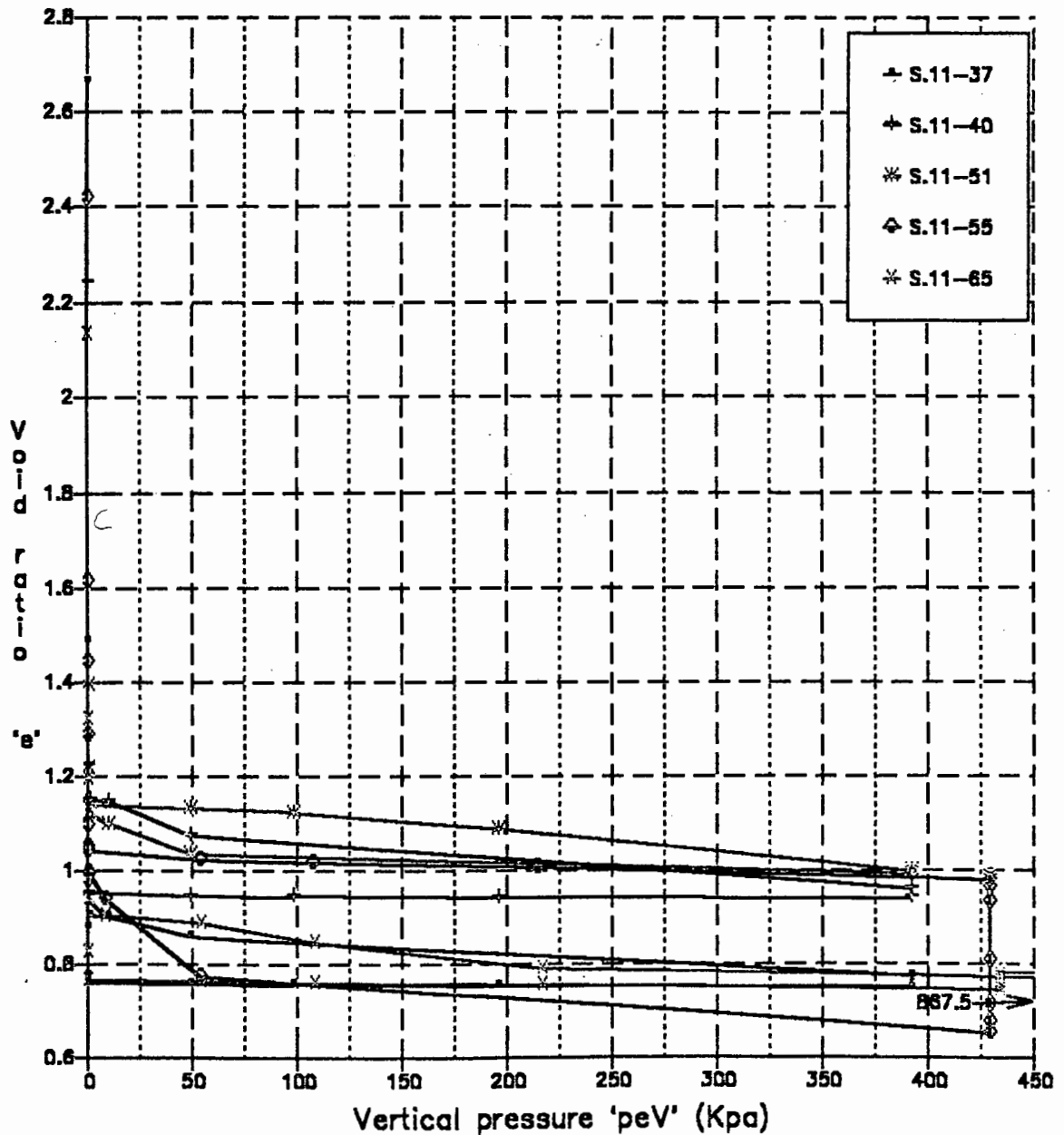


Figure E.12: Site 11, Rosebank [Remoulded samples - 400 Kpa overnight vertical pressure and wetted at 400 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.09: Site 11, Rosebank [Compacted samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
✓S.11-8/ II.162& II.191	0 53.6 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 160.9 214.6 268.2 321.9 53.6 8.3 0.8	0.687 0.666 0.661 0.660 0.668 0.679 0.697 0.727 0.753 0.758 0.761 0.762 0.760 0.754 0.744 0.736 0.774 0.895 0.900	0.272 0.272 0.272 0.289 0.358 0.427 0.510 0.606 0.703 0.750 0.799 0.827 0.813 0.799 0.785 0.771 0.854 0.862 0.865	✓S.11-13/ II.162& II.225	0 53.7 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 161.0 214.6 268.3 322.0 53.7 8.3 0.8	0.693 0.683 0.678 0.678 0.682 0.687 0.694 0.716 0.734 0.745 0.760 0.773 0.779 0.777 0.771 0.761 0.752 0.790 0.811 0.820	0.300 0.300 0.300 0.317 0.372 0.413 0.468 0.551 0.606 0.647 0.703 0.758 0.777 0.763 0.750 0.736 0.722 0.804 0.813 0.815
✓S.11-14/ II.162& II.238	0 53.7 107.3 107.3 107.3 107.3 107.3 107.3 107.3 161.0 214.6 268.3 322.0 53.7 8.3 0.8	0.593 0.588 0.584 0.592 0.620 0.655 0.687 0.704 0.704 0.703 0.699 0.694 0.688 0.716 0.752 0.770	0.446 0.446 0.446 0.468 0.523 0.592 0.661 0.703 0.708 0.694 0.681 0.667 0.653 0.736 0.744 0.747	✓S.11-27/ II.162& II.257	0 53.7 107.3 107.3 107.3 107.3 161.0 214.6 268.3 322.0 53.7 8.3 0.8	0.883 0.854 0.842 0.848 0.853 0.856 0.854 0.847 0.839 0.830 0.857 0.883 0.890	0.777 0.774 0.771 0.799 0.854 0.857 0.843 0.829 0.816 0.802 0.884 0.890 0.890

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.11-70/ ✓	1	0.863	0.634
IV.450&	54.2	0.848	0.634
IV.458	108.4	0.840	0.630
	108.4	0.844	0.661
	108.4	0.857	0.716
	108.4	0.861	0.771
	108.4	0.862	0.799
	162.6	0.850	0.797
	216.9	0.832	0.795
	433.7	0.776	0.787
	867.5	0.718	0.771
	433.7	0.726	0.799
	216.9	0.749	0.821
	108.4	0.764	0.832
	54.2	0.779	0.838
	8.4	0.806	0.843
	0.8	0.830	0.843

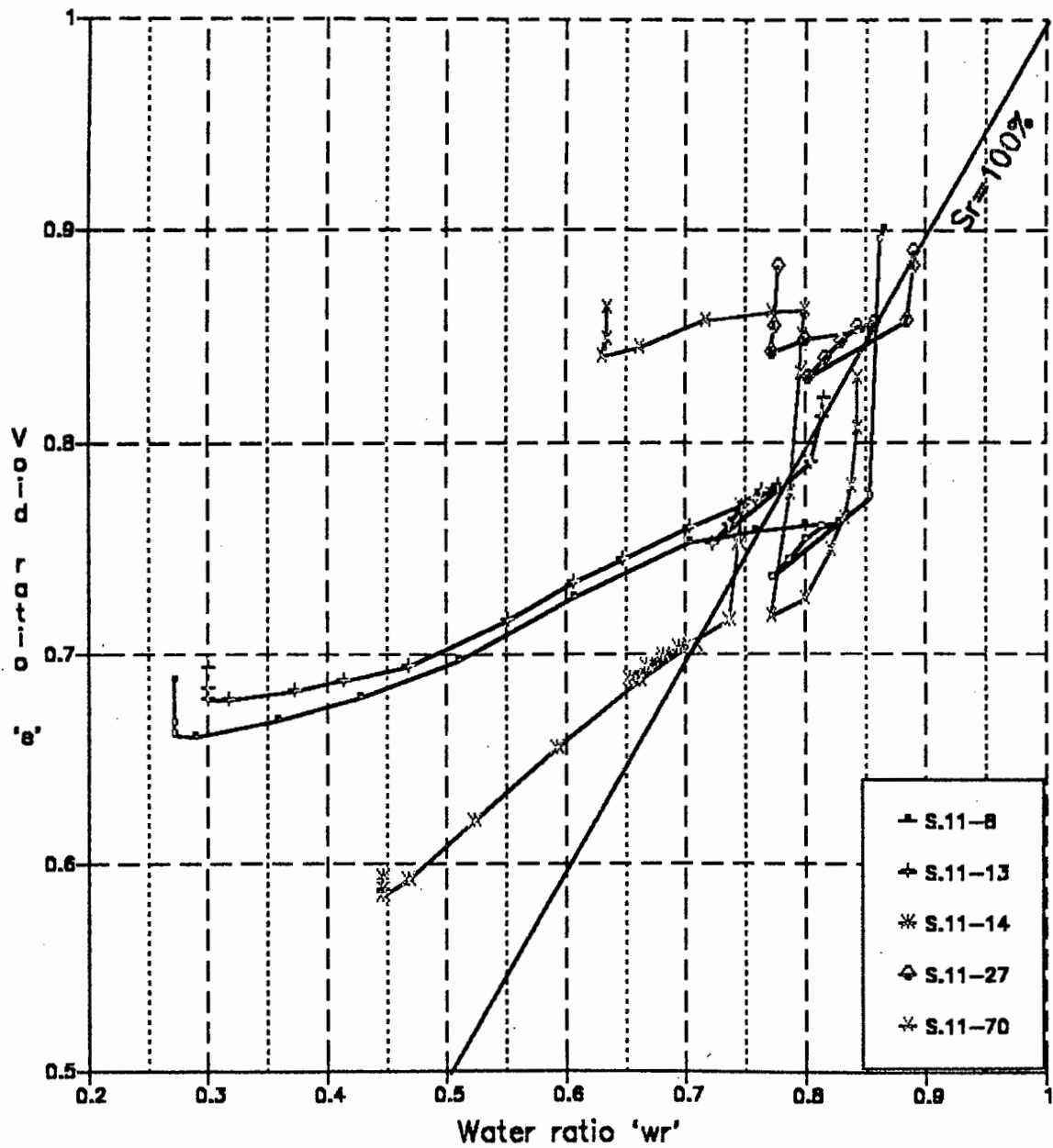


Figure E.13: Site 11, Rosebank [Compacted samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

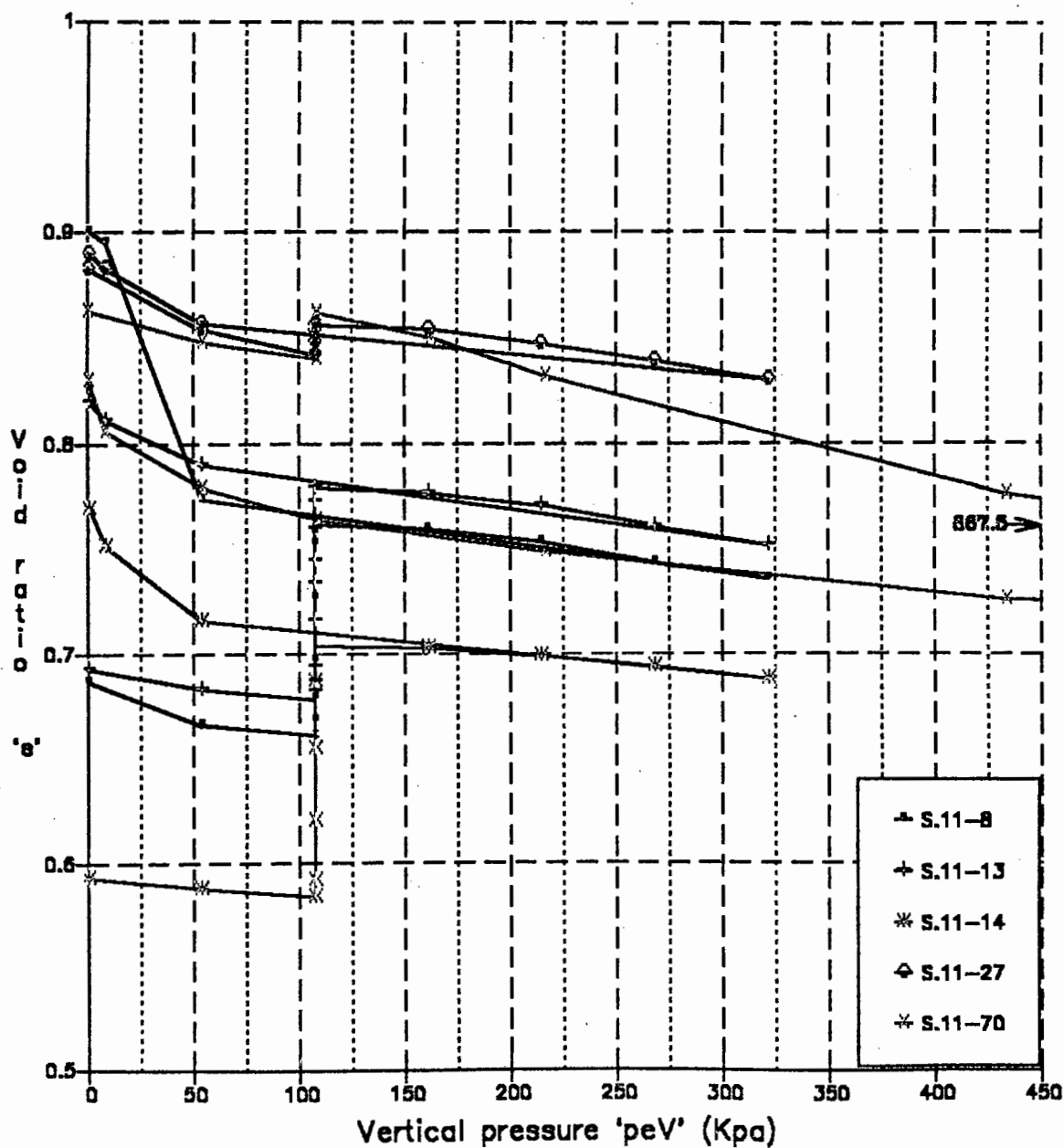


Figure E.14: Site 11, Rosebank [Compacted samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.10: Site 11, Rosebank [Undisturbed Samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
× S.11-6/ II.163& II.181	0 0 0	1.090 1.063 0.991	0.869 0.839 0.763	✓ S.11-12/ II.216& II.220	0 0 0	0.948 0.918 0.931	0.815 0.779 0.793
	0	0.943	0.719		0	0.880	0.749
ND	0	0.890	0.650		53.6	0.866	0.749
	0	0.857	0.603		107.3	0.856	0.749
	0	0.841	0.553		107.3	0.866	0.771
	0	0.815	0.433		107.3	0.877	0.799
	0	0.813	0.341		107.3	0.879	0.840
	0	0.816	0.193		107.3	0.881	0.868
	53.7	0.769	0.193		107.3	0.881	0.882
	107.3	0.753	0.193		160.9	0.879	0.868
	107.3	0.744	0.207		214.6	0.872	0.855
	107.3	0.739	0.289		268.2	0.864	0.841
	107.3	0.734	0.372		321.9	0.857	0.827
	107.3	0.735	0.455		53.6	0.886	0.882
	107.3	0.735	0.537		8.3	0.916	0.890
	107.3	0.742	0.634		0.8	0.922	0.893
	107.3	0.748	0.744				
	107.3	0.749	0.827				
	107.3	0.749	0.882				
	161.0	0.744	0.868				
	214.6	0.731	0.855				
	268.3	0.711	0.841				
	322.0	0.707	0.841				
	53.7	0.724	0.827				
	8.3	0.773	0.887				
	0.8	0.775	0.890				

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
✓S.11-15/ II.221& II.229	0 0 0 0 0 49.0 98.1 98.1 98.1 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 49.0 9.8 1.0	1.016 0.979 0.879 0.836 0.807 0.795 0.785 0.779 0.782 0.794 0.817 0.844 0.846 0.849 0.850 0.850 0.846 0.841 0.836 0.860 0.878 0.883	0.914 0.870 0.765 0.685 0.595 0.551 0.551 0.551 0.565 0.620 0.703 0.785 0.827 0.840 0.854 0.840 0.827 0.813 0.799 0.854 0.865 0.868	✓S.11-17/ II.244& II.247	0 0 53.6 107.3 107.3 107.3 160.9 214.6 268.2 321.9 53.6 8.3 0.8	1.117 1.099 1.068 1.047 1.050 1.050 1.035 1.016 1.001 0.989 1.020 1.054 1.057	1.069 1.050 1.049 1.047 1.061 1.074 1.060 1.047 1.033 1.019 1.058 1.061 1.061
✓S.11-19/ II.245& II.261	0 0 0 0 49.0 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 49.0 9.8 1.0	1.191 1.127 1.101 0.983 0.976 0.966 0.962 0.982 0.988 0.990 0.990 0.987 0.983 0.980 1.004 1.045 1.065	1.115 1.046 1.021 0.892 0.884 0.883 0.882 0.909 0.992 1.047 1.033 1.020 1.006 0.992 1.047 1.050 1.050	✓S.11-22/ II.246& III.279	0 0 0 0 0 53.7 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 161.0 214.6 268.3 322.0 53.7 8.3 0.8	1.090 1.011 0.868 0.750 0.726 0.715 0.708 0.708 0.713 0.722 0.735 0.757 0.785 0.799 0.801 0.800 0.797 0.792 0.787 0.817 0.848 0.849	0.994 0.904 0.751 0.589 0.522 0.463 0.463 0.463 0.468 0.523 0.579 0.647 0.703 0.758 0.785 0.771 0.758 0.744 0.730 0.785 0.793 0.796

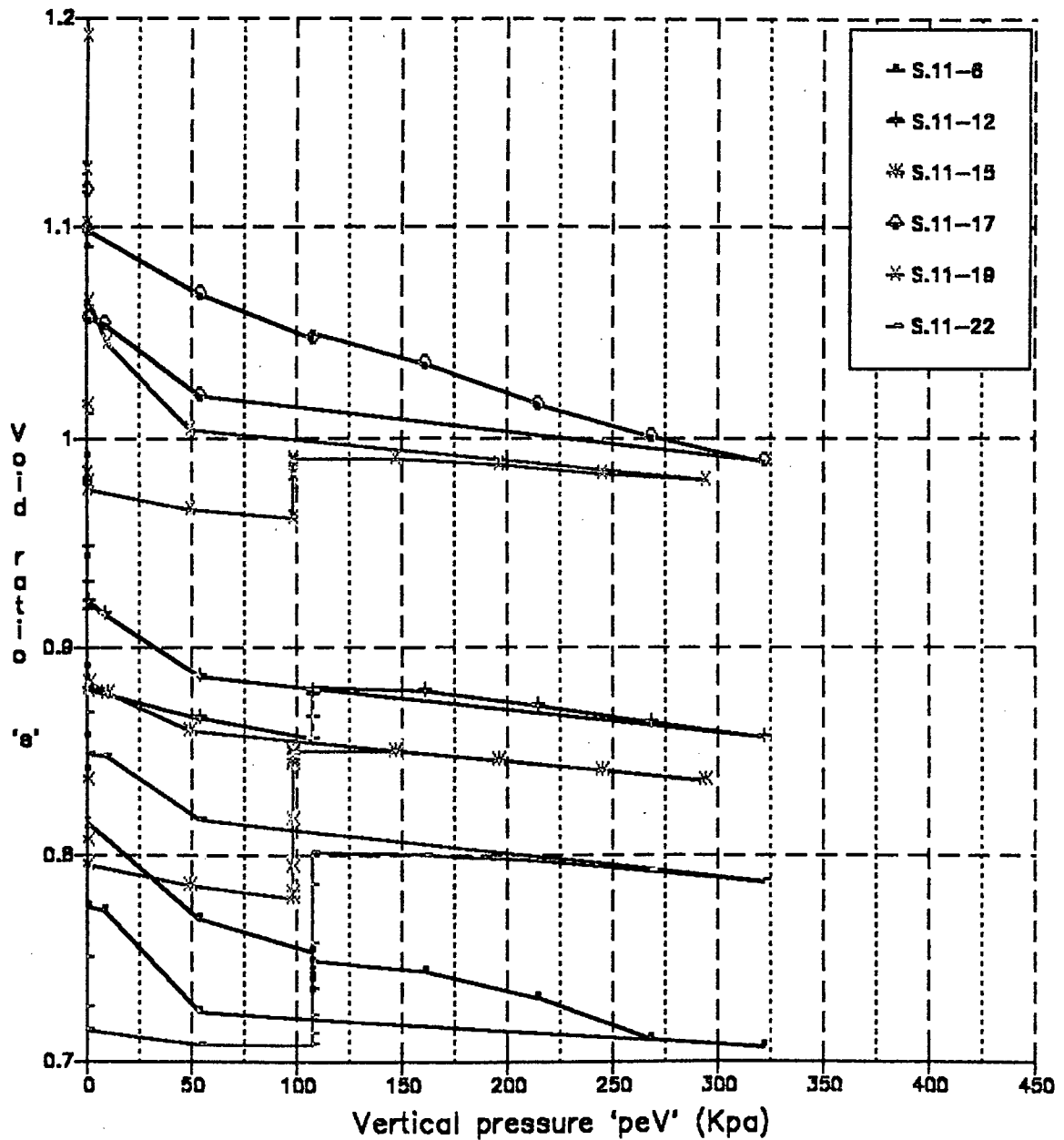


Figure E.16: Site 11, Rosebank [Undisturbed samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

E.4.2 Site 36 - Rondebosch, Cape

Table E.11: Site 36, Rondebosch [Remoulded sample - 1 Kpa vertical pressure overnight, and then water added at 1 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
✓ S.36-13/	0	1.239	1.133
IV.452L&	0	0.903	0.804
IV.460	0	0.679	0.489
	0	0.679	0.481
	0.8	0.679	0.481
	0.8	0.685	0.484
	0.8	0.707	0.524
	0.8	0.765	0.591
	0.8	0.809	0.632
	0.8	0.820	0.645
	53.8	0.741	0.641
	107.6	0.715	0.641
	161.4	0.699	0.636
	215.2	0.683	0.632
	268.9	0.675	0.623
	322.7	0.663	0.618
	53.8	0.679	0.637
	8.3	0.696	0.639
	0.8	0.709	0.640

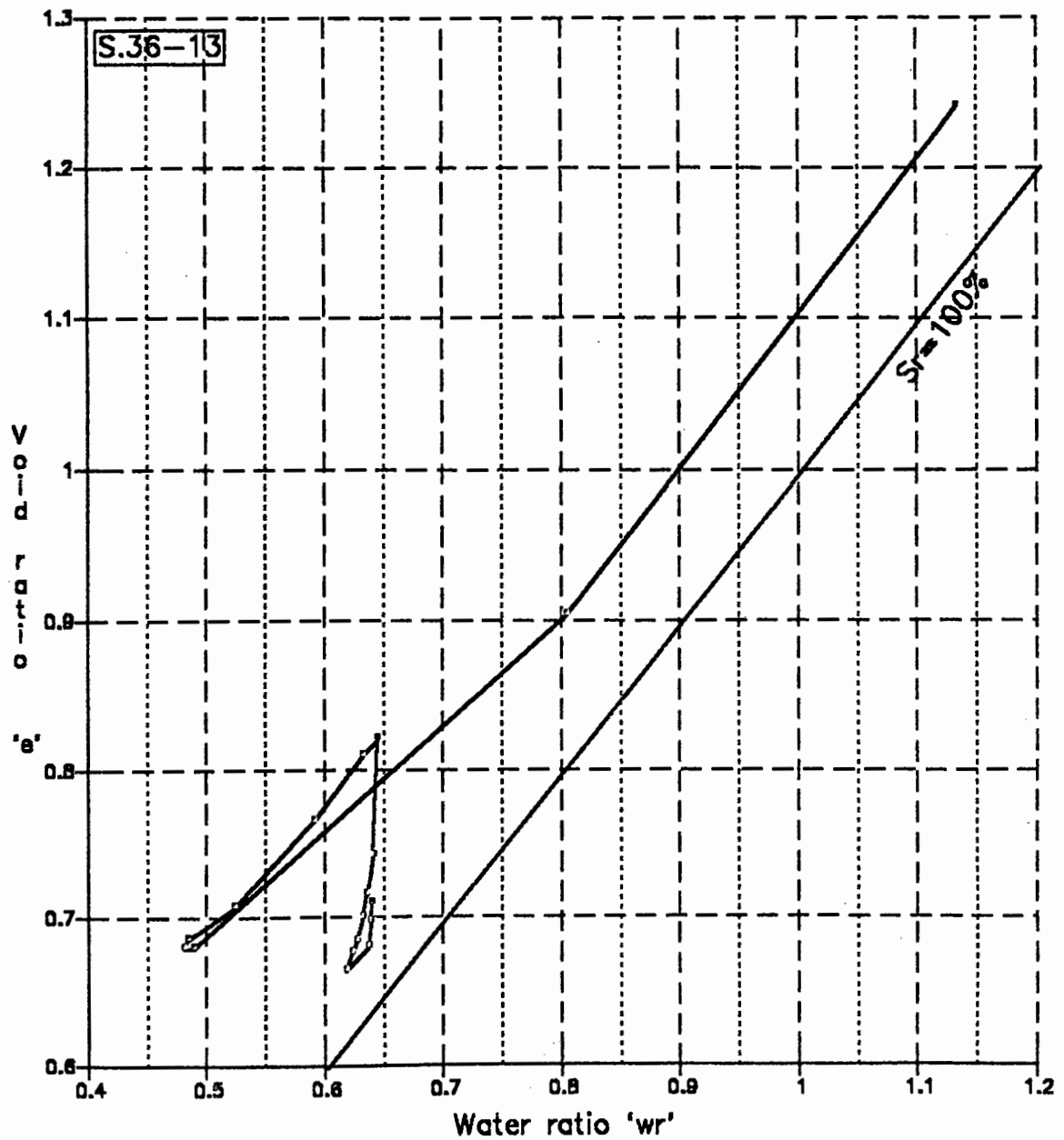


Figure E.17: Site 36, Rondebosch [Remoulded sample - 1 Kpa overnight vertical pressure and then wetted at 1 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

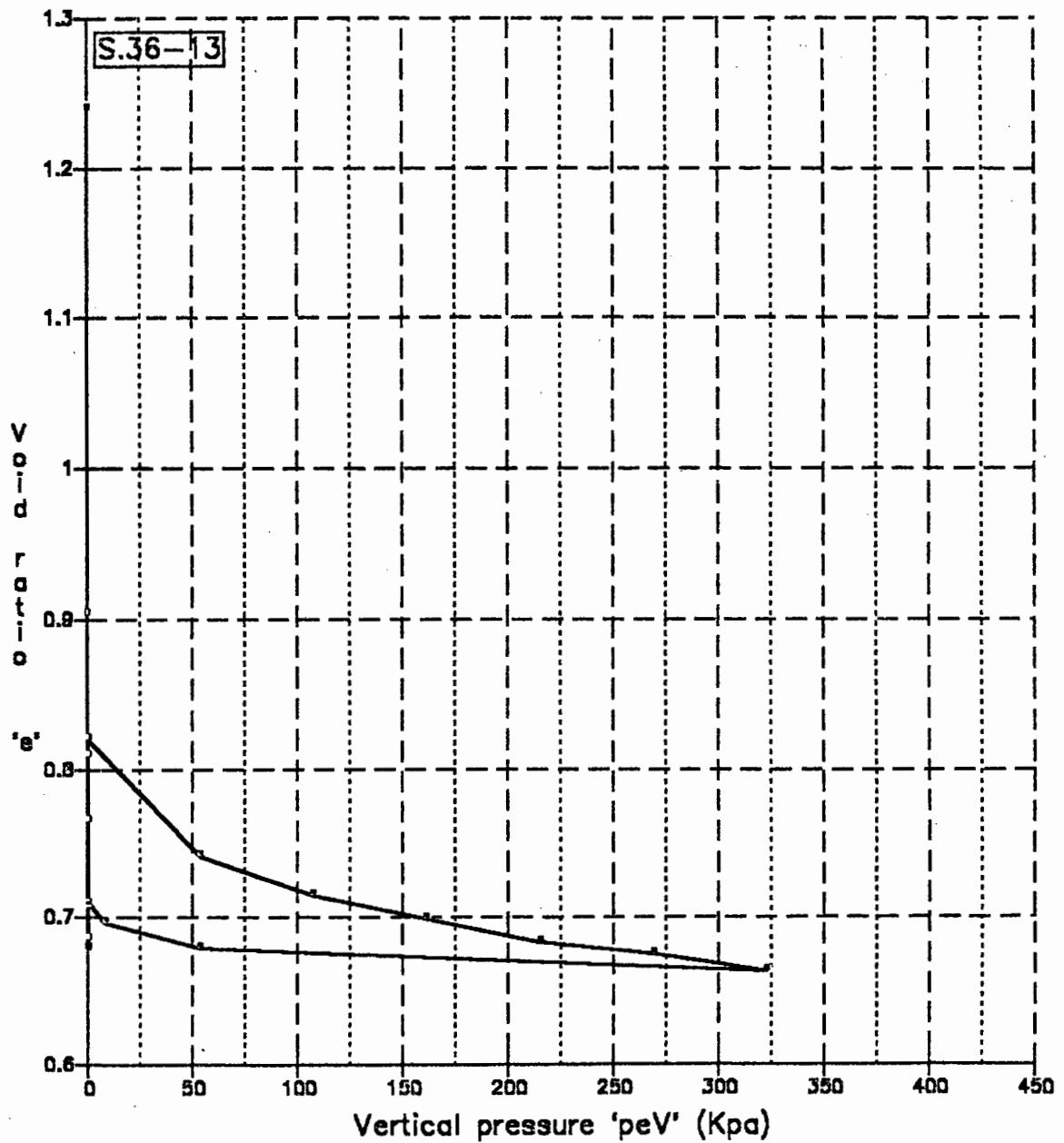


Figure E.18: Site 36, Rondebosch [Remoulded sample - 1 Kpa overnight vertical pressure and then wetted at 1 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.12: Site 36, Rondebosch [Remoulded sample - 50 Kpa vertical pressure overnight, and then water added at 50 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
✓S.36-14/	0	1.355	1.251
IV.452R&	0	1.007	0.903
IV.463	0	0.783	0.673
	0	0.734	0.594
	0	0.712	0.489
	53.8	0.711	0.487
	53.8	0.714	0.497
	53.8	0.723	0.551
	53.8	0.734	0.632
	53.8	0.734	0.645
	107.6	0.728	0.638
	161.4	0.720	0.630
	215.2	0.709	0.621
	268.9	0.704	0.613
	322.7	0.693	0.605
	53.8	0.707	0.618
	8.3	0.719	0.621
	0.8	0.724	0.621

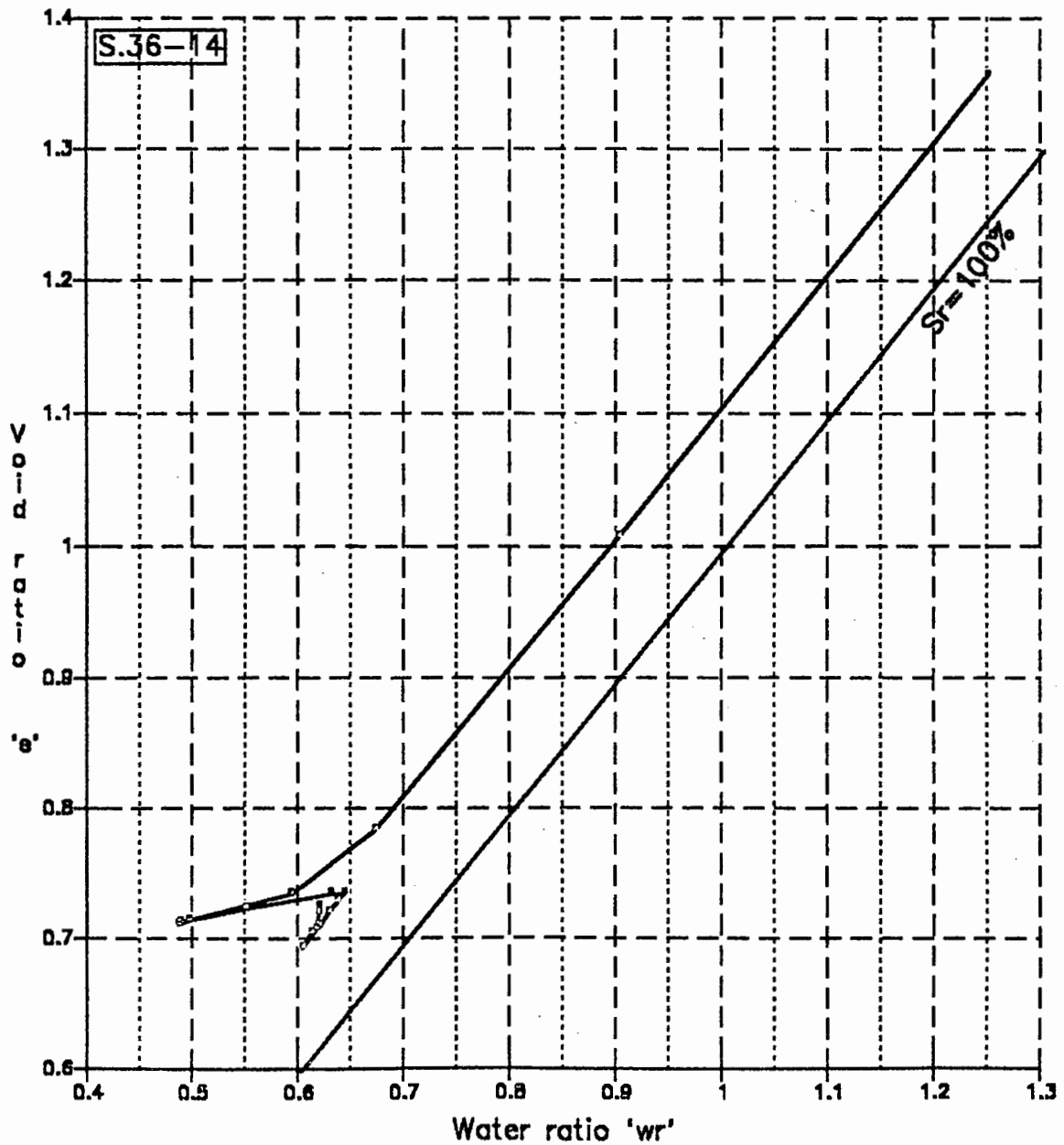


Figure E.19: Site 36, Rondebosch [Remoulded sample - 50 Kpa overnight vertical pressure and then wetted at 50 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

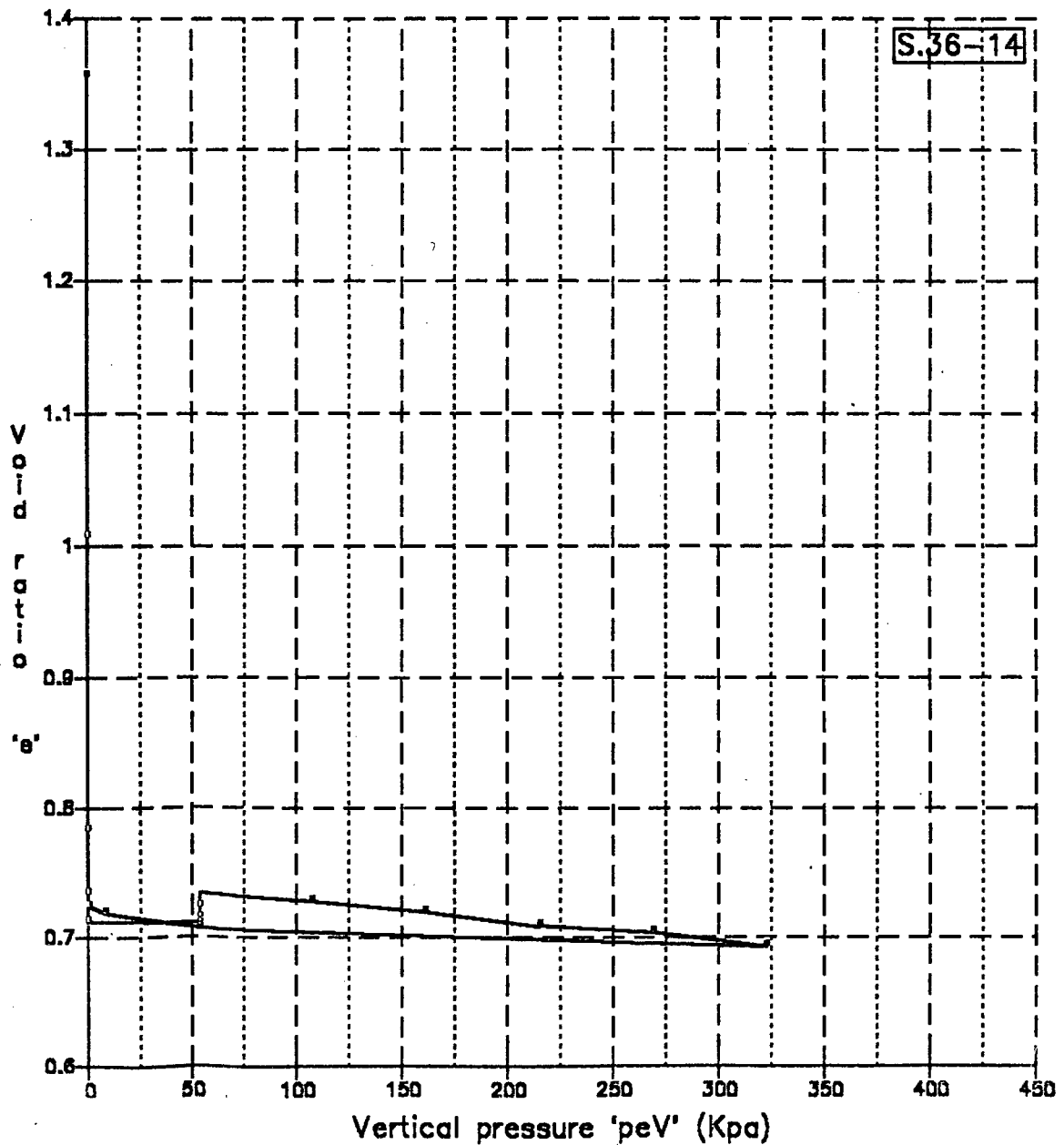


Figure E.20: Site 36, Rondebosch [Remoulded sample - 50 Kpa overnight vertical pressure and then wetted at 50 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.13: Site 36, Rondebosch [Remoulded samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
✓S.36-3/ III.331& III.363	0 0 0 0 0 53.6 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 160.9 107.3 160.9 214.6 268.2 321.9 53.6 8.3 0.8	1.415 1.003 0.801 0.705 0.695 0.689 0.687 0.685 0.686 0.687 0.690 0.693 0.698 0.698 0.696 0.691 0.685 0.680 0.695 0.701 0.703	1.310 0.922 0.725 0.581 0.534 0.468 0.468 0.468 0.476 0.511 0.551 0.591 0.632 0.645 0.635 0.625 0.615 0.605 0.618 0.624 0.624	×S.36-7/ III.360& III.393	0 0 0 0 53.6 107.3 107.3 107.3 107.3 107.3 107.3 107.3 160.9 214.6 268.2 321.9 53.6 8.3 0.8	2.690 1.487 1.325 1.261 1.256 1.243 1.238 1.210 1.055 0.841 0.796 0.789 0.740 0.710 0.682 0.661 0.678 0.686 0.684	1.021 0.658 0.520 0.433 0.433 0.433 0.444 0.470 0.524 0.551 0.564 0.578 0.560 0.550 0.548 0.538 0.551 0.555 0.556
×S.36-9/ III.376& IV.411	0 0 0 49.0 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 49.0 9.8 1.0	1.517 0.951 0.870 0.791 0.783 0.775 0.771 0.773 0.772 0.767 0.751 0.734 0.719 0.728 0.727 0.725	1.364 0.859 0.772 0.694 0.694 0.694 0.699 0.726 0.739 0.732 0.726 0.719 0.712 0.726 0.728 0.728	×S.36-10/ III.378& IV.412	0 0 53.7 107.4 107.4 161.2 214.9 268.6 322.3 53.7 8.3 0.8	0.844 0.782 0.725 0.695 0.694 0.672 0.669 0.654 0.666 0.639 0.662 0.629 0.659 0.643 0.672 0.646 0.672	0.690 0.667 0.667 0.667 0.672 0.669 0.666 0.662 0.659 0.672 0.672 0.672 0.672

✓ Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.36-5/ III.348& III.401	0 0 0 0 1.0 53.9 107.9 107.9 107.9 107.9 107.9 107.9 161.8 215.7 269.7 323.6 377.5 431.4 539.3 647.2 755.0 862.9 647.2 431.4 215.7 161.8 107.9 53.9 0.8	0.837 0.683 0.656 0.600 0.585 0.583 0.579 0.580 0.583 0.589 0.593 0.594 0.585 0.583 0.579 0.575 0.570 0.563 0.553 0.544 0.535 0.527 0.526 0.527 0.530 0.531 0.532 0.533 0.537	0.723 0.591 0.564 0.495 0.425 0.425 0.425 0.430 0.457 0.511 0.538 0.538 0.511 0.506 0.501 0.497 0.491 0.484 0.477 0.470 0.464 0.457 0.459 0.461 0.463 0.464 0.464 0.465 0.465	✓ S.36-12/ III.382& IV.426	0 0 0 0 0 1.0 53.9 107.9 107.9 107.9 107.9 107.9 161.8 215.7 431.4 862.9 431.4 215.7 107.9 53.9 8.3 0.8	0.908 0.837 0.803 0.742 0.672 0.655 0.655 0.646 0.641 0.643 0.645 0.647 0.648 0.643 0.636 0.606 0.559 0.564 0.564 0.575 0.589 0.606 0.650 0.695	0.739 0.704 0.672 0.610 0.532 0.481 0.481 0.481 0.511 0.538 0.538 0.591 0.589 0.583 0.579 0.564 0.618 0.645 0.658 0.665 0.671 0.672

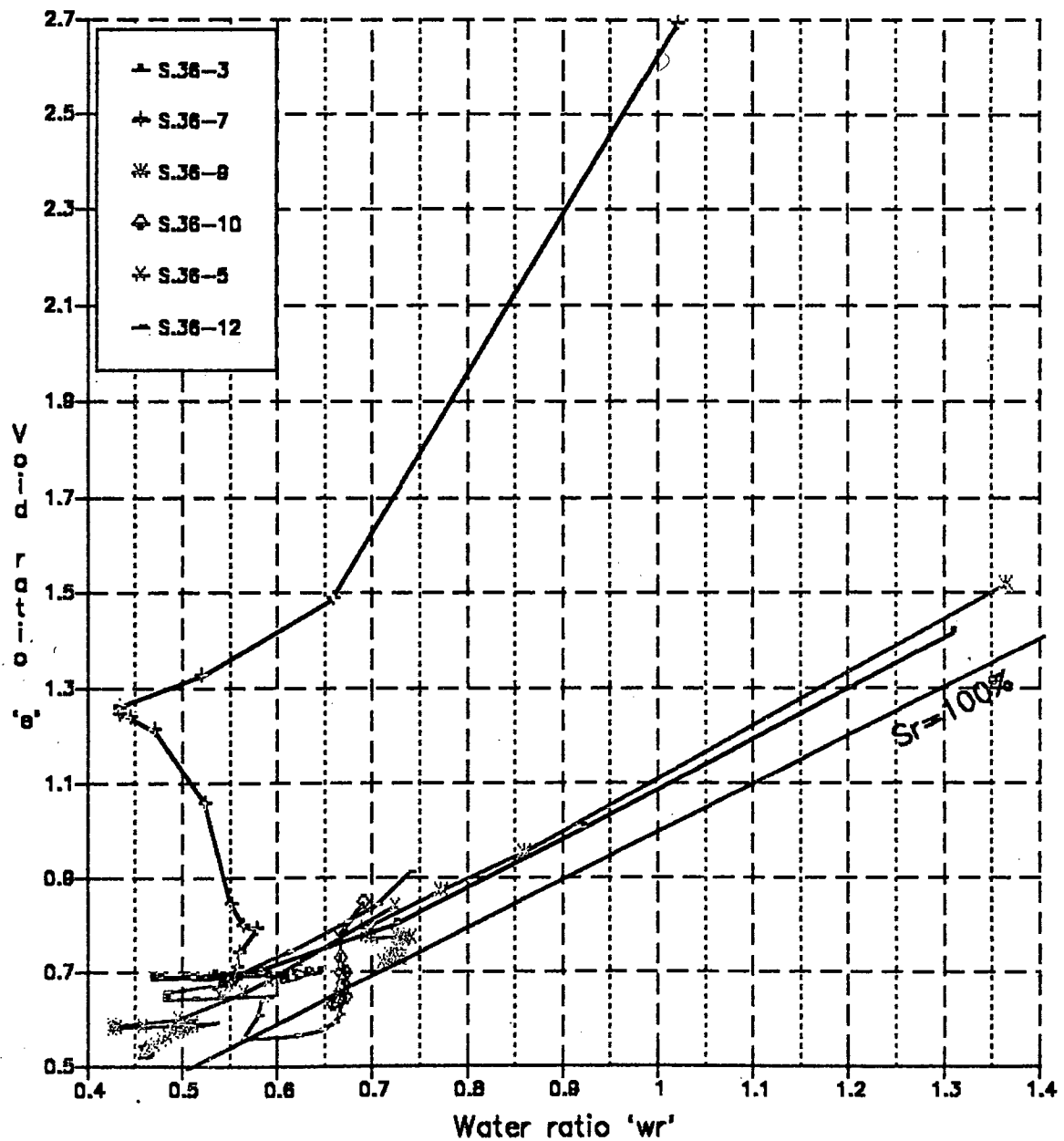


Figure E.21: Site 36, Rondebosch [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

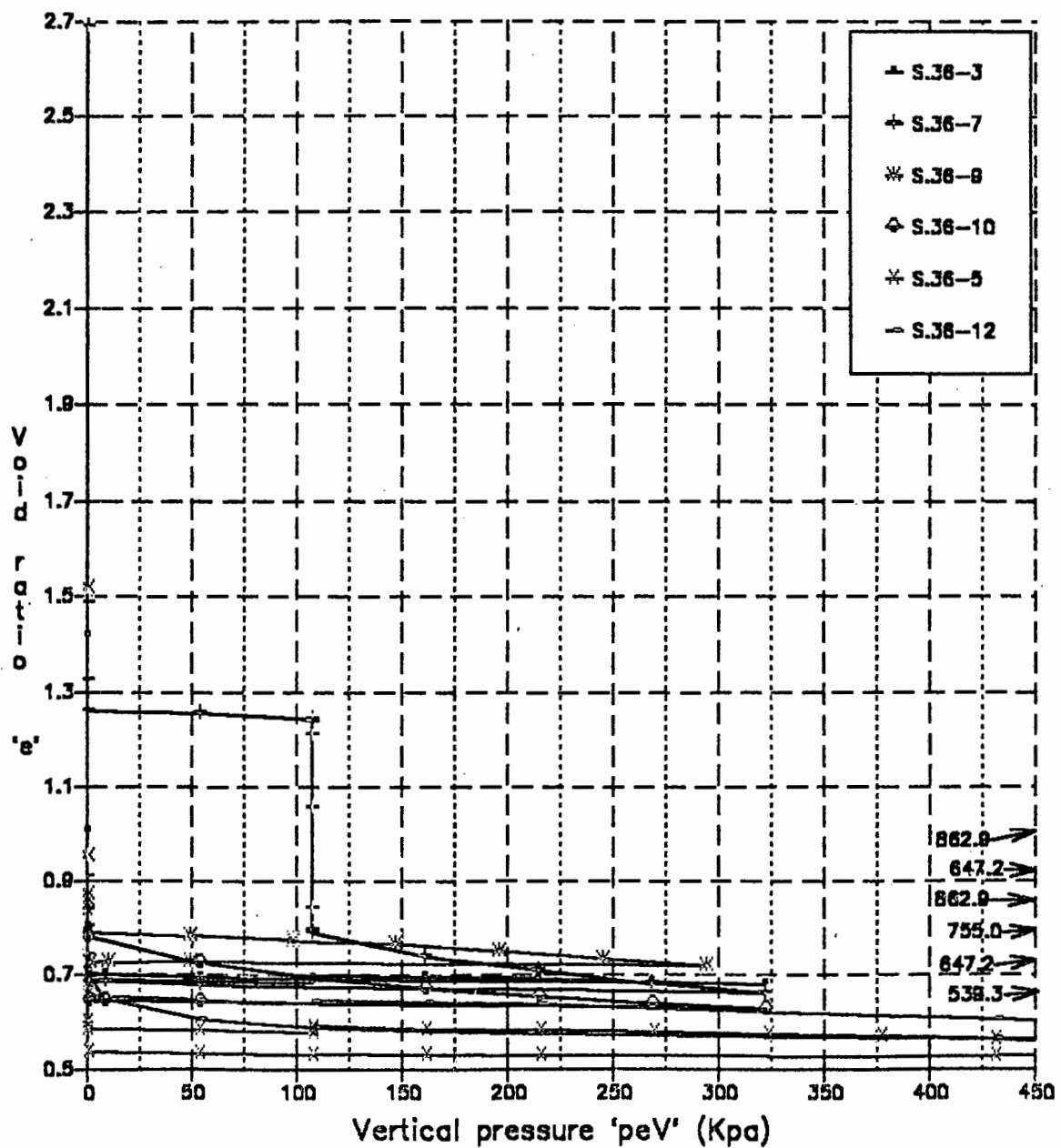


Figure E.22: Site 36, Rondebosch [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.14: Site 36, Rondebosch [Remoulded sample - 400 Kpa vertical pressure overnight, and then water added at 400 Kpa without prop] - Expansive and/or collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.36-15/	0	1.343	1.238
IV.453&	0	1.043	0.942
IV.466	0	0.868	0.766
	0	0.709	0.368
	53.8	0.707	0.367
	107.6	0.704	0.366
	215.2	0.699	0.365
	430.3	0.687	0.363
	430.3	0.685	0.376
	430.3	0.677	0.444
	430.3	0.671	0.524
	430.3	0.667	0.551
	53.8	0.690	0.578
	8.3	0.700	0.568
	0.8	0.704	0.568

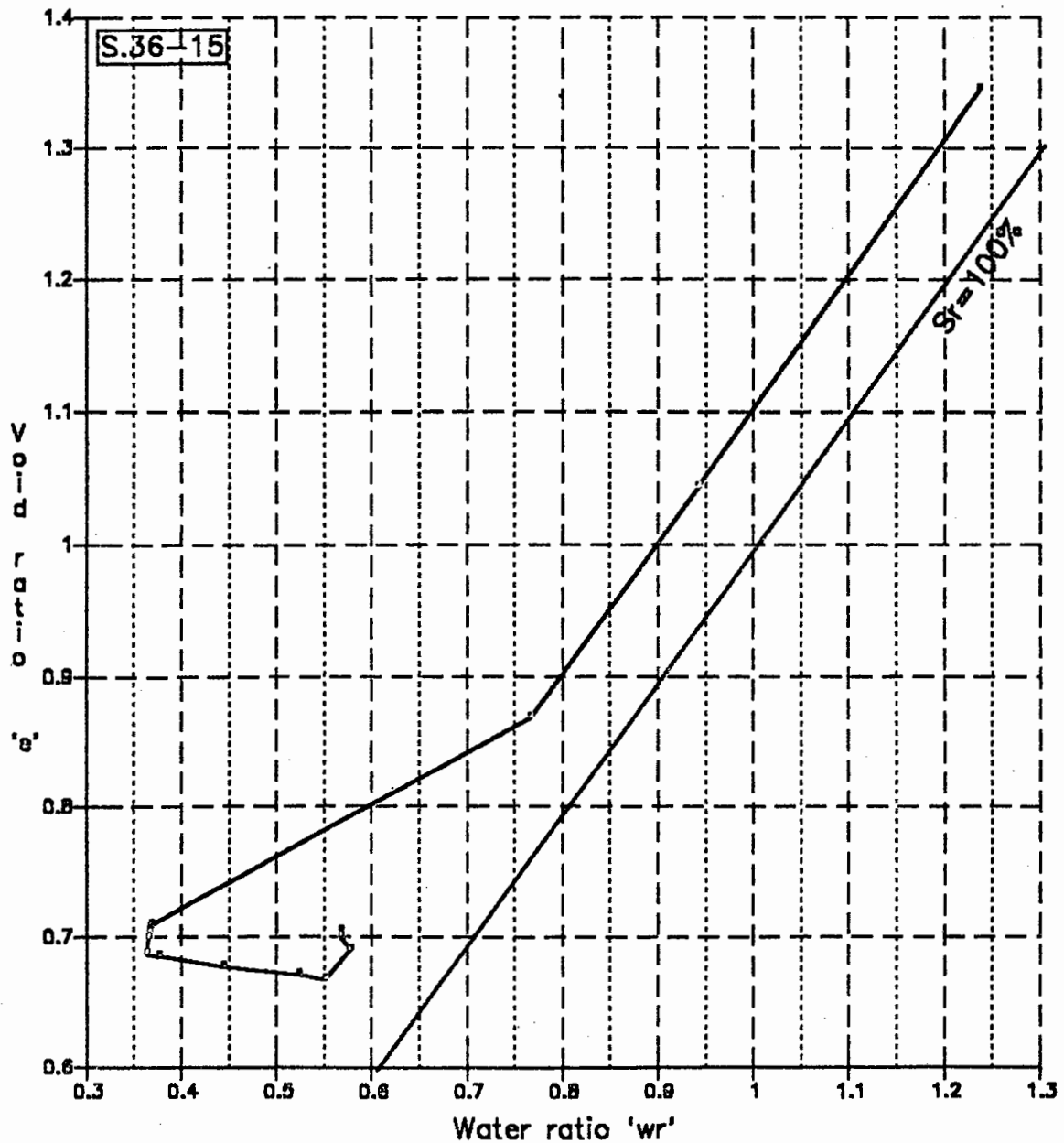


Figure E.23: Site 36, Rondebosch [Remoulded sample - 400 Kpa overnight vertical pressure and then wetted at 400 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

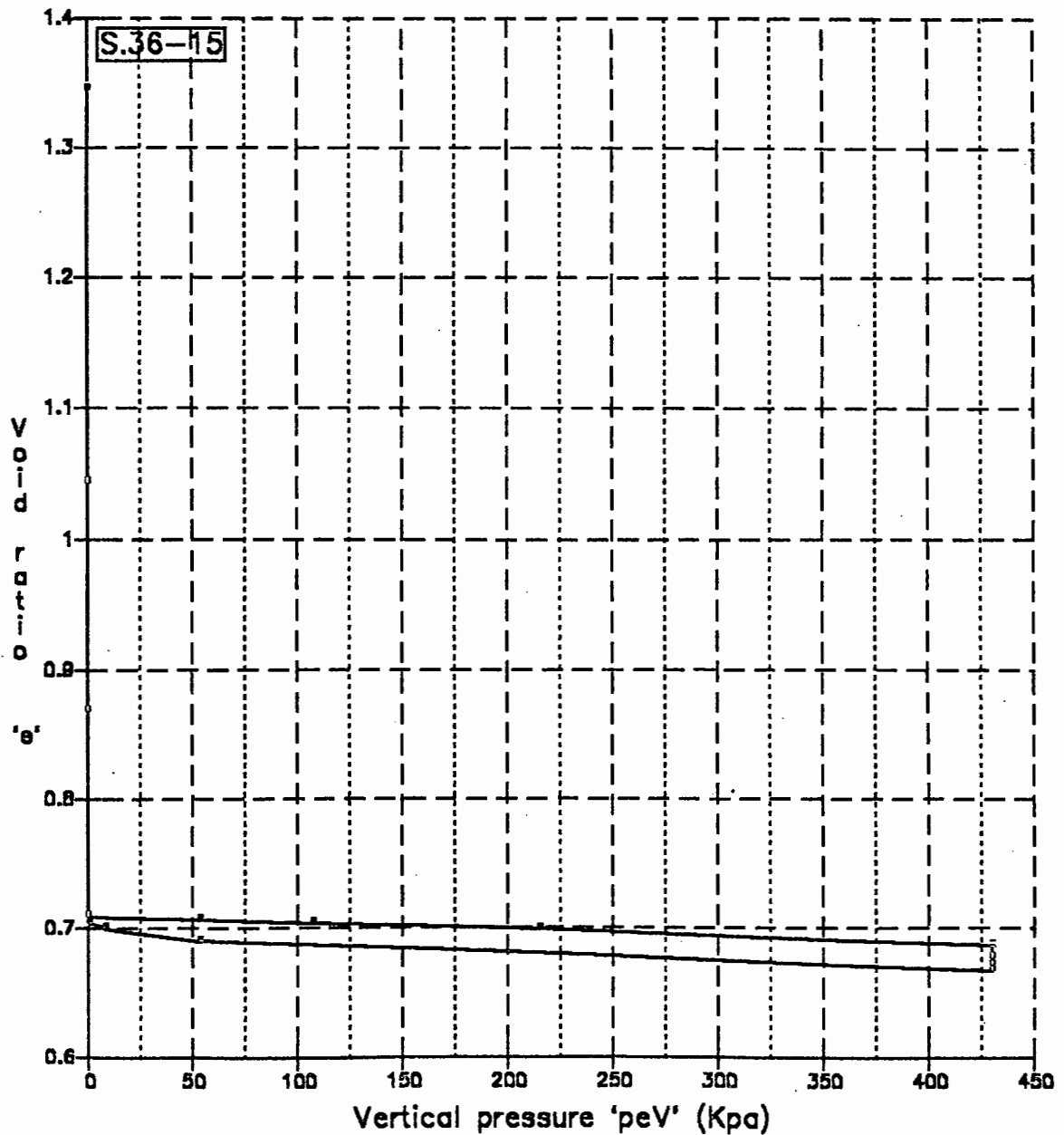


Figure E.24: Site 36, Rondebosch [Remoulded sample - 400 Kpa overnight vertical pressure and then wetted at 400 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.15: Site 36, Rondebosch [Compacted sample - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.36-18/	0	0.481	0.387
IV.453&	53.8	0.472	0.387
IV.457	107.5	0.470	0.387
	107.5	0.473	0.403
	107.5	0.477	0.470
	107.5	0.477	0.484
	161.4	0.475	0.475
	215.2	0.471	0.467
	268.9	0.468	0.458
	322.7	0.464	0.449
	53.8	0.483	0.454
	8.3	0.509	0.456
	0.8	0.512	0.457

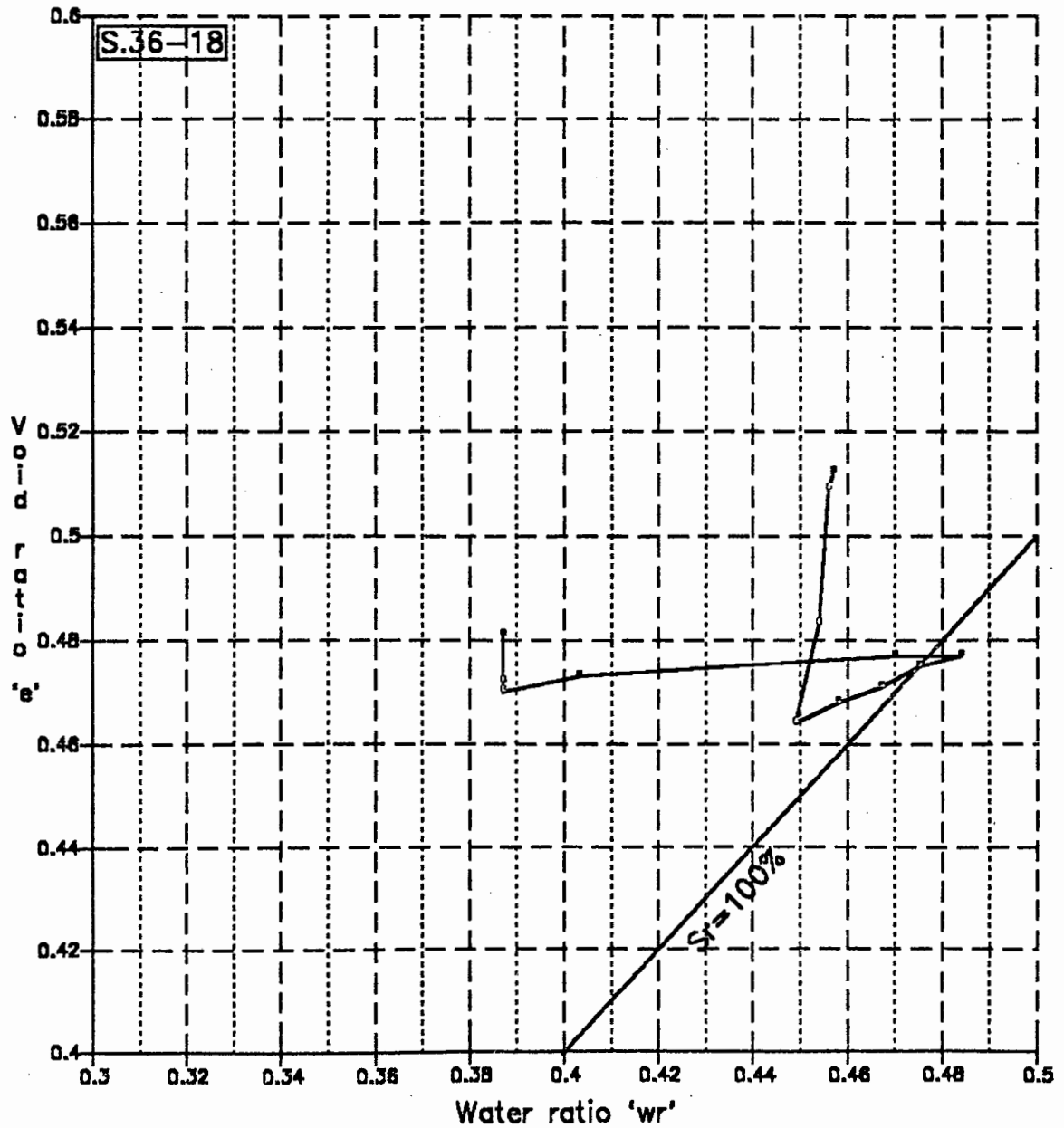


Figure E.25: Site 36, Rondebosch [Compacted sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

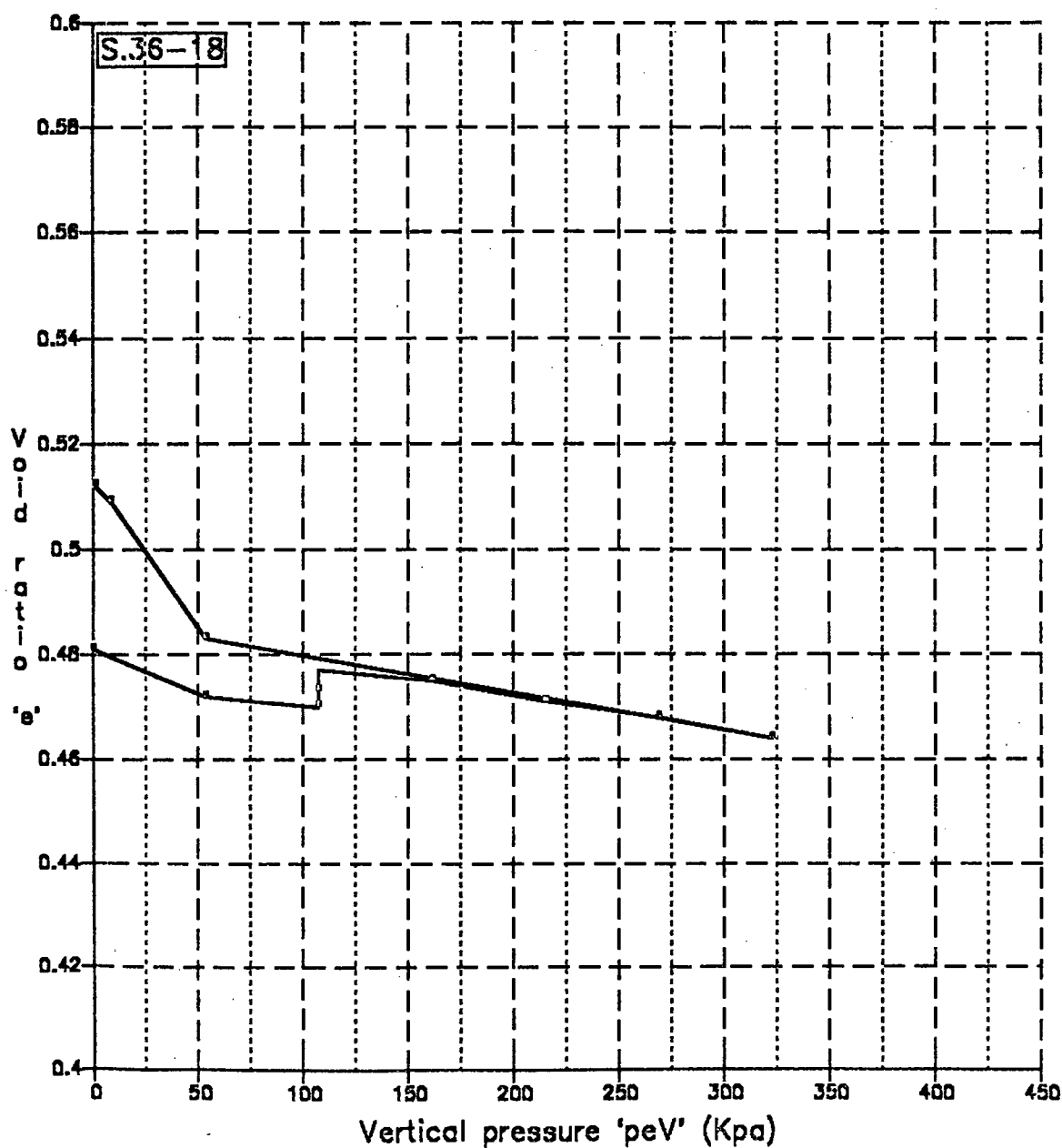


Figure E.26: Site 36, Rondebosch [Compacted sample - 100 kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.16: Site 36, Rondebosch [Undisturbed sample - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.36-16/	0	0.678	0.500
III.390&	0	0.670	0.478
IV.425	49.0	0.664	0.478
	98.1	0.661	0.478
	98.1	0.662	0.484
	98.1	0.665	0.524
	98.1	0.666	0.564
	98.1	0.668	0.632
	98.1	0.667	0.659
	147.1	0.665	0.651
	196.1	0.659	0.643
	245.2	0.654	0.634
	294.2	0.649	0.626
	49.0	0.661	0.629
	9.8	0.672	0.632
	1.0	0.679	0.632

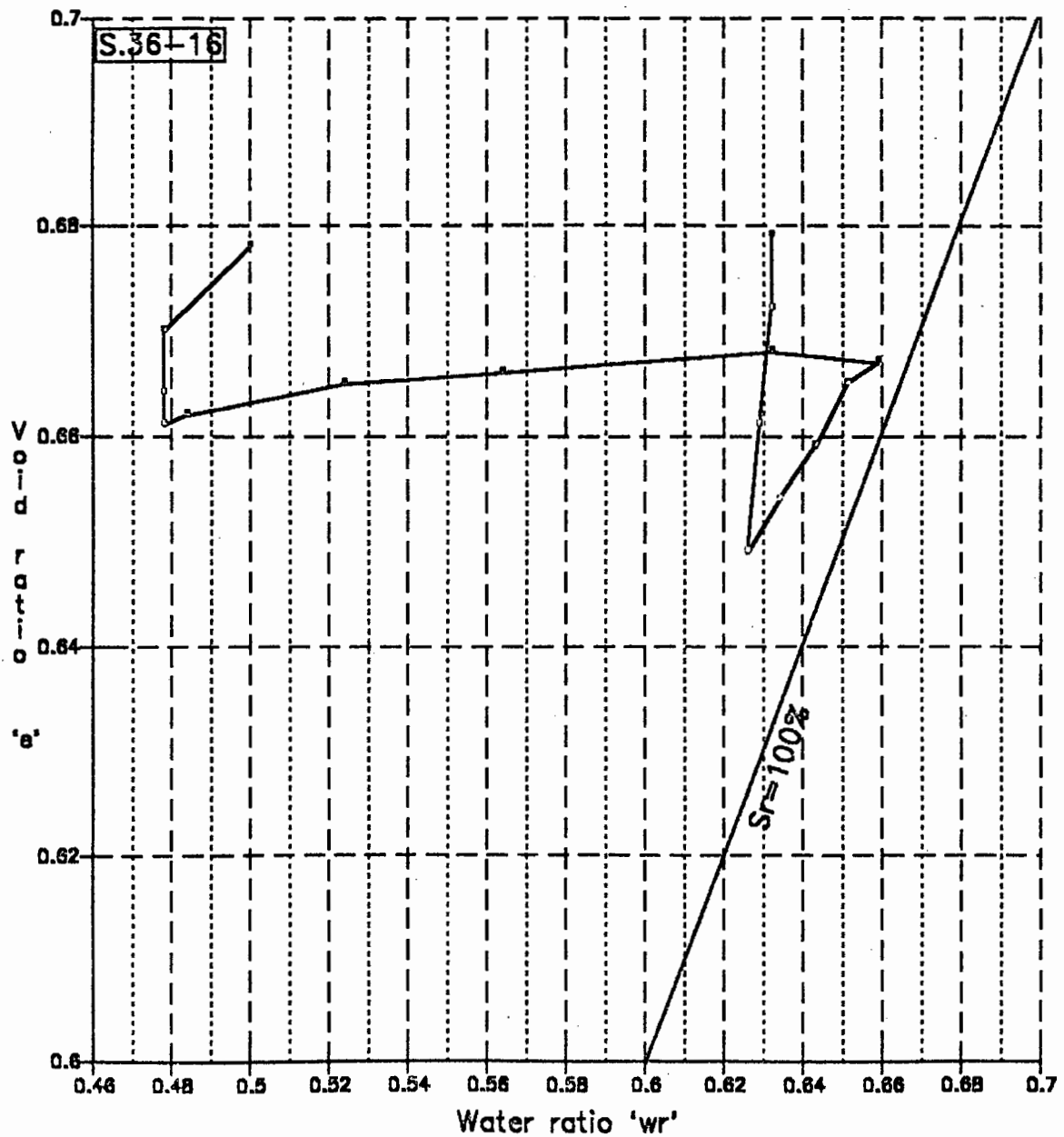


Figure E.27: Site 36, Rondebosch [Undisturbed sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

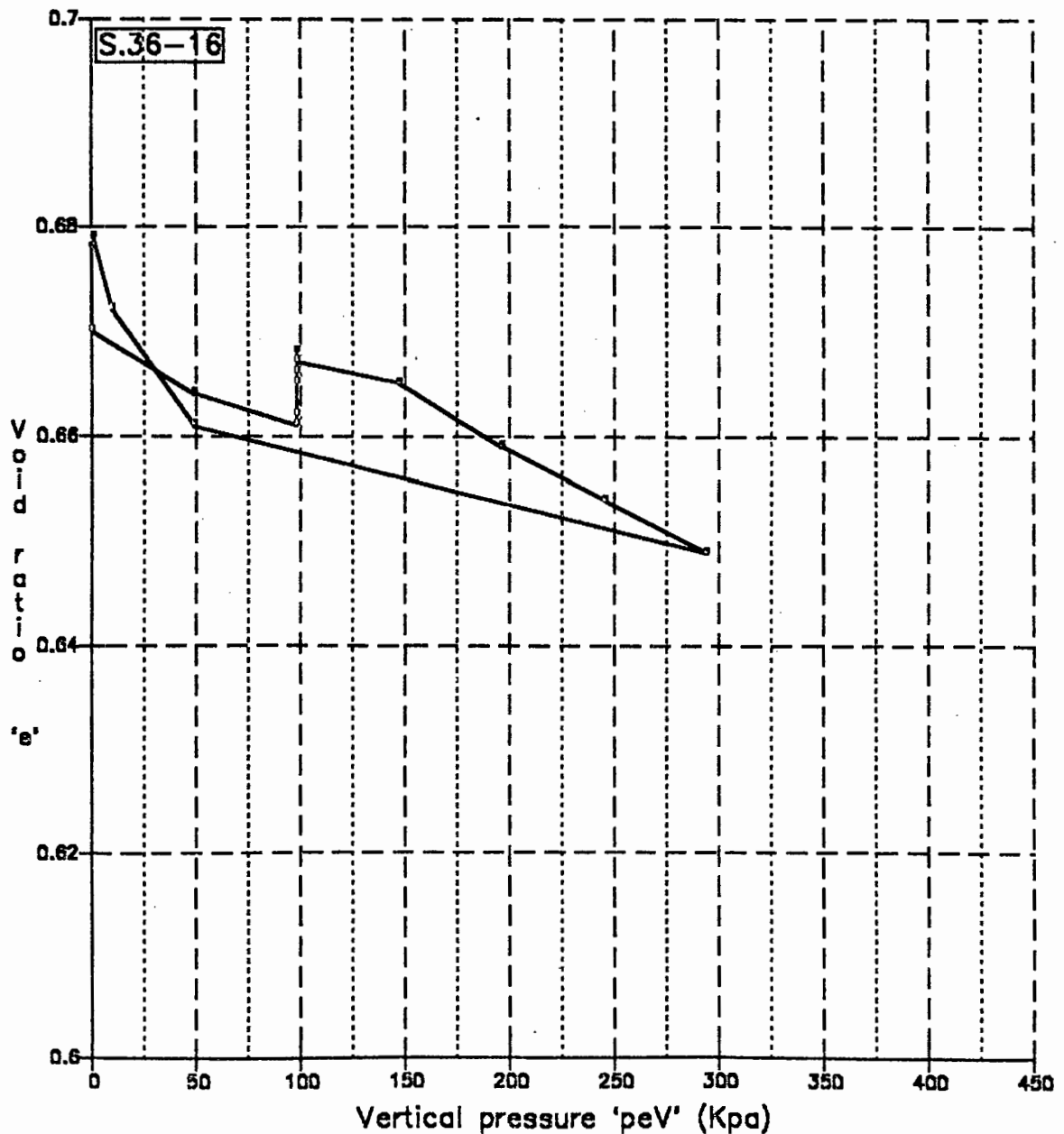


Figure E.28: Site 36, Rondebosch [Undisturbed sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

E.4.3 Site 30 - Hout Bay, Cape.

