UNIVERSITY OF CAPE TOWN

The use of natural site derived materials as concrete aggregate

Masters Dissertation

Barrie O'Neill-Williams

May 2012

PLAGIARISM DECLARATION

1. I know that plagiarism is wrong. Plagiarism is using another's work and to pretend that it is ones own.
2. I have used the Harvard convention for citation and referencing. Each significant contribution to, and quotation in, this dissertation from the work, or works of other people has been attributed and has been cited and referenced.
3. This dissertation is my own work.
4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.
5. I acknowledge that copying someone else's assignment or essay, or part of it, is wrong, and declare that this is my own work

SIGNATURE: Signed by candidate

DATE: 8th of May 2012

I. Abstract

This thesis focuses on the use of site-derived fine material, in its natural form, as aggregate in concrete construction. It is proposed that the utilisation of this type of concrete aggregate will lead to; the preservation of natural materials that would otherwise have to be beneficiated off site, the reduction of waste material produced on a construction site, and an overall energy saving.

In order to assess the suitability of site-derived fine materials for concrete aggregate, 17 soils were collected in the greater Cape Town area. These soils were selected such that they represent the range of soils that can be expected in this region. Their properties were assessed in terms of appearance, grading characteristics, methylene blue absorption value, silt and clay content and clay type through X-Ray diffraction. A wide range of properties were measured across the soils, with microfines (<75µm) contents varying between approximately 0% and 45%, silt (<20µm) contents varying between 0% and 20% and clay (<5µm) contents varying between 0% and 14%. Seven soils were found to have clay minerals present. The soils were also assessed in terms of the presence of deleterious organic chemicals, although all the soils and one of the two control sands failed the test, which meant that this was not a useful indicator of the soil properties.

Concrete was made, using the site-derived soils as fine aggregate. The w:c ratio was kept constant, as was the binder and the coarse aggregate type. The desired workability was achieved through manipulation of the water content of the mixes, which gave the water demand of the soil being used. The concrete was then evaluated in terms of physical and mechanical performance. Strength, shrinkage and durability characteristics were assessed, as well as a thermogravimetric analysis in order to determine whether any pozzolanic reactions were occurring.

By comparing the soils' properties with the corresponding concrete properties, the relationship between the two could be observed and interpreted. The results from the testing indicated that, of all the properties investigated, the microfines content of the site-derived material has the most significant effect when used in concrete.

High microfines contents in the site-derived material were found to lower workability, which needs to be countered by an increase in water content of the concrete. Since the w:c ratio needs to be kept constant to maintain the strength of the concrete, a higher water content also means a higher cement content. This is undesirable economically and environmentally.

Strength was found to be affected by microfines content. At low microfines contents, less than approximately 20%, the microfines were observed to increase strength performance. It is suggested that this is due to a fine filler effect. At higher microfines contents however, strength is negatively impacted by increasing microfines contents. It is suggested that this is due to an increase in porosity, as well as increasing concentrations of deleterious minerals and chemicals present in the microfines fraction.

Shrinkage was found to be affected by microfines in two ways; directly (through dimensional instability of the microfines fraction) and through the effect that microfines have on water demand.

An optimum microfines content of approximately 15% to 20% was observed. Below this optimum content, the microfines appear to be beneficial to concrete through the fine filler effect. Above the optimum content, microfines have a negative impact on durability.

With regard to the aims of sustainability, it is critical that the effects that microfines have on the performance of concrete, both beneficial and detrimental, be utilized and controlled. A suggested

method of achieving this is proposed, whereby the site-derived material is blended with traditional building sand. This blending sand will need to be beneficiated off site and then transported, which has negative environmental consequences. It is therefore important that an optimum blending ratio is achieved in order to further the aims of sustainability. This work suggests that the material be blended such that the microfines content falls between 5% and 15% depending on the desired performance of the concrete.

II. Acknowledgements

I would like to thank Professor Mark Alexander and Mr Vernon Collis for the valuable input that they provided through the currency of both time and knowledge. I would also like to thank Miss Karen Marie du Toit for sacrificing her weekends to edit out my many, many grammatical errors.

I would like to thank Kyle Wickins who laboured with me to dig up a particularly troublesome soil.

Finally, I would like to thank John Thuysbaert, who dug up the soil too, but also spent the better part of a month collecting other soils with me, and then stored, transported and re-stored them all too many times.

Table of Contents

List of Figures

List of Tables

1 Introduction

The world we live in has a finite quantity of natural resources. As the population of the world increases, so does the rate at which these resources are depleted. The construction industry is a major contributor to the consumption of both materials and energy; the industry consumes as much as one quarter of the world's energy, according to some estimates (Becchio, et al., 2009).

Concrete plays a major role in the construction industry and aggregates make up a substantial part of concrete. In the greater Cape Town area, it has been estimated that, if current practice is not changed, sand for concrete construction will be depleted between 2021 and 2035 (Cole & Viljoen, 2001). In addition, the continued mining at the second largest sand mine in the Cape Town area, the Macassar dunes, is under threat due to the detrimental effects that it is having on the environment and the opposition of the local community against such practices (Ferketic, et al., 2010).

A possible solution to this problem is proposed, whereby fine material from the construction site is used as fine aggregate in concrete. It is hypothesised that the site-derived fine aggregate can be used in concrete, with the intent that the utilization of this material will lead to; the preservation of natural materials that would otherwise have to be beneficiated off site, the reduction of waste material produced on a construction site and a reduction in the volume of material that needs to be transported onto a site.

The effects of fine aggregate on the properties of concrete are well studied and understood. The factors of particle size, shape and distribution, mineralogy and chemical composition of the fine aggregate all influence the properties of concrete. In the case of site-derived natural aggregate, the presence of microfines, clays and organic matter have been identified as having possible deleterious effects on concrete.

In order for site-derived materials to be used as concrete aggregate, it is important to understand the effect that this material will have on the concrete. In order to do this, the following methodology has been carried out:

- A wide range of soils were collected in the Cape Town area
- The properties of the soils were measured
- Concretes were made using these soils as fine aggregate
- The properties of these concretes were measured. Specifically, strength, shrinkage and durability were assessed.

From this testing the suitability of this material as concrete aggregate could be assessed.

1.1 Sustainable development in the construction industry

A broad description of sustainable development has been defined by the World Commission of Environmental Development (WCED) as follows; (WCED, 1987), (Glavinich, 2008):

> Humanity has the ability to make development sustainable- to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits- not absolute limits but limitations imposed by the present state of technology and social organisation on environmental resources and by the ability of the biosphere to absorb the effects of humanity.

This implies that in order for something to be sustainable, and in considering the consequences of our actions, we need to take into account not only the environment but also the social and economic consequences. This is illustrated in Figure 1.1.

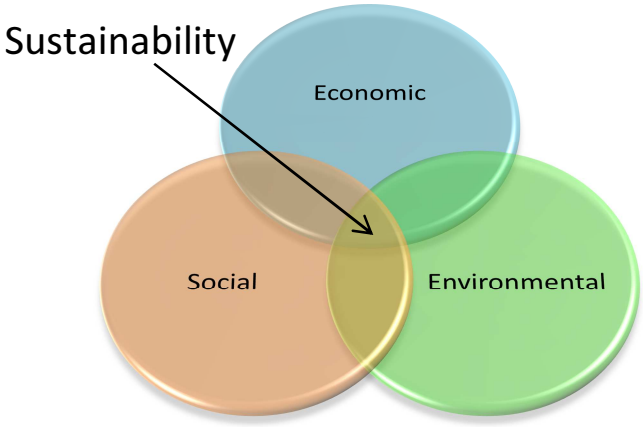


Figure 1.1. A holistic view of sustainability (Aitcin and Mindess 2011)

Construction is an important part of the concept of sustainable development. The primary aims of a construction project are to meet the needs of the current generation, be it the construction of more lanes on a highway to accommodate more traffic, or the construction of a house so that someone can live there. However, the construction process has the ability to compromise the needs of future generations.

A construction project makes use of the earth's resources to meet the aims of the project. Therefore, it is important that if the ideals of sustainable development are adhered to, to ensure that the use of the earth's resources to meet this generation's needs does not compromise future generation's needs (Glavinich, 2008). This leads to the idea of *green building* and *green construction*.

The term "green building" has been defined as follows; (ASTM, 2006), (Glavinich, 2008)

> A building that provides the specified building performance requirements while minimising disturbance to and improving the function of local, regional and global ecosystems both during and after its construction and specified service life.

This statement indicates that in order for a building to be considered green, it needs to have minimal impact on the environment, while not compromising on performance.

1.1.1 Environmental and social sustainability of concrete

1.1.1.1 Depletion of resources

In the period between 1900 and 2000, the world population grew from 1.5 billion people to 6 billion people. During this time, the proportion of people living in cities has grown from 10% to 50% (Mehta, 2002). Also, during the same time frame, the annual production of Portland cement went from 10 million metric tonnes to 2.5 billion metric tonnes (Aitcin & Mindess, 2011).

This has led to advances and massive expansions in the transportation, manufacturing, energy and construction sectors. The nature of the expansion in these industries has been, in large, governed by

monetary gain rather than on the full range of costs these industries engender. For instance, the annual global flow of material is in the order of 500 billion metric tons. Of all this material, it is estimated that only 6% ends up in consumer products (Mehta, 2002).

It is estimated that approximately 20-25% of the world's energy is spent on the production of construction materials (Becchio, et al., 2009). Of these materials, concrete is by far the most widely used. This is due to its availability, versatility, adaptability and durability. In fact, after water, concrete is the most widely used material in the world (Aitcin & Mindess, 2011) (Table 1.1).

Table 1.1. Annual world production of materials in 2007 (Aitcin & Mindess, 2011)

Material	Production (metric tons)
Concrete	13 billion
Portland cement	2.36 billion
Steel	1.34 billion
Coal	6.5 billion
Crude oil	3.8 billion
Wheat	607 million
Salt	200 million
Sugar	162 million

Concrete typically consists of 12 - 15% cement, 8 - 10% water and 75 - 80% aggregates by mass, although the exact figures do vary. The global concrete industry consumes 1.5 billion metric tons of cement annually. An estimated 9 billion metric tons of aggregate and 900 million metric tons of water are also used in the manufacture of concrete. (Mehta, 2002) (Aitcin & Mindess, 2011).

These data indicate that aggregate material makes up a very large proportion of any concrete construction. The aggregate is traditionally derived from a natural source, and transported to the site where the concrete is being made. Figure 1.2 indicates the sand mine sources in and around the City of Cape Town.

Aside from the issue of transportation of these materials, Figure 1.2 highlights the fact that there is a finite quantity of building sand available for the Cape Town area.

Table 1.2 indicates the volumes of sand available for construction in Cape Town in 2001, and these quantities are shown in a pie chart in Figure 1.3. Of the total volume of building sand available in the greater Cape Town area, 23 % had already been used by 2001, just over 51% was assured for use in building, and only 16% was assured for use in concrete. Annual consumption of sand in Cape Town in 2001 was 0.9 Mt. With zero growth in the industry, this gives a resource lifespan of the concrete sand of 35 years, or 21 years with 5% growth **(Cole & Viljoen, 2001)**.

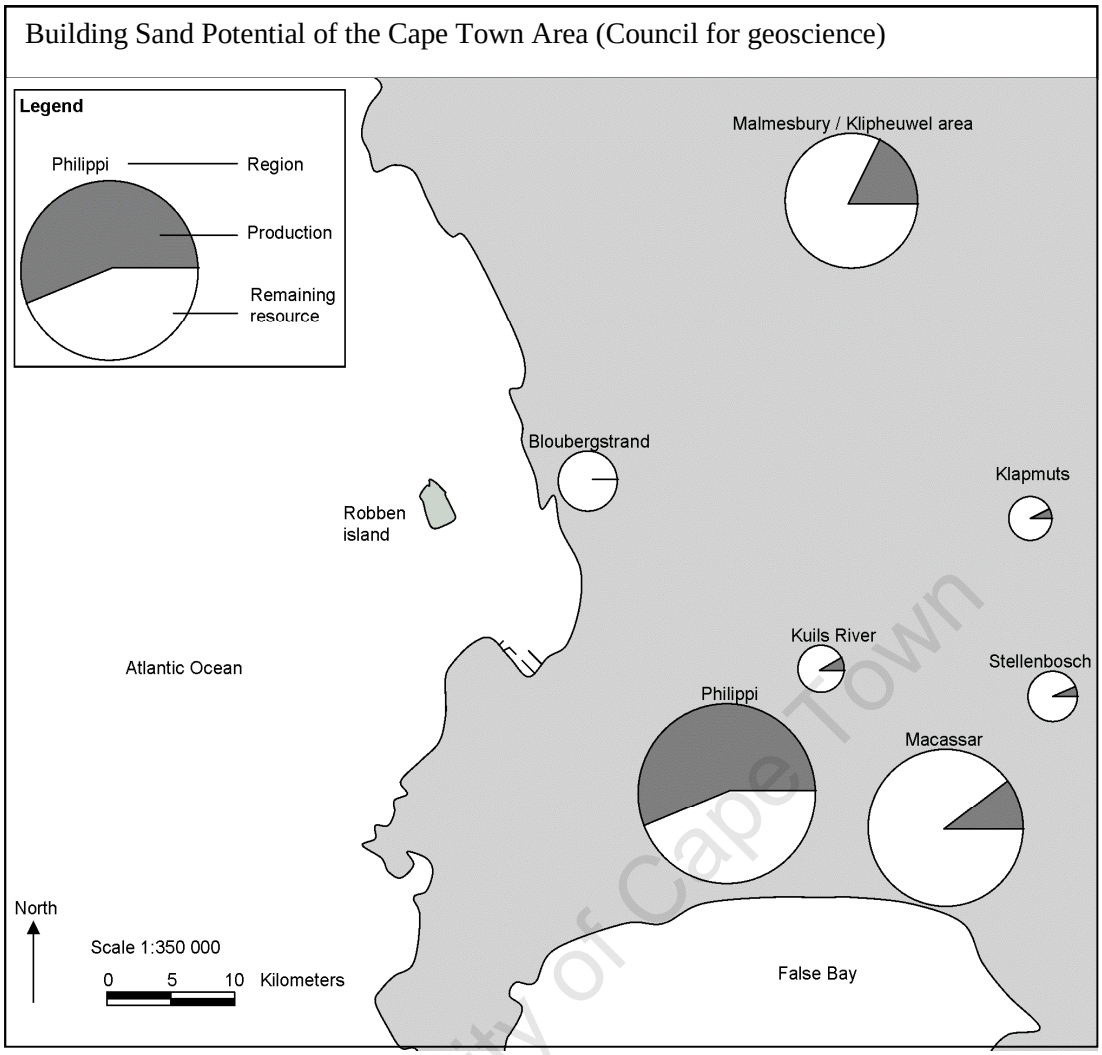


Figure 1.2. Building sand potential of the Greater Cape Town Area (Cole & Viljoen, 2001)

Table 1.2. Building sand resources of the Greater Cape Town Area (Cole & Viljoen, 2001).

Region	Total (Mt)	Production (Mt)	Remaining (Mt)	Reasonably assured resources (Mt)	Reasonably assured resources of concrete sand (Mt)
Philippi	59.67	33.55	26.12	20.0	5.0
Macassar	45.30	4.70	40.60	40.6	4.0
Malmesbury / Klipheuwel	34.20	6.00	28.20	19.0	13.0
Berg River	31.38	0.38	31.00	12.0	4.0
Darling	10.95	0.15	10.80	5.6	3.8
Klapmuts	3.53	0.23	3.30	2.2	1.5
Stellenbosch	4.60	0.20	4.40	0.4	0.4
Bloubergstrand	6.00	0.01	5.99	1.0	*No data*
Kuilsriver	4.46	0.36	4.10	1.5	*No data*
Total	200.09	45.58	154.51	102.3	31.7

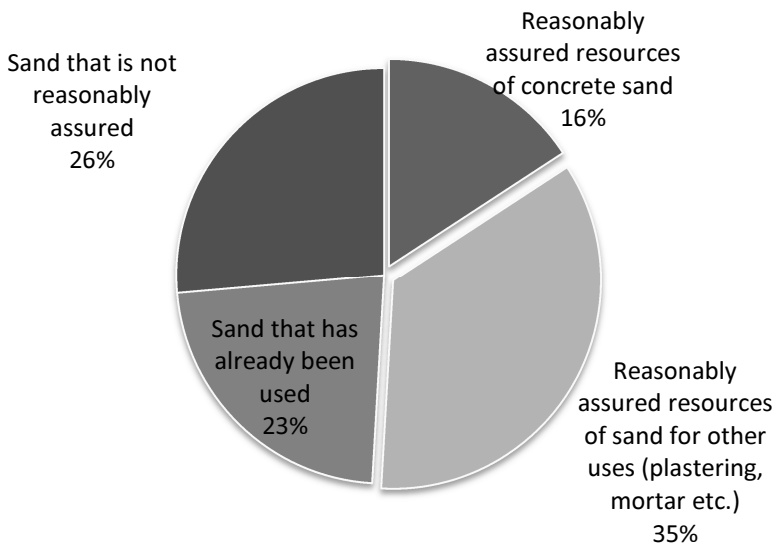


Figure 1.3. Pie chart showing building sand availability and potential usage in Cape Town

These data indicate that if the situation remains as it did in 2001, sand for concrete construction will be depleted sometime between 2021 and 2035. However, it is possible that the rate of use will increase, in which case the sand will be depleted even sooner.

Additionally, the continued mining of sand at Macassar is under threat due to the detrimental effects that it is having on the environment and the opposition of the local community against such practices. Figure 1.4 shows the Macassar dunes, where sand mining occurs, and the surrounding communities. The Macassar community is an ethnically mixed race community, and has resided on the edge of the Macassar dunes for more than 200 years. The community used the dunes for grazing traditionally, although these practices were stopped during the apartheid era. The dunes are currently being mined for building sand, a practice which is opposed by the Macassar community, particularly the older members. They feel that the mining of the dunes is an attack on their heritage. In addition to opposition from the community, there is also opposition to the mining practices from local conservation groups. The dunes are a conservation area; being the largest and most intact dunes in the Cape Flat's dune system, and one of the region's last surviving sections of the coastal dune Sandvelt vegetation. (Ferketic, et al., 2010).

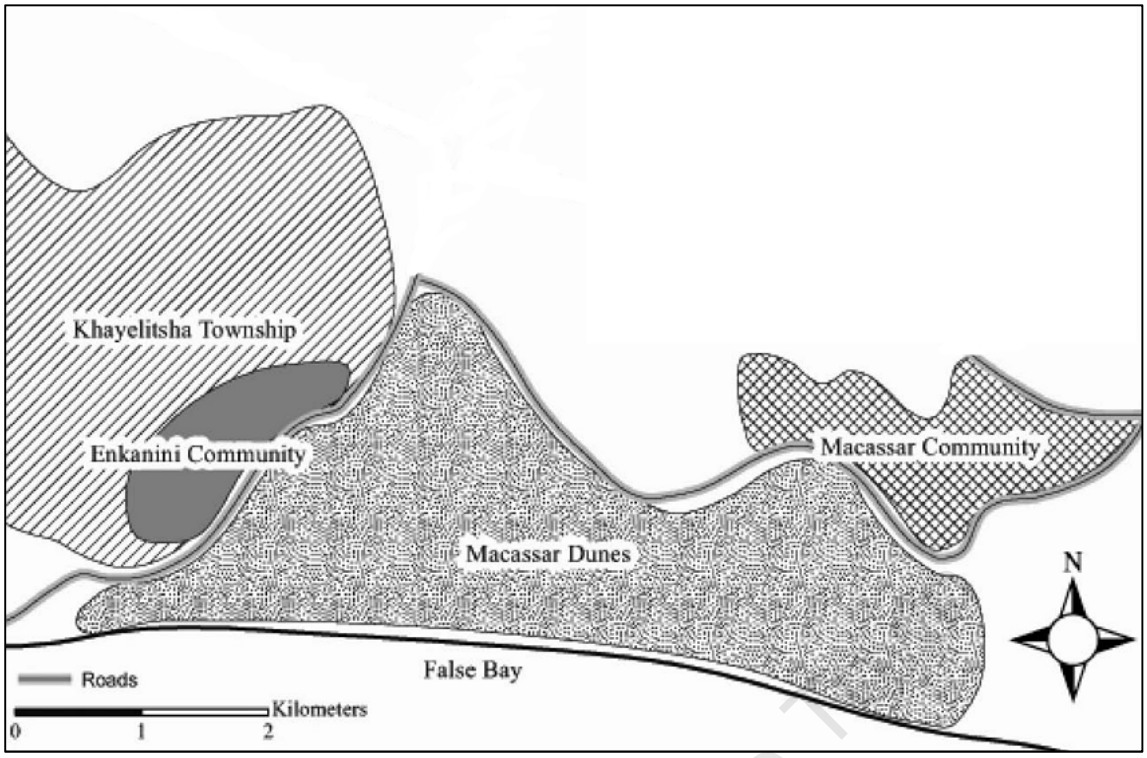


Figure 1.4. Map of the Macassar dunes and surrounding communities in Cape Town (Ferketic, et al., 2010)

The Macassar sand mines are Cape Town's second largest source of sand, and third largest source of concrete sand. There is considerable pressure being applied by various groups to stop mining practices in this region due to the negative environmental and social impact that this practice has. The implications of this are that if mining is stopped in this region, only two major sources of sand will be available to Cape Town, Philippi and Klipheuwel.

One solution to the problem of depleting natural resources and increased transportation distances is the use of manufactured fine aggregates derived from natural sources. These are generally crushed aggregates whereby rocks are blasted and crushed to fine aggregate size. From a qualitative perspective, this is an undesirable solution with regard to the effect it has on the environment; resources are depleted from the source of the rock, energy is used in reducing the rock to fine aggregate size and the material needs to be transported to the construction site. Therefore, alternative sources of sands need to be explored, such as the use of site-derived material.

1.1.2 Energy requirements of concrete

When a conventional house is constructed, the in situ material is excavated and taken away to be disposed of and more material is brought in from off the site to be used to construct the house. The excavation and transportation of materials requires a large amount of energy. Certain materials transported onto the site, e.g. bricks, insulation and cement, require energy in their manufacture. Importing these materials has the added negative effect of depleting the amount of available resources at their source. In contrast, houses built from in situ material make use of the on-site material, thus less material needs to be transported off or onto the site. This means that the energy required to build using in situ materials is less than that of a conventional house, and the resources at the sites where certain materials would be extracted for manufacture are kept intact. This is shown diagrammatically in Figure 1.5.

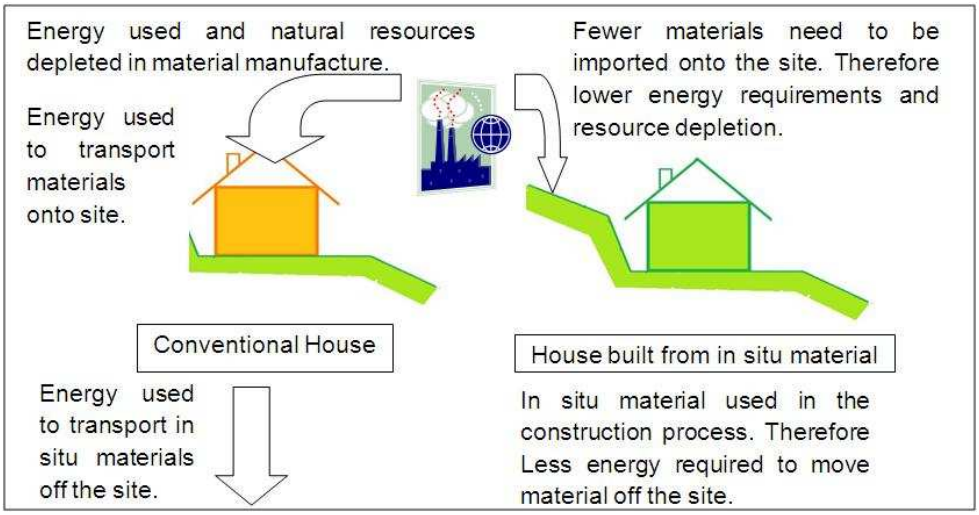


Figure 1.5. Energy required for conventional construction and construction using site-derived material

1.1.2.1 Quantification of energy requirements

The production of Portland cement results in large quantities of CO_2 emissions. For every one tonne of Portland cement that is produced, approximately 1 tonne of CO_2 is released into the atmosphere. In total, the production of cement amounts to approximately 5 - 7% of the world's CO_2 output. Figure 1.6 indicates the annual greenhouse gas emissions by sector (Aitcin & Mindess, 2011). Cement production makes up 7% of the gas emissions. This indicates that minimising the cement content in concrete construction will help minimise the greenhouse gas emissions produced by the construction industry.

A number of studies have been carried out that quantify the energy consumed in construction. One study estimated that a multi-storey reinforced concrete house consumes 8-10 GJ/m^2 (Suzuki, 1995), while another estimates the value to be nearer 3-5 GJ/m^3 in built up areas (Debnath, et al., 1995).

As mentioned previously, transportation of materials is a major consumer of energy. A study has estimated that for every 1km that sands are transported, 1.75MJ/m^3 are consumed (Reddy, 2003). The same study indicates that replacing conventional building sand with natural soil at a ratio of 1:3 reduces energy consumption of mortars by 25%, from 1270MJ/m^3 to 850MJ/m^3. The study concluded that through the use of alternative building materials, in particular the use of soil-cement blocks, energy consumption and embedded energy of the building could be reduced by as much as 50%.

Another study estimates that for every 1kg of concrete produced, 0.983 MJ is required. Of that, 0.028 MJ are produced as a result of fine aggregates, with coarse aggregates using the same (Struble & Godfrey, 1999). Assuming a density of 2400 kg/m^3 for concrete, this study assumes that fine aggregates require approximately 67.2 MJ per cubic meter. This is considerably less than Reddy's study, which estimates the value to be 420 MJ per cubic meter. Another study has produced a model which allows the energy consumption of a specific mix design to be calculated for South African conditions (InEnergy, 2010). This model estimates that 1m^3 of fine aggregate requires 10.4 MJ to be produced but only to the "factory gate". This figure will likely be much greater if the transportation of this material is considered.

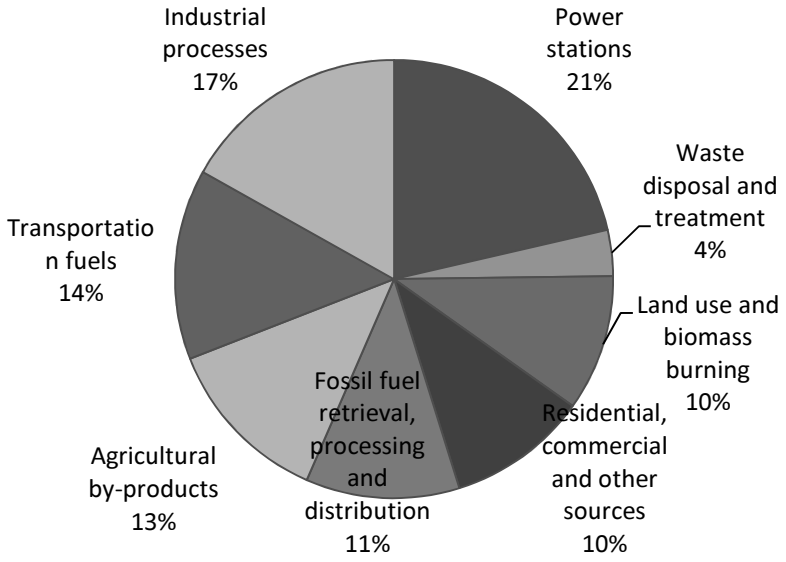


Figure 1.6. Annual Greenhouse Gas Emissions by Sector

It can be seen from the literature that the estimated quantity of energy in concrete of the coarse and fine aggregates vary widely. The C&CI InEnergy model allows the user to input the mix design, and it outputs the CO_2 emissions of that mix design. This is useful in that it allows for a comparison of the CO_2 emiemissionssssions of different mixes. In addition, is has been developed in South Africa and as such is more likely to accurately model materials used in this thesis.

Table 1.3 shows a comparison of mix designs and the corresponding CO_2 emissions in a study done on the use of site-derived soils in Cape Town (Wickins, 2010) (InEnergy, 2010). In order to calculate the CO_2 emissions for site-derived aggregates, the model was modified so that the CO_2 emissions of these materials is zero. In the model, coarse and fine aggregates are grouped together, so in order to reduce the emissions, the value was reduced by the ratio of fine:coarse aggregate.

The table indicates that more CO_2 is emitted when site-derived soil is used. This is because the low workabiliy of concrete made with these materials requires more water, and hence more cement, to be used. This increased cement content offsets the lowered emissions that are gained as a result of using site-derived material.

In this study, one of the soils was found to produce concrete that was 142% of the strength of the control (Wickins, 2010). In this case, the c:w ratio could theoretically be increased and still achieve the same grade concrete. If it assumed that the relationship between strength and c:w is linear, the c:w can be increased to 1.17 (w:c of 0.85). The water demand is likely to remain the same, so the cement content will be reduced. The emissions produced by this mix are shown in the table. In this case there is a marked decrease in emissions, a reduction of approximately 20% when compared to the control. This indicates that in order for the use of site-derived soil to reduce the emissions of concrete, the soil must allow for a higher w:c ratio of the mix to produce the desired strength.

This model does not take into account the transportation costs of the aggregate and concrete onto site. Therefore, while the model gives an indication of the CO_2 emissions produced in the manufacture of these concretes, it does not provide a complete picture. The quantification of the energy costs of the transportation of material onto and off a site fall outside the scope of this work, but it is logical to assume that by using site-derived materials instead of off-site materials the energy cost of transportation would be reduced.

Table 1.3. Effect of using site-derived soil on carbon emissions of concrete (Wickins, 2010) (InEnergy, 2010)

Mix (w:c)	W:C	Fine Aggregate (kg)	Coarse Aggregate (kg)	CEM I (kg)	Water (l)	CO_2 Emissions (kg/m^3)
Control; Imported sand	0.6	889	1050	300	180	316.7
Site-derived soil	0.6	889	1050	333	200	334.7
Site-derived soil; theoretical	0.85	889	1050	235	200	248.1

1.1.3 Economic sustainability of concrete

A group of scientists, economists and business people, known as the Factor Ten Club, stated in 1994 that a nation could achieve a tenfold increase in resource efficiency through a 90% reduction in its energy and materials within just one generation (Mehta, 2002). This means that the concrete industry would increase its resource efficiency by a factor of five if the service life of built structures were 250 years instead of the conventional 50 years. It is beyond question that it is wasteful to rebuild the entire world's civil infrastructure every 50 years (Aitcin & Mindess, 2011).

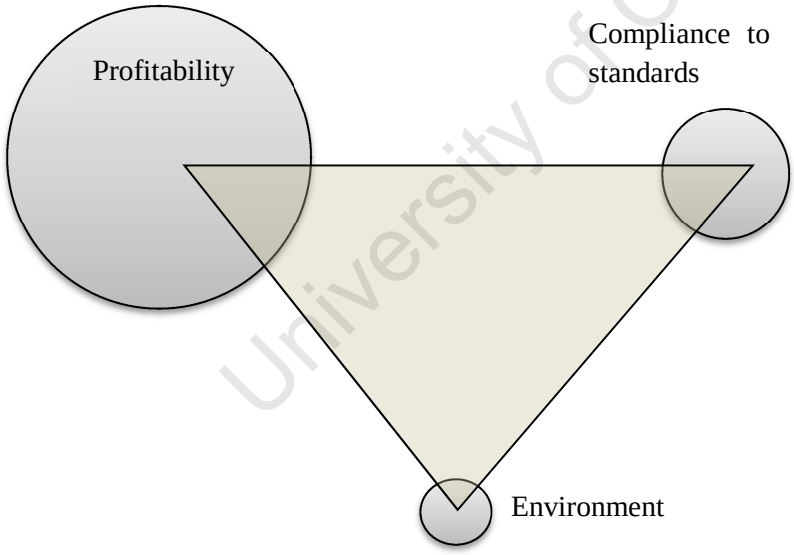


Figure 1.7. Schematic representation of the concerns of the cement and construction industries during the 20th century (Aitcin & Mindess, 2011)

Figure 1.7 shows a schematic of the concerns of the cement and construction industries during the 20th century. Companies have been primarily focused on financial gain and meeting construction standards. Predominantly the environment has been a minor concern. This has led to a situation where any change within the industry is slow and hard fought.

Ultimately, change needs to be realised within the industry, with a much greater focus on sustainability. This is shown in Figure 1.8, which describes an ideal situation with goals that are realistic and attainable in a short period. Industry will still need to be profitable, as indicated in the diagram, while the concerns of sustainability will have greater influence. Sustainability need not be distinct from profitability, although the profits may take time to materialise.

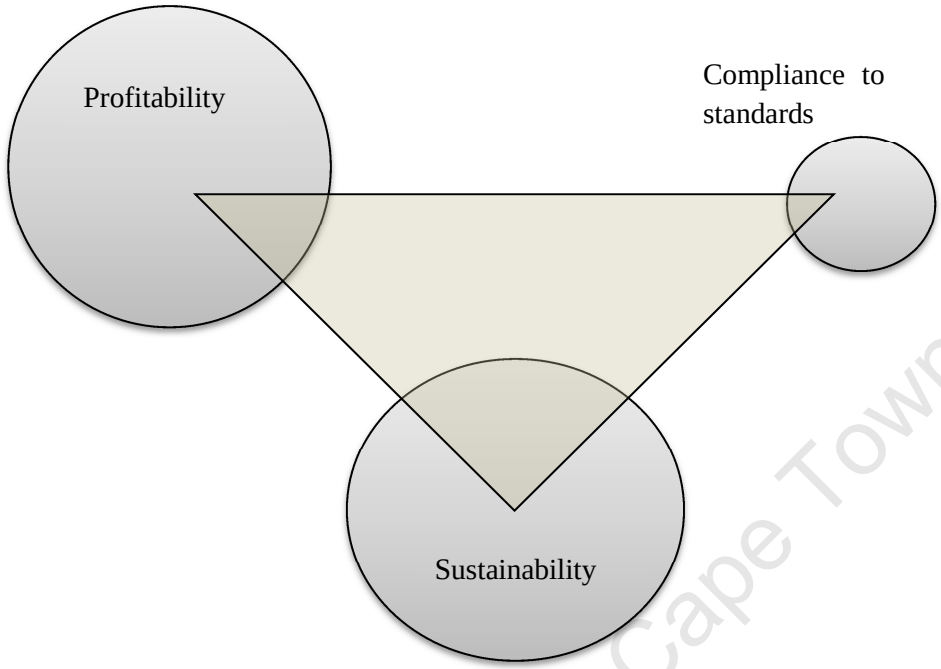


Figure 1.8. Idealised concerns of the concrete industry in the 21st century (Aitcin and Mindess 2011)

1.1.4 Steps to sustainability

Aitcin and Mindess (2011) list a number of approaches that can be taken in order to make concrete more sustainable:

1. The use of higher strength concretes
2. Making concrete more durable
3. Replacing Portland cement with supplementary cementing materials.
4. Use of fillers. These are materials that do not necessarily react chemically with Portland cement but are still beneficial through physical action.
5. Manufacturing Portland cement more efficiently
6. Using waste material as fuel in the production of cement
7. Using industrial wastes and recycled concrete as aggregate sources
8. Finding ways to capture or sequester CO_2 emissions
9. Using less water
10. Improving structural design and building codes

In the Greater Cape Town area, sand for concrete construction is expected to be depleted sometime between 2022 and 2036, or sooner if sand mining is stopped at Macassar. This indicates that point 7 in the list above (Using industrial wastes and recycled concrete as aggregate sources) is particularly relevant in the Cape Town context.

This thesis is concerned with the use of site-derived fine material as aggregate. The advantages and disadvantages of using this material, with regard to sustainable construction, are shown in Table 1.4.

Table 1.4. The advantages and disadvantages of using site-derived fine material as concrete aggregate

Advantages (assumed)	Disadvantages (assumed)
- Reduce the amount of sand that needs to be mined in the Cape Town area. This will have positive environmental and social consequences for the region. - Reduce the amount of material that needs to be transported off a site and onto a dump. - Filler material being used (Fine material causing fine filler effect) - Supplementary cementing material (Clays reacting pozzolanically with calcium hydroxide) - Increased durability (As a result of lower porosity due to an increase in fines in the fine aggregate)	- Decreased durability (Possible increase in shrinkage and porosity as a result of clay material and high water content) - Increased water and cement content (As a result of the high water demand of the aggregate)

1.2 Aim of the investigation

It has been predicted that current sources of natural building sands in the greater Cape Town area could be depleted sometime between the years 2022 and 2035. One of the largest sand mines in the area, the Macassar mine, is currently under threat due to the detrimental effect it is having on the environment as well as the negative effect it has on the local community. By utilising natural site-derived fine soil, it is proposed that the amount of material that needs to be mined from traditional sand mines will be reduced.

It is also proposed that by utilising site-derived soils that would otherwise need to be transported off a construction site; the waste produced through construction will be reduced.

In order for site-derived soils to be used as concrete aggregate, it is critical that their effect on the performance of concrete be investigated.

The aim of this work is to investigate the suitability of site-derived soils for use in concrete as fine aggregate. The suitability is to be investigated in terms of the effect that these soils have on the properties of concrete. It is expected that using site-derived materials will have a negative impact on the workability of concrete. The magnitude of this impact is to be investigated in this work, and through the investigation methods of mitigation are to be identified.

1.3 Objectives, scope and limitations of the investigation

The main objective of this work is to investigate the properties of site-derived soils in the greater Cape Town area and their effect on the performance of concrete when they are used as fine aggregate.

The specific objectives of the research are to:

- Review the current literature on the subject of fine aggregates and their effect on concrete performance.
- Investigate the range of soils that occur in the greater Cape Town area and collect samples of them.
- Evaluate the properties of the collected soils.
- Make concrete with these soils, utilising them as fine aggregate, and evaluate the properties of this concrete in terms of:
    - Workability
    - Strength
    - Drying shrinkage
    - Durability
- Evaluate what properties of the soils most affect the performance of concrete made with this material as fine aggregate.

From the findings of this research, this work aims to determine what soil properties need to be measured in order to predict the performance of concrete made with the soil as fine aggregate. It also aims to propose a process whereby these materials can be best utilised.

The scope of this work is to investigate the above-mentioned concrete properties by using a single water-to-cement ratio, but varying the water content of the mixes in order to achieve the desired workability. In each mix, the only variables are the water content, cement content (although the water-to-cement ratio will remain constant) and the fine aggregate type.

The limitations of the study are:

- Water reducing admixtures, such as super plasticisers, are not used to achieve desired workability. Although a valuable tool that would be beneficial in minimising the water and cement content of concrete made with site-derived soil, the added variability that these admixtures introduce into the concrete cause the use of these materials to fall outside the scope of this thesis. It is hoped that further research into this topic will include the use of these materials in their scope.
- It is acknowledged that the use of crusher sands is an alternative solution to the problem of depleting quantities of natural aggregates. Much work has been, and is still being done on this subject, particularly by David Fowler in the USA. However, crusher sands have not been studied in the scope of this thesis. It is thought that the increased energy cost of these sands, in terms of beneficiation and transport, make these sands a less desirable solution to the problem than the use of natural, site-derived aggregates.

1.4 Organisation of this thesis

The properties of the cement, coarse aggregate and water used in the concrete mixes are discussed in chapter 0. These materials are kept constant for each mix, and have therefore been discussed in the same chapter. Also discussed is the concrete mix design, mixing, casting and curing.

The influences that fine aggregates have on the performance of concrete are discussed in chapter 2. This chapter then discusses the soils that were collected for this work and the tests that were carried out on these soils.

The influences that the various soils have on the water demand of concrete are discussed in chapter 4.

The compressive strength characteristics of concrete made with site-derived soils are discussed in

chapter 5. This chapter also discusses the potential of pozzolanic activity in site-derived soils when used as fine aggregate. Details of shrinkage behaviour of the various mixes are discussed in chapter 6. The durability performance of concrete made with site-derived soils is discussed in chapter 7. The results from the testing are analysed critically with regard to the aims of the research, and recommended guidelines are discussed in chapter 8. Chapter 9 is a summary of the work carried out and the findings.

Chapters 4, 5, 6 and 7 consist of an introduction to the topic and its relevance, a methodology section where the method of investigation is discussed, a results section where the results from the investigation are provided, discussed and compared to results in the literature when relevant, and finally a conclusion where the findings of the investigation are discussed generally.

There is no specific literature review chapter in this work. Rather, the literature is discussed at the beginning of the chapter, or else wherever relevant. Literature is primarily discussed in chapters 4, 5, 6 and 7.

1.5 **Definition of terms**

To provide clarity, this section defines the meanings of terms as they are used in this thesis.

Aggregate: Material used in concrete that is not cementitious, an extender or water.
ASR: alkali silica reaction in concrete.
CH: An abbreviation for calcium hydroxide, a by-product of cement hydration.
Clay: The fraction of a fine aggregate smaller than 5µm.
Coarse aggregate: Aggregate retained on a 4.75mm sieve.
Fine aggregate: Aggregate passing a 4.75mm sieve.
Microfines content: The fraction of a sand or soil that passes a 75µm sieve.
Paste content: Cement content in a concrete mix.
Sand: A natural or manufactured commercial fine aggregate.
Silt: Material smaller than 20µm.
Soil: Site-derived material that can be potentially used as a fine aggregate.
TGA: An abbreviation for Thermogravimetric Analysis.
Total Fines: The sum of the microfines content and the cement content in a concrete mix.
Water content: The mass or volume of water per cubic meter of concrete.
Water demand: The amount of water that needs to be used to achieve a 75mm slump in concrete.
W/C: The water-to-cement ratio of concrete.
XRD: An abbreviation for X-Ray diffraction

2 Materials and Concrete Mixes

In this chapter, the general properties of the materials used in the production of concrete for this work are discussed. The chosen materials are commonly used in construction practice in the greater Cape Town area. Also discussed are the concrete mix design, mixing, casting and curing.

2.1 Materials

2.1.1 Cement

Two cement types were considered: CEM I and SureBuild, a local brand of cement (CEM II B-M). The advantages and disadvantages of each cement type, with regard to this thesis, are discussed in Table 2.1.

Table 2.1. Discussion of cement types

Property	Cement Type	Discussion
Use in industry	CEM I	This cement is no longer widely used in industry due to unavailability.
	SureBuild	Commonly used in concrete and mortar in the construction industry.
Use of Extenders	CEM I	This cement does not use extenders. This is beneficial for the purposes of research, since it minimises the number of variables in the concrete mix.
	SureBuild	This cement contains GGCS and limestone. This material is beneficial to the properties of concrete in that it slightly improves workability; increases later age strength of the concrete, refines pore structure, reduces porosity of the concrete and prevents or retards alkali reactions with aggregates. This binder varies by region, and SureBuild in the Cape Town area is likely to contain different constituents than SureBuild used elsewhere The use of this binder for the concrete has the disadvantage of introducing additional variables into the concrete mix in the form of the extenders present.

SureBuild was decided upon as the most suitable cement type. Since it is widely used in the construction industry, it will better simulate normal construction practices. Additionally, it improves workability of a concrete mix, when compared to CEM I.

If any of the aggregates used are alkali reactive, the use of SureBuild will lessen any reactions that may occur.

The composition of SureBuild cement (CEM II B-M) is as follows;

- 80-94% clinker
- 21 % (minimum) Corex slag
- 0-5% other constituents, including limestone

2.1.2 Coarse aggregate

2.1.2.1 Natural coarse aggregate in Cape Town

The majority of coarse aggregates used in South Africa are derived from crushed natural stone, or rock (Fulton, 2009). As a result, the effect of these aggregates on the properties of concrete has been thoroughly studied, and much information is available in the literature on this subject.

The origin and formation of the aggregate has a major effect on its properties, and therefore has an effect on the properties of the concrete produced with it. There are three major categories of rock (Kehew, 2006):

1. Igneous rocks. These are formed when magma, or occasionally lava, hardens. The rate of this hardening has a large effect on these rocks; a rapidly cooling magma, or in this case more likely lava, will not have time to crystallize fully. As a result the rock is likely to be glassy, with few crystals. On the other hand, a slow cooling magma will have more time to form crystals, and are likely to be highly crystallized. Also, particularly in rapidly cooling lavas, air in the lava can become trapped, as the lava hardens too quickly for it to escape. As a result, rocks formed this way often have many air voids in them (Kehew, 2006). As other types of rocks are formed from igneous rocks, the composition of these rocks is particularly important (Fulton, 2009). The total silica content is often used to classify igneous rocks chemically. The classification is shown in Table 2.2.
2. Sedimentary rocks. These form as a result of sedimentation of the broken down product of other rocks. The sedimentation usually takes place under water. The particles of the broken down rock can either be loosely joined, or cemented together (Kehew, 2006). Since sedimentary rocks are made from older rocks, their chemistry is usually simpler, and they are often more stable than the rock from which they were derived. (Fulton, 2009)
3. Metamorphic Rocks. Metamorphic rocks are formed through the transformation of other rock types. The transformation is usually due to high temperatures or high pressures (Kehew, 2006). It has been found that metamorphic rocks formed from sedimentary rocks have improved strength and durability than the original rock, while those formed from igneous rocks show little difference. (Fulton, 2009)

Table 2.2. Classification of Igneous Rocks (Dana, et al., 1985)

Classification	**% SiO_2**	**Examples**
Acid	>63	Granite, rhyolite
Intermediate	52-63	Andesite, dacite
Basic	45-52	Gabbro, basalt
Ultrabasic	<45	Picrite, komatite
Alkalic	5-15 % alkali (K_2O + Na_2O)	Phonolite, trachyte

With regard to the rocks found in Cape Town, there are three major types (Fulton, 2009), which are discussed below and the area where they occur is shown in Figure 2.1.

1. Table Mountain Sandstone. This name is inaccurate, since this rock consists of both sandstone and quartzite. This rock can produce favourable properties in concrete such as high strength and elastic modulus, although when beneficiated from certain sources can produce unfavourable properties such as undesirable alkali aggregate reactions. However, this material

is known to be highly variable, and in some cases produces concrete with high shrinkage and low modulus of elasticity. (Fulton, 2009)

2. Greywacke, also known as Malmesbury shale. This is a metamorphic rock, formed when the Cape Granite intruded into the original Malmesbury rocks. This rock is highly alkali reactive, and steps must be taken to minimise the negative effects that will result if this stone is used in a normal concrete mix (Fulton, 2009).
3. Cape Granite. While granite normally serves as a good aggregate, the granite in Cape Town is often highly weathered. The granitic materials have been replaced by clayey materials, specifically illite ($(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$) and kaolinite ($Al_2Si_2O_5(OH)_4$). Illite is not expansive, while kaolinite is slightly expansive. Neither of them is highly chemically active and only change structure when heated greatly. Metakaolin is formed by heating Kaolinite and is used as a cement extender, although kaolin does not have the same effect (Bezard, 2009). Cape granites have been found to exhibit slight alkali reactivity and appropriate precautions may need to be taken (Fulton, 2009).

2.1.3 Coarse Aggregate used in testing

For all the concrete mixes, the same coarse aggregate – greywacke – was used. This aggregate is commonly used in the Cape Town area (see Figure 2.1) and as such, is readily available and best simulates normal construction practice in the region.

Using a single type of coarse aggregate ensured that any variations in concrete properties were not due to this material.

This aggregate is known to be alkali reactive. This was taken into consideration during the mix design process – a cement with a low alkali content was used (SureBuild), and the w/c ratio was kept sufficiently high to mitigate any alkali reactions that may occur with the coarse aggregate.

A typical grading curve for the coarse aggregate is given in Figure 2.2.

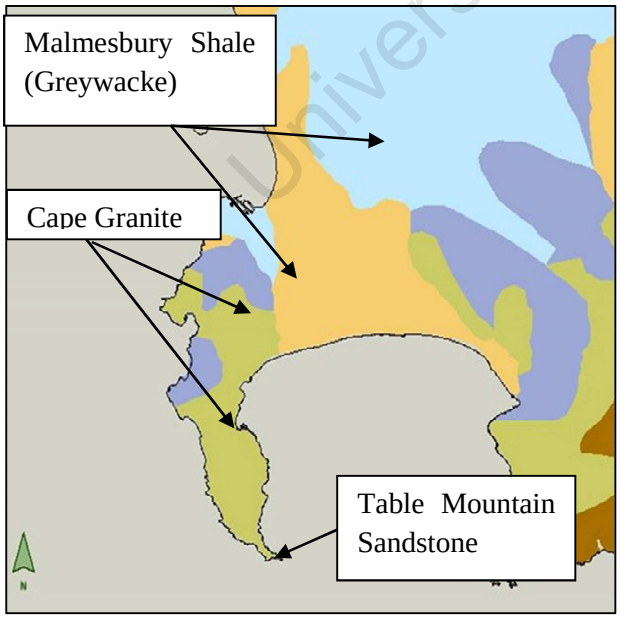


Figure 2.1. Simplified Geology of the Western Cape (AGIS 2010)

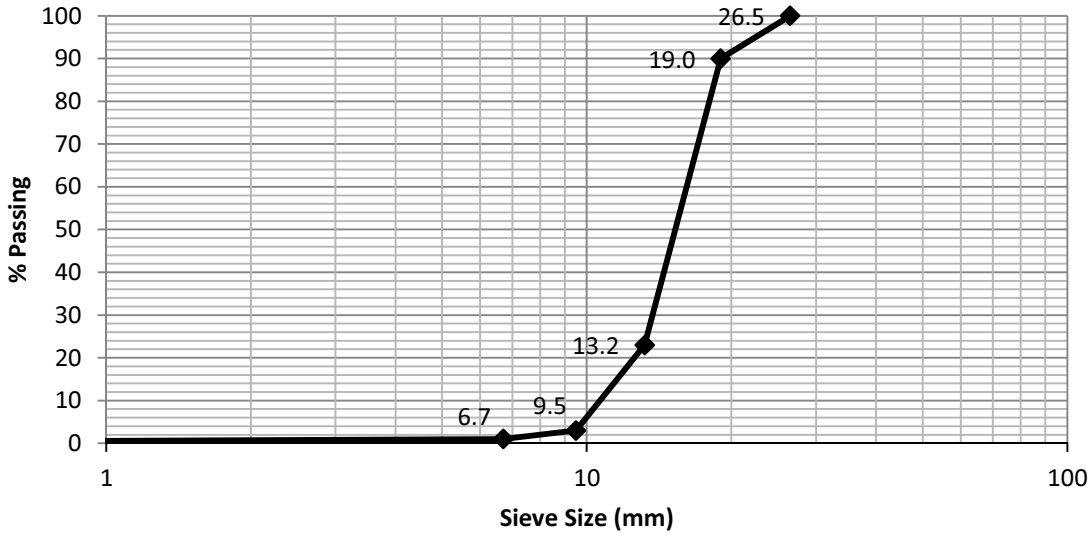


Figure 2.2. Grading curve for 19mm greywacke

2.1.4 Fine Aggregate

For each batch of concrete, a different fine aggregate was used. The beneficiation, testing and properties of the fine aggregates used are discussed in detail in chapter 3.

Only material passing a 4.75mm sieve was used as fine aggregate, in accordance with the SANS 1083 definition of fine aggregate.

2.1.5 Water

Ordinary, potable, tap water was used in all the mixes.

2.2 Concrete Mixes

2.2.1 Mix design

In this work, the only variables in the concrete are the sand type, the amount of water and the cement content. For all the concrete mixes, the same w/c ratio was used. The aim of this was to ensure that any variations in the properties of the concrete were because of the fine aggregate used and not any external factors. A w:c ratio of 0.7 was used to ensure low alkali content and hence mitigate any alkali aggregate reactions that may occur because of the coarse aggregate, which is known to be alkali reactive.

No admixtures were used, as there were concerns that the admixtures may react with the clays. By not using admixtures, any effects that clayey soils had on the properties of concrete could be attributed to the clay itself and not a combination of clay and an admixture. In practice, water-reducing admixtures could be used to combat the problem of workability.

The following mix design was used (per m^3 of concrete):

Table 2.3. Concrete mix design

Parameter	Mass (kg)
W/C	0.7
Water	180
Cement	260
Stone	1080
Sand	900

2.2.2 Mixing

The concrete was mixed in a 20L mixer, shown in Figure 2.3. The materials were weighed to an accuracy of 0.1g and then added to the mixer in the following order: Coarse aggregate, fine aggregate and then binder. The material was dry mixed for one minute, after which the water was added over the period of approximately 30 seconds. The concrete was mixed for another minute to ensure a uniform mixture.

A slump test was performed in accordance with SANS 862-1:1994. The mix was then adjusted by either adding aggregate or water, as discussed in section 4.2 in order to achieve the desired workability.

Between each mix, the machine was cleaned using tap water to ensure that there was no contamination between the mixes.

Figure 2.3. Mixer used to prepare concrete

2.2.3 Casting

For each batch, 17 x 100mm cubes were cast for strength determination and durability index testing, as well as 2 x (300mm x 50mm x 50mm) prisms for shrinkage testing.

Compaction was carried out using a vibrating table until the concrete was fully compacted, after 15-20 seconds.

2.2.4 Curing

The concrete was cured in the moulds for the first 24 hours. During this time, it was kept moist by placing a damp hessian sack over the moulds.

After 24 hours, the concrete was removed from the moulds and cured in a water bath at a temperature of 23 ± 1^{o}C.

3 Fine Aggregates

With regard to the physical properties of aggregates, fine aggregates are those with particles smaller than 4.75mm. These materials can be particularly effective at altering and modifying the concrete microstructure (Alexander & Mindess, 2005). This chapter discusses the effects that fine aggregates have on the properties of concrete. It then discusses the soils in the greater Cape Town area, and the soils that were collected for this research. Finally, it discusses the tests that were performed on the collected soils, and the results of these tests.

3.1 The effect of fine aggregates on the properties of concrete

3.1.1 Effect of Grading

The grading of fine aggregates used in concrete has an effect on the water demand of the concrete, its porosity and its workability. Particles of the fine aggregate smaller than 300µm have the greatest effect on these properties. It is generally assumed that the fine particles greater than this size contribute only by adding bulk and a level of coarseness to the concrete mix. (Fulton, 2009)

In terms of workability, fine aggregate lacking sufficient particles smaller than 300µm (fines) tend to cause concretes made with them to be non-cohesive and bleed excessively. On the other hand, fine aggregates with excess fines tend to cause the concrete to be sticky and consequently reduce the concrete's workability. (Fulton, 2009)

The very fine fraction of the fine aggregates, those particles smaller than 75µm (Ashman & Puri, 2002), absorbs and retains a relatively high quantity of water. This has both favourable and unfavourable effects on the concrete. By retaining a lot of water, this fraction of the aggregate controls the bleeding of the concrete and the negative effects associated with it, such as reduced strength and increased permeability. However, if an excess amount of particles smaller than 2µm is present in the concrete, it will have a higher water requirement. The consequences of this are excessive shrinkage in the concrete. (Fulton, 2009).

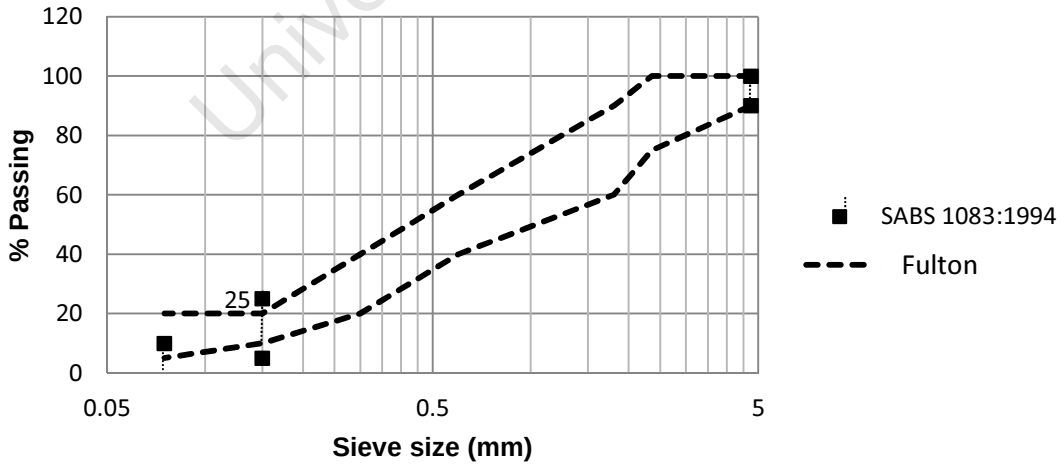


Figure 3.1. Requirements for fine aggregate grading. (Fulton, 2009), (SANS, 2006)

The grading of the fine aggregate in the concrete mix also has an effect on the ITZ (interfacial transition zone), which in turn has an effect on the porosity. The ITZ tends to have a relatively greater porosity than the porosity of the concrete paste (Scrivener & Nemati, 1996) (Aquino, et al., 1995).

There is evidence that very fine fillers, such as non-reactive fine aggregates and pozzolanic clays, alter and refine the ITZ microstructure, resulting in an increased strength of the concrete (Alexander & Mindess, 2005).

Various guidelines have been drawn up to ensure that fine aggregates used in concrete are adequately graded. Figure 3.1 shows the comparison of two guidelines graphically. SABS specifies three grading windows through which that aggregate must pass, while the CnCI offers a grading envelope.

In general, the influence of grading increases with decreasing cement content (Fulton, 2009). In other words, grading will have little influence on the workability of concrete that has a high cement content, and vice versa.

3.1.2 Effect of Clay Content

3.1.2.1 Effect of activity of clay

In general, clays are assumed to be made up of particles smaller than 2 µm diameters (Ashman & Puri, 2002). When this classification is used, the effect of clay on the properties of concrete will be the same as the effect mentioned in the section "Grading". However, clays are distinct minerals, and classifying them according to size does not necessarily provide a complete or accurate picture (although many types of clay are smaller than 2µm.) The major property of clays that affects the properties of concrete is their activity. (Fulton, 2009). The activity of the clay governs how much the clay shrinks or swells when dried or wetted. Clay with high activity is likely to cause the concrete to undergo excessive shrinkage or swelling.

Tests have been carried out that indicate that a higher proportion of clay, as long as it has a low activity, in the fine aggregate produces a higher strength concrete. This effect is likely due to the fine particles filling the spaces between the coarser aggregate and impeding the flow of water in the concrete mix, as well as improved interfacial transition zone (ITZ) performance. This reduces bleeding. (Fulton, 2009)

In addition to the problems caused by active clays, specifically shrinkage and swelling, certain clay minerals break down when exposed to a high alkalinity, such as that experienced in hydrating cement (Gaucher & Blanc, 2006). An example of one such clay is montmorillonite, also referred to as smectite. Montmorillonite is a widespread clay, with the chemical formula $(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2 \cdot nH_2O$ (Mineralogy Database, 2006). It is the main constituent of bentonite and is highly active. It occurs in the Helderberg mountains around Cape Town (Department of Minerals and Energy, South Africa, 2004). When montmorillonite is exposed to a high pH (in other words a high availability of OH^- ions), the following reaction occurs (Gaucher & Blanc, 2006):

$$Na_{0.33}Mg_{0.33}Al_{1.67}Si_4O_{10}(OH)_2 + 4.68OH^- + 2H_2O \leftrightarrow 0.33Na^+ + 0.33Mg^{2+} + 1.67Al(OH)_4^- + 4HSiO_3^-$$

The right hand side of this equation represents an expansive paste, or gel, that is deleterious to concrete. The reaction equation indicates that for every mole of montmorillonite involved in the reaction, 4.68 moles of OH^- are consumed. $1m^3$ of concrete containing 300kg of Portland cement will produce 2400 moles of OH^-, which means that if sufficient quantities of montmorillonite are present in the concrete 450 moles of OH^- will be consumed in the production of deleterious by products. These OH^- ions will not be able to be used in the cementitious hydration reactions. Therefore, in addition to producing deleterious by products, montmorillonite will retard the rate of cement hydration.

Illite and kaolinite are very similar in terms of water absorption and activity; they both have low absorption and activity properties. Smectite is known to be highly active, and therefore has a greater deleterious effect on the properties of concrete (Norvell, et al., 2007).

3.1.2.2 Effect of pozzolanic reactions

Clays have been used as pozzolans for thousands of years, and are still used in concrete construction worldwide (He, et al., 1995). Pozzolans are materials with siliceous content, either amorphous or crystalline, that react with calcium hydroxide (CH) in the presence of water to form cement hydration products (Walker & Pavia, 2011).

The activity of a pozzolan refers to the rate at which its reaction with CH takes place, as well as the pozzolan's ability to react. The activity of a pozzolan is dependent on a number of characteristics including (Walker & Pavia, 2011):

1. Chemical and mineral composition
2. The type and quantity of its active phases
3. The surface area of the pozzolan
4. The ratio of lime to pozzolan
5. The water content of the mix
6. The curing time
7. The temperature at which the mix is cured

Amorphous pozzolans are more reactive than crystalline ones. Indeed, at least one researcher, Walker (2011), has found that amorphousness governs pozzolanic activity more than any other factor. The same paper indicates that increasing amorphousness and decreasing particle size of the pozzolan result in an increase in strength. It was also found that chemical composition of the pozzolan is not instrumental in pozzolanic activity or strength (Walker & Pavia, 2011).

In order for a clay to be considered a natural pozzolan, the SiO_2+Al_2O_3+Fe_2O_3 content must be greater than 70% by weight and must have less than 10% weight loss on ignition (ASTM C618-91, 1991). Most clays, including kaolinite and montmorillonite, have SiO_2+Al_2O_3+Fe_2O_3 contents exceeding 80%. (He, et al., 1995). It has been found that heating clays by temperatures of between 650^{o}C and 960^{o}C significantly increases the effect of the pozzolanic reactions. Increases in 28 day compressive strength of 126% for kaolin clay and 162% for montmorillonite when heated have been observed (He, et al., 1995). The same study concluded that calcination (heating) of clays is necessary for pozzolanic reactions to occur. Investigations done on using metakaolin as cement replacement have indicated that up to approximately 30% replacement porosity decreases, but increases at greater fractions. It is suggested that this is partly due to pozzolanic reactions between the metakaolin and the CH in the concrete paste, and partly due to the fine filler effect of the fine clay particles (Khatib & Clay, 2003).

Pozzolanic materials are widely used to control deleterious ASR (Fulton, 2009). Clays have been successfully used in concrete as a pozzolanic material which reduces the deleterious ASR reaction between the cement paste and concrete aggregate. However, in order for the clay to be effective in this regard, it was found that it needs to be heated first, or calcinated. When clay is heated, the crystalline structure of the clay is broken down and an alumino silicate structure is formed. It is this structure that gives clay its pozzolanic properties (Turanli, et al., 2003).

As clay is most effective as a pozzolanic material only when it is heated, the literature indicates that the effectiveness of clay in its natural state as a pozzolanic material may be minimal. However, there is still value in looking into any pozzolanic reactions that may be occurring as a result of clays in the

soil. One way of investigating the occurrence of pozzolanic reactions is through the use of thermogravimetric analysis. CH ($Ca(OH)_2$) breaks down (dehydroxilates) at a temperature of between 520-580^oC. Since pozzolanic reactions consume CH and form CSH, concrete that has had pozzolanic reactions occur within it will show less mass loss at the dehydroxilation temperature than a sample that has not had pozzolanic reactions occur (Paya, et al., 2003).

In general, the effect of pozzolanic reactions is small in comparison with the overall strength of concrete. This is shown in Figure 3.2. This figure indicates that cement hydration contributes to the majority of the strength of concrete. The effects of microfillers have a lesser but still significant effect, while pozzolanic reactions have an overall small influence on strength.

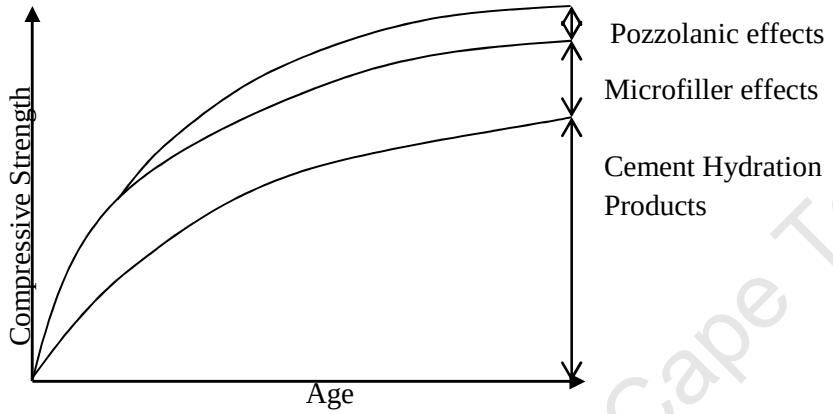


Figure 3.2. The development of concrete strength with time, showing the influence of microfillers and pozzolans (Alexander & Mindess, 2005)

3.1.3 Effect of Organic Matter

Organic matter has the effect of retarding the hydration of cement and usually leads to a reduction in strength of concrete (Alexander & Mindess, 2005).

There are three broad categories of organic matter in soils; humic, nonhumic and organic contaminants (Tremblay, et al., 2002). The nonhumic fraction consists of dead organisms and is made up of cellulose, hemicelluloses, sucrose, starch, proteins, amino acid, fats, waxes, resins, and organic acids (Tremblay, et al., 2002). The humic portion is made up of compounds formed when these materials are broken down by microorganisms and consists of alkanes, fatty acids, humic acid, fulvic acid and humis. The final category, organic contaminants, is broad and consists of material not falling into the other two categories. An example of such a contaminant is manufactured material such as fertilizer.

The various effects of these materials on the properties of concrete are discussed below (Tremblay, et al., 2002). The effect of organic material on the properties of concrete was investigated by making a concrete mix and contaminating the fine aggregate with specific compounds. The concentrations of calcium (Ca), sodium (Na), potassium (K) and sulphate (SO_4) were measured using atomic absorption techniques (Ca, Na, K) and ion chromatography (SO_4). The reasoning behind measuring the fractions of these particular chemicals is as follows; Sodium and potassium are the main components of the cement solution. The formation of ettringite consumes calcium and sulphate, so high concentrations of these indicate a low level of hydration. Therefore, the most important characteristics to measure with

regard to the hydration of cement are the concentrations of calcium and sulphate (Tremblay, et al., 2002).

The chemical reaction for the formation of ettringite is as follows (Merlini, et al., 2008):

$(CaO)_3Al_2O_3 + 3CaSO_4 + 32\ H_2O \rightarrow (CaO)_3(Al_2O_3)(CaSO_4)_3 \cdot 32\ H_2O$

Or, using cement chemistry notation

$C3A + 3\ CaSO_4 \rightarrow$ ettringite

In addition, the pH of the solution was measured and the samples were viewed under a scanning electron microscope. The findings of the research are summarized below (Tremblay, et al., 2002):

- Acetic Acid – This acid occurs naturally as an oxidation product of glucose. It has a pH of approximately 4. When mixed with cement (such as Portland) and water, it neutralizes the pH of the mixture. It has been found that if enough of this compound is present in the aggregate it will reduce the pH to 7. At this low pH, no cementitious reaction occurs. The samples containing acetic acid were found to have high levels of both Ca and SO_4, Indicating that the hydration of the cement was not occurring.
- Benzoic acid – This acid lowers the pH, but to a lesser extent than acetic acid. As a result, the concentrations of Ca and SO_4 are lower in samples contaminated with benzoic acid.
- Tannic acid – This acid has less effect on the hydration of cement than acetic and benzoic acid.
- Cellulose – This compound does not lower the pH, but does prevent the hydration of cement from occurring, indicated by a high concentration of Ca and SO_4 in the samples contaminated with cellulose. This indicates that a chemical reaction occurs between the reactants and cellulose, preventing ettringite from forming.

It has been found that these chemicals have the greatest effect on the properties of concrete with regard to organic compound contamination.

3.1.4 Effect of Particle Shape

The water demand of an aggregate is proportional to its surface area, although not directly or uniquely. The greater the surface area, the more water is required to wet the entire surface. Because a sphere has the smallest surface area to volume ratio, the closer an aggregate is in shape to a sphere, the lower its water demand will be. Similarly, a smoother surfaced aggregate will have a lower water demand than a rough surfaced one, although this effect is less pronounced. (Fulton, 2009).

In addition to the effect on water demand, the particle shape has an effect on the porosity of the concrete. Again, this is as a result of the surface area. The ITZ is the boundary between the cement paste and the aggregate. It has a lower porosity than the aggregate, and thus a concrete with a higher volume ITZ will have a lower porosity. Consequently, a concrete made with rounder particles in its aggregate will tend to have a lower porosity than an aggregate with more elongated or rough particles.

3.1.5 Effect of Deleterious Chemicals

Aggregates very often contain chemicals that have deleterious effects on the properties of concretes. These chemicals can be loosely categorized, as listed below: (Fulton, 2009)

1. Substances that dissolve in water. These substances will leach out of the aggregate when it is mixed with water. When they leach out, they weaken the aggregate itself by either cracking it or leaving behind voids. One example of this type of chemical is table salt.

2. Soluble chemicals that affect the hydration of cement. An example of this is humic acid, an organic acid produced from dead matter in the soil such as roots. This acid breaks down in the presence of alkalis, such as those produced in the hydration of cement and reacts with them (Lutzow, et al., 2006).

3. Substances that react directly with the cement paste and degrade it, for example, sodium sulphate.

4. Substances that react with the alkali components in the cement paste. This reaction forms a gel that causes the concrete to expand and as a result deteriorate. In order for the reaction to take place, three factors must be simultaneously present in the concrete:

- High alkalinity of the pore solution (>12.5). This normally occurs as a result of the hydration reactions of cement and the alkalis are normally the sulphates (Na_2SO_4, K_2SO_4) present in the cement. The alkalis may also come from outside sources, such as salt in sea water.
- Environmental conditions favourable to the reaction. At high temperatures, the expansion is greater. A moisture content of greater than 75% will allow the reaction to occur, and this moisture content is normally present in concrete due to the water added.
- Sufficient amount of the deleterious substances must be present in the concrete.

These substances are of particular concern in the Western Cape, as Malmesbury group minerals fall into this category. It has been found that just 20% of the aggregate needs to consist of Malmesbury group minerals for the reaction to take place.

In order to prevent this alkali reaction from occurring, cement extenders are often used. These reduce the alkalinity of the pore solution, thus preventing the reaction from occurring. The extenders and proportions are (Fulton, 2009):

- 40% blast furnace slag (S) by volume
- 15% condensed silica fume (CSF) by volume
- 20% Fly ash (FA) by volume

5. Substances that cause corrosion in steel, which is of concern when dealing with reinforcing. An example of such a substance is sodium chloride.

3.1.6 Effect of Deleterious minerals

Table 3.1 summarises minerals known to be deleterious to hardened concrete (Alexander & Mindess, 2005) (Fulton, 2009):

Table 3.1. Minerals known to have deleterious effects on hardened concrete (Alexander, et al., 2005) (Fulton, 2009)

Mineral Description	Effect on Concrete
Copper pyrite (chalcopyrite, $CuFeS_2$)	Reacts with water to form sulphates, which attack the cement hydration products.
Iron pyrites (Fools gold, FeS_2)	Oxidation to sulphates can occur which then further decompose to hydroxide. This is particularly severe in crushed fine aggregate. Results in surface pop outs.
Marcasite	This is another form of Iron pyrites, and forms sulphates when mixed with water. Results in

Mineral Description	Effect on Concrete
	brown staining and volume increase.
Sulphate minerals	These react with the aluminates and calcium hydroxide in the cement paste, forming expansive ettringite. Examples of such sulphates are; I. Aluminite, $K_2Al_6(OH)_{12}(SO_4)_4$ II. Epsomite, $MgSO_4.7H_2O$ III. Gypsum, $CaSO_4.2H_2O$
Minerals with large amounts of ferrous iron	Oxidation leads to staining and volume increase.
Mica	Increases water requirement and can reduce strength.
Alkali-susceptible minerals	These minerals react with alkalis in hardened concrete and form an expansive gel
Coal and lignite	Can reduce strength due to softness and swelling
Chalk and other soft or friable particles	Reduction in strength and can lead to excessive cracking

3.1.7 Effect of Deleterious Physical Characteristics

In general, soft, friable, flat, elongated or laminated material is deleterious to the properties of concrete made from those materials. (Fulton, 2009). Examples of such materials are coal, chalk and slate among others.