Table E.17: Site 30, Hout Bay [Remoulded sample - 1 Kpa vertical pressure overnight, and then water added at 1 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.30-10/	0	1.428	1.274
IV.465&	0	0.977	0.887
IV.469	0	0.805	0.681
	0	0.735	0.588
	0	0.708	0.554
	1.0	0.705	0.554
	1.0	0.724	0.567
	1.0	0.766	0.638
	1.0	0.783	0.691
	1.0	0.786	0.696
	49.0	0.758	0.689
	98.1	0.741	0.682
	147.1	0.726	0.675
	196.1	0.720	0.668
	245.2	0.715	0.661
	294.2	0.703	0.654
	49.0	0.713	0.657
	9.8	0.726	0.659
	1.0	0.733	0.659

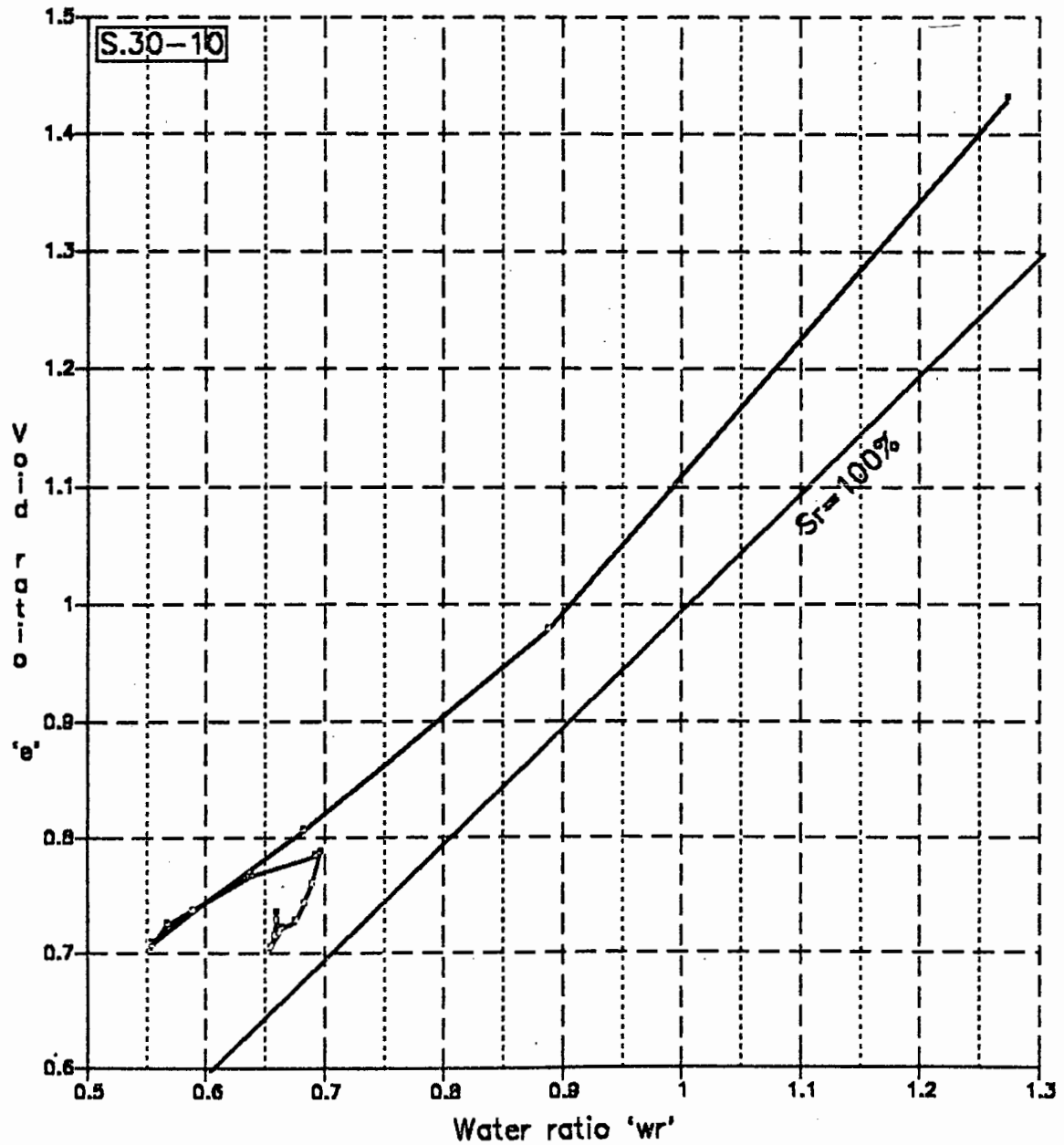


Figure E.29: Site 30, Hout Bay [Remoulded sample - 1 Kpa overnight vertical pressure and then wetted at 1 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

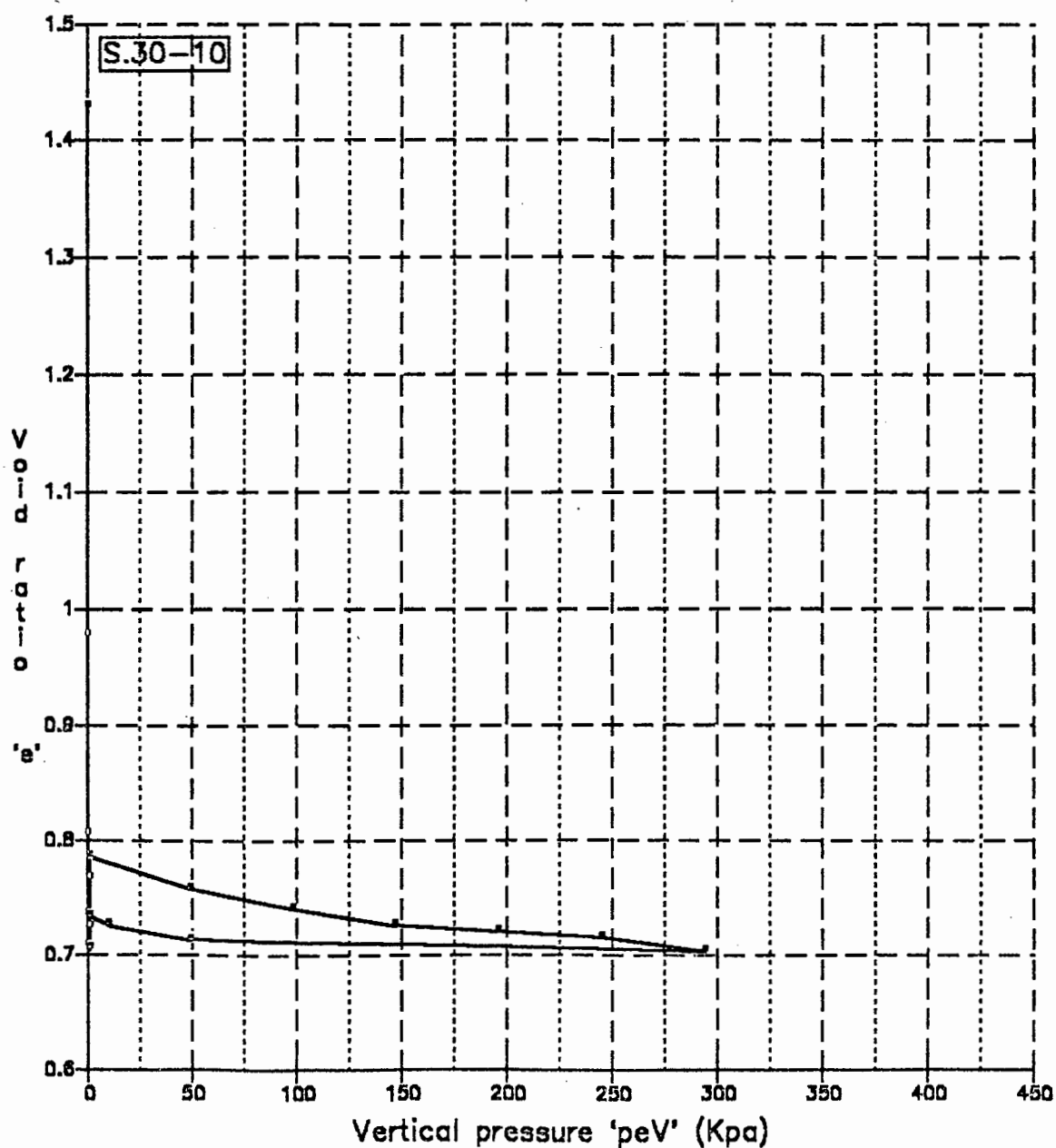


Figure E.30: Site 30, Hout Bay [Remoulded sample - 1 Kpa overnight vertical pressure and then wetted at 1 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.18: Site 30, Hout Bay [Remoulded sample - 50 Kpa vertical pressure overnight, and then water added at 50 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.30-11/	0	1.427	1.275
IV.465&	0	0.901	0.803
IV.470	0	0.725	0.582
	0	0.671	0.482
	0	0.664	0.472
	53.8	0.646	0.472
	53.8	0.653	0.488
	53.8	0.666	0.554
	53.8	0.674	0.620
	53.8	0.674	0.628
	107.6	0.669	0.620
	161.4	0.665	0.612
	215.2	0.659	0.604
	268.9	0.653	0.596
	322.7	0.643	0.588
	53.8	0.656	0.591
	8.3	0.662	0.599
	0.8	0.669	0.599

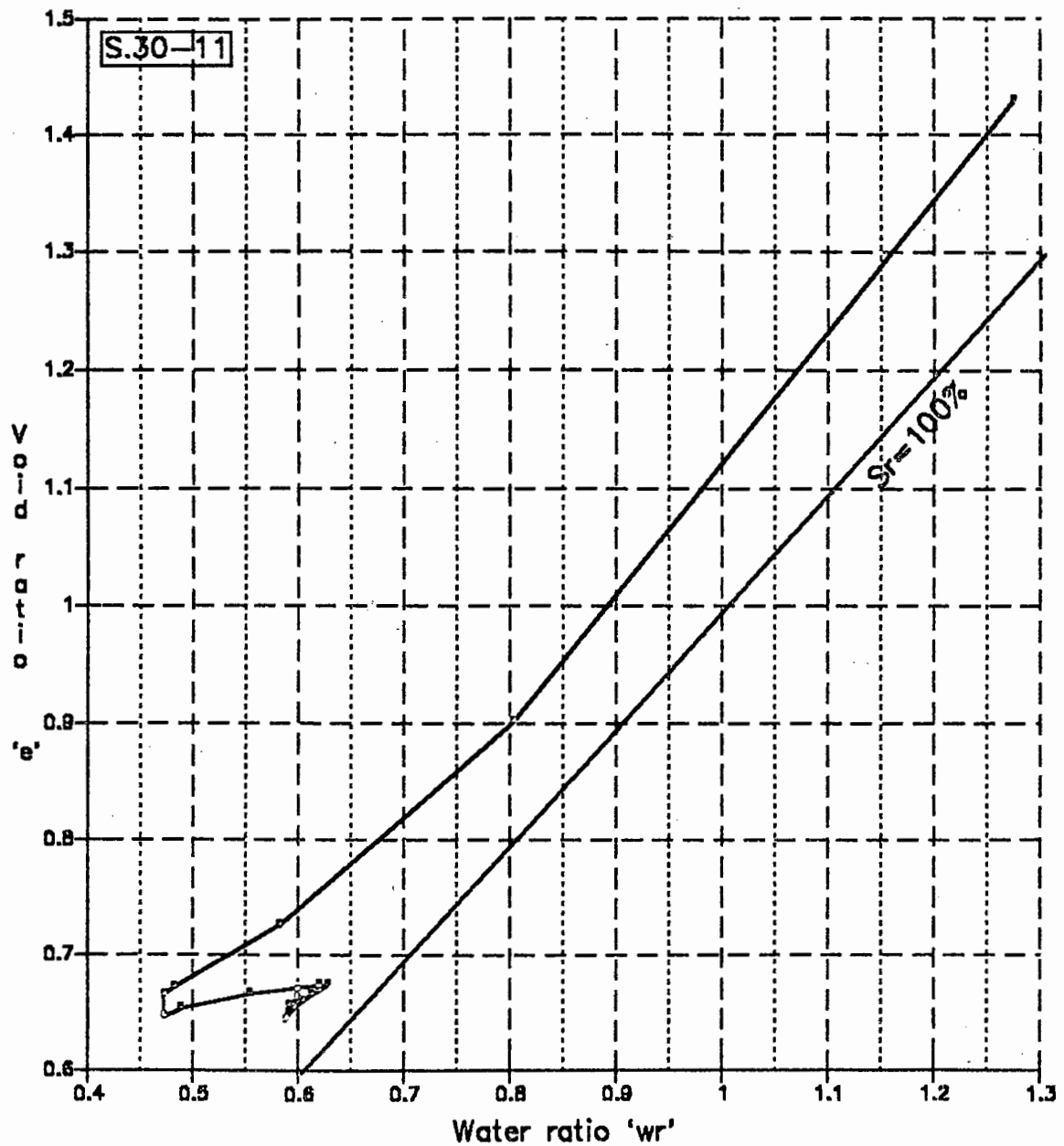


Figure E.31: Site 30, Hout Bay [Remoulded sample - 50 Kpa overnight vertical pressure and then wetted at 50 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

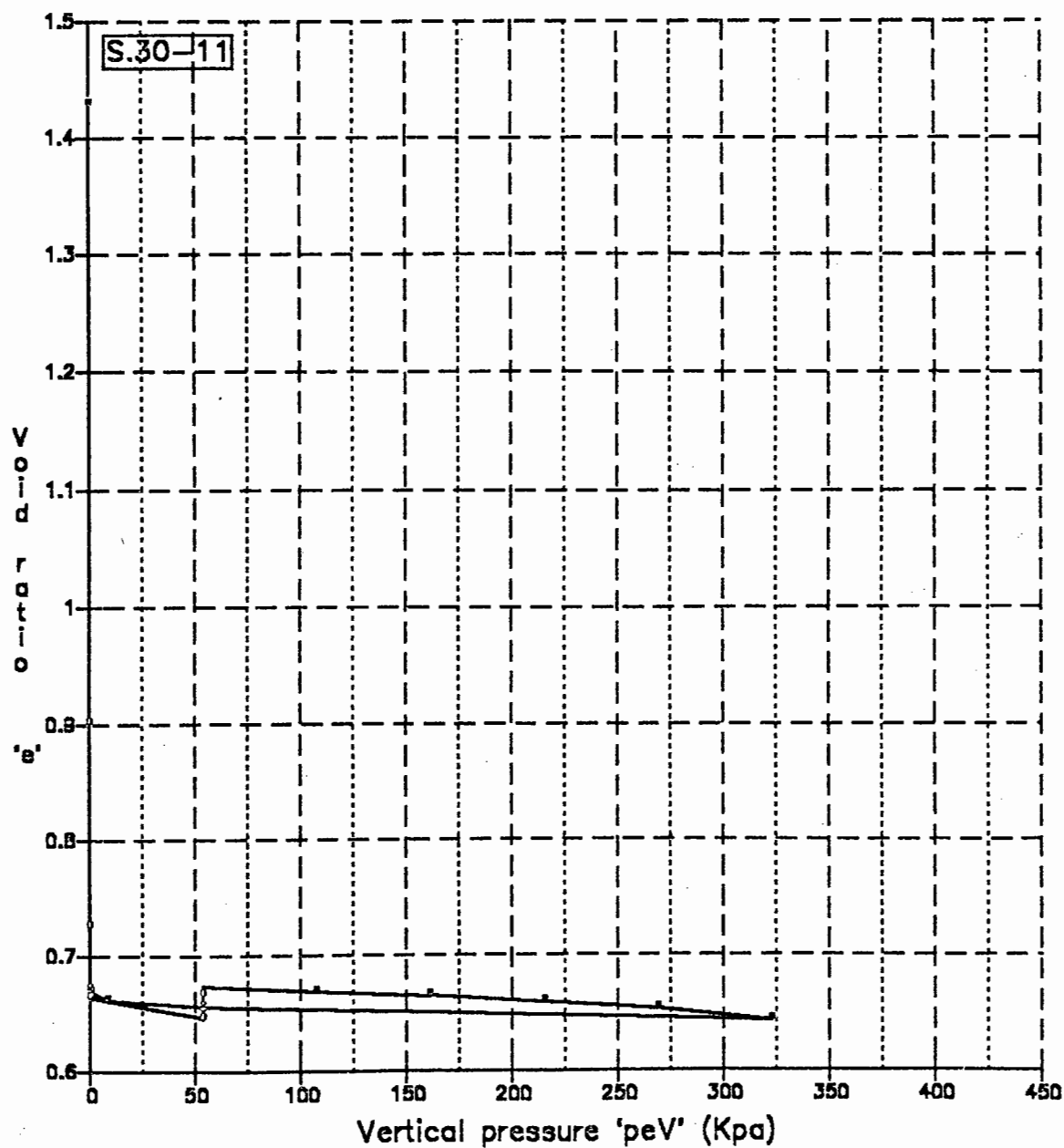


Figure E.32: Site 30, Hout Bay [Remoulded sample - 50 Kpa overnight vertical pressure and then wetted at 50 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.19: Site 30, Hout Bay [Remoulded samples - 100 Kpa vertical pressure] Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.30-3/	0	1.417	1.320	S.30-5/	0	1.021	0.890
III.336&	0	0.880	0.818	III.352&	0	0.866	0.764
III.373	0	0.815	0.747	IV.418	0	0.815	0.713
	0	0.733	0.625		0	0.712	0.587
	0	0.690	0.505		0	0.672	0.497
	0	0.685	0.448		0	0.677	0.461
	53.6	0.683	0.448		53.6	0.672	0.461
	107.3	0.680	0.448		107.3	0.669	0.461
	107.3	0.681	0.456		107.3	0.670	0.464
	107.3	0.683	0.488		107.3	0.671	0.477
	107.3	0.686	0.514		107.3	0.671	0.490
	107.3	0.690	0.567		107.3	0.680	0.530
	107.3	0.695	0.607		107.3	0.684	0.596
	107.3	0.699	0.659		107.3	0.685	0.622
	107.3	0.700	0.680		160.9	0.681	0.616
	160.9	0.697	0.671		214.6	0.674	0.611
	214.6	0.691	0.662		268.2	0.666	0.605
	268.2	0.686	0.652		321.9	0.661	0.599
	321.9	0.681	0.643		53.6	0.678	0.600
	53.6	0.700	0.645		8.3	0.687	0.601
	8.3	0.711	0.646		0.8	0.688	0.601
	0.8	0.715	0.646				
S.30-7/	0	2.233	1.131	S.30-9/	0	1.519	1.347
III.366&	0	1.381	0.833	III.388&	0	1.131	1.016
III.404	0	1.302	0.762	IV.423	0	1.064	0.954
	0	1.188	0.651		0	0.927	0.811
	0	1.068	0.457		0	0.878	0.757
	0	1.059	0.377		49.0	0.868	0.757
	53.6	1.051	0.377		98.1	0.857	0.757
	107.3	1.043	0.377		98.1	0.859	0.765
	107.3	1.042	0.385		98.1	0.860	0.791
	107.3	1.041	0.422		147.1	0.852	0.783
	107.3	1.037	0.475		196.1	0.837	0.774
	107.3	1.004	0.541		245.2	0.818	0.766
	107.3	0.910	0.607		294.2	0.802	0.757
	107.3	0.857	0.659		49.0	0.821	0.758
	107.3	0.843	0.672		9.8	0.824	0.762
	107.3	0.841	0.675		1.0	0.822	0.762
	160.9	0.792	0.670				
	214.6	0.761	0.665				
	268.2	0.739	0.659				
	321.9	0.719	0.654				
	53.6	0.744	0.655				
	8.3	0.748	0.657				
	0.8	0.747	0.657				

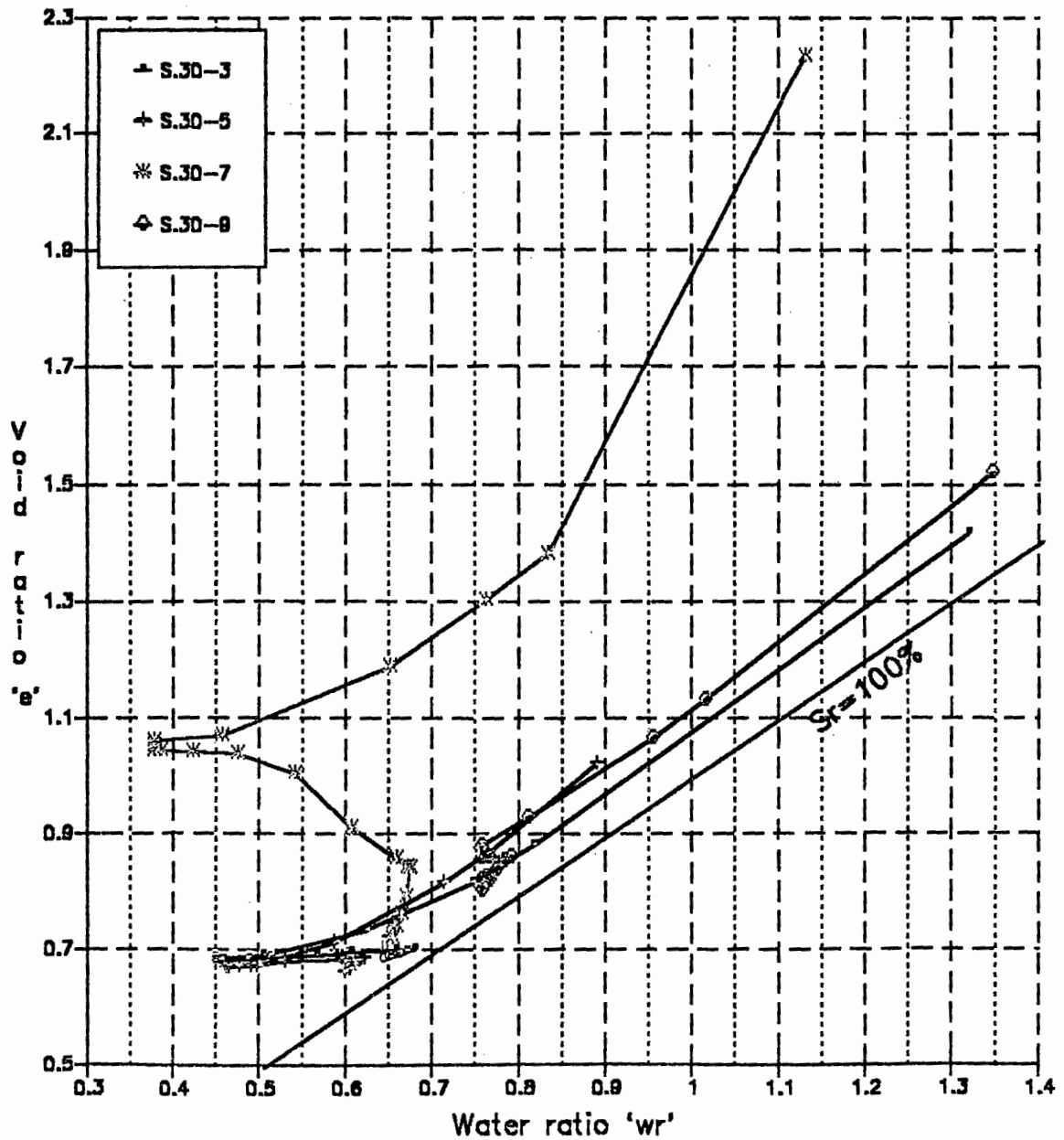


Figure E.33: Site 30, Hout Bay [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

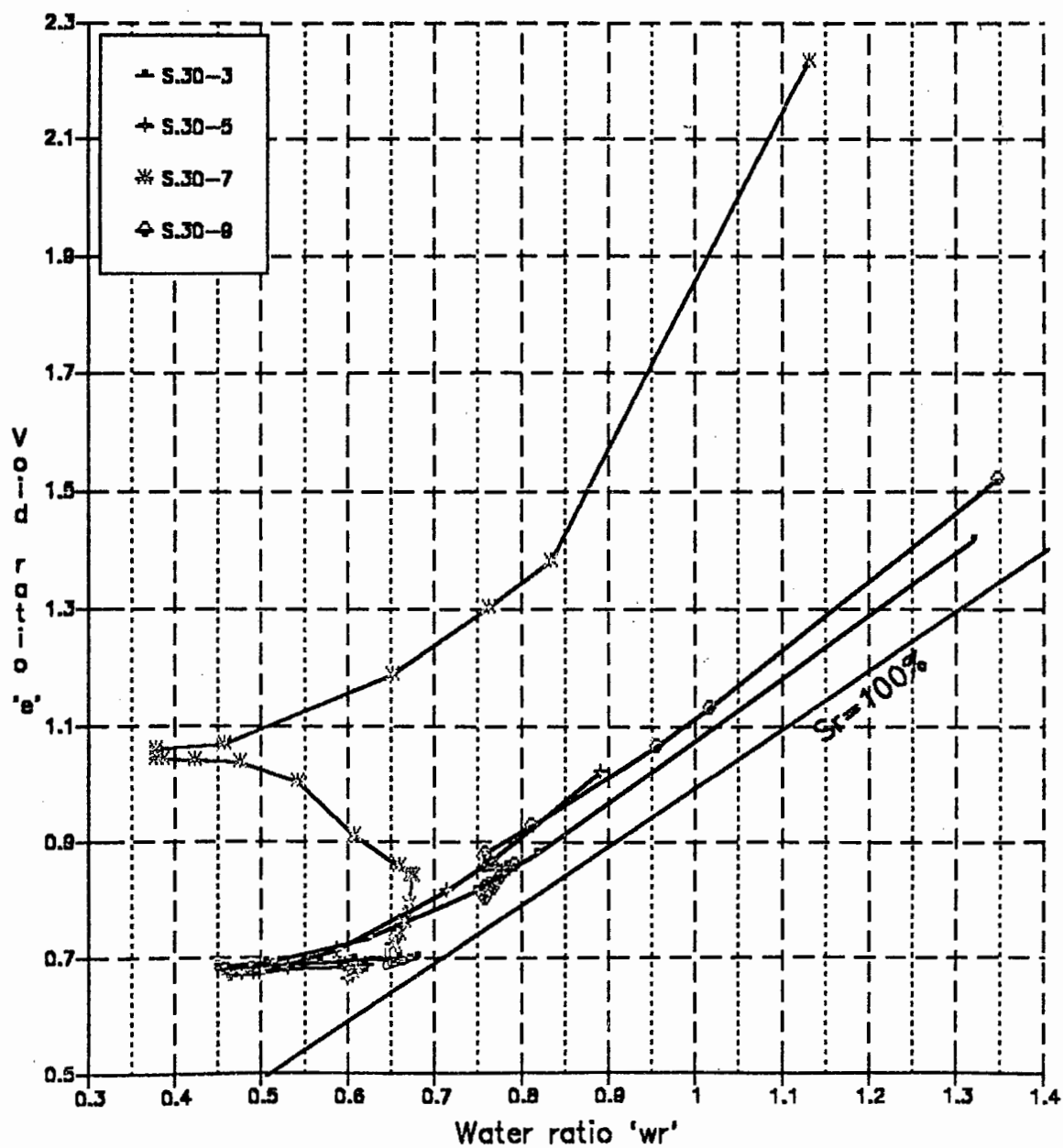


Figure E.33: Site 30, Hout Bay [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

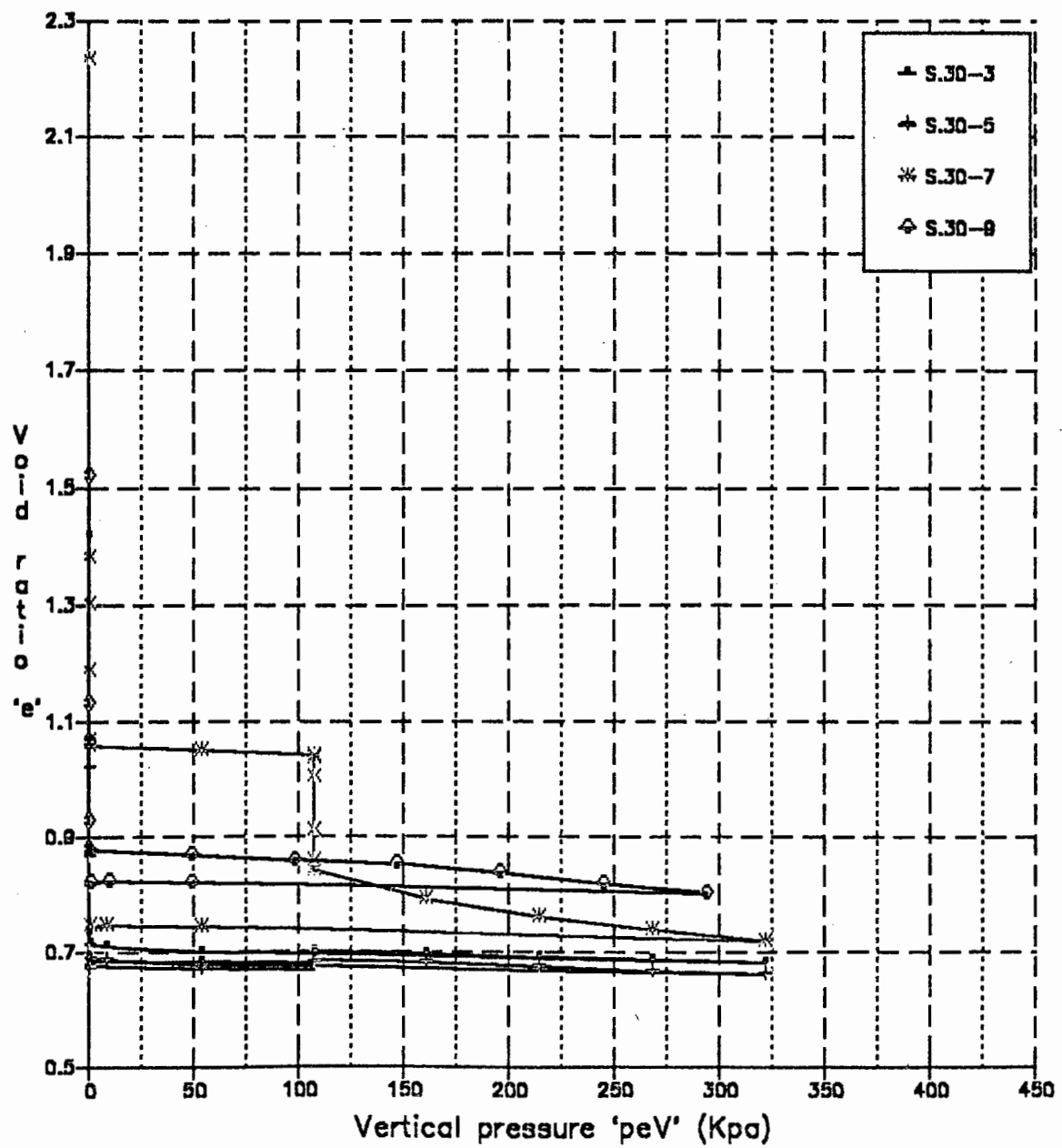


Figure E.34: Site 30, Hout Bay [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.20: Site 30, Hout Bay [Undisturbed sample - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.30-13/	0	0.692	0.364
IV.438&	53.8	0.684	0.364
IV.440	107.6	0.680	0.364
	107.6	0.679	0.382
	107.6	0.680	0.461
	107.6	0.683	0.541
	107.6	0.685	0.620
	107.6	0.685	0.651
	161.4	0.681	0.645
	215.2	0.673	0.640
	268.9	0.667	0.634
	322.7	0.662	0.628
	53.8	0.677	0.629
	8.3	0.695	0.630
	0.8	0.703	0.630

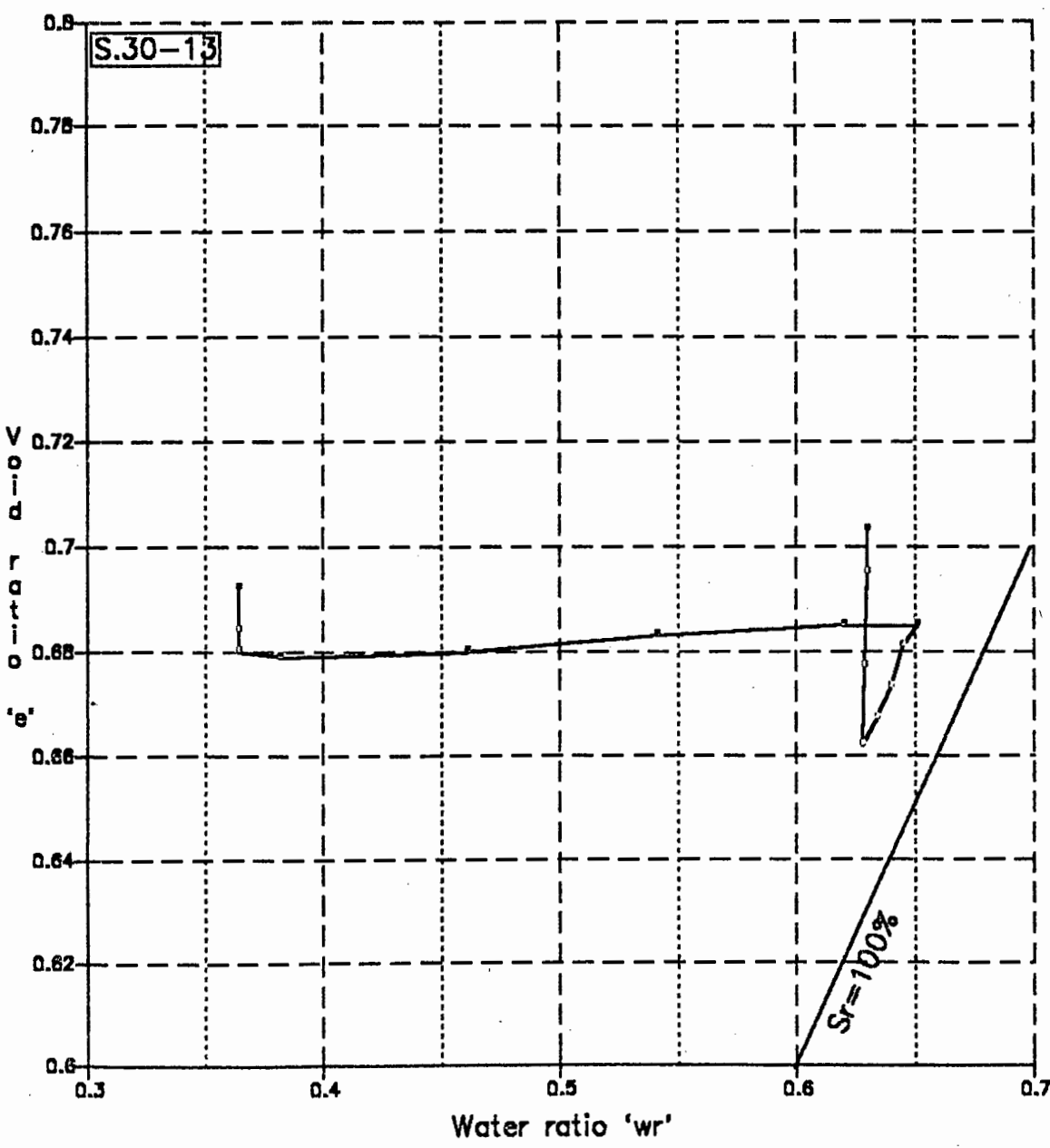


Figure E.35: Site 30, Hout Bay [Undisturbed sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

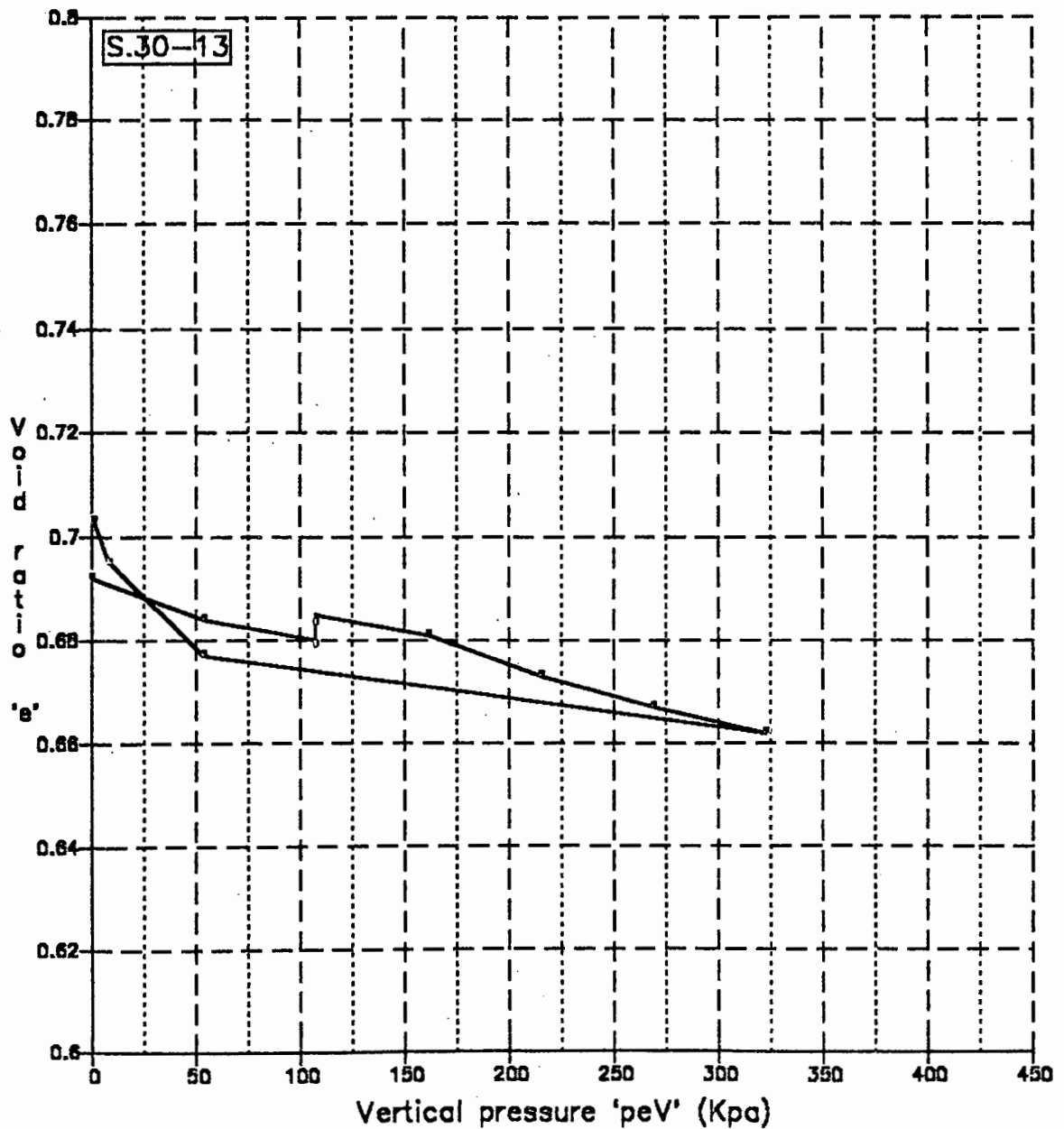


Figure E.36: Site 30, Hout Bay [Undisturbed sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or stress, 'peV'.

E.4.4 Site A - Berea Road, Durban.

Table E.21: Site A, Berea Road [Remoulded samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.A-1.A/ II.206& I.122	0 0 49.0	0.820 0.613 0.605	0.540 0.028 0.028	S.A-2/ I.113& II.154	0 0 0	0.924 0.516 0.502	0.611 0.355 0.277
	98.1	0.596	0.028		0	0.477	0.173
	98.1	0.592	0.040		0	0.480	0.124
	98.1	0.588	0.067		0	0.483	0.070
	98.1	0.583	0.107		0	0.481	0.045
	98.1	0.578	0.160		53.6	0.473	0.045
	98.1	0.575	0.213		107.3	0.467	0.045
	98.1	0.572	0.280		107.3	0.464	0.053
	98.1	0.570	0.346		107.3	0.460	0.080
	98.1	0.570	0.373		107.3	0.457	0.107
	196.1	0.544	0.368		107.3	0.453	0.160
	49.0	0.545	0.370		107.3	0.450	0.187
	1.0	0.547	0.373		107.3	0.446	0.227
					107.3	0.443	0.293
					107.3	0.442	0.306
					160.9	0.433	0.303
					214.6	0.427	0.300
					268.2	0.421	0.297
					321.9	0.417	0.294
					375.5	0.416	0.291
					429.2	0.415	0.288
					53.6	0.416	0.290
					0.8	0.420	0.293

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.A-3/ I.114& II.156	0 0 0 0 0 0 0 53.6 107.3 107.3 107.3 107.3 107.3 107.3 160.9 321.9 375.5 429.2 53.6 0.8	1.377 0.542 0.517 0.490 0.497 0.496 0.498 0.495 0.475 0.468 0.465 0.455 0.452 0.449 0.448 0.437 0.412 0.407 0.404 0.406 0.410	0.830 0.379 0.292 0.181 0.123 0.078 0.171 0.165 0.165 0.165 0.173 0.227 0.253 0.320 0.333 0.326 0.319 0.311 0.304 0.306 0.309	S.A-4/ I.115& II.164	0 0 0 0 0 0 0 0 49.0 98.1 98.1 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 343.2 392.3 49.0 1.0	0.978 0.394 0.367 0.363 0.363 0.360 0.398 0.394 0.369 0.363 0.360 0.359 0.357 0.356 0.355 0.351 0.347 0.345 0.343 0.341 0.340 0.341 0.342	0.768 0.321 0.179 0.123 0.088 0.044 0.206 0.197 0.197 0.197 0.205 0.219 0.245 0.272 0.306 0.301 0.296 0.291 0.287 0.282 0.277 0.280 0.282
S.A-6/ II.158& II.167	0 0 0 0 0 53.6 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 160.9 214.6 268.2 321.8 53.6 0.8	1.140 0.677 0.674 0.666 0.654 0.602 0.597 0.591 0.583 0.569 0.550 0.537 0.529 0.513 0.512 0.510 0.472 0.453 0.445 0.434 0.437 0.446	0.516 0.316 0.291 0.252 0.184 0.184 0.184 0.192 0.227 0.267 0.293 0.346 0.346 0.373 0.400 0.426 0.420 0.413 0.407 0.400 0.402 0.405	S.A-7/ II.159& II.173	0 0 0 0 0 0 53.7 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 161.0 214.6 268.3 322.0 53.7 0.8	1.209 0.810 0.798 0.787 0.776 0.776 0.776 0.729 0.721 0.713 0.706 0.703 0.692 0.670 0.632 0.604 0.575 0.573 0.533 0.516 0.499 0.494 0.496 0.496	0.548 0.361 0.353 0.307 0.214 0.171 0.091 0.091 0.107 0.133 0.173 0.213 0.253 0.293 0.333 0.373 0.400 0.392 0.384 0.376 0.368 0.370 0.373

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.A-8/	0	1.084	0.530
II.160&	0	0.923	0.360
II.169	0	0.727	0.345
	0	0.720	0.291
	0	0.717	0.259
	0	0.707	0.240
	53.7	0.677	0.240
	107.3	0.666	0.240
	107.3	0.658	0.248
	107.3	0.649	0.259
	107.3	0.640	0.269
	107.3	0.634	0.280
	107.3	0.619	0.306
	107.3	0.602	0.333
	107.3	0.591	0.386
	107.3	0.570	0.413
	107.3	0.567	0.426
	161.0	0.535	0.416
	214.6	0.514	0.406
	268.3	0.507	0.396
	322.0	0.496	0.386
	53.7	0.498	0.389
	0.8	0.503	0.392

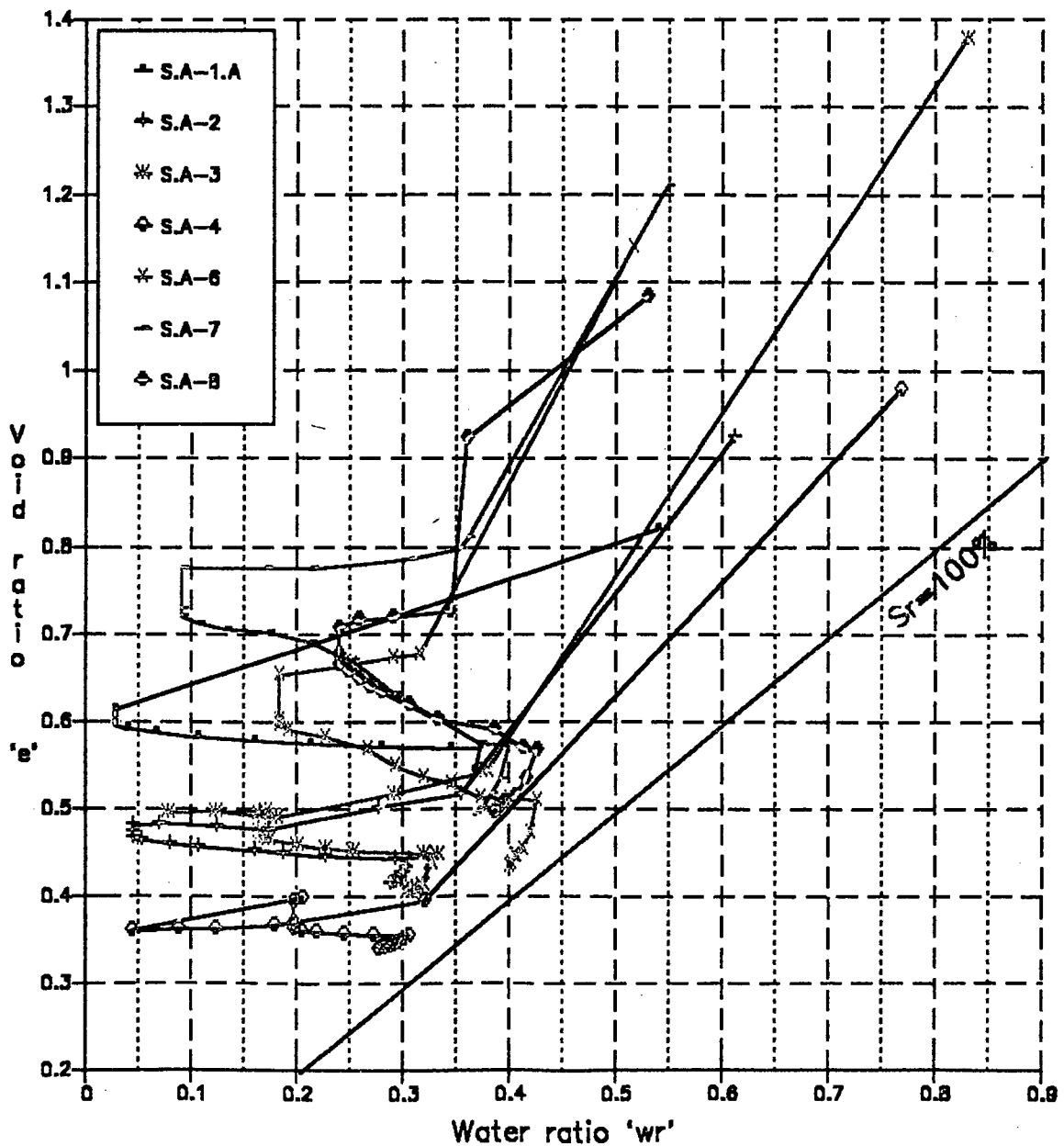


Figure E.37: Site A, Berea Road [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

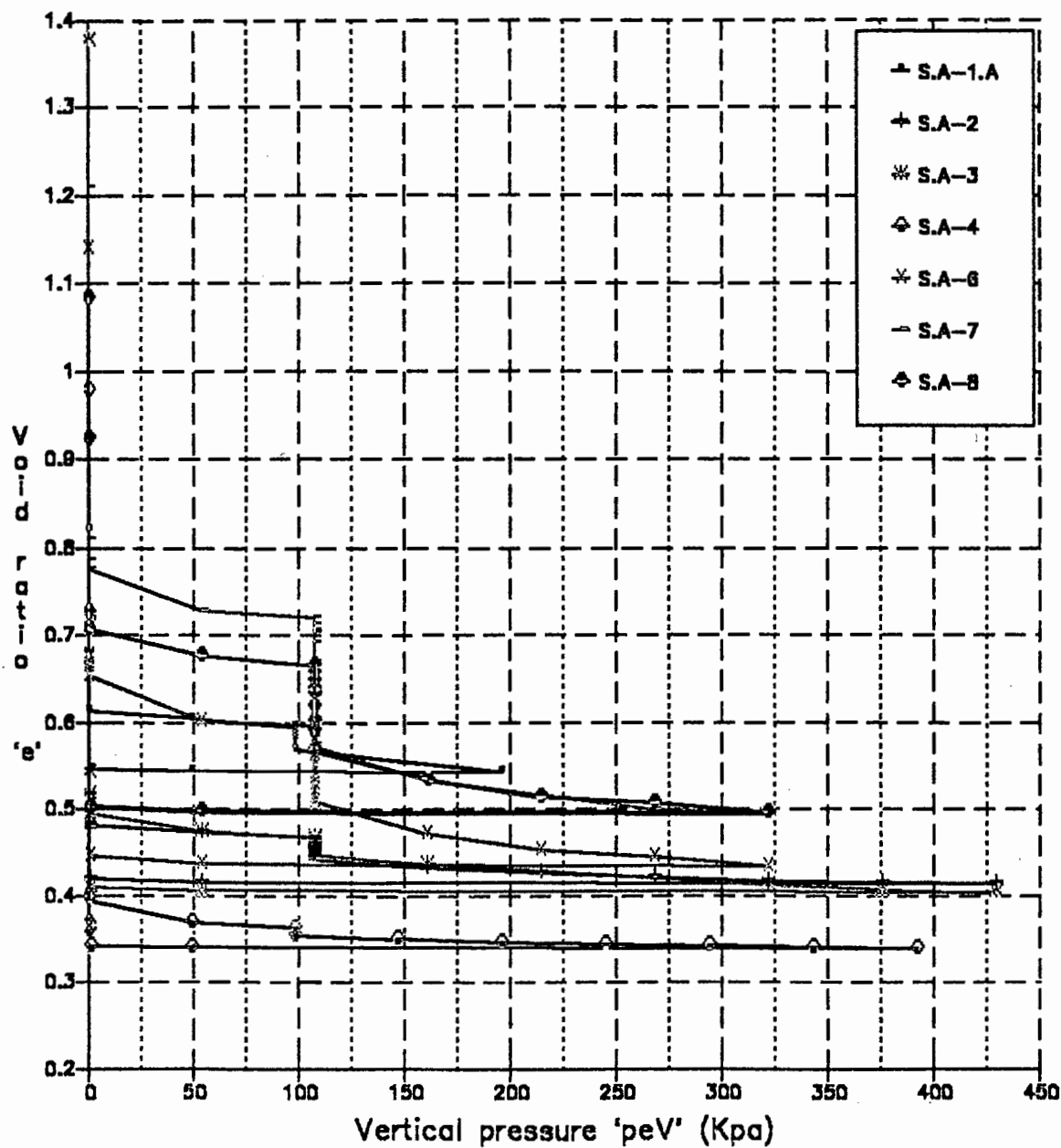


Figure E.38: Site A, Berea Road [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.22: Site A, Berea Road [Compacted samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.A-9/ II.163& II.175	0 53.6 107.3 107.3 107.3 107.3 107.3 160.9 214.6 268.2 321.9 53.6 0.8	0.443 0.291 0.282 0.280 0.279 0.278 0.277 0.274 0.270 0.266 0.265 0.266 0.284	0.147 0.147 0.147 0.160 0.213 0.293 0.320 0.317 0.313 0.310 0.306 0.309 0.312	S.A-10/ II.163& II.177	0 53.6 107.3 107.3 107.3 107.3 107.3 107.3 107.3 107.3 160.9 214.6 268.2 321.9 53.6 0.8	0.606 0.438 0.429 0.427 0.424 0.418 0.417 0.415 0.411 0.410 0.381 0.361 0.349 0.339 0.341 0.347	0.101 0.101 0.101 0.112 0.165 0.235 0.306 0.373 0.440 0.466 0.456 0.446 0.436 0.426 0.429 0.432
S.A-12/ II.163& II.187	0 53.7 107.3 107.3 107.3 107.3 107.3 161.0 214.6 268.3 322.0 53.7 0.8	0.350 0.243 0.237 0.237 0.236 0.236 0.235 0.234 0.232 0.231 0.230 0.231 0.239	0.213 0.213 0.213 0.227 0.253 0.293 0.333 0.329 0.325 0.321 0.317 0.320 0.322				

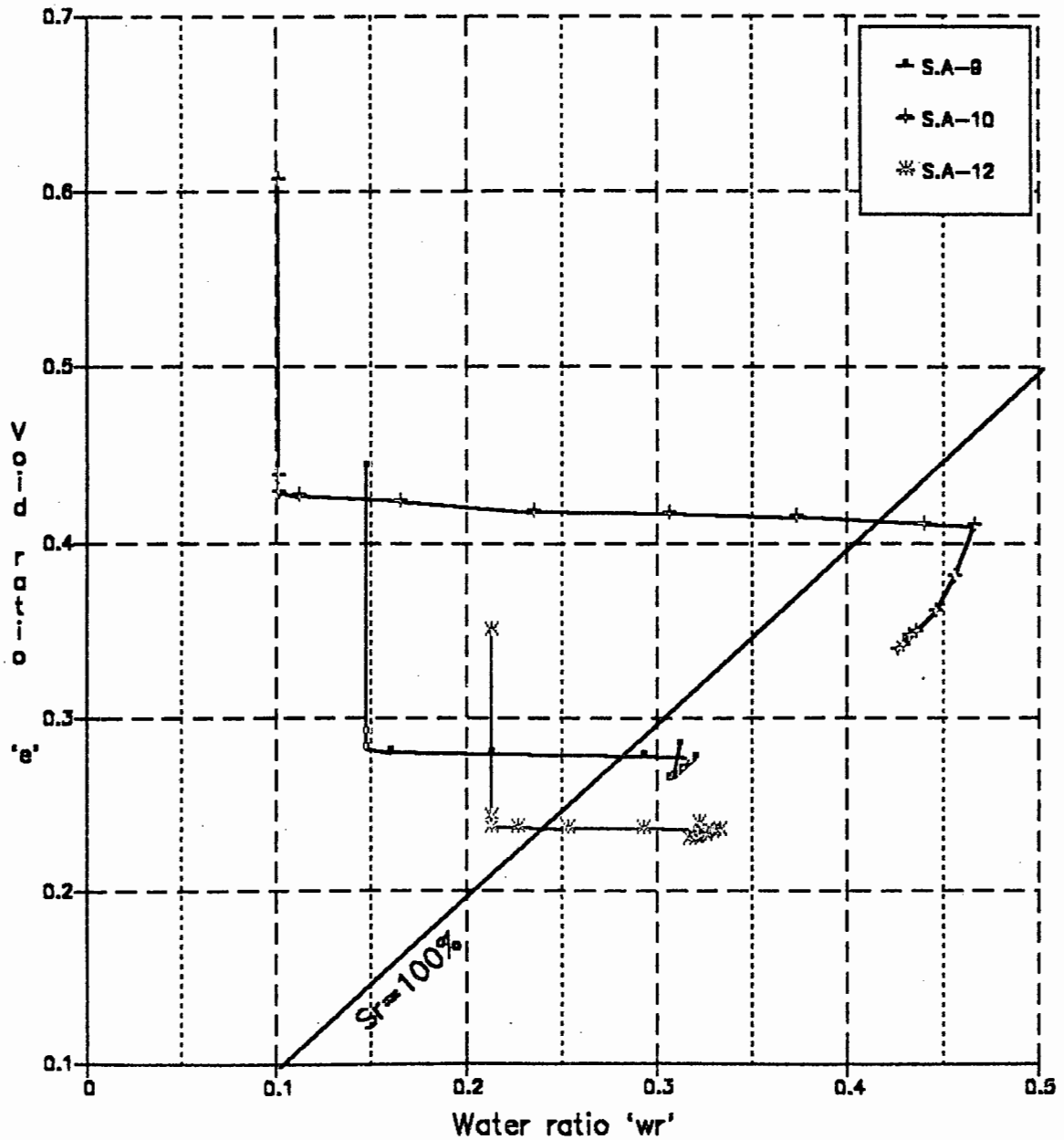


Figure E.39: Site A, Berea Road [Compacted samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

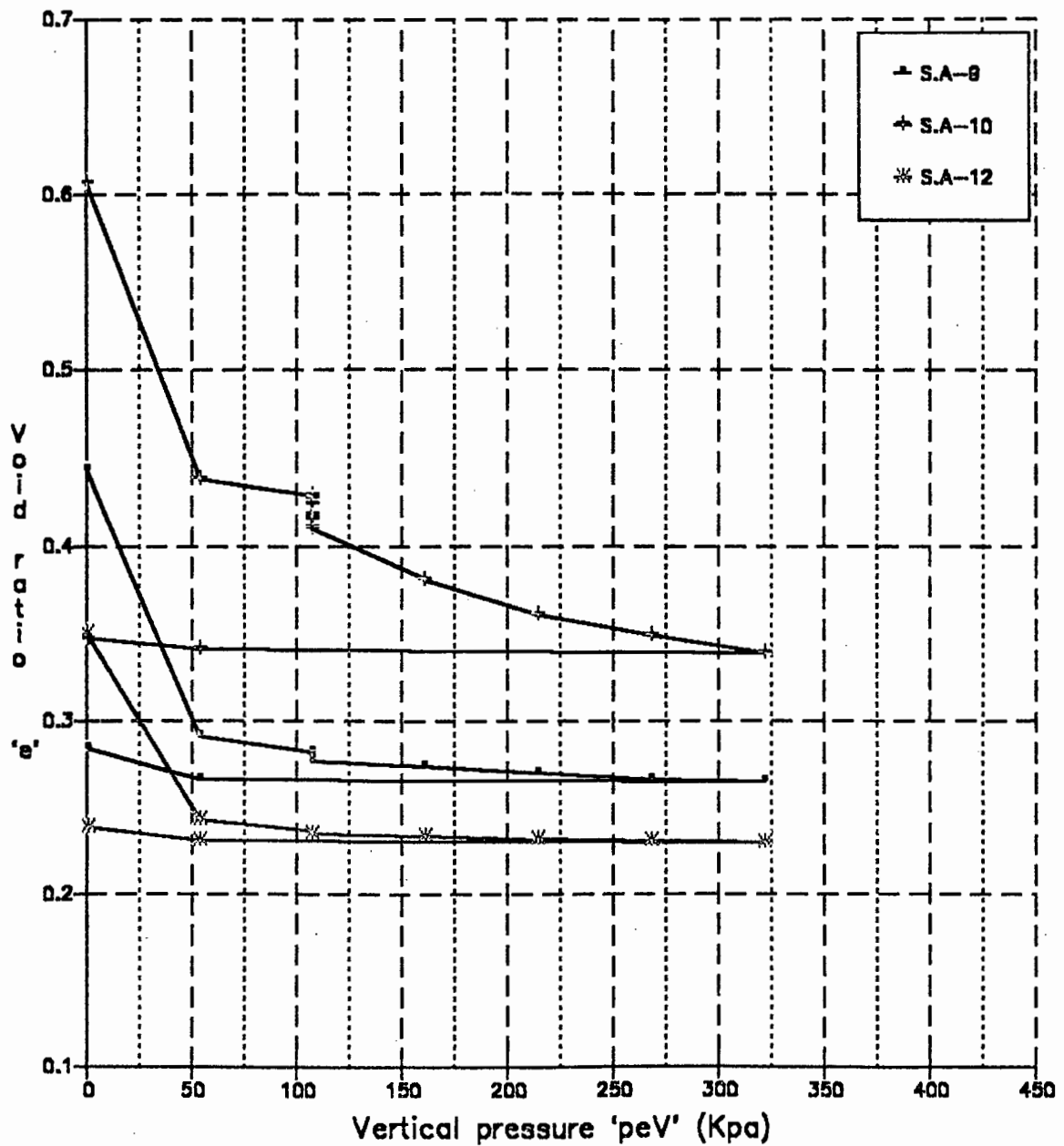


Figure E.40: Site A, Berea Road [Compacted samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.23: Site A, Berea Road [Undisturbed samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.A-11/ II.180& II.179	0 49.0 98.1 98.1 98.1 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 49.0 1.0	0.551 0.485 0.478 0.473 0.470 0.466 0.464 0.462 0.461 0.457 0.453 0.446 0.444 0.443 0.445	0.048 0.048 0.048 0.067 0.107 0.173 0.227 0.293 0.386 0.382 0.377 0.373 0.368 0.370 0.370	S.A-1/ Ba.78	1.0 49.0 98.1 98.1 98.1 98.1 98.1 98.1 147.1 196.1 49.0 1.0	0.6177 0.6088 0.6061 0.6009 0.5817 0.5813 0.5777 0.5777 0.5774 0.5669 0.5682 0.5767	0.044 0.043 0.043 0.093 0.173 0.253 0.346 0.402 0.401 0.400 0.400 0.401

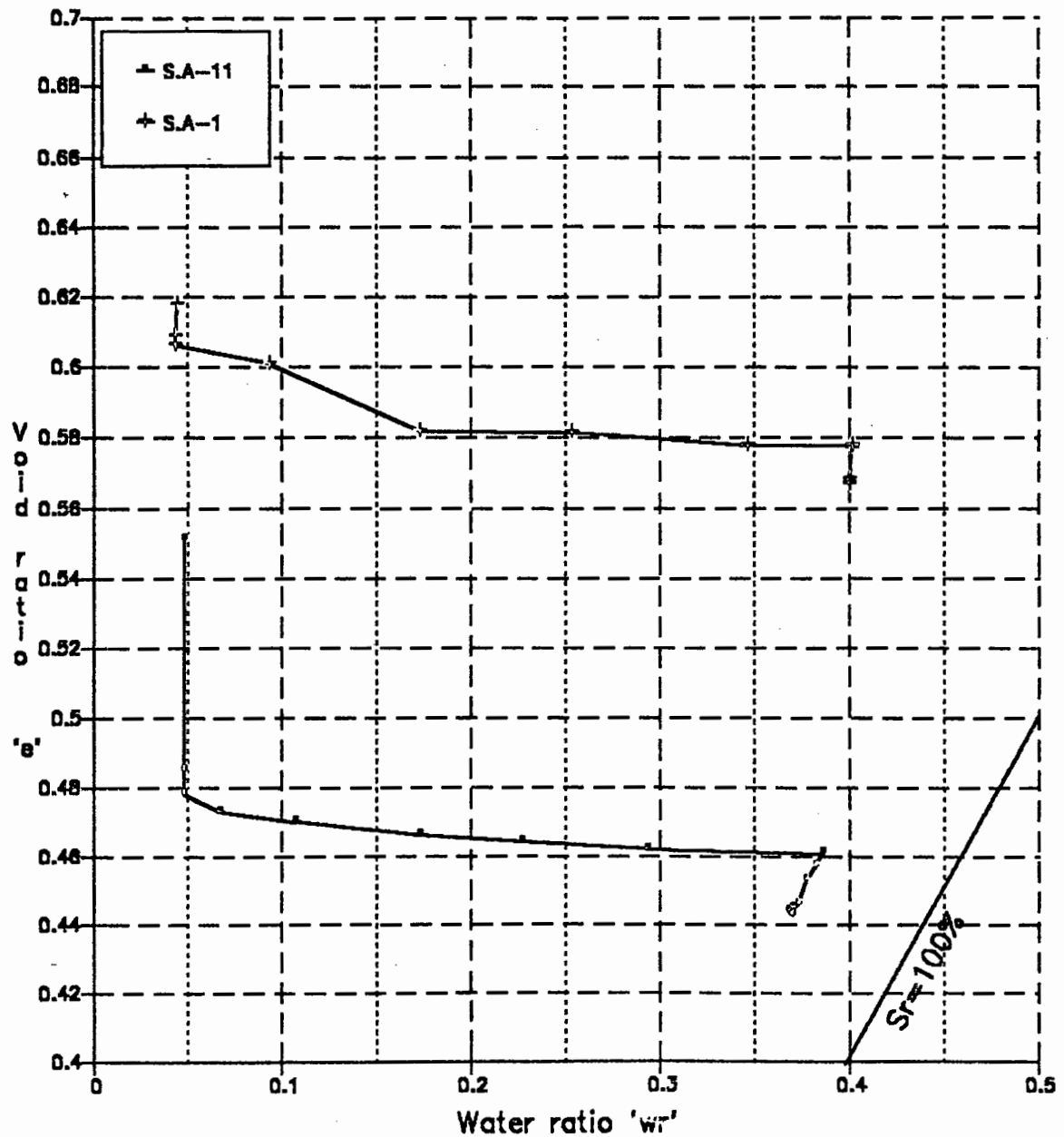


Figure E.41: Site A, Berea Road [Undisturbed samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

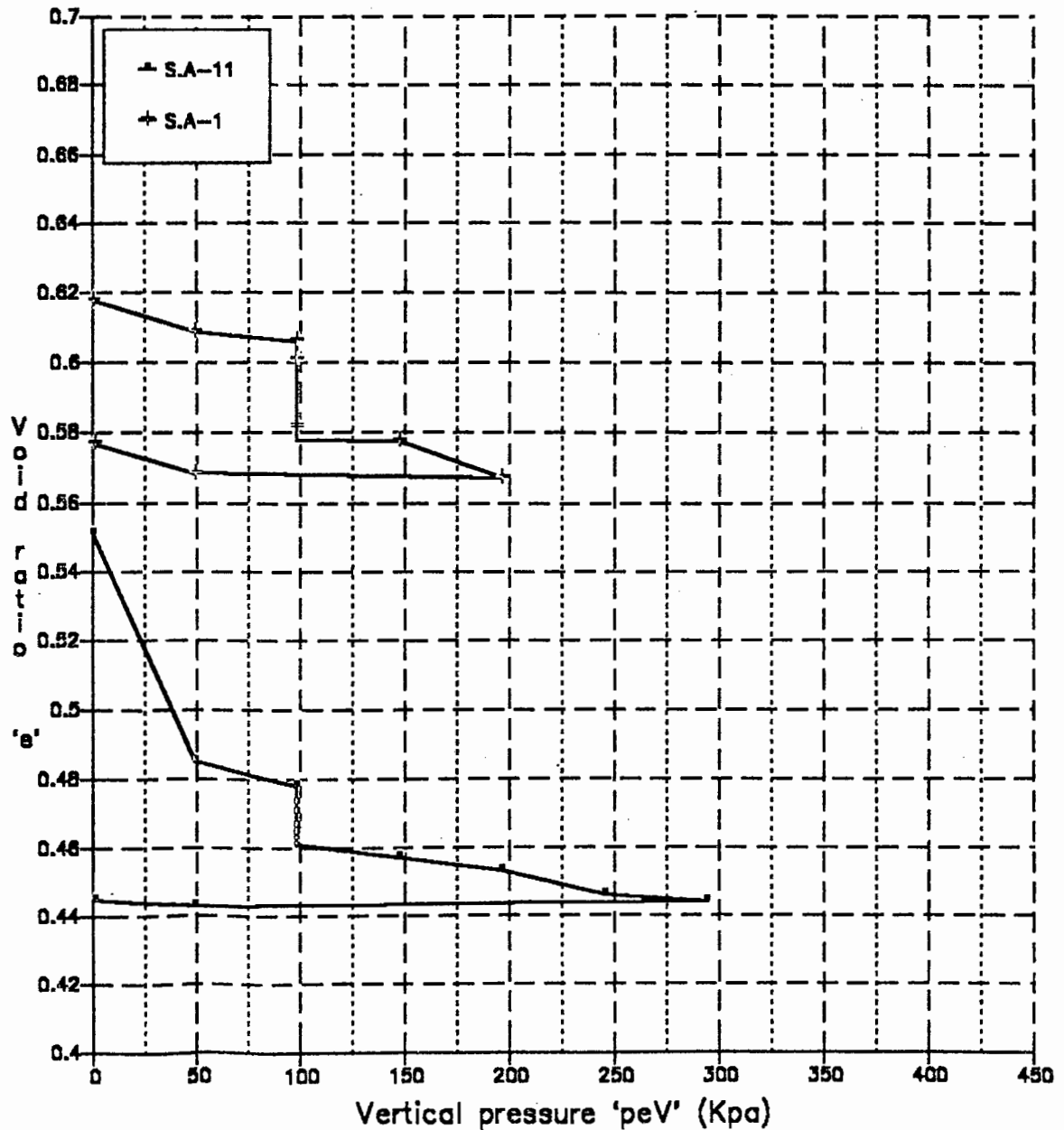


Figure E.42: Site A, Berea Road [Undisturbed samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

E.4.5 Site 7 - Mowbray - Cape.