3.1.8 Natural Fine Aggregates in Cape Town

The natural fine material contributing to the aggregate was made up of the soil present at the construction site. Therefore, in order to understand the natural fine aggregates that are present in Cape Town, it was important to understand the soil present there.

3.1.8.1 Underlying geology

Cape Town has a complex geological history. Table Mountain and the mountains surrounding Cape Town are part of a 700km mountain chain known as the Cape Fold Belt. The belt is made up of sandstone rocks. This belt coincides with a series of granite hills that run from Cape Agulhas to Cape Columbine (Compton, 2006).

The mountains surrounding Cape Town are made from harder rocks such as Table Mountain Group (TMG) sandstone and granite, while the flat areas, such as the Cape flats, are formed from softer shale. This is shown in Figure 3.3. This figure provides an approximate cross section of the underlying geology present in the Cape Town area. It runs along the line X-X shown in Figure 3.4. In general, underlying granite forms rounded hills, sandstone forms tightly jointed cliffs and shale forms flat areas (Compton, 2006).

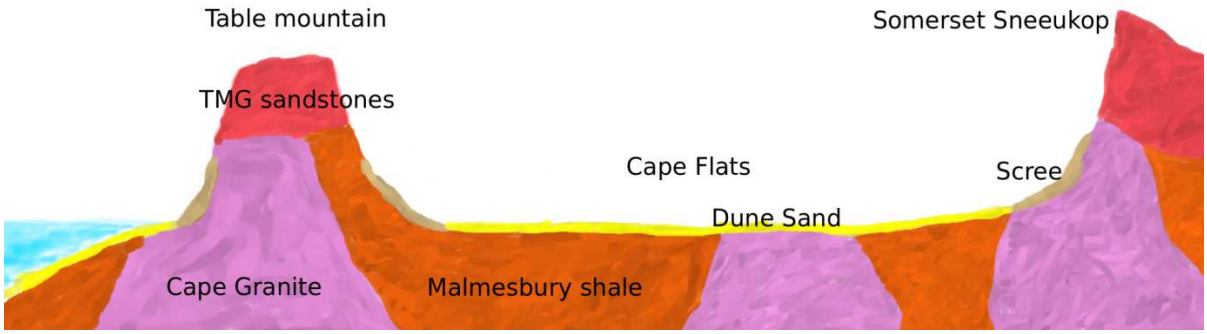


Figure 3.3. Geological cross section of Cape Town (Compton, 2006) (Not to scale)

This is of interest to this thesis as the soils in Cape Town are formed because of the weathering of these rocks. Cape granite breaks down to kaolinite clay, while sandstone breaks down predominantly into quartz minerals. The clays therefore tend to occur in low-lying areas of Cape Town, where dune sand has not yet covered them, while the higher areas tend to have inert quartz soils (Compton, 2006).

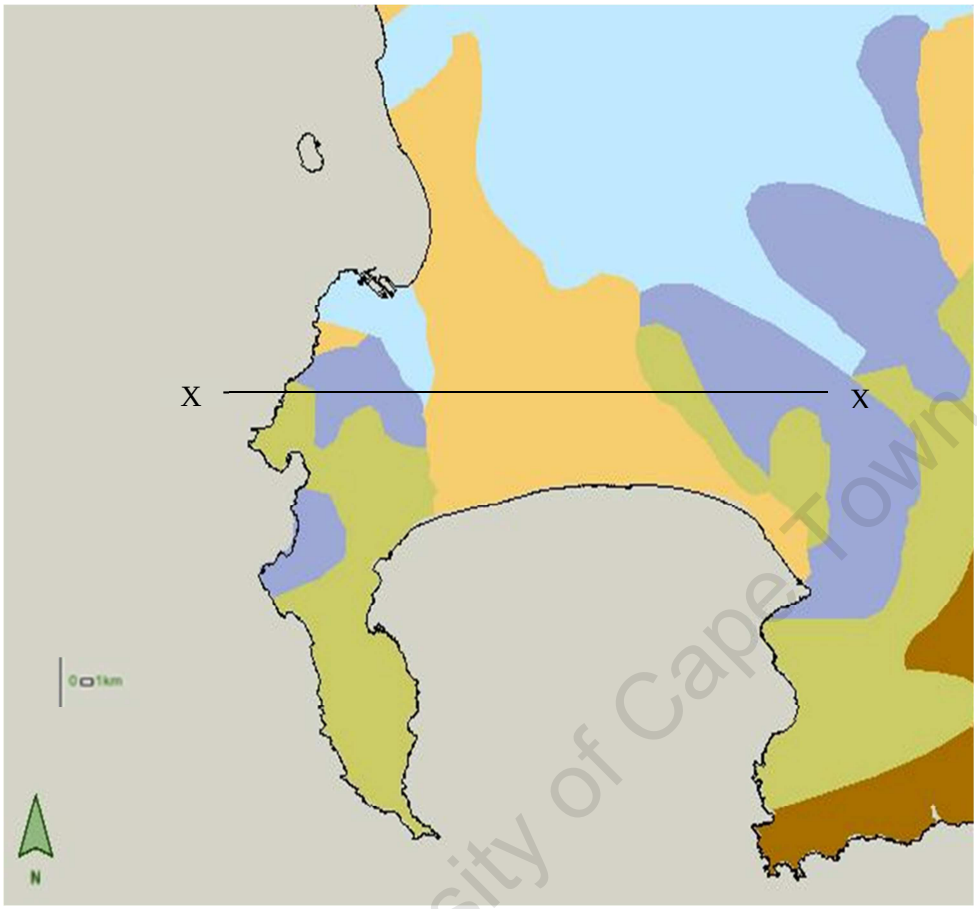


Figure 3.4. Simplified geology of Cape Town (AGIS, 2010)

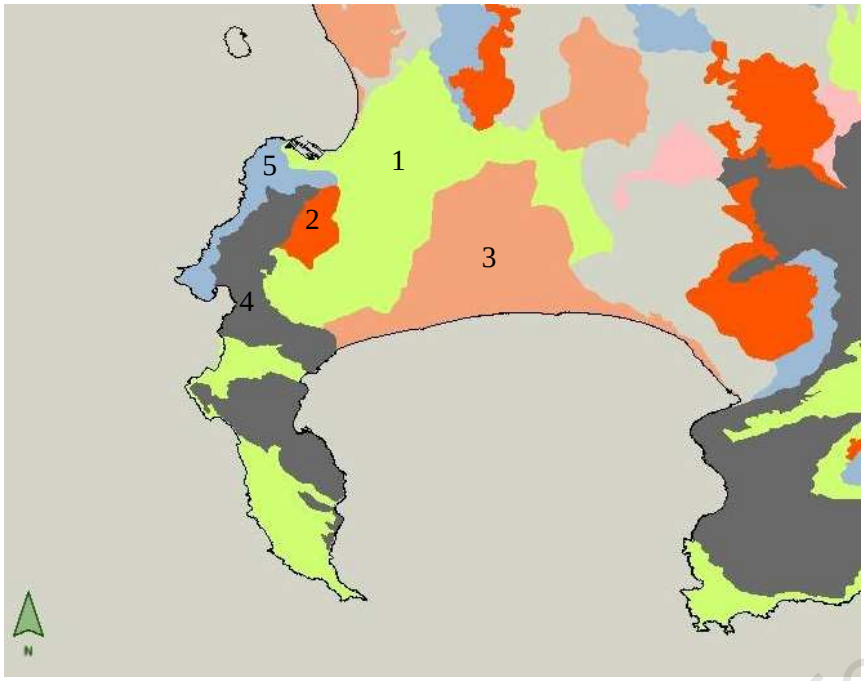


Figure 3.5. Generalised soil patterns in Cape Town (AGIS, 2010)

Figure 3.5 shows the generalised soil patterns in the areas in and around Cape Town. The map was attained from the Agricultural Geo-Referenced Information System (AGIS) website.

From the map it can be seen that there are a number of diverse soil types that can be found in and around Cape Town. These are namely:

1. Soils with a sandy texture, leached and with subsurface accumulation of organic matter and aluminium, with or without iron oxides, either deep or on hard weathering rock.
2. Red and yellow soils with low to medium base status. These soils are formed from degraded Malmesbury shale (Compton, 2006).
3. Greyish sandy soils.
4. Rock with limited soils.
5. Soils with minimal development, usually shallow, on hard or weathered rock, with or without intermittent dispersive soils. Lime rare or absent in the landscape.

While the descriptions given are general rather than specific, and therefore make drawing any conclusions about the soils difficult, the first soil on the list, "Soils with a sandy texture, leached and with subsurface accumulation of organic matter and aluminium, with or without iron oxides, either deep or on hard weathering rock", does highlight possibly favourable characteristics. Its chemical composition seems similar to that of lateritic soils, namely the accumulation of organic matter and aluminium. However, the sand and clay content is not specified more than "sandy texture" which means that given this information, conclusions about the soil at this stage cannot be drawn.

A more detailed map, indicating the soil classes in the areas in and around Cape Town is shown in Figure 3.6 (AGIS, 2010). The map indicates the following classes of soils in the areas in and around Cape Town, which are briefly discussed:

1. Podzols. These occur in the ranges defined as "Soils with a sandy texture, leached and with subsurface accumulation of organic matter and aluminium, with or without iron oxides, either deep or on hard weathering rock" and "Greyish sandy soils". Podzols are formed by a process

known as podzolisation. The soluble ions in the soil (calcium, sodium, magnesium, iron and some organic compounds) move downwards with the water in the soil. The top layer of the soil (top 400mm) is often acidic due to the build-up of organics and is described as friable. The Lower layers in the soil are more clayey and have a higher pH. Podzols occur in cool and temperate climates where the soil is normally humid to wet. (Rahn, 1986). Podzols have been found to prevent the hydration of cement (O'Flaherty, 1974).

2. Lithosols. These occur in the range defined as "Soils with minimal development, usually shallow, on hard or weathered rock, with or without intermittent diverse soils. Lime rare or absent in the landscape". Lithosols are soils formed from imperfect weathering of rock fragments. (Encyclopedia Brittanica, 2009). These soils occur geographically on the seaward side of Table Mountain. As such they are likely to consist of degraded granite and sandstone, hence their diverse nature.
3. Freely drained, structureless soils. These occur in ranges defined as "rock with limited soils" and "Red and yellow soils with low to medium base status". The amount of sand or fines material is not indicated. The latter range is more appropriate to investigate further (by means of collecting samples and categorising the soil) than the first range mentioned, since the first range has limited soils.
4. Imperfectly drained, sandy soils. These occur in the range defined as "greyish sandy soils".
5. Undifferentiated soils. These soils occur in the central business district area and are most likely rubble. The soils are likely to be very variable in this area.

The information on the soils present in the Cape Town area indicates that there is a wide variety of characteristics present in these soils. In order to characterize the effects that these soils have on the chemistry of hardening and hardened concrete, it follows that laboratory experiments will need to be carried out on the soils.

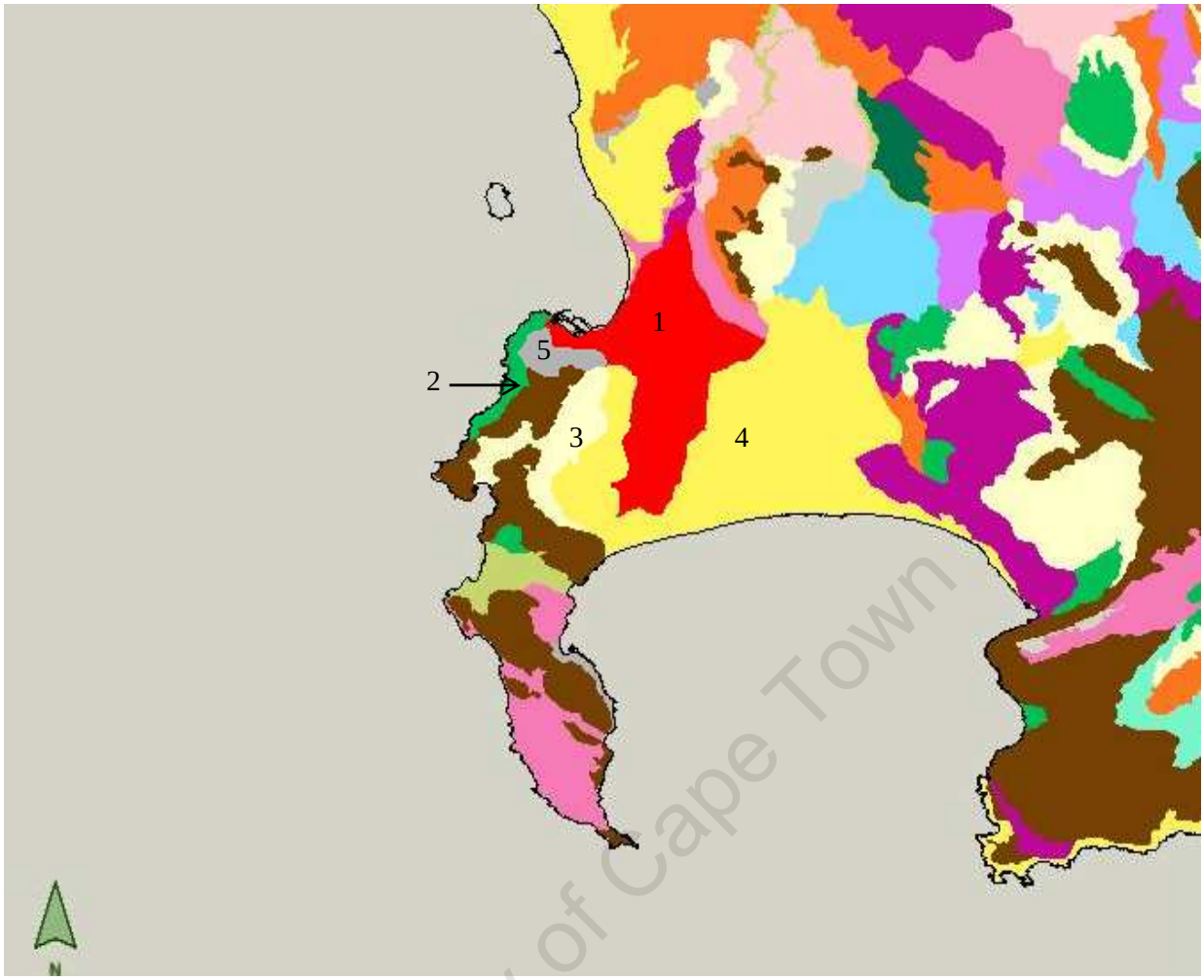


Figure 3.6. Soil classes in Cape Town (AGIS, 2010)

3.2 Soil Collection

Sixteen soils were collected in the areas in and around Cape Town, as shown in Figure 3.7. The soils were selected such that they would have a wide range of properties; from clays to sands, high and low microfines contents as well as different coloured soils with different origins.

Some of the soils were collected through manual labour, by simply digging the soil from the ground. An example of this is shown in Figure 3.8, where two fellow researchers are collecting a soil on the Vredehoek site. However, this was found to be extremely tiring and slow. The majority of soils were therefore obtained from sites that had already been excavated, more often than not with the kind help of the local labourers, at, typically, swimming pool excavations. An example is shown in Figure 3.9

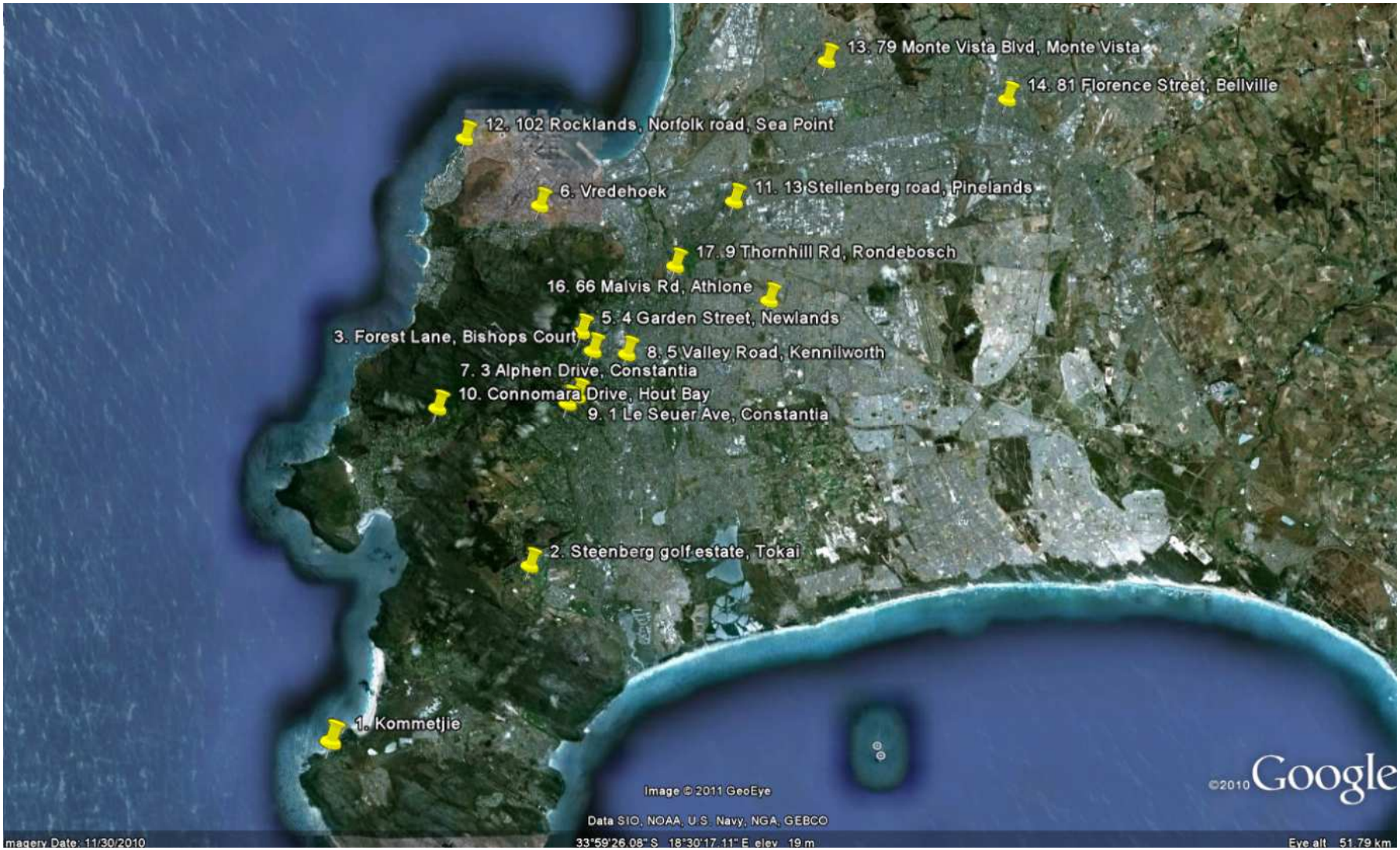


Figure 3.7. Soil Collection Sites (Google Maps, 2011)

Three x 50kg hessian bags full of soil were collected from each site.

Figure 3.8. An example of a soil being collected by researchers.

Figure 3.9. An example where soil was collected from an excavation site - in this case a swimming pool excavation.

In all cases, only soil below the top organic layer was collected. The organic layer was identified by its dark colour and was found to be approximately 500mm in depth. This is shown in Figure 3.10.

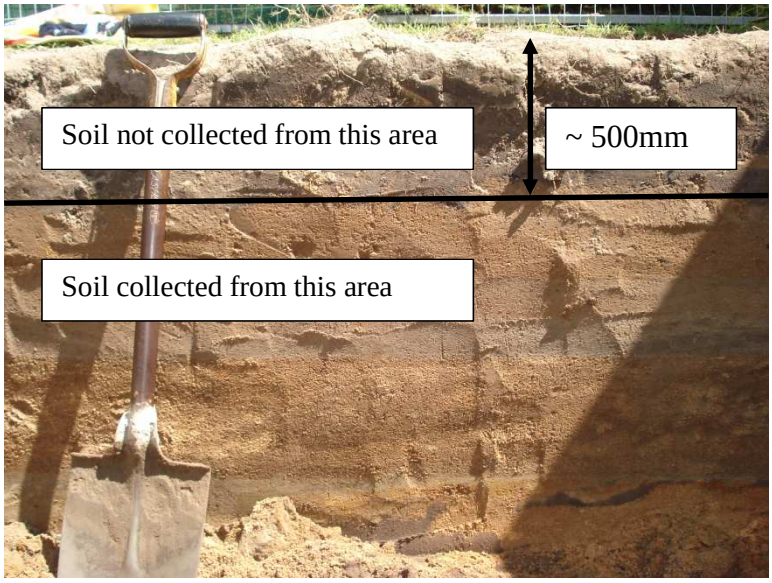


Figure 3.10. Diagram showing soil collection depth

The soil was stored in hessian bags for approximately three months. During this time, the bags were kept dry by placing a plastic cover over them. They were stored in doors for approximately one month and were then moved out doors for the next two months due to logistical reasons.

After a period of three months, the soil was transferred into metal drums, shown in Figure 3.11.

Figure 3.11. Drums in which the soil was stored

Table 3.2 indicates the origin of all the soils that were collected for testing. It also indicates their generalised soil type and soil class. 150kg of each soil was collected.

Table 3.2. Origin of soils collected

Soil Label	**Location**	**Sample Depth (m)**	**Activity at site**	**Generalised soil type** (AGIS, 2010)	**Soil Class** (AGIS, 2010)
Control 1	Klipheuwel		-		
Control 2	Phillipi		-		
1	Kommetjie	0.5	House Construction	Soils with a sandy texture, Leached and with a subsurface accumulation of organic matter and aluminium	Undifferentiated, poorly drained soil
3	Steenburg golf estate, Tokai	0.5	Pool Excavation	Soils with a sandy texture, Leached and with a subsurface accumulation of organic matter and aluminium	Red or yellow structureless soil with a plinthic horizon
4	17 Forest lane, Bishopscourt	0.5	House Construction	Red and Yellow Soil with low to medium base status	Red or yellow structureless soil with a plinthic horizon
5	4 Garden road, Newlands	0.5	House Construction	Red and Yellow Soil with low to medium base status	Red or yellow structureless soil with a plinthic horizon
6	Vredehoek	0.5	Empty Plot	Soils with minimal development, usually shallow on hard or weathering rock	Undifferentiated shallow soil
7	3 Alphen road, Constantia	0.5	House Construction	Red and Yellow Soil with low to medium base status	Red or yellow structureless soil with a plinthic horizon
8	5 Valley road, Kenilworth	0.5	Pool Excavation	Soils with a sandy texture, Leached and with a subsurface accumulation of organic matter and aluminium	Podzol
9	1 Le Seuer avenue, Constantia	0.5	House Construction	Red and Yellow Soil with low to medium base status	Red or yellow structureless soil with a plinthic horizon
10	Connomara road, Hout Bay	0.5	House Construction	Rock with limited soils	Lithosol
11	13 Stellenberg road, Pinelands	0.5	Pool Excavation	Soils with a sandy texture, Leached and with a subsurface accumulation of organic matter and aluminium	Podzol
12	102 Rocklands, Northfolk road, Sea Point	0.5	Pool Excavation	Soils with minimal development, usually shallow on hard or weathering rock	Lithosol
13	79 Monte vista road, monte Vista	0.5	Pool Excavation	Soils with a sandy texture, Leached and with a subsurface accumulation of organic matter and aluminium	Podzol
14	81 Florence street, Bellville	0.5	Pool Excavation	Soils with a sandy texture, Leached and with a subsurface accumulation of organic matter and aluminium	Red or yellow structureless soil with a plinthic horizon
15	21 Jamieson street, Blouberg	0.5	Pool Excavation	Soils with a sandy texture, Leached and with a subsurface accumulation of organic matter and aluminium	Podzol
16	66 Melvis road, Athlone	0.5	Pool Excavation	Soils with a sandy texture, Leached and with a subsurface accumulation of organic matter and aluminium	Podzol
17	9 Thornhill road, Rondebosch	0.5	Commercial Construction	Red and Yellow Soil with low to medium base status	Red or yellow structureless soil with a plinthic horizon

3.3 Soil Evaluation and Testing

3.3.1 Visual Inspection and Description

3.3.1.1 Particle Shape

Particle shape has an influence on the workability, and hence water demand, of concrete. Rounder particles tend to make more workable concrete when used as aggregate, when compared to angular particles. Particle shape may also have an influence on the strength of concrete, with angular aggregates generally making stronger concrete. It also has an influence on void content and packing densities of aggregates, with poorly shaped particles resulting in lower density and greater void contents (Alexander & Mindess, 2005).

Shape can be described in terms of 'sphericity' and 'roundness'. Sphericity describes how closely a particle approaches a sphere, while roundness describes the sharpness of the edges and corners. This is illustrated in Figure 3.12 (Alexander & Mindess, 2005).

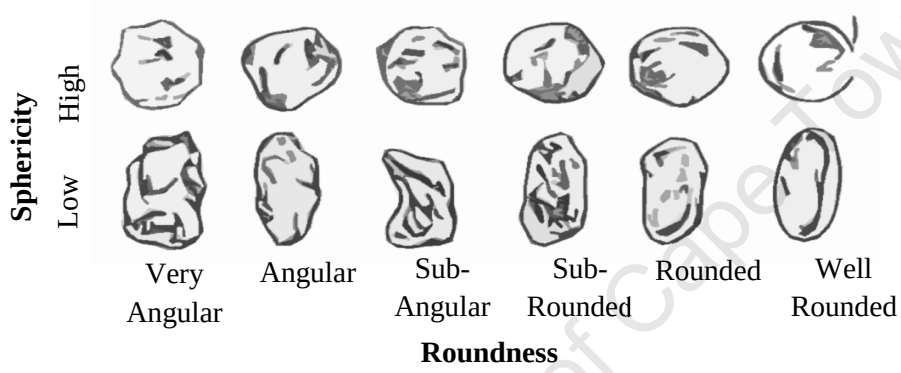


Figure 3.12. Sphericity and Roundness based on morphological observation

3.3.1.2 Particle Surface Texture

Surface texture depends on hardness, grain size, pore structure and texture of the parent rock, shown in Table 3.3.

Table 3.3. Surface Texture of aggregates (Alexander & Mindess, 2005)

Surface Texture	Characteristics	Examples
Glassy	Conchoidal (curved) fracture	Glassy or vitreous materials such as slag or certain volcanics
Smooth	Water-worn or smooth due to fracture laminated or fine-grained rock	Alluvial, glacial or windblown gravels and sands; fine grained crushed rocks such as quartzite, dolomite etc.
Granular	Fracture showing more or less uniform size rounded grains	Sandstone, coarse grained rocks such as certain granites etc.
Rough	Rough fracture of fine or medium grained rock containing no easily visible crystalline constituents	Andesite, basalt, dolerite, felsite, greywacke
Crystalline	Containing easily visible crystalline constituents	Granite, gabbro, gneiss
Honeycombed	With visible pores and cavities	Brick, pumice, foamed slag, klinker, expanded clay

Table 3.4 provides a description of the visual characteristics of each of the soils tested.

Table 3.4. Summary of visual characteristics of the soils and sands used in testing

Soil Label	Sphericity	Roundness	Surface Texture	Colour	Photograph
Control 1	High	Sub- Angular	Granular	Yellow-white	
Control 2	High	Rounded	Smooth	Yellow-white	
1	High	Sub-Rounded	Smooth	White	
3	High	Sub -Angular	Granular	Brown-Yellow	
4	High	Rounded	Granular	Red	
5	High	Sub- Angular	Granular	Grey-Brown	
6	High	Sub- Angular	Granular	Red- Brown	
7	High	Angular	Granular	Red- Brown	
8	High	Sub- Rounded	Granular	Red- Brown	
9	High	Sub - Angular	Granular	Red-Brown	
10	High	Sub- Rounded	Granular	White	

Soil Label	Sphericity	Roundness	Surface Texture	Colour	Photograph
11	High	Well rounded	Smooth	White-Brown	
12	High	Well rounded	Smooth	White	
13	High	Well rounded	Smooth	White-Brown	
14	High	Well rounded	Smooth	White	
15	High	Well rounded	Smooth	White-Red	
16	High	Rounded	Smooth	Light Brown	
17	High	Sub- Rounded	Smooth	Grey	

3.3.2 Grading

The soil was graded in accordance with SANS 201. This method is used to determine the particle size distribution of the coarse and fine aggregate down to 75µm.

2kg of the soil being graded was collected from the drum where it was being stored. This material was then dried in an oven at 50°C for 24 hours to ensure it was dry. It was dried at 50°C instead of the conventional 100°C to minimise any risk of the clay minerals breaking down, which may have affected the investigations into the soil chemistry. It was then halved twice, using a riffler apparatus similar to the one shown in Figure 3.13, to obtain a sample of 0.5kg.

This soil was weighed and then washed through a 75µm sieve, using potable tap water, prior to the sieve analysis so that the microfines content would not affect the results. The washed sample was then dried in the oven at 50°C for 24 hours and then weighed, as before. The mass of material passing the

75µm sieve and retained on the pan could now be calculated as the difference in dried mass before and after washing the soil.

The washed and dried soil sample was then sieved through a standard set of sieve sizes. In order to ensure that the soil was thoroughly sieved, it was placed on a mechanical vibrator for 2 minutes.

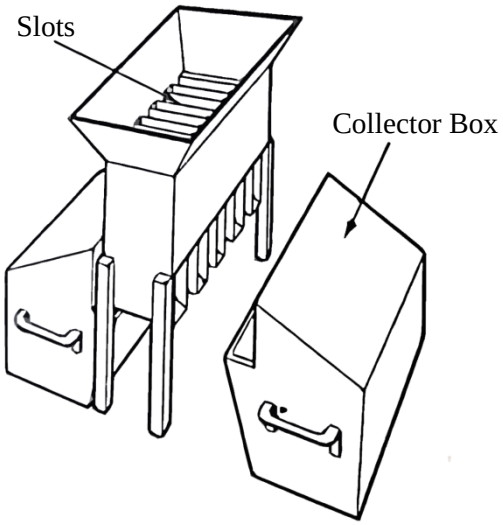


Figure 3.13. Schematic of a riffler (Alexander & Mindess, 2005)

Once the soil had been sieved, the mass of soil retained on each sieve could be measured. This allows for the cumulative mass of soil passing each sieve size to be calculated. The cumulative percentage of soil passing each sieve size is plotted against sieve size (on a log scale), an example of which is shown in Figure 3.14. In this figure, the sieve sizes are shown as labels next to the curve.

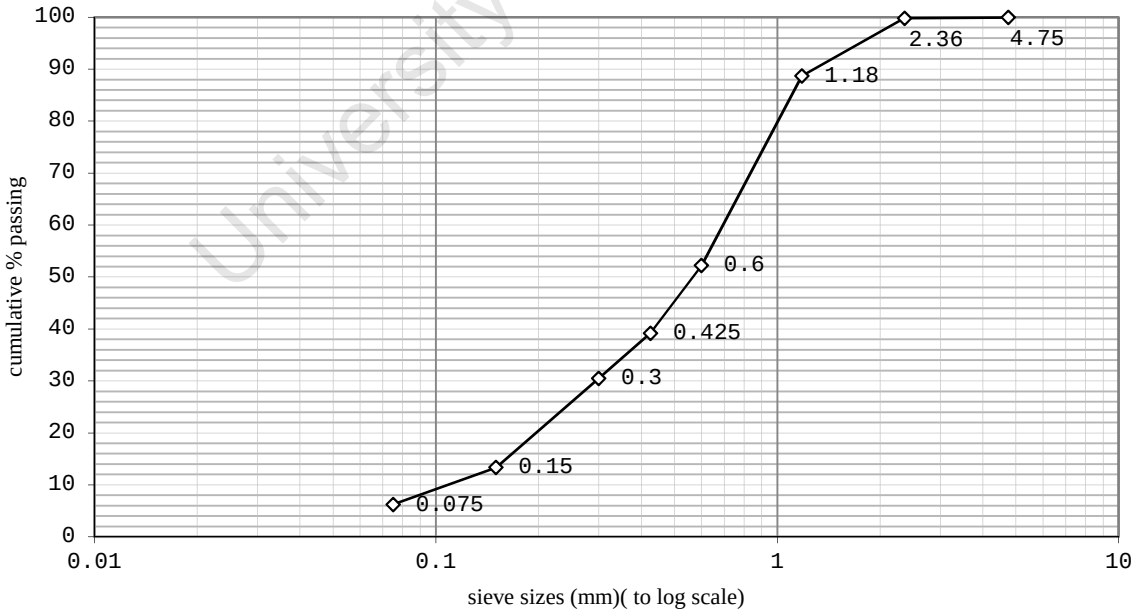


Figure 3.14. Grading curve for Klipheuwel sand

Figure 3.15 shows the grading curves for all of the soils used in the thesis. It also shows the limits set by SANS, as well as the C&CI recommended grading limits. It is clear from the figure that a wide range of soil grading is used in the testing and that many of the grading curves fall outside of the

limits recommended by the C&CI or set by SANS. Neither of the two controls that were used – Philippi dune sand and Klipheuwel sand – passed the C&CI or SANS recommended grading. Both of these aggregates have been used successfully in construction for many years. This suggests that current guidelines unnecessarily reject suitable aggregate material that could be used in construction.

By using a wide range of gradings in the fine aggregate used to make concrete, it is hoped that a better understanding of the effect that grading has on concrete can be established.

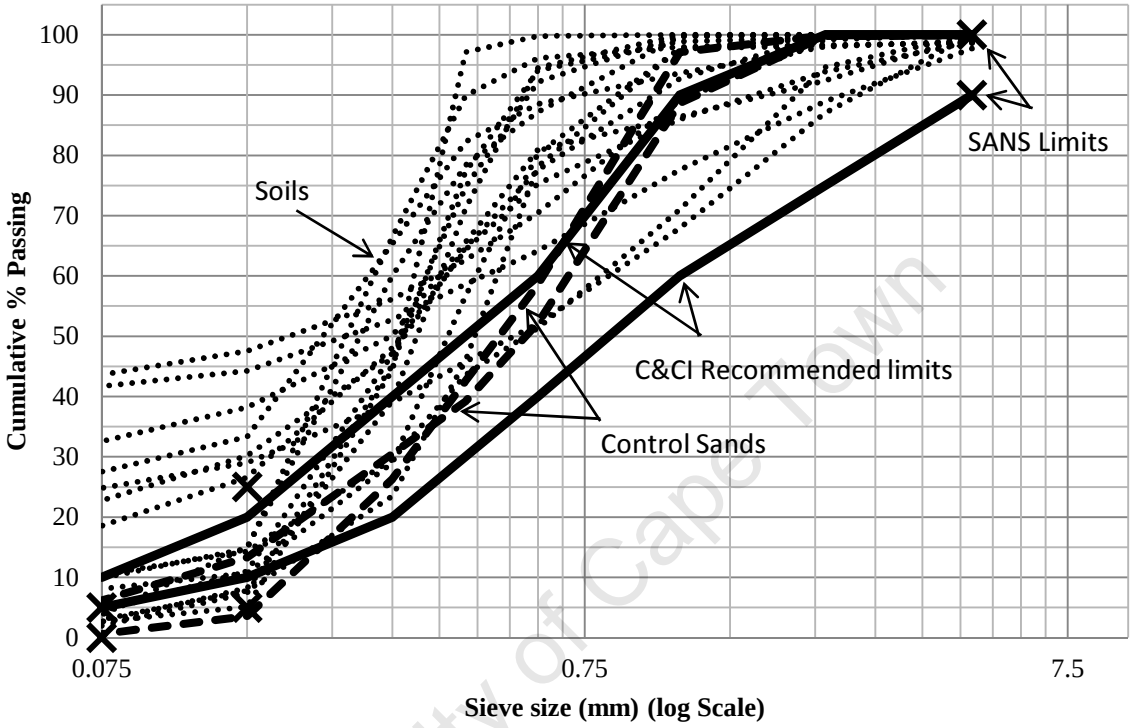


Figure 3.15. Grading curves for all the soils used in the thesis

Individual grading curves for each soil can be found in the appendix.

3.3.3 Fineness modulus

Fineness modulus is a measure of the average particle size of a sand or soil, with lower values representing finer soils.

The formula for calculating fineness modulus is shown in Equation 3.1 (SANS 201:2008):

$$\textit{Fineness Modulus} = \frac{\sum \textit{cumulative \% of material retained on specified sieves}}{100}$$

Where the specified sieves are (in mm): 4.25, 2.36, 1.18, 0.3, and 0.15

Equation 3.1. Fineness modulus

A summary of the fineness modulus for each soil can be found in Table 3.5, on page 42.