Table E.24: Site 7, Mowbray [Remoulded samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.7-2/	0	1.675	1.640	S.7-5/	0	1.079	0.983
I.91&	0	1.394	1.378	I.96&	0	0.904	0.809
I.99	0	1.101	1.078	I.120	0	0.748	0.653
	0	0.873	0.847		0	0.626	0.532
	0	0.742	0.683		0	0.493	0.371
	0	0.588	0.508		0	0.487	0.242
	0	0.549	0.337		0	0.540	0.398
	0	0.548	0.099		0	0.489	0.290
	0	0.575	0.385		0	0.487	0.226
	53.6	0.509	0.385		53.6	0.473	0.226
	107.3	0.505	0.385		107.3	0.467	0.226
	107.3	0.505	0.414		107.3	0.467	0.235
	107.3	0.509	0.441		107.3	0.468	0.276
	107.3	0.509	0.483		107.3	0.470	0.303
	107.3	0.522	0.510		107.3	0.474	0.331
	107.3	0.524	0.538		107.3	0.476	0.345
	107.3	0.543	0.566		107.3	0.493	0.414
	107.3	0.554	0.607		107.3	0.512	0.469
	107.3	0.557	0.635		107.3	0.532	0.524
	107.3	0.558	0.690		107.3	0.536	0.538
	107.3	0.560	0.773		107.3	0.537	0.593
	214.6	0.549	0.731		107.3	0.538	0.635
	53.6	0.575	0.745		214.6	0.529	0.593
	0.8	0.705	0.750		53.6	0.545	0.607
					0.8	0.626	0.612

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.7-7/	0	2.449	1.787	S.7-10/	0	2.770	1.515
I.116&	0	0.653	0.559	II.184&	0	0.845	0.574
II.143	0	0.506	0.389		0	0.741	0.459
	0	0.494	0.264		0	0.732	0.446
	0	0.488	0.200		0	0.723	0.430
	0	0.493	0.077		49.0	0.708	0.430
	49.0	0.486	0.077		98.1	0.699	0.430
	98.1	0.482	0.077		98.1	0.702	0.441
	98.1	0.480	0.091		98.1	0.713	0.510
	98.1	0.478	0.138		98.1	0.709	0.621
	98.1	0.478	0.193		98.1	0.704	0.648
	98.1	0.480	0.248		147.1	0.684	0.638
	98.1	0.483	0.290		196.1	0.663	0.628
	98.1	0.487	0.331		245.2	0.647	0.617
	98.1	0.492	0.386		294.2	0.632	0.607
	98.1	0.503	0.441		49.0	0.662	0.624
	98.1	0.519	0.497		1.0	0.724	0.629
	98.1	0.529	0.552				
	98.1	0.531	0.593				
	147.1	0.529	0.586				
	196.1	0.524	0.579				
	245.2	0.519	0.572				
	294.2	0.511	0.566				
	343.2	0.509	0.559				
	392.3	0.505	0.552				
	49.0	0.531	0.571				
	1.0	0.561	0.577				

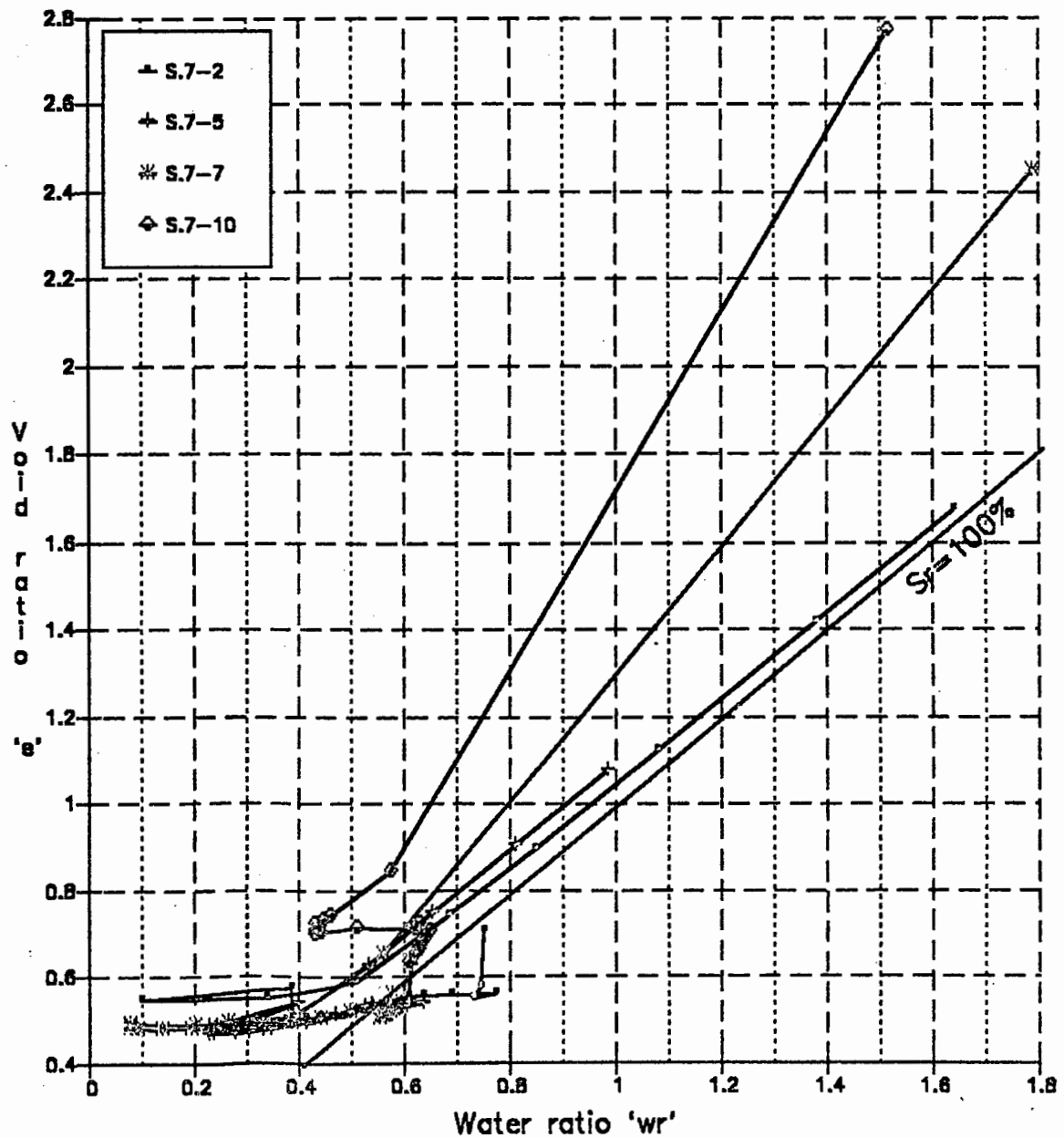


Figure E.43: Site 7, Mowbray [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

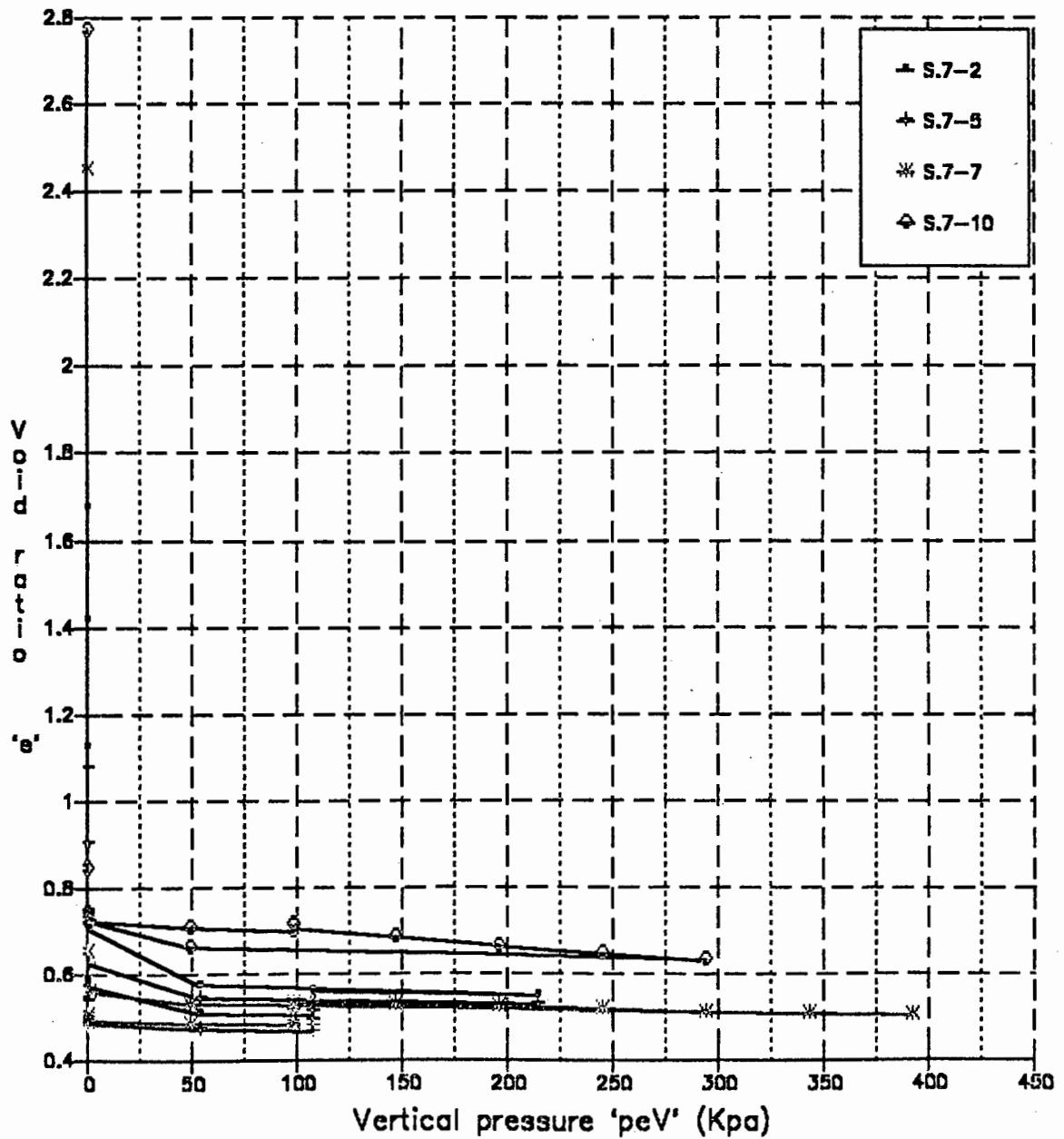


Figure E.44: Site 7, Mowbray [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.25: Site 7, Mowbray [Compacted sample - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.7-13/	0	0.469	0.215
II.195&	53.6	0.358	0.215
II.202	107.3	0.354	0.215
	107.3	0.363	0.235
	107.3	0.379	0.317
	107.3	0.397	0.400
	107.3	0.408	0.469
	107.3	0.411	0.552
	107.3	0.411	0.593
	160.9	0.409	0.583
	214.6	0.402	0.573
	268.2	0.393	0.562
	321.9	0.386	0.552
	53.6	0.408	0.568
	0.8	0.476	0.574

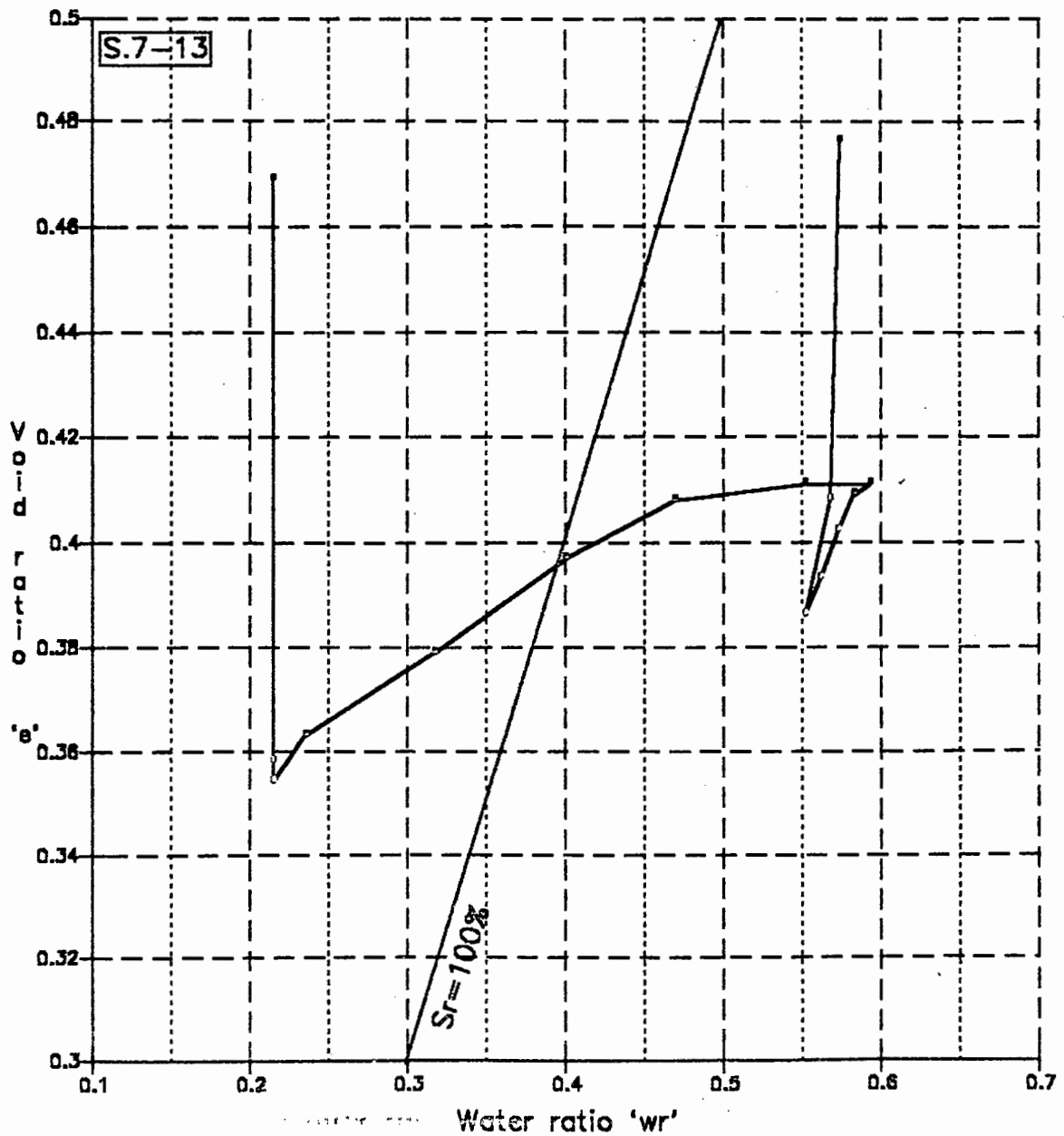


Figure E.45: Site 7, Mowbray [Compacted sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

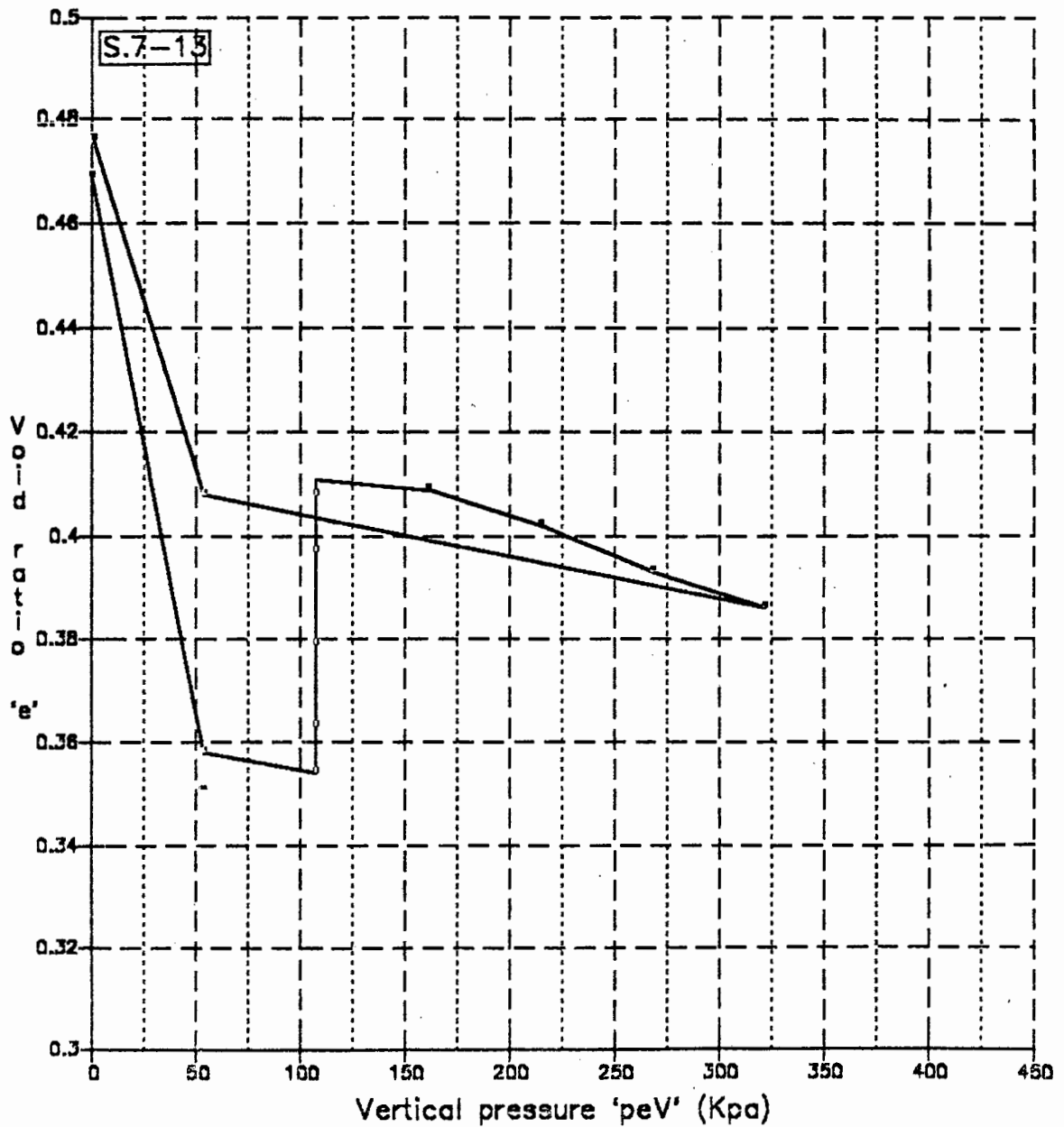


Figure E.46: Site 7, Mowbray [Compacted sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Table E.26: Site 7, Mowbray [Undisturbed samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.7-12/	0	0.574	0.505	S.7-1/	1.0	0.7206	0.581
II.185&	0	0.563	0.496	Ba.77	49.0	0.7115	0.579
II.193	0	0.548	0.487		98.1	0.7069	0.579
	0	0.541	0.445		98.1	0.7144	0.607
	0	0.535	0.439		98.1	0.7733	0.745
	53.7	0.494	0.439		98.1	0.7817	0.753
	107.3	0.489	0.439		147.1	0.7795	0.751
	107.3	0.497	0.497		196.1	0.7754	0.750
	107.3	0.502	0.566		147.1	0.7765	0.751
	107.3	0.503	0.607		98.1	0.7803	0.750
	107.3	0.503	0.648		49.0	0.7849	0.751
	161.0	0.501	0.631		1.0	0.8271	0.751
	214.6	0.498	0.614				
	268.3	0.495	0.596				
	322.0	0.494	0.579				
	53.7	0.505	0.590				
	0.8	0.534	0.596				

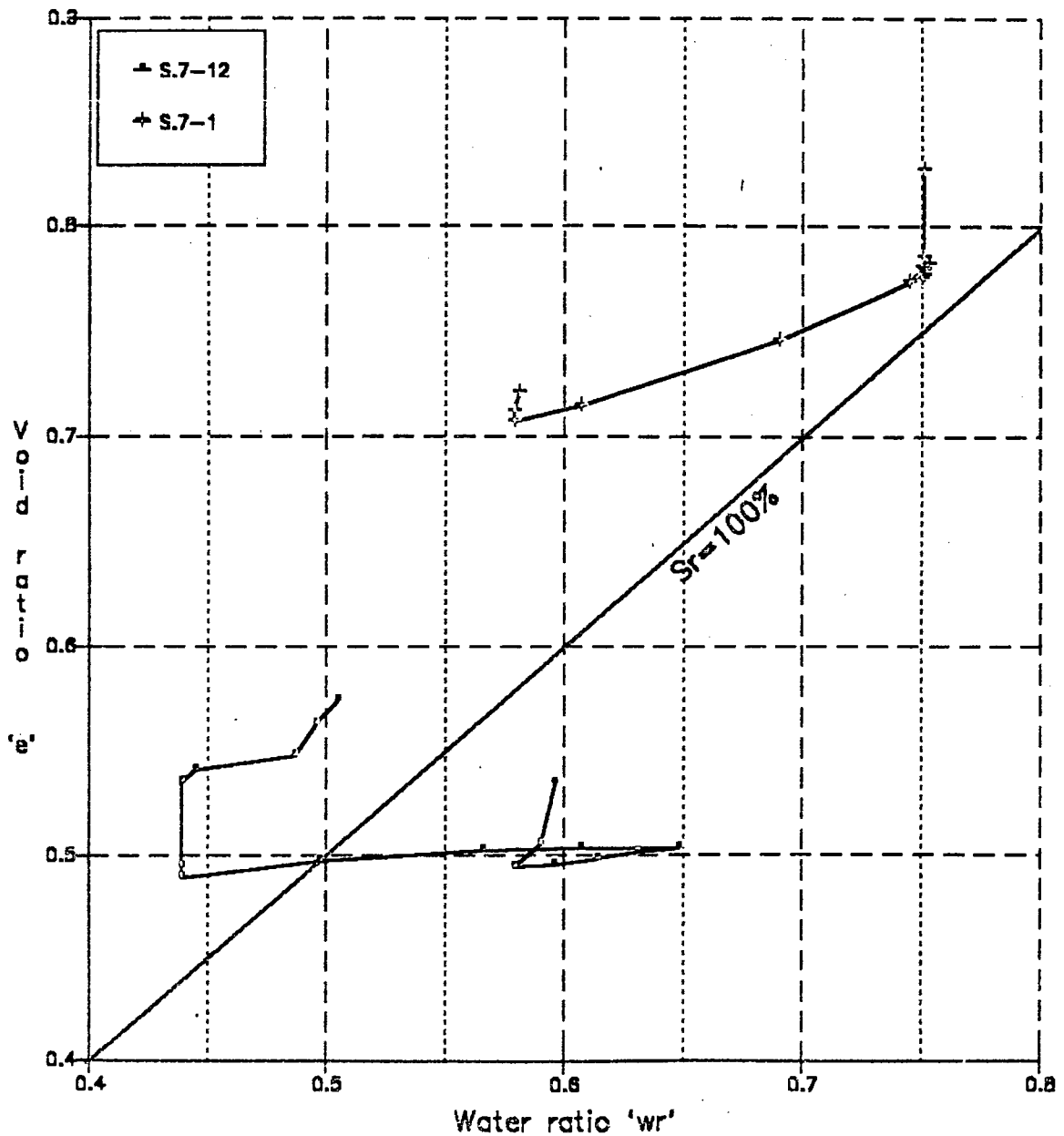


Figure E.47: Site 7, Mowbray [Undisturbed samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

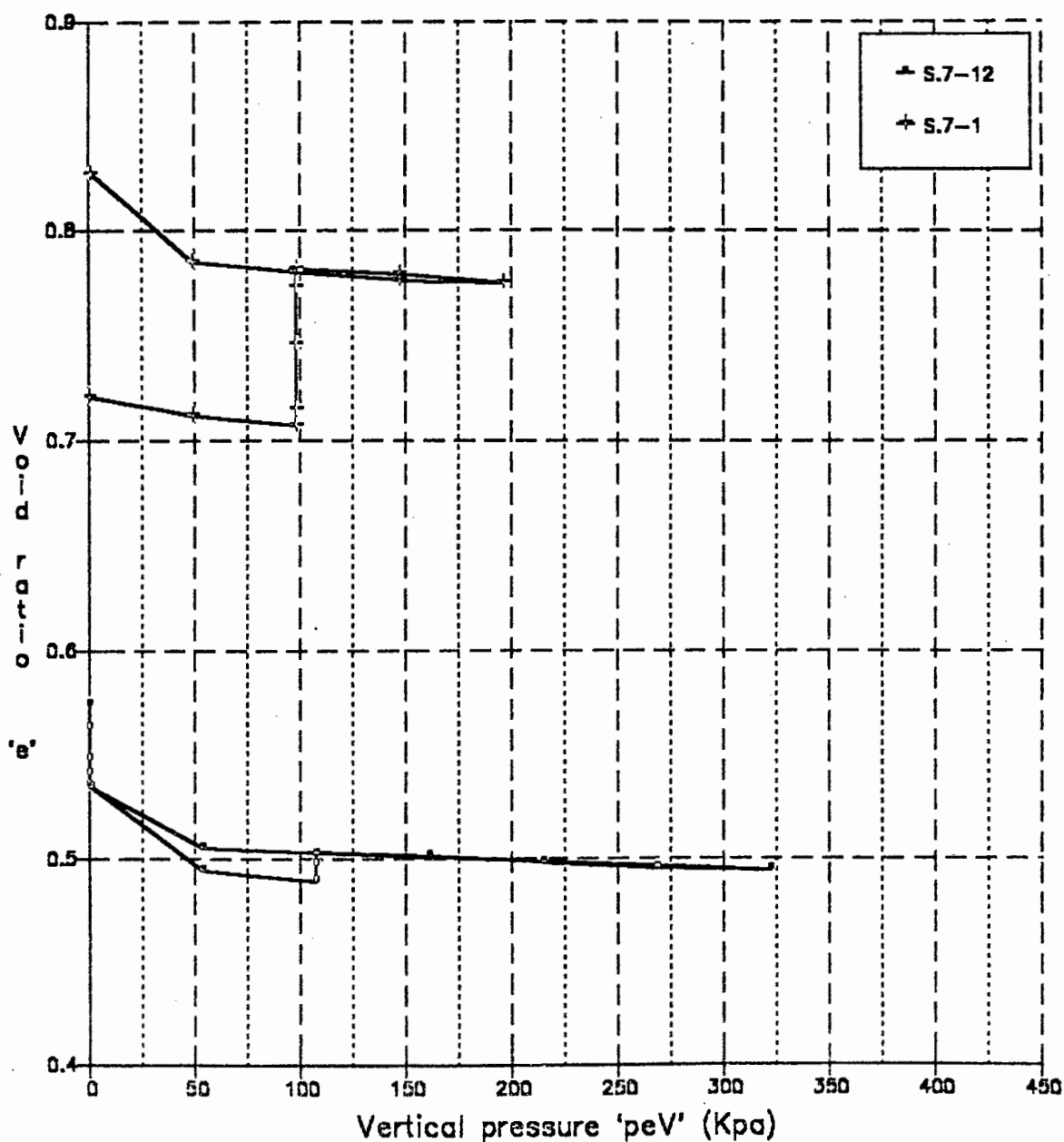


Figure E.48: Site 7, Mowbray [Undisturbed samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

E.4.6 Site B - Francois Road, Durban.

Table E.27: Site B, Francois Road [Remoulded sample - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.B-1A/	0	0.830	0.541
II.206&	0	0.653	0.019
I.124	49.0	0.645	0.019
	98.1	0.636	0.019
	98.1	0.632	0.041
	98.1	0.623	0.081
	98.1	0.623	0.122
	98.1	0.621	0.162
	98.1	0.620	0.246
	196.1	0.602	0.241
	49.0	0.603	0.243
	1.0	0.607	0.246

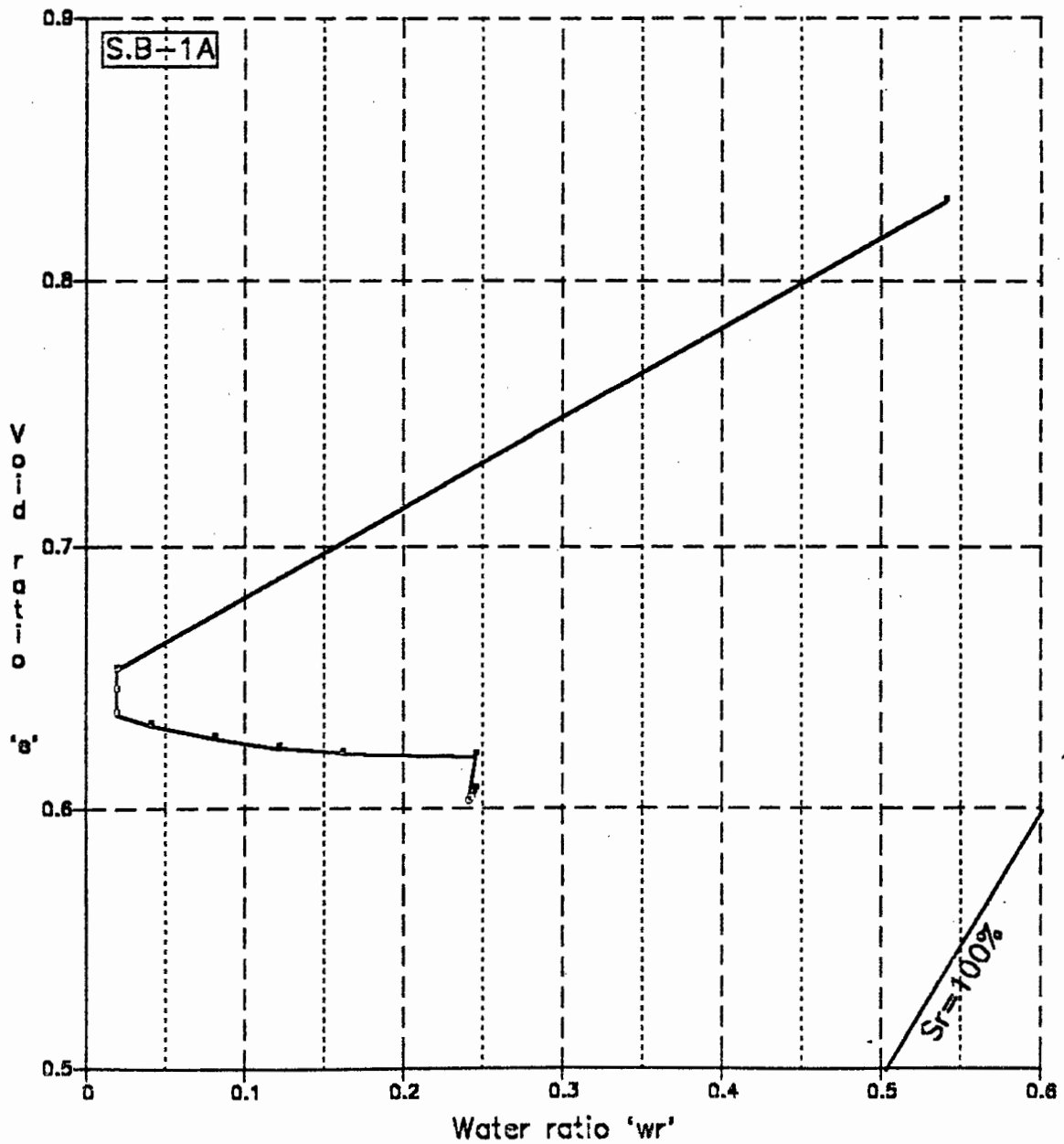


Figure E.49: Site B, Francois Road [Remoulded sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

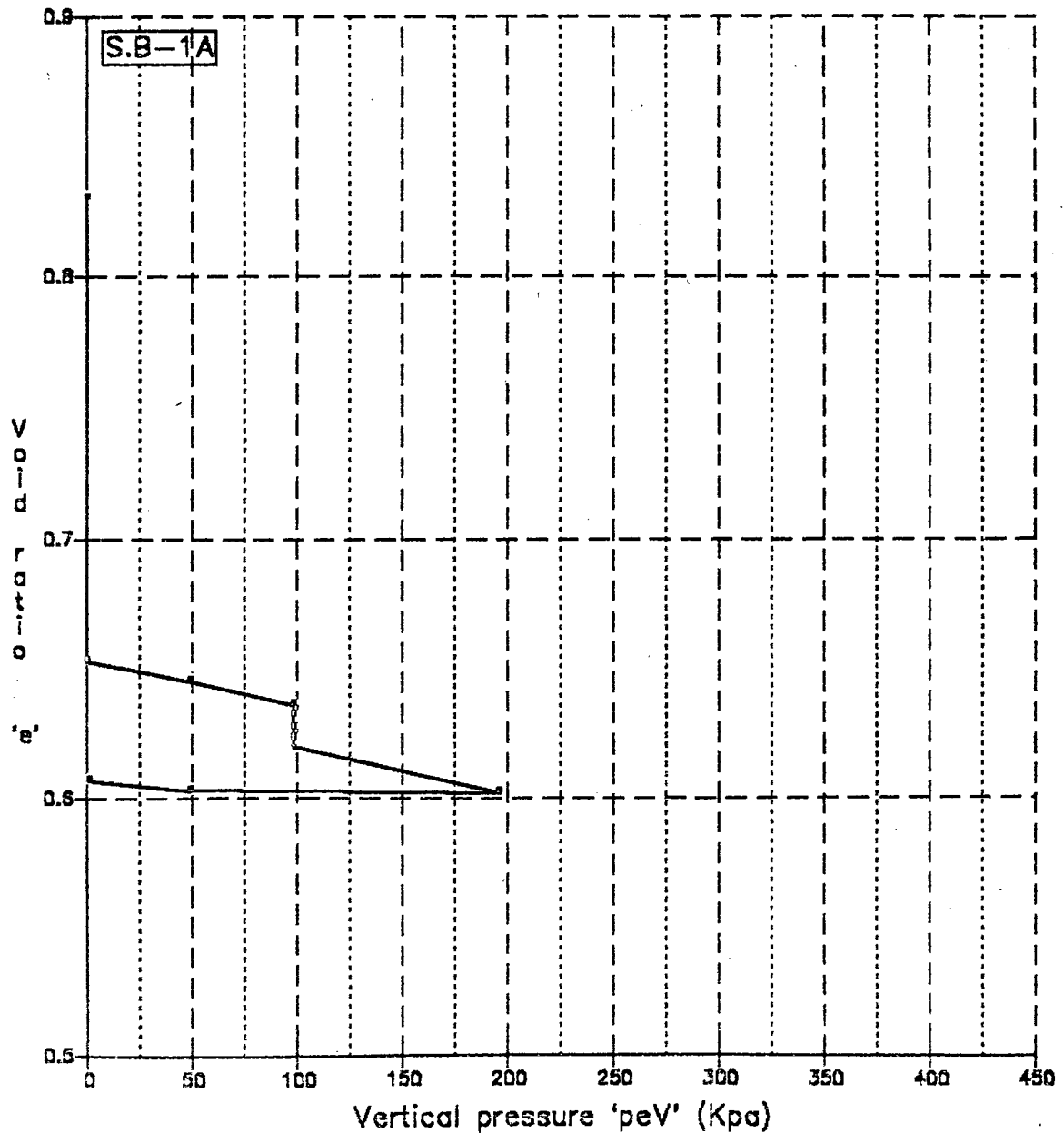


Figure E.50: Site B, Francois Road [Remoulded sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio ' e ' versus Effective Vertical Pressure, or Stress, ' p_{eV} ',

E.4.7 Site C - Margaret Mayton Avenue, Durban.

Table E.28: Site C, Margaret Mayton Avenue [Remoulded sample - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.C-1A/	0	0.820	0.530
II.206&	0	0.651	0.023
I.126	53.7	0.640	0.023
	107.3	0.629	0.023
	107.3	0.624	0.040
	107.3	0.621	0.066
	107.3	0.616	0.093
	107.3	0.612	0.132
	107.3	0.609	0.172
	107.3	0.607	0.212
	107.3	0.605	0.291
	214.6	0.578	0.286
	53.7	0.581	0.288
	0.8	0.585	0.291

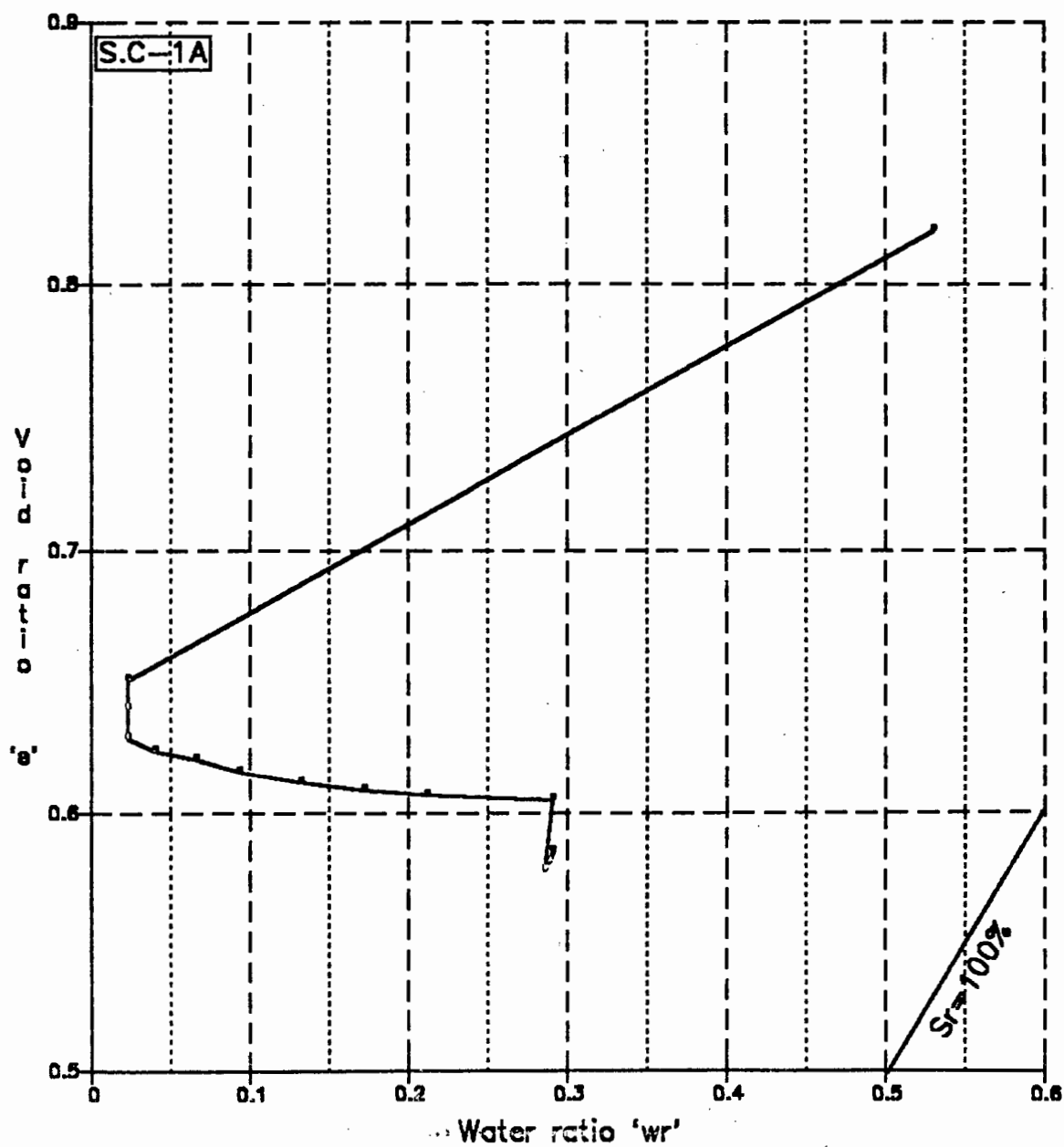


Figure E.51: Site C, Margaret Mayton Avenue [Remoulded sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

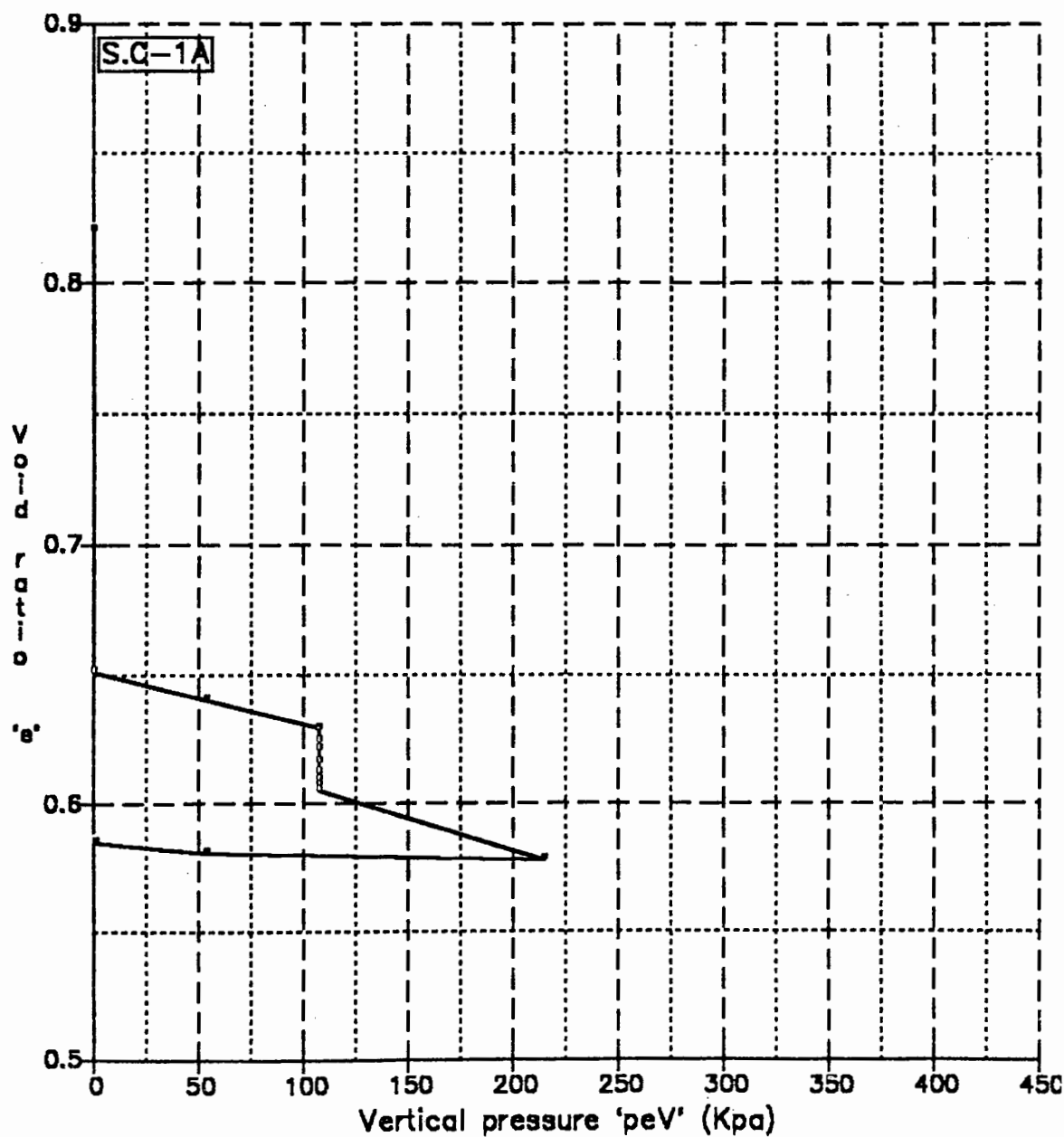


Figure E.52: Site C, Margaret Mayton Avenue [Remoulded sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio ' e ' versus Effective Vertical Pressure ' p_{eV} '.

E.4.8 Site D - Rose Hill, Durban.

Table E.29: Site D, Rose Hill [Remoulded sample - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.D-1A/	0	0.834	0.557
II.206&	0	0.626	0.027
I.128	49.0	0.620	0.027
	98.1	0.616	0.027
	98.1	0.614	0.035
	98.1	0.610	0.068
	98.1	0.607	0.095
	98.1	0.604	0.135
	98.1	0.602	0.189
	98.1	0.601	0.219
	196.1	0.588	0.213
	49.0	0.589	0.216
	1.0	0.590	0.219

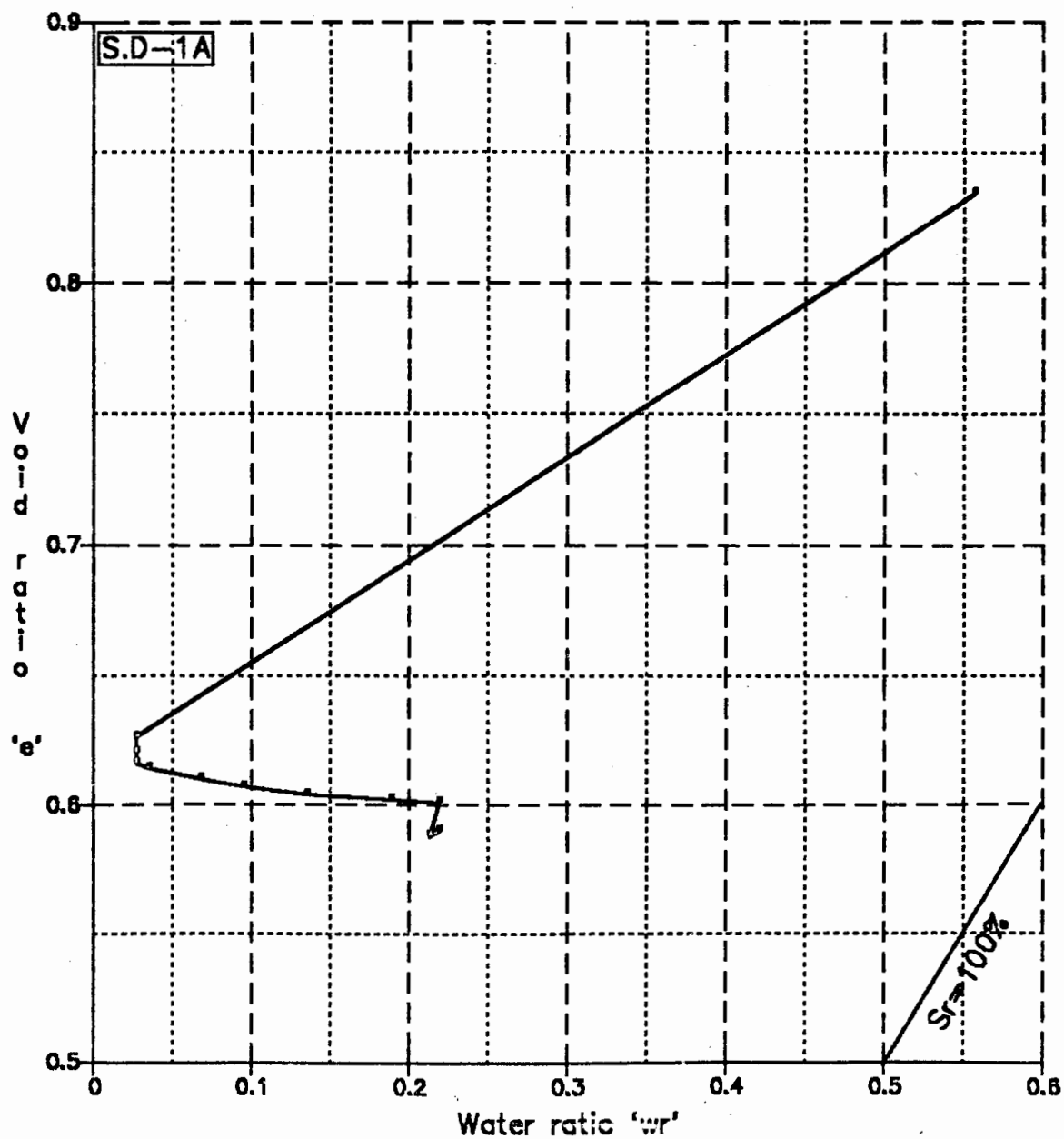


Figure E.53: Site D, Rose Hill [Remoulded sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

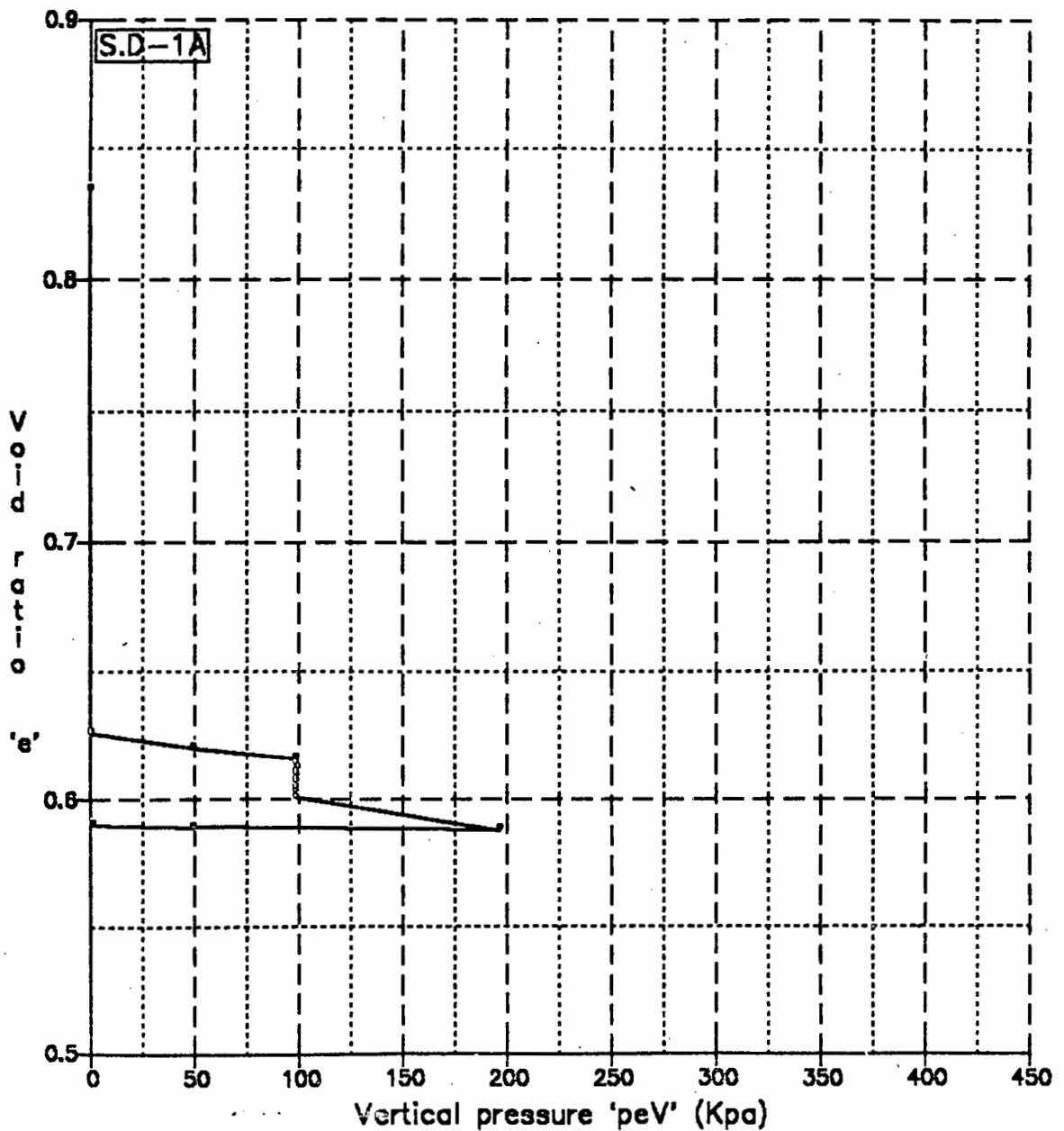


Figure E.54: Site D, Rose Hill [Remoulded sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio ' e ' versus Effective Vertical Pressure, or Stress, ' p_{eV} '.

E.4.9 Site 48, Lady Grey District Farm Unity, Natal.

Table E.30: Site 48, Lady Grey [Undisturbed sample - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.48-1/ Ba.78	1.0	0.5593	0.419
	49.0	0.5567	0.419
	98.1	0.5549	0.419
	98.1	0.5640	0.468
	98.1	0.5661	0.520
	98.1	0.5669	0.523
	122.6	0.5668	0.523
	147.1	0.5639	0.522
	196.1	0.5635	0.520
	245.2	0.5634	0.518
	294.2	0.5628	0.517
	343.2	0.5627	0.517
	245.2	0.5681	0.518
	147.1	0.5620	0.518
	98.1	0.5628	0.518
	49.0	0.5649	0.518
	1.0	0.5721	0.518

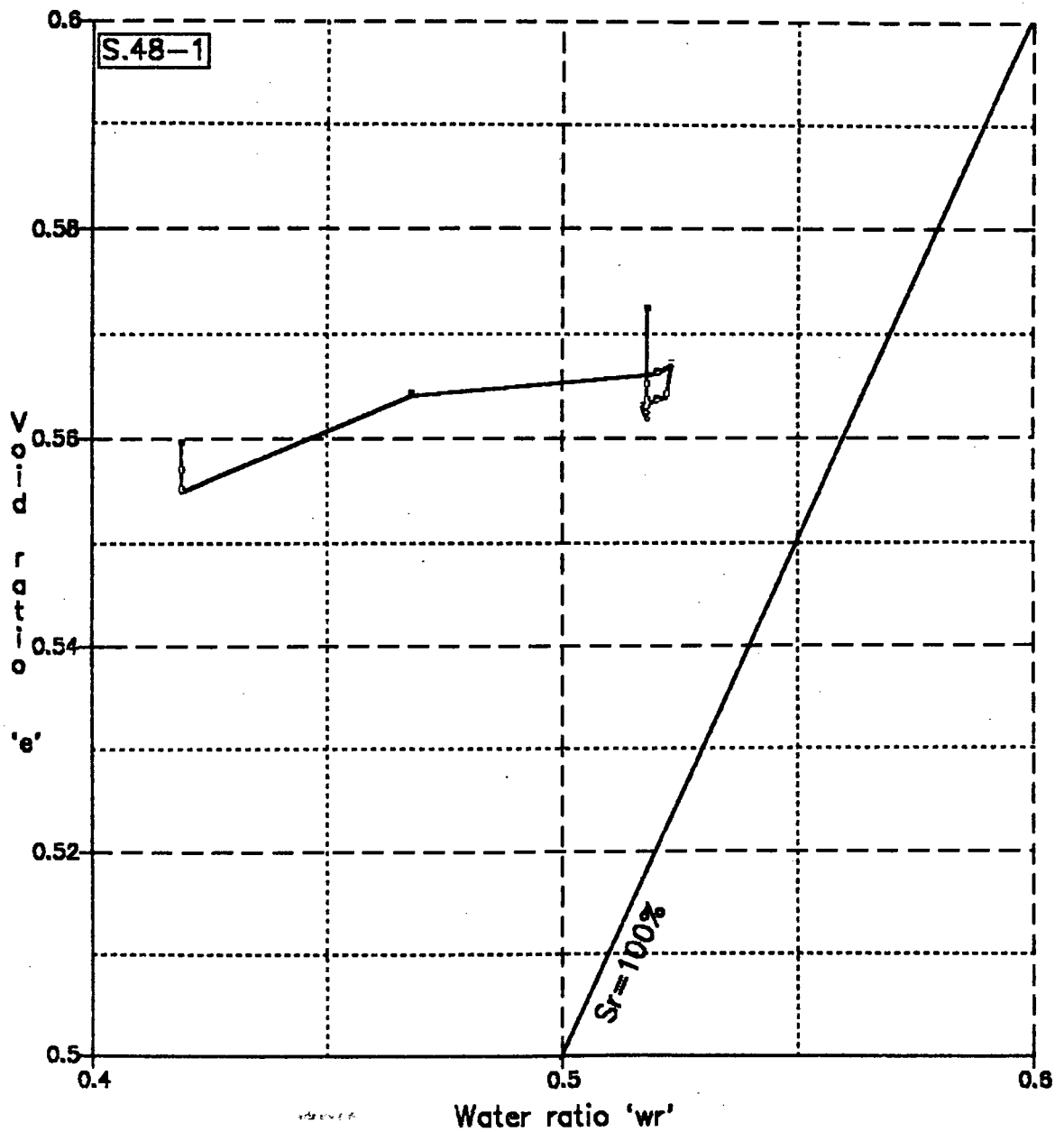


Figure E.55: Site 48, Lady Grey [Undisturbed sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

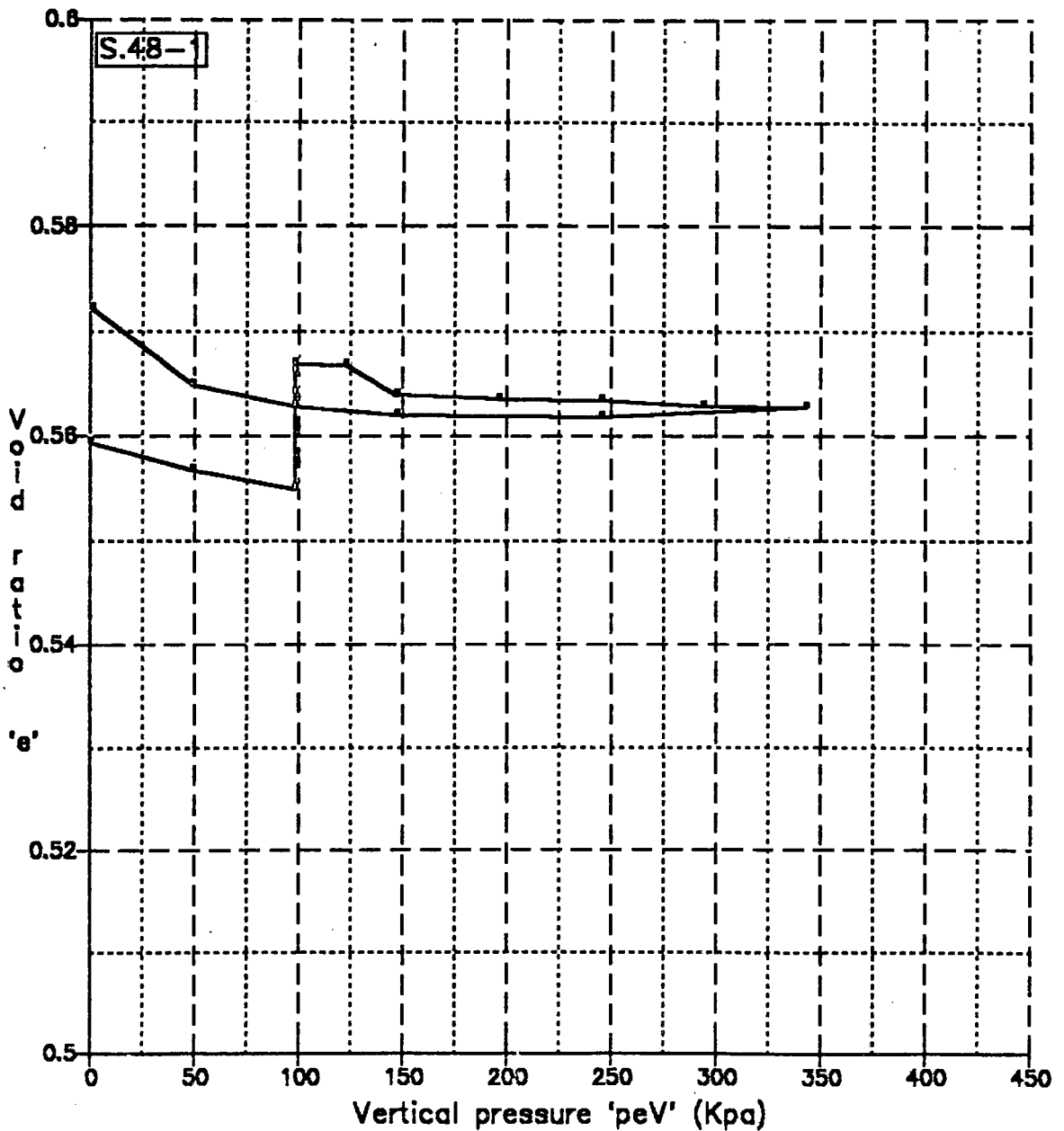


Figure E.56: Site 48, Lady Grey [Undisturbed sample - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'. (Using Rubber membrane method - Ballantyne and Sparks 1978).

E.5 TEST RESULTS FOR ARTIFICIAL SOILSE.5.1 Kaolin K.1 (13% clay size).

Table E.31: Kaolin K.1 [Remoulded samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
K.1-2/ III.296& III.353	0 0 0 0 0 0 0 0 49.0 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.5 49.0 9.8 1.0	0.749 0.630 0.603 0.599 0.596 0.592 0.589 0.592 0.588 0.585 0.582 0.579 0.578 0.576 0.572 0.572 0.561 0.561 0.558 0.554 0.552 0.551 0.551 0.551 0.553	0.598 0.382 0.353 0.323 0.272 0.230 0.200 0.009 0.009 0.009 0.027 0.067 0.107 0.147 0.187 0.253 0.293 0.291 0.288 0.286 0.283 0.284 0.285 0.285	K.1-3/ III.298& III.359	0 0 0 0 0 0 0 0 49.0 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 49.0 9.8 1.0	0.664 0.603 0.600 0.595 0.591 0.591 0.593 0.589 0.586 0.582 0.579 0.576 0.576 0.572 0.562 0.551 0.550 0.544 0.540 0.537 0.535 0.536 0.536 0.540	0.451 0.249 0.230 0.204 0.155 0.083 0.009 0.009 0.009 0.013 0.040 0.080 0.120 0.160 0.200 0.240 0.288 0.285 0.283 0.280 0.277 0.279 0.280 0.280

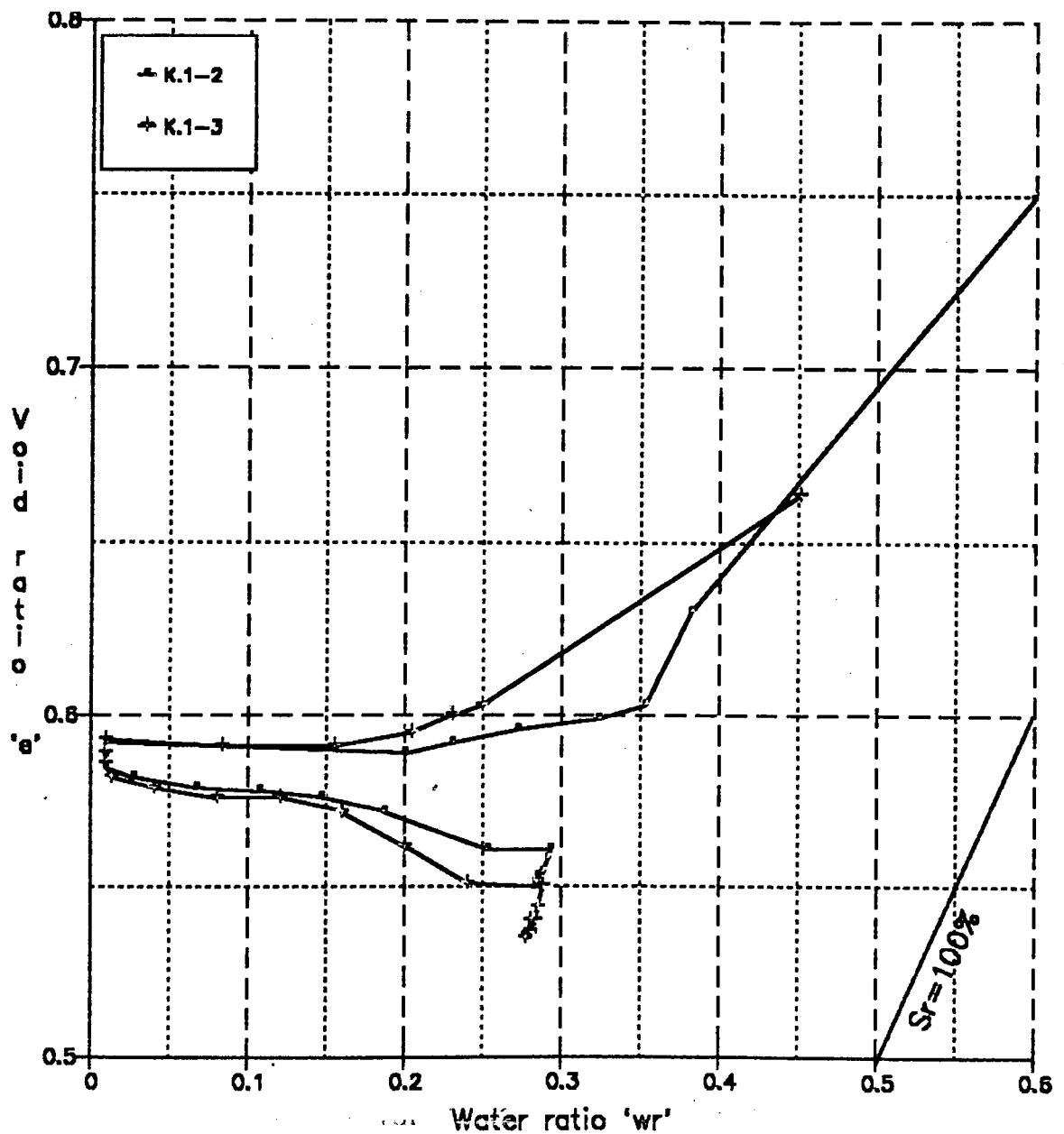


Figure E.57: Kaolin K.1 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

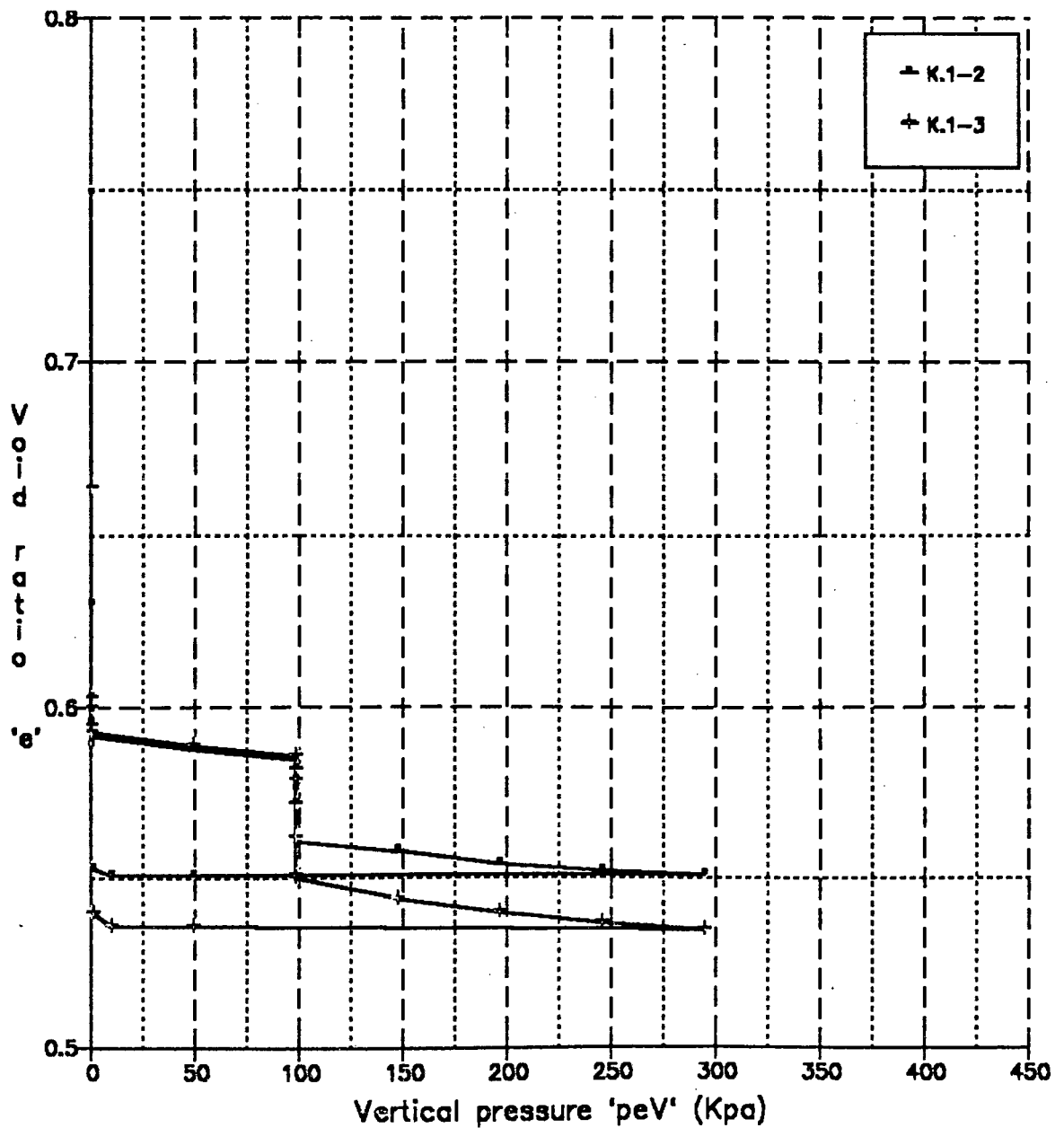


Figure E.58: Kaolin K.1 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

E.5.2 Kaolin K.2 (20% clay size).