3.3.4 Test for organic impurities

This test was done in accordance with SANS 5832. This test is used to determine the presence of deleterious organic impurities in fine aggregates. In the scope of this thesis, it is likely that some or all

of the material collected will have been contaminated with organic material. It was therefore appropriate to carry out this test.

The test is performed by mixing a known volume of the aggregate with a sodium hydroxide solution. The mixture is left for a period of 24 hours. A control mixture is prepared by mixing a known volume of tannic acid with the same sodium hydroxide solution and this too is left for 24 hours. After this time, the samples are compared. If the aggregate solution is lighter than the control, it has passed the test, whereas if the aggregate solution is darker, it has failed.

Figure 3.16 shows an example of this test, with the control on the left hand side. In this case, it is clear that the aggregate has failed the test.

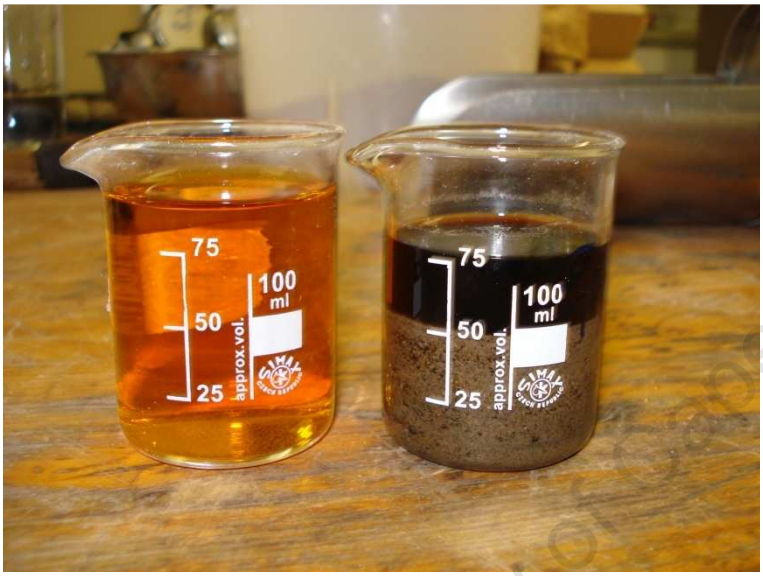


Figure 3.16. Example of the organic impurities test

All the soils were subjected to this test. All but one soil – the Philippi dune sand that was used as a control – failed the test. Considering that the other control (Klipheuwel sand) failed the test, even though it is widely used in construction, brings the validity of this test into question. Klipheuwel sand is commonly and successfully used in construction, which indicates that another test for organic impurities possibly needs to be developed, or that the reference solution for this test needs to be reassessed.

A summary of the organic test results for each soil can be found in Table 3.5, on page 42.

3.3.5 Test for silt and clay content

In order to determine the clay content of the mixes, the pipette method as specified by SANS 6244:2006 was used. This method determines the proportions of the aggregate not exceeding 20µm and 5µm in diameter. It divides the fractions indirectly using sedimentation. The relationship between the diameter of the aggregate and its settling velocity is given by Stokes' Law.

A known mass of the aggregate is mixed vigorously with a sodium hexametaphosphate solution (to prevent flocculation of the very fine particles) and water and left for a period of two hours. After this, the mixture is placed in a settling tube and remixed. At predetermined intervals, a known volume of the sample is removed at a prescribed depth from the tube using a pipette. The solution is then placed in a container and dried. From the dried mass, it is possible to determine the fraction of the aggregate

not exceeding 20µm and 5µm in diameter. Figure 3.17 shows the dried silt and clay fractions of one of the aggregates using this test procedure.

A summary of the silt and clay fractions for each soil can be found in Table 3.5.

Figure 3.17. Example of the silt and clay found in the aggregate. Silt is shown on the left, while clay is on the right

3.3.6 Methylene Blue Absorption

The methylene blue absorption test was carried out in accordance with SANS 6243:2008. SANS states that the purpose of the test is to determine whether the clay content of the fines of an aggregate contains deleterious swelling clay minerals, such as smectite. Correlations have also been established between the methylene blue absorption value of an aggregate and the workability of concrete made with that aggregate (Stewart, et al., 2007).

The test measures the surface area of the aggregate by determining the amount of methylene blue that can be absorbed by a fine aggregate.

The test is performed as follows;

1. 5g of the aggregate passing the 75µm sieve is boiled in 30% hydrogen peroxide for 30 minutes inside a beaker. The beaker is then vigorously shaken, and then left until the aggregate settles. This is repeated two more times. The aggregate is then collected and dried at 100^{o}C overnight. The purpose of this is to negate the effects that organic material has on the test.
2. 1g of the treated aggregate is mixed with 30mL of water.
3. Successive 0.5mL increments of a methylene blue-water solution are titrated into the aggregate-water mixture.
4. At each increment, the mixture is shaken for a period of 2 minutes. A drop of the mixture is placed on some filter paper. The filter paper is held up to natural light, and observed.
5. If no definitive blue halo is observed, the test is continued. If a definitive blue halo is observed, the test is completed.
6. The methylene blue value can be calculated using Equation 3.2:

$$Methylene\ blue\ absorption\ value = \frac{0.1 \times Volume\ of\ indicator\ added\ (in\ mL)}{Mass\ of\ sample\ tested}$$

Equation 3.2. Methylene blue absorption value

SANS specifies a maximum methylene blue absorption value of 0.7. Only one sample had a methylene blue value of greater than this, a kaolinite clay soil that had a value of 0.8. Although kaolinite clays are recognised as stable, in this case the clay fraction was 12.8%, which is much greater than the maximum value of 2% stipulated by SANS. This indicates that the aggregate failed the methylene blue test due to the high clay content and not because the clay itself is of a deleterious nature.

Only one smectite clay was used in testing and it had a methylene blue absorption value of 0.1. Smectite clays are specifically mentioned in the code as being deleterious. In this case, the clay fraction was just 0.8%, which is below the maximum recommended value by SANS (which is 2%). It is possible that even though there was potentially deleterious clay in the aggregate, it was not there in a high enough fraction to offset the test.

In summary, these results tend to indicate that the methylene blue test may be a useful indicator of clay content, as shown in Figure 3.18 (although the correlation is loose), but not necessarily as an indicator of whether the clay itself is deleterious or not. The figure indicates that high methylene blue absorption values were recorded for Kaolinite and Illite clays and low values were recorded for the montmorillonite and smectite clays. Montmorillonite and smectite are known to be problematic when used as concrete aggregate, whereas kaolinite and illite are known to be relatively innocuous.

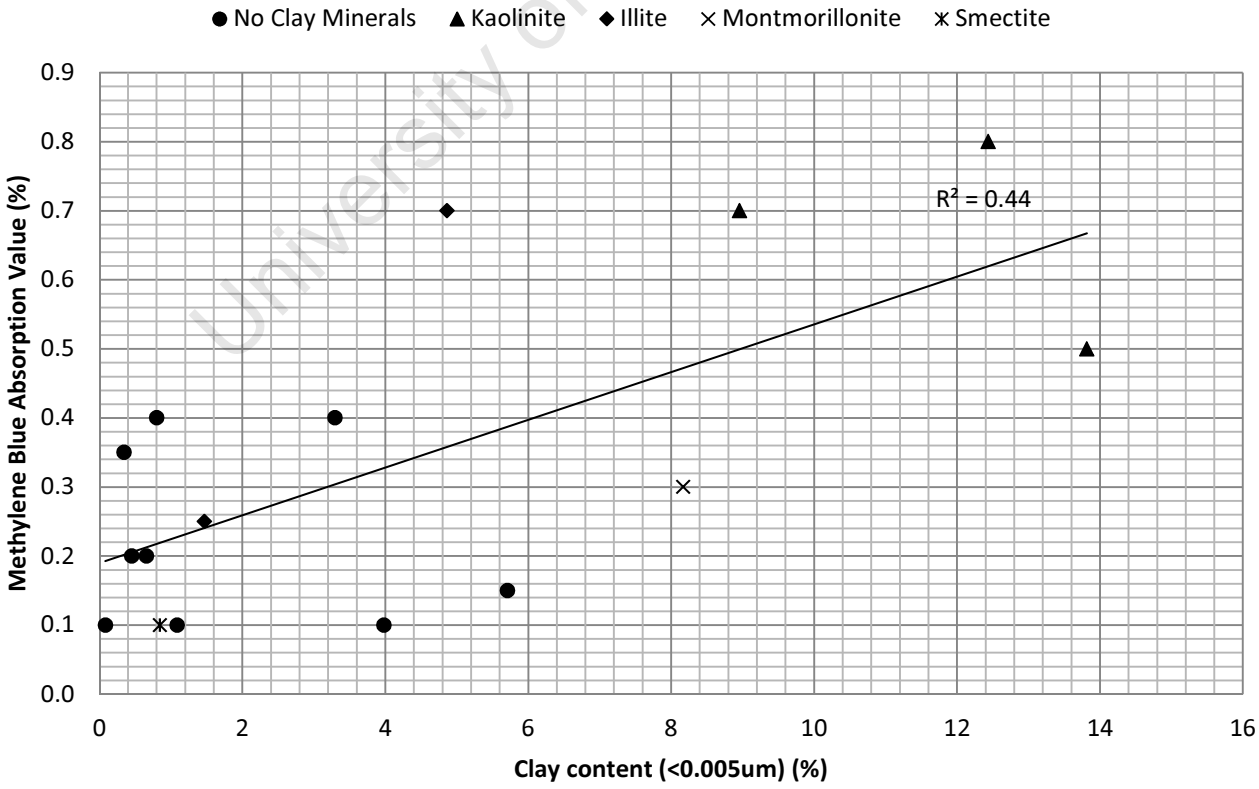


Figure 3.18. Relationship between clay content and methylene blue absorption value

These findings are in contrast to the work carried out by Norvell, et al (2007). In their work, they found that the methylene blue test was not sensitive to an increase in surface area but could detect the presence of clays. Figure 3.19 shows a summary of their findings in this regard. They found that the presence of montmorillonite greatly increased the methylene blue absorption value.

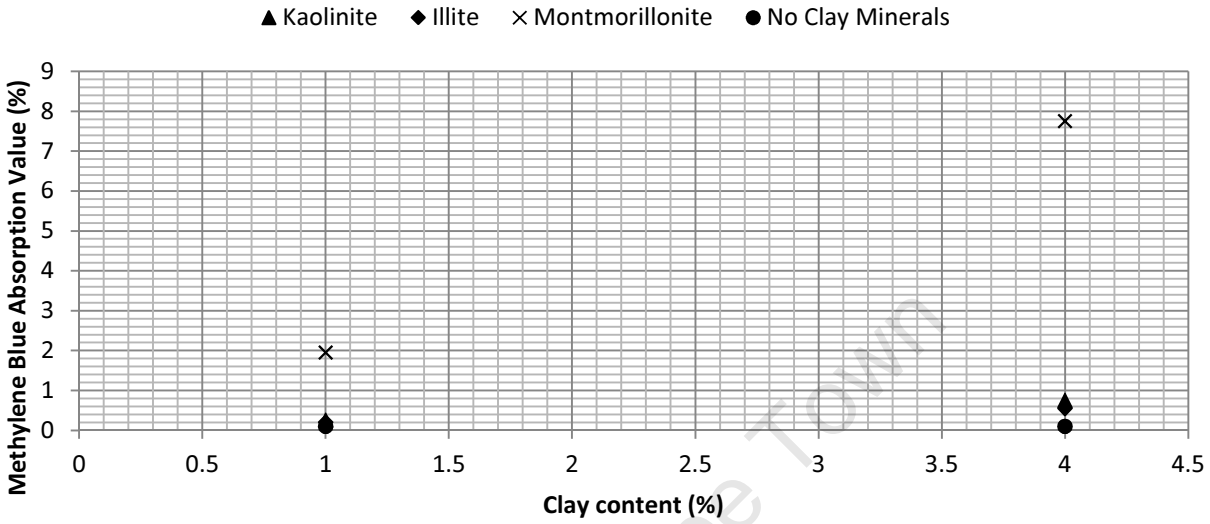


Figure 3.19. Effect of clay type on the methylene blue absorption value (Norvell, et al., 2007)

3.3.7 X-Ray Diffraction

X-Ray diffraction (XRD) was carried out on the microfines fraction of all the samples. The analysis helped to determine the clay types present, if any, within the soil.

A small amount (less than 1g) of the soil passing the 75µm sieve was dried and then loaded into the XRD for analysis. The instrument was a Philips PW 1390 XRD (Department of Geological Sciences, UCT), which uses a Copper K-α X-Ray tube with an x-ray wavelength of 1.542 A. Bragg 2Θ angles between 0 and 50° were used for analysis. An in-built algorithm in the computer attached to the XRD apparatus identified the presence and type of clay, if any, using the wavelength peaks from the scans.

A summary of the XRD analysis results for each soil is shown in Table 3.5. It should be noted that although montmorillonite and smectite are identified separately, montmorillonite falls under the broader smectite clay group (Newman, 1987).

Table 3.5. Summary of fineness modulus, clay and silt contents, XRD analysis and organic impurities testing

	Fineness Modulus	Silt (% <0.02µm)	Clay (% <0.005 µm)	Clay Type (XRD)	Organic Impurities test
Control 1	2.2	2.9	0.2		Fail
Control 2	2.1	0.0	0.0		Pass
1	1.9	1.5	0.8		Fail
3	1.5	11.1	9.0	Kaolinite	Fail
4	1.4	19.7	13.8	Kaolinite	Fail

	Fineness Modulus	Silt (% <0.02µm)	Clay (% <0.005 µm)	Clay Type (XRD)	Organic Impurities test
5	1.7	11.0	8.2	Montmorillonite (smectite)	Fail
6	1.5	12.4	4.9	Illite	Fail
7	1.7	17.9	12.4	Kaolinite	Fail
8	2.4	2.2	1.5	Kaolinite, Illite	Fail
9	2.2	1.3	0.8	Smectite	Fail
10	1.2	6.7	5.7		Fail
11	1.5	4.3	4.0		Fail
12	1.3	4.0	3.3		Fail
13	1.6	1.4	1.1		Fail
14	1.5	0.8	0.7		Fail
15	1.4	0.4	0.1		Fail
16	1.9	1.0	0.3		Fail
17	1.6	0.8	0.5		Fail

3.4 General discussion and conclusion

For this work, a number of soils were collected and their properties evaluated. The soils were collected from a wide range of locations within the greater Cape Town area. The soils properties were evaluated in terms of their surface texture, their grading characteristics, their silt and clay content, their methylene blue absorption value and their clay type.

It was found that the soils exhibit a wide range of properties, with a wide range of surface textures, grading characteristics, methylene blue absorption values and silt and clay contents. Seven of the soils were identified to contain clay minerals; Kaolinite, illite, montmorillonite and smectite have been identified.

A wide range of soils were collected in order to develop a fuller picture and a better understanding of the influence these soils have on concrete when used as fine aggregate. Furthermore, by investigating the influence that these soils have on concrete, the key soil properties that have the greatest effect on the performance of concrete can be identified.

4 Water Demand

4.1 Introduction

Water demand is one of the key factors in concrete mix design and performance. A concrete mix needs adequate water to achieve suitable workability in order that it may be cast easily and quickly. In addition, poor workability can lead to undesirable voids in concrete structures, normally behind dense reinforcing or in the corner of formwork (Fulton, 2009).

4.2 Methodology

In order to determine water demand, the concrete was initially made in a very workable state, with a greater slump than required. The slump was measured and a known mass of fine and coarse aggregate was added to the mix. The slump was measured again with the new mix. This was repeated until slumps greater and lesser than the required slump were measured.

A slump of 75 – 100mm was used, as this is the slump commonly achieved in practice.

In some cases, the initial mix was less workable than required. In these cases, more water needed to be added to the mix. Cement was also added so that the water-to-cement ratio was kept constant. The water content of the mix could be worked out using the mass of water and cement added to the mix.

From the results, it was possible to interpolate and estimate the mix that will result in the required slump.

Table 4.1 shows the mix designs that were used in batching. As the table indicates, the only parameters that vary in each mix are the stone and sand content. Therefore, it was possible to start with a water content of 250L/m^3 and then decrease this only by adding sand and stone. The mix designs indicated in Table 4.1 are a modification of the mix design shown in Table 2.3 on page 18, taking into account the variations in aggregate content to calculate the water content of each mix.

Table 4.1. Mix designs for varying water contents

Parameter	Mass (kg)			
	250 L	210 L	180 L	160 L
W/C	0.7	0.7	0.7	0.7
Water	4.3	4.3	4.3	4.3
Cement	6.2	6.2	6.2	6.2
Stone	18.6	22.2	25.9	29.1
Sand	15.6	18.5	21.6	24.3

Some mixes provided too low a slump at 250L/m^3 water. These mixes required water to be added in order to attain the required slump. Cement was added proportionally in order to maintain the w/c ratio of the mixes. With these mixes, the new volume of the mix needed to be calculated, which allowed the water content of the mix to be determined.

Table 4.2 shows an example of this, where 1 litre of water is added. By adding 1litre of water (and cement proportionally), the volume of the mix has changed to 20.4 litres. There are 5.3 litres of water in the mix, so the water content of the mix is therefore 260 L/m^3:

$$\left(\frac{1000}{20.4}\right)5.3 = 260\ L/m^3$$

Equation 4.1. Effect on water content when one litre of water is added to a concrete mix

Table 4.2. Water content of mixes where water and cement needed to be added

Add 1L of water to 250l/m^3 mix			
	Mass (kg)	**Density**	**Volume (L)**
W/C	0.7		
Water	5.3	1	5.3
Cement	7.6	3.14	2.4
Stone	18.6	2.7	6.9
Sand	15.6	2.7	5.8
Sum			20.4
Water Content (l/m^3)			**260**

Table 4.3 provides a summary of the water demand testing results. A wide range of water demands were observed; from 172L/m^3 to 350L/m^3 of concrete. Note that the control sands have the lowest water demands of any of the soils.

Table 4.3. Summary of water demand results for each soil tested

Soil	**Water (L/m^3)**
Control 1	172
Control 2	180
1	201
3	255
4	300
5	265
6	264
7	350
8	198
9	266
10	254
11	228
12	254
13	210
14	252
15	216
16	226
17	248

4.3 Results and discussion

4.3.1 Relationship between water demand and microfines content

The effects of this greater water demand are undesirable. In order to maintain the same w/c ratio, more cement is needed at higher water contents. At higher water contents, it has been found that, in general, concrete experiences higher shrinkages and reduced durability characteristics (Fulton, 2009).

Figure 4.1 indicates that there is a clear relationship between the fines content of a soil and the water demand of concrete made with this soil. This is expected as soils with greater fines contents will have a greater surface area per unit volume. In order to lubricate the soil so that it becomes workable, water needs to coat a greater area in soils with higher fines content.

Note that the control sands used less water than any of the soils in order to achieve the desired slump. This is despite the fact that one of the controls had greater fines content than some of the other soils.

Particle shape appears to have an influence on water demand as expected; soils with well-rounded, rounded and sub-rounded particles tend to have lower water demands than those with angular or sub-angular particles.

There are exceptions to this trend, with one soil with rounded particles having a water demand of 300L/m^3 of concrete. This soil has the greatest fines content of any of the soils tested, but it does not have the greatest water demand; another soil with slightly lower fines content has a water demand of 350L/m^3 of concrete. This phenomenon is evidence for the relationship between particle shape and water demand, since a soil with rounded particles was found to have higher fines content than a soil with angular particles and yet had a lower water demand.

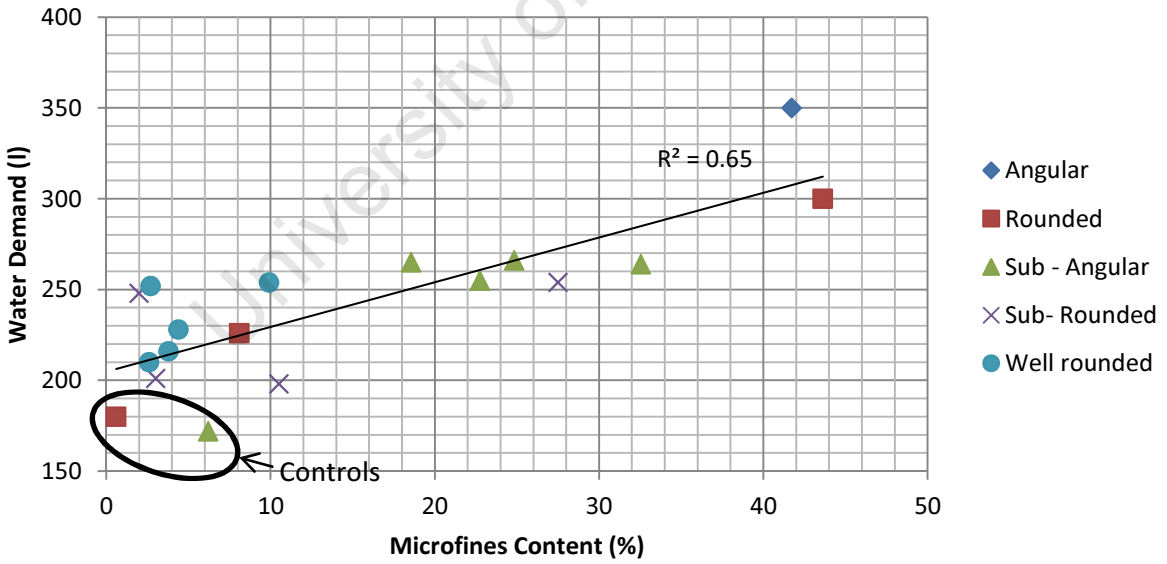


Figure 4.1. Relationship between water demand, microfines content and particle roundness

Similar relationships can be observed between water demand, silt and clay, as shown in Figure 4.2 and Figure 4.3 respectively. This is expected because the soils with higher microfines contents have high silt and clay contents as well.

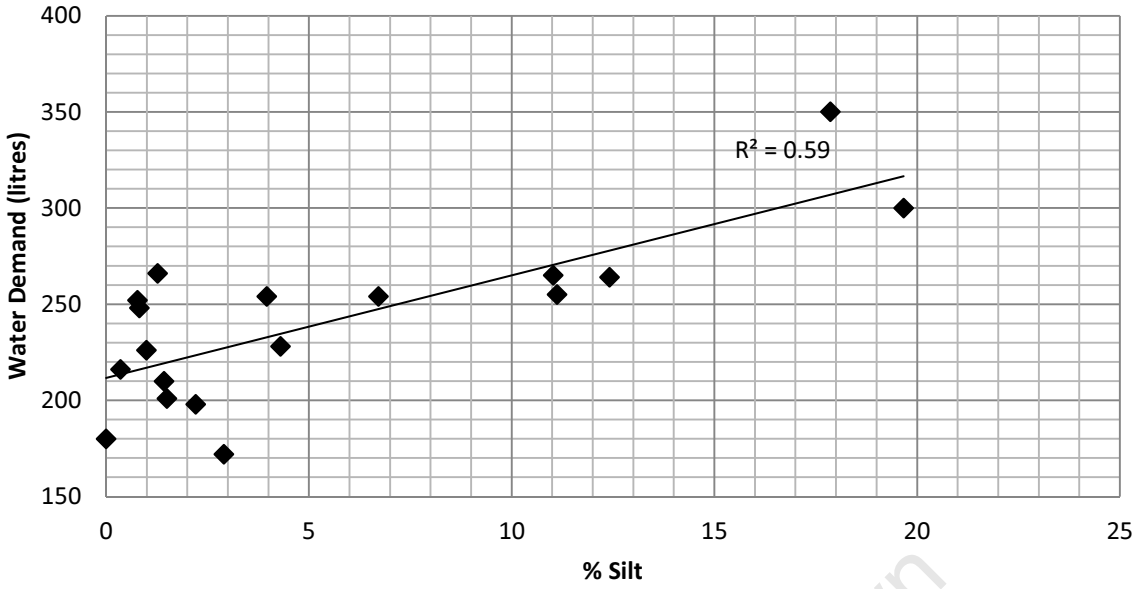


Figure 4.2. Relationship between silt content and water demand

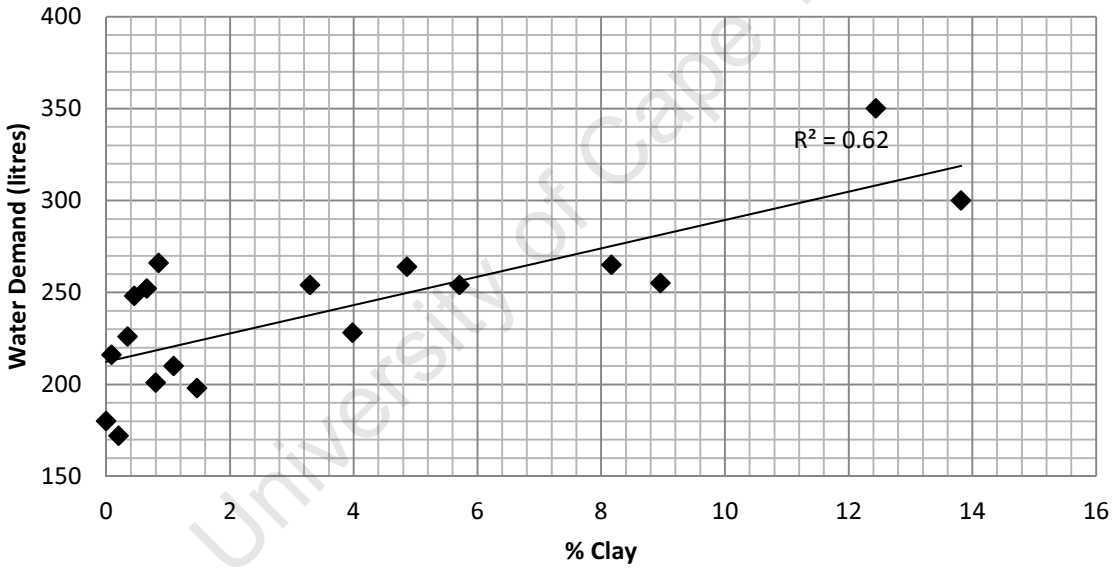


Figure 4.3. Relationship between clay content and water demand

From this data, it is unclear whether a single size property of a soil determines the water demand, or whether it is a combination of the microfines, silt and clay contents. The scatter of the data in each comparison is relatively similar, with a R^2 value of approximately 0.6.

These data indicate that if a soil has low microfines content, it will likely have a lower water demand.

4.3.2 Relationship between total fines content and water demand

Figure 4.4 shows the relationship between total fines content and water demand. In this figure, the fines content consists of aggregate passing a 0.075mm sieve, as well as the cement content of the mix.

This figure shows a strong relationship between total fines and water demand, as illustrated before in Figure 4.1. However, Figure 4.4 indicates that total fines are a more accurate indicator of water

demand than aggregate fines, by comparison of the R^2 values. This is expected, since cement makes up a large proportion of the fines content of a mix. Furthermore, when water is added, cement needs to be added in order to maintain a constant w:c ratio. Cement content is therefore a function of water demand. In Figure 4.4, the total fines content consists of fines in the aggregate and the cement content, which itself is a function of water demand. There is therefore a circular relationship, whereby a higher water demand results in a higher cement content, which in turn increases the total fines fraction, which increases the water demand. This illustrates the problem of trying to predict the water demand of a concrete mix without trial and error testing.

A solution to this problem, although outside the scope of this work, is the use of water reducing admixtures. These admixtures reduce the amount of water required to achieve the desired workability, which reduces the cement and total fines content of the mixes.

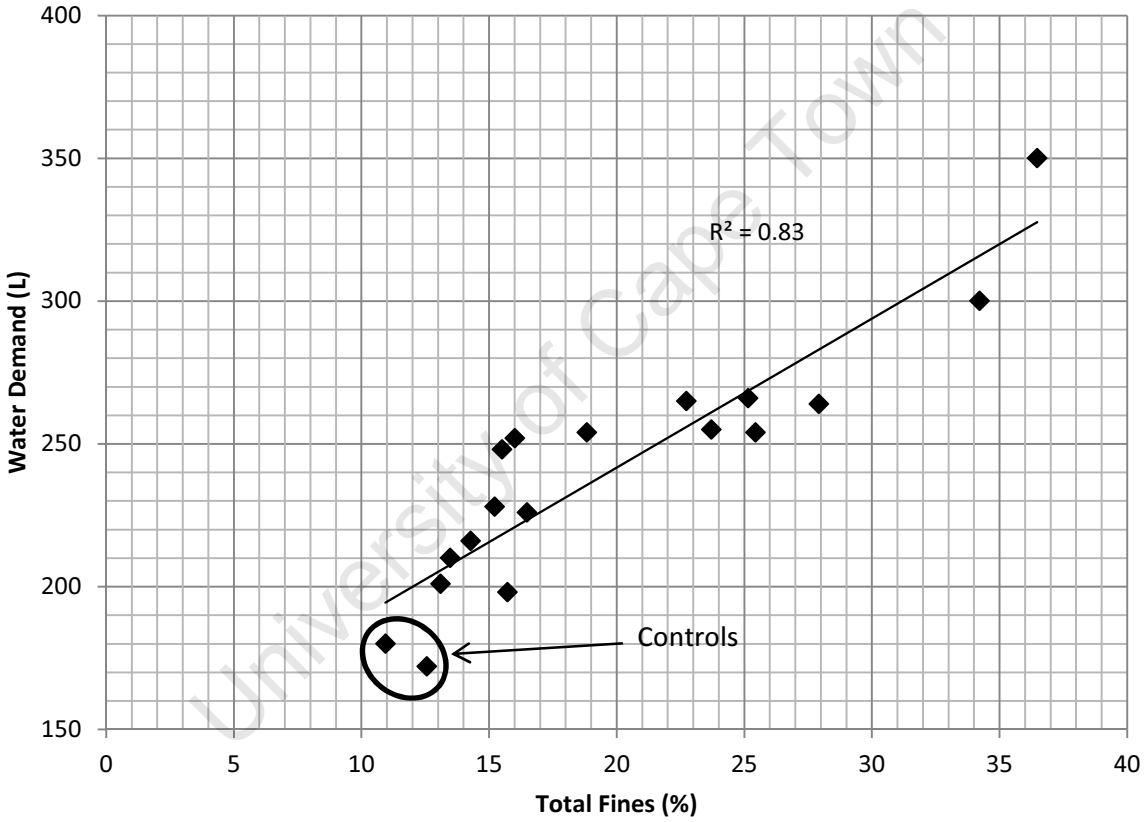


Figure 4.4. Relationship between total fines content and water demand

4.3.3 Relationship between surface area and water demand

In order to calculate the total surface area of the fine aggregate plus the cement content, the following was considered:

Cement Surface area;

The cement was assumed to have a surface area of 3500 cm^2/g, or $3.5x10^{10}$ mm^2/kg. Since the cement content of each mix, per cubic meter, was known, it was possible to calculate the surface area of cement for each mix in mm/m^3.

For example; If a mix has 500kg/m^3 cement content, the surface area of this cement is 500kg/m^3 x 3.5x10^{10}mm^2/kg = 1.75x10^{13}mm^2/m^3.

Soil surface area;

The total surface area of the fine aggregate was considered per cubic meter of concrete. In order to determine the total surface area of the fine aggregate per cubic meter, the fine aggregate was considered in terms of a number of particle sizes, corresponding to the various sieves used in the grading analysis.

From these fractions, it is possible to determine the total mass of that fraction of the fine aggregate per m^3 of concrete. From the mass of the fraction, it is possible to determine that fractions' volume, assuming a density of 2700kg/m^3.

For example; If it was found that 5% of a specific soil was retained on the 0.3mm sieve, and it is know that 900kg/m^3 of fine aggregate was used in the mix, it can be calculated that 5/100 x *900 = 45kg/m^3 of material retained on the 0.3mm sieve was used in the mix. The volume of this fraction is therefore 45kg/2700kg/m^3 = 0.0167m^3.*

In order to calculate the surface area of each fraction, per m^3 of concrete, it is necessary to calculate the number of particles of each size fraction, N, that can fit into the volume of that fraction in the mix. The formula for this is shown in Equation 4.2.

$$N = Packing\ density \times \frac{Volume}{Volume\ of\ 1\ particle}$$

Equation 4.2. Number of particles per meter cubed of concrete

Packing density is illustrated in Figure 4.5. When packing spheres, there are always voids between the particles. A maximum particle density for a very well packed sphere is 0.74, which was developed by Gauss. For the purposes of this research a value of 0.7 was assumed.

Figure 4.5. Illustration of packing density

Assuming that the soil particles are spherical, Equation 4.3 can be used to calculate the volume of one particle. Since the particles are not spheres in reality, this assumption is likely to underestimate the

surface area of the particles per unit volume; spheres have the lowest surface area to volume ratio of any solid shape.

$$Volume\ of\ one\ particle = \frac{4}{3} \times \pi \times r^3$$

Where r is the sieve size divided by two.

Equation 4.3. Volume of one soil particle

The total surface area, per m^3, of a size fraction could now be calculated using:

$$Total\ surface\ area\ of\ size\ fraction = N \times Surface\ area\ of\ one\ particle$$

Equation 4.4. Total surface area of a size fraction

The surface area of one particle is given in Equation 4.5.

$$Surface\ area\ of\ one\ particle = 4\pi r^2$$

Equation 4.5. Particle surface area

The total surface area of a mix can then be calculated by adding up the surface area of each size fraction.

Figure 4.6 shows the relationship between total surface area of the cement and fine aggregate, water demand and particle shape.

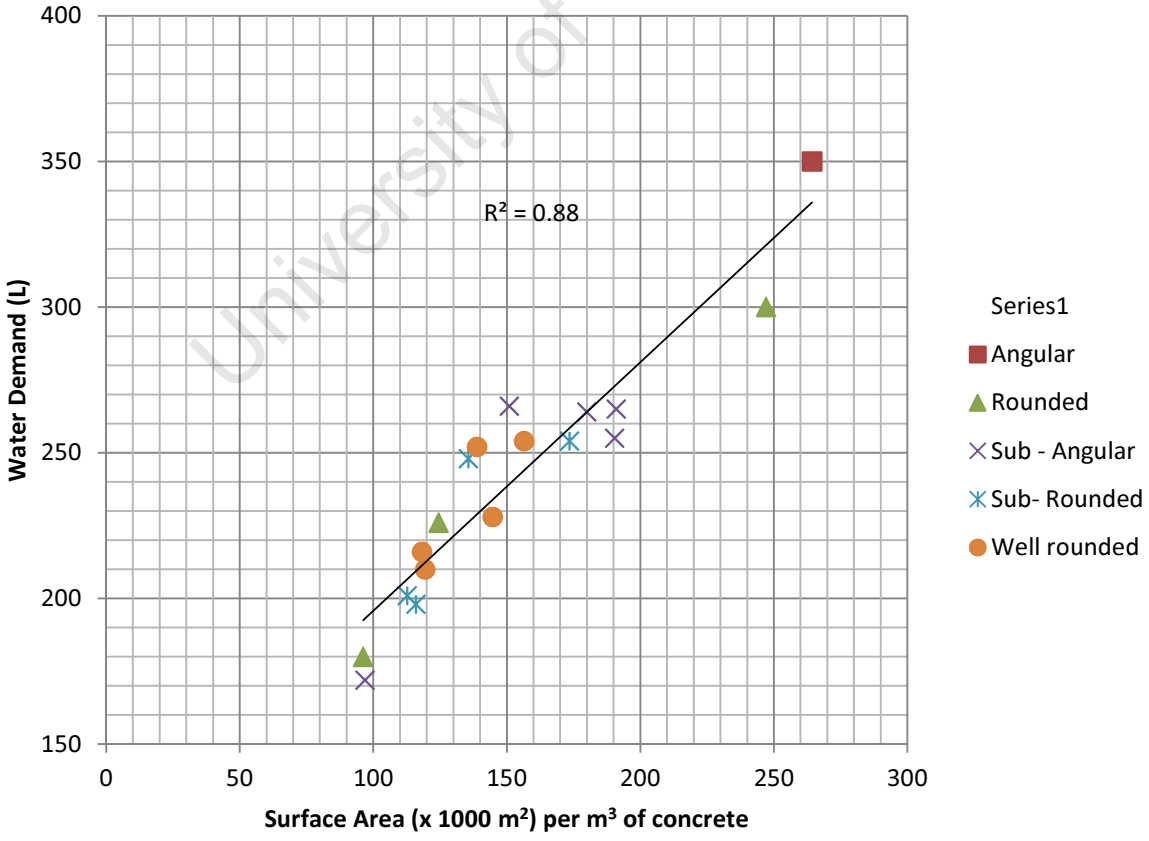


Figure 4.6. Relationship between water demand, surface area and particle shape

The figure highlights the direct relationship between surface area of the fines in a concrete mix and that mixes water demand.