Table E.32: Kaolin K.2 [Remoulded samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
K.2-2/	0	0.770	0.580	K.2-3/	0	0.644	0.447
III.313&	0	0.550	0.412	III.315&	0	0.510	0.354
III.361	0	0.515	0.334	III.367	0	0.495	0.325
	0	0.507	0.291		0	0.477	0.251
	0	0.503	0.238		0	0.474	0.200
	0	0.502	0.160		0	0.472	0.058
	0	0.502	0.012		0	0.476	0.010
	49.0	0.494	0.012		49.0	0.474	0.010
	98.1	0.492	0.012		98.1	0.472	0.010
	98.1	0.488	0.026		98.1	0.468	0.018
	98.1	0.485	0.040		98.1	0.467	0.053
	98.1	0.482	0.079		98.1	0.465	0.119
	98.1	0.481	0.159		98.1	0.460	0.238
	98.1	0.478	0.251		98.1	0.448	0.291
	98.1	0.473	0.291		98.1	0.445	0.336
	98.1	0.462	0.330		147.1	0.438	0.334
	147.1	0.456	0.329		196.1	0.433	0.332
	196.1	0.451	0.324		245.2	0.429	0.330
	245.2	0.447	0.320		294.2	0.426	0.328
	294.2	0.443	0.317		49.0	0.427	0.329
	49.0	0.445	0.318		9.8	0.433	0.330
	9.8	0.450	0.320		1.0	0.449	0.330
	1.0	0.462	0.320				

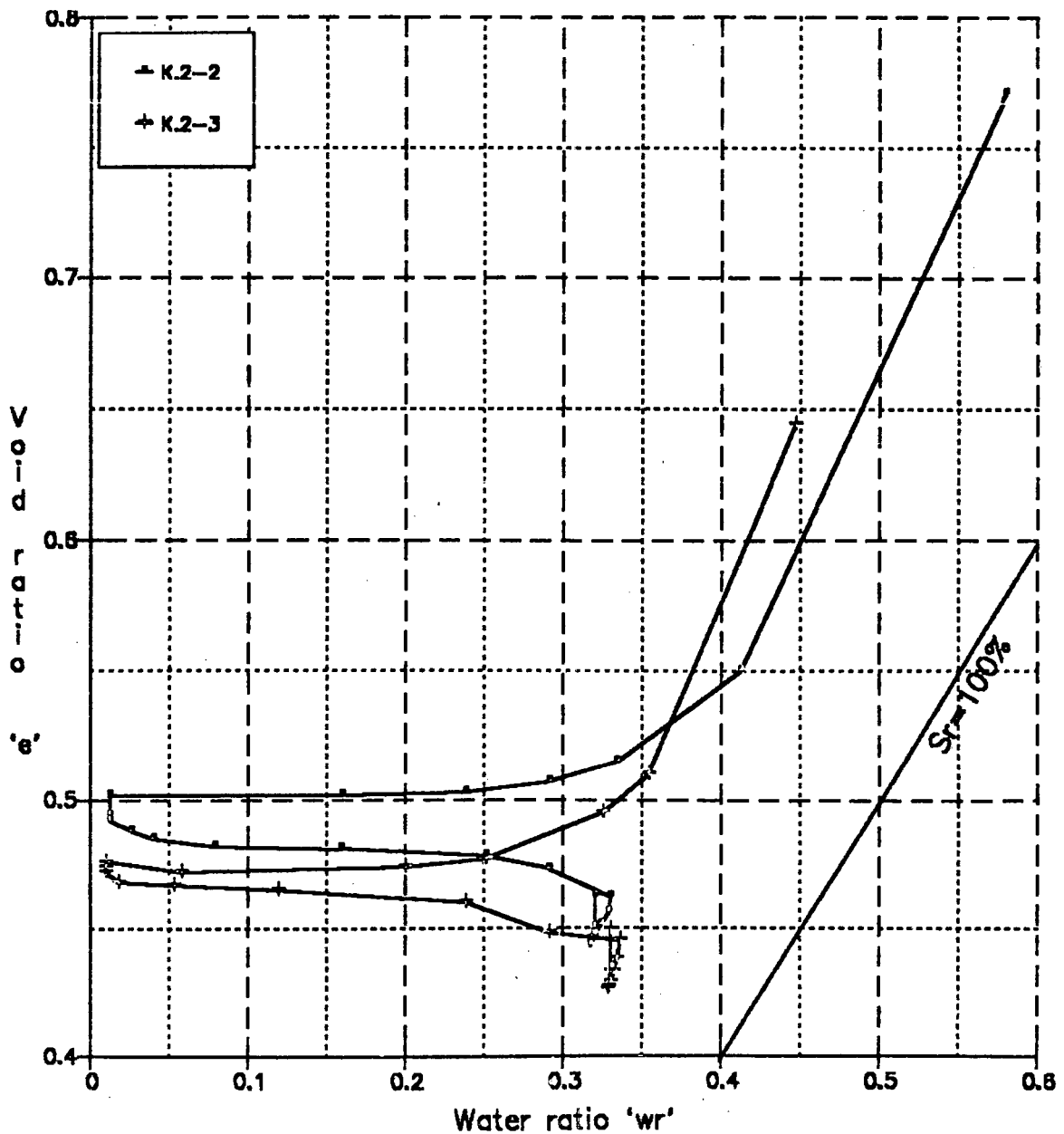


Figure E.59: Kaolin K.2 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

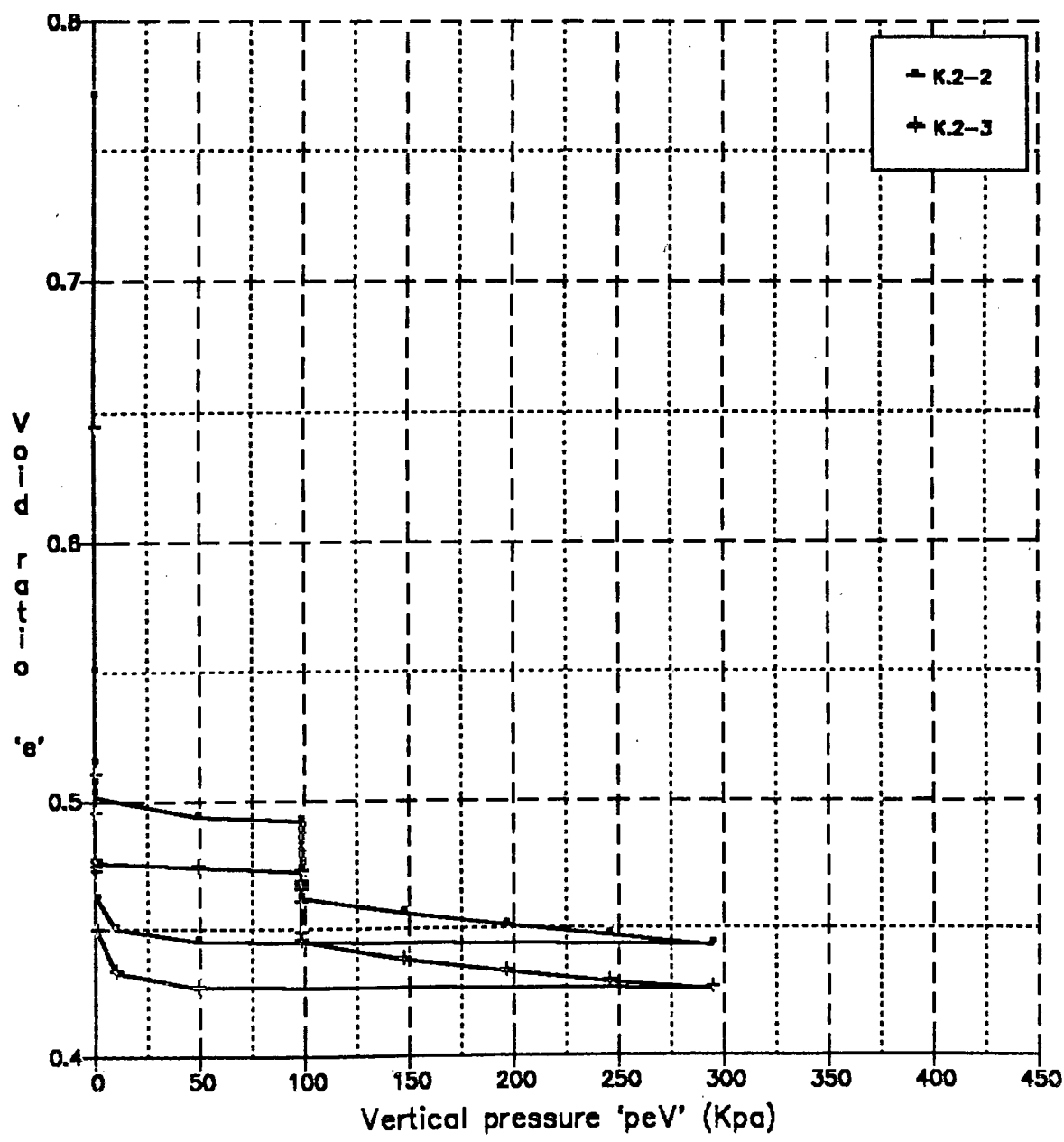


Figure E.60: Kaolin K.2 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

E.5.3 Kaolin K.3 (8.5% clay size).

Table E.33: Kaolin K.3 [Remoulded samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
K.3-2/ III.325& III.369	0 0 0 0 0 0 49.0 98.1 98.1 98.1 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 49.0 9.8 1.0	0.730 0.576 0.568 0.567 0.561 0.559 0.554 0.550 0.546 0.542 0.537 0.535 0.528 0.528 0.527 0.526 0.524 0.523 0.523 0.523 0.523 0.523	0.609 0.383 0.346 0.276 0.200 0.076 0.010 0.010 0.010 0.027 0.067 0.107 0.160 0.214 0.262 0.257 0.253 0.248 0.243 0.244 0.246 0.246	K.3-3/ III.327& III.375	0 0 0 0 0 0 0 49.0 98.1 98.1 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 49.0 9.8 1.0	0.720 0.633 0.626 0.624 0.623 0.615 0.616 0.613 0.611 0.604 0.599 0.595 0.592 0.591 0.590 0.588 0.587 0.586 0.587 0.587 0.588	0.475 0.264 0.229 0.167 0.076 0.042 0.009 0.009 0.009 0.040 0.107 0.147 0.214 0.243 0.241 0.239 0.237 0.235 0.236 0.238 0.238

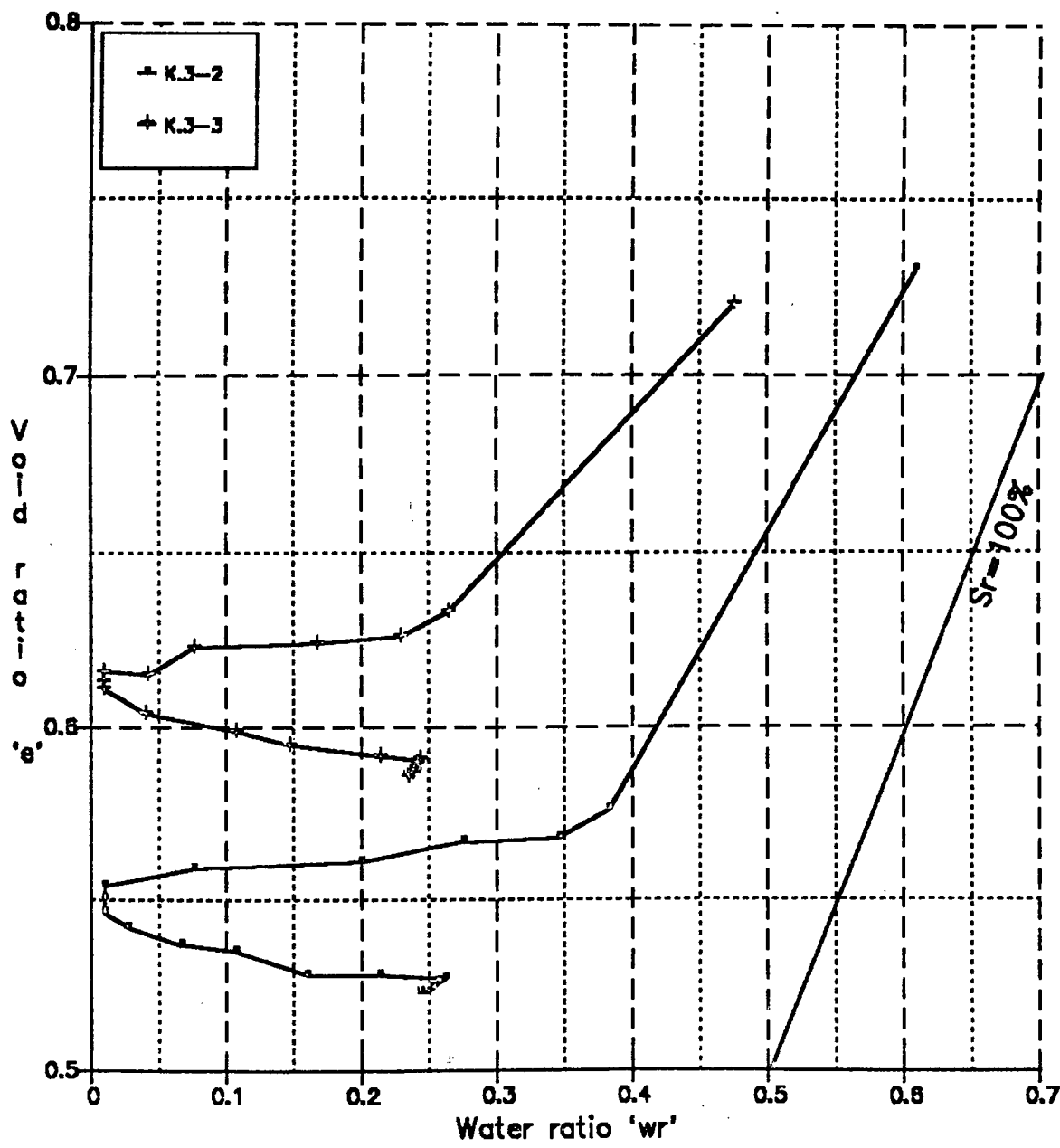


Figure E.61: Kaolin K.3 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

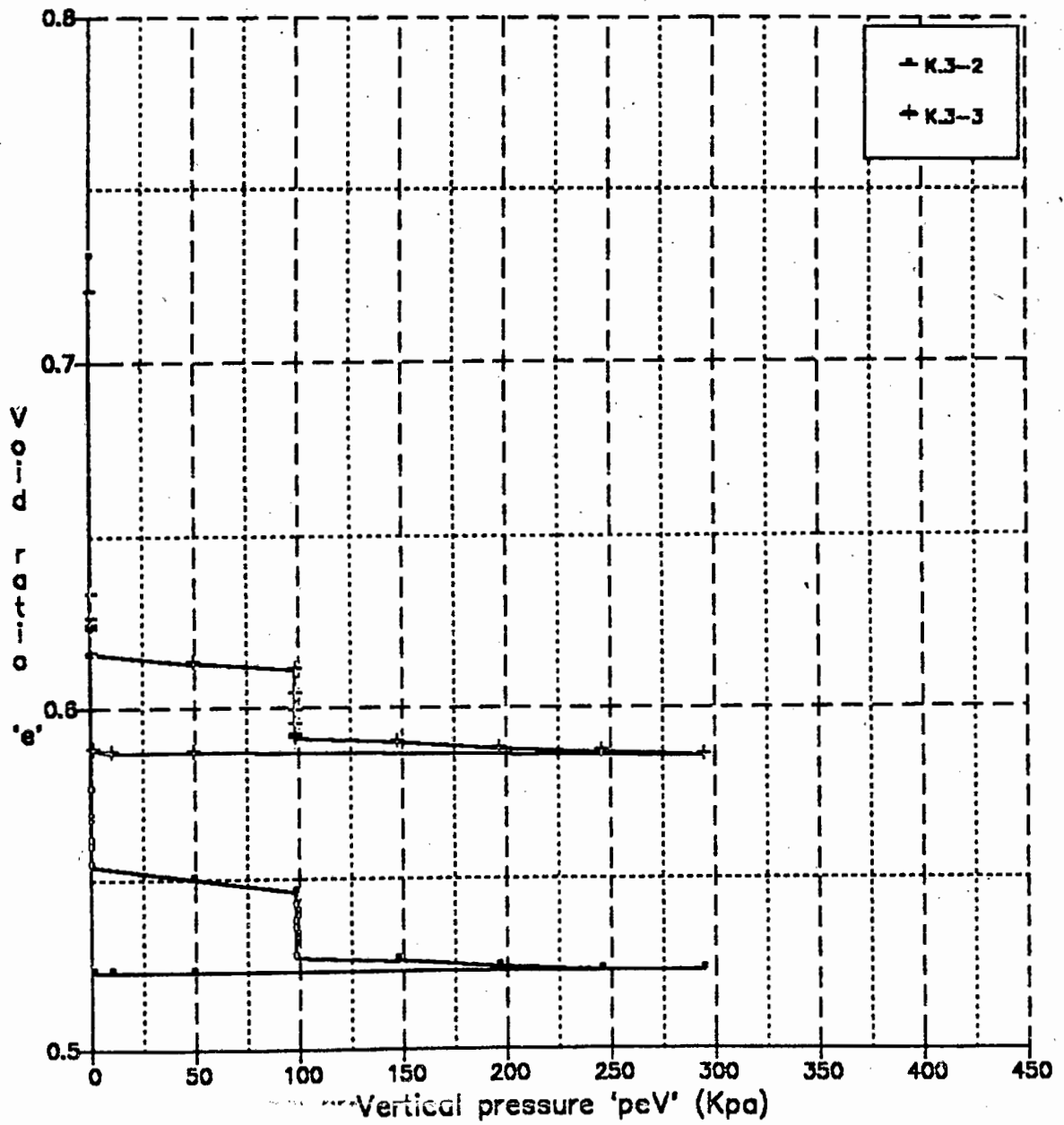


Figure E.62: Kaolin K.3 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
B.1-4/	0	0.725	0.003	B.1-5/	0	1.117	0.033
III.342&	0	0.778	0.021	III.362&	53.6	1.069	0.033
III.399	49.0	0.772	0.021	III.410	107.3	1.026	0.033
	98.1	0.763	0.021		107.3	0.831	0.066
	98.1	0.729	0.053		107.3	0.799	0.106
	98.1	0.715	0.119		107.3	0.780	0.145
	98.1	0.708	0.185		107.3	0.776	0.158
	98.1	0.705	0.251		107.3	0.773	0.169
	98.1	0.697	0.343		160.9	0.755	0.166
	98.1	0.694	0.422		214.6	0.748	0.163
	98.1	0.694	0.438		268.2	0.742	0.159
	147.1	0.690	0.435		321.9	0.737	0.156
	196.1	0.688	0.432		53.6	0.740	0.157
	245.2	0.686	0.428		8.3	0.742	0.158
	294.2	0.684	0.425		0.8	0.744	0.158
	49.0	0.684	0.426				
	9.8	0.688	0.428				
	1.0	0.688	0.428				

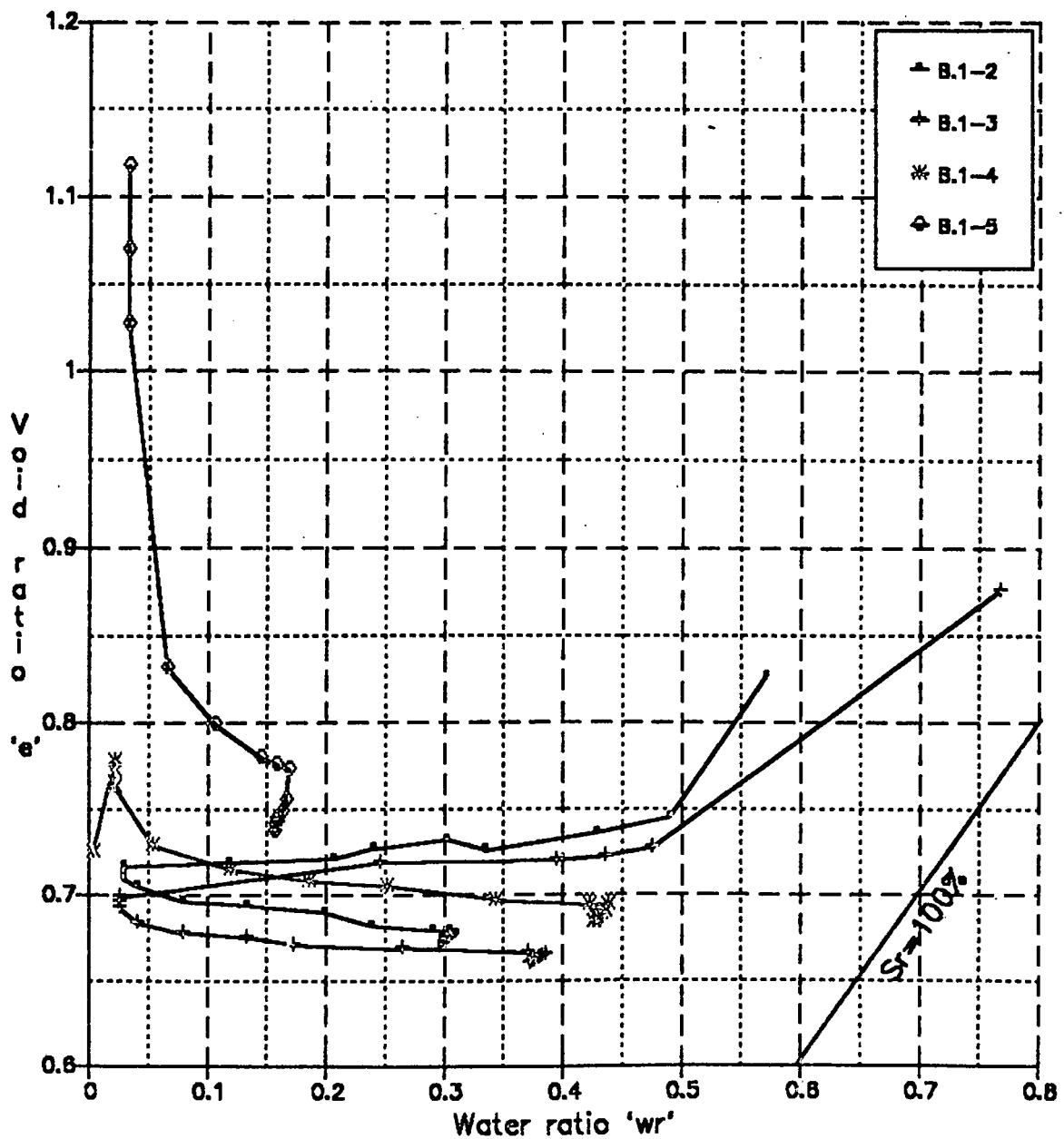


Figure E.63: Bentonite B.1 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

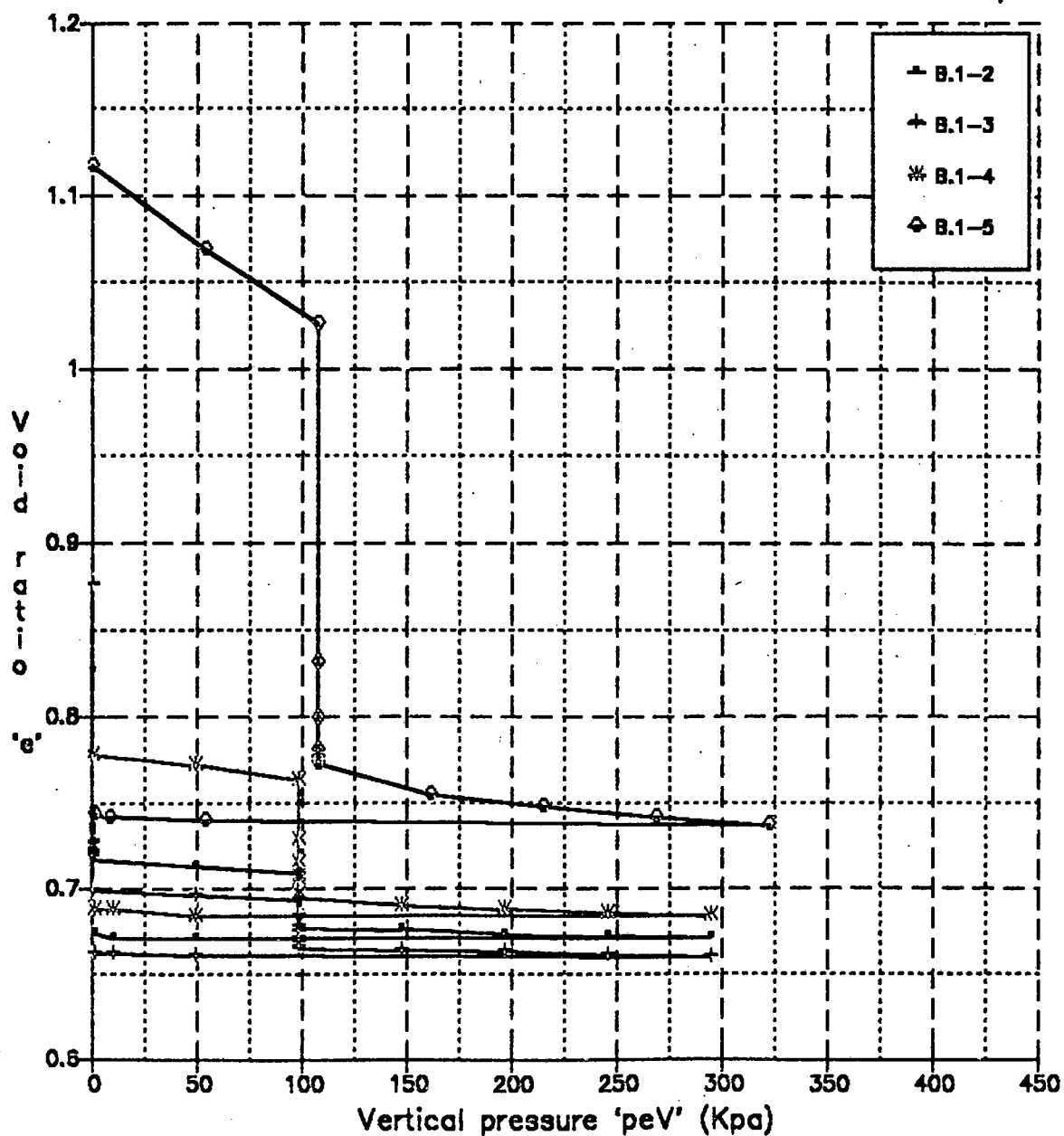


Figure E.64: Bentonite B.1 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
B.2-3/	0	2.041	0.749
III.370&	0	1.258	0.268
IV.415	0	1.252	0.218
	0	1.222	0.148
	0	1.232	0.049
	49.0	1.218	0.049
	98.1	1.208	0.049
	98.1	1.054	0.066
	98.1	0.904	0.119
	98.1	0.874	0.185
	98.1	0.827	0.278
	98.1	0.800	0.357
	98.1	0.782	0.423
	98.1	0.779	0.436
	98.1	0.776	0.442
	147.1	0.750	0.439
	196.1	0.742	0.435
	245.2	0.731	0.432
	294.2	0.725	0.428
	49.0	0.725	0.430
	9.8	0.725	0.431
	1.0	0.727	0.431

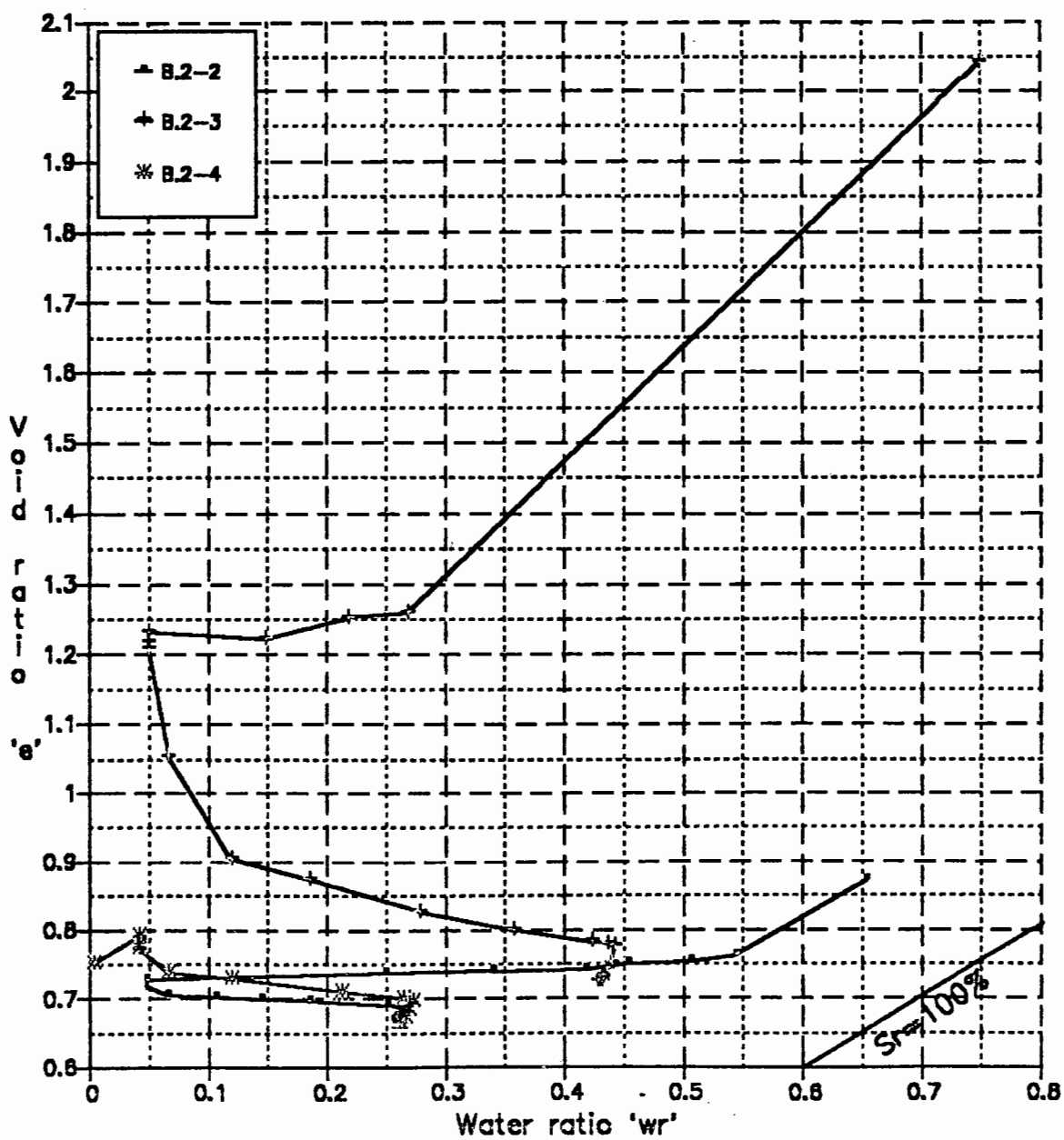


Figure E.65: Bentonite B.2 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

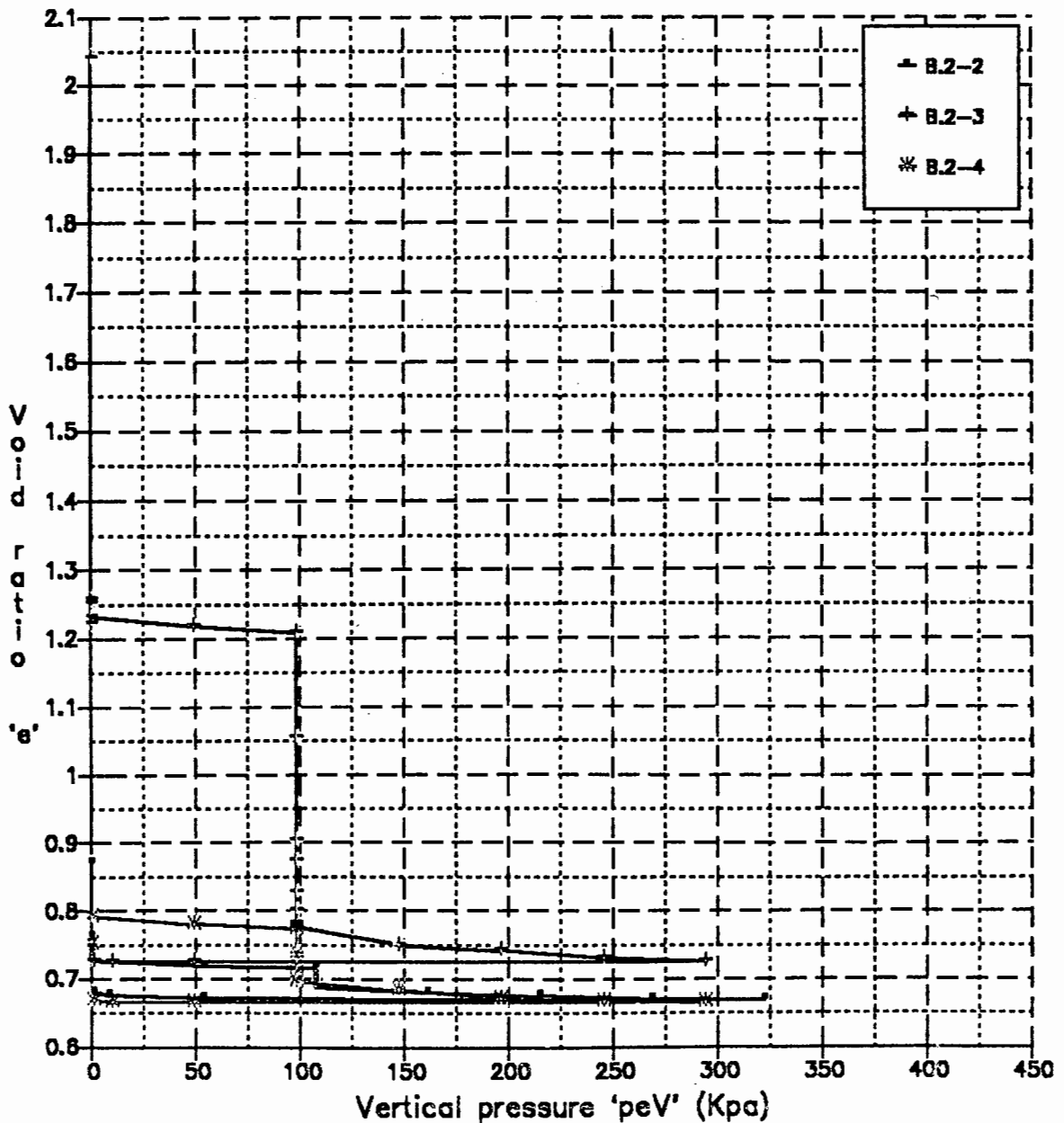


Figure E.66: Bentonite B.2 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

E.5.6 Bentonite B.3 (11.5% clay size)

Table E.36: Bentonite B.3 [Remoulded samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
B.3-2/ IV.432L& IV.445	0 0 0 0 0 0 53.8 107.6 107.6 107.6 107.6 107.6 107.6 161.4 215.2 268.9 322.7 53.8 8.3 0.8	0.778 0.687 0.685 0.675 0.674 0.667 0.661 0.656 0.653 0.643 0.638 0.632 0.628 0.625 0.621 0.616 0.614 0.612 0.615 0.621 0.625	0.563 0.444 0.384 0.291 0.208 0.145 0.068 0.068 0.068 0.093 0.160 0.239 0.319 0.378 0.375 0.371 0.368 0.364 0.366 0.367 0.367	B.3-3/ IV.432R& IV.444	0 0 0 0 49.0 98.1 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 49.0 9.8 1.0	1.609 1.226 1.212 1.208 1.197 1.186 1.098 1.054 0.807 0.787 0.778 0.746 0.730 0.722 0.707 0.707 0.709 0.714	0.738 0.366 0.213 0.091 0.091 0.091 0.133 0.253 0.372 0.466 0.484 0.481 0.478 0.474 0.471 0.472 0.473 0.473
B.3-4/ IV.433L& IV.448	0 0 49.0 98.1 98.1 98.1 98.1 98.1 98.1 98.1 147.1 196.1 245.2 294.2 49.0 9.8 1.0	0.938 0.777 0.769 0.767 0.744 0.729 0.710 0.694 0.684 0.681 0.671 0.660 0.652 0.647 0.648 0.657 0.661	0.002 0.077 0.077 0.077 0.106 0.213 0.306 0.412 0.505 0.567 0.564 0.560 0.557 0.553 0.555 0.556 0.556				

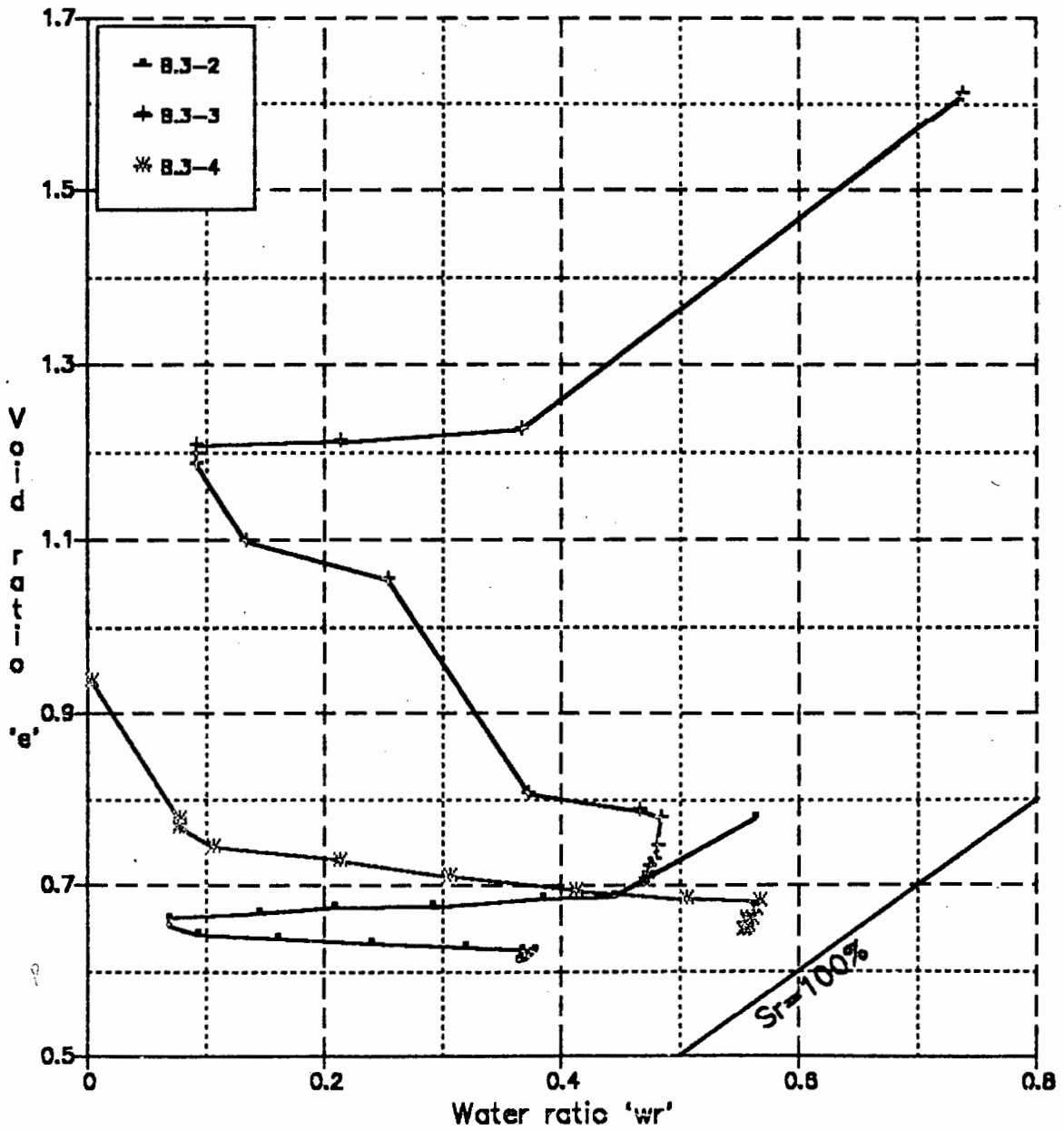


Figure E.67: Bentonite B.3 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

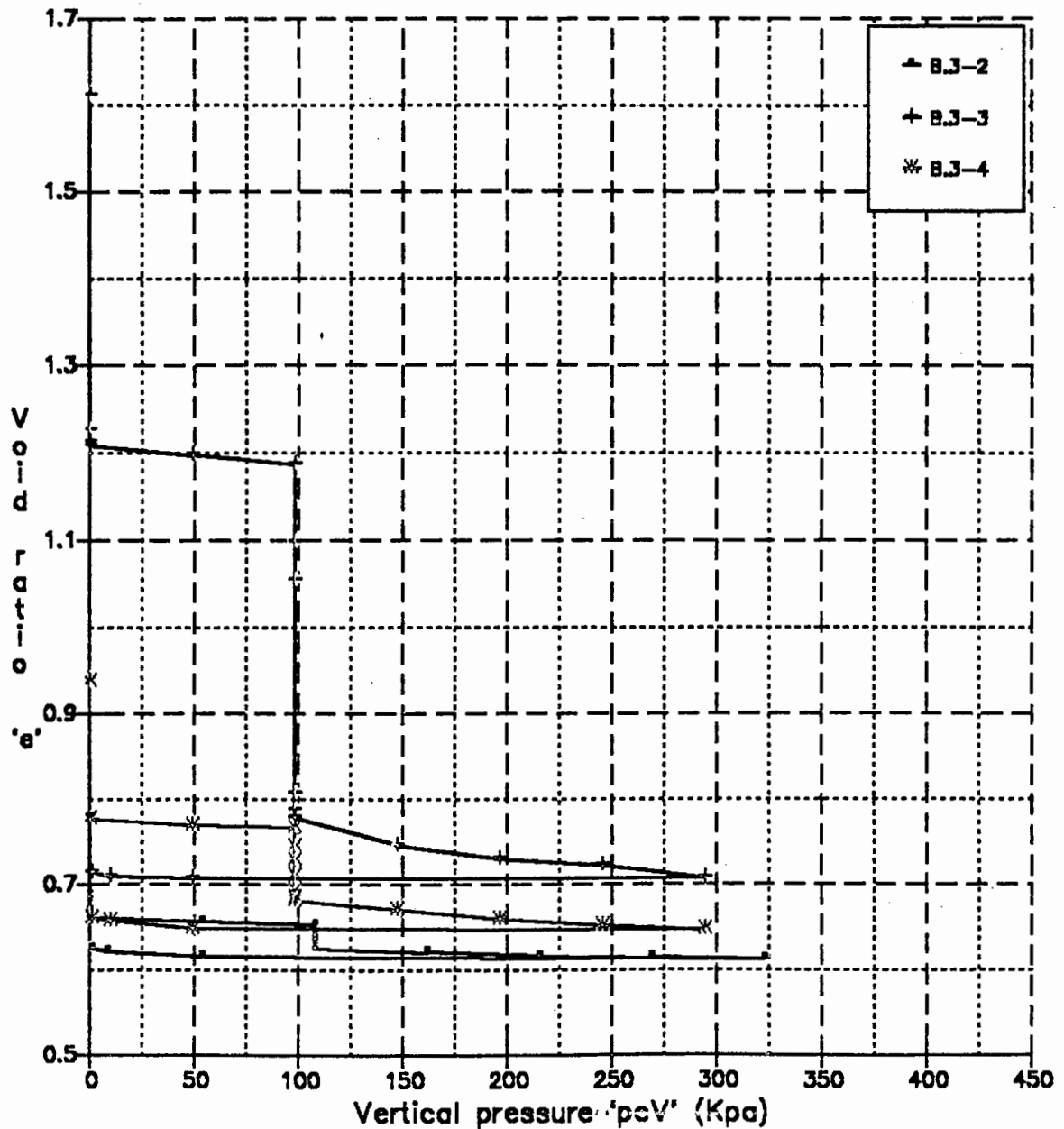


Figure E.68: Bentonite B.3 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

B.5.7 Bentonite B.4 (15.5% clay size).

Table E.37: Bentonite B.4 [Remoulded samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
B.4-2/ III.398& IV.434	0	1.064	0.827	B.4-3/ III.400& IV.435	0	2.925	1.372
	0	0.959	0.779		0	1.491	0.843
	0	0.922	0.722		0	1.371	0.676
	0	0.878	0.613		0	1.304	0.464
	0	0.844	0.436		0	1.289	0.367
	0	0.819	0.270		0	1.266	0.246
	0	0.806	0.190		0	1.261	0.166
	0	0.803	0.140		0	1.265	0.117
	0	0.798	0.086		49.0	1.249	0.117
	53.6	0.795	0.086		98.1	1.242	0.117
	107.3	0.792	0.086		98.1	1.146	0.161
	107.3	0.779	0.107		98.1	1.143	0.215
	107.3	0.774	0.188		98.1	0.907	0.282
	107.3	0.772	0.268		98.1	0.791	0.402
	107.3	0.756	0.349		98.1	0.756	0.523
	107.3	0.746	0.429		98.1	0.751	0.603
	107.3	0.732	0.510		98.1	0.718	0.617
	107.3	0.716	0.590		98.1	0.717	0.628
	107.3	0.710	0.601		147.1	0.693	0.622
	160.9	0.695	0.598		196.1	0.677	0.616
	214.6	0.685	0.594		245.2	0.662	0.609
	268.2	0.672	0.591		294.2	0.652	0.603
	321.9	0.663	0.587		49.0	0.653	0.605
	53.6	0.669	0.589		9.8	0.662	0.606
	8.3	0.680	0.590		1.0	0.691	0.606
	0.8	0.682	0.590				

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
B.4-4/	0	1.178	0.003
III.405&	0	0.906	0.121
IV. 428	49.0	0.890	0.121
	98.1	0.884	0.121
	98.1	0.860	0.161
	98.1	0.856	0.201
	98.1	0.852	0.255
	98.1	0.822	0.362
	98.1	0.804	0.469
	98.1	0.782	0.563
	98.1	0.770	0.617
	98.1	0.762	0.630
	98.1	0.761	0.646
	147.1	0.748	0.643
	196.1	0.733	0.640
	245.2	0.719	0.636
	294.2	0.708	0.633
	49.0	0.725	0.710
	9.8	0.759	0.730
	1.0	0.799	0.732

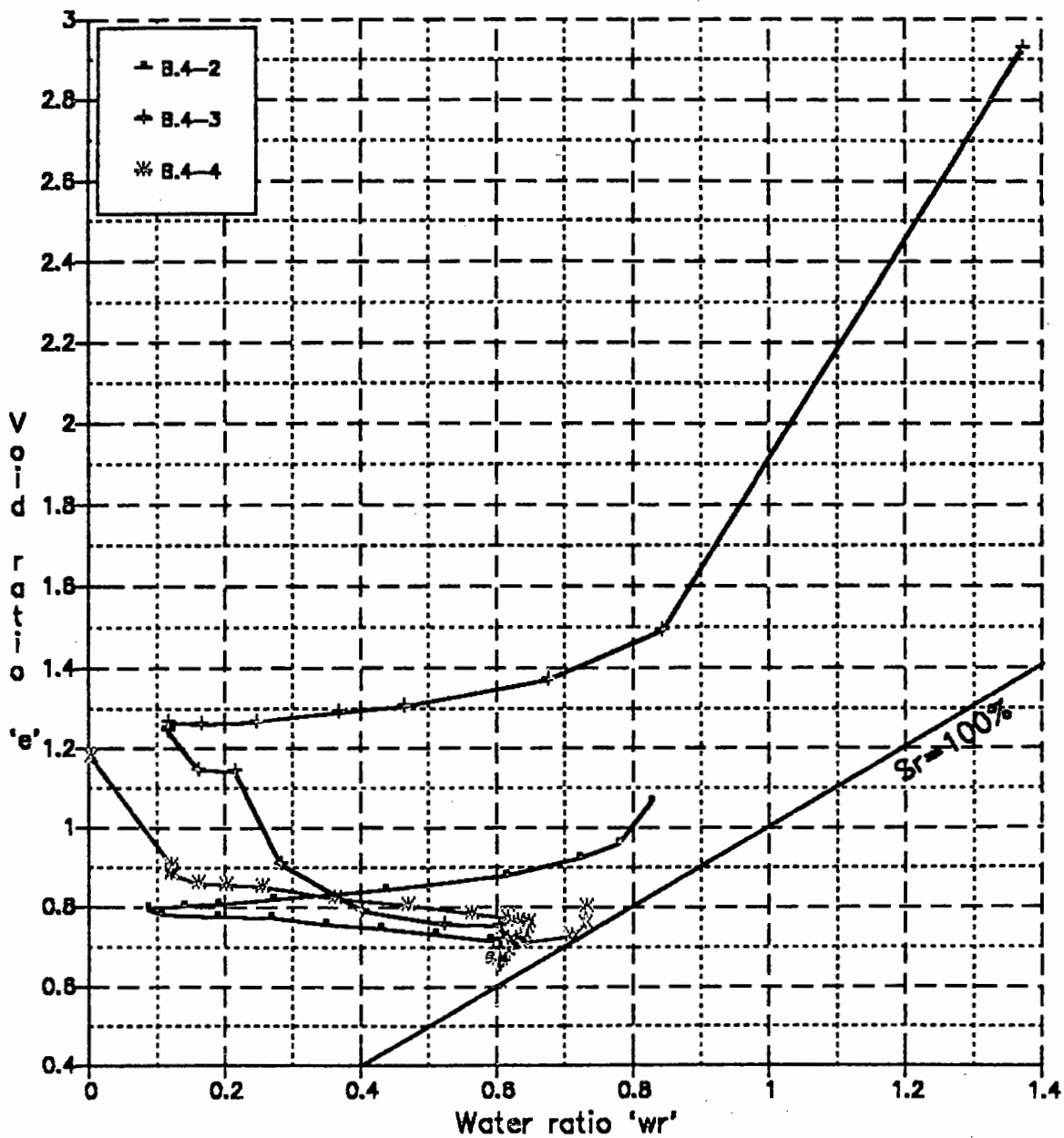


Figure E.69: Bentonite B.4 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

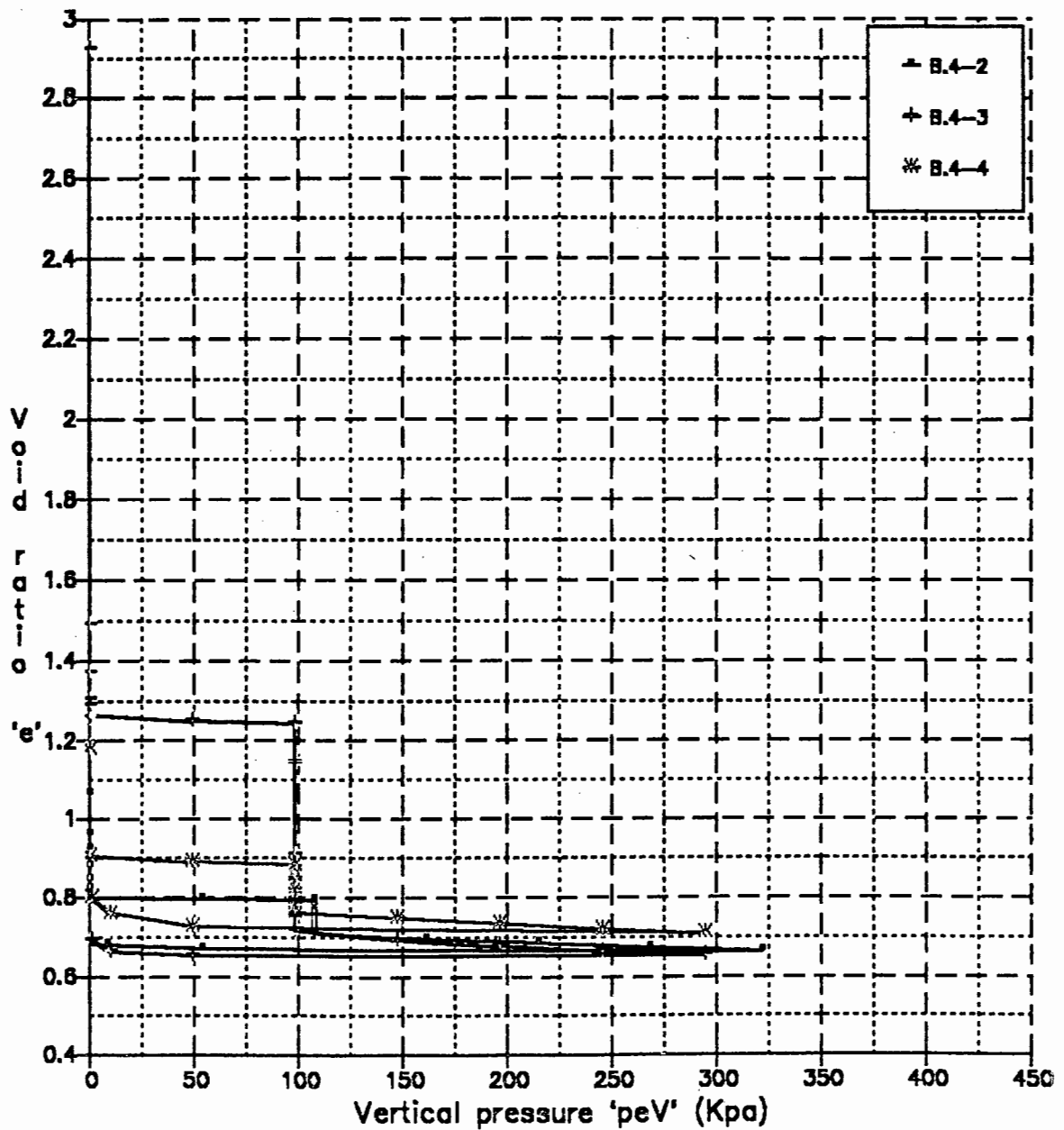


Figure E.70: Bentonite B.4 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

E.5.8 Bentonite B.5 (35% clay size).

Table E.38: Bentonite B.5 [Remoulded samples - 100 Kpa vertical pressure overnight, and then water added at 100 Kpa without prop] - Expansive and/or Collapsing test results.

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
B.5-2/ IV.426L	0	1.252	1.007	B.5-3/ 1V.426R	0	2.505	1.592
IV.448	0	1.090	0.920		0	1.942	1.435
	0	0.959	0.743	IV.456	0	1.684	1.216
	0	0.813	0.505		0	1.298	0.796
	0	0.738	0.351		0	1.147	0.587
	0	0.693	0.236		0	1.027	0.373
	0	0.686	0.213		0	1.009	0.333
53.8	0.682	0.213			0	0.988	0.321
107.6	0.679	0.213		49.0	0.978	0.321	
107.6	0.674	0.238		98.1	0.972	0.321	
107.6	0.680	0.318		98.1	0.963	0.357	
107.6	0.685	0.384		98.1	0.948	0.463	
107.6	0.694	0.450		98.1	0.942	0.556	
107.6	0.706	0.529		98.1	0.900	0.662	
107.6	0.721	0.609		98.1	0.841	0.767	
107.6	0.732	0.688		98.1	0.831	0.820	
107.6	0.747	0.714		147.1	0.781	0.812	
107.6	0.747	0.722		196.1	0.734	0.805	
161.4	0.732	0.719		245.2	0.716	0.797	
215.2	0.709	0.716		294.2	0.673	0.789	
268.9	0.701	0.712		49.0	0.693	0.790	
322.7	0.678	0.709		9.8	0.702	0.791	
53.8	0.705	0.709		1.0	0.743	0.791	
8.3	0.736	0.709					
0.8	0.739	0.712					
B.5-4/ IV.447L	0	1.543	0.003				
IV.461	0	0.920	0.165				
	49.0	0.891	0.165				
	98.1	0.877	0.165				
	98.1	0.865	0.198				
	98.1	0.828	0.304				
	98.1	0.826	0.516				
	98.1	0.847	0.669				
	147.1	0.834	0.666				
	196.1	0.787	0.663				
	245.2	0.777	0.659				
	294.2	0.740	0.656				
	49.0	0.752	0.658				
	9.8	0.758	0.659				
	1.0	0.761	0.659				

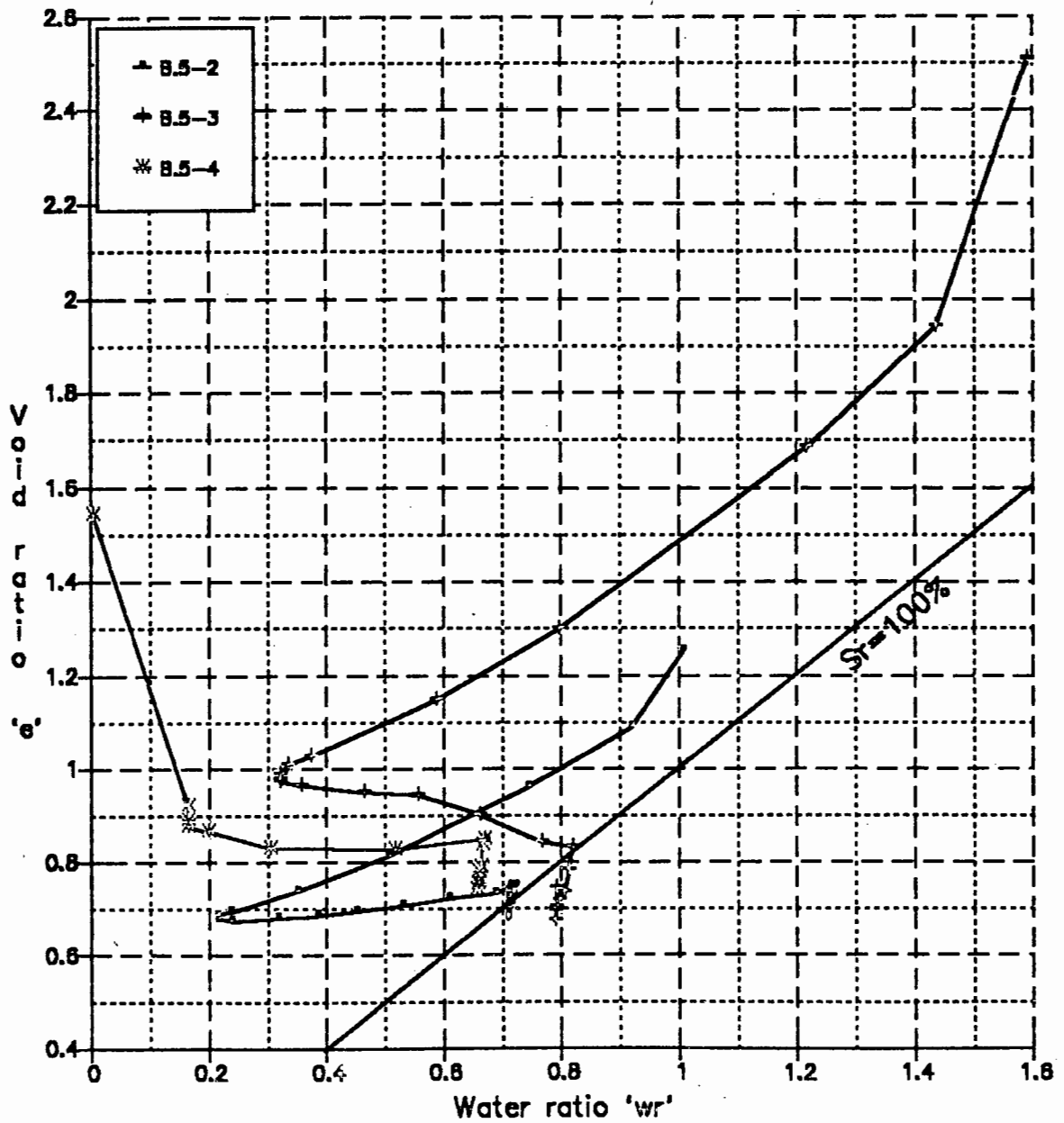


Figure E.71: Bentonite B.5 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path.

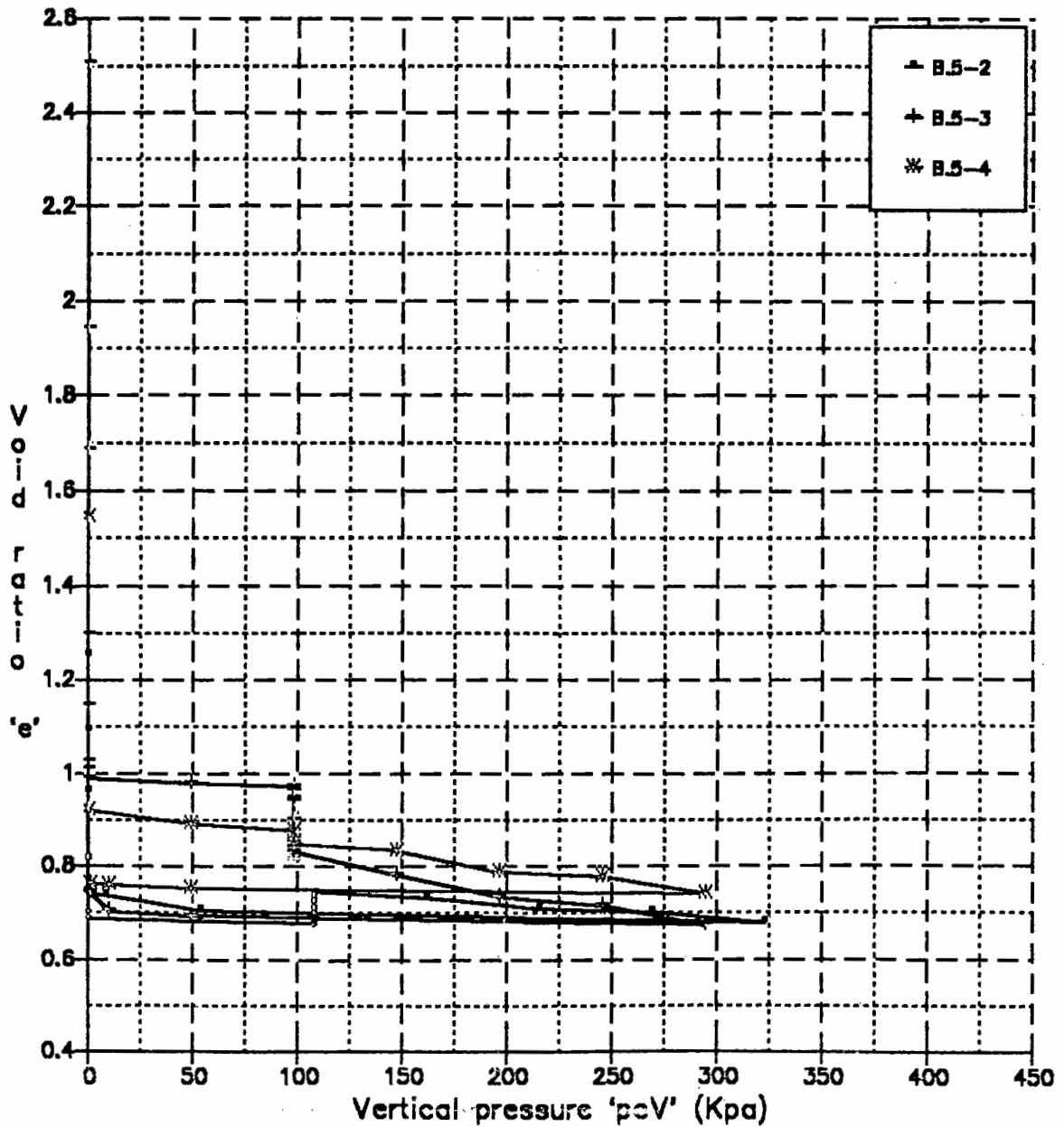


Figure E.72: Bentonite B.5 [Remoulded samples - 100 Kpa overnight vertical pressure and then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

APPENDIX F

SWELL PRESSURE TESTS FOR EXPANSIVE SOILS - TEST PROCEDURE AND RESULTS

F.1 INTRODUCTION

Appendix F presents the detailed test procedure and results. The test method and results are summarized in Chapter Seven "Swell Pressures".

F.2 TEST PROCEDURE

Preparation of test samples:-

Test samples are prepared from either remoulded, compacted or undisturbed soil samples. The 'step by step' detailed procedure for sample preparation is included in the preparation of soil samples for testing¹.

Remoulded samples.

Method 1:

The basic remoulded test sample consists of soil mixed with water to form a wet paste, which is subsequently moulded into a suitable container. The water content varies from about the Plastic Limit to a value equal to, or greater than, the Liquid Limit.

Method 2:

Test samples with higher void ratios can be obtained by the addition of suitable chemical substances. An homogeneous dry mixture is prepared by mixing known amounts of soil, Tartaric Acid and Sodium Bicarbonate. Water is added to the mixture, quickly mixed and placed in a suitable container. The pH value is monitored and kept unchanged from the original sample by using Calcium Hydroxide.

Compacted samples.

On the basis of the 'Dry Density versus Water Content' curve for the soil sample obtained in the compaction tests²: Select a point on the curve and obtain the required water content; Compact the soil to either the Standard or Modified AASHTO specifications (whichever is required) aiming for the water content previously obtained; Remove the compacted sample from the mould, and cut the test sample from it.

¹ - refer to section A.3 of Appendix A.

² - refer to section A.5 of Appendix A.

Undisturbed samples.

The test sample is cut from the undisturbed block of soil - refer to section on 'Soil Sampling' included in Appendix A.

Apparatus required:-

- (i) - (xii) Refer to "Consolidometer: One-dimensional consolidation test procedure", Appendix D¹.
- (xiii) Loading frame with an extension 'upwards' to accommodate a proving ring to measure swell pressures.
- (xiv) Proving rings for swell pressure measurements - Nos. 6711, and 1575².

Procedure:-

A) Calibration of equipment: Assemble all the consolidometer parts as for an actual test (refer to subsequent steps), except that a metal spacer is used in place of the test sample; Ensure that all the parts are properly positioned, and that the dial gauges of the proving rings are correctly set; Record the reading of the vertical strain gauge for the zero reading of load being applied to the sample; Apply gradual increments of load (that is, turn the screw fitted to the top of the loading frame extension, which will cause the proving ring to push against the top of the consolidometer's arm and transmit to the metal spacer 8.5 times the applied load, due to the lever arm ratio), and record the readings of applied load and corresponding vertical strain; Continue until the upper limit of expected swell pressure is reached; Unload by placing the necessary weights onto the loading platform; For each stage of loading (or unloading) measure the vertical deformation that takes place due to the 'bedding in' of the consolidometer parts, as a result of the applied load or pressure after taking into account the contact area of the sample; Tabulate the corrections to be applied to the amount of total vertical movement for each vertical pressure increase or decrease.

B) The soil sample is removed from the desiccator, where it had been drying to the required initial water content. The sample is cut and trimmed to size, until the steel ring (consolidometer) just slides over it. The top and bottom surfaces of the sample are made level.

The mass is recorded. Air dry masses should also be recorded for the following items: Top and bottom plates; Filter papers; Plastic disc; Container plus collar and screws; Plastic cover and elastic bands.

Note: The mass of the stainless steel ring, its internal diameter and height should be checked before each test.

¹ - see section D.1, apparatus required, steps (i) to (xii).

² - manufactured by Wykeham Farrance, UK.

C) The parts of the consolidometer container are assembled in the following order:

- (i) Position and center the bottom plate and filter paper inside the consolidometer pot;
 - (ii) Position the steel ring with the sample in the center of the bottom filter paper;
 - (iii) The top filter paper and the loading plate are placed on top of the sample;
 - (iv) The top collar is fitted over the steel ring and tightened against the consolidometer pot;
 - (v) Enclose the assembled parts with a loose fitting plastic cover, using rubber bands to keep it in place;
- Note: It is important that the sample remains covered throughout the entire test.

D) Position the consolidometer container in the loading device. Adjust the following parts: The counterweight alongside the lever arm of the consolidometer, until it balances firmly (a small pressure is exerted against the sample); The micrometer dial gauge for the zero reading; The proving ring for swell pressure measurements, in order to touch the seating on top of the lever arm with a slight pressure, and its dial gauge to be set to the zero reading. Note: The lever arm ratio for the swell pressure measurement test is 8.5 to 1.

E) By means of an hypodermic syringe, add a known amount of water to the sample through the bottom filter paper. Allow the sample to expand (or even settle, which can happen during the first water increment), and cause the consolidometer's arm to press against the proving ring for the swell pressure. Record the readings of vertical movement and swell pressure with time - as the soil expands, apply vertical pressure to the sample by tightening the proving ring against consolidometer's arm until the sample is back to its original height - monitor the vertical movement by means of the dial gauge at the front of the consolidometer. Record the reading of swell pressure for no change in height of the sample.

Note: The readings obtained¹ are converted to applied load using the calibration data for the proving ring used. The calibration factors, for each of the proving rings, are used as follows:

- * Ring No.6711, Load in KN = divisions (dial gauge) x 1/158
- * Ring No.1575, Load in KN = divisions (dial gauge) x 0.027

F) Repeat step E) until no further noticeable vertical movement occurs. At this stage, the pressure required to keep the sample from expanding (vertically) reaches a constant value.

Note: Any excess of water, left on the bottom filter paper, should be removed, and its amount recorded.

¹ - from the proving ring gauge.

G) The unloading or recovery characteristics of the soil are measured next. This is carried out as follows: Support the lever arm of the consolidometer and place weights on the loading platform to provide about 1/3 of the maximum swell pressure previously obtained; The proving ring is released, and the increase in sample thickness is recorded for $\frac{1}{4}$ min, $\frac{1}{2}$ min, 1 min, etc, (as for the standard consolidometer test) from the time of releasing the proving ring; Readings should be continued (at least) until the slope of expansion versus square root of time becomes a straight line; The sequence of unloading (ie. decrease of applied pressure) should be to 50 Kpa, 10 Kpa, and zero - repeat the above time readings for each pressure decrease.

H) At the completion of the test, remove the assembled parts from the consolidometer, and record the mass of the soil sample. Take note of the following masses - top plate, bottom plate, filter papers, top collar and screws, plastic cover and elastic band.

The soil is then placed inside and oven previously set at $105 \pm 5^{\circ}\text{C}$ for a few hours, preferably overnight. After the sample is removed from the oven it is allowed to cool down, and its oven dried mass recorded.

Calculations and Report:-

1) Information to be recorded for each test.

a) Before adding the first amount of water to the sample - the initial reading of the vertical deflection for zero swell pressure (refer to step D above);

b) Each amount of water added to the bottom of the sample;

c) Readings of vertical deflection and swell pressure with time, as well as the swell pressure reading for no further change in the height of the sample (steps E & F);

Note: Convert the proving ring readings to load and swell pressure, as follows:

* Ring No.6711, Load in KN = division (dial gauge) x 1/158;

* Ring No.1575, Load in KN = division (dial gauge) x 0.027;

calculated load x 8.5(lever arm)

Pressure applied = $\frac{\text{-----}}{\text{plain area of the sample}}$

d) For each unloading stage - total load placed on the loading platform, time and vertical deflection readings (step G);

e) The moisture content of the soil sample at the start, end, as well as after each water increment,

$$= \frac{(\text{Mass of moist soil} + \text{water added}) - \text{Mass of oven-dry soil}}{\text{Mass of oven-dry soil sample}}$$

f) The diameter, height and mass of the soil sample were obtained in stages B to H.