This figure also indicates that rounded aggregates do tend to have a lower water demand and angular aggregates tend to have a higher water demand. There are exceptions, for instance the soil with the lowest water demand was described as having sub-angular particles and the soil with the second greatest water demand was described as having rounded particles. This indicates that the subjective assessment of particle shape may be a useful preliminary indicator for water demand, although not an entirely accurate one.

The relationship between surface area and workability of concrete observed in this work is in agreement with literature on the subject. In their work, He, Osbaeck and Makovicky (1995) varied the water content but kept a constant cement content in order to achieve the desired workability. In their work, the correlation between workabilty (measured in terms of varying the w/c ratio, as opposed to water demand in this work) and surface area (measured in m^2/g as opposed to mm^2/m^3) is similar to the correlation found in this work. They found a R^2 value of 0.89, while in this work the R^2 value was 0.88.

4.3.4 Correlation between water demand and methylene blue absorption value

Stewart et al (2007) found a direct relationship between the workability of concrete and the methylene blue absorption value. In their work, workability was not varied by changing the water content of the mixture, but rather by using high range water reducing (HRWR) admixtures. They found that there was a correlation coefficient of 0.35 between the methylene blue absorption value and the volume of HRWR needed to be added to the mix in order to achieve the desired workability (Stewart, et al., 2007). The relationship is show in Figure 4.7.

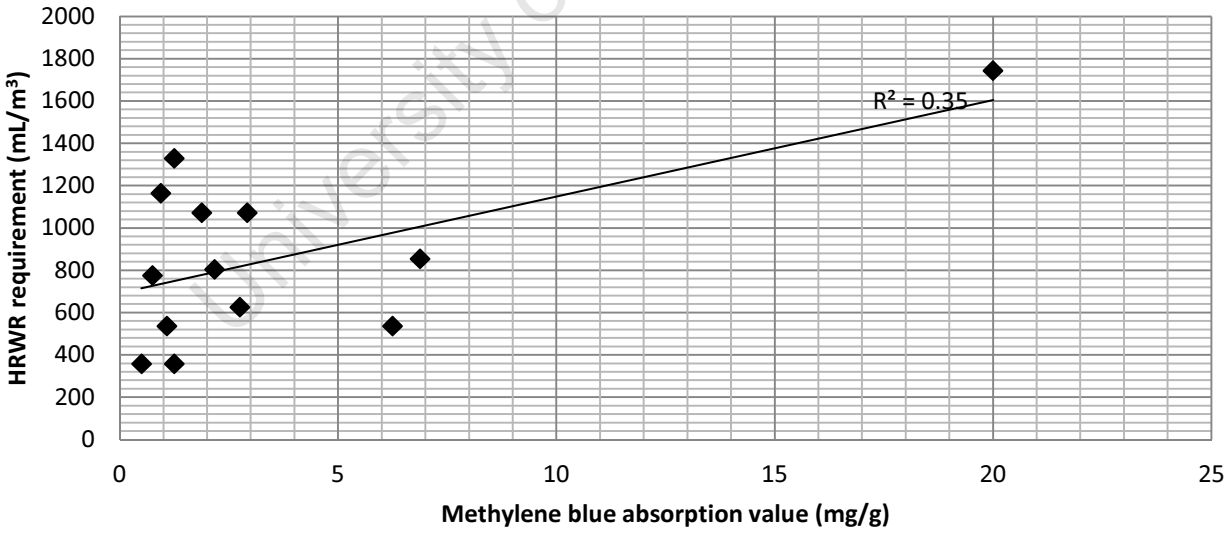


Figure 4.7. Relationship between HRWR requirement and methylene blue absorption value (Stewart, et al., 2007)

In this work, desired workability was achieved through the addition of water and cement. A direct correlation was found between the methylene blue absorption value of an aggregate and its corresponding water demand, as shown in Figure 4.8. In this figure, the methylene blue absorption value has been reported as mg/g instead of the SANS standard of expressing the value as a percentage. This is purely so that a comparison can be made between figures 4.7 and 4.8.

This work backs up Stewart et al's findings, in that there is a correlation between methylene blue absorption value and the workability of an aggregate. This is expected; the methylene blue absorption value is a measure of the total surface area of an aggregate. Since it has been established that there is a relationship between total surface area and water demand, it is not surprising that there is a relationship between the methylene blue absorption value and the water demand of an aggregate.

Figure 4.9 (which is a re-plot of Figure 4.3, but in this case the clay types are shown) shows the relationship between the type of clay in a fine aggregate and the subsequent water demand of concrete made with that aggregate. The figure indicates that the amount of clay in the aggregate primarily affects water demand rather than the type of clay. This in contrast to the findings made by Norvell et al (2007), shown in Figure 4.10. In their work, they found that the clay type has a significant influence on the workability of concrete made with clay in the aggregate. They found that at a constant clay content, more water was required to achieve the desired workability for montmorillonite clayey aggregate than for aggregate with illite or kaolinite.

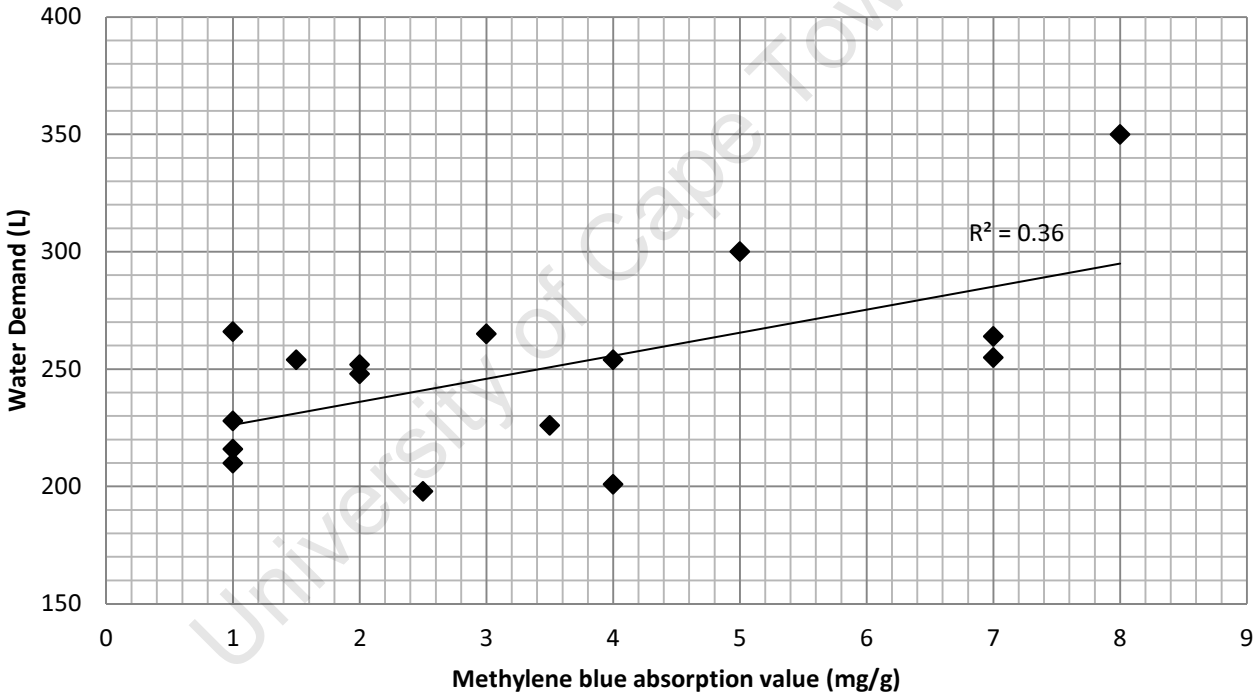


Figure 4.8. Relationship between methylene blue absorption value and water demand

4.3.5 Relationship between clay type and water demand

Furthermore, Norvell et al (2007) found that the montmorillonite clay had a higher methylene blue absorption value, which was not observed in this work (see section 3.3.6 on page 40). This, coupled with the discrepancy between the findings of the relationship between montmorillonite and workability, could indicate that although montmorillonite was found in one of the soils used in this research, it is not as active as the clay used in Norvell et al's work.

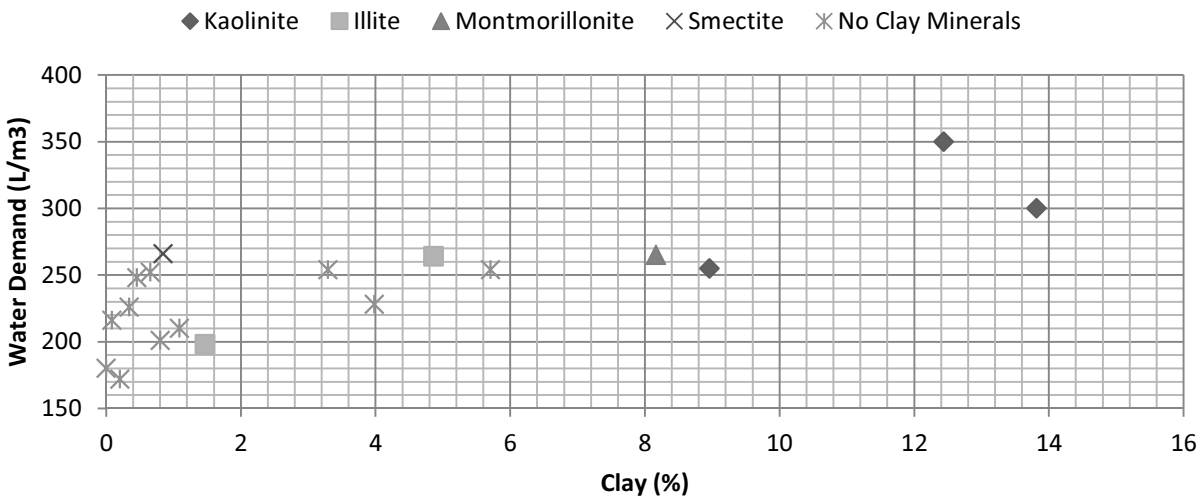


Figure 4.9. Relationship between clay fraction and water demand

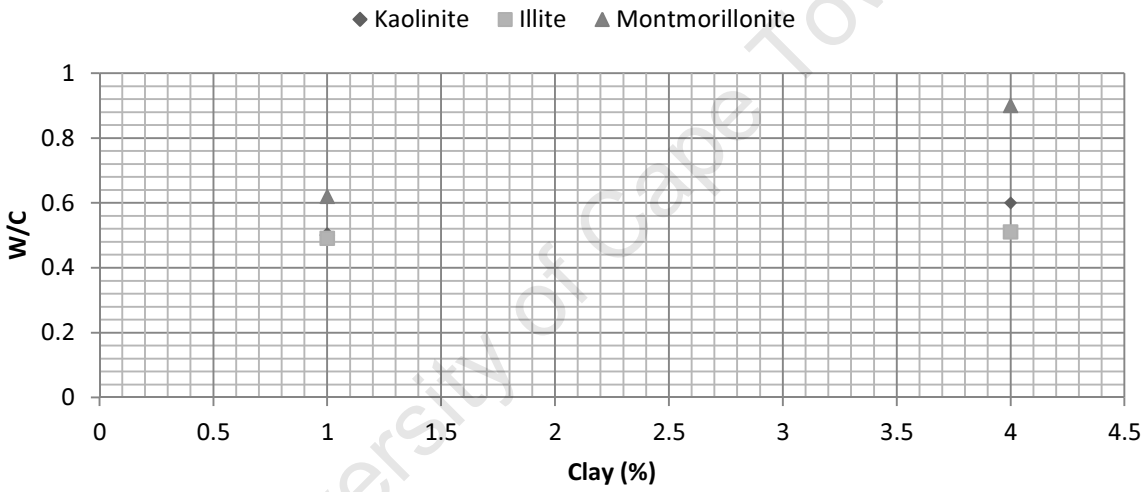


Figure 4.10. Relationship between clay type and workability (Norvell, et al., 2007)

4.4 General Discussion

It has been found that site-derived soils, when used in concrete, have a greater water demand than commercial building sands, which in turn results in increased cement content. Ultimately, this increases the negative impact that these concretes have on the environment, which is contrary to the aims of sustainability. It is therefore imperative that the reasons for this increased water demand are investigated and understood in order that the negative effects can be mitigated.

Water demand is dependent on a number of factors which primarily occur in the fine (<75µm) fraction of the concrete. This fraction includes the microfines, silt and clay content of the aggregate and the cement content.

The relationship between cement content and water demand is complex, in that water cannot be added independently from cement. By increasing the cement content, the total fines content increases, which in turn increases the water demand. This circular relationship between cement content and water demand is the reason why traditionally water demand is determined by trial and error.

This research is primarily focused on the effect that site-derived aggregates have on the performance of concrete. Both the microfines content and the methylene blue absorption value of the aggregate have been found to predict water demand. In essence, the microfines content and the methylene blue absorption values are both measures of the same property; the surface area of the aggregate. An aggregate with a greater microfines content will have a greater surface area, while the methylene blue test measures the surface area of the aggregate by coating the particles. If it is accepted that water demand is dependent on surface area, it is not surprising that both the microfines content and the methylene blue absorption value of an aggregate both predict water demand. This work has found that although the methylene blue absorption value is an indicator of water demand, the microfines content is a more accurate predictor. This is likely due to the fact that it is difficult to determine the end point of the methylene blue test, which makes determining the methylene blue absorption value of an aggregate less accurate. In contrast, it is possible to determine accurately and simply the microfines content of an aggregate through a sieve analysis.

These data indicate that in order to control the water demand, the microfines content of the aggregate needs to be controlled.

4.5 Conclusion

Based on the investigations carried out with regard to the water demand of natural site-derived fine aggregates, the following conclusions can be made:

- There is a relationship between the microfines content of an aggregate and its workability when used in concrete; an increase in the microfines fraction of the aggregate has a negative impact on workability.
- The shape of the particles in the fine aggregate has some influence on workability; in general, angular particles negatively influence workability, while rounded particles have a positive influence. The process to determine particle shape is subjective, and is therefore not an entirely accurate process. Although particle shape is a useful indicator it cannot be used as an independent predictor of the workability or water demand of an aggregate.
- There is a relationship between the total microfines content of a concrete mix and its workability. That is, workability is dependent on the total microfines fraction of the aggregate and the amount of cementitious material in the mix.
- The total surface area of the fine material in the concrete mix (that is all the material that would pass a 4.75mm sieve) has a direct impact on workability. The relationship between total surface area and water demand had the highest R^2 value of any of the relationships investigated in this part of the work, 0.88. This indicates that total surface area of the fines fraction in the concrete is an accurate predictor of workability.
- This work found that clay type had a negligible influence on the workability of the aggregate when used in concrete. Rather, the total fraction of clay-sized particles had an influence. This contrasts the findings by Norvell et al (2007). It is suggested that the reason for the contrasting findings is that the clays investigated in this work are not as active as those investigated in the work carried out by Norvell et al.
- There is a correlation between the methylene blue absorption value of an aggregate and its water demand. The R^2 value for this relationship was found to be 0.36, while the relationship between microfines content and water demand was found to have an R^2 of 0.65. This suggests that the measurement of microfines is a better predictor of water demand than the methylene blue test.

In general, the effect that an aggregate has on the water demand of concrete is dependent on its surface area. Aggregates with greater microfines contents will have greater surface areas and therefore have a greater impact on the water demand of a concrete mix. The methylene blue test goes some way in predicting the surface area, but impreciseness in the test procedure means that the prediction is not very accurate. A grading analysis was found to predict accurately the water demand that that aggregate would have, and it is therefore suggested that this test be used as an indicator for the water demand of an aggregate.

In order to control the effect that an aggregate has on water demand, it is important that the microfines content be controlled. A low microfines content will result in a low water demand and vice versa.

5 Strength

5.1 Introduction

The strength of a material is defined as the capability of the material to resist stress without failure (Fulton, 2009). The strength of hardened concrete is fundamental in structural design, and is widely used as an index to predict other concrete properties.

Therefore, it is important to this work that the effect that site-derived soils have on the strength of concrete be investigated.

5.2 Factors that affect the strength of concrete

There are a multitude of variables that affect the strength of concrete. The factors that are likely to influence the strength of concrete in this work are discussed in this section.

5.2.1 Porosity

All concrete is porous to some extent, primarily because of excess water in the concrete mix. More water is added to concrete than is necessary for hydration in order to achieve acceptable workability. It is this excess water that remains unreacted in the concrete and results in pores (Fulton, 2009).

Pores introduce flaws into the concrete matrix, whereby stress is not transferred through the pores but through the adjacent concrete. This results in localised areas of higher stress than the surrounding concrete. At high stress, failure starts at these localised areas of increased stress. Strength therefore decreases with increasing porosity (Fulton, 2009).

In this work, all the concrete was mixed, cast, cured and tested in the same way. The only variables in the mixes are the fine aggregate type, and the water and cement content. Any variation in porosity in the mixes can therefore be attributed to these factors.

5.2.2 Aggregates

It has been found that in concrete with compressive strength of lower than approximately 35 MPa, the coarse aggregate has little influence on the strength (Fulton, 2009). The concrete manufactured in this work falls below this strength, with compressive strengths of approximately 25 to 30 MPa observed at 28 days. Additionally, in all the concrete mixes, the same coarse aggregate was used. Therefore, it can be assumed that any variability in the strength of the concrete observed in this work is independent of the coarse aggregate.

The effect that fine aggregates have on the strength of concrete are discussed in chapter 3.

5.2.3 Aggregate paste interface

The interface between the aggregate and the concrete has been found to be the weakest area in the concrete matrix (Fulton, 2009).

A number of factors influence the strength of the aggregate-paste interface and therefore the overall strength of concrete (Fulton, 2009):

- Water-to-cement ratio. It has been found that at lower water-to-cement ratios, the strength of the aggregate-paste interface increases.
- Age of concrete. The strength of the aggregate-paste interface has been found to increase with age, provided there is sufficient water.

- Bleeding. Strength decreases with increased bleeding
- Type of cementitious material. Materials containing very fine particles develop stronger aggregate-paste bonds due to the fine filler effect.
- Ultrafines in aggregates. It has been found that ultrafine material reduces bleeding and causes a fine filler effect at the aggregate-paste interface. Both of these effects will increase the strength of concrete.
- Surface texture of aggregates. Strength has been found to increase with increasing roughness of aggregates.

5.3 Methodology

The compressive strength of concrete made with site-derived soils was investigated for this work.

Three 100mm x 100mm x 100mm cubes of water cured concrete were tested from each batch at 1, 3, 14, 28 and 70 days. The tests were carried out on an Amsler testing machine, shown in Figure 5.1, in accordance with SANS 5863:2006.

The cubes were tested in a saturated state and the compressive strength was determined as the average of the compressive strength results of the three cubes tested for each batch at each age.

Figure 5.1. Compression testing machine

5.4 Results and discussion

5.4.1 Relationship between strength and water demand

Figure 5.2 shows the relationship between compressive strength and the water demand of a soil. The figure indicates no clear relationship. There also appears to be little or no correspondence between the 28 day and 70 day compressive strength when compared to the water demand of the soil.

This indicates that when using natural fine material as concrete aggregate, the water demand of these aggregates is not an indicator of the strength of the concrete made with these aggregates.

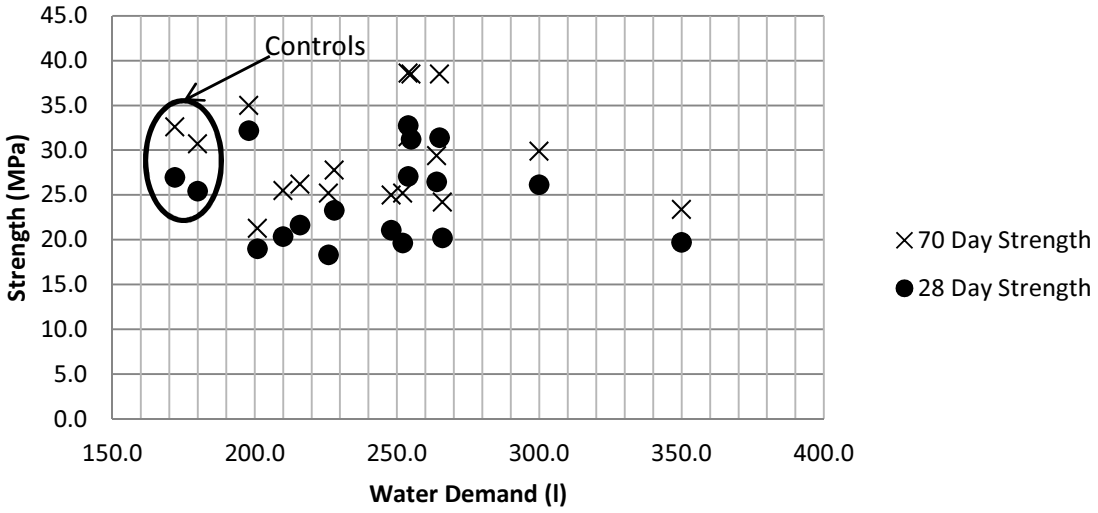


Figure 5.2. Relationship between strength and water demand

5.4.2 Relationship between strength and microfines content of fine aggregates

The relationship between microfines content of an aggregate and the corresponding strength of concrete made with this aggregate is shown in Figure 5.3. From the figure a trend is apparent, whereby low microfines aggregates produce relatively low strength concrete, intermittent microfines aggregates produce relatively high strength concretes and high microfines aggregates produce low strength concretes.

This trend suggests that the aggregate is being used as a fine filler. Aggregates with low microfines content produce concrete with a relatively high porosity and hence the relatively low compressive strength. As microfines content increases, up to a content of approximately 10%, porosity decreases. In this range, the compressive strength increases. This supports the argument that the microfines are reducing the pore content and as a result increasing the compressive strength of the concrete.

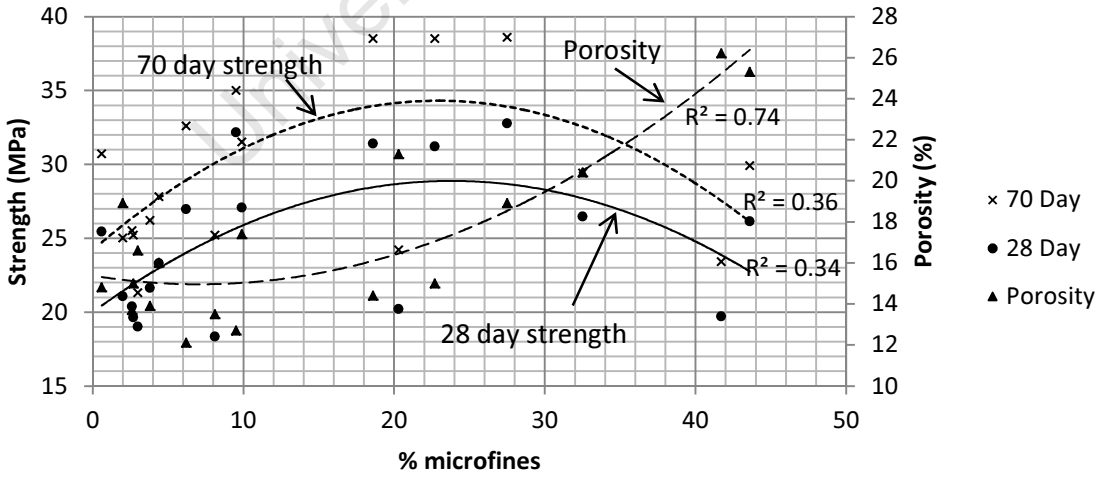


Figure 5.3. Relationship between microfines content and strength

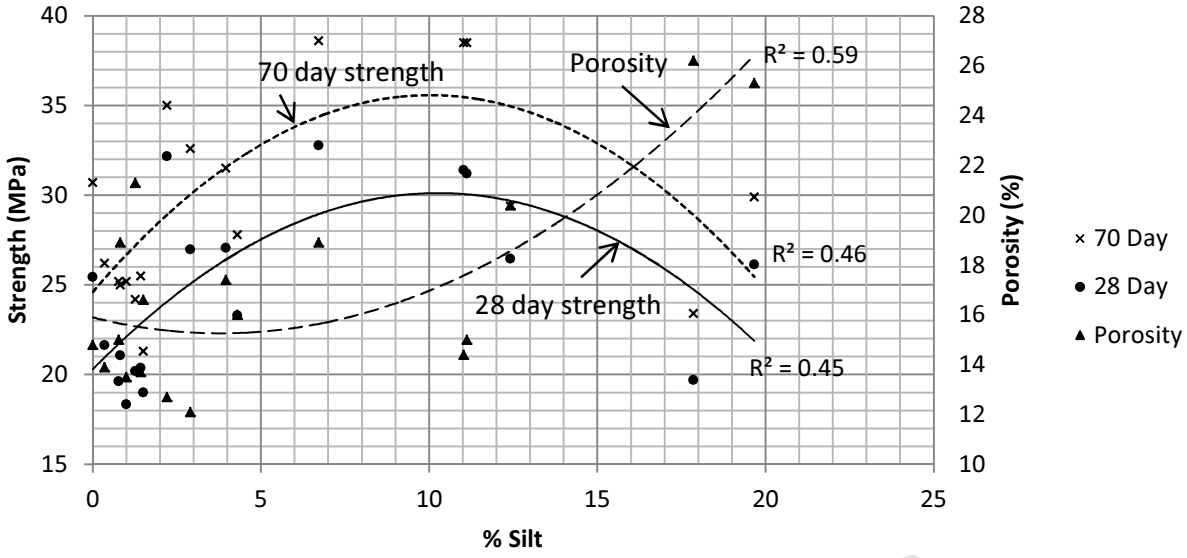


Figure 5.4. Relationship between silt and strength

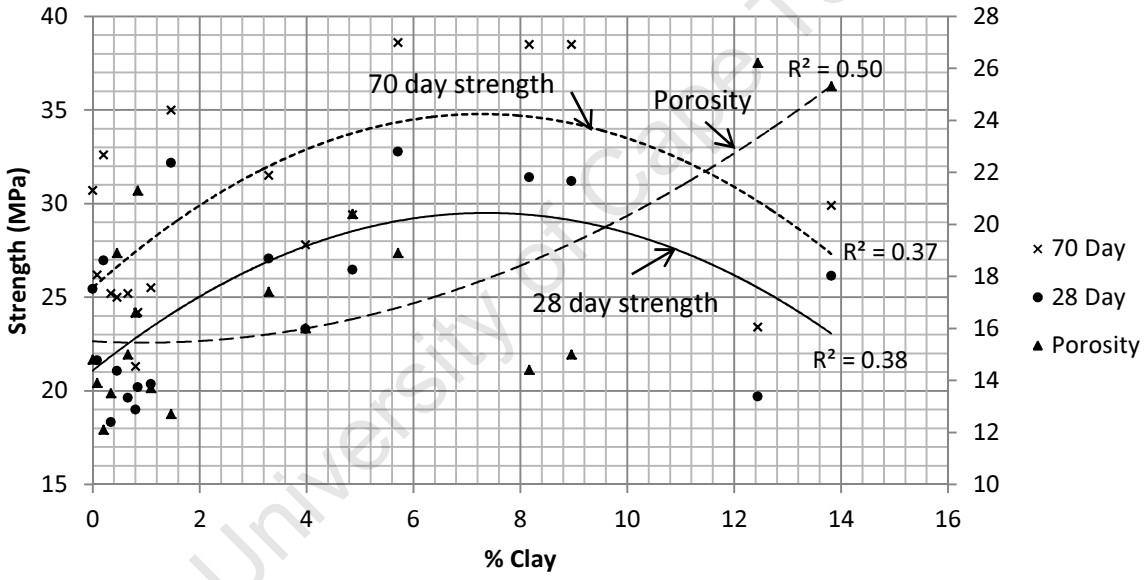


Figure 5.5. Relationship between clay content and strength

As the microfines content increases above 10%, the porosity increases. However, there is still an increase in strength until a microfines content of approximately 22%. This indicates that the strength behaviour of the concrete observed in this work cannot be explained solely by the microfines content acting as a fine filler.

Figure 5.4 shows the relationship between silt content, strength and porosity. This figure shows similar relationships to those in Figure 5.3. However, in this figure, the silt content at which porosity starts increasing, 5%, correlates more closely with the silt content at which strength starts decreasing, approximately 10%.

Figure 5.5 shows the same relationship again, but with clay content instead. This figure indicates that porosity starts increasing at a clay content of approximately 3%, while strength starts decreasing at

approximately 7%. This indicates that clay content is the most accurate indicator of the fine filler effect resulting in an increase in strength.

These data indicate that microfines, silt and clay contents of 22%, 10% and 7% respectively in natural fine aggregates are optimum for the strength of concrete made with these aggregates. There is a considerable amount of variability in the results, and as such these optimum values are only preliminary indicators. Further research into this will be required to confidently establish recommended optimum microfine contents.

In all the figures, there is a discrepancy between the fine material content at which porosity starts increasing and the fine material content at which strength starts decreasing. This indicates that the strength of concrete made with natural fine aggregates cannot be predicted purely on the effect that the aggregate will have on the fine filler effect. However, the data does indicate that the strength of a concrete made with natural fine aggregates can be predicted by measuring the microfines, silt and clay contents of the aggregate, even though the mechanisms of the strength development are not fully understood.

5.4.3 Relationship between strength and total fines content

The total fines content consists of the sum of the microfines content and the cement content as a percentage of the total mass of the concrete. Figure 5.6 indicates that the strength of concrete is independent of its total fines content.

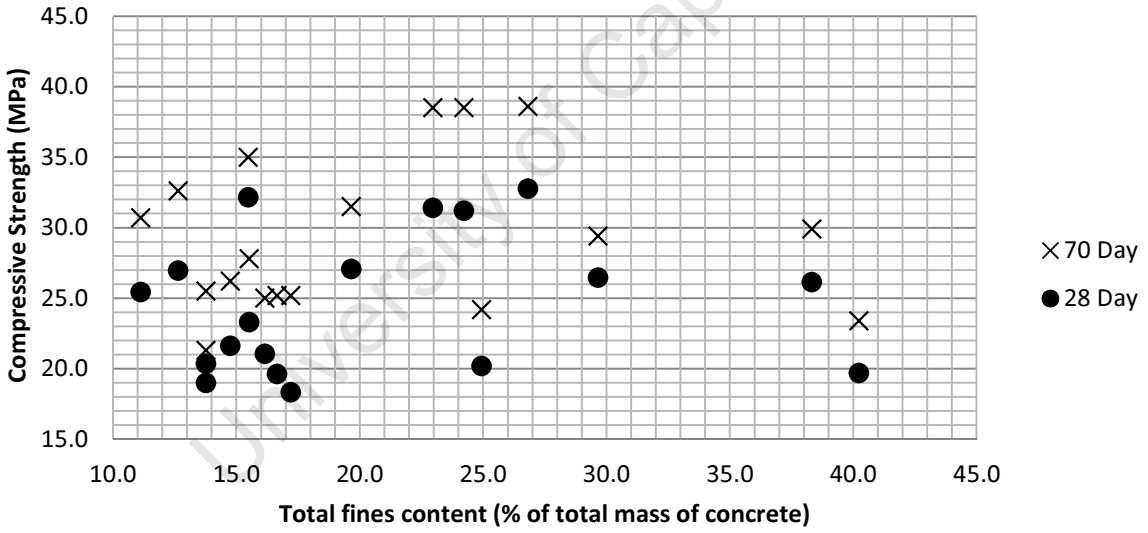


Figure 5.6. Effect of total fines content on strength

5.4.4 Correlation between compressive strength and methylene blue absorption value

Stewart et al (2007) reported a correlation between the methylene blue absorption value of an aggregate and the corresponding strength of concrete made with that aggregate, as shown in Figure 5.7.

In this work, however, no such relationship was observed, as indicated in Figure 5.8. This could be due to the different nature of the aggregates tested; Stewart et al were testing crusher sand, while in this work only natural sands were considered. It is possible that the effects of clay, or other deleterious clays and minerals affecting the strength of concrete in this work, while these factors may not have been an issue in Stewart et al's work.

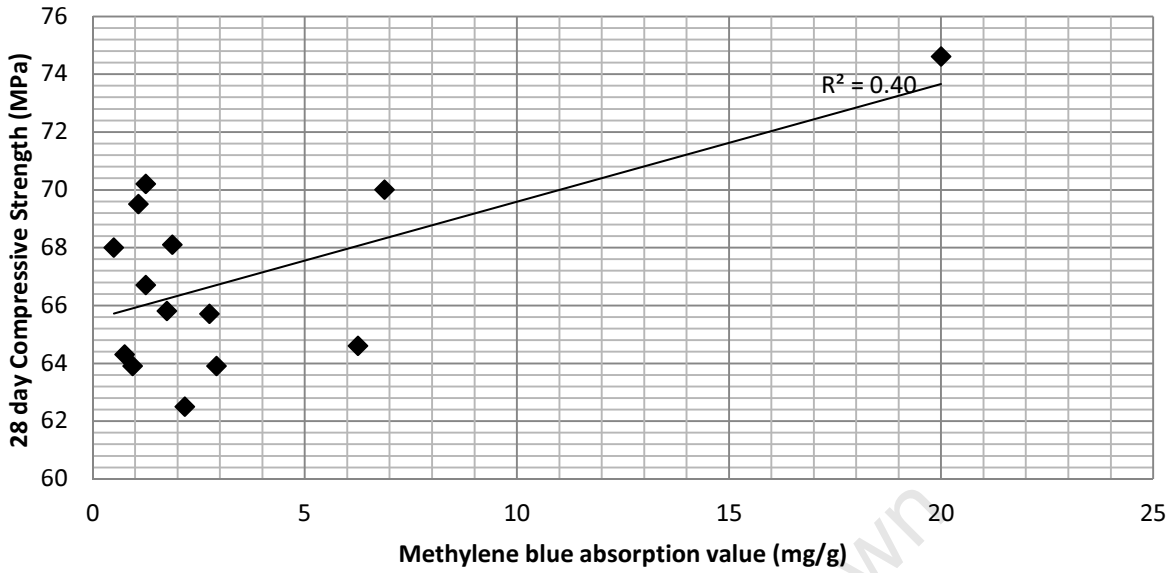


Figure 5.7. Relationship between methylene blue absorption value and compressive strength (Stewart, et al., 2007)

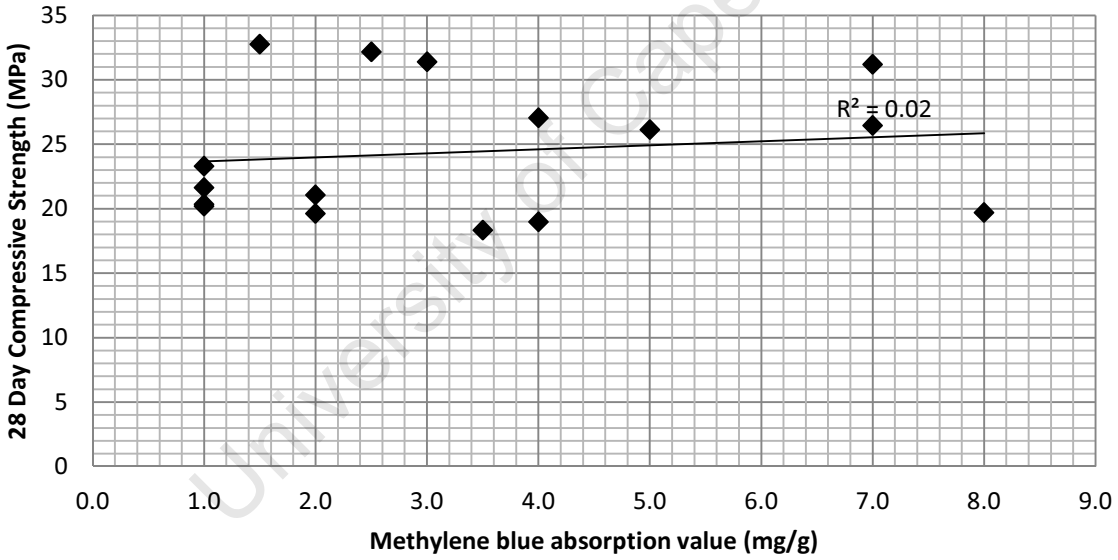


Figure 5.8. Relationship between methylene blue absorption value and compressive strength

The data indicate that for natural aggregates, the standard methylene blue test is not an indicator of strength.