2) To determine the void ratio at the initial, final and intermediate stages.

a) The initial void ratio 'e' of the soil sample:

$$'e' = \frac{\text{Volume of voids } 'V_v'}{\text{Volume of solids } 'V_s'} = \frac{\text{Total volume } 'V_T' - 'V_s'}{'V_s'}$$

Where:

$$V_T = \frac{\pi \times D^2}{4} \times \text{original height of soil sample } 'ht';$$

$$\text{and, } V_s = \frac{\text{Mass of oven-dry soil } 'M_D'}{\text{Specific Gravity of soil particles } 'G_s'}$$

b) Intermediate and final void ratios are obtained by using the corrected vertical deflection 'hi' (refer to Calibration of equipment - step A), and then by calculating the 'e' value as follows:

$$e = \frac{\pi \times D^2/4 (ht - hi) - V_s}{V_s}$$

3) The information obtained for each test will enable the following relationships to be illustrated:

- a) Vertical deformation (settlement or expansion) and time (square root or log) for each applied pressure increase or decrease¹;
- b) Void ratio, water ratio (or water content), and effective swell pressure, for either the full test path or controlled wetting path.

Note: All the preliminary test procedures are included in Appendix A.

¹ - for more details refer to Appendix D.

F.3 REFERENCES FOR APPENDIX F

10. DE S. VINAGRE, T.J.V. (1978): Postgraduate course project for Advanced Soil Mechanics, C.E. 500 "Expansive Soils: Review of the main aspects including their identification; An experimental study of potential expansive soils from the Cape Peninsula". Department of Civil Engineering, University of Cape Town.

16. DE S. VINAGRE, T.J.V. (1976/77): Masters Thesis - Diaries One, Two, Three, Four, Five, and Six.

F.4 TEST RESULTS FOR NATURAL SOILS

F.4.1 Site 11 - Rosebank, Cape

Table F.01: Site 11, Rosebank [Remoulded Samples] - Swell Pressure test results.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Brief description of test procedure:				Void ratio 'e'	Water ratio 'wr'
S.11-16/ II.251	0	* Air dried outside consolidometer.				2.16	2.003
	0					1.17	1.085
	0					1.03	0.942
	0					0.93	0.843
	0					0.72	0.617
	0					0.69	0.562
	1	Placed in consolidometer				0.674	0.466
	9	* Eventual swell				0.674	0.523
	330	pressures due to				0.674	0.606
	545.1	wetting to new				0.674	0.661
	660	water content.				0.674	0.730
	612.5	(void ratio virtually				0.674	0.744
	592.7	constant)				0.674	0.744
	98.1	Unloading.				0.761	0.758
	9.9					0.777	0.758
	1					0.782	0.758
S.11-26/ II.285	0	1.77	1.667	S.11-24	0	2.08	1.934
	0	1.11	1.052	III.293	0	1.40	1.298
	0	0.93	0.879		0	1.22	1.113
	0	0.87	0.810		0	1.12	1.033
	0	0.79	0.692		0	0.97	0.887
	0	0.77	0.625		0	0.85	0.760
	0	0.76	0.579		0	0.73	0.565
	0	0.761	0.557		0	0.71	0.488
	1	0.761	0.557		0	0.71	0.364
	54.2	0.761	0.579		0	0.704	0.328
	341.8	0.761	0.634		1	0.704	0.328
	525.3	0.761	0.689		29.9	0.704	0.331
	914.4	0.761	0.744		128.9	0.704	0.441
	865.1	0.761	0.799		230.2	0.704	0.468
	844.6	0.761	0.827		391.3	0.704	0.551
	831.4	0.761	0.827		568.5	0.704	0.606
	98.1	0.862	0.840		909.1	0.704	0.689
	9.9	0.874	0.840		817.1	0.704	0.771
	1	0.878	0.840		842.4	0.704	0.799
					860.8	0.704	0.799
					98.1	0.833	0.815
					9.9	0.875	0.815
					1	0.880	0.815

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.11-44/ III.318	0	1.43	1.289	S.11-45/ III.341	0	2.19	2.063
	0	1.00	0.890		0	1.58	1.474
	0	0.93	0.813		0	1.46	1.364
	0	0.86	0.741		0	1.37	1.273
	0	0.74	0.562		0	1.206	1.116
	0	0.733	0.482		1	1.206	1.116
	1	0.733	0.482		84.6	1.206	1.130
	134.7	0.733	0.496		102.7	1.206	1.157
	466.7	0.733	0.606		97.1	1.206	1.185
	591.5	0.733	0.634		98.2	1.206	1.212
	693.4	0.733	0.744		99.7	1.206	1.240
	633.4	0.733	0.799		49.1	1.226	1.240
	649.1	0.733	0.827		9.9	1.312	1.251
	654.0	0.733	0.827		1	1.331	1.251
	98.1	0.834	0.838				
	9.9	0.895	0.838				
	1	0.927	0.838				
S.11-47/ III.337	0	1.37	1.234	S.11-63/ IV.449	0	2.28	2.108
	0	1.22	1.119		0	1.42	1.322
	0	1.16	1.058		0	1.26	1.168
	0	1.087	0.992		0	1.08	0.992
	1	1.087	0.992		0	0.86	0.758
	82.8	1.092	1.047		0	0.71	0.548
	71.1	1.092	1.047		0	0.696	0.504
	75.7	1.092	1.074		1	0.696	0.504
	71.3	1.092	1.102		1	0.696	0.551
	73.9	1.092	1.102		206.0	0.696	0.606
	71.8	1.092	1.102		567.7	0.696	0.689
	75.1	1.092	1.102		704.2	0.696	0.771
	78.9	1.092	1.102		662.4	0.696	0.799
	9.9	1.129	1.121		215.2	0.747	0.909
	1	1.149	1.121		107.5	0.773	0.928
					53.9	0.844	0.931
					8.4	0.898	0.934
					0.9	0.939	0.934

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.11-39/ III.300	0	2.81	1.510	S.11-53/ III.345	0	2.55	1.515
	0	1.82	1.022		0	1.49	0.876
	0	1.61	0.904		0	1.24	0.675
	0	1.40	0.730		0	1.15	0.579
	0	1.23	0.584		0	1.13	0.545
	0	1.13	0.438		0	1.107	0.499
	0	1.113	0.408		0	1.107	0.499
	1	1.113	0.408		1	1.107	0.499
	48.3	1.113	0.413		55.7	1.107	0.523
	234.8	1.113	0.523		138.8	1.107	0.551
	227.9	1.113	0.579		224.4	1.107	0.606
	48.3	1.113	0.689		193.8	1.107	0.661
	92.1	1.113	0.744		72.1	1.107	0.744
	36.8	1.113	0.827		100.5	1.107	0.799
	55.2	1.113	0.909		72.3	1.107	0.854
	46.0	1.113	0.964		76.4	1.107	0.909
	9.9	1.167	0.967		76.9	1.107	0.909
	1.0	1.236	0.967		78.0	1.107	0.909
					49.1	1.114	0.937
					9.9	1.214	0.956
					1.0	1.244	0.956
S.11-34/ III.297	0	2.27	2.127				
	0	1.35	1.278				
	0	1.10	1.028				
	0	1.01	0.945				
	0	0.98	0.912				
	0	0.84	0.766				
	1	0.863	0.785				
	22	0.863	0.827				
	431.3	0.863	0.909				
	455.2	0.863	0.909				
	453.2	0.863	0.923				
	98.1	0.944	0.931				
	9.9	0.988	0.931				
	1	0.996	0.931				

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.11-3/ II.217	0	2.84	1.763	S.11-2/ II.207	0	2.89	1.679
	0	1.61	1.273		0	1.81	1.312
	0	1.58	1.254		0	1.68	1.237
	0	1.45	1.124		0	1.52	1.113
	0	1.31	1.006		0	1.45	1.061
	0	1.12	0.840		0	1.39	1.018
	0	0.92	0.645		0	1.33	0.967
	0	0.88	0.584		0	1.25	0.896
	0	0.86	0.537		0	1.04	0.711
	0	0.85	0.457		0	0.91	0.470
	0	0.85	0.405		0	0.90	0.325
	0	0.84	0.388		0	0.90	0.249
	0	0.853	0.413		0	0.90	0.183
	1	0.853	0.413		0	0.900	0.157
	4.6	0.853	0.441		1	0.900	0.157
	23.0	0.853	0.468		295.9	0.900	0.248
	23.0	0.853	0.468		85.9	0.900	0.303
	43.7	0.853	0.523		338.5	0.900	0.358
	66.7	0.853	0.551		244.3	0.900	0.413
	149.6	0.853	0.606		925.6	0.900	0.496
	195.6	0.853	0.689		695.2	0.900	0.551
	255.5	0.853	0.744		1528.1	0.900	0.606
	221.0	0.853	0.799		1075.3	0.900	0.634
	211.7	0.853	0.799		1721.1	0.900	0.689
	207.1	0.853	0.799		1556.1	0.900	0.716
	98.1	0.878	0.835		2180.0	0.900	0.771
	49.1	0.904	0.835		1942.2	0.900	0.799
	9.9	0.937	0.835		1744.2	0.900	0.854
	1.0	0.949	0.835		1510.9	0.900	0.909
					2055.9	0.900	0.950
					1971.3	0.900	0.964
					2129.1	0.900	0.992
					196.0	0.901	1.019
					98.1	0.902	1.019
					49.1	0.902	1.019
					9.9	0.913	1.019
					1.0	0.946	1.019

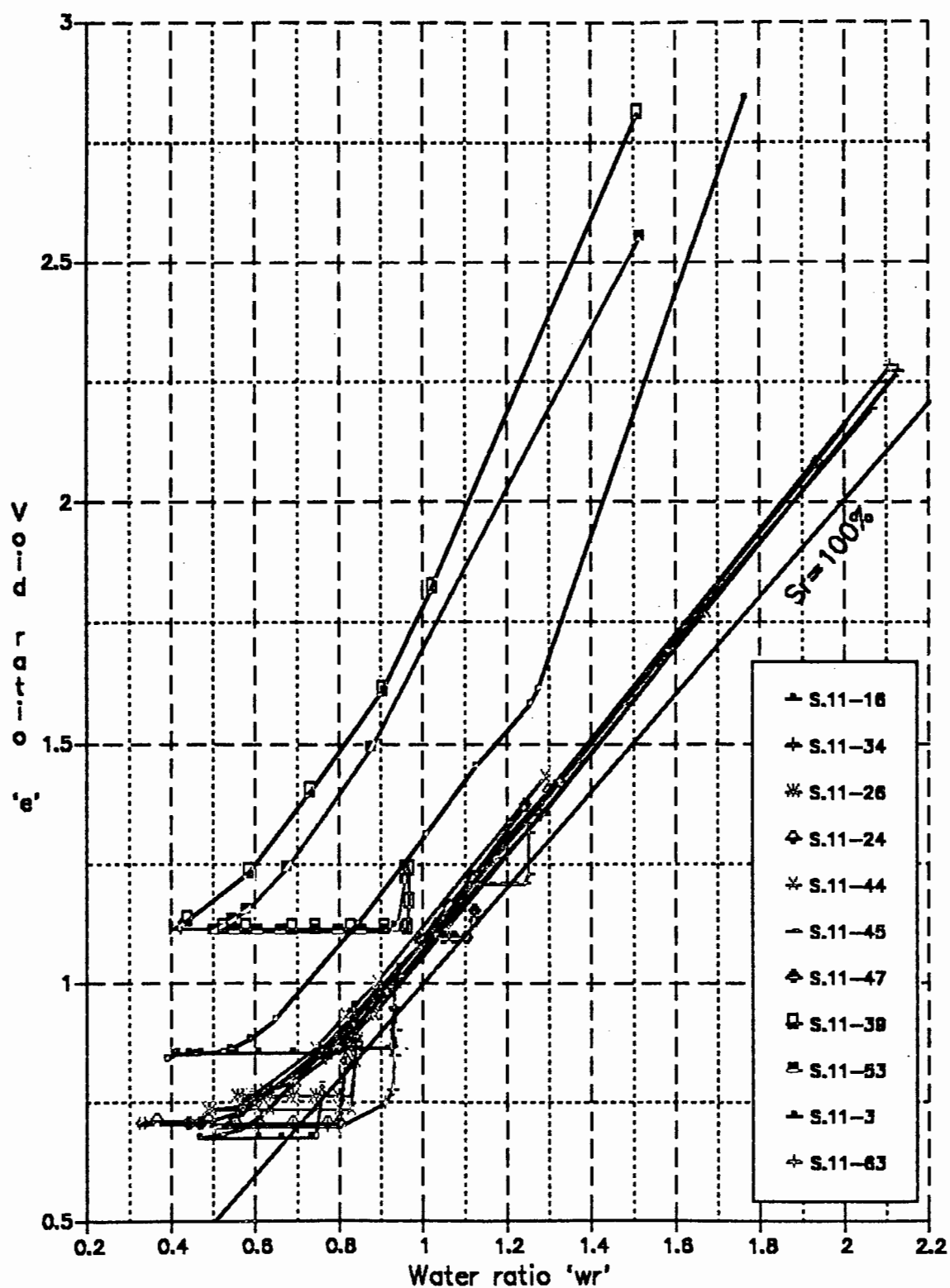


Figure F.01: Site 11, Rosebank [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr' for the full test path. Swelling at "constant void ratio" from "zero loading".

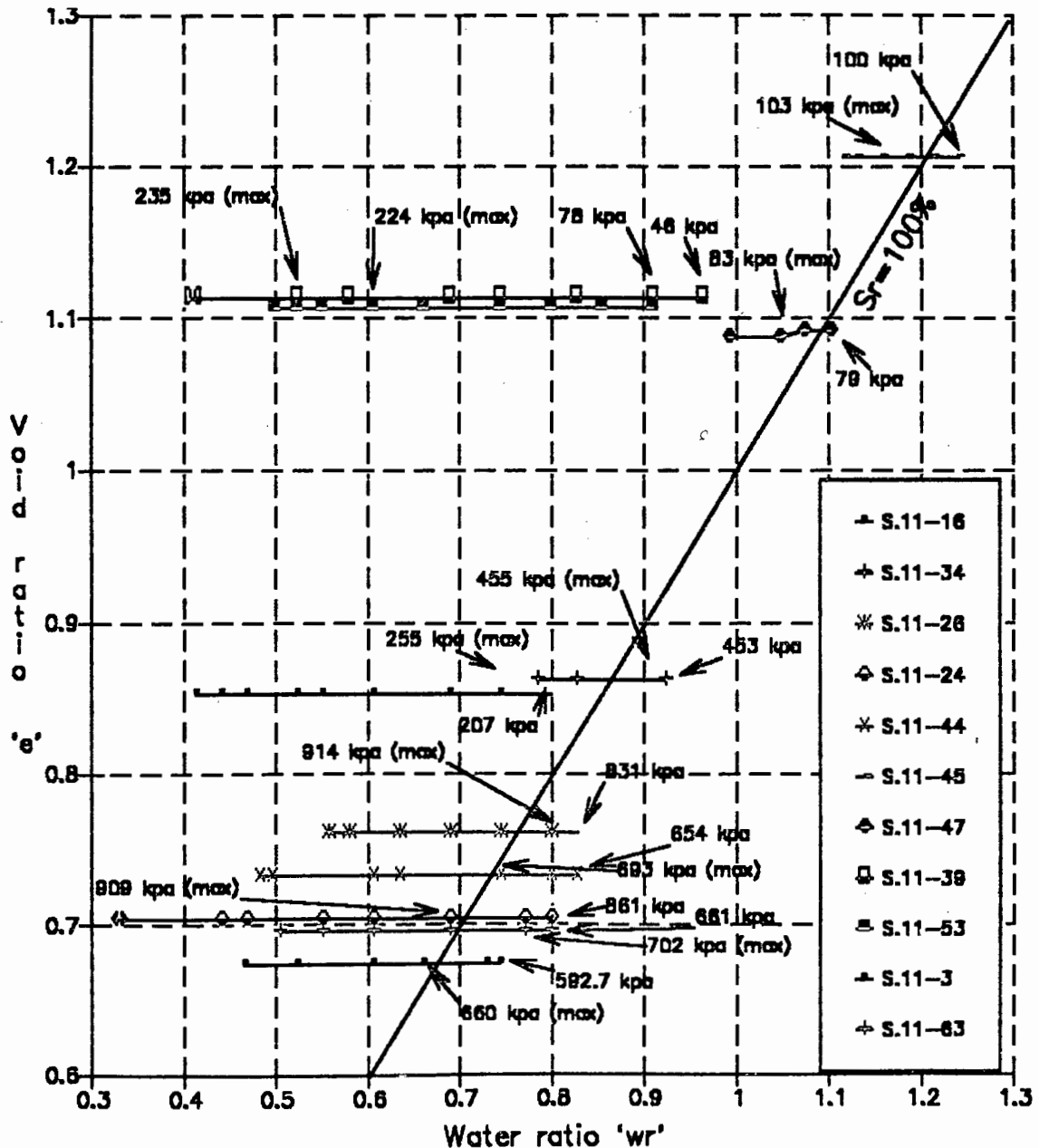


Figure F.02: Site 11, Rosebank [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).

Table F.02: Site 11, Rosebank [Compacted Samples] - Swell Pressure test results.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'
S.11-9/ II.223	1.0	0.648	0.295	S.11-10/ II.240	1.0	0.599	0.463
	23.0	0.648	0.331		451.1	0.599	0.523
	32.2	0.648	0.386		391.3	0.599	0.565
	115.0	0.648	0.441		552.4	0.599	0.634
	180.3	0.648	0.496		522.5	0.599	0.661
	276.1	0.648	0.551		98.1	0.675	0.680
	383.7	0.648	0.606		49.0	0.693	0.680
	405.9	0.648	0.661		9.8	0.702	0.680
	412.9	0.648	0.689		1.0	0.706	0.680
	395.5	0.648	0.689				
	98.1	0.690	0.700				
	49.0	0.702	0.700				
	9.8	0.713	0.700				
	1.0	0.709	0.700				
S.11-28/ II.259	1.0	0.873	0.697	S.11-71/ IV.459	1.0	0.872	0.760
	32.9	0.873	0.730		1.0	0.872	0.771
	71.8	0.873	0.771		31.2	0.872	0.799
	86.4	0.873	0.840		46.6	0.872	0.909
	81.7	0.873	0.882		45.0	0.872	0.937
	79.7	0.873	0.909		8.7	0.889	0.967
	49.0	0.880	0.928		0.9	0.936	0.973
	9.8	0.922	0.928				
	1.0	0.935	0.928				

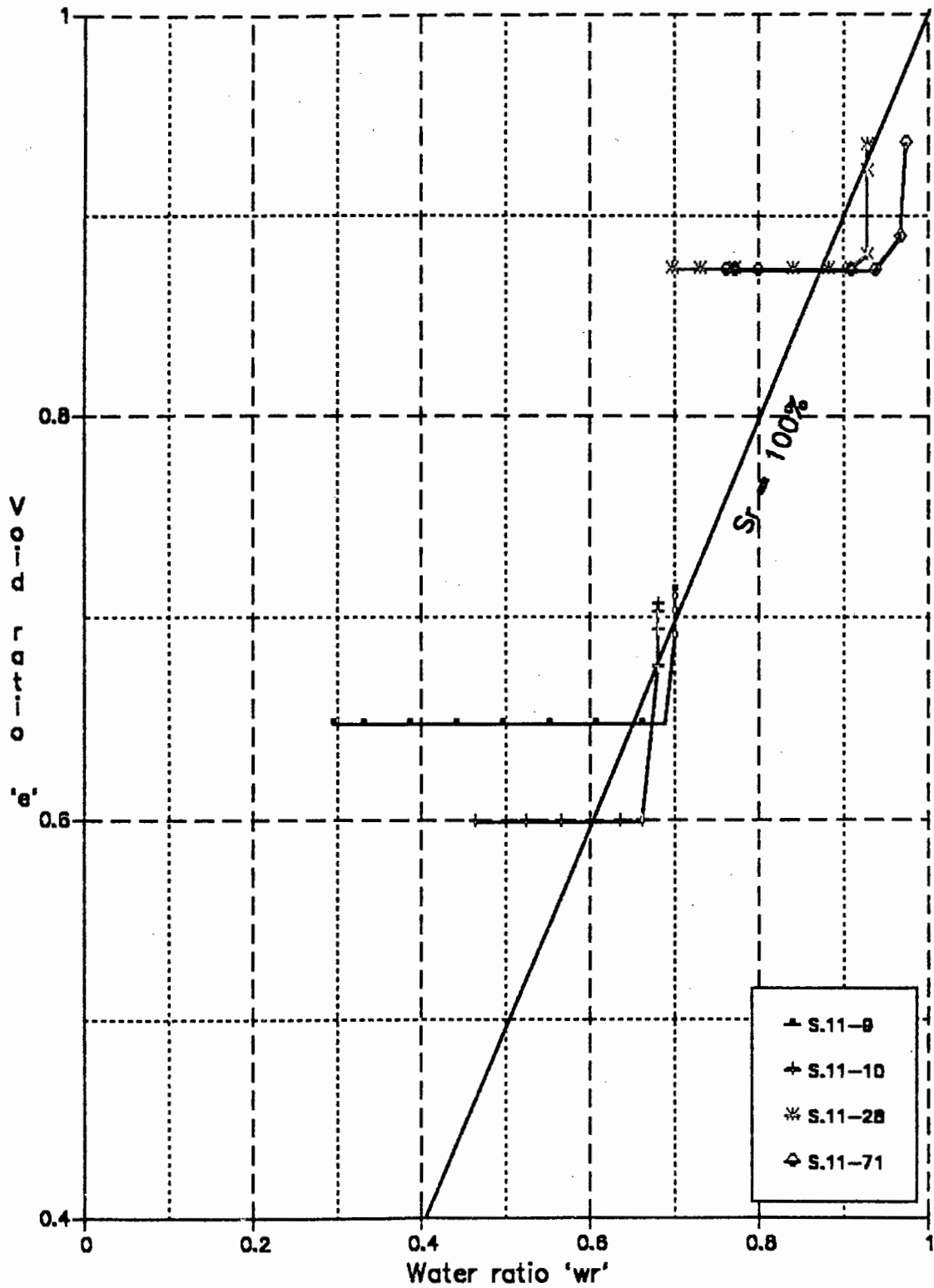


Figure F.03: Site 11, Rosebank [Compacted Samples] - Void ratio 'e' versus Water Ratio 'wr', for the full test path.

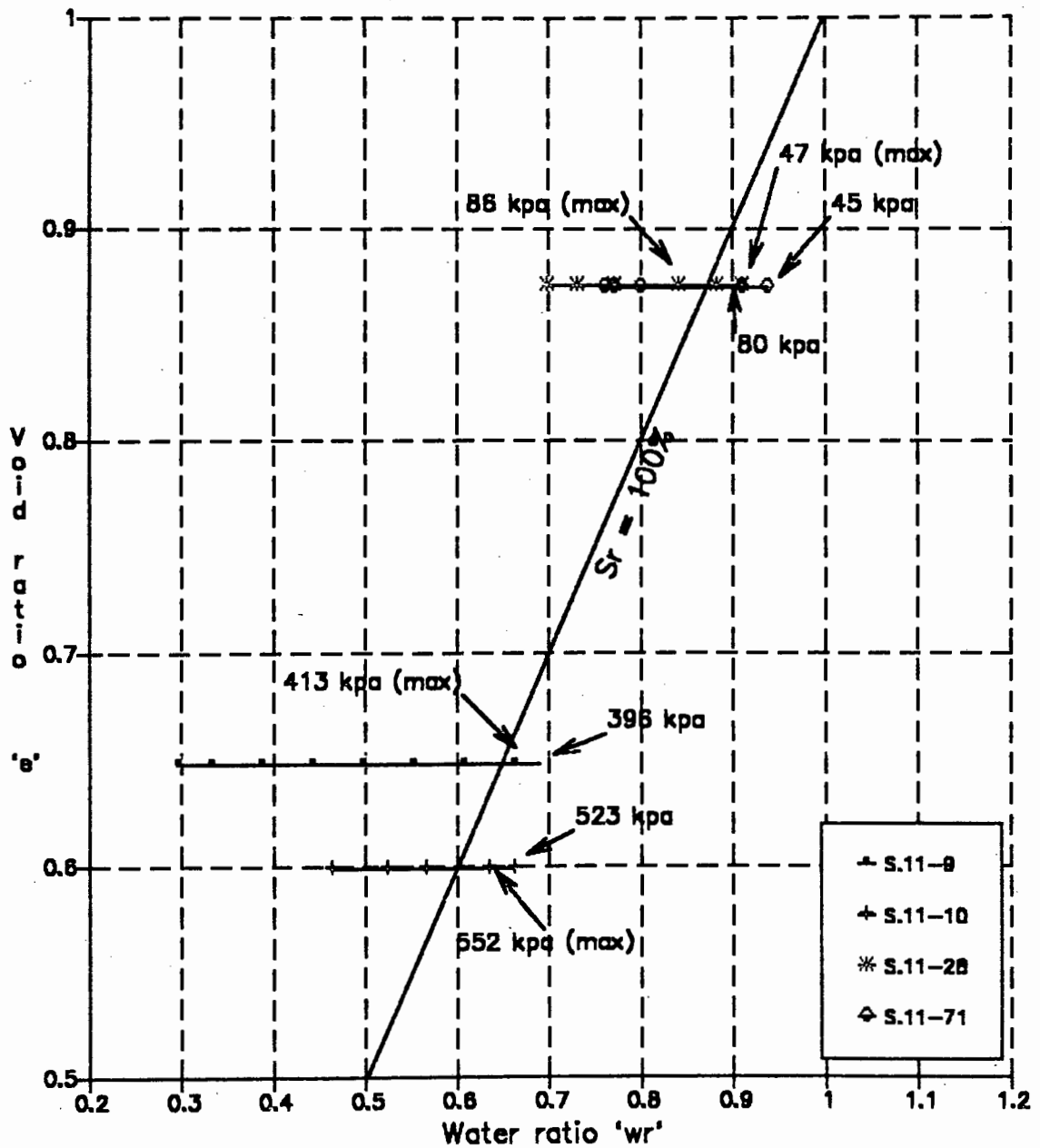


Figure F.04: Site 11, Rosebank [Compacted Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).

Table F.03: Site 11, Rosebank [Undisturbed Samples] - Swell Pressure test results.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'
S.11-7/ II.213	0	1.081	0.917	S.11-18/ II.249	0	1.101	1.055
	0	1.054	0.893		0	1.081	1.028
	0	0.985	0.824		1.0	1.081	1.028
	0	0.934	0.777		23.0	1.081	1.047
	0	0.852	0.700		27.6	1.081	1.102
	0	0.837	0.681		36.8	1.081	1.110
	0	0.819	0.659		39.1	1.081	1.121
	0	0.812	0.643		34.5	1.081	1.130
	0	0.783	0.490		9.8	1.082	1.141
	0	0.777	0.383		1.0	1.106	1.141
	0	0.780	0.279				
	1.0	0.780	0.279				
	10.7	0.780	0.474				
	24.9	0.780	0.526				
	62.2	0.780	0.568				
	130.3	0.780	0.628				
	256.4	0.780	0.689				
	213.8	0.780	0.752				
	229.2	0.780	0.793				
	216.2	0.780	0.813				
	53.7	0.811	0.815				
	8.3	0.854	0.815				
	0.8	0.868	0.815				
S.11-20/ II.269	0	1.170	1.068	S.11-21/ III.281	0	1.114	1.022
	0	1.104	0.998		0	1.006	0.909
	0	1.082	0.976		0	0.881	0.769
	0	1.057	0.942		0	0.758	0.609
	0	1.037	0.925		0	0.751	0.588
	0	0.959	0.841		0	0.726	0.515
	0	0.938	0.821		1.0	0.726	0.515
	1.0	0.938	0.821		46.0	0.726	0.523
	195.6	0.938	0.840		271.6	0.726	0.579
	218.7	0.938	0.882		354.4	0.726	0.634
	214.1	0.938	0.909		593.8	0.751	0.689
	186.4	0.938	0.937		550.1	0.726	0.744
	197.9	0.938	0.950		570.8	0.726	0.771
	184.1	0.938	0.964		98.1	0.797	0.777
	202.5	0.938	0.978		9.8	0.833	0.777
	49.0	0.978	0.986		1.0	0.839	0.777
	9.8	1.015	0.986				
	1.0	1.034	0.986				

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.11-31/ III.275	0	1.081	1.005	S.11-29/ II.271	0	1.073	1.003
	0	0.995	0.904		0	1.050	0.975
	0	0.883	0.784		1.0	1.050	0.975
	0	0.774	0.645		24.3	1.050	0.992
	1.0	0.774	0.645		29.6	1.050	1.019
	110.1	0.774	0.661		30.8	1.050	1.033
	570.2	0.774	0.730		26.1	1.050	1.061
	496.2	0.774	0.785		29.6	1.050	1.074
	479.8	0.774	0.799		8.3	1.071	1.085
	491.3	0.774	0.807		0.8	1.102	1.085
	98.1	0.821	0.813				
	9.8	0.863	0.813				
	1.0	0.868	0.813				
S.11-30/ II.273	0	1.035	0.987				
	0	1.090	1.040				
	0	1.162	1.112				
	0	1.262	1.226				
	1.0	1.262	1.226				
	3.3	1.262	1.240				
	3.9	1.262	1.254				
	3.3	1.262	1.281				
	1.0	1.266	1.284				

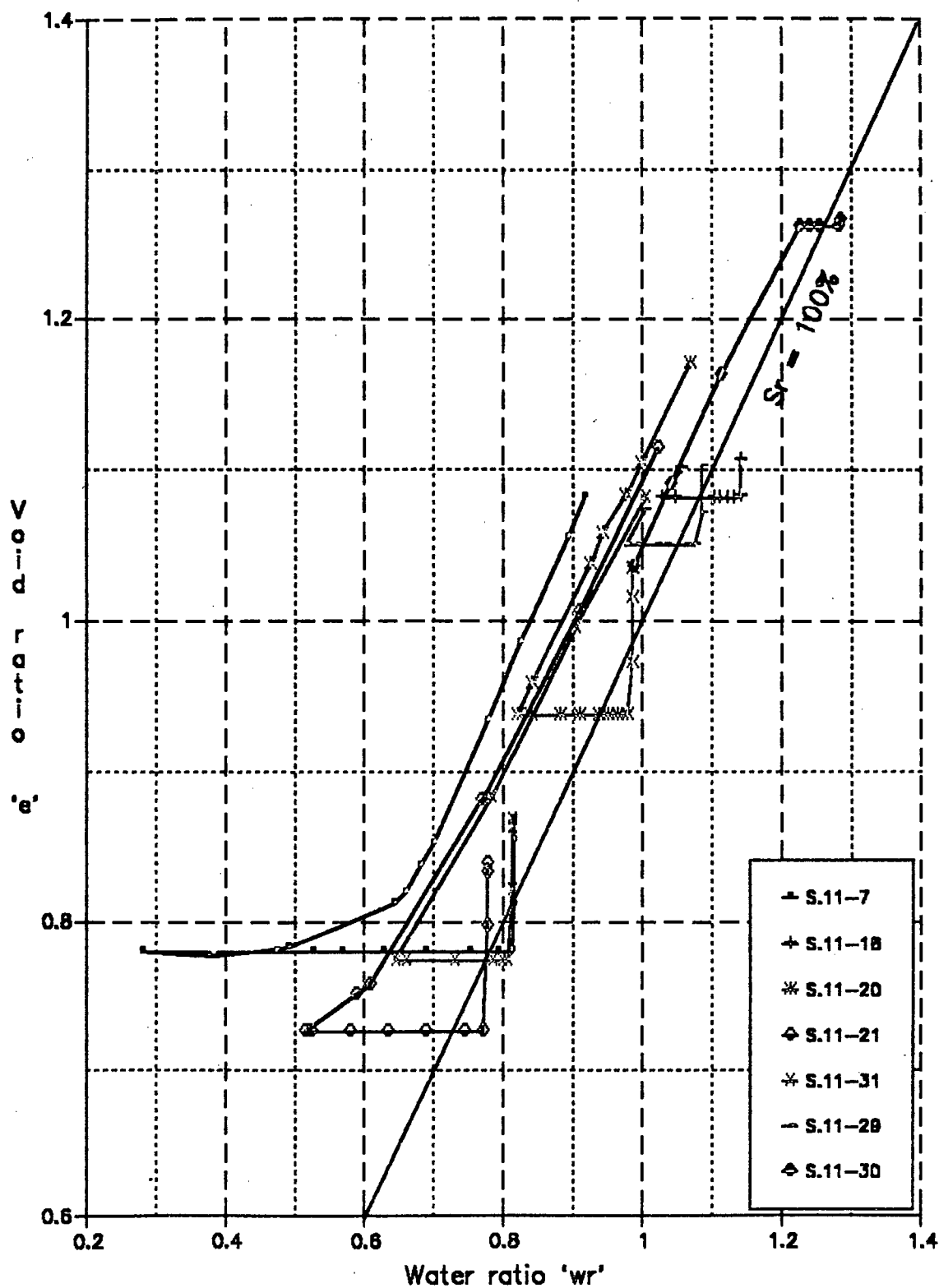


Figure F.05: Site 11, Rosebank [Undisturbed Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

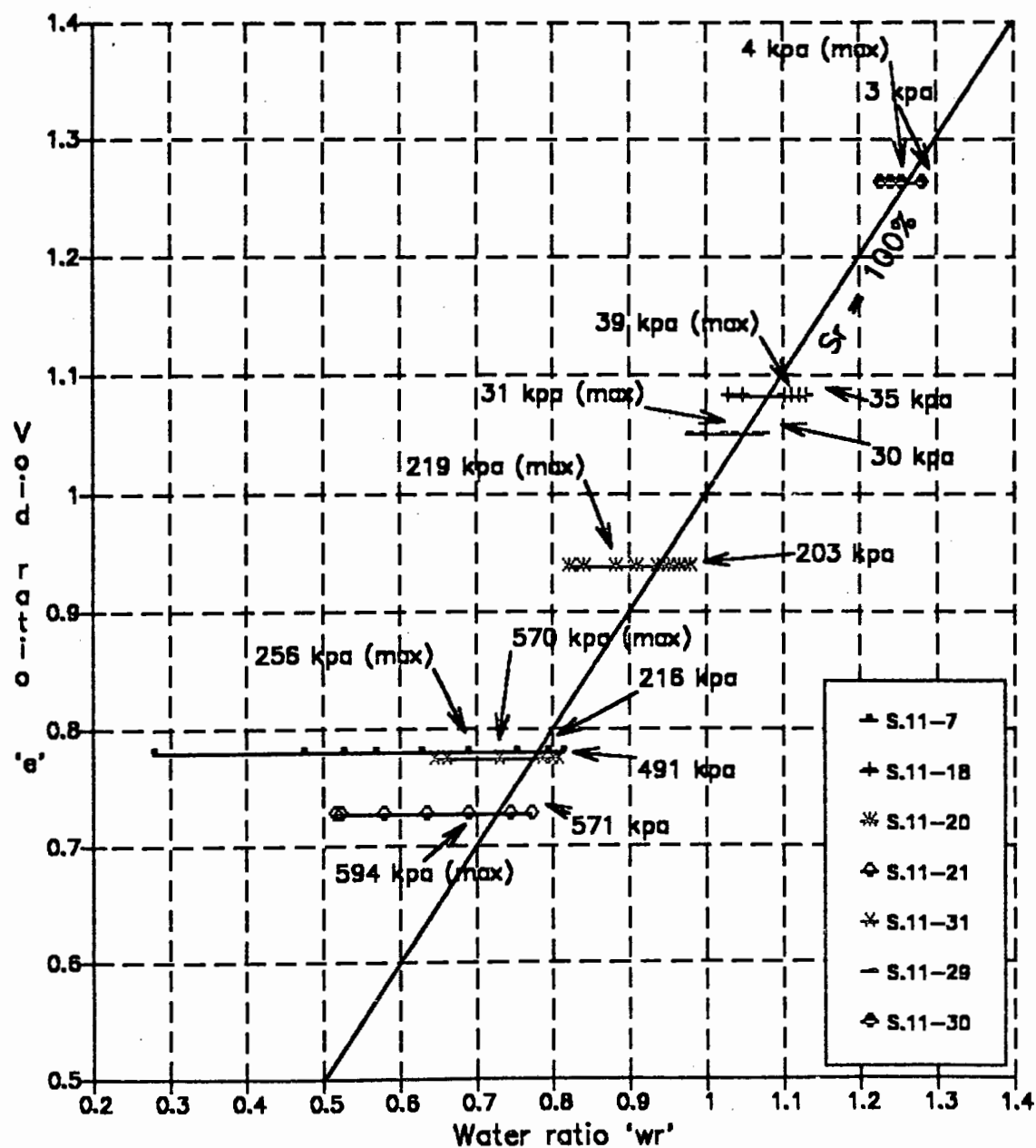


Figure F.06: Site 11, Rosebank [Undisturbed Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).

F.4.2 Site 36 - Rondebosch, Cape

Table F.04: Site 36, Rondebosch [Remoulded Samples] - Swell Pressure test results.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'
S.36-2/ III.365	0	1.37	1.277	S.36-4/ III.371	0	0.87	0.750
	0	0.97	0.900		0	0.68	0.591
	0	0.77	0.710		0	0.65	0.562
	0	0.69	0.594		0	0.61	0.500
	0	0.68	0.532		0	0.599	0.457
	0	0.673	0.465		1	0.599	0.457
	1	0.673	0.465		20.7	0.599	0.470
	12.4	0.673	0.484		68.1	0.599	0.484
	36.7	0.673	0.511		124.3	0.599	0.524
	77.0	0.673	0.538		114.3	0.599	0.538
	120.2	0.673	0.591		121.4	0.599	0.538
	142.1	0.673	0.618		125.5	0.599	0.538
	123.7	0.673	0.645		53.7	0.609	0.543
	127.3	0.673	0.645		8.3	0.624	0.543
	112.5	0.673	0.645		0.9	0.627	0.543
	121.4	0.673	0.659				
	107.2	0.673	0.669				
	8.3	0.727	0.669				
	0.9	0.733	0.699				
S.36-8/ III.408	0	1.48	1.344	S.36-11/ III.409	0	0.85	0.728
	0	1.01	0.933		0	0.783	0.702
	0	0.81	0.734		1	0.783	0.702
	0	0.76	0.677		2.0	0.783	0.702
	0	0.713	0.613		5.3	0.783	0.704
	1	0.713	0.613		6.7	0.783	0.707
	27.9	0.713	0.618		6.4	0.783	0.707
	82.2	0.713	0.645		4.9	0.783	0.710
	85.9	0.713	0.659		1.0	0.783	0.710
	75.6	0.713	0.659				
	49.1	0.718	0.669				
	9.9	0.733	0.669				
	1.0	0.735	0.669				

Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV'	Void ratio 'e'	Water ratio 'wr'
S.36-6/	0	2.57	1.024				
III.395	0	1.39	0.656				
	0	1.24	0.511				
	0	1.177	0.403				
	1	1.177	0.403				
	19.7	1.177	0.403				
	20.2	1.177	0.484				
	23.7	1.177	0.538				
	19.4	1.177	0.591				
	9.0	1.177	0.645				
	4.6	1.177	0.645				
	3.3	1.177	0.726				
	2.8	1.177	0.739				
	1.0	1.179	0.745				

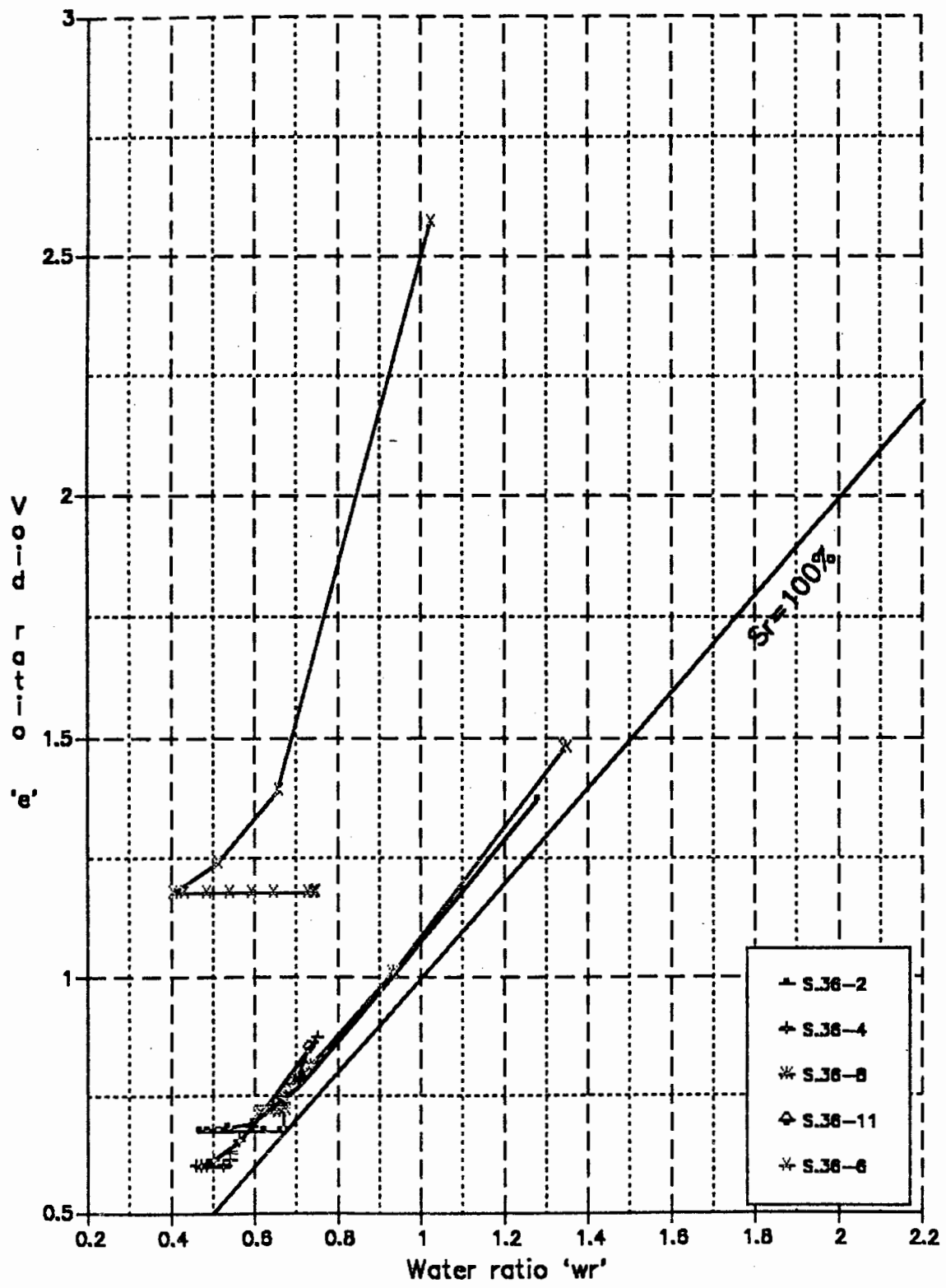


Figure F.07: Site 36, Rondebosch [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

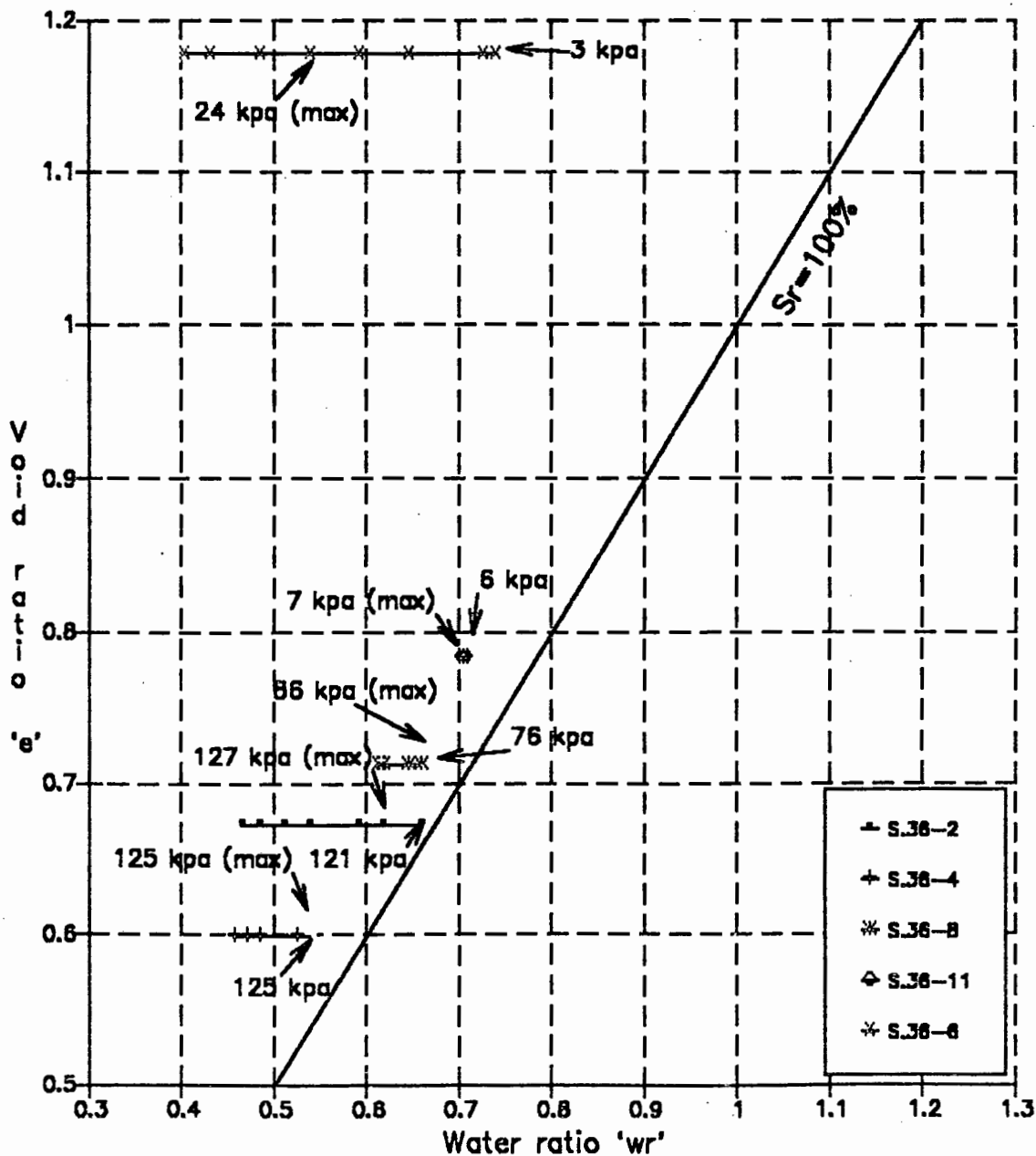


Table F.05: Site 36, Rondebosch [Compacted Sample] - Swell Pressure test results.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'
S.36-19/ IV.454	0	0.598	0.425
	1.0	0.598	0.425
	13.1	0.598	0.430
	55.9	0.598	0.457
	56.7	0.598	0.484
	77.3	0.598	0.511
	85.5	0.598	0.564
	81.4	0.598	0.578
	49.0	0.609	0.589
	9.8	0.640	0.589
	1.0	0.652	0.589

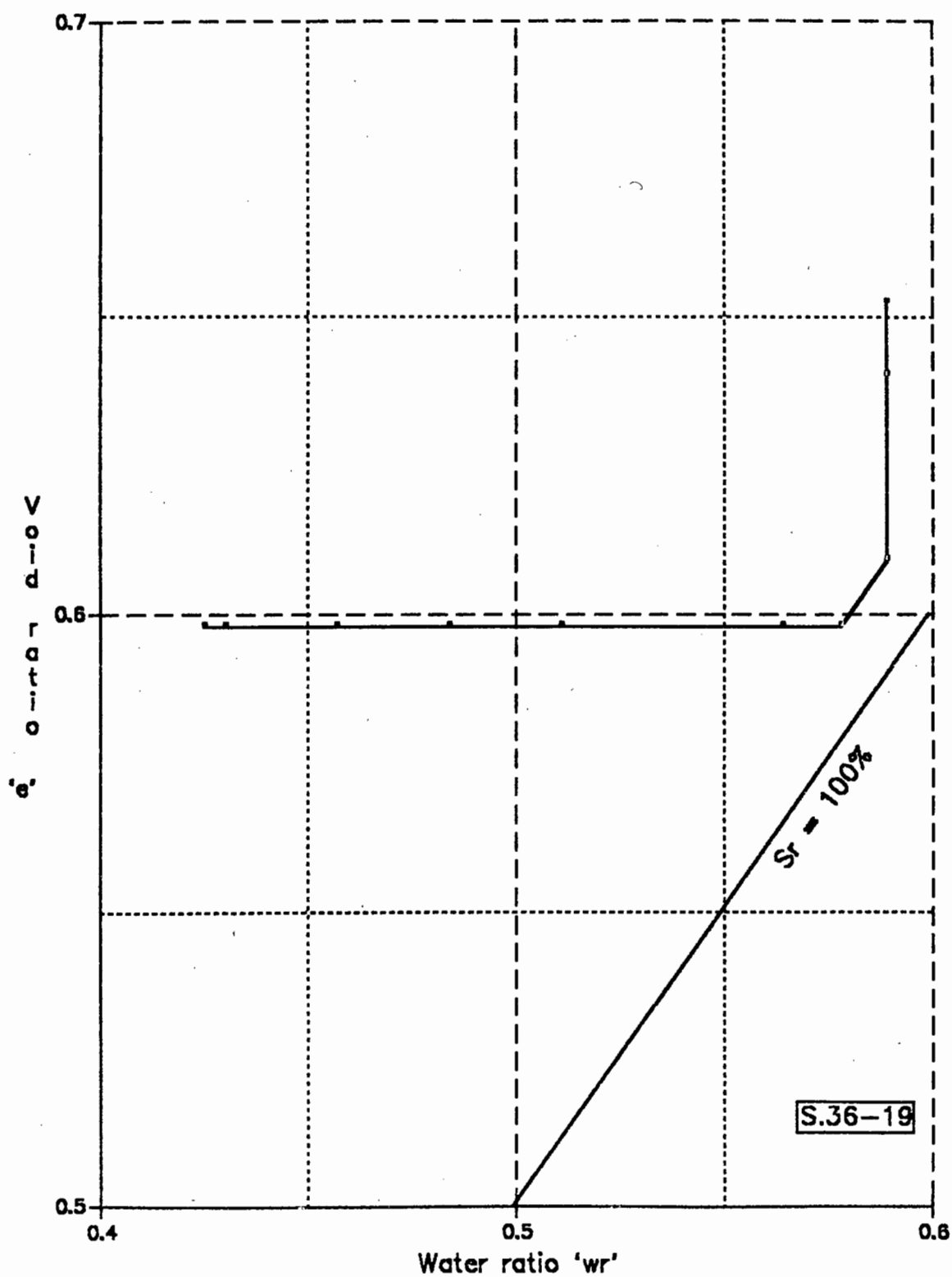


Figure F.09: Site 36, Rondebosch [Compacted Sample] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path. (No air drying between compaction and start of wetting).

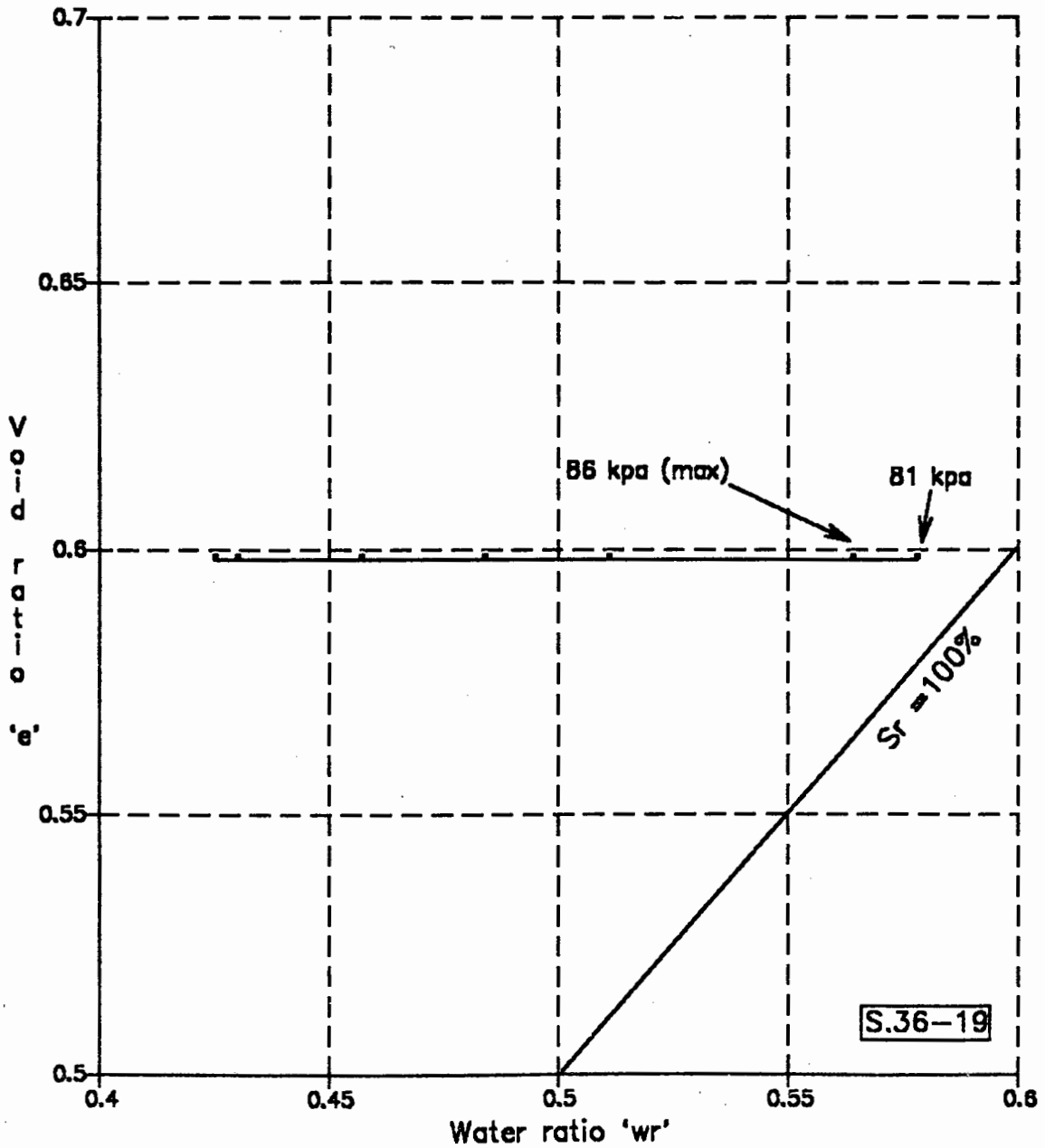


Figure F.10: Site 36, Rondebosch [Compacted Sample] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures). (No air drying between compaction and wetting).

Table F.06: Site 36, Rondebosch [Undisturbed Sample] - Swell Pressure test results.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'
S.36-17/	0	0.677	0.462
IV.424	0	0.711	0.543
	1.0	0.711	0.543
	7.4	0.711	0.564
	15.6	0.711	0.591
	18.7	0.711	0.618
	22.2	0.711	0.645
	23.0	0.711	0.659
	22.7	0.711	0.672
	9.8	0.782	0.685
	1.0	0.897	0.685

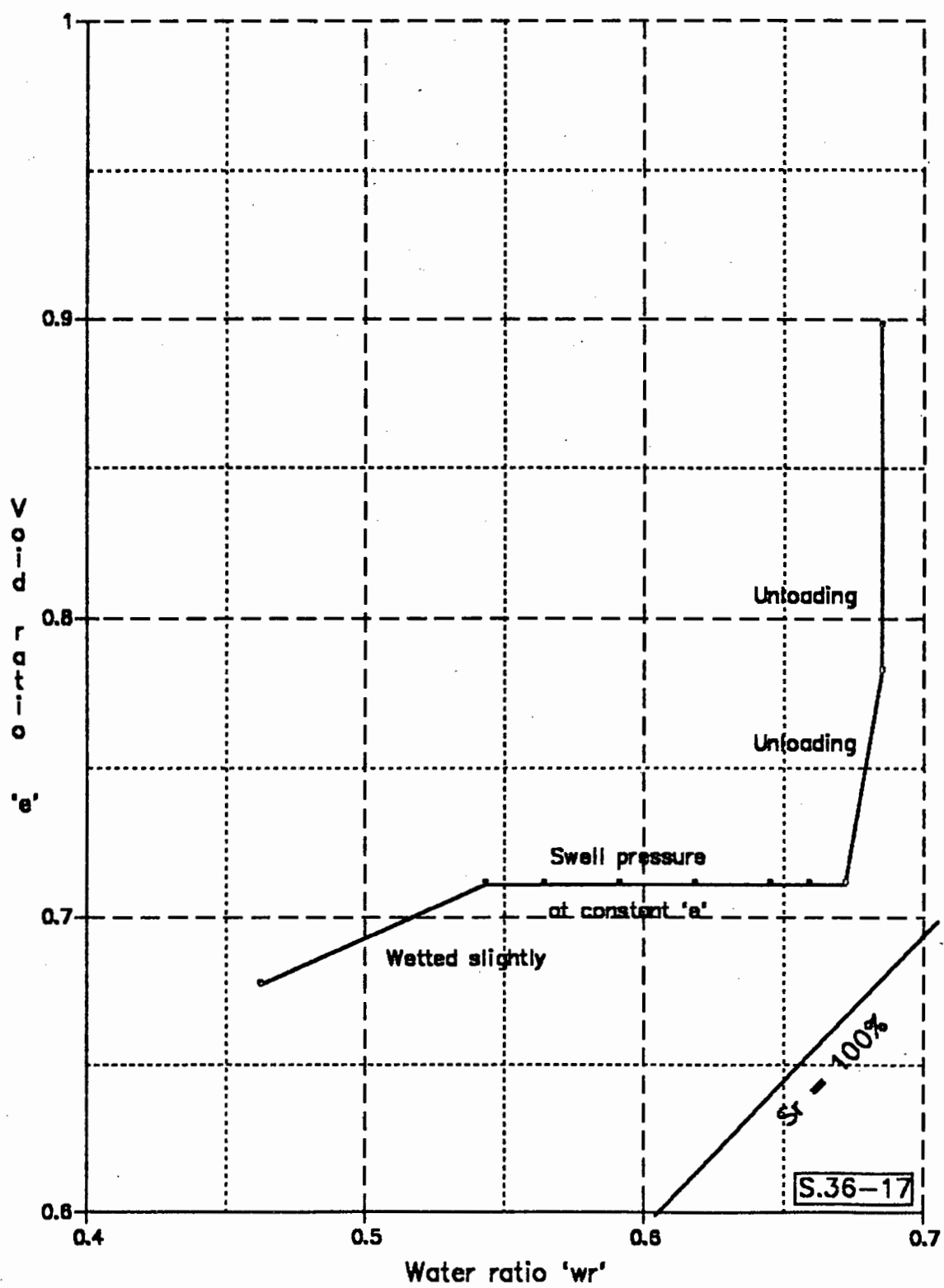


Figure F.11: Site 36, Rondebosch [Undisturbed Sample] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

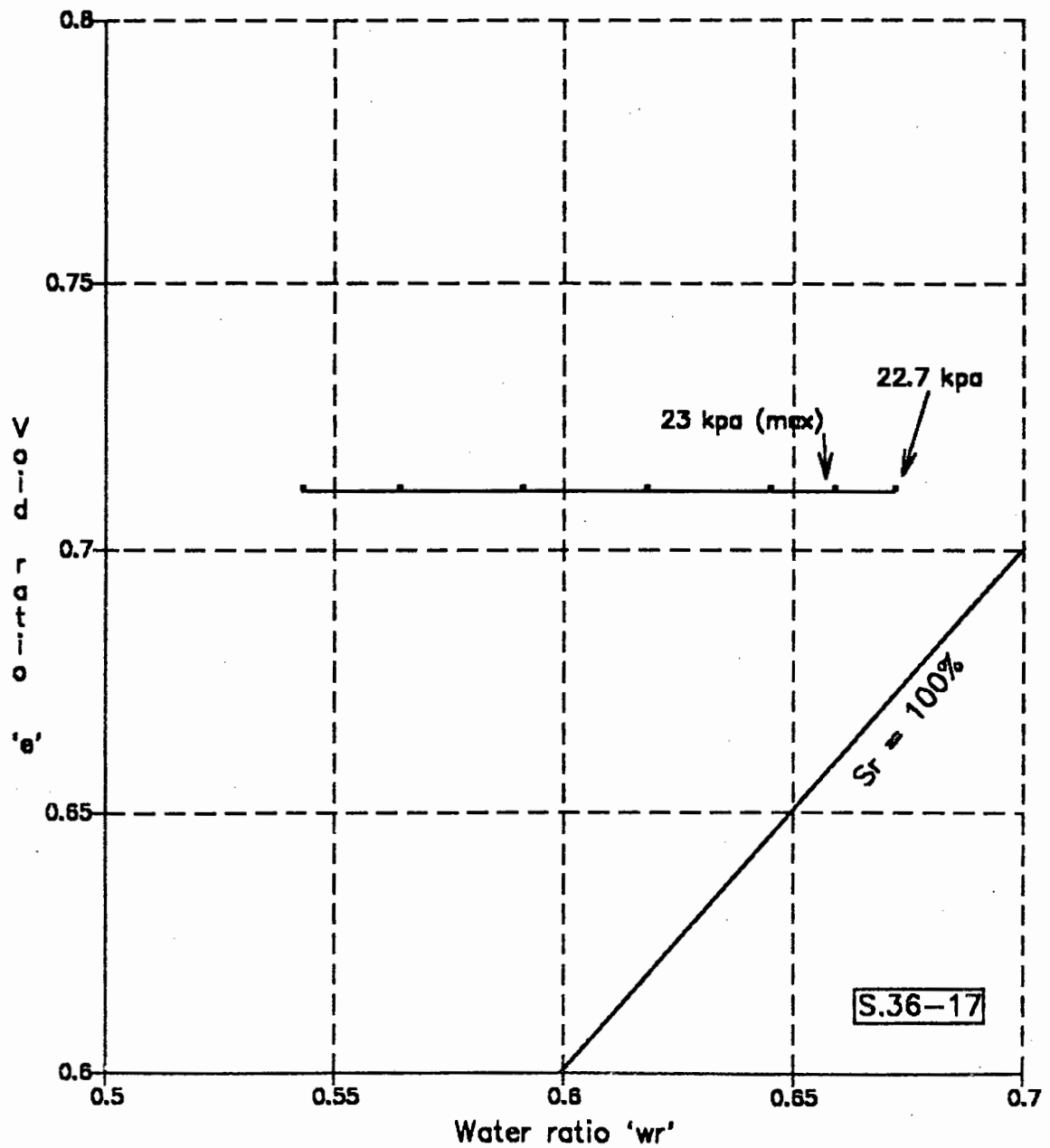


Figure F.12: Site 36, Rondebosch [Undisturbed Sample] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).

F.4.3. Site 30 - Hout Bay, Cape

Table F.07: Site 30, Hout Bay [Remoulded Samples] - Swell Pressure test results.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'
S.30-2/ III.379	0	1.55	1.406	S.30-4/ III.389	0	1.04	0.904
	0	0.95	0.852		0	0.87	0.767
	0	0.86	0.765		0	0.84	0.746
	0	0.77	0.649		0	0.71	0.588
	0	0.72	0.533		0	0.69	0.546
	0	0.711	0.448		0	0.673	0.461
	1	0.711	0.448		1	0.673	0.461
	13.6	0.711	0.461		21.9	0.673	0.475
	26.1	0.711	0.501		61.0	0.673	0.501
	45.6	0.711	0.527		112.5	0.673	0.541
	74.6	0.711	0.554		127.9	0.673	0.580
	94.1	0.711	0.607		169.3	0.673	0.620
	130.3	0.711	0.633		145.1	0.673	0.646
	124.3	0.711	0.646		148.0	0.673	0.646
	125.5	0.711	0.659		146.2	0.673	0.659
	53.7	0.723	0.662		53.7	0.691	0.662
	8.3	0.743	0.662		8.3	0.731	0.662
	0.9	0.748	0.662		0.9	0.738	0.662
S.30-8/ IV.422	0	1.49	1.324	S.30-6/ III.406	0	2.16	1.229
	0	1.06	0.936		0	1.40	0.907
	0	1.01	0.889		0	1.29	0.815
	0	0.91	0.786		0	1.21	0.738
	0	0.885	0.749		0	1.11	0.641
	1	0.885	0.749		0	1.04	0.556
	27.9	0.885	0.765		0	0.991	0.425
	49.3	0.885	0.817		1	0.991	0.425
	44.4	0.885	0.831		13.8	0.991	0.448
	9.9	0.915	0.836		23.8	0.991	0.475
	1.0	0.925	0.836		54.2	0.991	0.501
					65.7	0.991	0.554
					62.8	0.991	0.593
					42.9	0.991	0.633
					26.3	0.991	0.686
					27.1	0.991	0.699
					9.9	1.005	0.704
					1.0	1.012	0.704

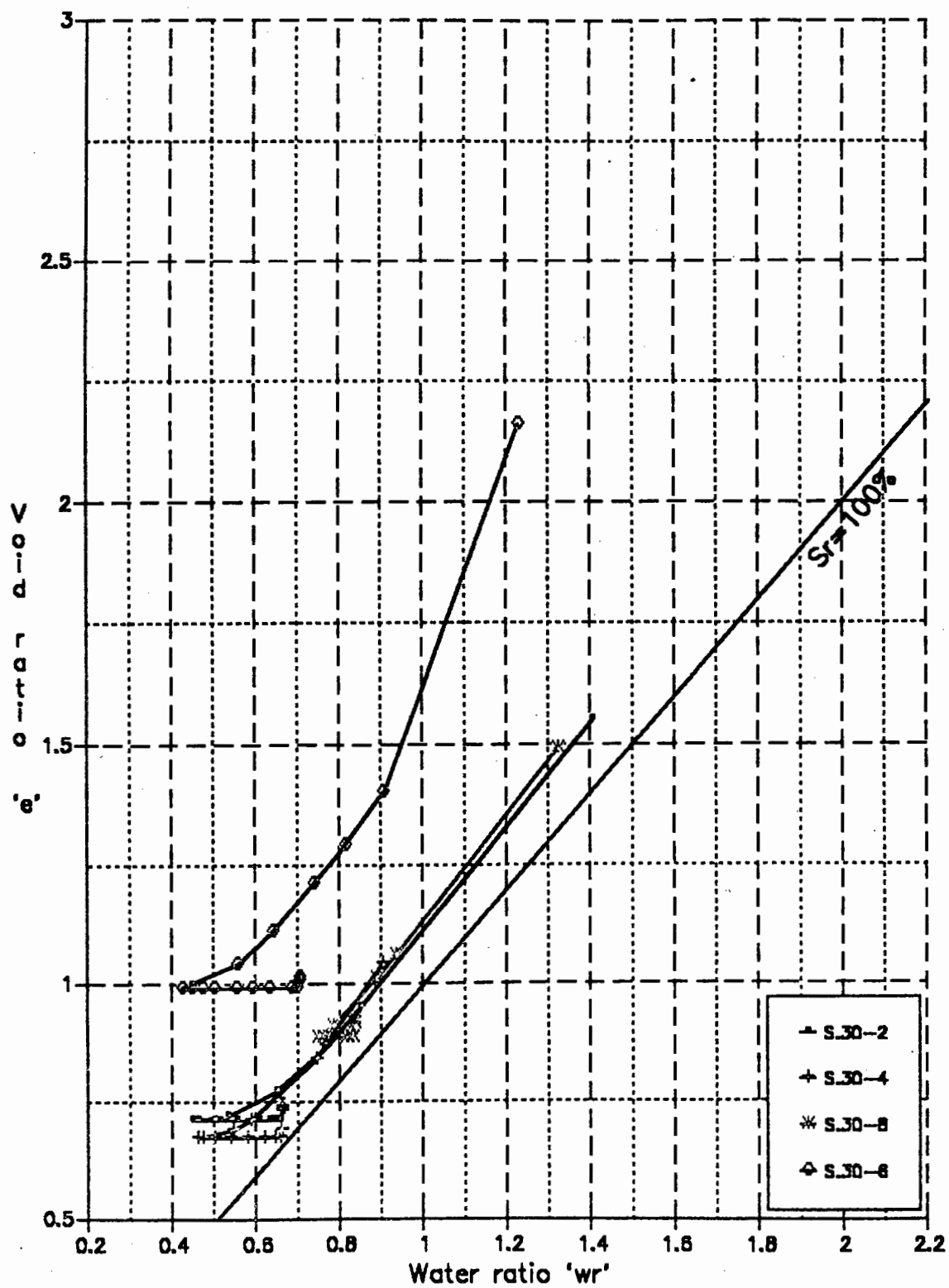


Figure F.13: Site 30, Hout Bay [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

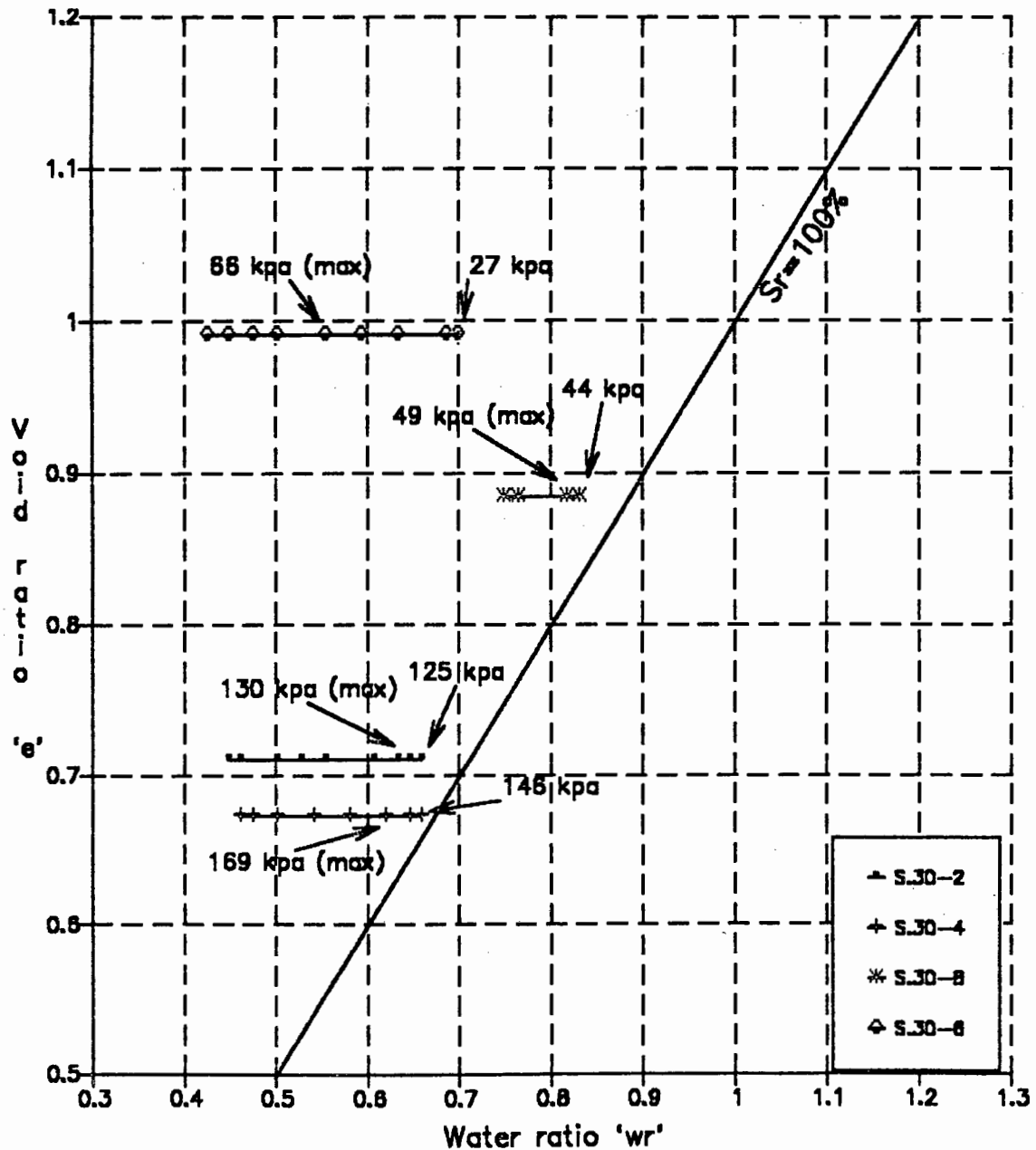


Figure F.14: Site 30, Hout Bay [Remoulded Samples] - Void ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).