5.4.5 Effect of type of clay on strength

The relationship between the type of clay used as fine aggregate and the 28 day compressive strength is shown in Figure 5.9. It can be seen that the montmorillonite produced the highest average 28 day strength, followed by illite, then kaolinite and smectite clays produced the weakest compressive strength. These findings are comparable to the findings of He, Osbaeck and Makovicky, as shown in the figure. In their work, they too found that montmorillonites (in their case an average of two – an

Na-montmorillonite and a Ca-montmorillonite) produced the greatest strength concrete, followed by illite, then kaolinite and finally smectite.

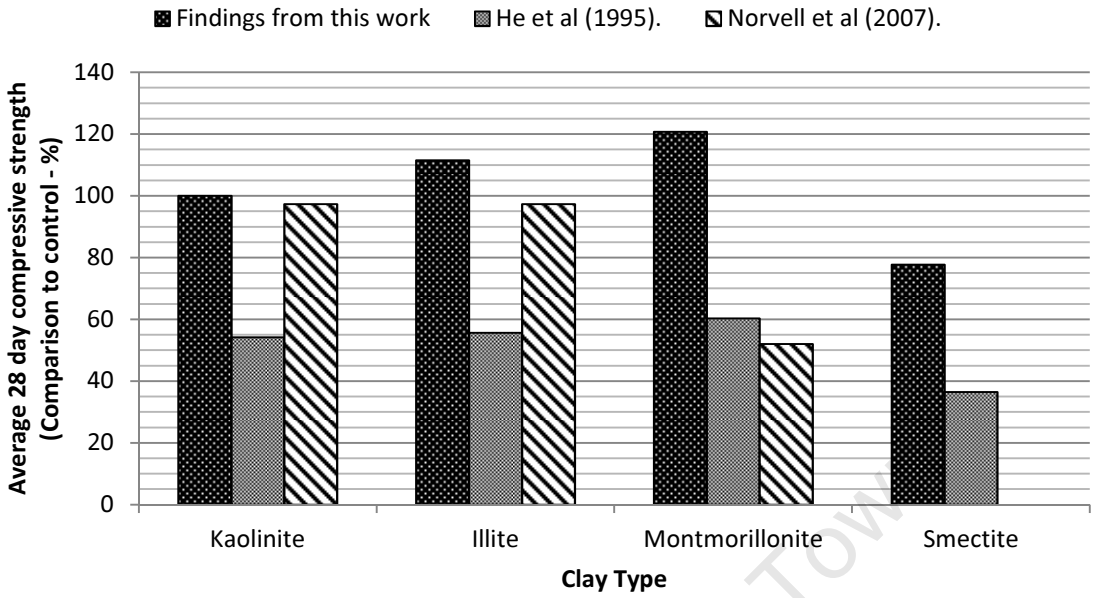


Figure 5.9. Relationship between clay type and compressive strength

When compared to the average strength of the control, the samples in this work performed better than in the work performed by He, Osbaeck and Makovicky (1995). This could be because in their work, mortar was tested as opposed to concrete, and the fine aggregate consisted only of the clays being evaluated. Therefore, the effects of these clays on the performance of the concrete would be far more pronounced than in this work, where the clay made up only a small fraction of the fine aggregate.

The findings from this work differ, however, from the findings of Norvell et al (2007). The figure shows the strengths of concrete made with 4% of the specified clays in the aggregate. In their work, they found that illite and kaolinite had little effect on strength performance, as in this work. However, they did find that montmorillonite clays greatly reduced strength. As discussed in section 4.3.5, this could be because the clay use in Norvell et al's (2007) work was more active than the clay used in this work.

The findings of this work indicate that Illite and montmorillonite clays perform slightly better than the control, kaolinite clays are comparable to the control and smectite clays perform considerably worse than the control, when comparing compressive strength of concrete made with these materials.

5.4.6 Pozzolanic reactions and strength

5.4.6.1 Methodology

The concrete samples that were found to have a form of clay present using the X-Ray Diffraction (XRD) analysis were subjected to Thermogravimetric Analysis (TGA). Tests were carried out on 28 day and 70 day samples, all were water cured. Not all the soils that were tested for this thesis had clay present, and as such the number of samples used in this part of the testing was smaller than the total sample size.

Thermogravimetric analysis allows for the proportion of calcium hydroxide in the concrete to be quantified. Calcium hydroxide is a by-product of the cement hydration process, and is consumed in

pozzolanic reactions. Since pozzolanic reactions take longer than cement hydration reactions, it will be possible to determine whether pozzolanic reactions occur by comparing the amount of calcium hydroxide in the concrete at 28 and 70 days.

Samples of the concrete were collected at 28 and 70 days. These samples were stored in acetone for at least 7 days before being removed. The purpose of this was to ensure that all hydration reactions had stopped in the concrete. The concrete was then crushed in a pestle and mortar by hand and sieved through a 75µm sieve. The fraction passing the 75µm sieve was then subjected to thermogravimetric analysis.

The thermogravimetric conditions were: N_2 gas atmosphere, heating rate of 10^0C/min and the samples were stored in open top crucibles. The samples were heated from 55^0C to 600^0C.

In concrete, the following zones can be observed (de Souza A & Sichieri, 2006):

- ~25 – 123.3^{0}C : dehydration of pore water
- ~123.3-420^{0}C: Dehydration of calcium silicate hydrates
- ~420-480^{0}C: Dehydroxylation of calcium hydroxide
- ~480-730^{0}C: Decarbonation of $CaCO_3$.

The thermogravimetric analysis apparatus outputs a graph showing the mass of the sample at a given temperature. The first derivative of this curve provides the rate of change of mass with regard to temperature. This derivative curve shows a significant peak between 420 and 480^{0}C. This peak signifies the Dehydroxylation of calcium hydroxide. From this, it is possible to determine the mass of the sample before and after the calcium hydroxide dehydroxylates. This allows the fraction of the concrete that is calcium hydroxide to be determined.

The fraction of CH in the sample is determined using the following formula;

$$CH(\%) = \left(\frac{Mass\ at\ 480^{O}C - Mass\ at\ 420^{O}C}{Initial\ Mass}\right) X\ 100$$

Equation 5.1. CH fraction

5.4.6.2 Results and discussion

Figure 5.10 shows the strength of the samples tested against their respective fractions of calcium hydroxide (CH). The control samples, which did not have any clay in them, have been highlighted so that the individual controls can be identified.

As the fraction of CH present in hydrated cement is proportional to its degree of hydration, one would expect that an increase in CH would be represented by an increase in strength. However, both of the controls show the opposite of this. This is most likely because SureBuild cement was used for the testing as opposed to CEM I. Cement extenders, namely GGCS, are present in the SureBuild cement. These data indicate that it can be assumed that these extenders are undergoing pozzolanic reactions, whereby CH is consumed and converted into compounds that provide strength such as CSH or CAH. This explains why a decrease in CH in these samples results in a gain in strength.

In region B, shown in Figure 5.10, the smectite samples have similar CH fractions to the controls but show lower strength. The kaolinite samples have similar strength values, but greater CH fractions. This indicates that even though there does not appear to be a reduction in the formation of CH, there is retardation in the strength of these samples. From this data, it is not clear whether this effect is from the clay or another influence.

Region A shows lower CH fractions but at equal or greater strengths than the controls. A possible explanation is that the clay in the concrete is retarding the hydration of the cement. However, since these samples do not show any reduction in strength, this argument can be refuted. Another explanation is that the clay in the concrete is undergoing pozzolanic reactions. These reactions would explain the reduction in CH and the positive influence on strength.

It is also worth noting the correlation between clay type and the way it has performed. Montmorillonite and Illite type clays both seem to undergo pozzolanic reactions, with both these clay types showing reduced CH concentrations. The pozzolanic reaction seems particularly effective with montmorillonite clay; this clay shows a large increase in strength with decreasing CH concentration. Smectite seems to have little effect on the hydration of cement.

Kaolinite shows mixed effects on the formation of CH. Most of the samples show lower CH fractions than the control, indicating some pozzolanic activity. However, one sample shows a CH concentration typical of that of the controls, with slightly decreased strength. From these data, it is difficult to explain the unpredictable behaviour of the Kaolinite clay.

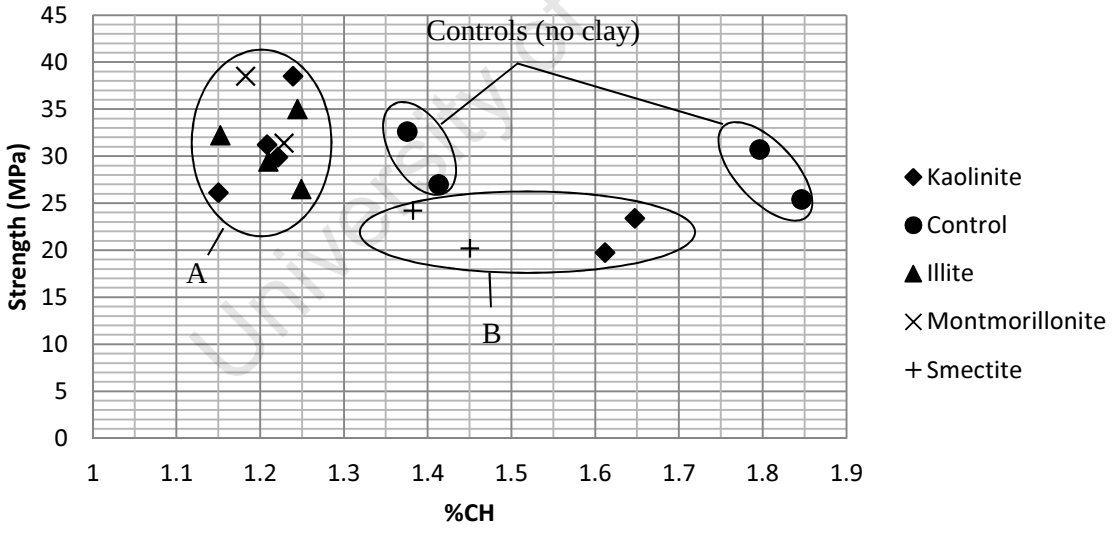


Figure 5.10. Comparison between strength and fraction of Calcium Hydroxide

Figure 5.11 shows the percentage change in the fraction Calcium Hydroxide (CH) in the samples between 28 and 70 days on the horizontal axis. The vertical axis indicates the percentage change in strength of the samples over the same period.

The percentage change in strength was calculated using Equation 5.2:

$$\%\ Change\ in\ strength = \frac{70\ day\ strength - 28\ day\ strength}{28\ day\ strength} \times 100$$

Equation 5.2. Percentage change in strength

This parameter indicates the extent to which strength is gained after 28 days and since it is a fraction of the change in strength over the initial strength, the magnitude of the initial strength does not affect the analysis. Since the control samples do not contain any clay, it is assumed that any change in strength between 28 days and 70 days is due to the hydration of the cement fraction in the concrete.

The control samples gained approximately 20% strength between 28 days and 70 days. The kaolinite, montmorillonite and smectite clays gained approximately the same amount of strength during this time. Illite clays gained less strength, approximately 10%, over the same time.

The percentage change in CH between 28 days and 70 days was calculated using Equation 5.3:

$$\%\ Change\ in\ CH = \frac{70\ day\ CH\ fraction - 28\ day\ CH\ fraction}{28\ day\ CH\ fraction} \times 100$$

Equation 5.3. Percentage change in CH between 28 days and 70 days

The CH fraction is calculated using Equation 5.1 on page 63. The percentage change in CH indicates the extent to which the amount of CH in the concrete has increased or decreased. CH is a by-product of normal cement hydration and is commonly used as a measure of the degree to which cement has hydrated. In OPC, one would expect an increase in the fraction of CH in hydrated cement to correlate to an increase in strength. Pozzolanic reactions consume CH and result in an increase in strength through the production of cement hydration products. Therefore, a decrease in the CH fraction corresponding to an increase in strength can be assumed to be due to pozzolanic activity.

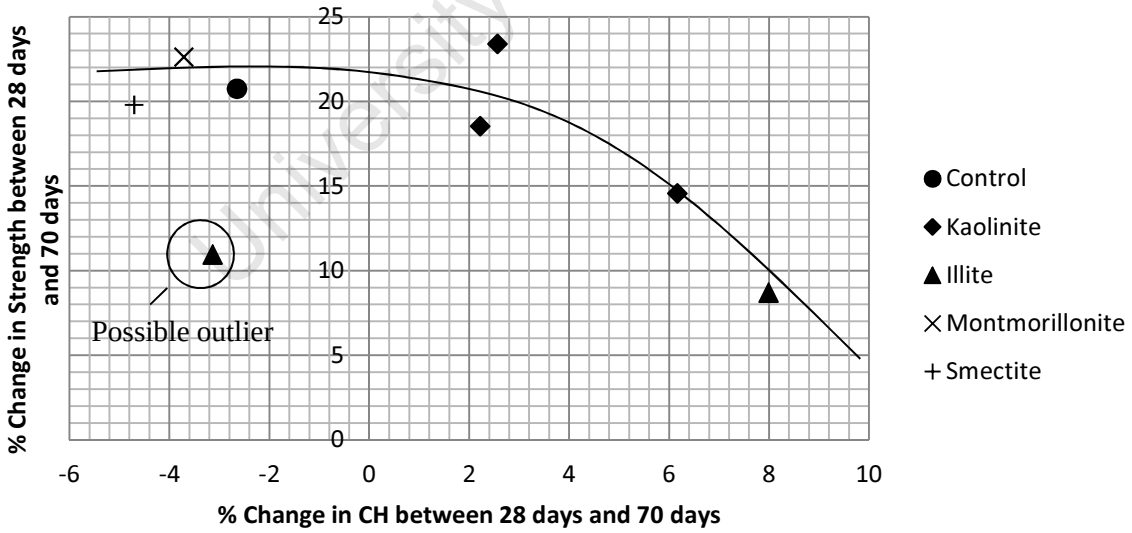


Figure 5.11. Relationship between change in strength and change in Calcium Hydroxide fraction

With the exception of the possible outlier (circled), these data indicate a trend where an increase in the % change in CH results in a lesser increase in % change of strength. This supports the previous discussion regarding possible pozzolanic reactions occurring. When the compounds in the cement, either extenders or clay, undergo pozzolanic reactions with the CH in the cement, the CH is consumed and CSH, CAH or other strength providing hydrates are formed.

Both of the control samples show a decrease in the CH fraction between 28 and 70 days. This indicates that there is something in the cement itself, most likely an extender, consuming CH. From this, one would expect that all the samples would show some reduction in their CH fraction, since all mixes used the same cement. However, this is not the case; all the kaolinite samples showed an increase in the percentage of CH. This means that more CH was produced than consumed between 28 and 70 days in the kaolinite samples.

Both the montmorillonite and the smectite show a greater reduction in the percentage of CH than the control, with the montmorillonite showing a greater strength gain. This is indicative of pozzolanic activity between these clays and the CH in the cement.

The illite shows unpredictable behaviour, with one sample showing an increase in the percentage of CH, while the other shows a decrease. They both show similar increases in strength.

From these data, there is evidence of possible pozzolanic reactions occurring between the clay and the cement paste. However, the magnitude and effectiveness of the reactions appear to vary even within soils with the same clay type. While pozzolanic reactions do appear to occur and such reactions would be beneficial for the long-term performance of the concrete, these reactions cannot be relied upon to provide desirable concrete properties due to their variable nature, unless one can be established for a given soil type.

If more research is done into this field, using soils in and around Cape Town, this statement may need to be modified and designers will be able to make use of the beneficial properties of the pozzolanic reactions occurring between the CH and clay.

5.5 General Discussion

The strength of concrete is a key criteria used in concrete design. In addition to determining the size of concrete members in a structure, the strength of concrete is often used as a predictor for other concrete performance criteria such as durability. With this in mind, it is highly important in the scope of this work to understand the effect that site-derived fine materials have on the strength performance of concrete.

The w:c ratio determines the strength of the cementitious paste in concrete. In this work, the w:c ratio was kept constant, and since the only variable in the mixes was the fine aggregate, any variation in the strength performance of concrete is assumed to be due to this material.

This work has highlighted the difficulty in predicting the effect that site-derived soils have on the strength performance of concrete. There is some evidence for an optimum microfines content, where it is suggested that the fine filler effect results in an increase in strength performance. However the reliability of this relationship needs to be critically evaluated – the R^2 values are around 0.35. In order for the relationship to be accurate enough for a designer to predict confidently the strength of concrete made with these materials, more research into this area is required. Until such research is undertaken, it is critical that if these materials are used as concrete aggregate, their effect on the strength of concrete must be investigated on a case-by-case basis.

5.6 Conclusion

From the investigations carried out in this work on the relationship between the properties of natural site-derived soils and their influence on the strength of concrete made with them as aggregate, the following conclusions have been made:

- The strength of the concrete is independent of the water demand of the aggregate. In this work, the water-to-cement ratio was kept constant, but if the cement content was kept constant, it is likely that an increase in water demand will result in a lower strength concrete, since the w/c ratio will be greater.
- There is evidence for an optimum microfines, silt and clay content of 22%, 10% and 7% respectively with regard to strength. It is suggested that this is due to a fine filler effect. At low fractions, these size particles are acting as a fine filler, reducing porosity. At high fractions, the increased water and cement content required because of these materials eclipses the fine filler effect, and porosity is reduced. This reduction in porosity is reflected in lower strength concrete.
- The sum of the cement content and the microfines content appears to be independent of the strength performance of the concrete.
- The strength of concrete appears to be independent of the methylene blue absorption value of the fine aggregate material. This is in contrast to the findings of Stewart et al. who found that a high methylene blue absorption value of the aggregate indicated a reduction in compressive strength of the concrete made with this aggregate. This could be because the clays tested in this work are less active that those tested in Stewart et al's work.
- Montmorillonite type clay was found to produce the greatest strength concrete, followed by illite, then kaolinite. The strength of the concrete made with these clays in the aggregate is comparable to the control, where there was no clay present. The relationship between clay type and compressive strength is in agreement with the findings of He et al, but differs from the findings of Norvell et al. In Norvell et al's work, it was found that montmorillonite type clay greatly reduced the strength of concrete. As suggested previously, the difference in findings is possibly due to the activity of the montmorillonite clay used in this work being less as compared to that used in Norvell et al's work. This work is in agreement with Norvell et al in that kaolinite clay and illite clay have negligible influence on strength. This work is also in agreement with He et al that smectite clay negatively impacts the strength of concrete.
- Evidence of pozzolanic activity between the clay in the aggregate and the CH in the cement paste was observed. There was a high degree of variability between the pozzolanic activity even of clays of the same type. This suggests that while these reactions would prove to be beneficial to the performance of concrete, more work is needed in order that they can be better understood.

In general, it was found that a microfines, silt and clay content of 22%, 10% and 7% respectively produce the greatest strength concrete. These contents appear to be related to the porosity of concrete, although more research is required before these values can be confidently relied upon. There is evidence that pozzolanic activity is occurring between clay in the aggregate and the cement paste, and these reactions could be beneficial to the performance of concrete.

6 Shrinkage

6.1 Introduction

Concrete undergoes volumetric changes throughout its life. This section covers the aspect of drying shrinkage, which occurs because of the loss of moisture in the concrete (Fulton, 2009). Autogenous shrinkage, which occurs because of hydration reactions, was not directly investigated in this work.

Shrinkage is important from a design point of view, as it is a measure of the degree to which a concrete will deform even when external loads are not applied. This influences cracking of the concrete, as well as additional curvature in unsymmetrically reinforced members (Fulton, 2009).

The shrinkage of concrete is primarily influenced by the paste. Lower w:c ratios have been found to result in lower shrinkage (Fulton, 2009). In this work the water-to-cement ratio was kept constant for all the mixes and this can therefore be excluded as a possible influence.

An increase in aggregate proportion in the concrete mix has been found to decrease shrinkage. Aggregates reduce shrinkage in two ways: dilution and restraint. Dilution refers to the fact that shrinkage decreases with increased aggregate concentration, while restraint refers to the fact that shrinkage decreases with increased aggregate stiffness (Fulton, 2009). In this work, the water content was varied with each mix. Cement content was varied proportionally to water. Therefore, at lower water contents, the paste volume was low and the aggregate concentration was relatively high. At high water contents, the paste volume was high and the aggregate concentration was relatively low. Therefore, higher shrinkage is expected at high water contents, due to the increase in paste concentration and decrease in aggregate concentration.

6.2 Methodology

From each batch, two 300mm x 50mm x 50mm prisms were cast. The prisms were water cured for 14 days, and then transferred from the water into a room with a controlled environment, kept at 22^{o}C. Shrinkage was monitored along two opposite sides of each prism at 1, 3, 14 and 28 days after being placed in the controlled environment.

Strain targets were placed on the sides of the concrete specimens, at a gauge length of 100mm. Two sets of targets were placed on each prism, enabling four readings to be made for each batch when measurements were taken. The strain measurements were taken using a mechanical strain gauge (Staeger – Type Pfender).

6.3 Results and discussion

6.3.1 Relationship between shrinkage and Water demand

As expected, a direct relationship was observed between shrinkage and water demand, as shown in Figure 6.1.

This relationship is useful in that it will be possible to predict the effect on shrinkage that a soil will have, when used as aggregate, if its water content is known.

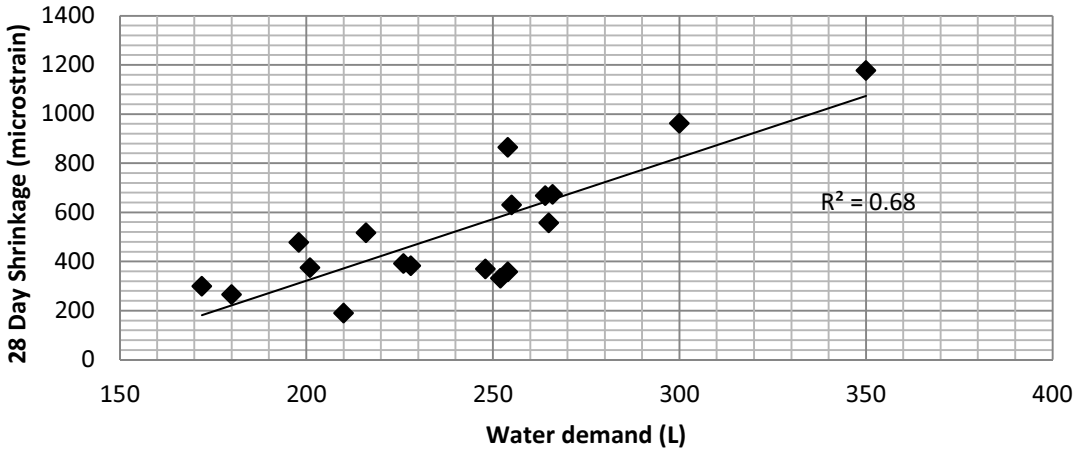


Figure 6.1. Relationship between shrinkage and water demand

6.3.2 Relationship between shrinkage and microfines content

Since the water demand is proportional to the microfines content, as discussed previously, it is therefore expected that there will be a relationship between microfines content and shrinkage. This relationship is shown in Figure 6.2.

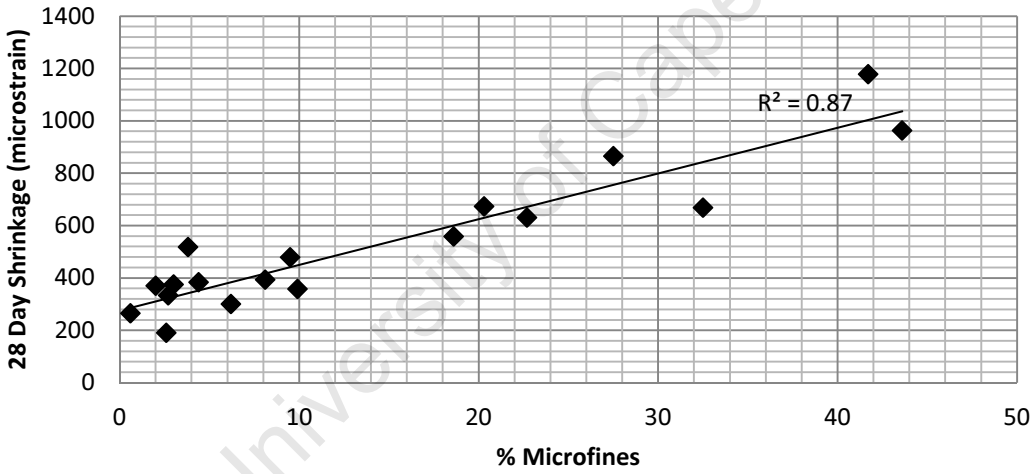


Figure 6.2. Relationship between microfines content and shrinkage

It should be noted that there appears to be a closer correlation between shrinkage and microfines content than between shrinkage and water content. This indicates that it is perhaps more reliable and accurate to measure microfines content than water demand as a predictor for shrinkage.

Since the mixes were cast at varying water contents, it would be useful to see the effect that an increase in microfines content would have if the concrete were cast at a given water content. For this work, this has been done using the following formula:

$$Normalised\ Shrinkage = Actual\ Shrinkage \times \left(\frac{Target\ Water\ Content}{Actual\ Water\ Content}\right)$$

Equation 6.1. Normalised Shrinkage

A target water content of 200 L/m^3 was used since this is commonly used in concrete construction.

The relationship between this normalised shrinkage and microfines content is shown in Figure 6.3.

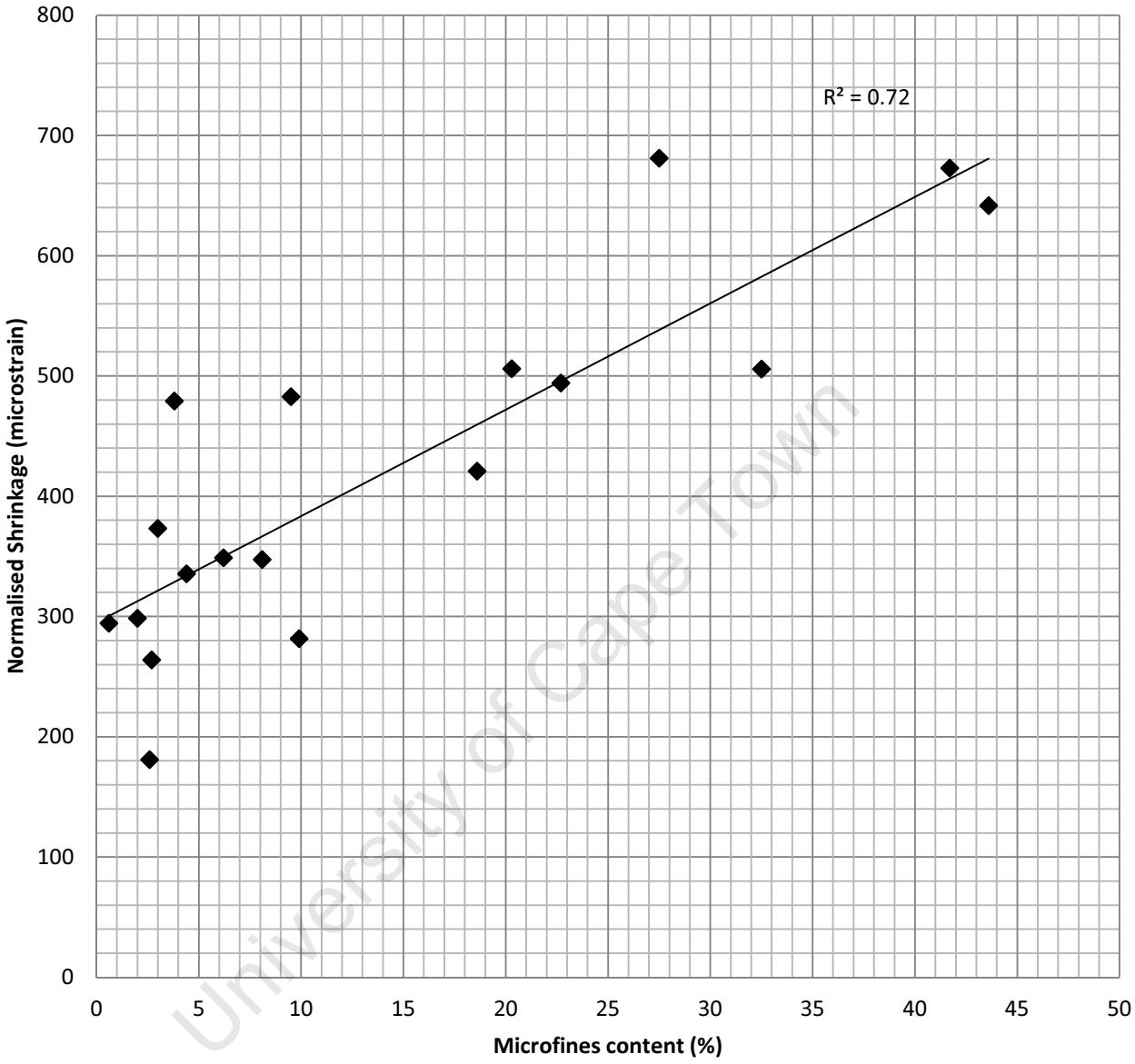


Figure 6.3. Relationship between microfines content and shrinkage normalised for water content

The figure shows a relationship between microfines content and shrinkage, even when water content is normalised. This indicates that the presence of microfines in the concrete aggregate introduces some form of dimensional instability, resulting in increased drying shrinkage.

These findings are in agreement with the work of Walker (1995). In Walker's work, the shrinkage of cement stabilised concrete blocks made with various aggregates were investigated. This work identified a direct relationship between drying shrinkage and microfines content, as shown in Figure 6.4.

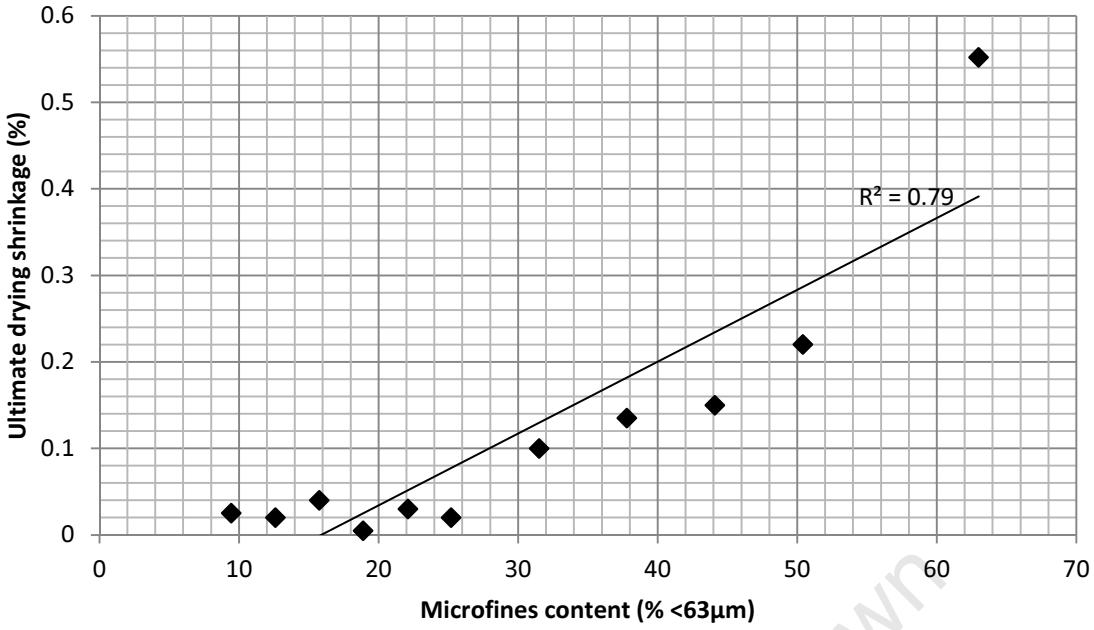


Figure 6.4. Relationship between drying shrinkage and microfines content for compressed concrete blocks (Walker, 1995)

6.3.3 Relationship between shrinkage and total microfines content of the concrete

The total microfines content of the concrete consists of both microfines from the aggregate and cement. Since both of these influence the water demand of concrete and the shrinkage is influenced by the water demand, it is expected that there will be a relationship between the total microfines content of the concrete and the resulting shrinkage. This relationship is shown in Figure 6.5.

If the R^2 value is taken as an indicator of the accuracy of the correlation, a few points can be made regarding this figure. The relationship between total microfines content has the greatest R^2 value of all the variables that have been compared to shrinkage. This indicates that the total microfines content of the concrete is a good indicator of the expected shrinkage values of concrete.

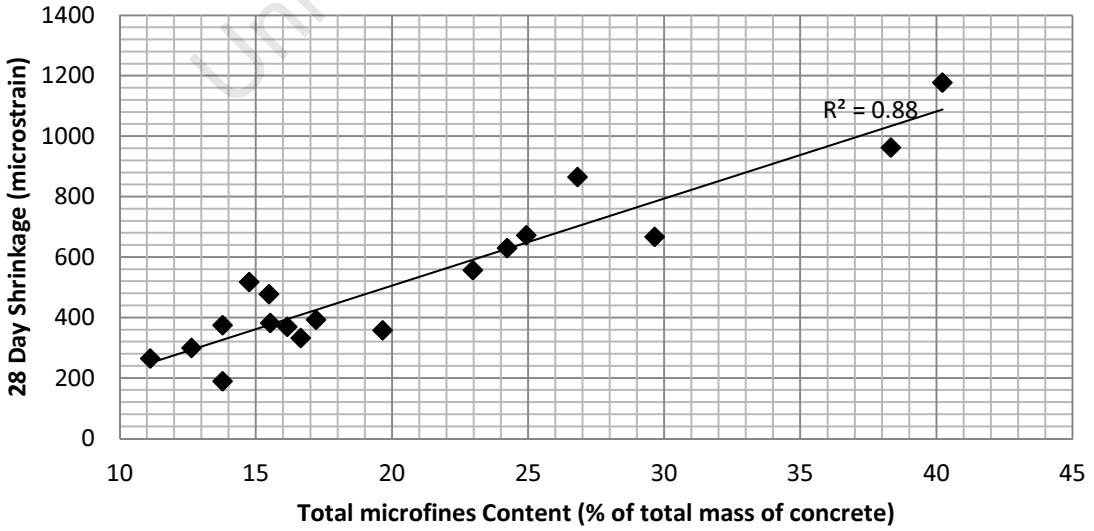


Figure 6.5. Relationship between shrinkage and total microfines in the concrete

6.3.4 Relationship between shrinkage and clay type

Figure 6.6 shows the relationship between microfines content, clay type and shrinkage. From the figure, it appears that clay type does not have a direct influence on shrinkage. The greatest shrinkage is experienced where the aggregate contained Kaolinite type clay, but these aggregates have high microfines contents. Where the aggregate had kaolinite clay in it and had a low microfines content, the concrete experienced lower shrinkage.

From these data, it appears that the type of clay in the aggregate has little influence on the drying shrinkage of concrete made with the aggregate.

These findings are in contrast to those made by Norvell et al (2007), shown in Figure 6.7. In their work, they found that an increase in the fraction of clay sized particles does have an influence on drying shrinkage, in agreement with the findings of this work. However, they found that montmorillonite clay had a significant influence on shrinkage, which was not found by this work. The discrepancy in the findings could be due to the montmorillonite in their work being more active that the montmorillonite that was used in this work.

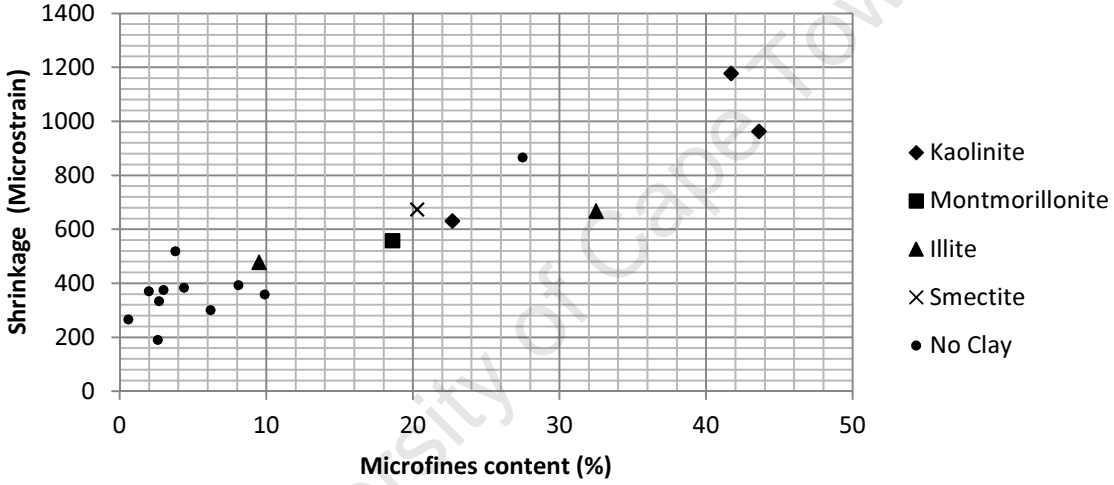


Figure 6.6. Relationship between clay type, microfines content and shrinkage

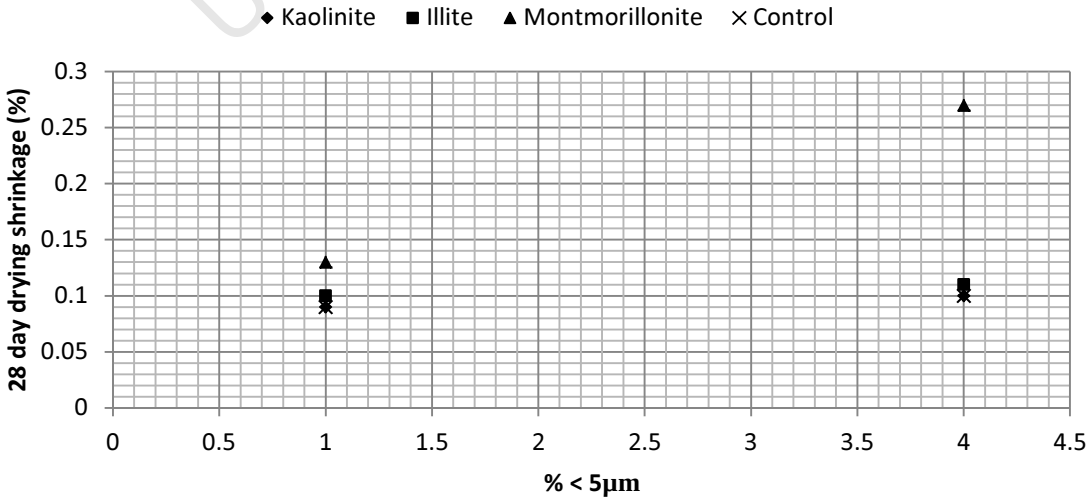


Figure 6.7. Influence of clay type on drying shrinkage (Norvell, et al., 2007)

6.4 General discussion

It is generally accepted that shrinkage is dependent on paste content and therefore water demand. Because water demand is dependent on microfines content (as already established), it follows that shrinkage is also dependent on microfines content. This relationship was observed in this work as predicted.

However, when the shrinkage is normalised for the effect that the microfines have on water demand, a relationship is still apparent between shrinkage and microfines content. This indicates that microfines affect shrinkage independently of the effect of water demand. Therefore, the microfines affect the shrinkage of concrete in two ways; through a direct influence (possibly due to dimensional instability of this fraction of the aggregate) and through the affect that microfines have on water demand. This is shown in Figure 6.8.

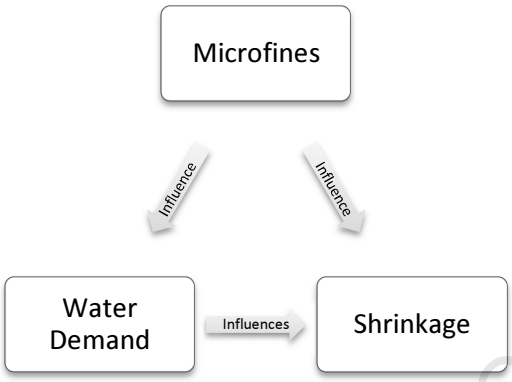


Figure 6.8. Microfines influence on the shrinkage of concrete

By using the knowledge of this relationship, the required performance criteria can be met when concrete is made with these materials.

6.5 Conclusion

From the work carried out on the shrinkage performance of concrete made with site-derived soil as its fine aggregate, the following conclusions can be drawn:

- There is a direct relationship between the water demand of an aggregate and the shrinkage of concrete made with this aggregate. In this work, the water-to-cement ratio was kept constant, and therefore a higher water demand signifies a greater cement content. There is a relationship between paste content in concrete and the shrinkage of that concrete and this would explain the relationship between shrinkage and water demand.
- There is a relationship between shrinkage and the microfines content of the aggregate. There is a direct relationship between microfines and water demand and a direct relationship between water demand and shrinkage, this relationship could be explained by the effect that the microfines have on the water demand. However, when shrinkage is normalised for water demand, there is still an apparent relationship between microfines content and shrinkage. This suggests that the presence of microfines introduces dimensional instability into the concrete and therefore results in an increase in shrinkage.
- The total microfines content, which is the sum of the cement content and the microfines content of the aggregate, has a direct relationship on the shrinkage of concrete. In order to control the shrinkage of concrete, it is important to control the total microfines on the concrete mix.

- This work found, in contrast to the work by Norvell et al, that the type of clay has little influence on the shrinkage performance of concrete. Rather, this work has found that the shrinkage is influenced by the fraction of clay sized particles in the concrete mix. It is suggested that the contrasting findings are due to the clays in Norvell et al's work being more active than the clays used in this work.

The microfines content has been found to be an accurate predictor of the shrinkage performance of concrete. The knowledge of this relationship can be used to achieve the desired performance properties with regard to shrinkage when concrete is made with site-derived fine aggregates.

7 Durability

7.1 Introduction

Durability in concrete relates to the ability of the concrete in a member or structure to perform adequately in a specified environment over its intended design life. Concrete is generally perceived to be inherently durable, and given the many examples of concrete that has survived the ravages of time and nature for centuries, this is an understandable perception. However, concrete that was made during Roman times, for example, is different to the concrete made today. These early concretes tended to be made with pozzolanic binders, which give it inherent durability, while this is not always the case today (Fulton, 2009).

Durability is not an intrinsic property of concrete, but rather a measure of the ability of concrete to perform in a certain environment for a desired period. This concept is explored in Figure 7.1. In this figure, both concrete A and concrete B deteriorate over time, and eventually deteriorate to such an extent that they no longer meet the minimum required quality. Concrete A only reaches an unacceptable quality level after its service life and is therefore of acceptable durability. Concrete B on the other hand needs to be rehabilitated before its service life is complete, and is therefore of unacceptable durability (Fulton, 2009).

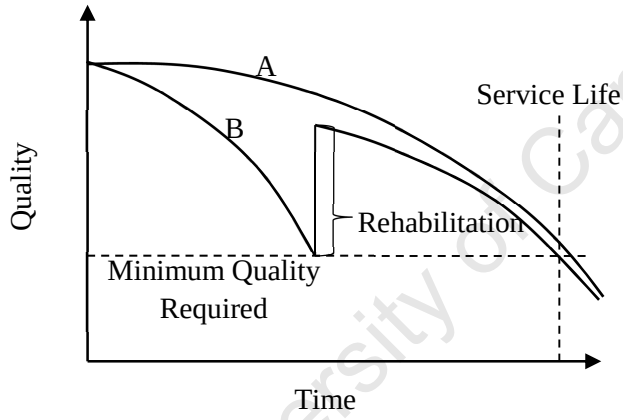


Figure 7.1. The performance of concrete during its service life (Fulton, 2009)

Durability performance is largely governed by concrete penetrability, which is broadly defined as the degree to which concrete permits gases, liquids or ionic species to move through the pore structure of the concrete. The transport of these materials leads to the deterioration of concrete through chemical attack, chloride ingress, leaching and carbonation. The material properties of sorptivity, permeability and diffusivity relate to the transport mechanisms of capillary action, flow under pressure and flow under a concentration gradient respectively (Fulton, 2009).

7.2 Methodology

The Oxygen Permeability Index (OPI) and water sorptivity of each batch were measured at 28 days. These tests provide an indication of the long-term durability of concrete made from each soil.

OPI is defined as the negative log of the coefficient of permeability. The test measures the loss of pressure through a 30mm slice of concrete, 70mm in diameter. The test assesses the micro and macro structure of concrete, and is particularly sensitive to macro voids and cracks. There has been found to

be a correlation between OPI and carbonation depth, with falling OPI values corresponding to greater carbonation depths (Fulton, 2009).

The water sorptivity test measures the porosity of concrete and quantifies the rate of absorption of water. Concrete samples, the same samples used in the OPI test, are dried at 50°C to ensure a low moisture content. The sides of the samples are sealed to ensure that water is only absorbed through one face of the sample. The samples are exposed to a few mm of water and at regular intervals are weighed. The mass of water absorbed at specific time intervals can then be calculated. After a specified time, the experiment stops. The samples are then vacuum-saturated to determine porosity. The mass of water is plotted against the square root of time (which gives a linear relationship). The sorptivity is determined from the slope of this line. Water sorptivity has been found to be an indication of construction quality (Fulton, 2009).

7.3 Results and discussion of results

7.3.1 Permeability

A relationship between microfines content and oxygen permeability index (OPI) values emerge, as shown in Figure 7.2.

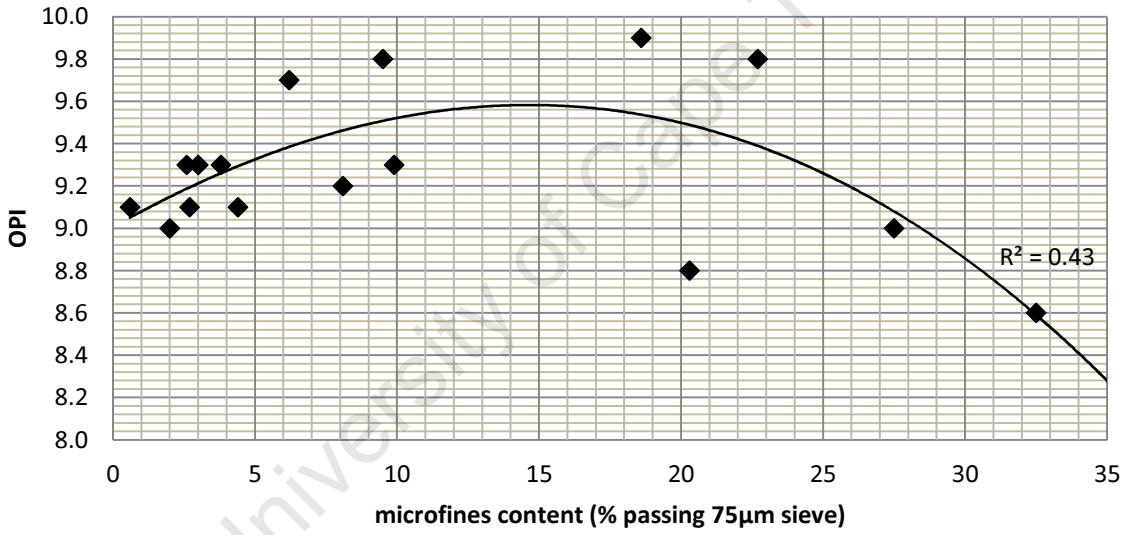


Figure 7.2. Relationship between OPI and microfines content of the aggregate

The figure shows the relationship between OPI and microfines content of an aggregate. These data suggest that at low microfines content values, microfines content has little to no effect on the OPI values of concrete. However, at higher microfines contents, around 10-20 %, microfines content appears to positively impact the OPI of concrete.

This effect is likely because aggregates with high microfines contents have high water demands, and therefore high cement contents. Since the cement paste is the permeable component in concrete, it has a direct relationship to the OPI of concrete.

The figure does provide evidence for a possible optimum microfines content of approximately 15%.

Since the OPI of concrete is dependent on the cement paste content, the results of the OPI were normalised for water, and therefore cement, content. The same procedure was used as described in section 6.3.2. The relationship between normalised OPI and microfines content is shown in Figure

7.3. The figure shows that the presence of microfines in the aggregate does affect the OPI of concrete. This figure indicates that increasing microfines negatively impact the OPI.

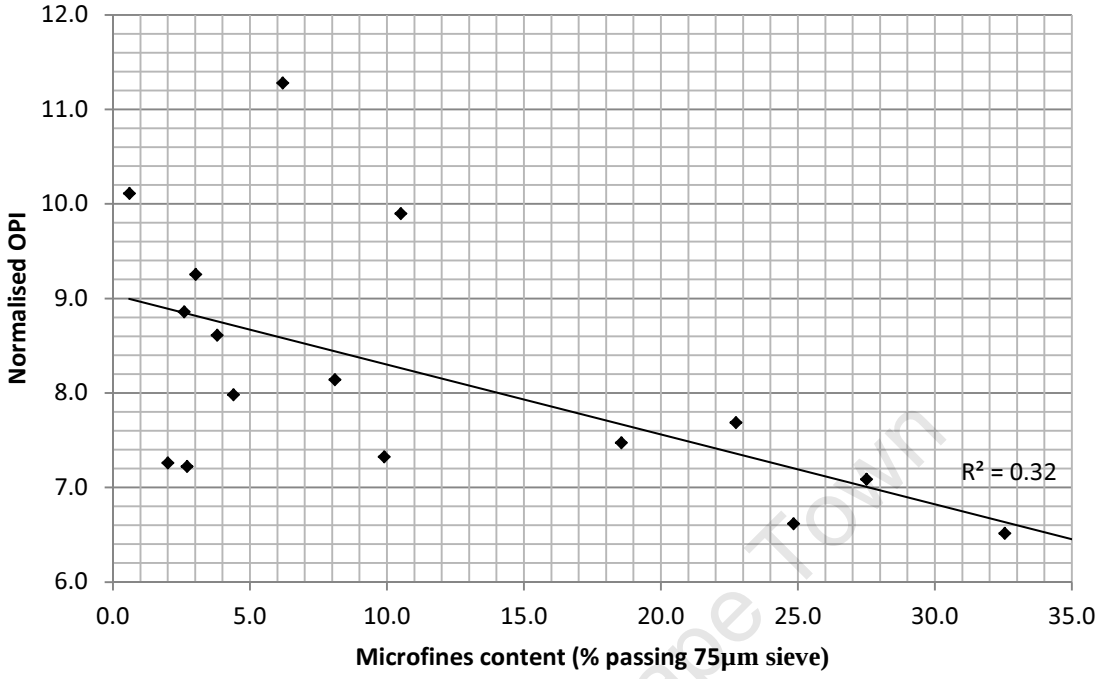


Figure 7.3. Normalised OPI and microfines content

7.3.2 Sorptivity

Sorptivity is a measure of the rate of advance of a wetting front in concrete. Figure 7.4 shows the relationship between sorptivity and water content. From this, a trend emerges where higher water contents in the concrete mix correspond with higher sorptivity values.

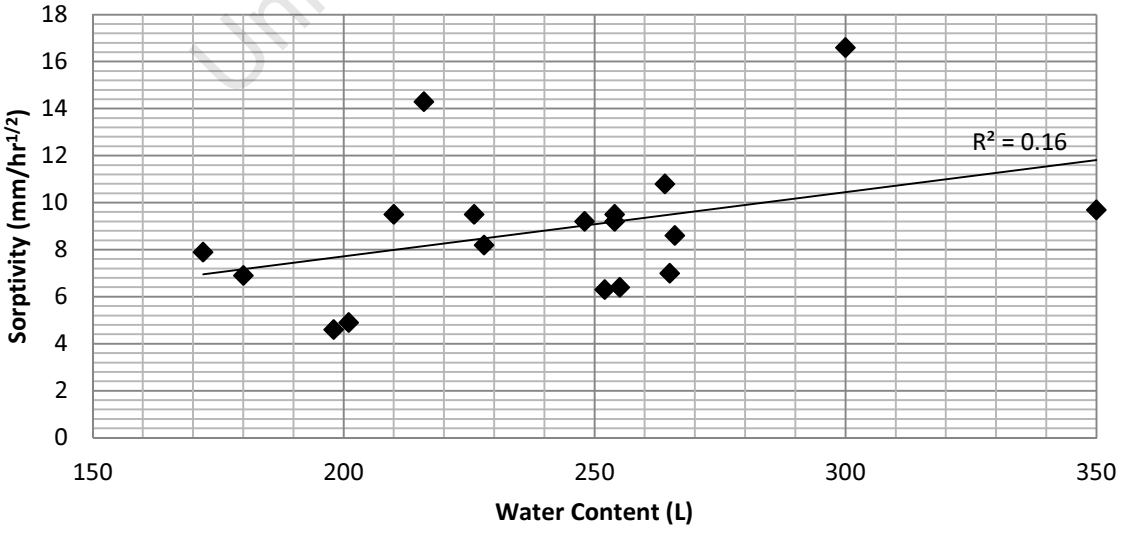


Figure 7.4. Relationship between sorptivity and water content

A similar trend is observed in Figure 7.5, which shows the relationship between microfines content and sorptivity. The trend, whereby an increase in microfines content results in an increase in sorptivity, is most likely due to the fact that soils with high microfines content have high water demands and therefore high cement contents. The figure does provide evidence for an optimum microfines content of approximately 15%.

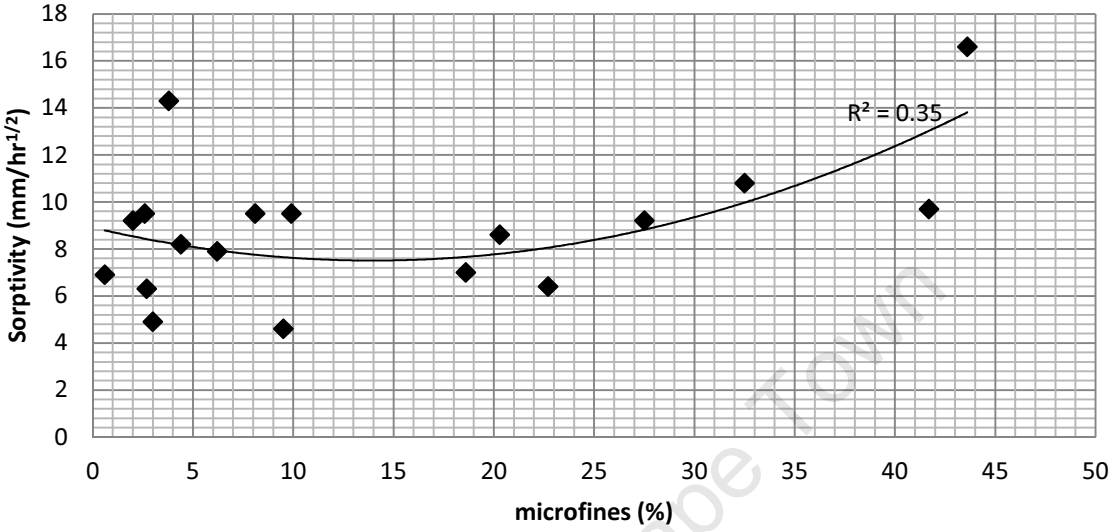


Figure 7.5. Relationship between sorptivity and microfines content

Another trend is observed in Figure 7.6, which compares sorptivity to fineness modulus. Fineness modulus is a measure of the average particle size of a sand or soil, with lower values representing finer soils. The figure indicates that finer graded soils tend to have higher sorptivity values.

In order to negate the influence of the varying cement and water contents used in this work, the sorptivity results were normalised to a water content of 200L/m^3 and a cement content of 285kg/m^3.

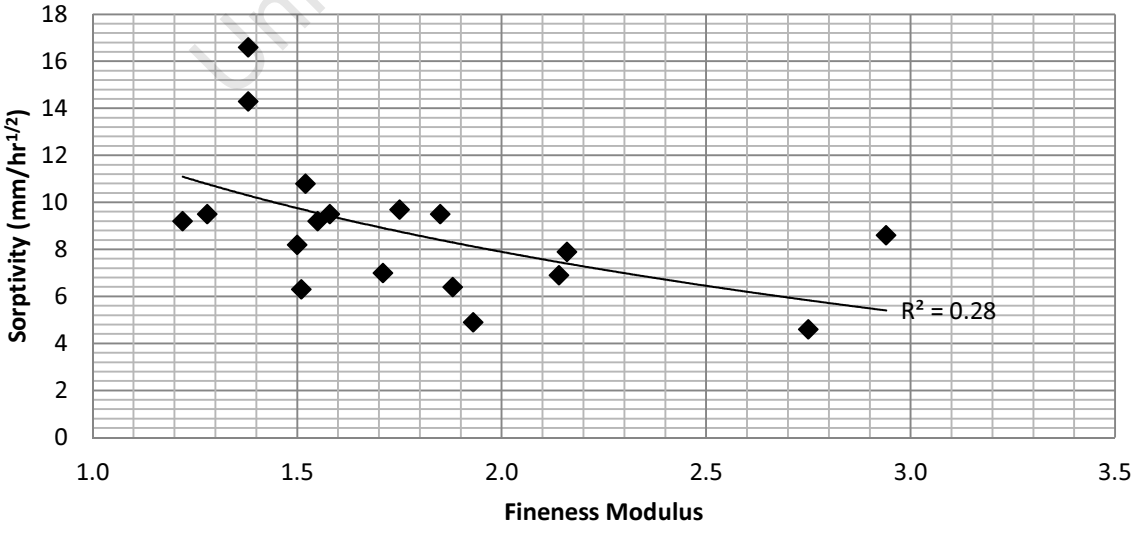


Figure 7.6. Relationship between sorptivity and fineness modulus

The relationship between normalised sorptivity and microfines content is shown in Figure 7.7. This figure indicates that the microfines content of the aggregate influences the sorptivity of concrete made with the aggregate independently of water or cement content. There appears to be an optimum microfines content of approximately 15% with regard to sorptivity.

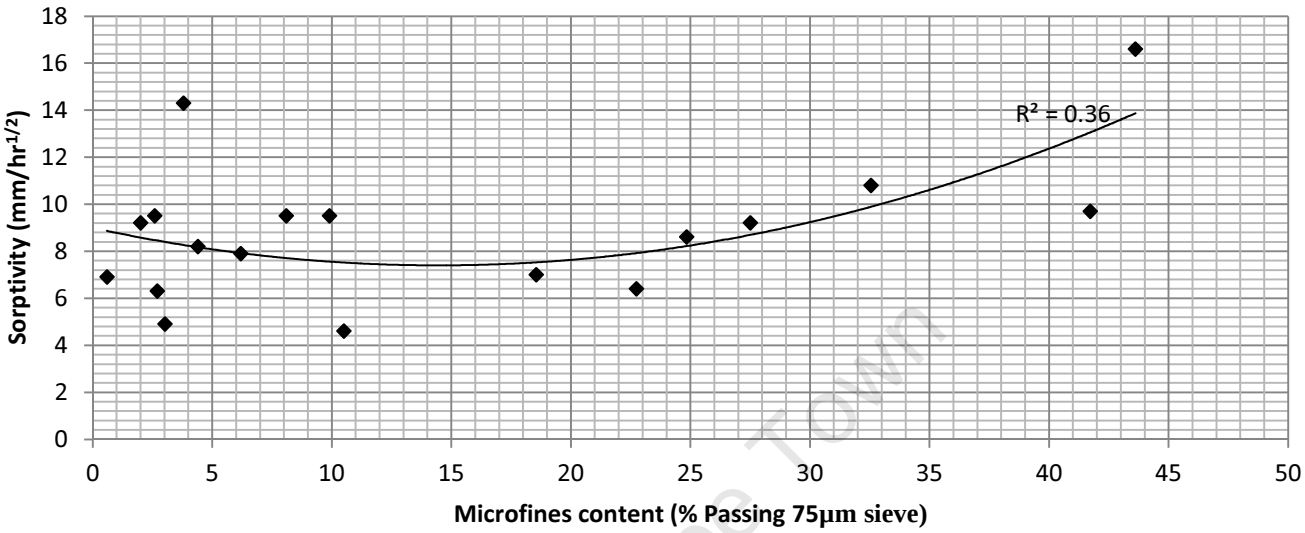


Figure 7.7. Normalised sorptivity and microfines content

7.3.3 Porosity

The relationship between porosity and water demand is shown in Figure 7.8. From the figure, a clear linear type relationship is apparent between water demand of a soil and the porosity of concrete made with this soil. This is expected, as a higher cement content is required at higher water demands and pores occur within the cement paste.

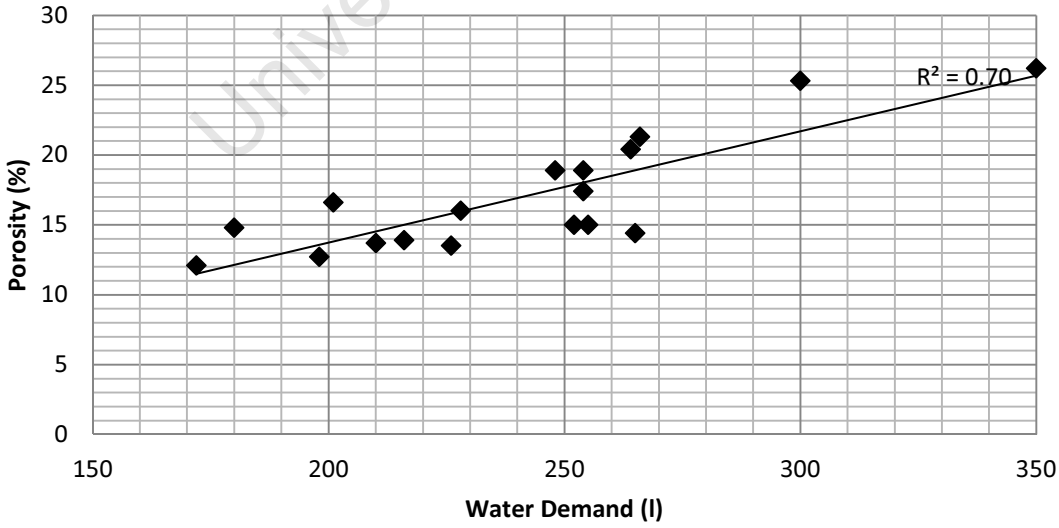


Figure 7.8. Relationship between water demand and porosity

Figure 7.9 shows the relationship between microfines content and porosity. At high microfines contents, an increase in microfines content is shown to increase porosity. This is likely due to the increase in water demand because of the presence of the microfines.

At low microfines contents, those smaller than 10% or so, a decrease in microfines content results in an increase in porosity. A reason for this could be that the fines act as fine fillers. At low microfines contents, the fine material fills in pores in the cement paste thereby decreasing porosity. However, as microfines content rises, so does the water demand and consequently so does the porosity. Therefore, at high microfines contents (>10%), the fines content has a negative effect on porosity.

From the data, there appears to be an optimum microfines content of approximately 10%. Below this value, the porosity increases slightly, while above this value the porosity increases rapidly.

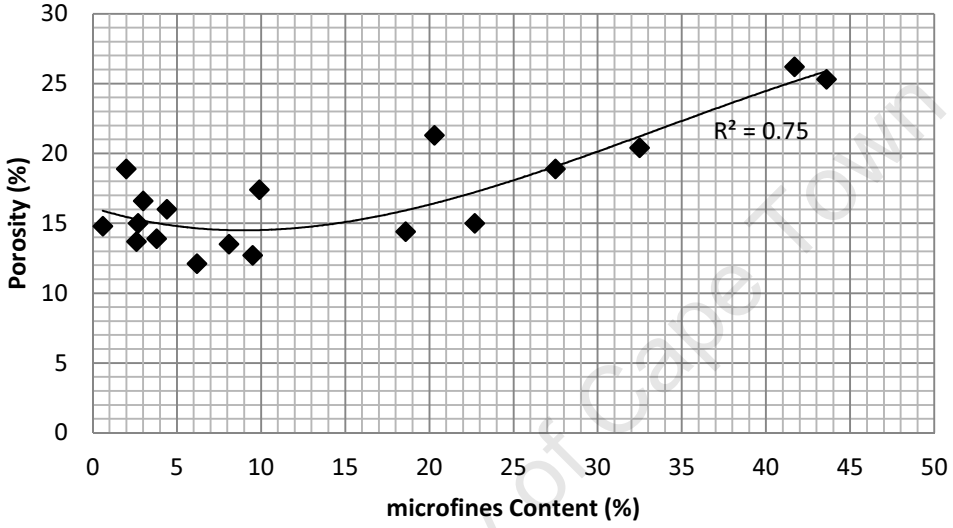


Figure 7.9. Relationship between microfines content and porosity

Figure 7.10 shows the relationship between the total fines content and porosity. From the figure, a relationship is apparent between the total fines content of concrete and its porosity.

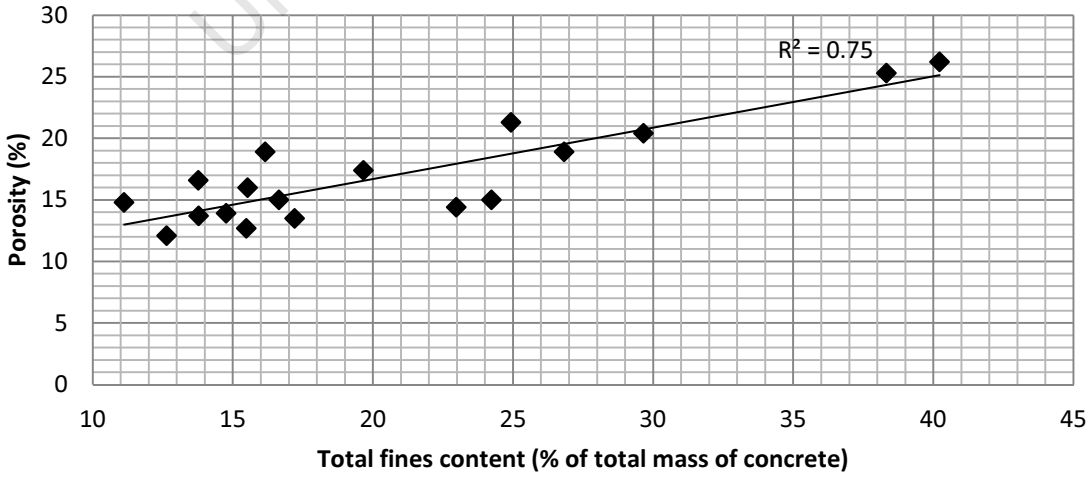


Figure 7.10. Relationship between porosity and paste content

The data indicates that in order to minimise porosity, the microfines fraction (<75µm) needs to be kept to a minimum.

In order to mitigate the effect that cement content of the concrete has on the porosity, the porosity results were normalised to a cement content of 285 kg/m^3 and a water content of 200L/m^3. The relationship between normalised porosity and microfines content are shown in Figure 7.11. This figure indicates that the microfines content of the aggregate has an influence on porosity, independent of the cement content. The figure indicates an optimum microfines content of approximately 15-17 %.

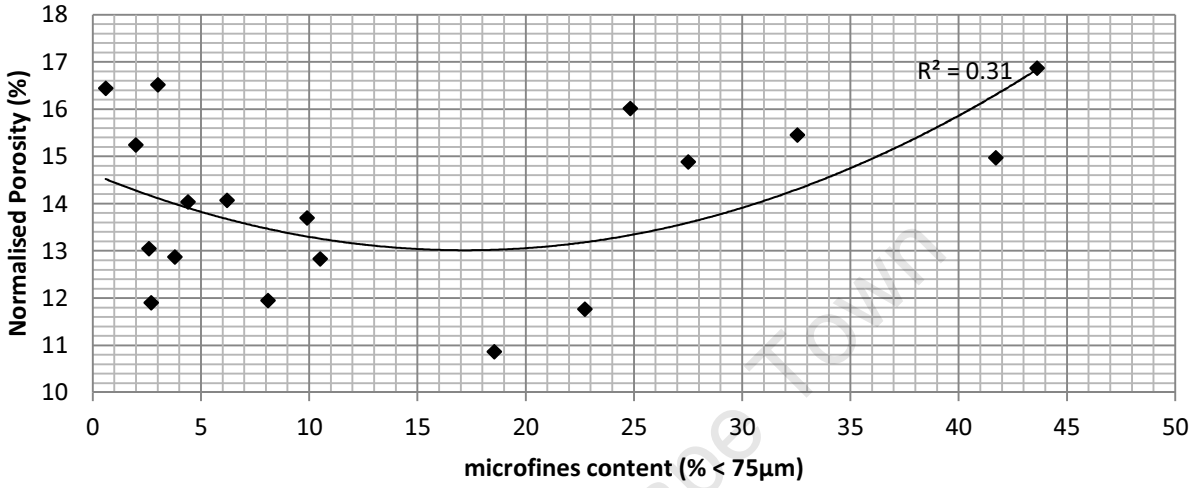


Figure 7.11. Normalised porosity and microfines content

7.4 General discussion

In the scope of this work, durability is a key component of concrete performance, as it is an indicator of the long-term endurance of concrete. Good durability performance will ensure that a concrete will perform satisfactorily throughout its service life, while in contrast poor durability performance will result in concrete that requires high maintenance or may need to be replaced. The latter scenario is in direct contrast to the aims of sustainability, both environmentally and economically.

With this in mind, it is important to identify the properties of the site-derived material which are most influential on the durability performance of concrete.

Porosity is dependent on paste content and water demand. It is therefore expected that high microfines contents will result in high porosity. At high microfines content, this was found to be the case. However, there appears to be an optimum microfines content where the negative effect that the microfines have on the water demand are offset by the microfiller effect that the microfines have on the concrete paste.

An optimum microfines content with regard to OPI and sorptivity was observed that corresponded to the optimum microfines content with regard to porosity. By taking advantage of the fine filler effect caused as a result of the microfines, the durability performance of concrete can be increased.

7.5 Conclusion

From the investigation into the durability performance of concrete made using site-derived soils as the fine aggregate, the following conclusions can be made:

- An aggregate microfines content of approximately 15% is optimum for the maximisation of the OPI of concrete. The microfines have an influence on the OPI of concrete, independently of the effect that microfines have on water, and therefore cement, content.
- An aggregate microfines content of approximately 15% is optimum for the minimisation of the sorptivity of concrete. The microfines influence sorptivity independently of cement content.
- When the relationship between microfines content and permeability is observed, an optimum microfines content of 10% becomes apparent in order to minimise permeability. When the permeability is corrected for the effect that the microfines have on the water and cement content of the concrete, an optimum value of 15% is observed.
- The research has found that in general, microfines contents up to approximately 15% are good for the durability performance of concrete.

8 Recommended Guidelines

8.1 General discussion

In this work, a number of soils were collected which exhibited a wide range of properties. These soils were used as fine aggregate in concrete, which too exhibited a wide range of properties. By comparing the soils' properties with the corresponding concrete properties, relationships between the two could be observed and interpreted.

From the results, it appeared that the microfines content of soil was a key factor in determining the properties of concrete.

Microfines have a direct effect on the water demand of concrete, with higher microfines contents resulting in concrete with a greater water demand. A high water demand is undesirable; in order to maintain a constant w/c ratio, more cement is required. This negatively influences the economic cost of the concrete, as well as increasing the CO_2 emissions. As mentioned in the literature, cement is the biggest contributor to the embedded CO_2 of concrete. An increase in the cement content of the concrete results in an increase in the embedded CO_2.

High microfines contents have been found to result in high shrinkage values. The microfines have been identified as affecting the shrinkage in two ways; directly (possibly due to dimensional instability of this fraction of the soil) and through the effect that they have on the water demand. In terms of concrete construction, if the issue of the microfines content is not addressed, the shrinkage problem will need to be resolved in other ways such as the use of extra reinforcing steel. A solution such as this would counter the aims of sustainability – both economically and environmentally.