Table F.08: Site 30, Hout Bay [Undisturbed Sample] - Swell Pressure test results.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'
S.30-14/ IV.436	1.0	0.677	0.382
	3.3	0.677	0.396
	17.6	0.677	0.422
	43.5	0.677	0.461
	48.6	0.677	0.488
	90.4	0.687	0.527
	114.2	0.677	0.567
	109.3	0.677	0.593
	116.2	0.677	0.633
	113.9	0.677	0.646
	49.0	0.782	0.657
	9.8	0.970	0.657
	1.0	1.074	0.657

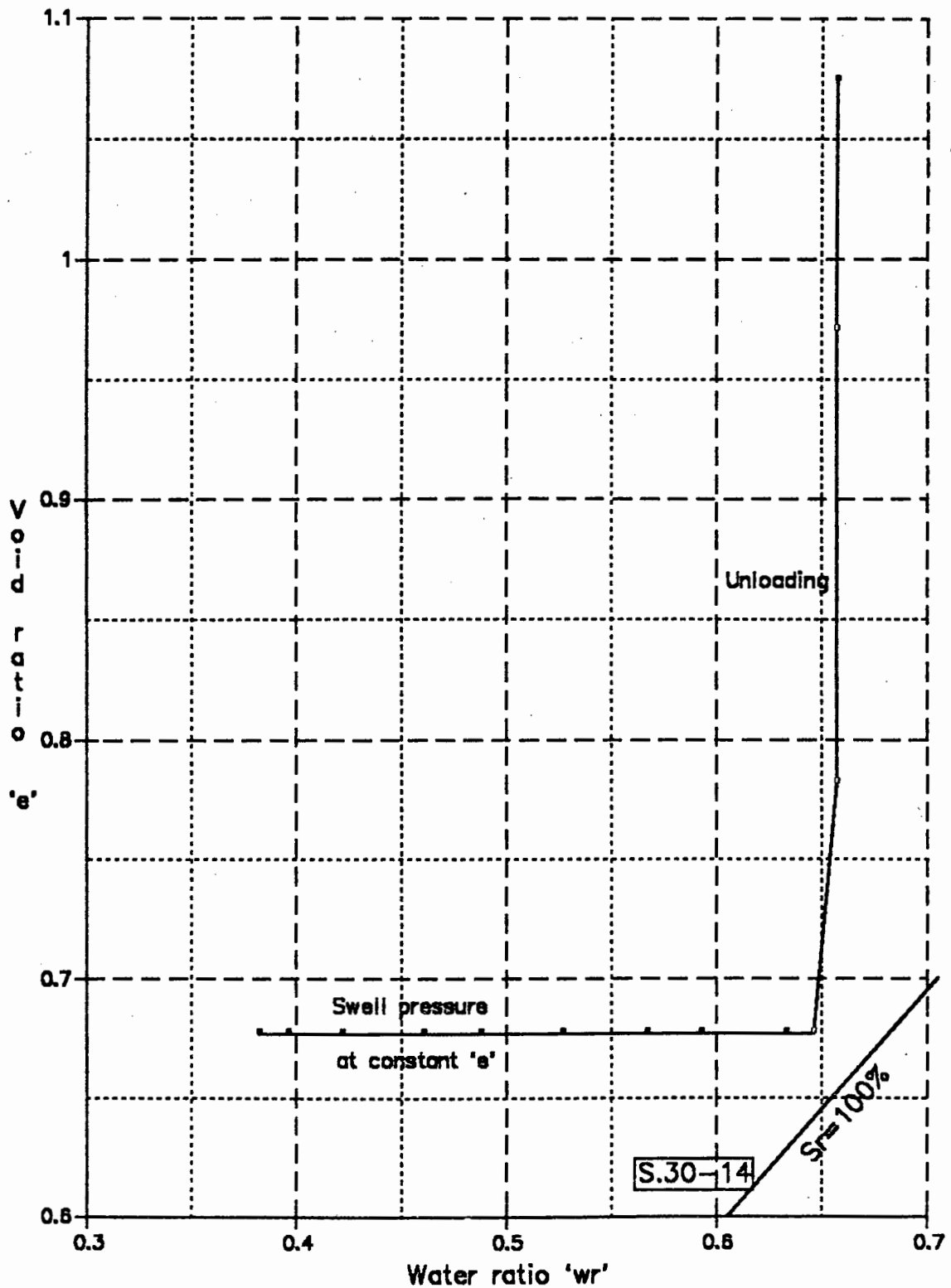


Figure F.15: Site 30, Hout Bay [Undisturbed Sample] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

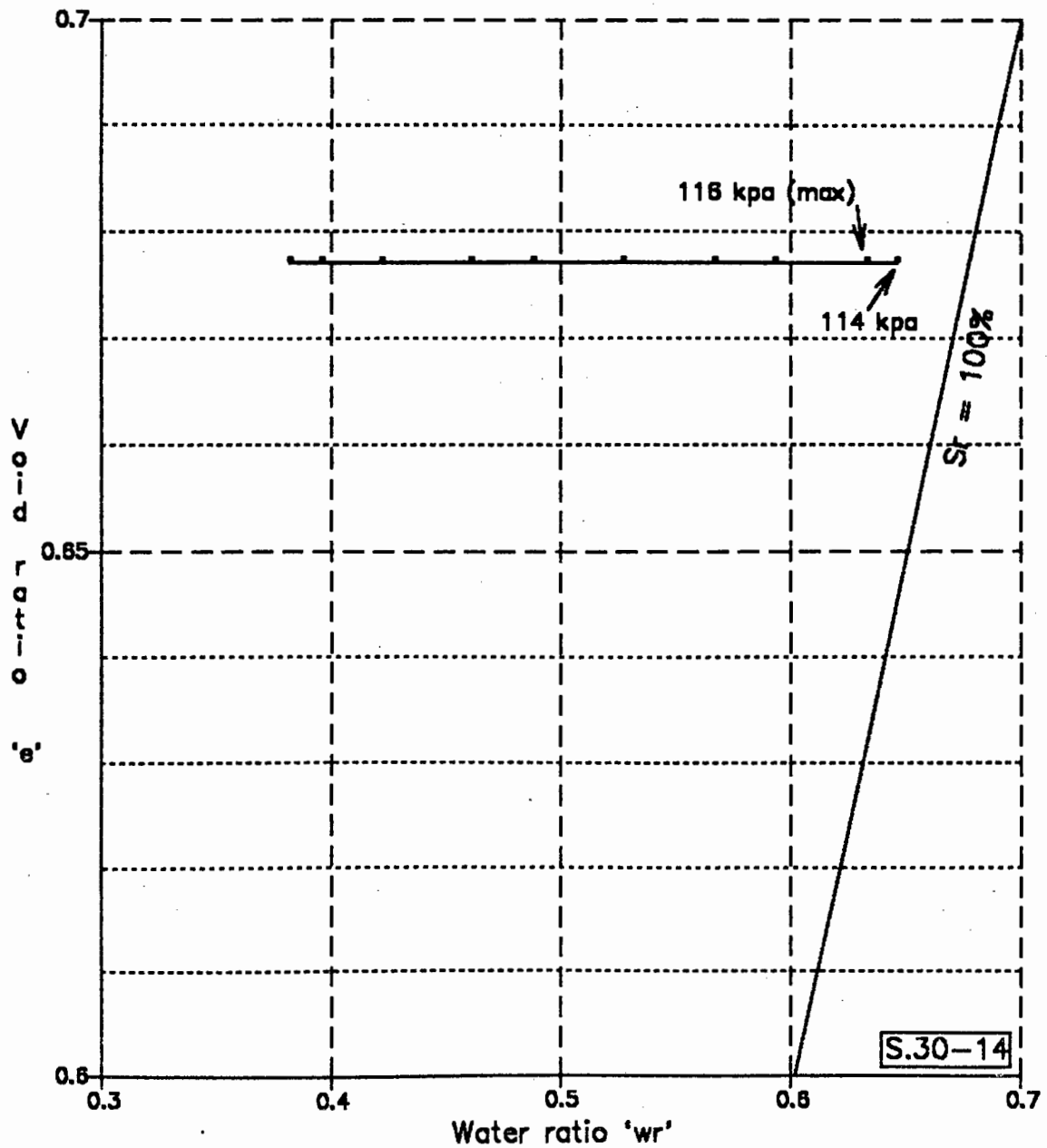


Figure F.16: Site 30, Hout Bay [Undisturbed Sample] - Void Ratio ' e ' versus Water Ratio ' w_r ', for the controlled wetting path (includes swell pressures).

F.4.4. Site A - Berea Road, Durban

Table F.09: Site A, Berea Road [Compacted Sample] - Swell Pressure test results.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'
S.A-31/ IV.467	1.0	0.434	0.171
	6.6	0.434	0.187
	7.2	0.434	0.227
	9.4	0.434	0.267
	10.5	0.434	0.307
	12.8	0.434	0.333
	12.3	0.434	0.352
	4.9	0.434	0.352
	1.0	0.436	0.352

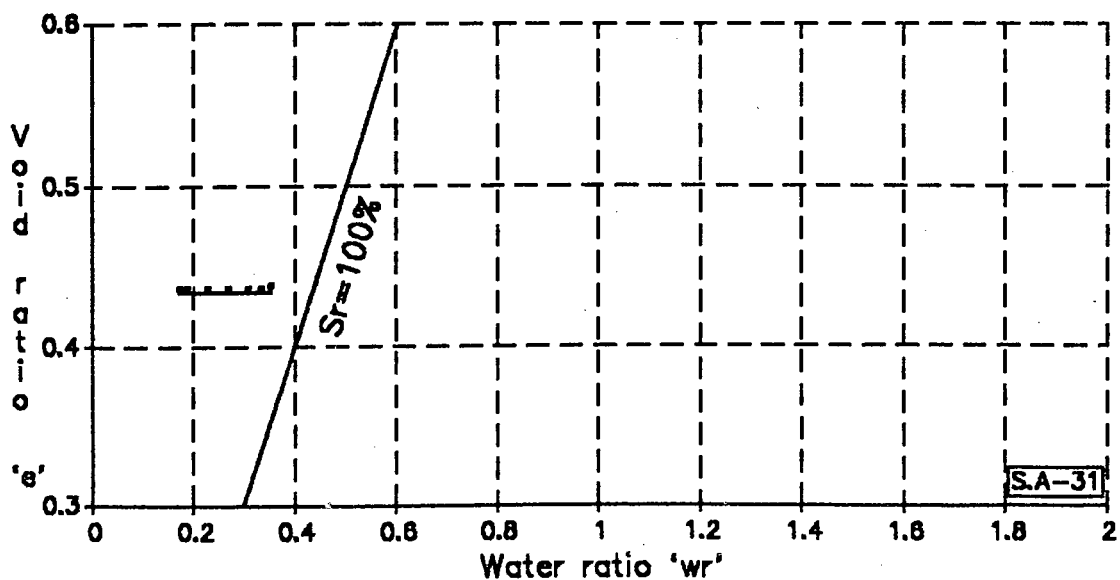


Figure F.17: Site A, Berea Road [Compacted Sample] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

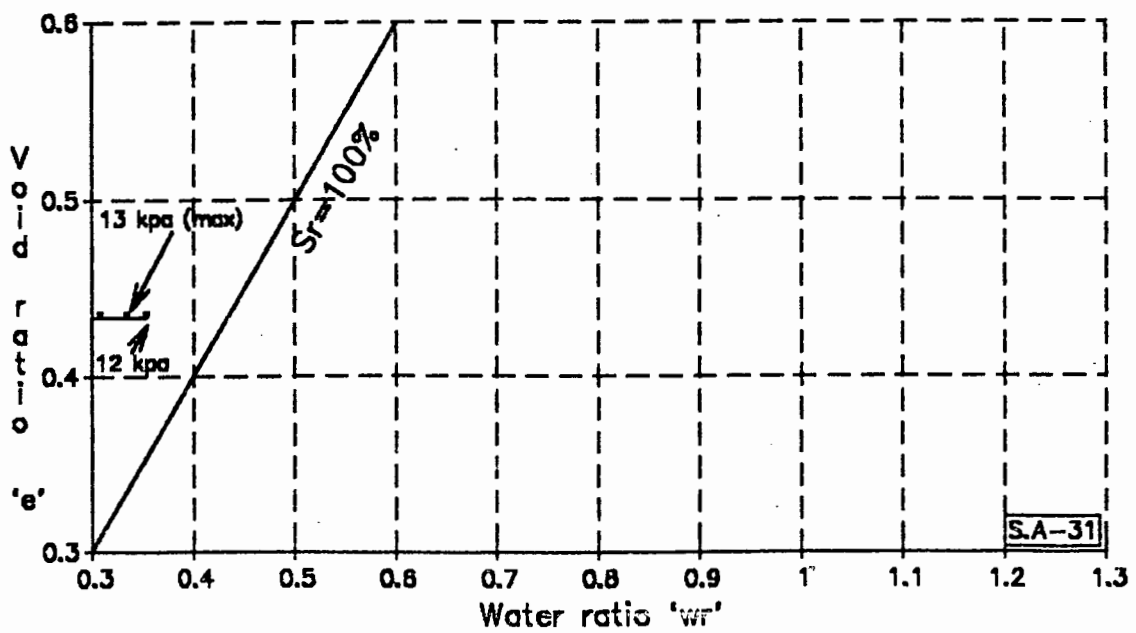


Figure F.18: Site A, Berea Road [Compacted Sample] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).

F.4.5. Site 7 - Mowbray, Cape

Table F.10: Site 7, Mowbray [Remoulded Samples] - Swell Pressure test results.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'	Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'
S.7-9/ II.196	0	2.81	1.335	S.7-8/ II.150	0	1.755	1.311
	0	1.01	0.56		0	0.459	0.386
	0	0.88	0.466		0	0.414	0.229
	0	0.85	0.447		0	0.408	0.146
	0	0.84	0.436		0	0.416	0.071
	0	0.823	0.417		1.0	0.416	0.071
	1	0.823	0.417		276.9	0.416	0.097
	973.6	0.823	0.483		602.1	0.416	0.110
	1364.9	0.823	0.566		1219.7	0.416	0.124
	1061.0	0.823	0.621		1767.7	0.416	0.152
	805.6	0.823	0.648		2088.2	0.416	0.193
	605.3	0.823	0.648		1546.4	0.416	0.207
	377.5	0.823	0.648		2916.1	0.416	0.248
	151.9	0.823	0.662		1149.6	0.416	0.276
	402.8	0.823	0.662		2348.3	0.416	0.284
	704.3	0.823	0.662		3166.3	0.416	0.295
	598.4	0.823	0.662		1799.4	0.416	0.303
	777.9	0.823	0.662		3623.4	0.416	0.312
	1270.5	0.823	0.662		3070.3	0.416	0.323
	1703.2	0.823	0.676		4960.8	0.416	0.339
	1187.6	0.823	0.676		3948.6	0.416	0.350
	1081.8	0.823	0.676		4899.8	0.416	0.359
	702.0	0.823	0.690		3757.3	0.416	0.367
	49.1	0.824	0.698		490.3	0.420	0.378
	9.9	0.825	0.698		49.0	0.420	0.378
	1.0	0.849	0.698		1.0	0.420	0.378

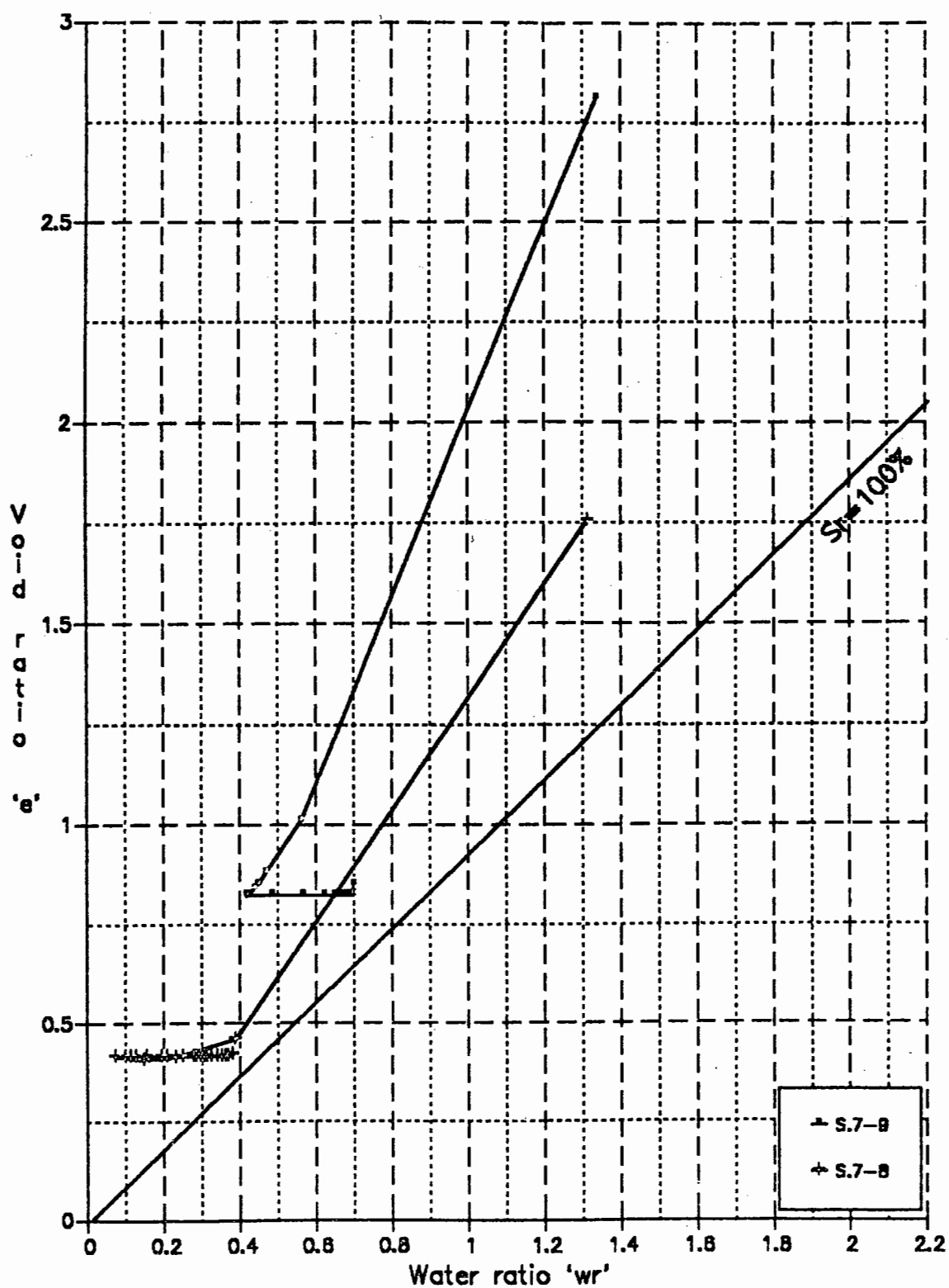


Figure F.19: Site 7; Mowbray [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

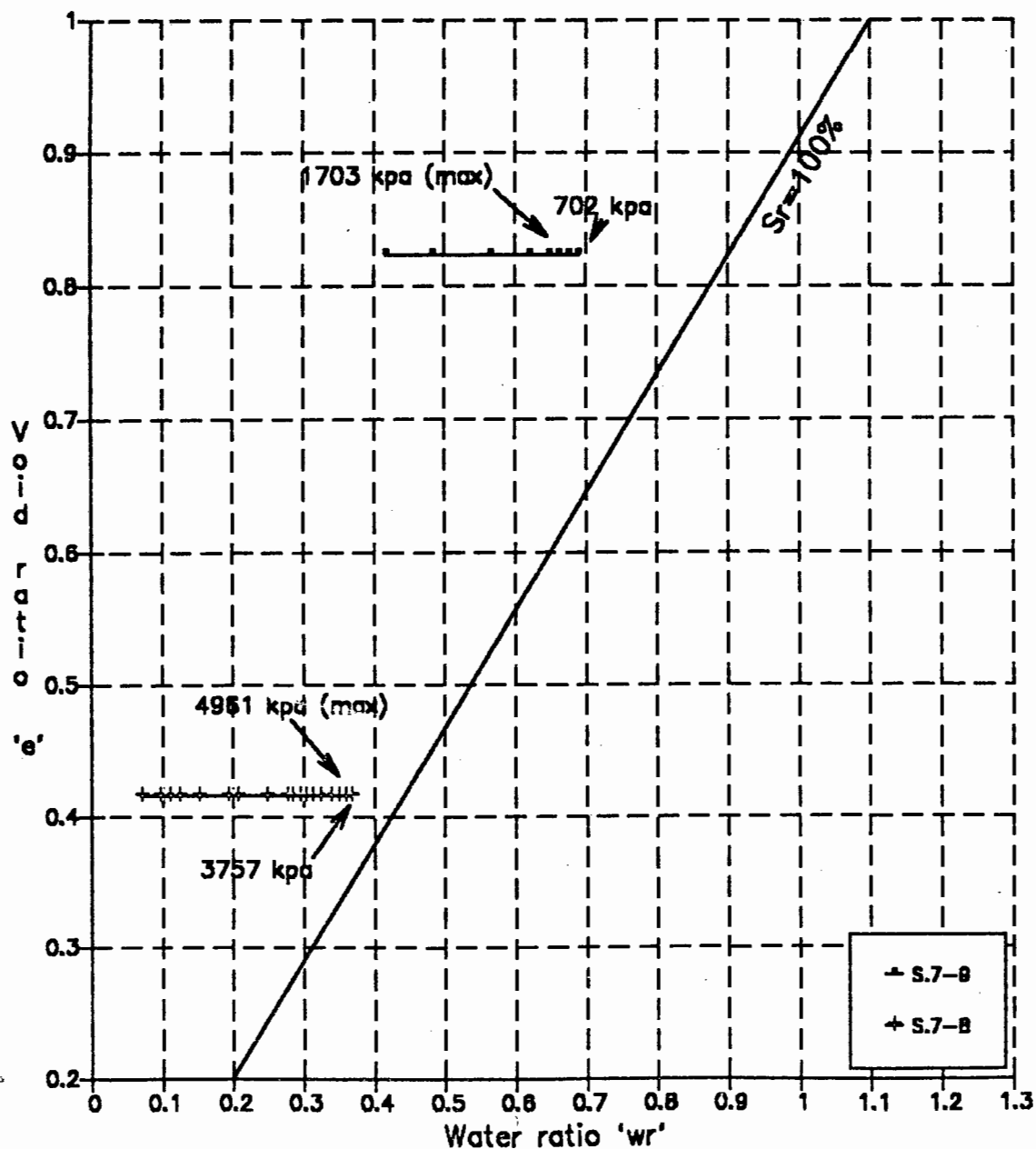


Figure F.20: Site 7, Mowbray [Remoulded Samples] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).

Table F.11: Site 7, Mowbray [Undisturbed Sample] - Swell Pressure test results.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Water ratio 'wr'
S.7-11/	0	0.563	0.529
II.200	0	0.538	0.499
	0	0.511	0.463
	0	0.491	0.403
	0	0.490	0.392
	0	0.488	0.377
	1.0	0.488	0.377
	2556.6	0.488	0.441
	8235.9	0.488	0.497
	2818.9	0.488	0.524
	2878.2	0.488	0.532
	3023.2	0.488	0.544
	3132.8	0.488	0.552
	3041.6	0.488	0.560
	1516.7	0.488	0.571
	2142.6	0.488	0.579
	53.7	0.490	0.582
	0.9	0.544	0.582

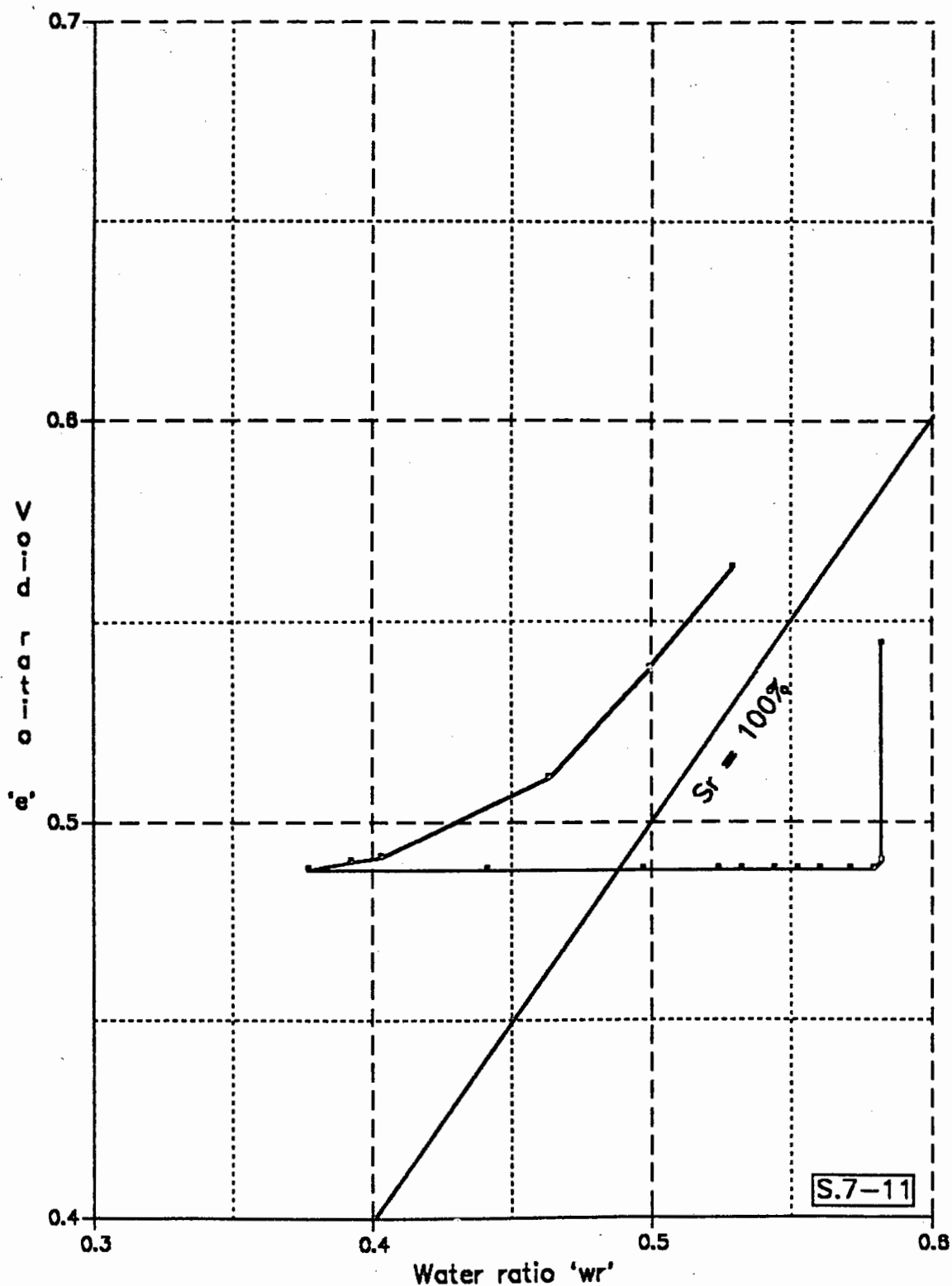


Figure F.21: Site 7, Mowbray [Undisturbed sample] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

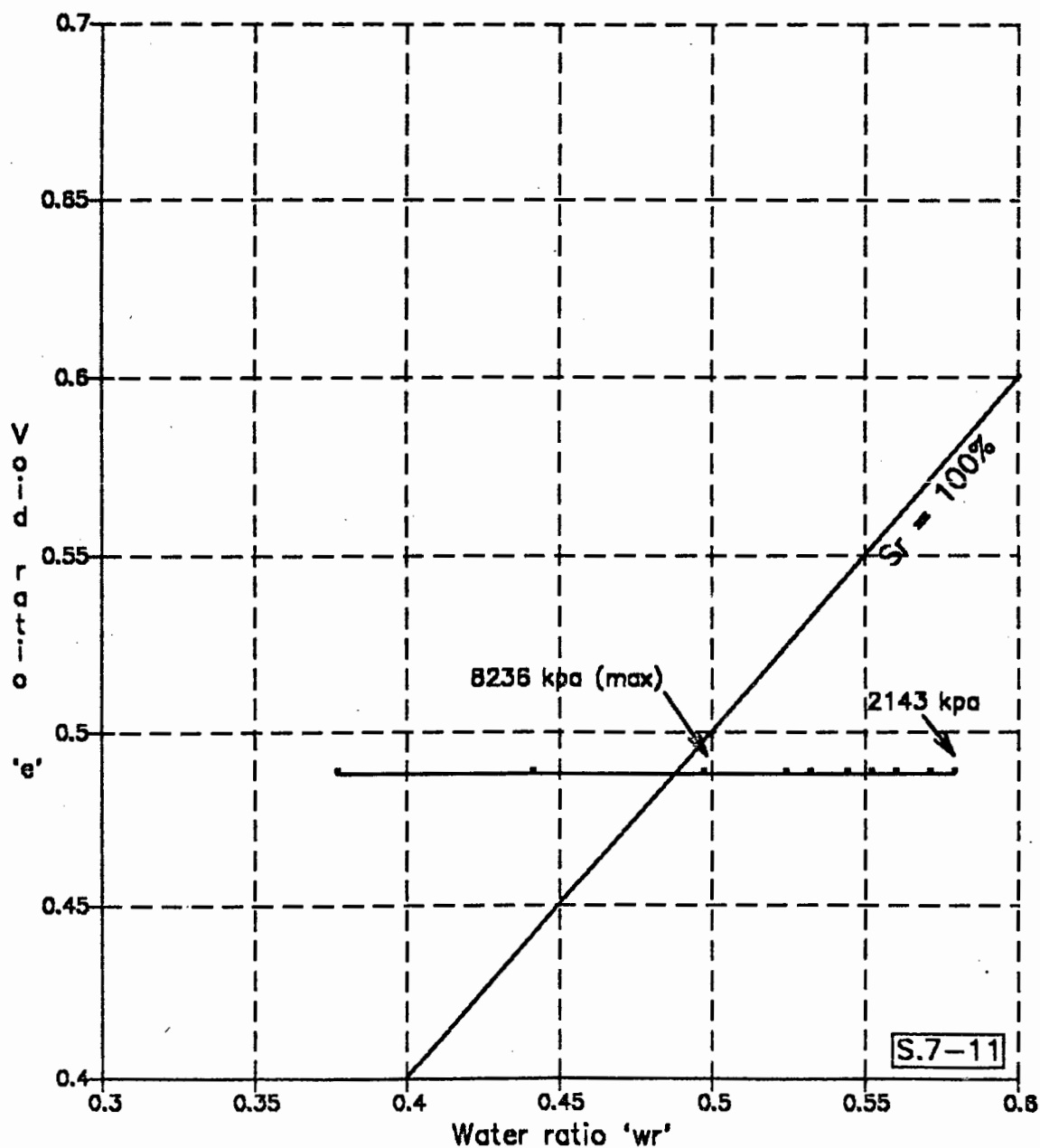


Figure F.22: Site 7, Mowbray [Undisturbed Sample] - Void Ratio 'e' versus Water Ratio 'wr', for the controlled wetting path (includes swell pressures).

APPENDIX G

CONSOLIDOMETER TESTS WITH LATERAL PRESSURE MEASUREMENTS - TEST PROCEDURES AND RESULTS

G.1 INTRODUCTION

Appendix G describes in detail the consolidometer test methods, or procedures, for Chapter Eight. These test procedures enable relevant observations and measurements to be recorded, for a test sample, as the result of either changes in the applied vertical pressure or the addition of a known volume of water.

Measurements were obtained for the following:

- (i) One-dimensional changes in vertical strain, or deflection;
 - (ii) Applied vertical pressures, or stresses, against which the sample expands, collapses, or is prevented from increasing its volume, when wetted; and,
 - (iii) The corresponding changes in strain that take place along the horizontal axis of the sample.
- This Appendix also includes all the test results used in Chapter Eight.

The test method and results are summarized in Chapter Eight "Axisymmetric Stress Behaviour Expansive and Collapsing Soils". The basic consolidometer test procedure for expansive and collapsing soils is detailed in Appendix E, and the swell pressure test in Appendix F. The standard one-dimensional consolidation test procedure is described in Appendix D. Additional details, including the measurement of horizontal strains and photographic plates, are detailed in Chapter Eight of the thesis.

G.2 TEST PROCEDURE

Preparation of test samples:-

Test samples are prepared from either remoulded, compacted or undisturbed soil samples. The 'step by step' detailed procedure for sample preparation is included in the preparation of soil samples for testing¹.

¹ - refer to section A.3 of Appendix A.

*Remoulded samples.*Method 1:

The basic remoulded test sample consists of soil mixed with water to form a wet paste which is subsequently moulded into a suitable container. The water content of the mixture varies from about the Plastic Limit to a value equal to, or greater than, the Liquid Limit. This latter condition is also a requirement for the determination of the Shrinkage Limit (refer to Appendix A).

Method 2:

Test samples with higher void ratios can also be obtained by the addition of suitable chemical substances. A homogeneous dry mixture is prepared by mixing known amounts of soil, Tartaric Acid and Sodium Bicarbonate. Water is added to the mixture, quickly mixed and placed in a suitable container. The pH value is monitored and kept unchanged from the original sample.

Compacted Samples.

Based on the 'Dry Density versus Water Content' curve for the soil type being used, as obtained in Appendix A¹: Select points on the curve and obtain the corresponding values for water contents; Compact the soil to either Standard or Modified AASHTO specifications, as per requirements, aiming for one of the previously selected water contents; Remove the compacted sample from the mould and cut the required test sample from it.

Undisturbed samples.

The test sample is cut from the undisturbed block of soil - refer to the procedure for 'Soil Sampling' included in Appendix A.

Apparatus required:-

- (i) A standard consolidometer loading device and fittings - refer to the test procedure for "Consolidometer: One-dimensional consolidation test procedure" in section D.1 of Appendix D, step (i) of apparatus required.
- (ii) Loading frame with 'upwards' extension for a proving ring to measure swell pressure, as well as suitable proving rings for swell pressure measurements - refer to test procedure for "Swell pressure tests for expansive soils - test procedure and results", Appendix F².

¹ - refer to section A.5, "Compaction Tests".

² - see section F.2, (xiii) and (xiv) of apparatus required.

(iii) The stainless steel 'strain unit' for measuring the stresses developed in the sample. The 'strain unit' essentially consists of a stainless steel ring (dimensions: internal diameter = 70.0 mm; height = 19.0 mm; and thickness = 1.0 mm) incorporating, on its outer side, strain gauges which are connected to a strain measuring device. A custom made perspex container, with grooves on its bottom to facilitate controlled water increments and drainage, and incorporating centering screws for the 'strain unit'. Two filter papers (Whatmans no. 1), the top one to fit into the steel ring (ie, to be of the same diameter as the top 'loading' plate), and the bottom one about 40 mm larger than the ring, in order to facilitate water being added to the sample. Two plates, which can be made of silicon carbide, aluminium oxide¹, or alternatively of good quality perspex. The top 'loading' plate should be about 0.2 mm to 0.5 mm less than the internal diameter of the steel ring, and should have a built-in balljoint seating to receive the "plunger" from above the top loading plate. The top loading plate should be the equivalent of applying an initial pressure of about 1 Kpa to the sample.

Note: A detailed description is included in the next section 'Measurement of horizontal strains, and stresses'.

(iv) The 'ring/membrane unit' to measure horizontal pressures, or stresses, which are equal and opposite to the stresses developed in the soil sample. The 'ring/membrane unit' consists basically of a consolidometer ring lined with a rubber membrane, which is connected to a piston pump by means of high pressure tubing. The system also incorporates a pressure gauge and a stop cock valve, which enable the measurement of water pressure and the control of its flow, respectively.

A specially made container with a 'grooved'² flat bottom plate, and a fixed wall all round. The consolidometer ring fits in the centre of the bottom plate.

Two filter papers, both of the same size, to fit into the steel ring.

A top loading plate, as described for (iii) above, and a bottom porous plate which fits into the bottom of the consolidometer ring.

(v) - (xi) Refer to test procedure for the "Consolidometer: One-dimensional consolidation test procedure", Appendix D, steps (vi) to (xii) of apparatus required.

¹ - or other suitable metal.

² - facilitates water ingress/drainage.

G.2.1 The One-dimensional Consolidometer Test.

Procedure:-

A) Calibration of equipment:

(i) [Consolidometer with 'strain unit'] Assemble all the consolidometer parts as for the actual test, except that a metal spacer is used in place of the soil sample - refer to test procedure for the "Consolidometer; One-dimensional consolidation test procedure", Appendix D¹. Table G.01 and Figure G.01 (refer to end of this test procedure) quantify the corrections to be applied.

(ii) [Strain unit] Use the following parts: A 250 mm length (to avoid end restrain effects) of hose pipe with an external diameter equal to, or slightly smaller than, the diameter of the steel ring; Grooved end plates and clamps; and, threaded pieces with bolts for holding down the end plates. In addition thin canvas 'packing' material was used around the hose pipe, in the area where the ring was calibrated, in order to provide a better and 'just tight' fit - that is, to avoid the hose expanding before coming into full contact with the ring, and also, to prevent the ring becoming strained before the calibration itself starts. At the end of this test procedure, Table G.02 and Figure G.02 provide a correlation for the readings of horizontal strain to corresponding values of horizontal pressure.

B) The soil sample is allowed to air dry, until the required initial water content is reached. During the drying of the sample, the shrinkage path of the soil is obtained from the measurements of mass and volume described in "Free shrinkage and free swell - test procedure and results"². The soil sample is removed from the dessicator when the initial water content is reached. The sample is cut and trimmed to size, until the steel ring with the strain gauges (ie, the 'strain unit') just slides over it. The top and bottom surfaces of the sample are made level. The final dimensions of the sample are measured and its mass recorded. Air dry masses should also be recorded for the following items: 'Strain unit'; Perspex container; Filter papers; Metal top plate; Plastic cover and elastic bands.

Note: The mass of the 'strain unit', and the internal diameter and height of the stainless steel ring should be checked before each test, or at regular intervals.

¹ - step A of section D.1.

² - refer to section C.2 of Appendix C.

C) The parts, that make up the consolidometer container, are assembled in the following order:

- (i) The internal surfaces of the perspex container are slightly moistened, to help preventing evaporation, and the larger size filter paper is positioned on its centre;
- (ii) The 'strain unit' ring, containing the soil sample, is centered on the filter paper, and the unit's electrical wires are passed through the access grooves built into the container itself;
- (iii) The smaller size filter paper and the top loading plate are carefully placed, in that order, on top of the soil sample;
- (iv) The perspex cover is positioned and tightened against the container by means of wingnuts;
- (v) Use is made of centering screws to enable small adjustments to be made to the position of the 'strain unit'.
- (vi) Enclose the assembled parts with a loose fitting plastic cover, and use rubber bands to hold it firmly in place.

Note: It is important that the sample remains covered throughout the entire test, in order to prevent movement of air around the sample.

D) Position the perspex container in the loading device of the consolidometer and connect the electrical wires¹ to the 'strain measuring device'. Ensure that the electrical wires are properly connected. Adjust and/or record the following: The counterweight alongside the lever arm of the consolidometer until it balances firmly - that is, a small pressure is being exerted to the soil sample; The 'zero reading' of the dial gauge for measuring the vertical travel; Allow the assembled parts to stand for a period of time, sufficiently long for no strain reading fluctuations to be observed, and record the initial strain reading for no applied load.

E) Ensure that the readings² for vertical deflection and horizontal strain are unchanged. Place the necessary weights on the loading platform (of the consolidometer) in order to apply, to the soil sample, the required sequence of pressure increments, as follows: 8.3 Kpa -> 53.6 -> 107.3 -> 214.6 -> 429.2 -> 858.4 Kpa.

Record the readings for vertical deflection (on the micrometer dial gauge of the consolidometer) and horizontal strain (on the 'strain gauge measuring device'), before each vertical pressure increment is applied, and at the following time intervals after each one starts acting on the sample - 0.25 minutes, 0.5, 1.0, 2.25, 4, 9, 16, 30, 60, 120 minutes, and so on. Readings should continue until the soil has consolidated or, at least until the slope of the characteristic linear secondary settlement becomes apparent.

¹ - from the strain unit.

² - on the dial gauges.

Notes: (1) Concerning (in particular) remoulded saturated samples, during the course of the loading stages water can be observed being squeezed out of the sample. At the end of the full loading sequence, this water should be removed by means of a calibrated syringe and the amount recorded; (2) The 'strain unit' should be switched off between readings, in order to avoid unnecessary drainage of the batteries.

F) The unloading, or recovery characteristics, of the sample, are determined. The maximum external vertical pressure applied to the sample is gradually decreased using the following sequence: 858.4 Kpa → 214.6 → 53.6 → 8.3 → 1.0 Kpa. Readings of vertical deflection and horizontal strain are recorded before each vertical pressure decrease and, beginning immediately after decreasing the pressure, at the same time intervals given in the previous step¹. The readings should continue until no more expansion is observed.

G) At the end of the unloading sequence, a set of final readings are recorded for the vertical deflection and horizontal strain. The perspex container is removed from the consolidometer and each part is carefully removed from the container. The soil sample is very carefully extracted from the steel ring.

A check reading is obtained for horizontal strain - it should be the same, or close to the initial reading for no strain, recorded before starting the loading stage.

Notes: The difference between the two readings (that is, between before loading and after unloading), should be corrected proportionately and applied to each one of the other readings for horizontal strain.

H) The following masses are recorded - soil sample, filter papers and at regular intervals also the metal top plate, perspex container, plastic cover with elastic bands, and strain gauge unit.

The soil sample is placed inside the oven, previously set to $105 \pm 5^{\circ}\text{C}$ for a few hours, preferably overnight. After the sample is removed from the oven, it is allowed to cool down to room temperature, and its oven dried mass recorded.

¹ - that is, 0.25, 0.5, 1.0, 2.25 minutes, etc.

Calculations and report:-

1) Information to be recorded for each test:

- a) Before starting the loading stage - the initial readings for vertical deflection and horizontal strain¹;
- b) For each loading stage - the total load placed on the loading platform, time and readings for vertical deflection and horizontal strain, and any excess water removed;
- c) For each stage of unloading - as for the loading stage (refer to b) above);
- d) The moisture content of the soil sample at the start and end of the test,

$$\text{Mass of wet soil sample} - \text{Mass of oven-dry soil sample} \\ = \frac{\text{Mass of oven-dry soil sample}}{\text{Mass of oven-dry soil sample}}$$

Note: Intermediate water contents can also be estimated (refer to Appendices E and F, and to "The one-dimensional consolidation tests for expansive and collapsing soils"²).

e) The diameter, height and mass of the soil sample were obtained in steps B to G above;

2) To determine the void ratio at the initial, final and intermediate stages:

a) The initial void ratio 'e' of the soil sample:

$$'e' = \frac{\text{Volume of voids 'Vv'}}{\text{Volume of solids 'Vs'}} = \frac{\text{Total volume 'Vt'} - V_s}{V_s}$$

Where:

$$V_t = \frac{\pi \times D^2}{4} \times [\text{Original height of soil sample 'hi'}] ;$$

and,

$$V_s = \frac{\text{Mass of oven-dry soil 'M}_D'}{\text{Specific Gravity of soil particles 'Gs'}}$$

b) Intermediate and final void ratios are obtained by using the corrected vertical deflection 'hi' (refer to Calibration of equipment - step A (i) above), and then calculating the 'e' value as follows:

$$e = \frac{\pi \times D^2/4 (h_t - h_i) - V_s}{V_s}$$

¹ - refer to previous step D.

² - section G.2.2 of this Appendix.

3) The readings of horizontal strain are correlated to corresponding values of horizontal pressure (refer to Calibration of equipment¹), and then by calculating the values of average pressure, or stress, as follows:

$$\text{Average stress} = 1/3 [\text{Vertical stress} + (2 \times \text{Horizontal stress})]$$

4) The information obtained for each test will enable the following relationships to be illustrated:

a) Vertical deformation (settlement or expansion) and time (square root, or log) for each applied pressure increase or decrease²;

b) Void ratio 'e' and effective vertical pressure 'peV';

c) Void ratio 'e' and effective horizontal pressure 'peH'.

Note: All the preliminary test procedures and definitions are included in Appendix A.

¹ - see previous step A (ii).

² - for more details refer to Appendix D.

Calibration tests:-

1) The bedding-in that takes place due to the equipment adjusting itself to the load sequence used.

Table G.01: Consolidometer tests with horizontal strain measurements - Calibration of equipment.

Load -> Pressure		Vertical deflection:		Correction to be	
(lbs)	Kpa	Reading	Difference	applied (accumulative):	
		0.0001"	0.0001"	0.0001"	-> cm
	1	1432.0	0	0	0
5	53.6	1366.0	-66.0	-66.0	-0.0168
10	107.3	1351.3	-14.7	-80.7	-0.0205
15	160.9	1341.0	-10.3	-91.0	-0.0231
20	214.6	1333.0	- 8.0	-99.0	-0.0251
30	321.9	1320.0	-13.0	-112.0	-0.0284
40	429.2	1312.0	- 8.0	-120.0	-0.0305
50	536.5	1307.2	- 4.8	-124.8	-0.0317
60	643.8	1302.0	- 5.2	-130.0	-0.0330
40	429.2	1307.2	5.2	-124.8	-0.0317
20	214.6	1314.8	7.6	-117.2	-0.0298
10	107.3	1326.5	11.7	-105.5	-0.0268
5	53.6	1333.6	7.1	- 98.4	-0.0250
	1	1360.0	26.4	- 72.0	-0.0183

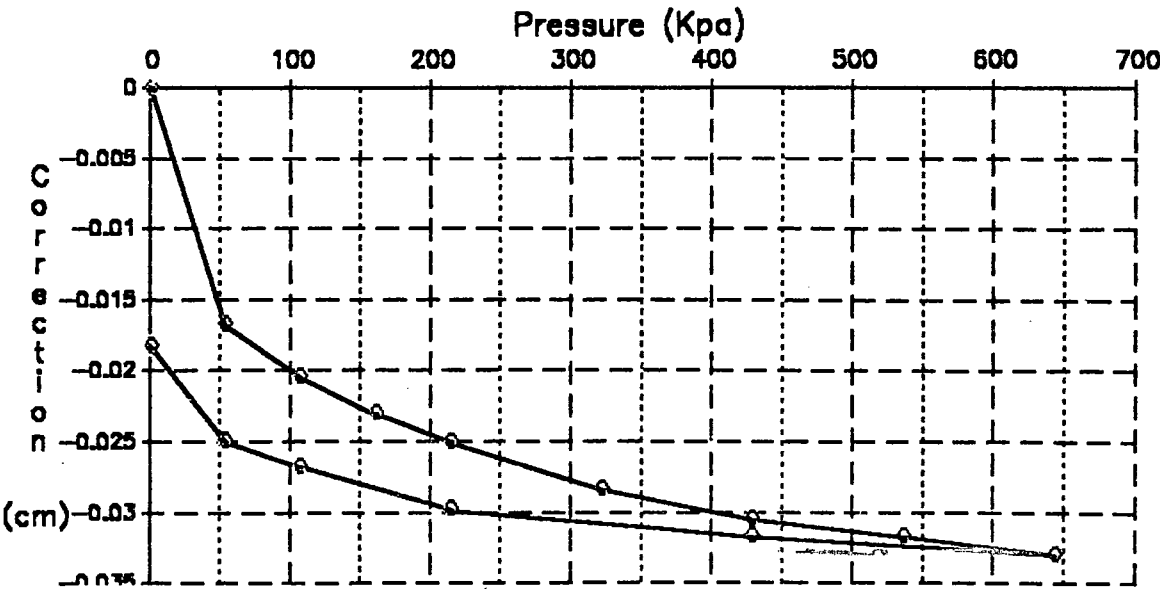


Figure G.01: Consolidometer tests with horizontal strain measurements - Calibration of equipment.

2) Correlation between the observed strain readings on the strain bridge and the corresponding internal applied pressure.

Table G.02: Calibration of internal pressure and strain readings on the strain bridge¹.

Pressure applied		Strain measurement 'strain unit'	
lbs/in ²	Kpa	Reading	Cumulative difference
0	0	11120	0
3	20.7	130	10
7	48.3	154	34
15	103.4	215	95
30	206.8	355	235
45	310.3	500	380
60	413.7	11640	520

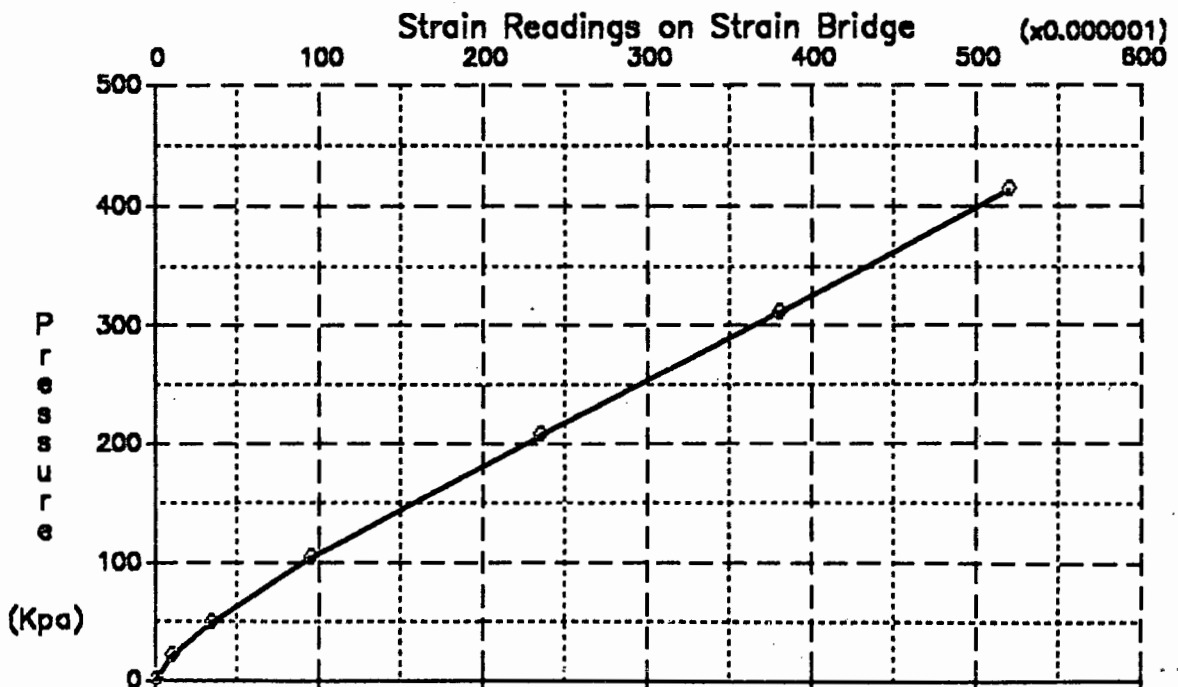


Figure G.02: Consolidometer tests with horizontal strain measurements - Correlation between strain measurement and pressure applied.

¹ - see section 8.8, Chapter Eight, in Volume One of Thesis.

G.2.2 The One-dimensional Consolidation Test for Expansive and Collapsing Soils.

Procedure:-

A) Calibration of equipment:

(i)-(ii) Refer to test procedure for "The one-dimensional consolidation test"¹.

(iii) [Consolidometer with 'Ring/membrane unit'] Similar to G.2.1 part A) (i), except that the 'Ring/membrane unit', with its own container and requiring other parts, is used instead. Table G.03 and Figure G.03 (refer to the end of this test procedure) show the corrections to be applied.

B) and C) refer to section G.2.1 part B) and C), except that the 'Ring/membrane unit' is used instead of the 'Strain unit'.

C) In the case of using the 'Ring/membrane unit', the parts that make up the consolidometer container are assembled in the following order:

(i) The internal surfaces of the container are slightly moistened, to help preventing evaporation, and the bottom porous plate is positioned on the centre of its (grooved) bottom plate;

(ii) A filter paper is placed on top of the porous plate, and the 'Ring/membrane unit', containing the soil sample, is centred on top of the filter paper;

(iii) The other filter paper and the top loading plate are placed, in that order, on top of the sample;

(iv) The container is enclosed with a loose fitting plastic cover, and rubber bands are used to hold it firmly in place. Note: The container should remain covered throughout the entire test.

(v) The equipment used to measure the pressure applied (by means of the piston pump) is assembled on a table next to the consolidometer.

D) Position the container in the loading device of the consolidometer, and adjust and/or record the following: Counterweight alongside the lever arm until it exerts a small pressure to the soil sample; The initial, or zero, reading for vertical deflection; The initial reading on the strain gauge measuring device (horizontal strain), or pressure gauge for the piston pump (horizontal stress²).

¹ - section G.2.1, part A), (i) and (ii).

² - via the 'ring/membrane unit'.

E) Place the necessary weights on the loading platform in order to apply to the soil sample the required sequence of pressure increments, leading up to the vertical pressure against which the sample expands, or collapses, when wetted. The required sequence of pressure increments, for each of the three external pressures applied, is as follows:

(i) 50 Kpa test - one single load increment from the initial reading;

(ii) 100 Kpa test - 0 -> 50 -> 100 Kpa; and,

(iii) 400 Kpa test - 0 -> 50 -> 100 -> 400 Kpa.

Record the readings for vertical deflection and horizontal strain ('strain gauge measuring device'), or horizontal pressure ('ring/membrane unit'), before each vertical pressure increment is applied, and at the following time intervals after each of these increments starts acting on the sample - 0.25 minutes, 0.5, 1.0, 2.25, 4, 9, 16, 30, 60, 120 minutes, and so on, until no further settlement takes place. Readings should continue, at least, until the stage of the characteristic linear secondary settlement becomes apparent.

Note: Following the application of the last pressure increment, it is preferable that the sample should be allowed to consolidate overnight.

F) By means of an hypodermic syringe, add a known amount of water to the sample through the bottom filter paper. Allow the soil sample to expand, or to settle further, while being subjected to the same external vertical pressure. Record the vertical deflection and horizontal strain, or pressure, readings at the same time intervals from start of wetting as given in the previous step - that is, the vertical and horizontal 'dynamic' response, with time, are recorded.

Note: The specimen usually expands rapidly at first, followed by slowing down to a 'peak' value, after which it tends to settle down to a constant lower value. It should be added that, depending on the particular sample and initial water content at the start of the test, it may take a matter of minutes, or hours, before a constant value is reached.

G) Repeat the procedure until no further noticeable vertical movement, increase or decrease, takes place. Remove and measure any excess of water. Record the amount of water added at each stage, and also take note of the total water added for the whole wetting stage.

H) Support the lever arm of the consolidometer, and use weights on its loading platform to enable the measurement of the loading characteristics of the soil. Apply further pressure increments of 50 Kpa until a vertical pressure of 300 Kpa is reached. It should be noted that for the 400 Kpa test no further loading takes place after the controlled wetting stage. For each pressure increment record the changes in vertical deflection (or thickness of the sample) and horizontal strain, at the same time intervals as those given above - refer to step E.

Note: Observe if any water is being squeezed out of the soil at the end of each loading stage and, if so happens, remove the water by means of a syringe and note the amount.

(I) The unloading characteristics of the sample are also recorded. The sequence of pressure decrease is as follows: 300 (or 400) Kpa $\rightarrow$ 50 $\rightarrow$ 10 $\rightarrow$ 1 Kpa. Vertical deflection and horizontal strain, or pressure, readings are recorded before each applied pressure decrease and, immediately following the application of the pressure, at the same time intervals as before - that is, $\frac{1}{4}$, $\frac{1}{2}$, 1, $2\frac{1}{4}$ minutes, etc. The readings should be continued at least until the slope of the characteristic expansion versus square root of time becomes a straight line, which usually happens quickly.

J) At the end of the unloading sequence, a set of final readings are obtained for vertical deflection and horizontal strain, or pressure, measurements.

Note: The remainder of step J is virtually identical to step G of section G.2.1. "The One-dimensional consolidation test."

K) Refer to section G.2.1, step H.

Calculations and report:-

1) Information to be recorded for each test:

- a) Before starting the loading stage - the initial readings for vertical deflection and horizontal strain, or pressure (refer to step D above);
- b) For each stage of initial loading - the total load placed on the loading platform, time and readings for vertical deflection and horizontal strain, or pressure;
- c) For each stage of incremental wetting - amount of water added, timed readings for vertical deflection, horizontal strain (when using the 'strain unit'), or pressure ('Ring/membrane unit'), and any excess water (sometimes necessary towards the end of the wetting stage);
- d) For each stage of further loading - as for the stage of initial loading (refer to a) above);
- e) For each stage of unloading - as for the loading stages (refer to a) and d) above);
- f) The moisture content of the soil sample at the start, and end; as well as after each step of water increment,

$$\begin{aligned} & (\text{Mass of moist soil} + \text{water added}) - \text{Mass of oven-dry soil} \\ = & \frac{\text{Mass of oven-dry soil sample}}{\text{Mass of oven-dry soil sample}} \end{aligned}$$

- g) The diameter, height and mass of the soil sample were obtained in steps B to J above;

2) To determine the void ratio at the initial, final and intermediate stages - refer to Section G.2.1 "The one-dimensional consolidation test", part 2 of Calculations and report.

3) The readings of horizontal strain (after being correlated to values of horizontal pressure), and the readings for horizontal pressure, are used to calculate the values of average pressure, or stress - refer to section G.2.1, part 3 of calculations and report.

4) The information obtained for each test will enable the following relationships to be plotted;

- a) Vertical deformation and time for each applied pressure increase or decrease - refer to section G.2.1, part 4 a) of calculations and report;
- b) Void ratio 'e' versus water ratio 'wr';
- c) Void ratio 'e' vs effective vertical pressure 'peV';
- d) Void ratio 'e' vs effective horizontal pressure 'peH'.

Note: All the preliminary test procedures and definitions are included in Appendix A.

Calibration test:-

3) The bedding-in that takes place in the Consolidometer with the 'Ring/membrane unit', as the result of the equipment adjusting itself to the load sequence used.

Table G.03: Consolidometer tests with horizontal pressure measurements - Calibration of equipment.

Load (Kg/cm ²)	Pressure Kpa	Correction to be applied mm
	1	0
0.5	49.0	-0.0838
1.0	98.1	-0.1359
1.25	122.6	(-0.1475)
1.5	147.1	-0.1588
2.0	196.1	-0.1808
2.5	245.2	-0.2037
3.0	294.2	-0.2273
3.5	343.2	(-0.2500)
2.5	245.2	(-0.2050)
1.5	147.1	(-0.1610)
1.0	98.1	(-0.1400)
0.5	49.0	-0.1181
	1	-0.0419

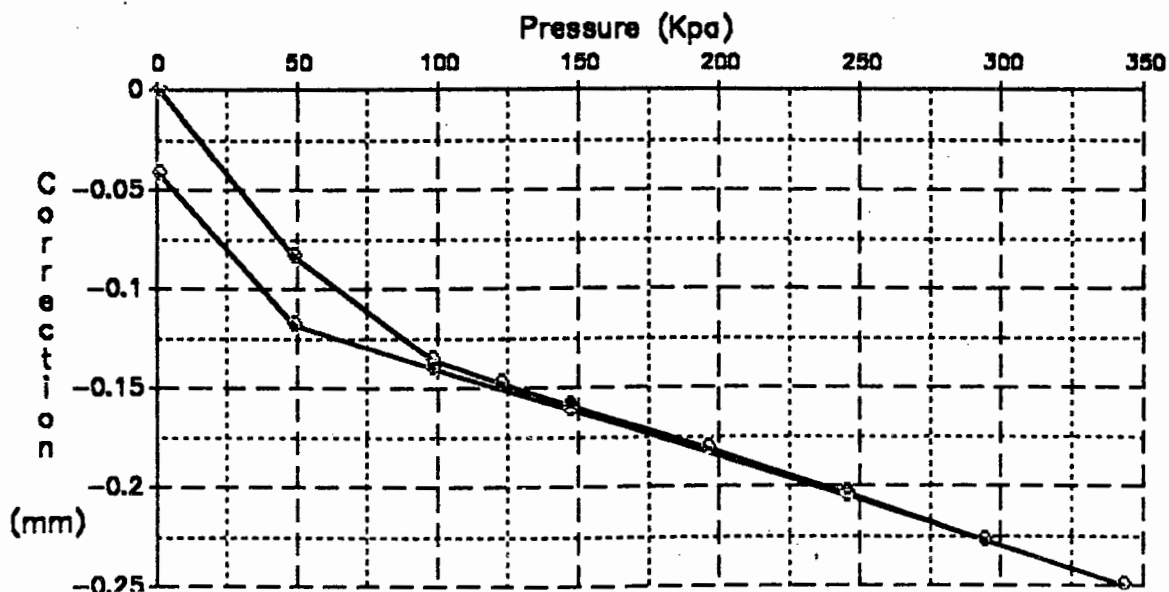


Figure G.03: Consolidometer tests with horizontal pressure measurements - Calibration of equipment.

G.2.3 The Swell Pressure Test for Expansive Soils

Procedure:-

A) Calibration of equipment:

- (i) [Consolidometer with 'strain unit'] Assemble all the consolidometer parts as for an actual test (described in subsequent steps), except that a metal spacer is used in place of the soil sample - refer to test procedure for "Swell pressure tests for expansive soils", Appendix F, step A of the procedure. It should be noted that Table G.01 and Figure G.01 (refer to the end of test procedure for "Consolidometer: One-dimensional consolidation test procedure")¹ provide the corrections to be applied.
- (ii) Refer to test procedure in Section G.2.1 part A, (ii).

B) and C) Refer to section G.2.1 parts B and C.

D) Refer to test procedure in section G.2.1., part D, and include the following addition to the adjustments: Proving ring for swell pressure measurements to touch the seating on the top of the lever arm with a slight pressure, and its dial gauge to be set to the zero reading. Record the initial readings on the micrometer dial gauge (vertical deflection), strain gauge measuring device (horizontal strain), and proving ring dial gauge (swell pressure). Note: The lever arm ratio, for the swell pressure measurement test, is 8.5 to 1.

E) By means of an hyperdermic syringe add a known amount of water to the sample through the bottom filter paper. Allow the sample to expand, or settle (can happen during the initial water increments) and record the readings of vertical movement, horizontal strain and swell pressure with time. As the soil expands apply vertical pressure to the sample, by tightening the proving ring against the consolidometer's arm, until the sample is back to its original height. Use the dial gauge at the front of the consolidometer to monitor the vertical movement. Record the reading of swell pressure, for no change in height of the sample, as well as the reading of horizontal strain. Note: The readings obtained, from the proving ring gauge, are converted to applied load using the calibration factor for the proving ring used, as follows:

Ring no. 6711, Load in KN = divisions of dial gauge x 1/158.

F) Repeat step E) until no further noticeable vertical movement occurs.

Notes: Any excess water left on the bottom filter paper should be removed, and the amount recorded; The strain gauge unit should be switched off between readings.

¹ - section G.2.1 of this Appendix.

G) The unloading, or recovery characteristics, of the soil are measured next. This is carried out as follows: The lever arm of the consolidometer is supported, and weights are placed on its loading platform to provide about 1/3 to 1/4 of the swell pressure previously obtained; The proving ring is released and readings of vertical deflection and horizontal strain are recorded before each pressure release and at $\frac{1}{4}$, $\frac{1}{2}$, 1, 2, 25 minutes, etc¹, from time of releasing the proving ring - the readings should continue until no more expansion is observed; The sequence of unloading should be to 50 Kpa, 10 Kpa, and zero - repeat the above sequence of time readings for each pressure decrease.

H) and I) Refer to test procedure for "The one-dimensional consolidation test", Section G.2.1, parts G) and H).

Calculations and report:-

1) Information to be recorded for each test:

a) Before adding the first amount of water to the sample - the initial reading of vertical deflection and horizontal strain for zero swell pressure (refer to Step D above);

b) Each amount of water increment added to bottom of sample;

c) Readings of vertical deflection, horizontal strain, and swell pressure with time, as well as the reading of swell pressure for no change in height of sample (steps E and F);
Note: After converting the proving ring reading to load (refer to step E), calculate swell pressure, as follows:

$$\text{Pressure applied} = \frac{\text{Calculated load} \times 8.5 \text{ (lever arm)}}{\text{Area of top plate applying pressure}}$$

d) For each unloading stage - total load placed on the loading platform, time, vertical deflection and horizontal strain readings (step G);

e) and f) Refer to test procedure for "The one-dimensional consolidation test for expansive and collapsing soils", Section G.2.2, part 1, f) and g).

2) To determine the void ratio at the initial, final and intermediate stages - refer to section G.2.1 "The one-dimensional consolidation test"².

3) Refer to Section G.2.1, part 3 - calculations and report.

4) Refer to Section G.2.2, part 4 - calculations and report.

Note: Appendix A includes all preliminary test procedures.

¹ - refer to section G.2.1.

² - see part 2 of calculations and report.

G.3 MEASUREMENT OF HORIZONTAL STRAINS, OR PRESSURES.

The stainless steel 'Strain unit':-

The measurement of horizontal strain was obtained by means of strain gauges as part of a custom made 'strain unit'. Chapter Eight includes photographic plates illustrating the following: (A) The making of the Strain Unit; (B) Calibration of the Strain Unit; (C) Equipment used in the consolidometer test.

The 'Strain Unit' basically consists of a stainless steel ring (dimensions: internal diameter = 70.0 mm; height = 19.0 mm; and thickness - 1.0 mm) with strain gauges on its outer side. This 'Strain unit' is connected to a strain gauge measuring device by means of electrical wires. A specially made container is used to facilitate the controlled increments of water.

The equipment used for the calibration¹ of the 'Strain unit' consists of the following parts: 'Dead weight tester' - provides an accurate means of calibrating equipment which requires a known applied pressure; Rubber hose unit - connected with pressure tubing to the dead weight tester. The rubber hose unit consisted of the following components: Bottom plate - includes grooved ends (to provide a water-tight fit) and radial holes for the holding down bolts; Rubber hose - minimum of 250 mm length, in order to avoid 'end restrain' effects; Top plate - includes a pressure inlet; Clamps used to tighten the hose pipe against the grooved ends of the top and bottom plates; Threaded bars with nuts were used for holding down the end plates and prevent pressure built up pushing them outwards.

The procedure for calibration of the ring with strain gauges consisted of two stages:

- 1 - To read and record the reading on the strain gauge bridge for zero pressure;
- 2 - To gradually increase the pressure by placing weights on the loading plate of the dead weight tester and, for each pressure increment, to read the strain gauge measuring device.

Note: Water, instead of oil, should be used for calibrating the strain unit, to avoid damaging the expansion joint². Section G.2.1 "The one-dimensional consolidation test" part 2 of calibration tests, shows the correlation between the observed horizontal strain readings and the corresponding applied pressures - refer to Table G.02 and Figure G.02.

¹ - refer to section 8.8 of Chapter Eight.

² - consisting of cast-in rubber.

The equipment used in the consolidometer test consisted of the following parts, and includes their particular features/uses: Base plate - slots for rubber 'O' ring and electric wire, threaded pieces for wing nuts and centering bolts (spring loaded for holding the 'strain unit' in position); Filter papers - bottom (facilitates water feed into the sample) and top; The 'Strain unit' - includes stainless steel ring, electrical strain gauges, expansion joint, and outer ring; Top loading plate - made of steel or perspex; Top cover (provides guide for loading sample) - includes access holes for water feeding, and wing nuts for holding down the top cover; Plastic cover with windows for water feed; Rubber 'O' Rings for plastic cover. The previously assembled container¹, is positioned on the consolidometer's loading device and the electrical wires are connected to the strain gauge measuring device placed next to the consolidometer machine.

The Ring/Membrane Unit:-

The measurement of stresses was obtained by using a piston pump to provide the required pressure, or stress, to overcome the horizontal stress previously developed within the sample, as the result of either an increase in vertical pressure or water content.

The horizontal pressure, developed in the soil, is measured by pumping known pressure of water, in increments, into the inlet port of a custom made consolidometer ring until it just starts to dribble out at the outlet points.

The equipment used to measure the horizontal stresses in the soil consists of the following parts: Consolidometer ring lined with a rubber membrane and connected to a piston pump by means of high pressure tubing - which to control/measure the water pressure it also includes a pressure gauge and a stop cock valve; A water reservoir to provide water to the piston pump by means of a hose (includes a stop cock to enable this section to be isolated during the pressure increase stage); A custom made container - its bottom is grooved and the consolidometer ring fits in the centre; Filter papers - top and bottom of same size, to fit the Consolidometer ring; The loading plate - provides initial pressure of 1 Kpa; Porous plate fits into bottom of ring.

¹ - containing the strain unit with the sample.

The final setting up of the equipment for testing is to be done as follows:

- (i) The previously assembled container is positioned on the loading device of the consolidometer, and the flexible high pressure tubing is connected to the inlet of the 'ring/membrane unit';
- (ii) The stop cock on the water reservoir side is opened, and water is allowed into the piston pump cylinder by turning its handle anticlockwise - the stop cock on the pressure gauge and ring side are kept closed;
- (iii) Close the stop cock on the reservoir side and open the other side - turn the handle (of the piston pump) clockwise - water is pushed through the tubing into the gap between the ring and the rubber membrane;
- (iv) At a certain pressure, the water will start going through - the sample is pushed radially inwards by the pressure (just enough to allow through a drop or two of water);
- (v) The pressure at which the water just dribbles out as read on the gauge fitted to the high pressure tubing is recorded as the applied pressure which overcame the horizontal stress which had developed in the soil sample.

G.4 REFERENCES FOR APPENDIX G

16. DE S. VINAGRE, T.J.V. (1976/77): Masters Thesis - Diaries One, Two, Three, Four, Five, and Six.
20. BALLANTINE, P.A. (1978): Consolidometer tests to determine the stress path in a soil subject to vertical load - post B.Sc. thesis tests for Prof. Sparks. Department of Civil Engineering, University of Cape Town.

G.5 TEST RESULTS FOR NATURAL SOIL TYPESG.5.1 Site 11 - Rosebank, Cape

Table G.04: Site 11, Rosebank [Remoulded sample - one-dimensional consolidation] - Consolidometer test with horizontal strain, or stress, measurements.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.11-66/ IV.455	1.0	1.683	0	1.576
	8.3	1.624	0	-
	53.6	1.497	0	-
	107.3	1.361	0	-
	214.6	1.240	75	-
	429.2	1.087	102	-
	858.4	0.977	225	-
	214.6	1.027	57	-
	53.6	1.104	0	-
	8.3	1.168	0	-
	1.0	1.219	0	1.204

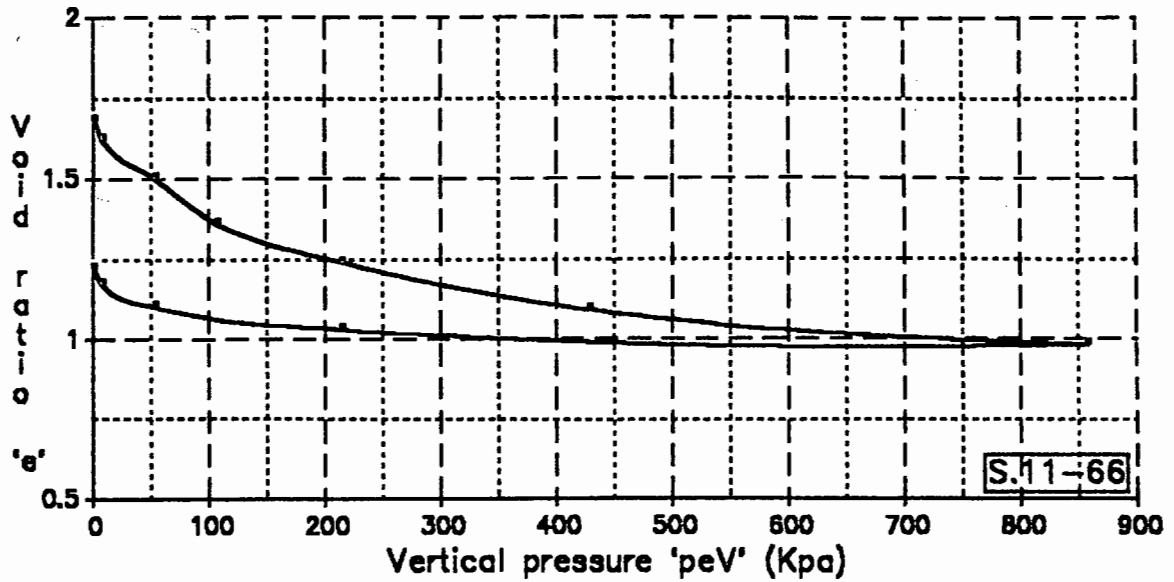


Figure G.04: Site 11, Rosebank [Remoulded sample - one-dimensional consolidation] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

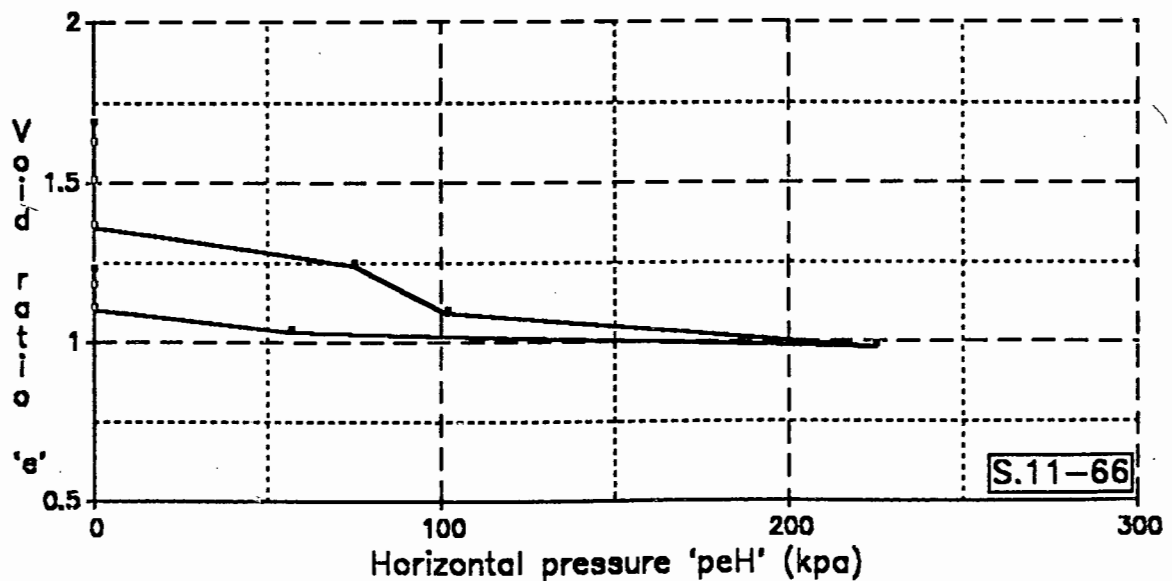


Figure G.05: Site 11, Rosebank [Remoulded sample - one-dimensional consolidation] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.

Table G.05: Site 11, Rosebank [Remoulded sample - vertical pressure of 50 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.11-64/	0	2.17	0	1.962
IV.451&	0	1.36	0	1.237
IV.455	0	0.87	0	0.752
	0	0.79	0	0.623
	0	0.767	0	0.557
	1.0	0.767	0	0.557
	54.6	0.758	90	0.551
	54.6	0.764	232	0.579
	54.6	0.781	338	0.634
	54.6	0.816	342	0.716
	54.6	0.903	268	0.827
	54.6	0.906	289	0.854
	109.3	0.900	295	0.85
	163.9	0.886	312	0.847
	218.6	0.870	337	0.843
	437.2	0.810	430	0.827
	874.4	0.753	560	0.799
	437.2	0.765	470	0.964
	218.6	0.789	380	0.975
	109.3	0.827	330	0.980
	54.6	0.842	307	0.983
	8.4	0.944	250	0.986
	0.8	0.973	223	0.986

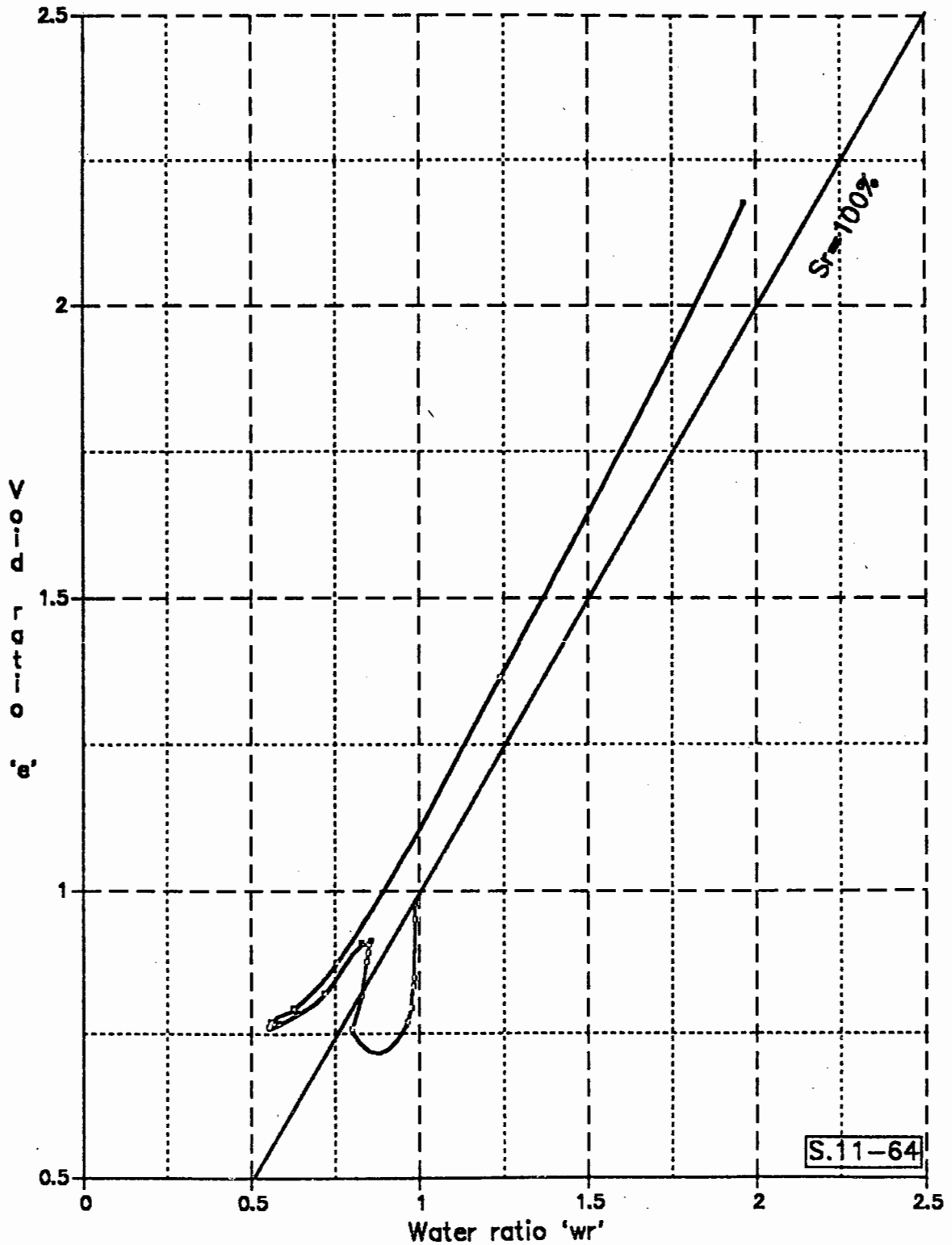


Figure G.06: Site 11, Rosebank [Remoulded sample - overnight vertical pressure of 50 Kpa, then wetted at 50 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

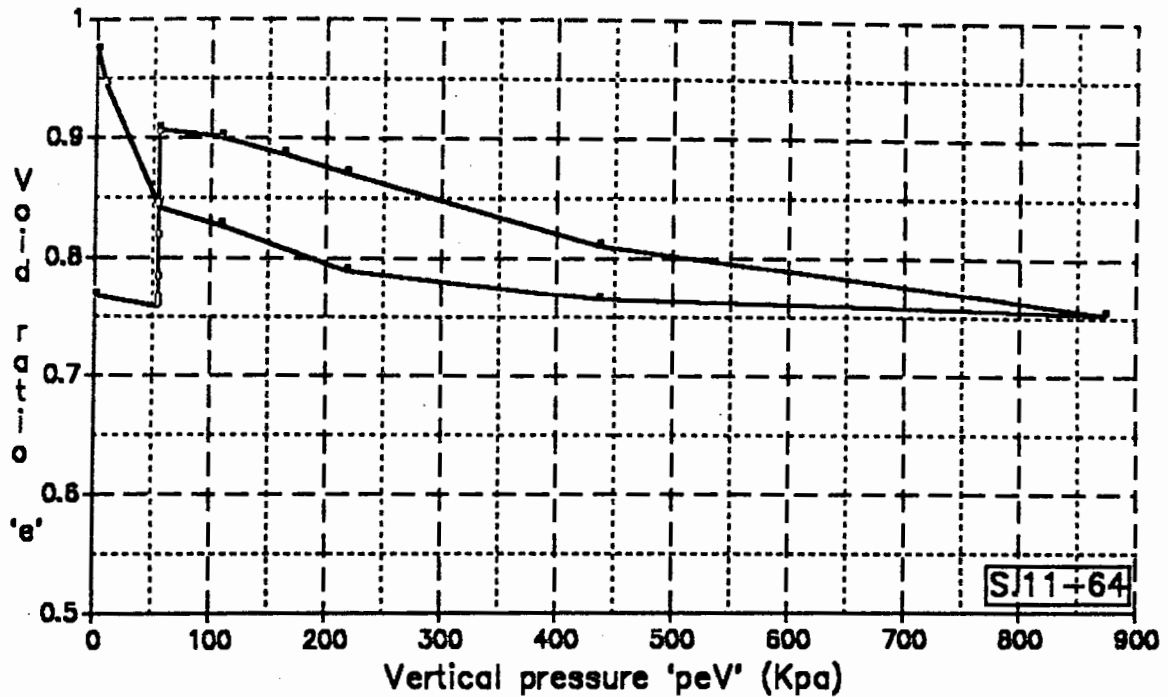


Figure G.07: Site 11, Rosebank [Remoulded sample - overnight vertical pressure of 50 Kpa, then wetted at 50 Kpa] - Void Ratio ' e ' vs Effective Vertical Pressure, or Stress, ' peV '.

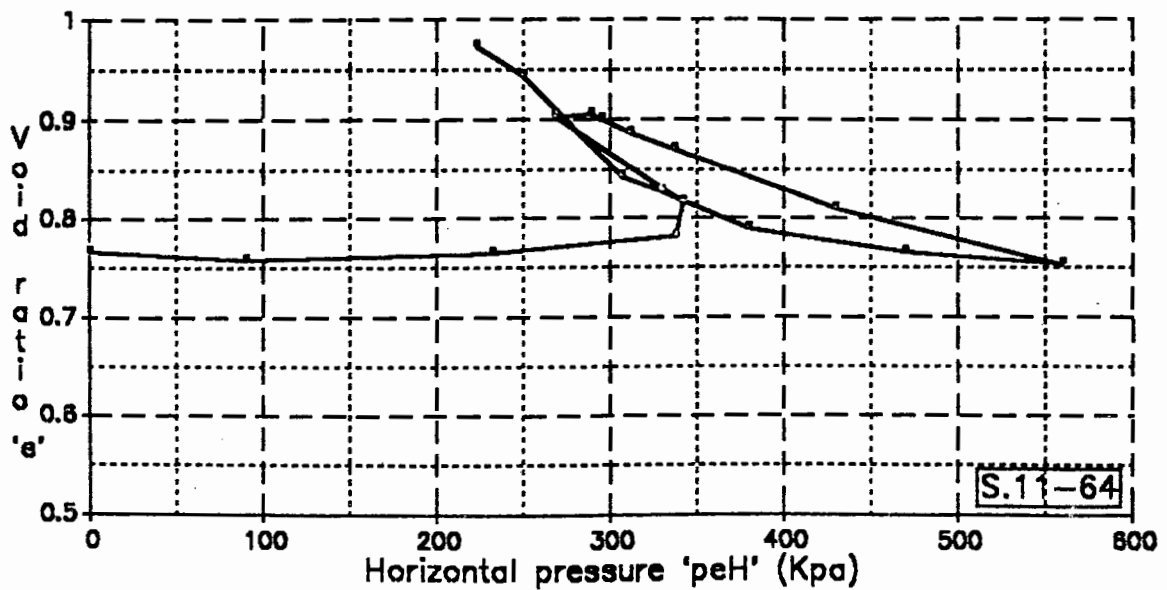


Figure G.08: Site 11, Rosebank [Remoulded sample - overnight vertical pressure of 50 Kpa then wetted at 50 Kpa] - Void Ratio ' e ' vs Effective Horizontal Pressure, or Stress ' peH '.

Table G.06: Site 11, Rosebank [Remoulded samples - vertical pressure of 100 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.11-62/	0	1.462	0	1.248
III.396&	0	1.184	0	1.028
IV.430	0	1.095	0	0.950
	0	0.996	0	0.854
	0	0.783	0	0.612
	0	0.741	0	0.482
	0	0.735	0	0.518
	1.0	0.735	0	0.518
	54.2	0.721	(-7)	0.496
	108.4	0.718	(-7)	0.496
	108.4	0.720	(-55)	0.523
	108.4	0.726	(-120)	0.579
	108.4	0.736	(-105)	0.606
	108.4	0.748	(-77)	0.634
	108.4	0.763	32	0.661
	108.4	0.803	112	0.744
	108.4	0.819	140	0.827
	108.4	0.827	142	0.854
	108.4	0.829	145	0.882
	162.6	0.827	150	0.882
	216.9	0.821	162	0.882
	433.7	0.784	225	0.882
	867.5	0.736	365	0.854
	433.7	0.746	267	0.854
	216.9	0.767	212	0.882
	108.4	0.790	171	0.882
	54.2	0.819	143	0.882
	8.4	0.878	103	0.882
	0.8	0.937	65	0.956

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.11-61/	0	1.380	0	1.190
IV.416&	0	0.996	0	0.873
IV.437	0	1.140	0	1.017
	0	1.319	0	1.287
	1.0	1.319	0	1.287
	54.9	1.153	128	1.267
	109.9	1.090	150	1.240
	109.9	1.088	150	1.267
	109.9	1.087	152	1.212
	164.8	1.051	172	1.196
	219.8	1.012	215	1.181
	439.5	0.915	266	1.118
	879.0	0.816	385	0.992
	439.5	0.829	295	1.033
	219.8	0.856	226	1.054
	109.9	0.883	188	1.064
	54.9	0.913	164	1.069
	8.5	0.976	147	1.073
	0.8	1.008	130	1.074
S.11-60/	0	2.016	0	1.865
III.384&	0	1.486	0	1.375
IV.420	0	1.394	0	1.287
	0	1.345	0	1.243
	0	1.271	0	1.165
	0	1.013	0	0.917
	0	0.919	0	0.821
	0	0.835	0	0.730
	1.0	0.835	0	0.730
	54.4	0.819	0	0.723
	108.7	0.812	10	0.716
	108.7	0.820	65	0.744
	108.7	0.833	85	0.771
	108.7	0.819	94	0.799
	108.7	0.899	184	0.882
	108.7	0.908	202	0.964
	108.7	0.909	199	0.964
	163.1	0.906	205	0.960
	217.4	0.900	213	0.956
	434.9	0.863	275	0.940
	869.8	0.814	440	0.909
	434.9	0.825	337	0.993
	108.7	0.881	206	1.055
	54.4	0.918	170	1.066
	8.4	1.014	77	1.074
	0.8	1.118	0	1.165

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.11-59/	0	2.07	0	1.898
III.394&	0	1.60	0	1.471
IV.442	0	1.46	0	1.342
	0	1.28	0	1.168
	0	1.12	0	1.006
	0	0.93	0	0.815
	0	0.82	0	0.689
	0	0.79	0	0.656
	0	0.738	0	0.501
	1.0	0.738	0	0.501
	54.2	0.737	10	0.498
	108.4	0.735	12	0.496
	108.4	0.738	96	0.523
	108.4	0.755	223	0.579
	108.4	0.785	236	0.661
	108.4	0.829	143	0.744
	108.4	0.859	143	0.827
	108.4	0.865	138	0.854
	162.6	0.863	147	0.850
	216.9	0.857	156	0.846
	433.7	0.817	210	0.830
	867.5	0.766	318	0.799
	433.7	0.778	232	0.964
	216.9	0.804	160	0.969
	108.4	0.838	118	0.971
	54.2	0.872	93	0.972
	8.4	0.954	32	0.973
	0.8	0.987	0	0.973

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.11-58/	0	2.76	0	1.554
III.356&	0	1.80	0	1.099
IV.413	0	1.63	0	0.964
	0	1.43	0	0.799
	0	1.29	0	0.667
	0	1.19	0	0.559
	0	1.15	0	0.482
	0	1.135	0	0.444
	1.0	1.135	0	0.444
	54.5	1.135	3	0.442
	109.0	1.129	7	0.441
	109.0	1.130	(-3)	0.468
	109.0	1.131	(-82)	0.496
	109.0	1.134	(-215)	0.523
	109.0	1.140	(-284)	0.579
	109.0	1.152	(-232)	0.634
	109.0	1.163	(-132)	0.716
	109.0	1.140	(-73)	0.771
	109.0	1.106	37	0.827
	109.0	1.055	140	0.882
	109.0	1.050	143	0.937
	163.5	1.006	174	0.928
	218.0	0.971	195	0.919
	436.0	0.863	298	0.882
	872.1	0.765	420	0.854
	436.0	0.778	304	0.937
	218.0	0.806	260	1.002
	109.0	0.842	220	1.034
	54.5	0.875	197	1.050
	8.4	0.977	175	1.065
	0.8	1.047	140	1.066

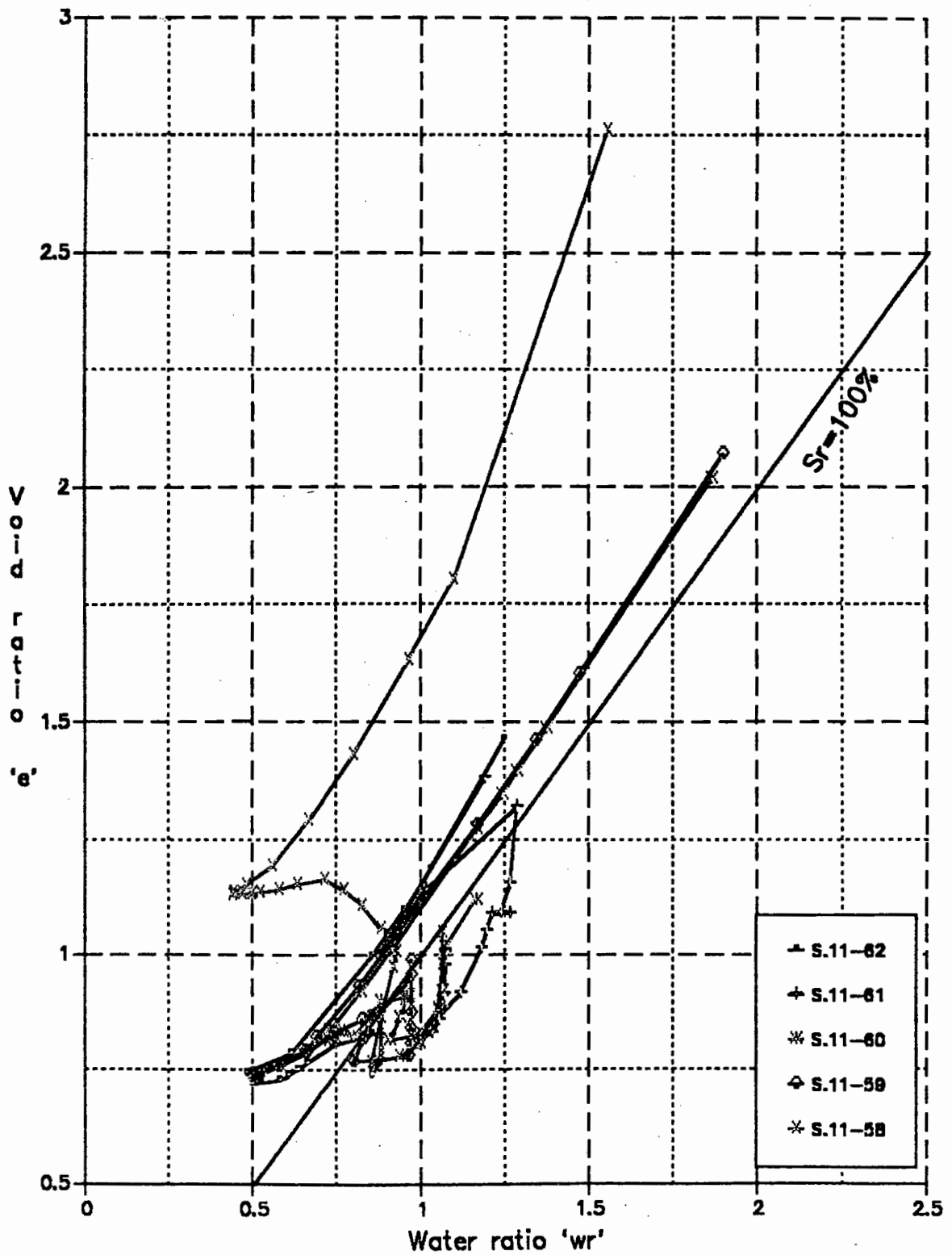


Figure G.09: Site 11, Rosebank [Remoulded samples - overnight vertical pressure of 100 Kpa then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

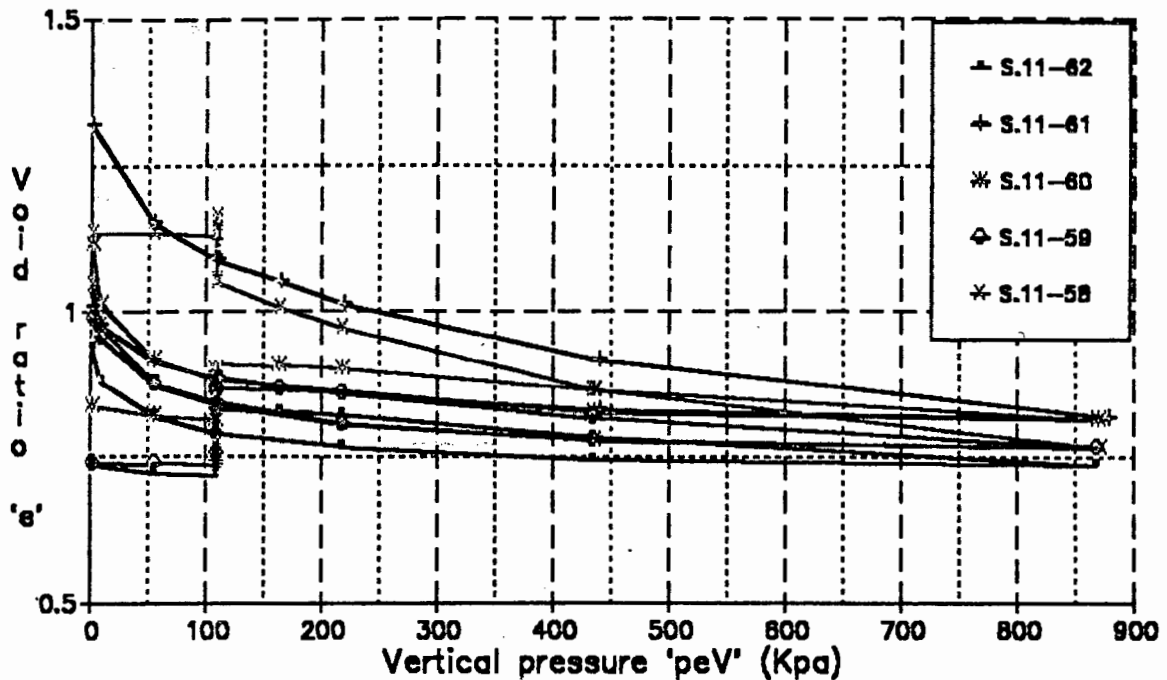


Figure G.10: Site 11, Rosebank [Remoulded samples - overnight vertical pressure of 100 Kpa then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

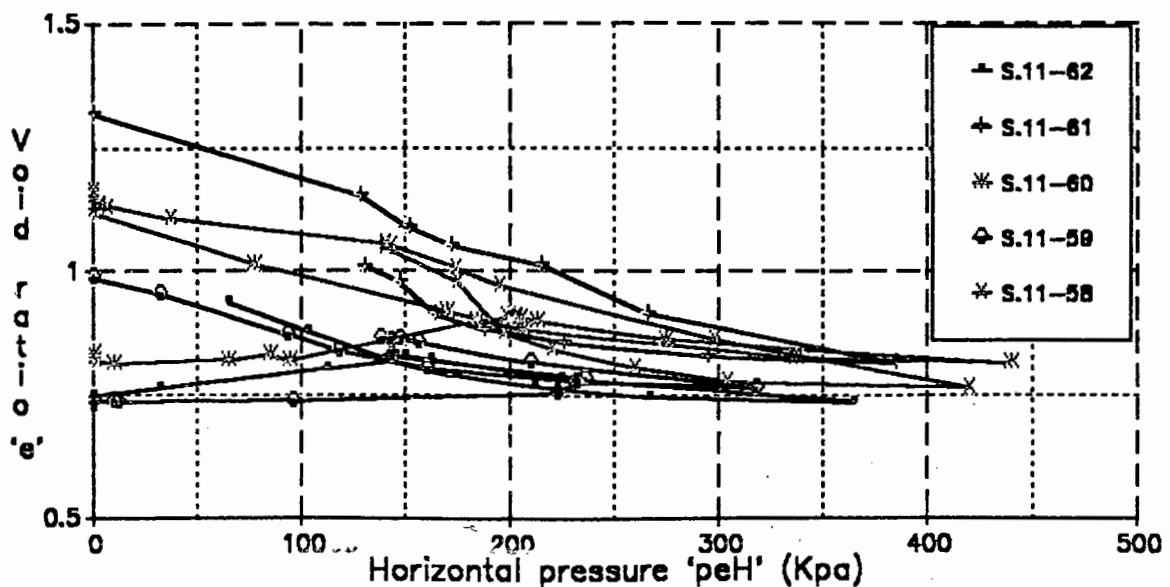


Figure G.11: Site 11, Rosebank [Remoulded samples - overnight vertical pressure of 100 Kpa then wetted at 100 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.

Table G.07: Site 11, Rosebank [Compacted sample - vertical pressure of 100 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.11-70/	1.0	0.863	0	0.634
IV.450&	54.2	0.848	(-26)	0.634
IV.458	108.4	0.840	14	0.630
	108.4	0.844	(-18)	0.661
	108.4	0.857	(-35)	0.716
	108.4	0.861	(-30)	0.771
	108.4	0.862	(-47)	0.799
	162.6	0.850	(-25)	0.797
	216.9	0.832	(-23)	0.795
	433.7	0.776	83	0.787
	867.5	0.718	210	0.771
	433.7	0.726	151	0.799
	216.9	0.749	113	0.821
	108.4	0.764	81	0.832
	54.2	0.779	56	0.838
	8.4	0.806	33	0.843
	0.8	0.830	26	0.843

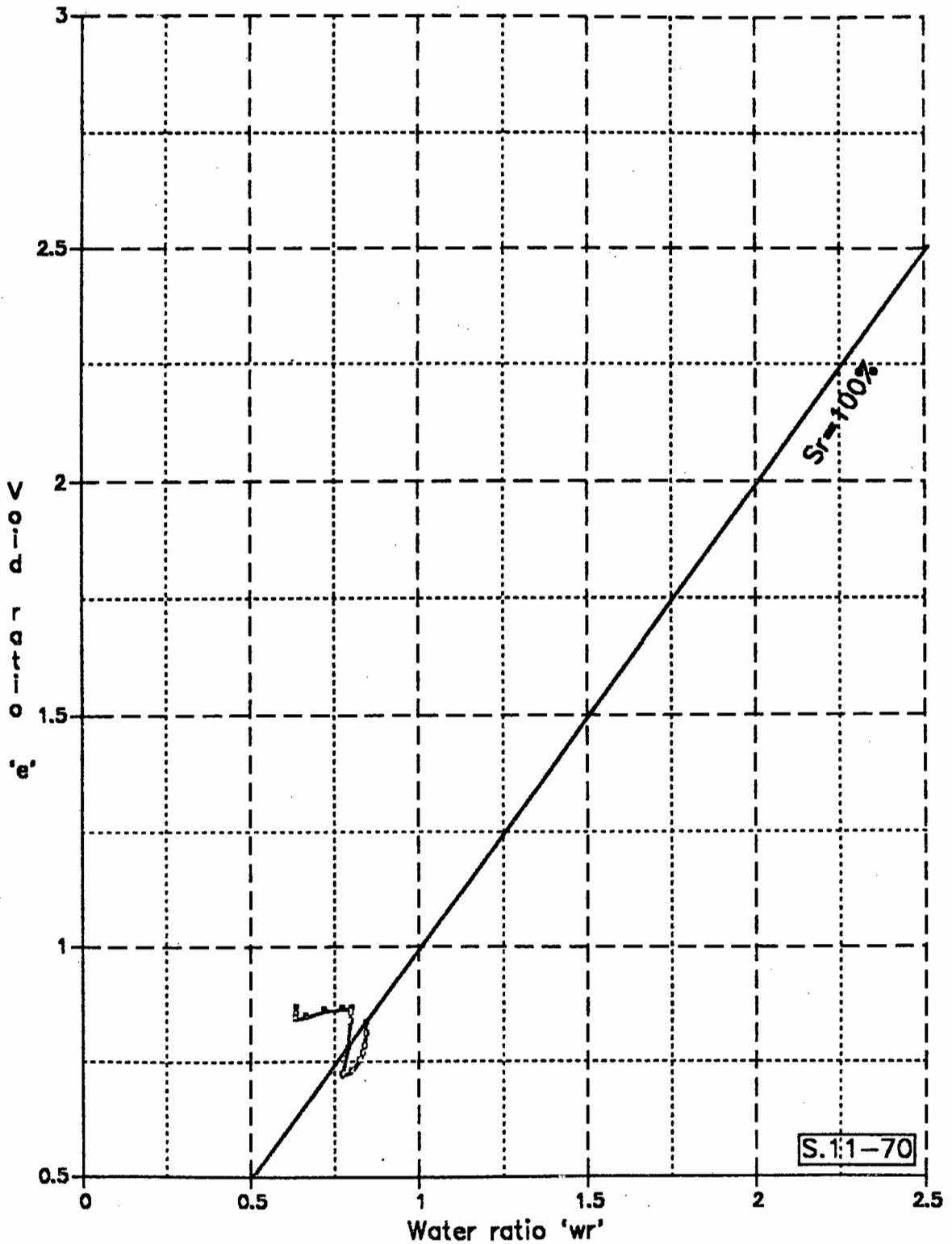


Figure G.12: Site 11, Rosebank [Compacted sample - overnight vertical pressure of 100 Kpa then wetted at 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

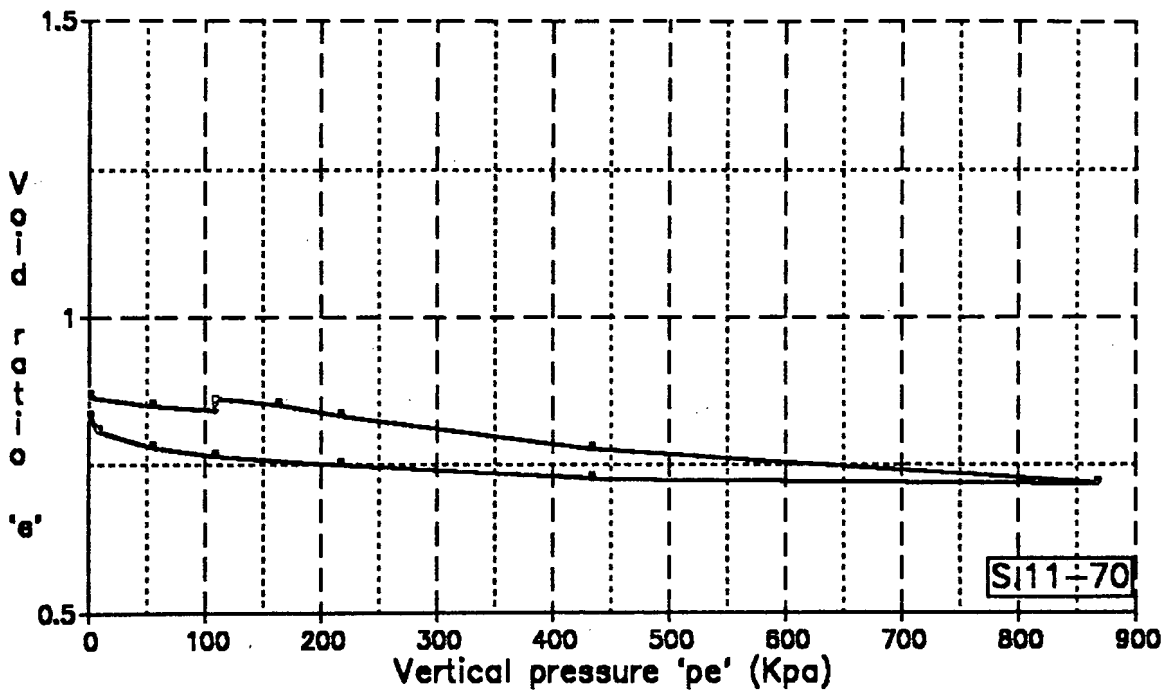


Figure G.13: Site 11, Rosebank [Compacted sample - overnight vertical pressure of 100 Kpa then wetted at 100 Kpa] - Void Ratio ' e ' vs Effective Vertical Pressure, or Stress, ' p_eV '.

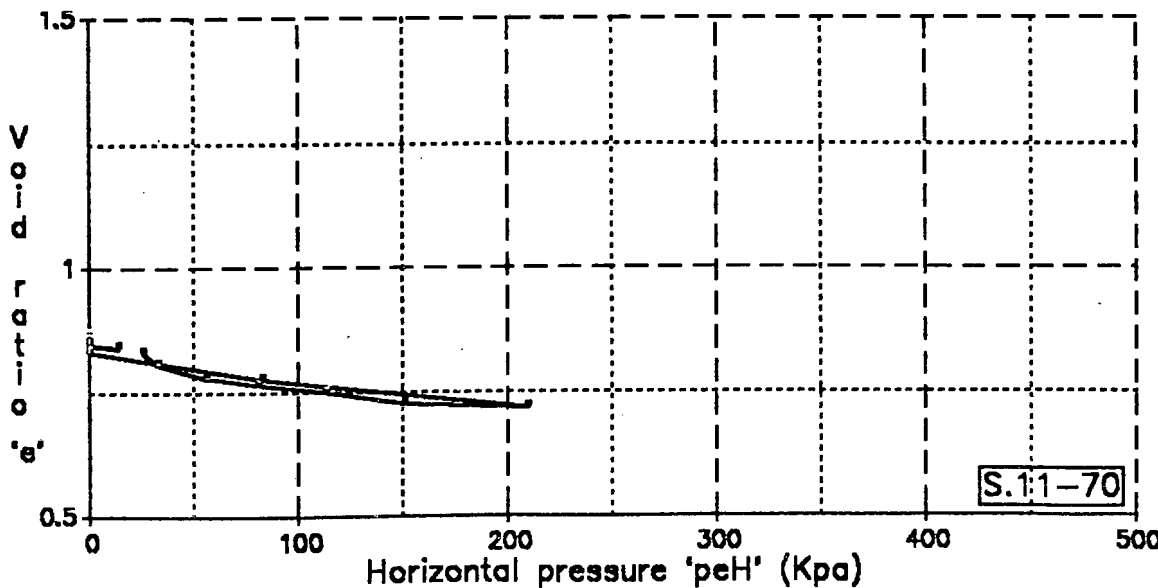


Figure G.14: Site 11, Rosebank [Compacted sample - overnight vertical pressure of 100 Kpa then wetted at 100 Kpa] - Void Ratio ' e ' vs Effective Horizontal Pressure, or Stress ' p_{eH} '.

Table G.08: Site 11, Rosebank [Remoulded sample - vertical pressure of 400 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.11-65/	0	2.133	0	1.915
IV.451&	0	1.320	0	1.171
IV.468	0	1.194	0	1.050
	0	0.958	0	0.821
	0	0.826	0	0.683
	0	0.765	0	0.543
	1.0	0.765	0	0.543
	54.2	0.763	25	0.540
	108.4	0.760	42	0.538
	216.9	0.756	57	0.533
	433.7	0.746	112	0.523
	433.7	0.747	136	0.579
	433.7	0.759	113	0.634
	433.7	0.774	184	0.716
	433.7	0.782	233	0.771
	433.7	0.782	240	0.799
	867.5	0.759	282	0.799
	433.7	0.771	232	0.882
	216.9	0.790	178	0.896
	108.4	0.846	127	0.902
	54.2	0.887	77	0.906
	8.4	0.903	60	0.909
	0.8	0.939	50	0.915

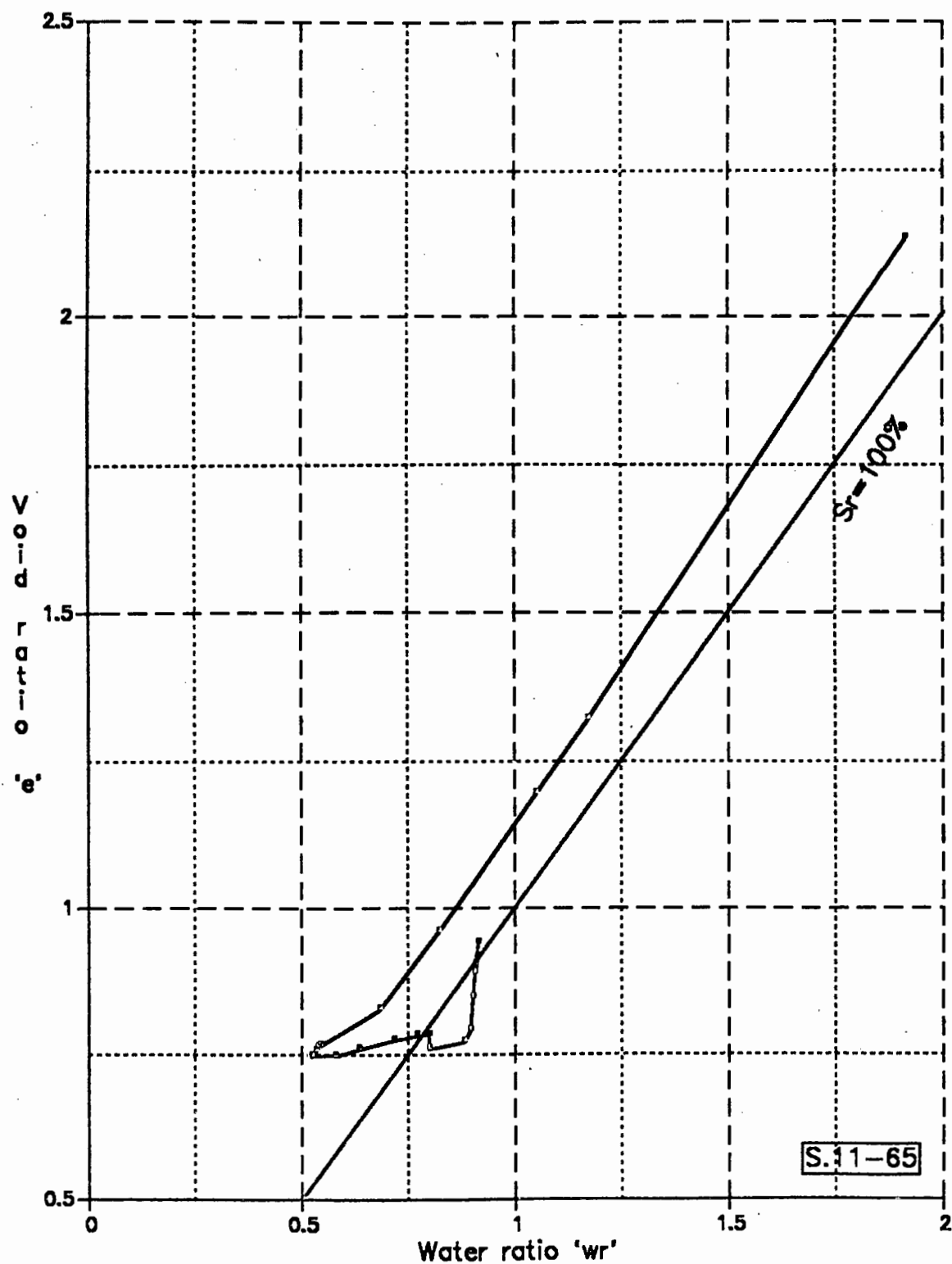


Figure G.15: Site 11, Rosebank [Remoulded sample - wetted at vertical pressure of 400 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

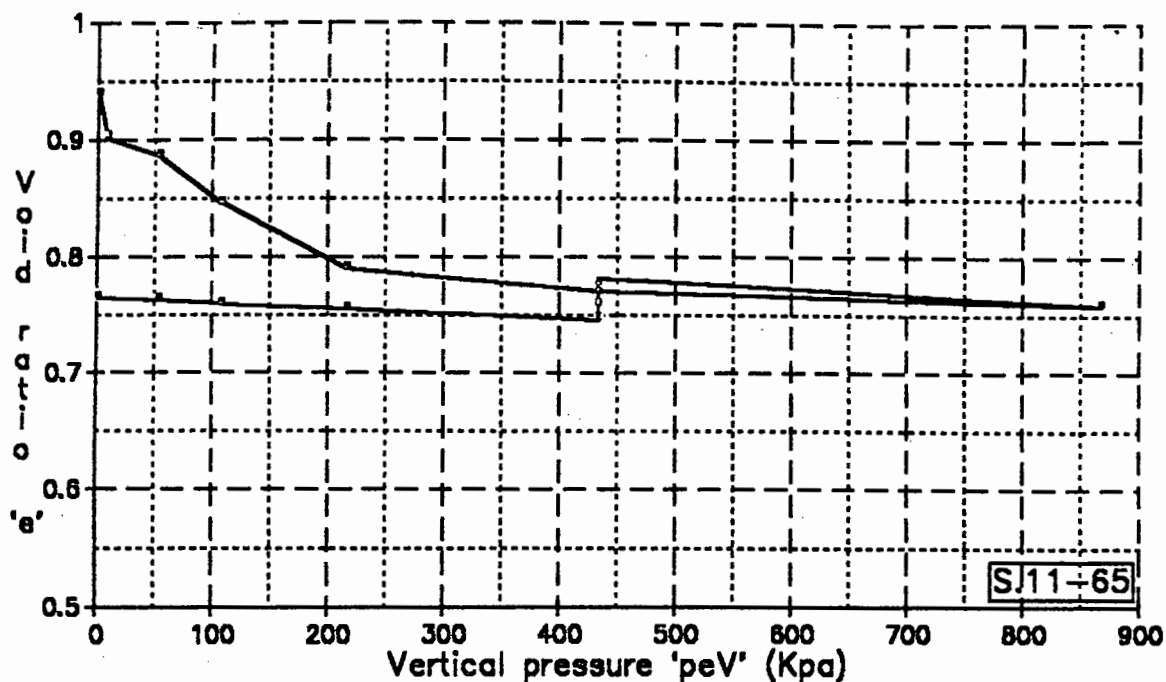


Figure G.16: Site 11, Rosebank [Remoulded sample - wetted at vertical pressure of 400 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

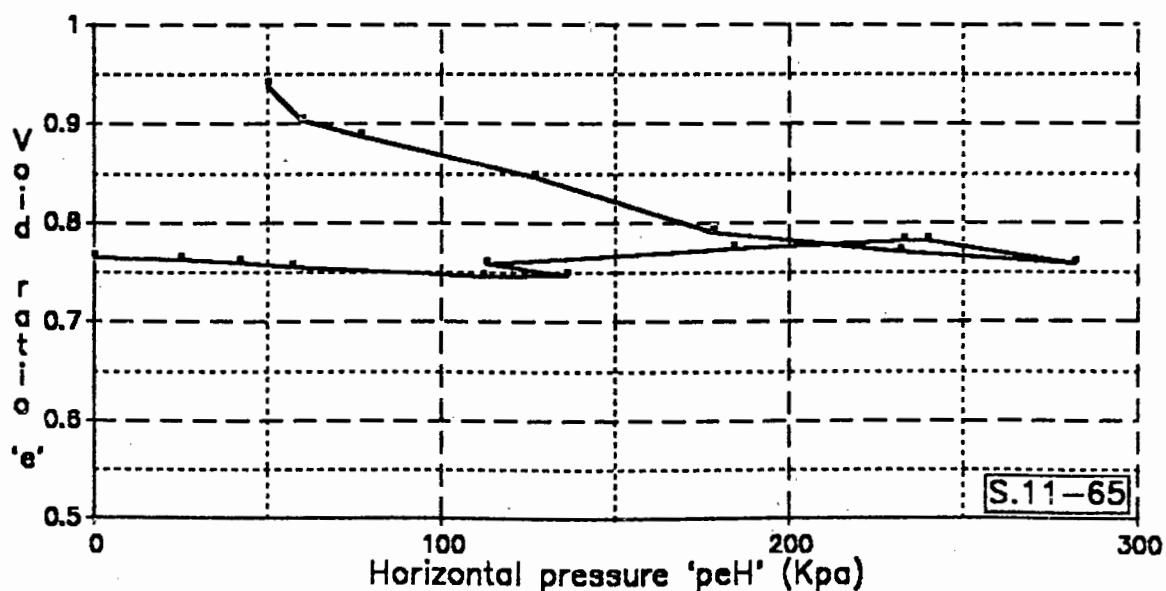


Figure G.17: Site 11, Rosebank [Remoulded sample - wetted at vertical pressure of 400 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.

Table G.09: Site 11, Rosebank [Remoulded sample - swell pressure] - Consolidometer test with horizontal strain, or stress, measurements.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S11-63/	0	2.28	0	2.108
IV.421&	0	1.42	0	1.322
IV.449	0	1.26	0	1.168
	0	1.08	0	0.992
	0	0.86	0	0.758
	0	0.71	0	0.548
	0	0.696	0	0.504
	1.0	0.696	0	0.504
	1.0	0.696	196	0.551
	206.0	0.718	267	0.606
	567.7	0.725	318	0.689
	704.2	0.726	400	0.771
	662.4	0.726	396	0.799
	215.2	0.720	225	0.909
	107.5	0.748	134	0.928
	53.9	0.822	50	0.931
	8.4	0.880	33	0.934
	0.9	0.923	25	0.934

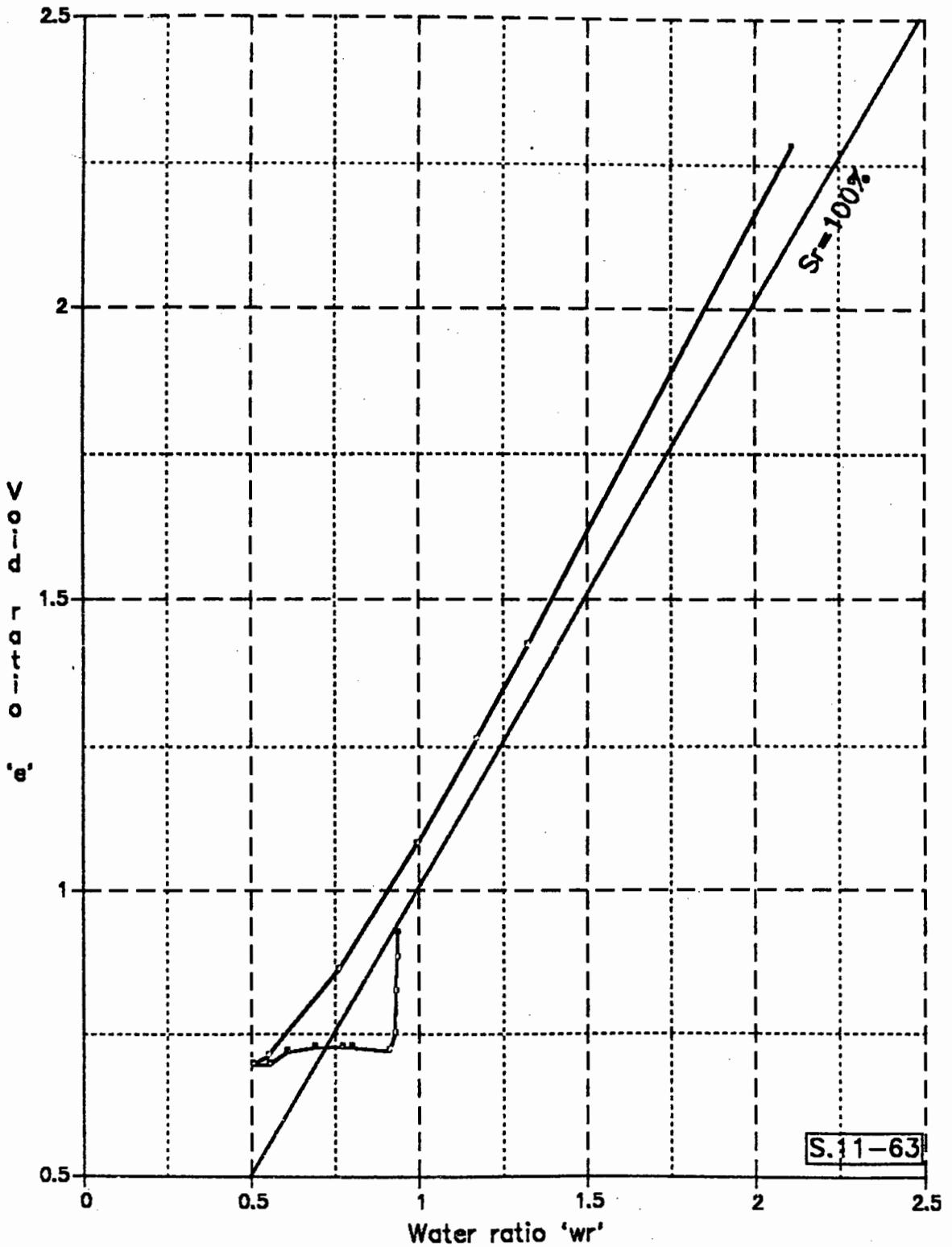


Figure G.18: Site 11, Rosebank [Remoulded sample - swell pressure] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

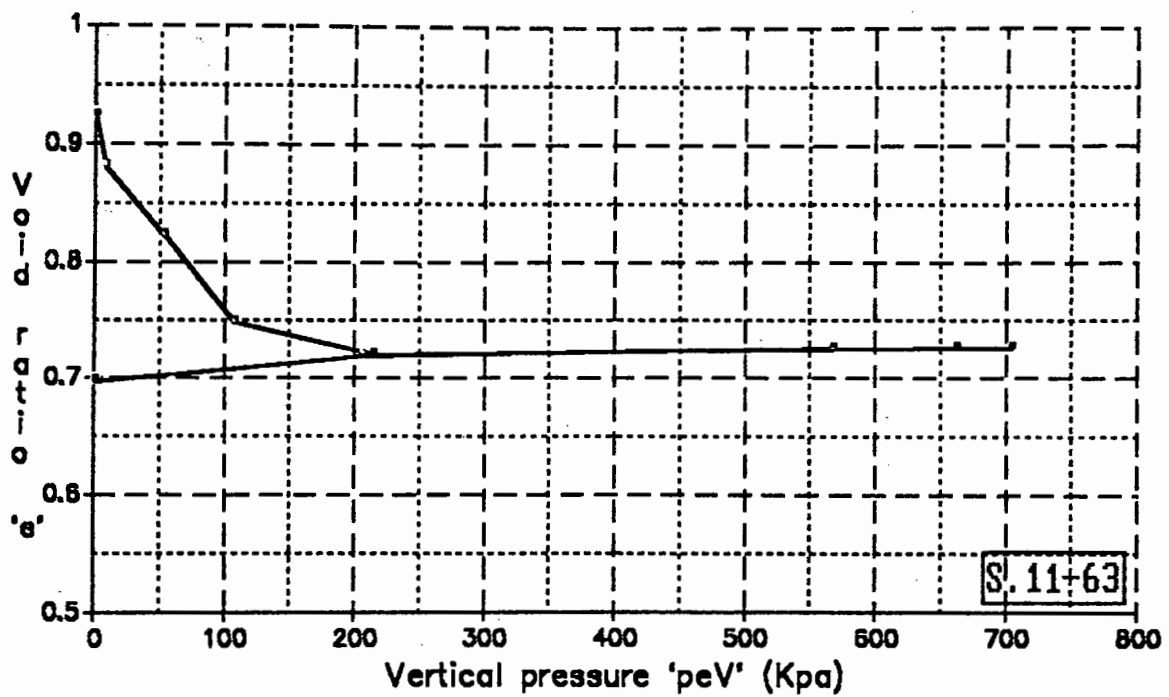


Figure G.19: Site 11, Rosebank [Remoulded sample - swell pressure] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

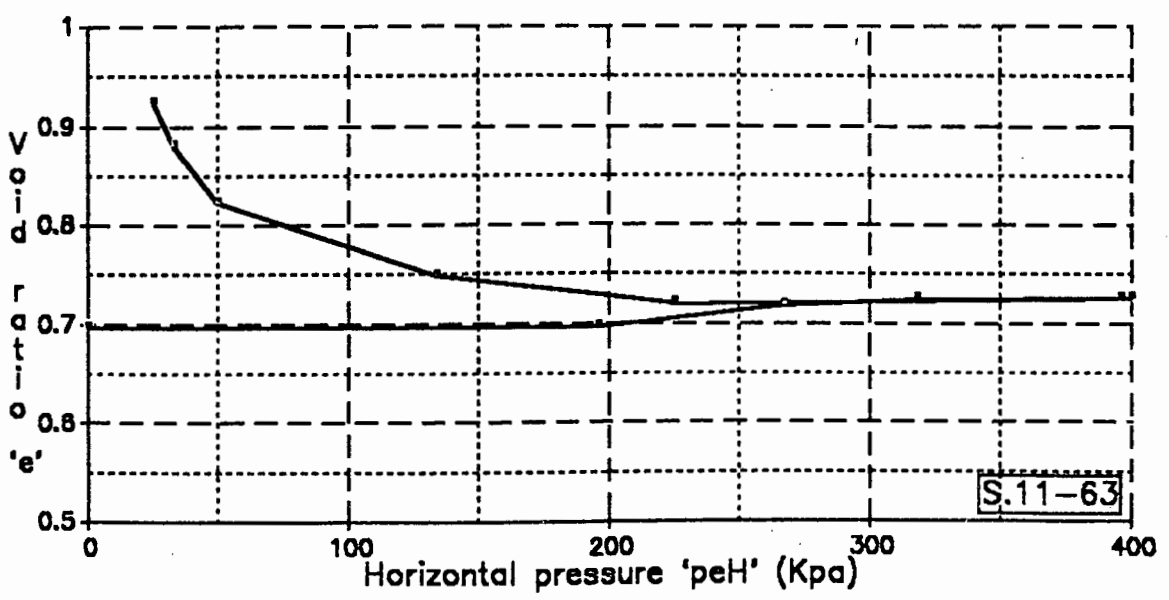


Figure G.20: Site 11, Rosebank [Remoulded sample - swell pressure] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.

Table G.10: Site 11, Rosebank [Compacted sample - swell pressure] - Consolidometer test with horizontal strain, or stress, measurements.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.11-71/	1.0	0.872	0	0.760
IV.450&	1.0	0.872	67	0.771
IV.459	31.2	0.882	68	0.799
	46.6	0.887	136	0.909
	45.0	0.887	140	0.937
	8.7	0.881	134	0.967
	0.9	0.928	128	0.973

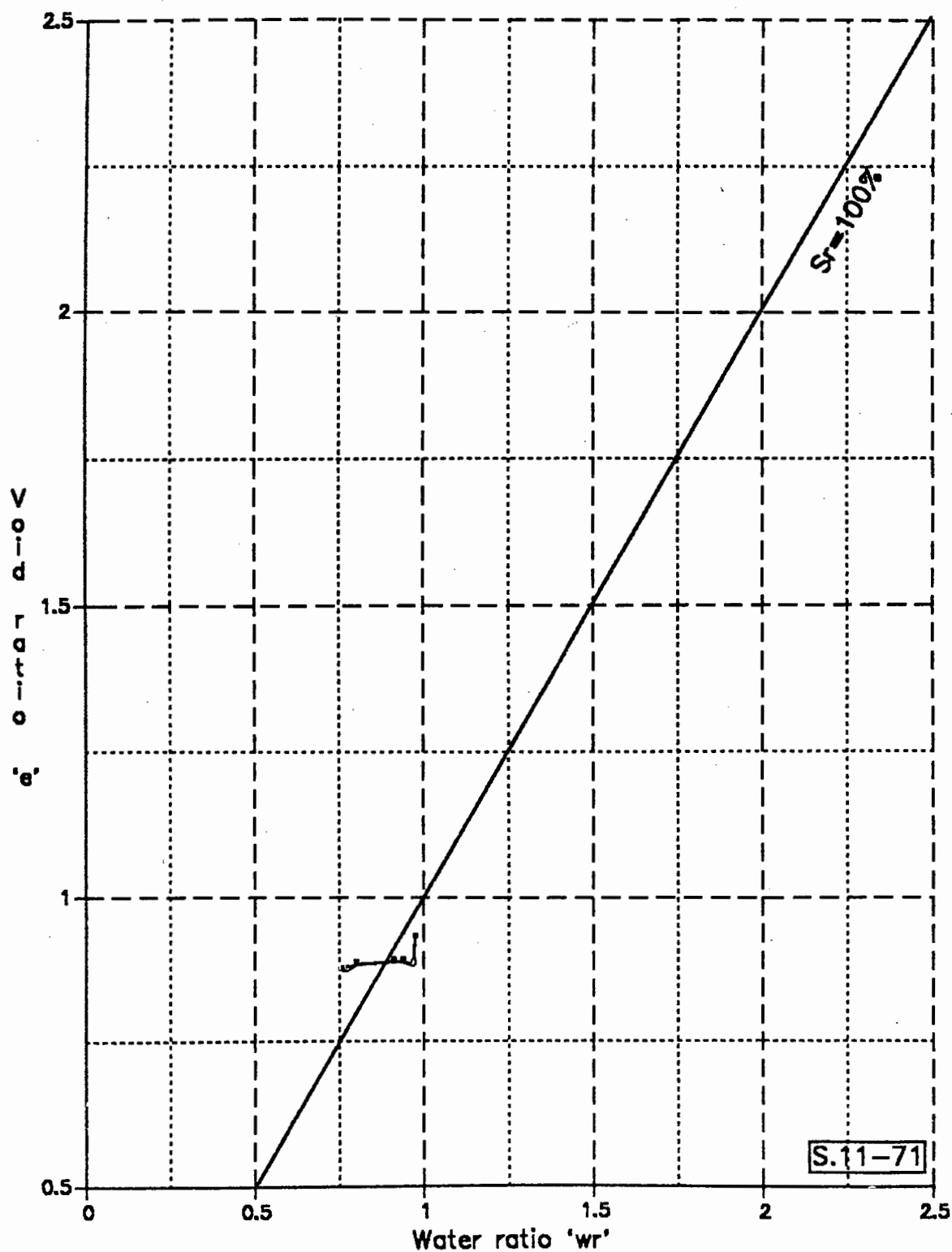


Figure G.21: Site 11, Rosebank [Compacted sample - swell pressure] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

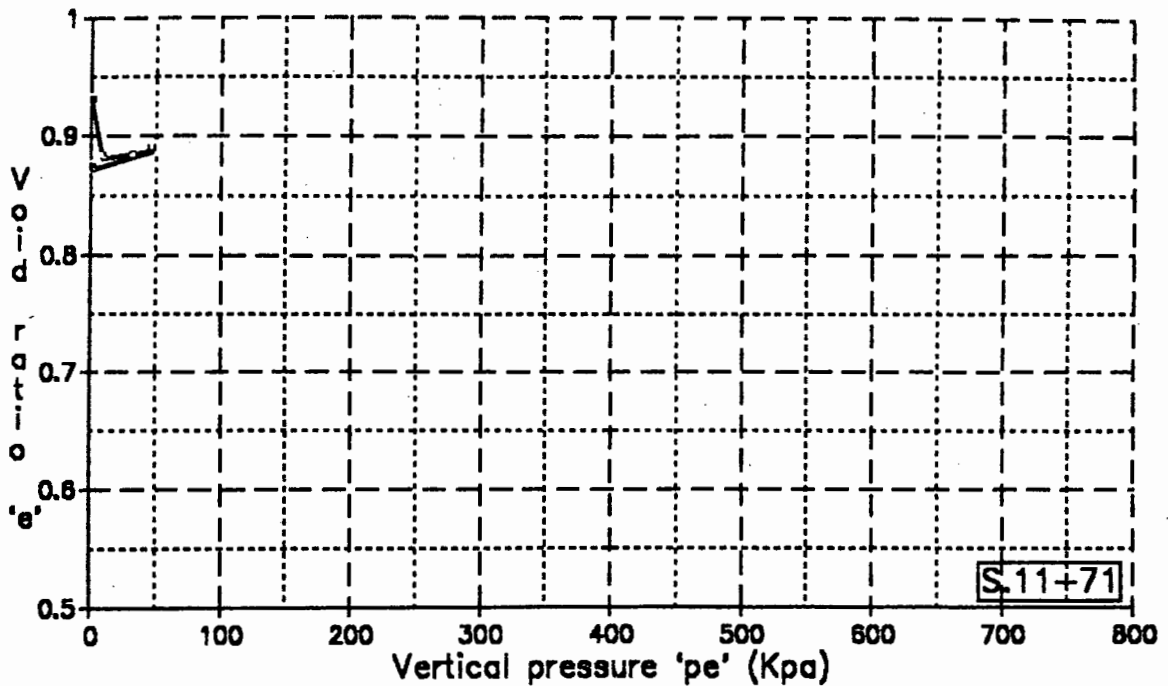


Figure G.22: Site 11, Rosebank [Compacted sample - swell pressure] - Void Ratio ' e ' versus Effective Vertical Pressure, or Stress, ' p_e '.

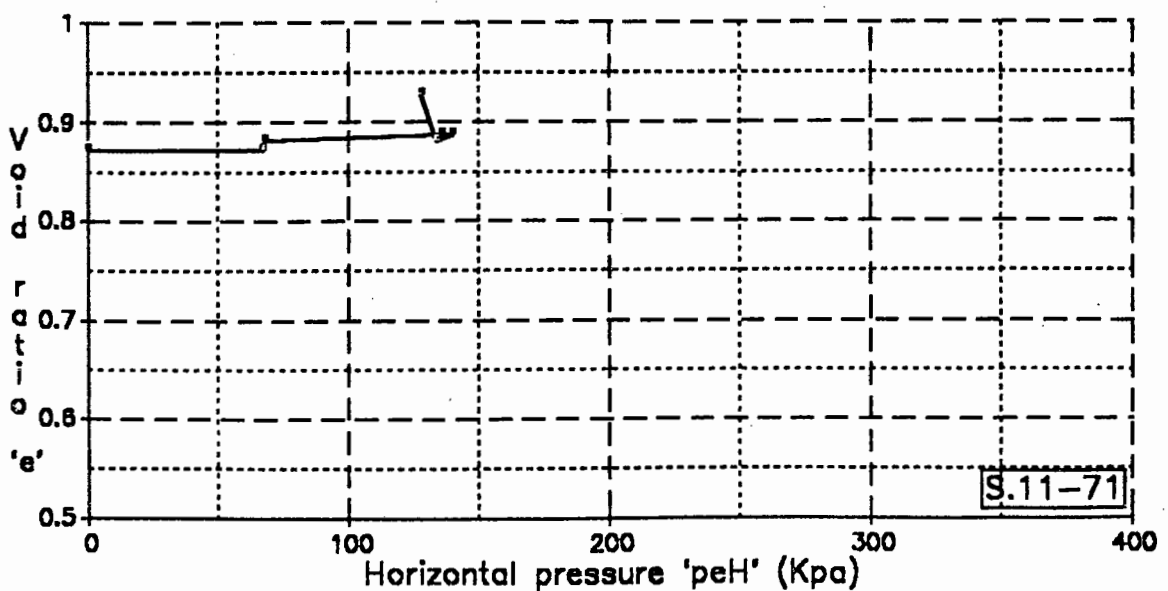


Figure G.23: Site 11, Rosebank [Compacted sample - swell pressure] - Void Ratio ' e ' versus Effective Horizontal Pressure, or Stress, ' p_{eH} '.

G.5.2 Site 36 - Rondebosch, Cape.

Table G.11: Site 36, Rondebosch [Remoulded samples - vertical pressure of 100 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.36-5/ III.348& III.401	0	0.837	0	0.723
	0	0.683	0	0.591
	0	0.656	0	0.564
	0	0.600	0	0.495
	0	0.585	0	0.425
	1.0	0.585	0	0.425
	53.9	0.583	7	0.425
	107.9	0.579	10	0.425
	107.9	0.580	26	0.430
	107.9	0.583	86	0.457
	107.9	0.589	102	0.511
	107.9	0.593	123	0.538
	107.9	0.594	118	0.538
	161.8	0.585	127	0.511
	215.7	0.583	132	0.506
	269.7	0.579	143	0.501
	323.6	0.575	154	0.497
	377.5	0.570	155	0.491
	431.4	0.563	173	0.484
	539.3	0.553	187	0.477
	647.2	0.544	200	0.470
	755.0	0.535	215	0.464
	862.9	0.527	240	0.457
	647.2	0.526	141	0.459
	431.4	0.527	75	0.461
	215.7	0.530	42	0.463
	161.8	0.531	28	0.464
	107.9	0.532	10	0.464
	53.9	0.533	65	0.465
	0.8	0.537	85	0.465

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.36-12/	0	0.908	0	0.739
III.382&	0	0.837	0	0.704
IV.426	0	0.803	0	0.672
	0	0.742	0	0.610
	0	0.672	0	0.532
	0	0.655	0	0.481
	1.0	0.655	0	0.481
	53.9	0.646	0	0.481
	107.9	0.641	3	0.481
	107.9	0.643	122	0.511
	107.9	0.645	175	0.538
	107.9	0.647	174	0.538
	107.9	0.648	193	0.591
	161.8	0.643	204	0.589
	215.7	0.636	220	0.583
	431.4	0.606	275	0.579
	862.9	0.559	400	0.564
	431.4	0.564	312	0.618
	215.7	0.575	246	0.645
	107.9	0.589	207	0.658
	53.9	0.606	187	0.665
	8.3	0.650	155	0.650
	0.8	0.695	121	0.695

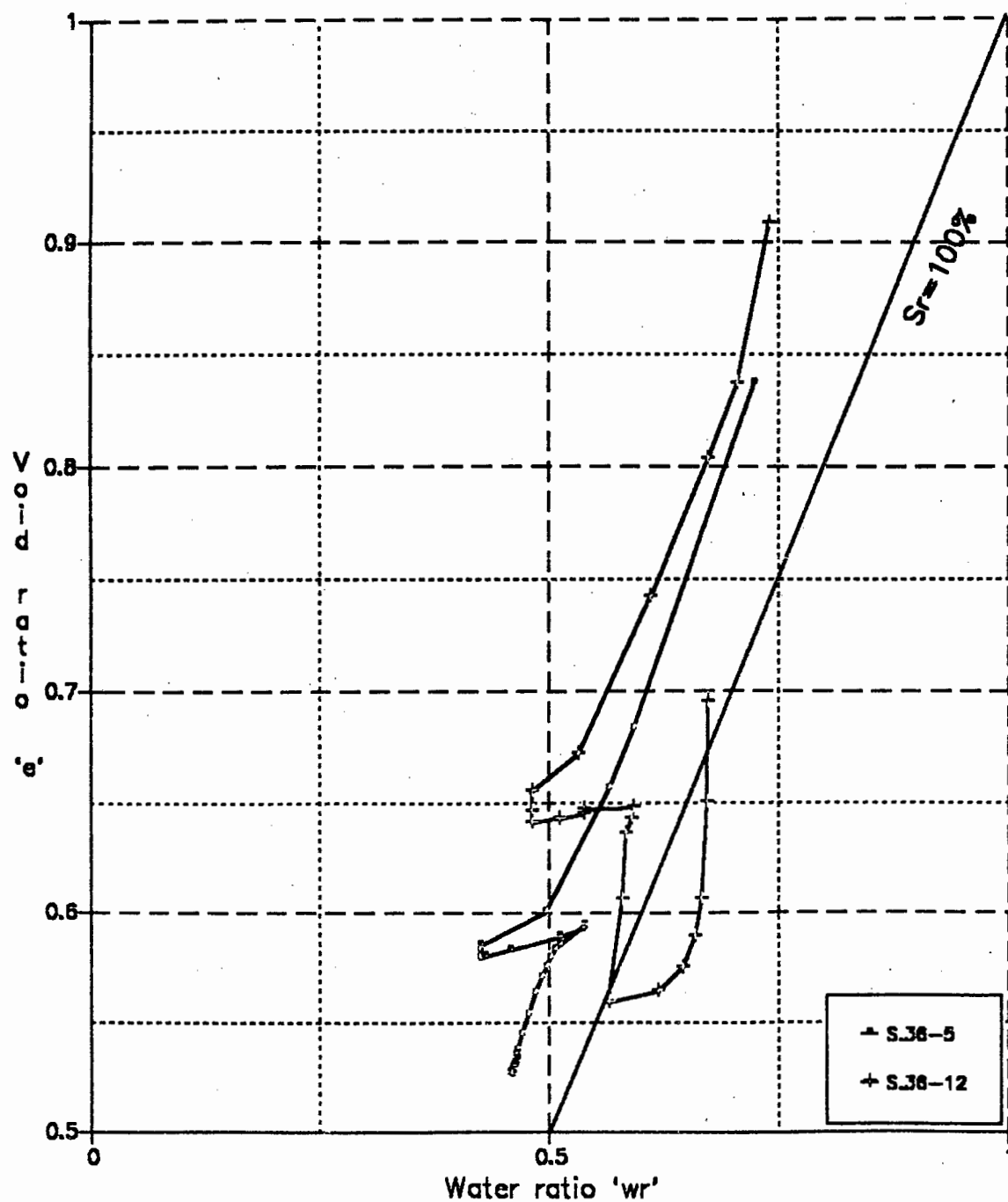


Figure G.24: Site 36, Rondebosch [Remoulded samples - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

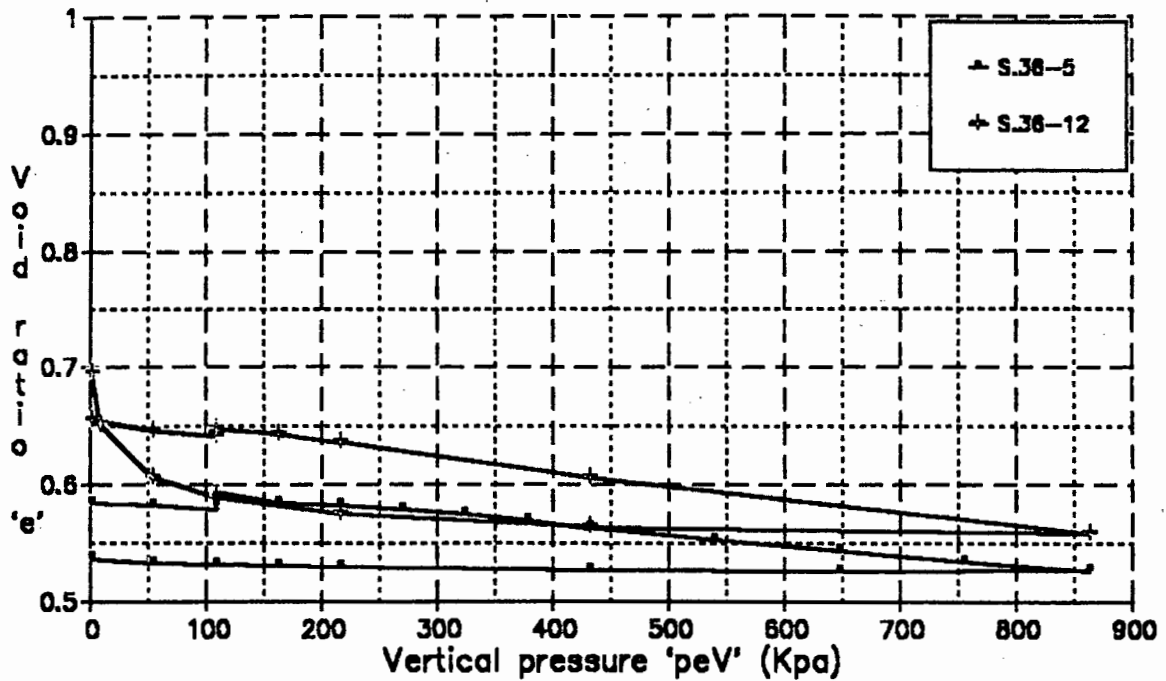


Figure G.25: Site 36, Rondebosch [Remoulded samples - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

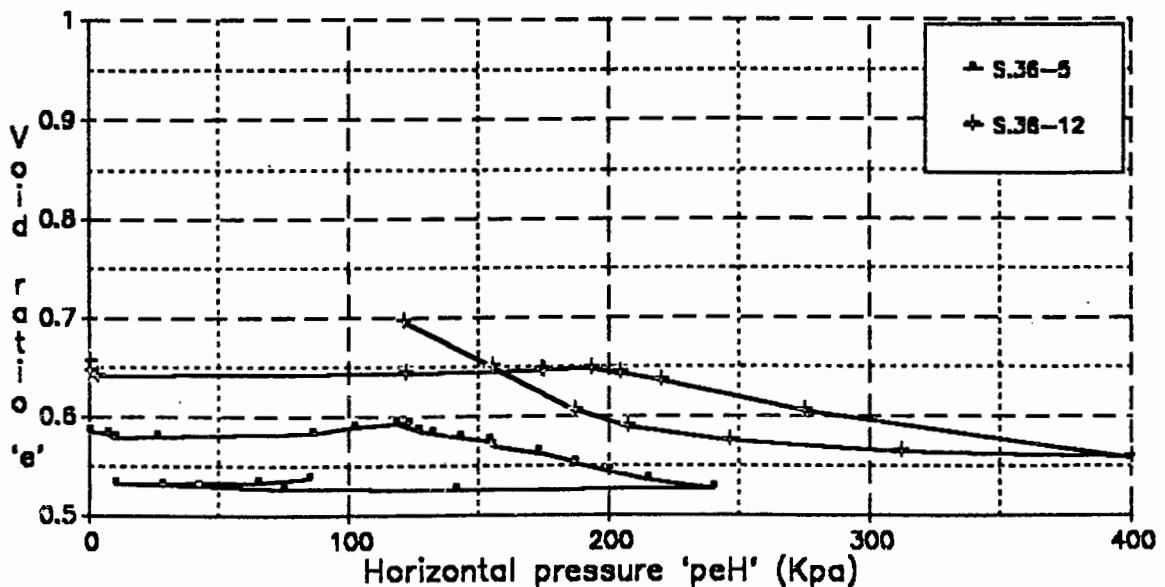


Figure G.26: Site 36, Rondebosch [Remoulded samples - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.

G.5.3 Site A - Berea Road, Durban.

Table G.12: Site A, Berea Road [Undisturbed sample - vertical pressure of 100 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.A-1/ Ba.78	1.0	0.6177	0	0.044
	49.0	0.6088	21.0	0.043
	98.1	0.6061	25.0	0.043
	98.1	0.6009	13.0	0.093
	98.1	0.5817	7.0	0.173
	98.1	0.5813	28.0	0.253
	98.1	0.5777	35.5	0.346
	98.1	0.5777	52.0	0.402
	147.1	0.5774	60.5	0.401
	196.1	0.5669	75.0	0.400
	49.0	0.5682	42.0	0.400
	1.0	0.5767	0	0.401

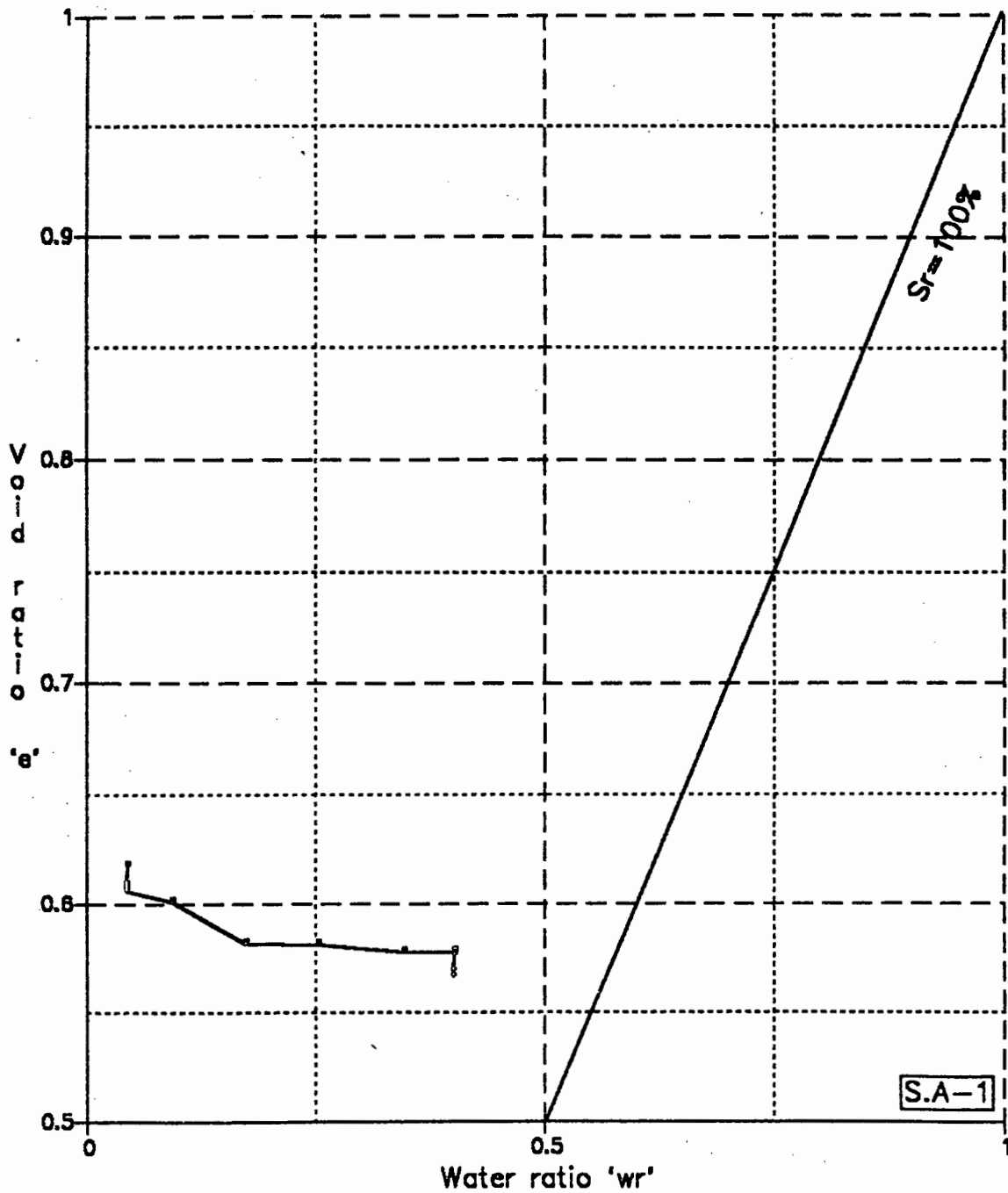


Figure G.27: Site A, Berea Road [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

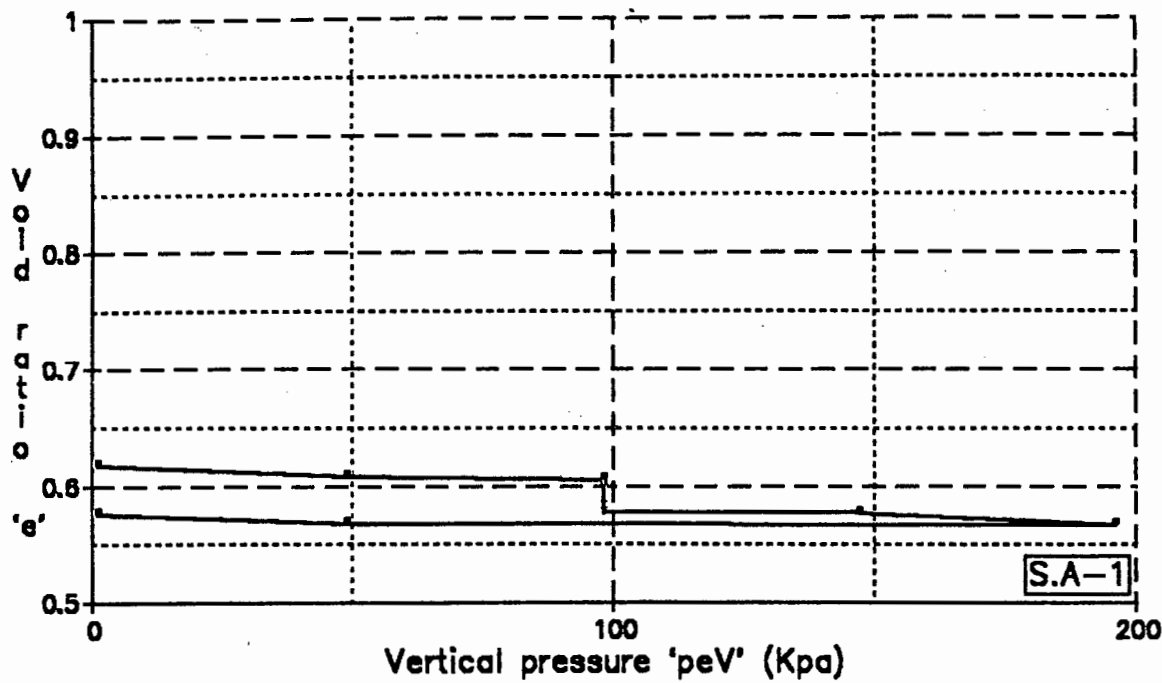


Figure G.28: Site A, Berea Road [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

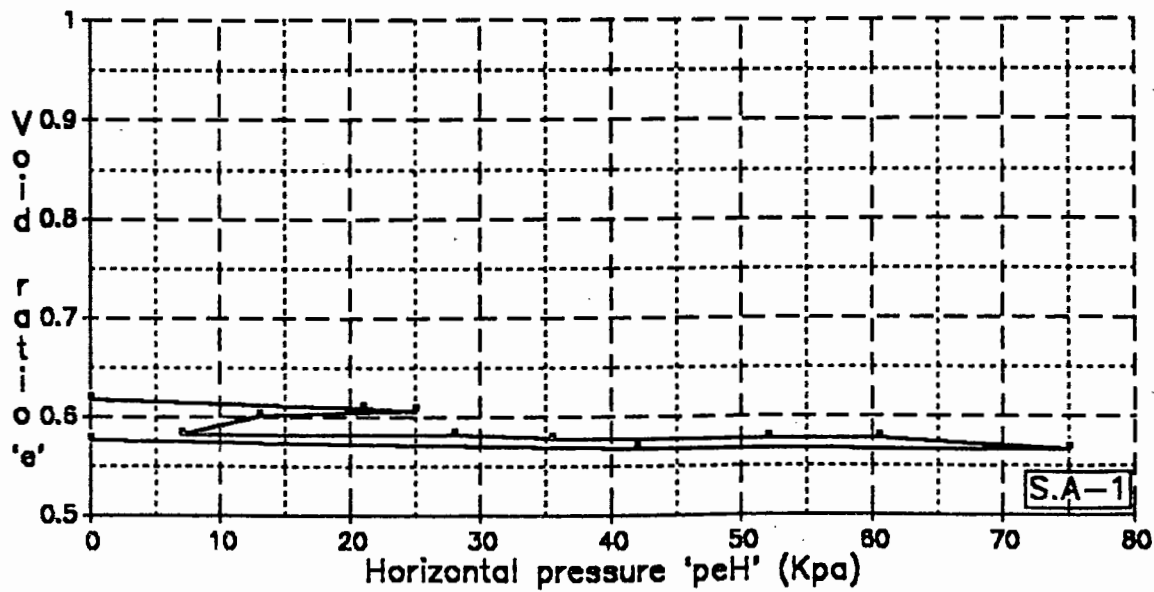


Figure G.29: Site A, Berea Road [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.

G.5.4 Site 7 - Mowbray, Cape.

Table G.13: Site 7, Mowbray [Undisturbed sample - vertical pressure of 100 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.7-1/ Ba.77	1.0	0.7206	0	0.581
	49.0	0.7115	12	0.579
	98.1	0.7069	6	0.579
	98.1	0.7144	40	0.607
	98.1	0.7455	155	0.690
	98.1	0.7733	186	0.745
	98.1	0.7817	160	0.753
	147.1	0.7795	184	0.751
	196.1	0.7754	230	0.750
	147.1	0.7765	205	0.751
	98.1	0.7803	182	0.750
	49.0	0.7849	132	0.751
	1.0	0.8271	57	0.751

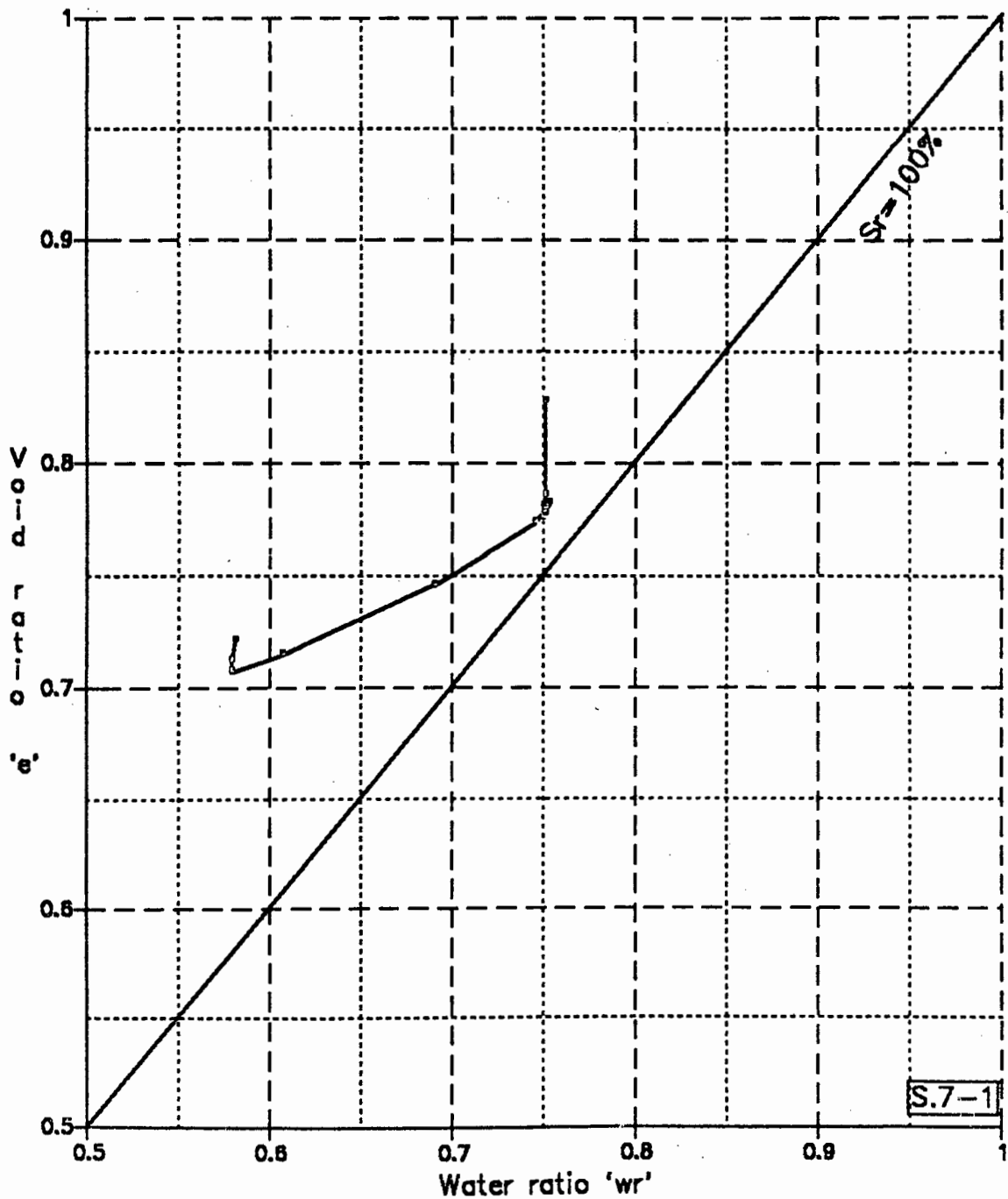


Figure G.30: Site 7, Mowbray [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

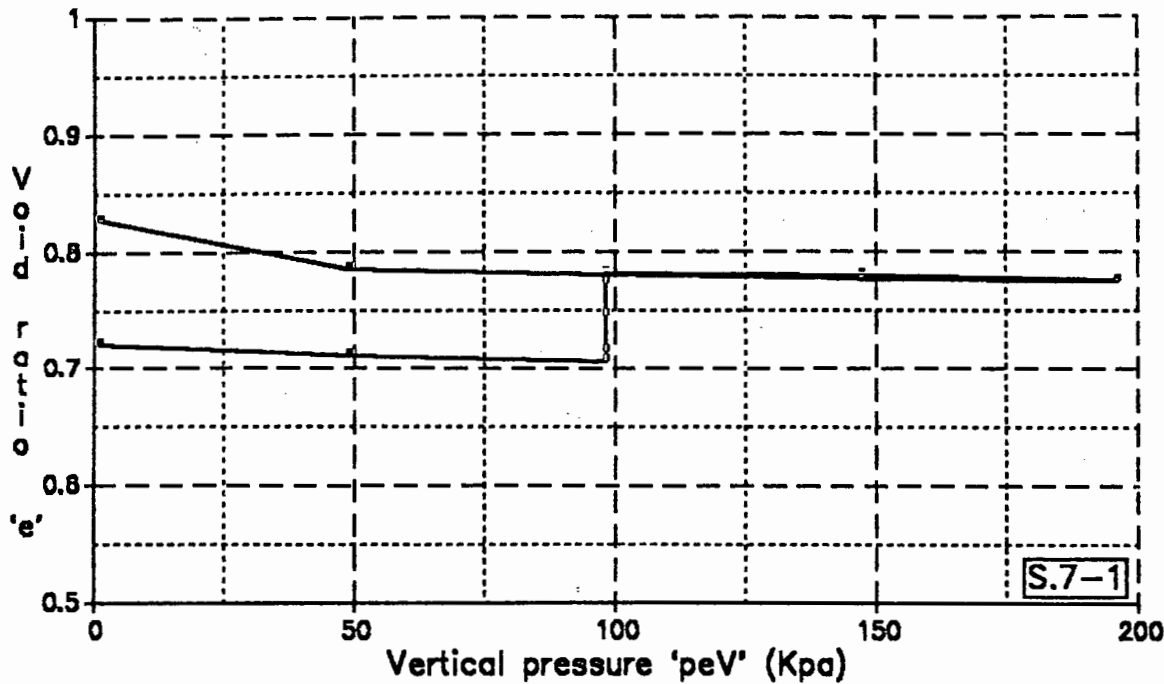


Figure G.31: Site 7, Mowbray [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

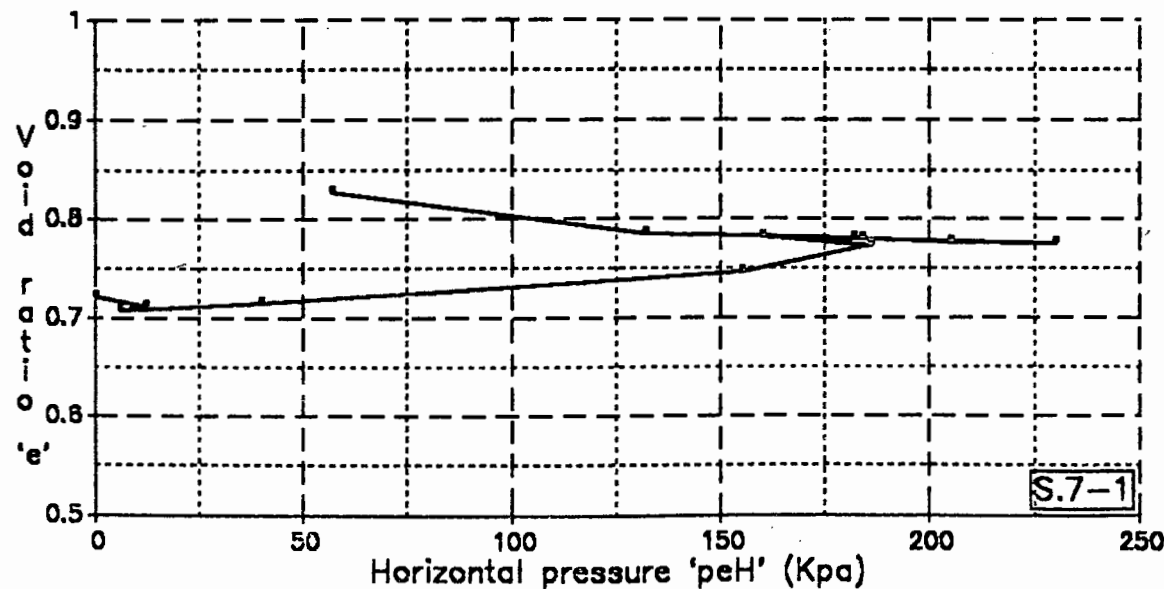


Figure G.32: Site 7, Mowbray [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.

G.5.5 Site 48 - Lady Grey District Farm Unity, Natal.

Table G.14: Site 48, Lady Grey [Undisturbed sample - vertical pressure of 100 Kpa] - Consolidometer test with horizontal strain, or stress, measurements.

Sample number/ ref.	Vertical pressure 'peV' (Kpa)	Void ratio 'e'	Horizontal pressure 'peH' (Kpa)	Water ratio 'wr'
S.48/ Ba.78	1.0	0.5593	0	0.419
	49.0	0.5567	0	0.419
	98.1	0.5549	0	0.419
	98.1	0.5640	35	0.468
	98.1	0.5661	95	0.520
	98.1	0.5669	130	0.523
	122.6	0.5668	165	0.523
	147.1	0.5639	142	0.522
	196.1	0.5635	161	0.520
	245.2	0.5634	166	0.518
	294.2	0.5628	180	0.517
	343.2	0.5627	232	0.517
	245.2	0.5618	206	0.518
	147.1	0.5620	209	0.518
	98.1	0.5628	169	0.518
	49.0	0.5628	180	0.518
	1.0	0.5721	116	0.518

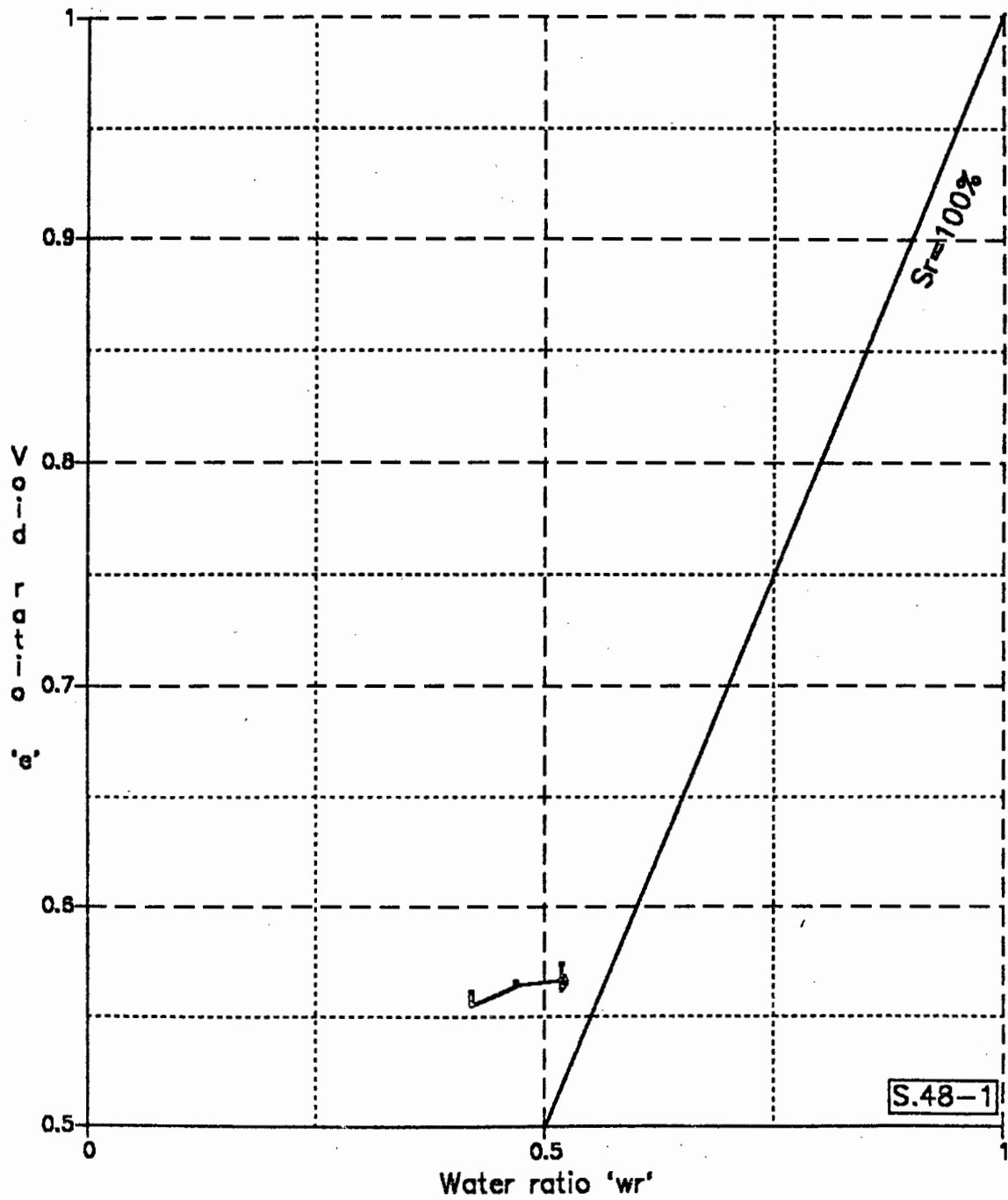


Figure G.33: Site 48, Lady Grey [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Water Ratio 'wr', for the full test path.

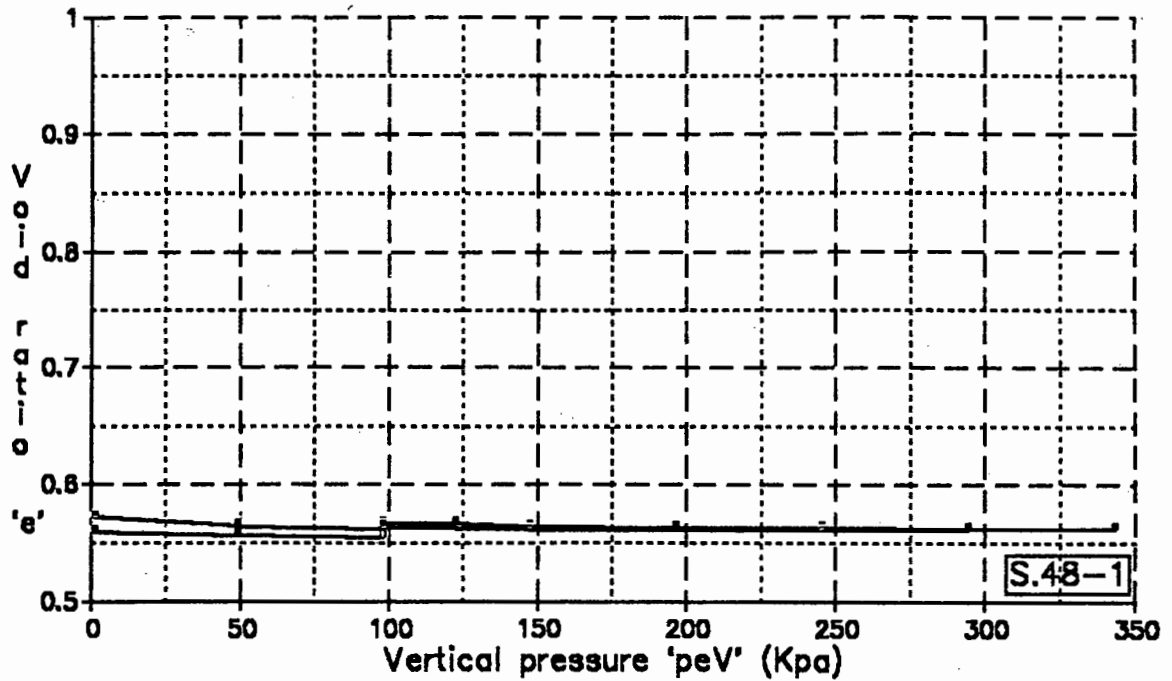


Figure G.34: Site 48, Lady Grey [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Vertical Pressure, or Stress, 'peV'.

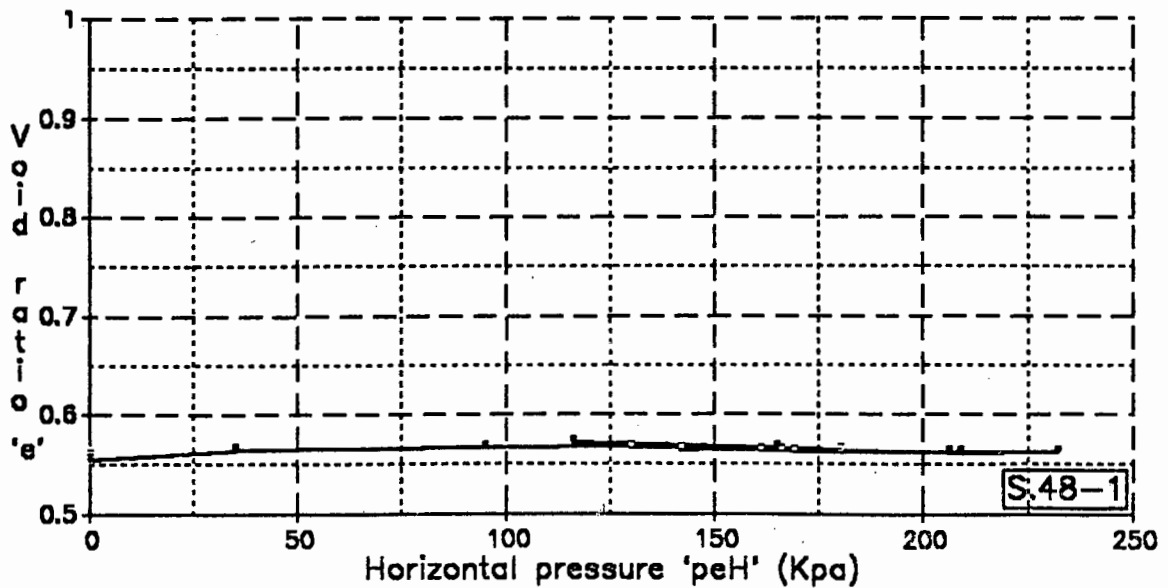


Figure G.35: Site 48, Lady Grey [Undisturbed sample - wetted at vertical pressure of 100 Kpa] - Void Ratio 'e' versus Effective Horizontal Pressure, or Stress, 'peH'.

APPENDIX H

TRIAXIAL TESTS FOR EXPANSIVE AND COLLAPSING SOILS - TEST PROCEDURES AND RESULTS

H.1 INTRODUCTION

Appendix H describes in detail the triaxial test method for expansive and collapsing soils, as well as related test procedures, used in chapter nine. These detailed test procedures enable the necessary measurements, obtained from a test sample, to be recorded. These measurements of volume change, as well as other relevant observations, are the result of isotropic consolidation under drained conditions, and/or the addition of a measured amount of water. A triaxial machine was used to apply the required cell pressure, all around the sample, under which it expands or collapses, when its water content is increased.

This Appendix also includes all the test results used in Chapter Nine. The test method and results are also summarized in Chapter Nine "All Round, three-dimensional, expansion or collapse". Photographic plates are included in Chapter Five which illustrate the use of the triaxial machine.

H.2 TEST PROCEDURE

Preparation of test samples:-

Test samples are prepared from either compacted or undisturbed samples. The detailed procedure for sample preparation is included in Appendix A (refer to 'Preparation of soil samples for testing').

Compacted samples.

Based on the 'Dry Density versus Water Content' curve for the soil type, as obtained from the compaction tests¹, carry out the following steps: Select points on the curve and obtain the corresponding values for water contents; Compact the soil to Standard AASHTO specification, as per requirements, aiming for the selected water content; Remove the compacted sample from the mould and cut the required test sample from it.

Undisturbed sample.

The test sample is cut from the undisturbed block of soil - refer to Appendix A².

¹ - refer to section A.5 of Appendix A.

² - see section A.2 "Soil Sampling".

Apparatus required:-

- (i) - (iv) Refer to test procedure for "Triaxial: Isotropic consolidation test procedure" in section D.2 of Appendix D¹.
- (v) Top loading plate with flexible tubing, to connect to the base of the cell, enables air to escape from the sample.

Note: The 10 cc burette² - used to add measured increments of water to the sample.

Procedure:-

A) Calibration of equipment - refer to the test procedure for "Triaxial: Isotropic Consolidation test procedure" in Appendix D, part 3, Calibration of equipment, and Table D.03 and Figure D.05 (part 8 of Appendix D) for the corrections to be applied to the volume readings.

B) Measurement of masses, dimensions, and positioning of the test sample:

(i) to (ii) Refer to Appendix D, part 4 (i) and (ii).

(iii) A moist porous disc is weighed, then slid onto the pedestal, and followed by a moist filter paper. The sample is carefully placed on top of the filter paper. The upper filter paper, porous plate, and top loading plate with flexible tubing, are positioned (in that order) on top of the test sample.

(iv) to (vi) Refer to Appendix D, part 4 (iv) to (vi).

C) Assembly of triaxial components:

(i) When the equipment is assembled a connection is made between a burette and one of the orifices on the pedestal where the sample is placed; Between the sample and the pedestal there is a porous plate and a filter paper, which together will facilitate the ingress of water into the sample; On top of the sample, a somewhat similar arrangement (by means of a special top plate with flexible tubing connecting it to the base of the cell) enables air to escape from the sample.

Note: At the start of the test, the water in the burette is kept level with the top of the pedestal.

(ii) - (vi) Refer to Appendix D, part 5, Assembly of triaxial components, steps (i) to (iv), and (vi) and (vii).

¹ - see "Apparatus Required", steps (i) to (iv).

² - refer to Appendix D, part 2 step (iv).

D) Testing:

(i) The following is the required sequence of cell pressure increments during the initial loading stage:
0 Kpa -> 10.3 -> 51.7 -> 103.4 Kpa.
The pressure supply is adjusted, to each required cell pressure value, in the manner described in section D.2 of Appendix D¹.

(ii) Volume change as a function of time is recorded during each stage of loading the sample. Consolidation is completed when no noticeable changes occur to the volume change indicator over a considerable period of time. At the completion of the initial loading stage, the sample is being confined by the required pressure, or all round stress.

(iii) To add water to the sample, the burette is gradually raised, in small steps, in order to generate a slight 'head' which will cause the water to slowly flow onto the top of the pedestal, be absorbed by the porous plate and filter paper, and reach the soil sample. The procedure is repeated until the required amount of water increment is reached (usually about 1 cc), and then waiting at least 6 hours this extra water to distribute itself upwards throughout the sample. The volume changes with time that take place in the sample, from the start of wetting, are observed in the 'volume change indicator'.

(iv) The loading characteristics of the soil, under saturated conditions, are determined by adjusting the pressure supply to the required cell pressure. The following is the sequence of cell pressure increments:
103.4 Kpa -> 206.8 -> 413.7 -> 620.5 -> 827.4 Kpa.
Volume change, as a function of time is recorded during each stage of loading the sample.
Note: The pressure supply is adjusted in the manner described in Appendix D¹.

(v) The unloading, or recovery, characteristics of the soil sample (as a function of time) are also recorded for the following sequence of pressure decrease:
827.4 Kpa -> 206.8 -> 51.7 -> 10.3 -> 1 Kpa.
Note: For details of the unloading stage, refer to part 6 of Appendix D, step (v).

(vi) The volume and pressure supply systems are isolated (refer to part 6 of Appendix D, step (vi)) - the equipment is disassembled and the soil sample is weighed, measured and oven dried².

1 - see part 6, steps (i) and (ii).

2 - as described in Appendix D, part 6 step (vii).

Calculations and report:-

1) Information to be recorded for each test:

- a) Before starting the cell pressure increments - the initial, or 'zero', reading for the Volume Change Indicator (refer to step D (i), above);
- b) For each step of cell pressure increase, during the initial loading stage of the sample - the cell pressure applied, time and corresponding readings on the volume change indicator (refer to step D (ii) above), as well as the height of the sample (as measured by the vernier telescope - refer to above step C, (ii) to (vi));
- c) Before adding the first amount of water to the sample - the initial reading on the volume change indicator, and the height of the sample;
- d) Each amount of water added to the bottom of the sample and, for each of these stages of controlled wetting, the readings taken on the volume change indicator, with time, from the start of wetting (refer to D (iii) above);
- e) The next loading stage of the sample - the cell pressure applied, time and volume change readings, and height of the sample (refer to D (iv) above);
- f) The unloading of the sample - cell pressure, time and volume changes, and height of sample (refer to D (v) above);
- g) The moisture content of the soil sample at the start, as well as after each step of water increment,

$$\begin{aligned} & (\text{Mass of moist soil} + \text{water added}) - \text{Mass of oven-dry soil} \\ & = \frac{\text{Mass of oven-dry soil sample}}{\text{Mass of oven-dry soil sample}} \end{aligned}$$

- h) The diameter, height and mass of the soil sample were obtained in steps B to D.

2) To determine the void ratio at the initial, final and intermediate stages:

- a) The initial void ratio 'e' of the soil sample:

$$e = \frac{\text{Volume of voids 'Vv'}}{\text{Volume of solids 'Vs'}} = \frac{\text{Total volume 'Vt'} - \text{'Vs'}}{\text{'Vs'}}$$

Where:

$$V_t = \frac{\pi \times D^2}{4} \times \text{original height of soil sample 'ht'};$$

and,

$$V_s = \frac{\text{Mass of oven-dry soil 'M}_D\text{'}}{\text{Specific Gravity of Soil Particles 'G}_S\text{'}}.$$

b) Intermediate and final void ratios are obtained by using the corrected reading of volume change indicator 'Vc' (refer to Appendix D part 8, calibration test, and Table D.03 - accumulative difference correction), and then by calculating the 'e' value as follows:

$$e = \frac{[(\pi \times D^2/4 \times \text{ht}) - V_c] - V_s}{V_s}.$$

3) The information obtained for each test will enable the following relationships to be plotted:

- a) Volume change, either settlement or expansion, and time (square root or log), for each applied cell pressure increase or decrease;
- b) Void ratio 'e' and water ratio 'wr'.
- c) Void ratio 'e' and effective all round pressure 'peAr';

Note: All the preliminary test procedures and definitions are included in Appendix A.

H.3 REFERENCES FOR APPENDIX H

16. DE S. VINAGRE, T.J.V. (1976/77): Masters Thesis
Diaries One, Two, Three, Four, Five, and Six.

88. BISHOP, A.W. and HENKEL, D.J. (1962): The
measurement of soil properties in the triaxial test - Second
Edition. Edward Arnold (Publishers) Ltd., London.

H.4 TEST RESULTS FOR NATURAL SOIL TYPES.H.4.1 Site 11 - Rosebank, Cape.

*Table H.01: Site 11, Rosebank [Undisturbed sample - 100 Kpa]
- Triaxial tests for expansive and collapsing soils.*

Sample Number/ Reference	All Round Pressure 'peAr'	Void Ratio 'e'	Water Ratio 'wr'
S.11-T3/ V.28	1	0.831	0.609
	10.3	0.793	0.609
	53.7	0.599	0.608
	103.4	0.599	0.606
	103.4	0.625	0.661
	103.4	0.676	0.771
	103.4	0.689	0.937
	103.4	0.663	1.102
	103.4	0.637	1.130
	206.8	0.650	1.102
	413.7	0.534	1.047
	620.5	0.528	1.019
	827.4	0.521	0.992
	206.8	0.618	0.992
	51.7	0.628	1.019
	10.3	0.728	1.074
	1	0.864	1.152

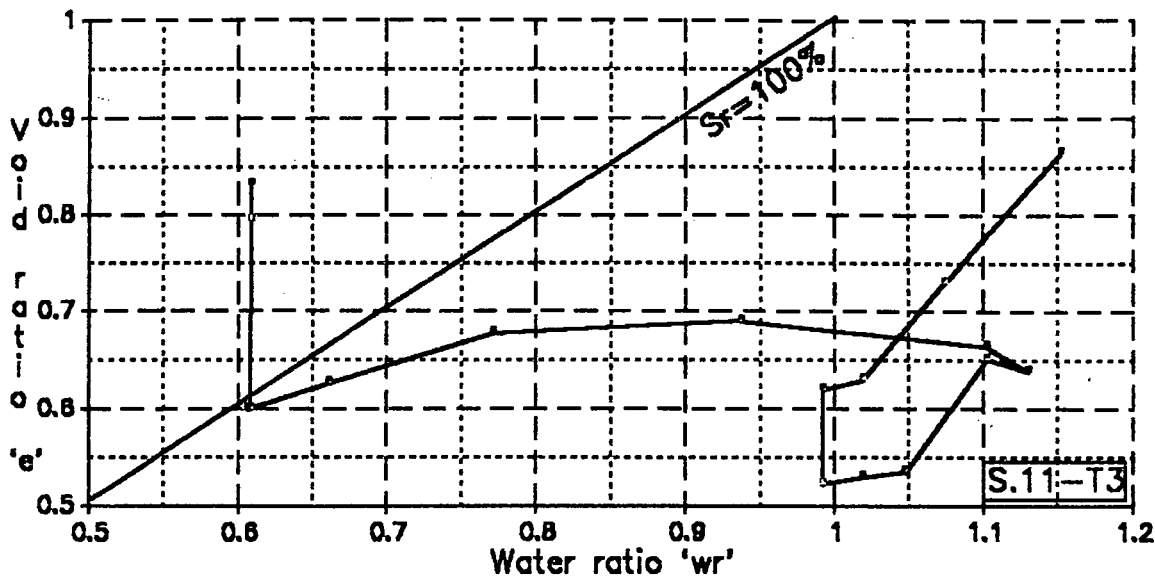


Figure H.01: Site 11, Rosebank - [Undisturbed sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and the Water Ratio 'wr'.

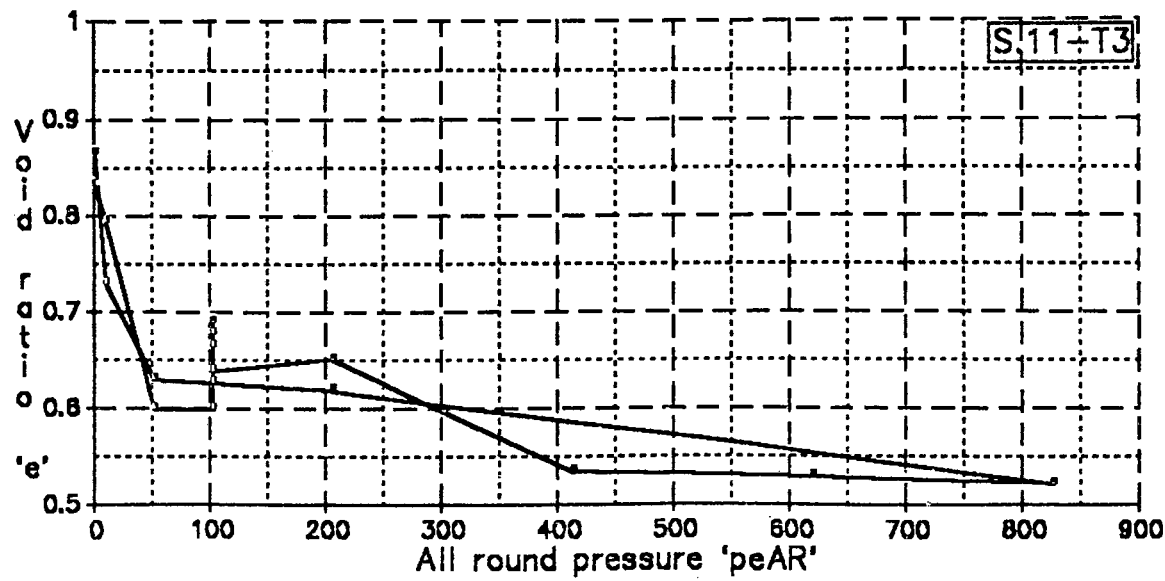


Figure H.02: Site 11, Rosebank - [Undisturbed sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and Effective All Round Pressure 'peAR'.

Table H.02: Site 11, Rosebank [Compacted sample - 100 Kpa] -
Triaxial tests for expansive and collapsing soils.

Sample Number/ Reference	All Round Pressure 'peAr'	Void Ratio 'e'	Water Ratio 'wr'
S.11-T4/ V.30	1	0.960	0.835
	10.3	0.943	0.832
	51.7	0.904	0.829
	103.4	0.856	0.827
	103.4	0.858	0.854
	103.4	0.860	0.909
	103.4	0.857	0.937
	206.8	0.835	0.909
	413.7	0.756	0.854
	620.5	0.717	0.799
	827.4	0.702	0.771
	206.8	0.769	0.799
	51.7	0.834	0.854
	10.3	0.885	0.909
	1	0.954	0.964

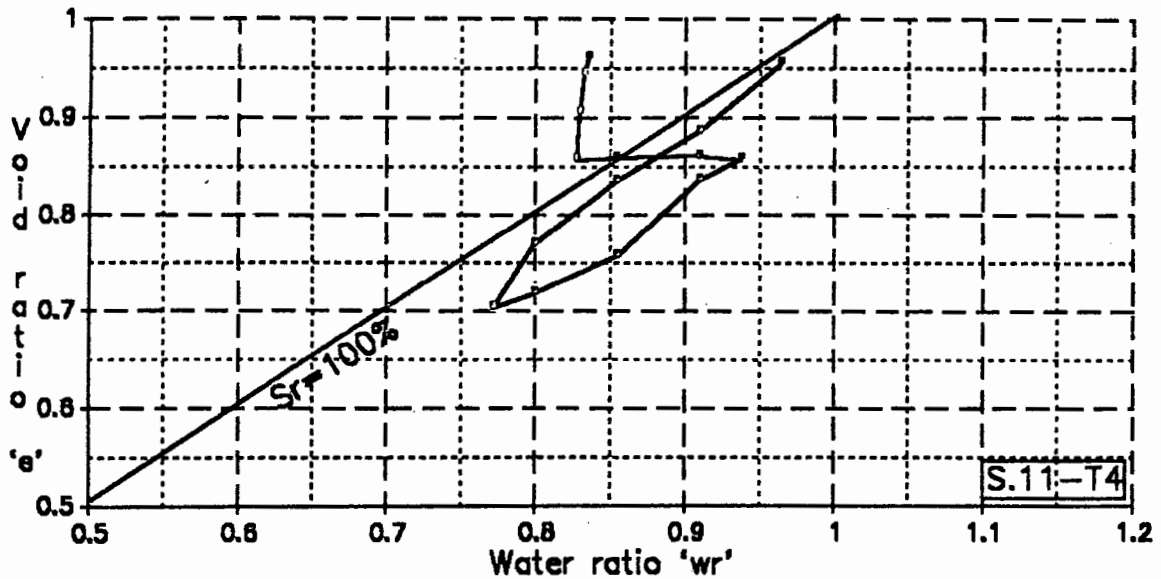


Figure H.03: Site 11, Rosebank - [Compacted sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and Water Ratio 'wr'.

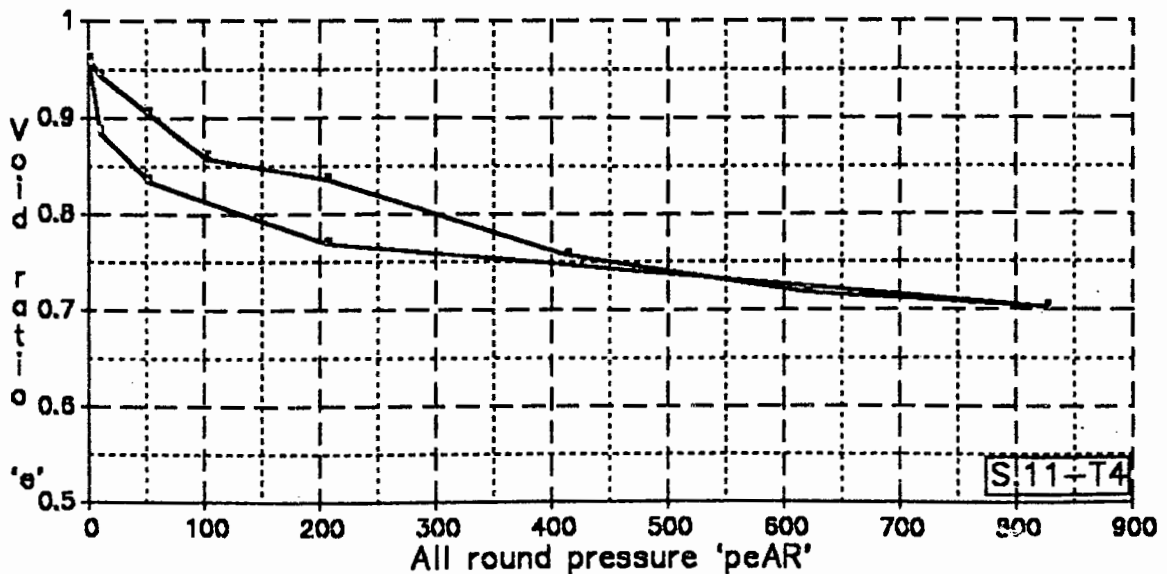


Figure H.04: Site 11, Rosebank - [Compacted sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and the Effective All Round Pressure 'peAR'.

H.4.2 Site A - Berea Road, Durban.*Table H.03: Site A, Berea Road [Undisturbed samples - 100 Kpa] - Triaxial tests for expansive and collapsing soils.*

Sample Number/ Reference	All Round Pressure 'peAr'	Void Ratio 'e'	Water Ratio 'wr'
S.A-T3/ V.25	1	0.649	0.059
	10.3	0.506	0.059
	51.7	0.341	0.056
	103.4	0.319	0.053
	103.4	0.319	0.080
	103.4	0.308	0.107
	206.8	0.298	0.120
	413.7	0.297	0.107
	413.7	0.551	0.552
S.A-T4/ V.26	1	0.616	0.069
	10.3	0.498	0.069
	51.7	0.463	0.067
	103.4	0.428	0.064
	103.4	0.420	0.107
	103.4	0.412	0.133
	103.4	0.402	0.187
	103.4	0.398	0.267
	103.4	0.397	0.400
	206.8	0.395	0.373
	413.7	0.360	0.346
	620.5	0.358	0.320
	827.4	0.355	0.293
	206.8	0.395	0.320
	51.7	0.397	0.346
	10.3	0.409	0.346
	1	0.435	0.376
S.A-T5/ V.32	1	0.732	0.032
	10.3	0.702	0.032
	51.7	0.662	0.029
	103.4	0.635	0.027
	103.4	0.630	0.107
	103.4	0.625	0.213
	103.4	0.623	0.426
	206.8	0.622	0.400
	413.7	0.591	0.373
	620.5	0.575	0.346
	827.4	0.573	0.320
	206.8	0.579	0.346
	51.7	0.587	0.346
	10.3	0.614	0.373
	1	0.627	0.386

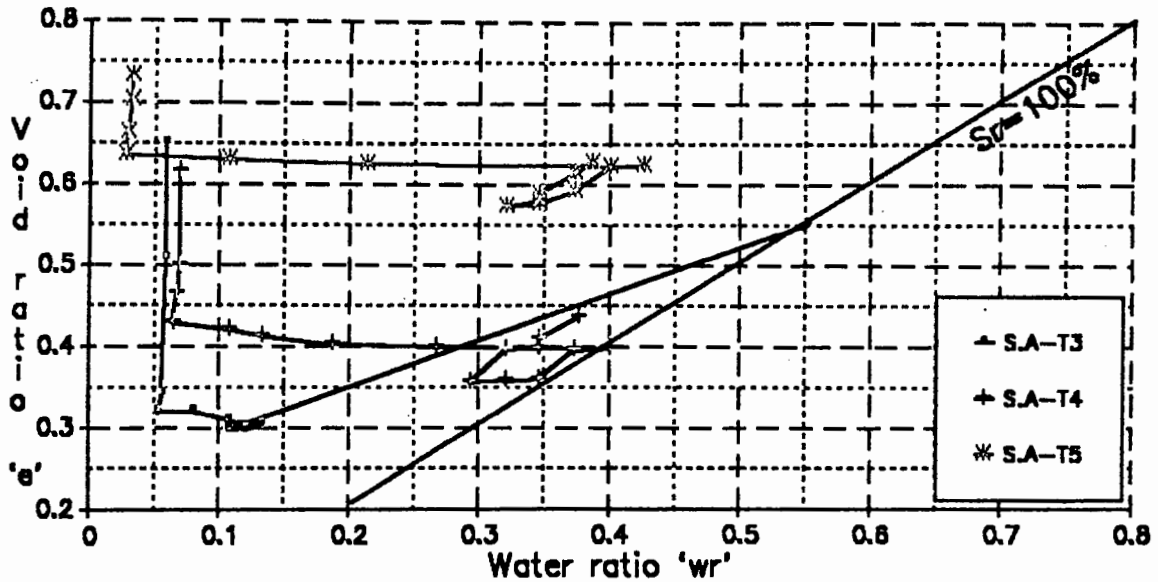


Figure H.05: Site A, Berea Road - [Undisturbed sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and the Water Ratio 'wr'.

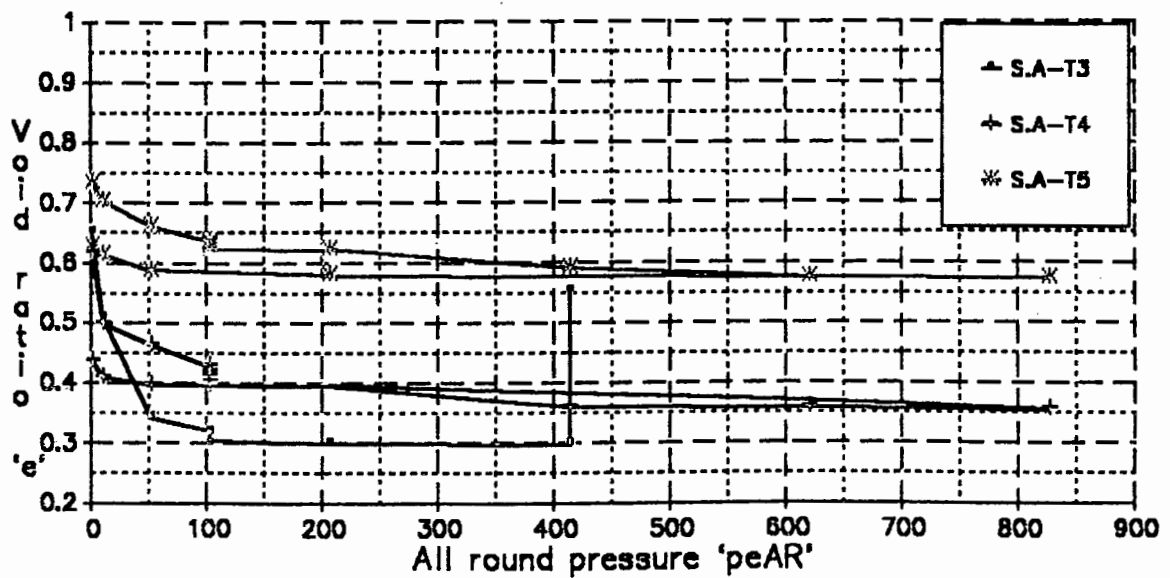


Figure H.06: Site A, Berea Road - [Undisturbed sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and Effective All Round Pressure 'peAR'.

Table H.04: Site A, Berea Road [Compacted sample - 100 Kpa]
- Triaxial tests for expansive and collapsing soils.

Sample Number/ Reference	All Round Pressure 'peAr'	Void Ratio 'e'	Water Ratio 'wr'
S.A-T2/ V.33	1	0.466	0.248
	10.3	0.455	0.245
	51.7	0.396	0.243
	103.4	0.372	0.240
	103.4	0.369	0.320
	206.8	0.368	0.320
	413.7	0.367	0.293
	620.5	0.354	0.293
	827.4	0.352	0.267
	206.8	0.356	0.267
	51.7	0.371	0.293
	10.3	0.374	0.320
	1	0.386	0.344

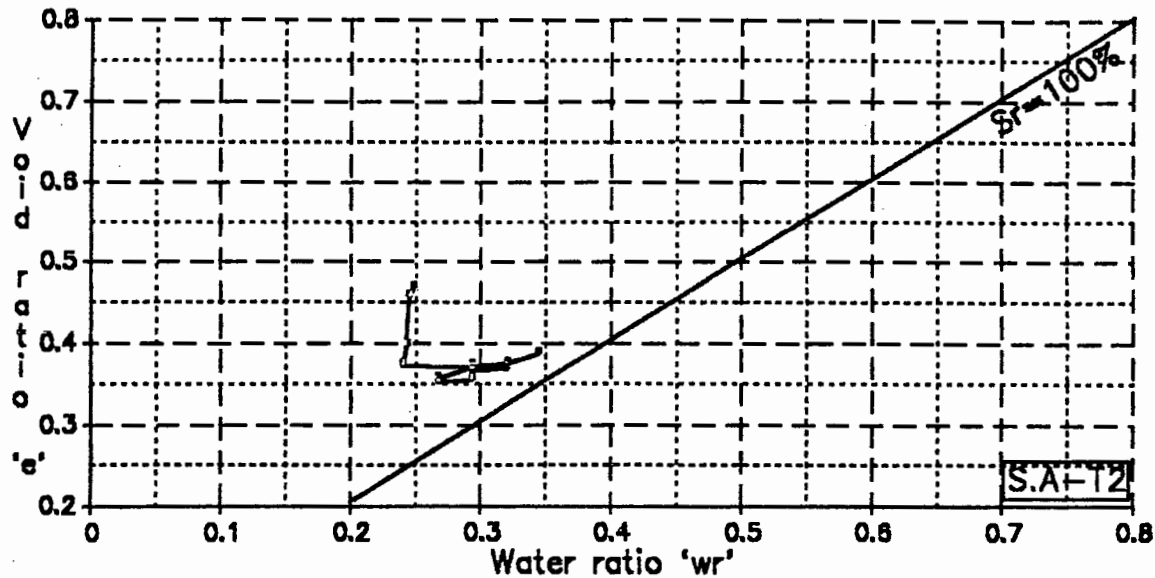


Figure H.07: Site A, Berea Road - [Compacted sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and the Water Ratio 'wr'.

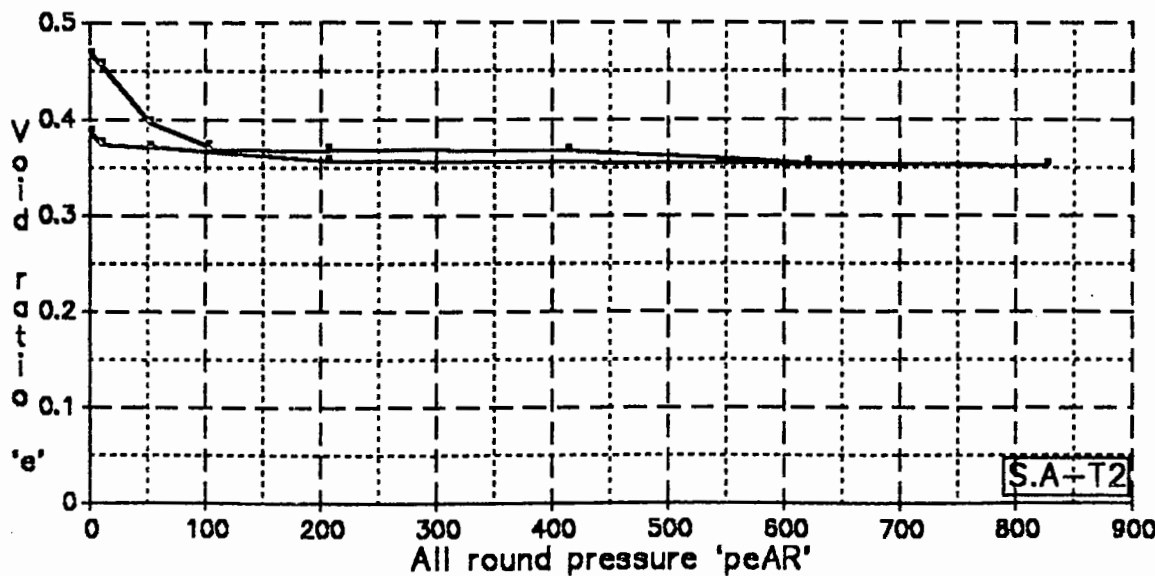


Figure H.08: Site A, Berea Road - [Compacted sample - wetted when cell pressure was 100 Kpa] Relationship between the Void Ratio 'e' and the Effective All Round Pressure 'peAR'.

APPENDIX IPOSTGRADUATE COURSES COMPLETED AND
EXPERIMENTAL RESULTS USED FOR PUBLICATIONI.1 POSTGRADUATE COURSES COMPLETED

This candidate's Master's degree program consists of postgraduate course work plus a thesis in partial fulfilment of the requirements for the degree. A total of 40 credits is required - the value of the thesis should be one-half. The other 20 credits are to be obtained from course work. This candidate has completed five postgraduate courses, for a total of 30 credits. He has therefore, more than met the requirements for the course work.

COURSES COMPLETED IN PARTIAL FULFILMENT
OF THE M.SC (ENG.) DEGREE AT THE UNIVERSITY OF CAPE TOWN

<u>COURSE</u>	<u>YEAR CREDITED</u>	<u>CREDIT VALUE/ PASS MARK</u>
CE 513 - Waste Water Treatment	1975	10 / 2nd(+)
CE 527 - Unit Processes in Water Treatment	1976	5 / 2nd
CE 525 - Coastal Engineering	1976	5 / 1st
CE 529 - Field Theory and Groundwater Flow	1977	5 / 1st
CE 500 - Advanced Soil Mechanics	1979	5 / 2nd(+)

Total credit requirements for the M.Sc. (Eng.) Degree: 40

Half Thesis: 20
Course Credits: 30 (As per above)
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Total Credits: 50

The contents for each course, as stated in the official prospectus of the Faculty of Engineering, are as follows:-

CE 500: ADVANCED SOIL MECHANICS

(course rating = 5 credits) - UPPER SECOND CLASS PASS.

- (a) Soil Physics and equilibrium theory: Failure and creep concepts, stress path, cam clay model, behaviour of partly saturated soils, expansive clays, collapsing soils.
- (b) General: Finite difference methods applied to Soil Mechanics. Dimensional analysis. Statistics and Soil Design.
- (c) Foundation design and analysis: General foundations including pile and raft systems. Foundations for expansive and collapsing soils. Settlement analysis using numerical methods and stress path. Soil-structure interaction.
- (d) Design of Dams: Dam systems, flownets for complicated dams, non-circular slips, analysis and design procedures, instrumentation for dams, piping, filters, drainage.
- (e) Extra options: Aspects of Soil Exploration and site investigation, introduction to Rock Mechanics, introduction to Sokolovsky failure fields, introduction to Finite Elements.
- (f) Practical Work: Laboratory and Model Tests. Projects. Seminars. Examination.

CE 529: FIELD THEORY AND GROUNDWATER FLOW

(course rating = 5 credits) - FIRST CLASS PASS.

This course contains theoretical and practical approaches. The first portion is the theoretical treatment of fields, and includes the classification of fields such as stress distribution in materials, water velocity distributions, heat flow, gravity fields, seepage and consolidation of soils, deflection fields. This portion also includes an introduction to vector calculus, superposition of fields, functions of a complex variable, conformal plotting, finite difference methods. Special attention will be given to irrotational flow problems.

The second portion of the course relates mainly to groundwater flow, wells, aquifers, transient flow, consolidation due to varying loads and water levels. Solutions by finite differences, finite elements, graphical methods, models and analogs. Problems of partly saturated flow will be mentioned.

Laboratory work and project.
Examination.

CE 525: COASTAL ENGINEERING

(Course rating = 5 credits) - FIRST CLASS PASS.

The course is concerned with establishing the design criteria for coastal structures. This involves the prediction from meteorological data of swell characteristics (wave height, period and angularity) approaching a coastal line. The associated dynamics of water and sediment motion in the coastal zone will be studied, leading to estimates of the water surface elevations and forces acting on structures constructed in this area. Some consideration will be given to stability of armour units used in marine construction, but in general the course will not involve structural design.

Demonstrations and projects.
Examination.

CE 527: UNIT PROCESSES IN WATER TREATMENT

(course rating = 5 credits) - SECOND CLASS PASS.

Theory and design of coagulation and flocculation units; sedimentation and flotation; rapid and gravity sand filters; softening and stabilisation; iron and manganese removal; disinfection by chlorination and ozonation; control of colour, taste and odour problems. Design methods for energy losses through a waste treatment works. Disposal of waste sludge.

Examination.

CE 513: WASTE WATER TREATMENT

(rating = 10 credits) - UPPER SECOND CLASS PASS.

Introduction to pollution of the aquatic environment, pollution parameters and process of self-purification; principles of inorganic, organic, biochemical and physical chemistry as required in the study of environmental phenomena; microbiology, structure, metabolism, growth, etc. of micro-organisms; general concepts of biological treatment; unit processes.

Laboratory methodology for developing biological treatment information, application to design of activated sludge, aerated lagoon, trickling filter and other processes.

Project, Seminars and Laboratory work.
Examination.

I.2 EXPERIMENTAL RESULTS USED FOR PUBLICATION

Experimental results obtained by this candidate were, prior to the date of submission of the thesis, made available for publication, including the following:

- A.D.W. Sparks, F.J. Retief, L.A. Errera, and T.J.V. de S. Vinagre (South Africa): "Soil-structure interaction and volume change soils", Proceedings of the Tenth International Conference on Soil Mechanics and Foundation Engineering, Volume 2, 1981, pages 263 to 269.
 - "Soil-structure interaction, general report (session 5) - Discussion by H.G. Poulos (Australia) of the "Soil-structure interaction and volume change soils" technical paper by Sparks et al; Proceedings of the Tenth International Conference on Soil Mechanics and Foundation Engineering, Volume 4, 1982, pages 325 and 326.
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