The microfines content has been found to influence the strength of concrete. At low microfines contents, less than approximately 22%, the microfines appear to have a positive impact on the strength of concrete through a microfiller effect. Above this value, however, microfines negatively affect the strength of concrete. It is suggested that the reduction in strength is due to the increase in porosity of concrete at high microfines contents, as well as deleterious chemicals and minerals present in this fraction of the soil. This is an issue, which needs to be addressed; strength is a key concrete performance criteria. If the issue is not addressed, either concrete members will need to be increased in size or the w:c ratio will be reduced. Either of these solutions will result in more cement being used and an overall reduction in the sustainability of the construction process.

Microfines have also been found to affect the durability characteristics of concrete. Up to a microfines content of between 15% and 20%, this fraction has been observed to have a positive impact on the durability performance of concrete. Above this value, however, increased microfines have a negative impact on durability. This indicates that a structure built with concrete containing microfines content above 20% would have a shorter than expected lifespan and therefore require more maintenance. It may also need to be replaced earlier than expected. This has negative economic and environmental consequences.

From the results, it is clear that it is imperative that the microfines content of soils used as fine aggregate be controlled.

A proposed method of controlling the microfines content is to blend the soil with another soil or sand with very low microfines content. The ratio of blending can be calculated so that a desired microfines content of the blended material is achieved. By blending, it is suggested that the water demand, shrinkage, strength and durability characteristics of the concrete will be able to be controlled. In

conjunction to blending, the use of water reducing admixtures will likely allow the water demand of the soils to be reduced, which in turn will reduce the cement content. Through blending, the reduction the water and cement content, reduction shrinkage, and increase in strength and durability performance of concrete, the sustainability of construction will be increased both environmentally and economically.

The blended materials, however, will need to be transported and beneficiated off site. Therefore the greater the amount of blending required the higher the environmental and economic cost. It is therefore important that an optimum amount of blending is used, where the benefits in concrete performance are balanced by the costs of beneficiation and transportation of materials. Indeed, higher blending values are not necessarily better for performance; some microfines, up to a content of approximately 15%-20%, have been found to increase the strength and durability performance of concrete. It is key to the aims of sustainability that the beneficial properties site-derived materials provide the concrete made with them, be fully utilised, and that a desired and optimal microfines content be established.

8.2 Desired microfines content

From the data, it appears that in order to minimise the negative impact that microfines have on concrete, it would be best to control the microfines content of the aggregate. However, if this is to be achieved by blending, it should be considered that the lower the microfines content of the blended material, the greater the volume of material that will need to be transported onto the site. This has negative environmental impacts because the off-site material needs to be both beneficiated and transported.

8.2.1 Blending ratio

Once the desired microfines content has been established, the ratio of clean (low microfines content) soil to site-derived soil can be calculated. The following formula is proposed to establish the ratio:

$$F = \left(\frac{S - D}{S - C}\right) \times 100$$

Where

- F is the sand replacement as a % of the total mass of fine aggregate
- S is the microfines content (%) of the site-derived soil
- D is the desired microfines content (%)
- C is the microfines content (%) of the clean soil

A proof of this formula is provided in the appendix.

8.2.2 Performance based approach

An alternative to limiting microfines content values, as stipulated in SANS, is to use a performance-based approach. By using a performance-based approach, the specific requirements of the concrete can be considered and the desired microfines content can be adjusted accordingly.

8.2.2.1 Water demand

A direct relationship between microfines content and water demand has been established, as shown in Figure 8.1. This figure is a simplified version of figure 4.1 in order to highlight the relationship

between microfine content and water demand. From this figure, it is possible to predict the water demand that a specific natural fine aggregate will have.

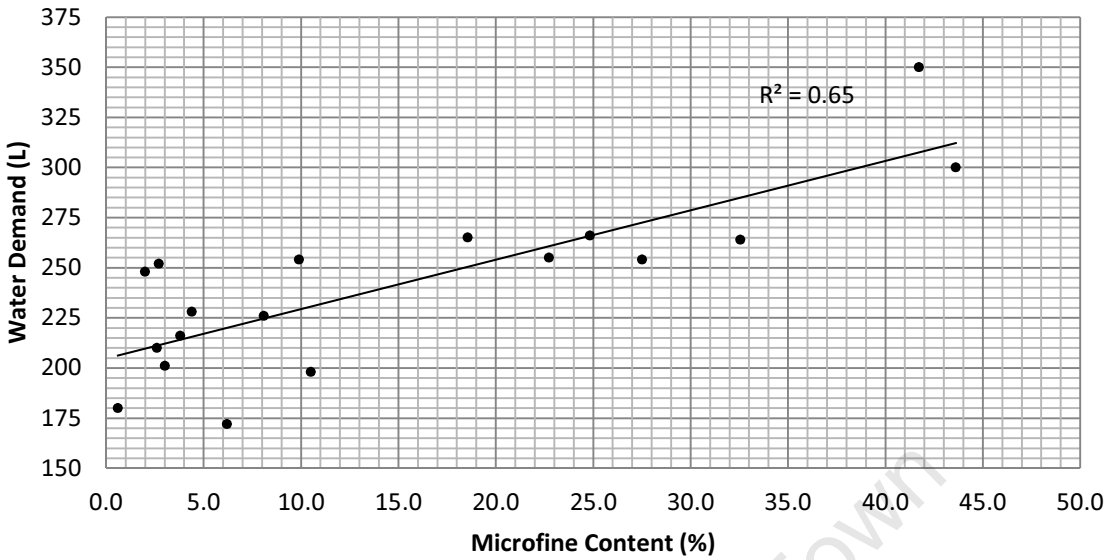


Figure 8.1. Relationship between the water demand of a natural fine aggregate and its microfines content

8.2.2.2 Strength

A relationship between strength and the microfines content was observed in this work, as discussed in chapter 5, and shown in Figure 8.2. This figure indicates an optimum microfines content of approximately 22%. The wide scatter observed in the relationship between strength and microfines content suggests, however, that the microfines content is not sufficient on its own to predict the strength behaviour of concrete.

The control samples were found to have strengths greater than those predicted by the overall trend observed in this work. If these materials (Klipheuwel and Philippi dune sand) are used as blending material, it is possible that they will increase the strength of concrete made with natural aggregates in Cape Town.

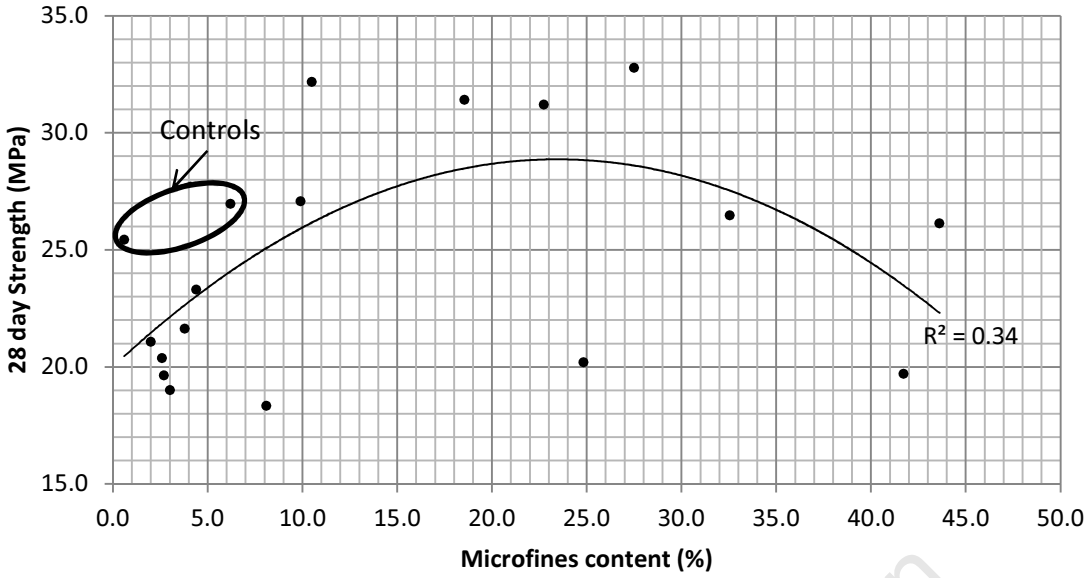


Figure 8.2. Relationship between strength and microfines content

8.2.2.3 Shrinkage

SANS 2001 stipulates what shrinkage, as a percentage of the control, is acceptable for specified members. The code specifies three categories depending on the member type, which are shown in Figure 8.3 and Table 8.1.

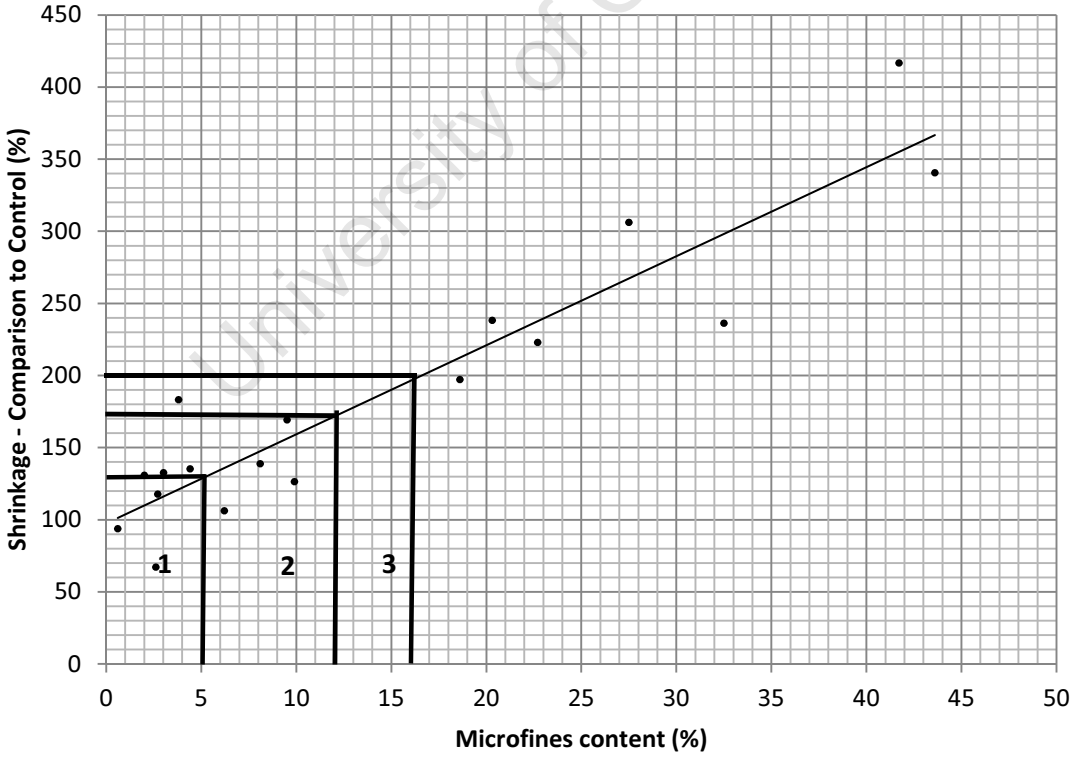


Figure 8.3. Relative shrinkage compared to microfines content

Table 8.1. Performance based limiting microfines contents

Category	Maximum Shrinkage (Comparison to Control)	Member Type	Microfines Content (%)	Approximate Water Demand (L)
1	130 %	Prestressed concrete, bridge decks and slender columns	5	220
2	175% (for fine aggregate)	Reinforced concrete	12	230
3	200%	Other Uses	16	240

Using these data, the desired microfines content can be established based on the desired performance of the member. Table 8.1 indicates that a member that is not reinforced could have a microfines content of 16%. However, Figure 4.1 indicates that at this microfines content, a water demand of 240l/m^3 is to be expected. This will need to be taken into consideration, since higher water contents will result in higher cement contents and therefore greater economic and environmental costs.

By comparing Table 8.1 and the formula given in section 8.2.1, it is possible to draw up a relationship between the microfines content of a site-derived soil and the amount of clean sand it will need to be blended with, depending on the desired shrinkage performance of the concrete. This relationship is shown in Figure 8.4.

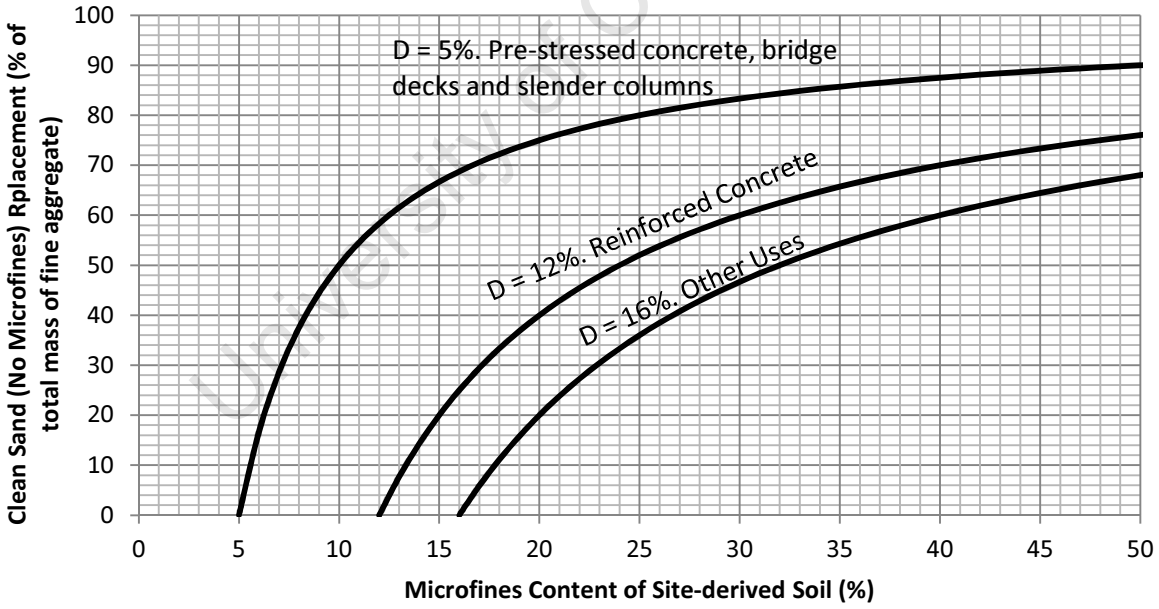


Figure 8.4. Clean sand replacement values based on shrinkage performance.

From this, the clean sand replacement value can be established.

For example;

> A reinforced concrete slab (D = 12%) is to be built on a site with a soil with microfines content of 20%. From Figure 8.4, it can be seen that a clean sand replacement value of 40% by mass is required. If a mix is drawn up that requires a fine aggregate content of 700kg/m^3, 60% of this

(420kg) will need to consist of the site-derived soil, and 40% (280kg) will need to be imported clean sand.

Table 8.1 indicates that a microfines content of 12% will have a water demand of approximately 230L.

If sand is used that does not have a microfines content of zero, the formula in section 8.2.1 can be used to calculate the sand replacement value.

8.2.2.4 Durability

An optimum microfines content of 15% has been observed with regard to the OPI and sorptivity of concrete made with natural fine aggregates. An optimum microfines content of 10% has been observed with regard to the porosity of concrete made with this material.

The durability performance of concrete (either OPI, sorptivity or porosity) has been observed to vary very little between microfines contents of 10% and 15%, and therefore it can be assumed that a microfines content of 15% will result in optimal overall durability performance of concrete without requiring excessive material for blending.

The negative effect of microfines contents lower than 15% on the durability performance of concrete are small, whereas durability performance rapidly deteriorates at microfines contents greater than 15%. This is shown in Figure 7.2,Figure 7.5 and Figure 7.9. Therefore, it is more desirable to have a microfines content of less than the optimum 15% rather than greater.

8.2.3 Limiting value approach

SANS 1080 recommends a maximum microfines value of 5% in natural aggregates. If blending is used to achieve this microfines content, a greater limiting microfines value will result in less material needing to be transported to the site and beneficiated off site. This is therefore more desirable from an environmental perspective.

This work has shown that a microfines content of 15% is optimal for durability performance of concrete. This value lies under the calculated microfines content of 16% required for normal construction (no reinforcement) with regard to shrinkage.

The optimum microfines content with regard to strength has been found to be 22%. However, the strength performance of concrete made with site-derived natural materials has been found to be unpredictable. By using a lower microfines content, more material will need to be blended and it is predicted that this blending material will bring some control to the strength behaviour of concrete. By blending the natural aggregate, which would contain the deleterious material, with a clean aggregate, it is thought that the deleterious material will be diluted by the clean aggregate.

A microfines content of 15% will result in a water demand of approximately 240L/m^3 in the concrete mix. This value is high, and is classified in Fulton's concrete technology as the water content of very poor sand.

If a limiting value approach is used, it is therefore rational, with the results from this work, to ensure that the microfines content does not exceed 15%. This value is significantly higher than the 5% stipulated by SANS. BS 882: 1992 stipulates that the microfines content not exceed 4% in natural fine aggregates, which is increased to 16% for aggregates derived from crushed rock.

Due to the unpredictable strength behaviour of concrete made with these materials, it is critical that any blend that is made be tested for its effect on the strength of concrete.

9 Conclusion

It has been hypothesised that the site-derived fine aggregate can be used in concrete, with the belief that the utilization of this material will lead to; the preservation of natural materials that would otherwise have to be beneficiated off site, the reduction of waste material produced on a construction site and the reduction of material that needs to be transported onto a site.

In order to test this hypothesis, a number of soils have been collected in the Cape Town area and concrete has been made using these soils as fine aggregate. The properties of this concrete have been tested and assessed.

Soils were collected in such a way as to ensure a wide range of soil properties. These soils were tested in terms of particle size distribution, presence and type of clay (if any) and the presence of deleterious organic impurities. Concrete was then made, using the collected soils as fine aggregate. In the concrete, the water-to-cement ratio was kept constant, while the water content was varied to ensure constant workability. Cement admixtures were not used to increase workability, as studies have shown that these may interact with clay material. The concrete was then tested for compressive strength at various ages up to 70 days, shrinkage and durability characteristics. In addition, the concrete underwent thermogravimetric testing to assess whether any pozzolanic reactions were occurring and to what extent.

The results of the testing have led to the following conclusions:

- There is evidence for an optimum microfines, silt and clay content of 22%, 10% and 7% respectively with regard to strength. It is suggested that this is due to a fine filler effect.
- Evidence of pozzolanic activity between the clay in the aggregate and the CH in the cement paste was observed. There was a high degree of variability between the pozzolanic activity even of clays of the same type. This suggests that while these reactions would prove to be beneficial to the performance of concrete, more work is needed in order that they can be better understood.
- Water demand of the concrete is directly proportional to the amount of microfines in the aggregate, as well as the total surface area of the fine fraction in the concrete mix.
- There is a direct correlation between the shrinkage of the concrete and both overall cement content and the microfines content of the aggregate. The relationship between shrinkage and microfines content is apparent even after shrinkage has been normalised for water (and therefore cement) content.
- An optimum microfines content of 15% has been observed with regard to OPI and Sorptivity
- Porosity is proportional to the microfines and total paste content of the aggregate. An optimum microfines content of 10% with regard to porosity was observed.
- There is a loose correlation between increasing sorptivity and increasing microfines and fineness of the aggregate.
- There was little correlation between the presence and type of clay and the corresponding concrete properties.

Microfines content was found to have the greatest effect on the properties of concrete, with high microfines contents corresponding to undesirable concrete properties.

A proposed solution to the problem of microfines is an approach where the microfines content is limited according to the desired performance of the concrete. It is proposed that this is done through blending of the site-derived material with cleaner sand, which is believed to be simple to implement.

By comparing the microfines content with the corresponding shrinkage, limiting values for microfines content based on performance have been established:

- 5% for pre-stressed concrete, bridge decks and slender columns
- 12% for reinforced concrete
- 16% for other uses

A formula has been developed that allows the amount of blended, clean sand as a fraction of total fine aggregate.

By blending the aggregate, the negative effects on workability, shrinkage and durability will be minimised. It is expected that the deleterious components in the fine aggregate, although not measured, will be diluted by the addition of clean aggregate. It is projected that this will minimise the unpredictable behaviour of the concrete with regard to strength.

By optimally blending the aggregate, site-derived fine aggregate will be suitable for use in concrete. By making use of this material, less material needs to be beneficiated off site and less material will need to be transported onto and off the site. By taking advantage of this otherwise overlooked resource, it is hoped that the rate of depletion of Cape Town's resources will be slowed.

9.1 Recommendations

9.1.1 Blending

Blending has been proposed as a solution to the problems that microfines cause in concrete. The effectiveness of this solution needs to be assessed through further research.

By blending, it has been suggested that the water demand of site-derived natural fine materials will be reduced. This would be a major benefit to the aims of sustainability, since the water demand is linked to the cement content, and by reducing the water demand, the cement content and economic and environmental cost will be reduced. However, research needs to be carried out to investigate whether blending is indeed an effective solution.

It has been suggested that the erratic strength behaviour of concrete made with site-derived soils could be due to deleterious minerals and chemicals in the microfines fraction, and that blending will dilute these minerals and chemicals thereby reducing the uncertainty in strength performance that has been observed. This needs to be checked through further research.

Blending has been suggested to control the shrinkage and durability performance of concrete made with site-derived soils. If it does, this will greatly aid the aims of sustainability, but this proposal needs to be researched.

Finally, the overall sustainability of blending in the context of this work needs to be assessed. Does the increased transportation and beneficiation cost to the environment outweigh the benefits in terms of increased performance? If so, does the use of site-derived materials provide a more sustainable solution than current practice, or should other avenues be explored?

9.1.2 Admixtures

Admixtures have the potential to reduce the water demand observed in the soils. If the water demand is reduced, the cement content will itself be reduced. This will lower the embedded energy of the concrete, while potentially minimising the negative effects that are caused as a result of high paste contents. It is therefore important that the effect of using admixtures, specifically water reducing ones

such as super plasticisers, have on the properties of concrete made with natural site-derived aggregates.

The use of admixtures in conjunction with blending has been proposed as a method of controlling undesirable properties of concrete made with site-derived soils. The environmental impact of this needs to be researched.

9.1.3 Sustainability framework

The findings of this research indicate that it is possible to use site-derived natural soils as fine aggregate in concrete. However, it is important that the effectiveness of the use of this material as a sustainable solution is evaluated. Due to the high water demand of these soils, and the subsequent high cement content, their embedded energy is likely to be high. It is therefore important that the embedded energy of concrete made with these soils be quantified. This solution can then be compared to other solutions, such as the use of crusher sand, in order to establish the most sustainable solution to the problem of depleting fine aggregates.

10 References

AGIS, 2010. *AGIS Atlas Viewer.* [Online] Available at: http://www.agis.agric.za/agismap_atlas/AtlasViewer.jsp?MapService=agis_atlas2006&ProjectId=6&LId=0&OId=0
[Accessed 20 April 2010].

Aitcin, P. & Mindess, S., 2011. *Sustainability of Concrete.* New York: Spon Press.

Alexander, M. & Mindess, S., 2005. *Aggregates in concrete.* Oxon: Taylor and Francis.

Aquino, M., Li, Z. & Shah, S., 1995. Mechanical Properties of the Aggregate and Cement Interface. *Advn Cem Bas Mat (2),* pp. 221-223.

Ashman, M. & Puri, G., 2002. *Essential soil science.* Oxford: Blackwell Science Ltd.

ASTM C618-91, 1991. *Standard specifications for fly ash and raw or calcined pozzolan for use as a mineral admixture in portland cement concrete,* s.l.: s.n.

ASTM, 2006. *Standard Terminology for Sustainability Relative to the Performance of Buildings,* s.l.: ASTM Standard E 2114-06a.

Becchio, C., Corgnati, S., Kindinis, A. & Pagliolico, S., 2009. Improving environmental sustainability of concrete products: Investigation of MWC thermal cracking and mechanical properties. *Energy and buildings,* pp. 1127-1134.

Bezard, D., 2009. *Specific features of metakaolin.* [Online] Available at: http://metakaolin.info/general_description/index.htm
[Accessed 30 November 2010].

Cole, D. & Viljoen, J., 2001. *Building sand potential of the greater Cape Town Area.* Cape Town: Council for Geoscience.

Compton, J., 2006. *The Rocks and Mountains of Cape Town.* Cape Town, South Africa: Double Storey Books.

Dana, J., Hurlbut, C. & Conelis, K., 1985. *Manual of Mineralogy.* s.l.:John Wiley & Sons Inc.

de Souza A, A. E. & Sichieri, E., 2006. Thermogravimetric Analyses and Mineralogical Study of Polymer Modified Mortar with Silica Fume. *Materials Research, Vol. 9,* pp. 321-326.

Debnath, A., Singh, S. & Singh, Y., 1995. Comparative assessment of energy requirements for different types of residential buildings in India. *Energy abd Buildings 23,* pp. 141-146.

Department of Minerals and Energy, South Africa, 2004. *Bentonite, Pyrophyllite and Talc in the Republic of South Africa,* Pretoria, South Africa: Department of Minerals and Energy.

ecoBiz, 2007. *Conversions and units,* Queensland, Australia: ecoBiz Queensland.

Encyclopedia Brittanica, 2009. *Litosol - Brittanica online encyclopedia.* [Online] Available at: http://www.britannica.com/EBchecked/topic/343779/lithosol [Accessed 22 October 2009].

Ferketic, J., Latimer, A. & Silander, J. J., 2010. Conservation justice in Metropolitan Cape Town: A study at the Macassar Dunes Conservation Area. *Biological Conservation,* pp. 1168-1174.

Fulton, 2009. *Fulton's concrete technology.* Midrand, South Africa: Cement & Concrete Institute.

Gaucher, E. & Blanc, P., 2006. Cement/clay interactions - A review: Experiments, natural analogues, and modeling. *Elsevier, Waste Management 26,* pp. 776-788.

Glavinich, T., 2008. *Contractors Guide to Green Building Construction.* John Wiley & Sons: Hoboken, New Jersey.

He, C., Osbaeck, B. & Makovicky, E., 1995. Pozzolanic reactions of six principal clay minerals: activation, reactivity assessments and technological effects. *Cement and Concrete Research 25,* pp. 1961-1702.

InEnergy, 2010. *Cement and concrete institute concrete industry greenhouse gas emissions,* Northcliff: Cement and Concrete Institute.

Kehew, A., 2006. *Geology for Engineers and Environmnetal Scientists (3rd Edition).* Upper Saddle River, New Jersey, USA: Prentice Hall.

Khatib, J. & Clay, R., 2003. Absorption characteristics of metakaloin concrete. *Cement and concrete research.*

Lutzow, M. et al., 2006. Stabilization of organic matter in temperate soils: mechanism and their relevance under different soil conditions - a review. *European Journal of Soil Science, 57,* pp. 426-445.

Mehta, P., 2002. Greening of the Concrete Industry for Sustainable Development. *Concrete International,* pp. 23 - 28.

Merlini, M. et al., 2008. Tricalcium aluminate hydration in additivated systems. A crystallographic study by SR-XRPD. *Cement and Concrete Research,* 15 April.pp. 477-486.

Mineralogy Database, 2006. *Montmorillonite.* [Online] Available at: http://www.mindat.org/min-2821.html [Accessed 30 November 2010].

Newman, A. C. D., 1987. *Chemistry of clays and clay minerals.* s.l.:John Wiley & Sons.

Norvell, J. K., Stewart, J., Juenger, M. & Fowler, D., 2007. Influence of Clays and Clay-Sized Particles on Concrete Performance.

O'Flaherty, C., 1974. *Vol 2 Highway Engineering.* London: Edward Arnold (Publishers) Ltd..

Paya, J., Monzo, J., Borrachero, M. & Velaquez, S., 2003. Evaluation of the pozzolanic activity of fluid catalyst residue (FC3R). Thermogravimetric analysis on F3CR-Portland cement pastes. *Cement and Concrete Research,* pp. 603-609.

Rahn, P., 1986. *Engineering Geology, An Environmental Approach.* New York: Elsevier Science Publishing Company, Inc..

Reddy, B., 2003. Embodied energy of common and alternative building materials and technologies. *Energy and Buildings 35,* pp. 129-137.

SANS 201:2008, 2008. *SANS 201:2008,* s.l.: SANS.

SANS, 2006. *Aggregates from natural sources- Aggregates for concrete.* Pretoria, South Africa: South African Bureau of Standards.

Scrivener, K. & Nemati, K., 1996. Percolation of pore space in the cement paste/aggregate interfacial zone of concrete. *Cement and Concrete Research,* pp. 35-40.

Stewart, J., Norvell, J., Juenger, M. & Fowler, D., 2007. Influence of Microfine Aggregate Characteristics on Concrete Performance. *Journal of Materials in Civil Engineering (c) ASCE,* pp. 957-964.

Struble, L. & Godfrey, J., 1999. *How sustainable is concrete.* University of Illinois at Urbana-Champaign, USA, University of Illinois, pp. 201-211.

Suzuki, M. O. O., 1995. The estimation of energy consumption and CO2 emission due to housing construction in Japan. *Energy and Buildings 22,* pp. 165-169.

Tremblay, H., Duchesne, J., Locat, J. & Leroueil, S., 2002. Influence of the nature of organic compounds on fine soil stabilization with cement. *Canadian Geotech Journal 39,* pp. 535-546.

Turanli, L., Bektas, F. & Monterio, P., 2003. Use of ground clay brick as pozzolanic material to reduce the alkali-silica reaction. *Cement and concrete research,* pp. 1539-1542.

Walker, P., 1995. Strength, durability and shrinkage characteristics of cement stabilised soil blocks. *Cement and Concrete Composites 17,* pp. 301-310.

Walker, R. & Pavia, S., 2011. Physical properties and reactivity of pozzolans, and their influence on the properties of lime–pozzolan pastes. *Materials and Structures (44),* p. 1139–1150.

WCED, 1987. *Our Common Future,* New York: Oxford Press.

Wickins, K., 2010. *The use of site-derived fine aggregates in concrete,* Cape Town: University of Cape Town.

Yang, C. & Su, J., 2002. Approximite migration coefficient of interfacial transition zone and the effect of aggregate content on the migration coefficient of mortar. *Cement and Concrete Research 32,* pp. 1559 - 1565.

11 Appendices

11.1 Blending ratio formula

The following is a proof of the blending ratio formula from section 8.2.1.

- F is the clean sand replacement ratio as a %
- f is the clean sand replacement as a ratio out of 1
- S is the microfines content (%) of the site-derived soil
- D is the desired microfines content (%)
- C is the microfines content (%) of the clean soil

The microfines content of the blended soil (D), is the sum of the microfines content of the control (C) multiplied by its proportion in the blend (f) and the microfines content of the site-derived soil (S) multiplied by its proportion in the blend (1-f);

$$D = fC + (1 - f)S$$

Therefore

$$D = f\,(C - S) + S$$

Solving for f gives

$$f = \frac{D - S}{C - S}$$

Rearranging the right hand side

$$f = \frac{S - D}{S - C}$$

As f is a ratio, but F is a percentage,

$$F = 100 \times f$$

Substituting gives:

$$F = \left(\frac{S - D}{S - C}\right) \times 100$$

11.2 **Results from soil and concrete analysis and testing**

Property		Control 1	Control 2	1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Grading (% Passing) (Sieve sizes in mm)	4.75	99.9	100.0	100.0	100.0	100.0	98.8	99.8	97.7	100.0	100.0	98.9	100.0	98.6	100.0	100.0	100.0	98.7	99.8
	2.36	99.8	99.9	99.4	99.8	99.2	93.9	92.4	89.0	94.6	87.0	98.0	99.9	98.3	100.0	100.0	100.0	98.2	99.5
	1.18	88.7	97.1	97.7	92.7	89.1	86.0	86.4	77.6	71.0	67.9	93.6	99.8	98.0	100.0	100.0	99.7	97.7	98.9
	0.6	52.2	58.6	78.2	77.6	70.5	75.3	80.9	64.2	51.4	52.1	88.5	92.2	96.1	94.5	99.8	87.2	80.3	94.1
	0.425	39.2	42.6	46.0	64.7	62.6	64.4		58.7	43.6	45.8	82.3	74.8	89.9	71.2	97.1	78.4	56.7	77.3
	0.3	30.5	26.3	23.5	47.1	56.1	48.1	50.1	52.7	29.6	39.0	65.3	47.0	66.5	39.3	44.4	60.0	29.0	45.2
	0.15	13.3	3.6	7.8	30.2	47.5	26.6	38.2	44.2	14.3	29.0	33.3	11.0	14.8	8.2	5.1	15.0	10.7	7.4
	0.075	6.2	0.6	3.0	22.7	43.6	18.6	32.5	41.7	10.5	24.8	27.5	4.4	9.9	2.6	2.7	3.8	8.1	2.0
	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Silt (0.02)	2.9	0.0	1.5	11.1	19.7	11.0	12.4	17.9	2.2	1.3	6.7	4.3	4.0	1.4	0.8	0.4	1.0	0.8
	Clay (0.005)	0.2	0.0	0.8	9.0	13.8	8.2	4.9	12.4	1.5	0.8	5.7	4.0	3.3	1.1	0.7	0.1	0.3	0.5
	FM	2.16	2.15	1.93	1.53	1.38	1.71	1.52	1.75	2.39	2.25	1.22	1.50	1.28	1.58	1.51	1.38	1.85	1.55
Water (L)		172	180	201	255	300	265	264	350	198	266	254	228	254	210	252	216	226	248
Strength (Mpa)	28 day	27.0	25.4	19.0	31.2	26.1	31.4	26.5	19.7	32.2	20.2	32.8	23.3	27.1	20.4	19.6	21.6	18.3	21.1
	70 day	32.6	30.7	21.3	38.5	29.9	38.5	29.4	23.4	35.0	24.2	38.6	27.8	31.5	25.5	25.2	26.2	25.2	25.0
	Change (Mpa)	5.6	5.3	2.3	7.3	3.8	7.1	2.9	3.7	2.8	4.0	5.8	4.5	4.4	5.1	5.6	4.6	6.9	3.9
	Change (%)	20.9	20.7	12.1	23.4	14.4	22.6	11.1	18.8	8.8	19.8	17.8	19.3	16.4	25.2	28.4	21.1	37.5	18.7
Shrinkage (microstrain)	28 day	300.0	265.0	375.0	630.0	962.5	557.5	667.5	1177.5	478.0	673.0	865.0	382.5	357.5	190.0	332.5	517.5	392.5	370.0
Durability	OPI	9.7	9.1	9.3	9.8		9.9	8.6		9.8	8.8	9.0	9.1	9.3	9.3	9.1	9.3	9.2	9.0
	Sorptivity	7.9	6.9	4.9	6.4	16.6	7.0	10.8	9.7	4.6	8.6	9.2	8.2	9.5	9.5	6.3	14.3	9.5	9.2
	Porosity	12.1	14.8	16.6	15.0	25.3	14.4	20.4	26.2	12.7	21.3	18.9	16.0	17.4	13.7	15.0	13.9	13.5	18.9
Clay Type					Kaolinite	Kaolinite	Montmorillonite	Illite	Kaolinite	Kaolinite, Illite	Smectite								
Generalised Soil Type				PZ	PZ	AC	AC	LP1	AC	PZ	AC	R	PZ	LP1	PZ	PZ	PZ	PZ	AC
Soil Class				A	B	B	B	C	B	D	B	E	D	E	D	B	D	D	B
Methylene Blue Value				0.40	0.70	0.50	0.30	0.70	0.80	0.25	0.10	0.15	0.10	0.40	0.10	0.20	0.10	0.35	0.20

MASTERS IN LAW DISSERTATION

Is there a place for the Public Interest Considerations in the Competition Legislation of a Developing Country like South Africa – Generally, and specifically with respect to Merger Evaluation: an Economic and Legal Analysis.

STUDENT NAME: Yariv Pavese

STUDENT NUMBER: PVSYAR001

PLAGIARISM DECLARATION

1. I know that plagiarism is wrong. Plagiarism is to use another's work and pretend that it is one's own.
2. I have used the **FOOTNOTE** convention for citation and referencing. Each significant contribution to and quotation in this essay from the work(s) of other people has been attributed, and it has been cited and referenced.
3. This assignment is my own work.
4. I have not allowed, nor will I allow anyone to copy my work with the intention of passing it off as his or her own work.
5. Word count: 25 267 (*Exl. Bibliography*)

Signature: Yariv Pavese (PVSYAR001)

DEDICATION:

To my parents Dr. Piercarlo Pavese and Dr. Reuva Herz, and to my sisters Dr. Yasmin Pavese and Madam Osnat Pavese, for having encouraged and provided me the opportunity to complete these many years of study, I am forever grateful. Thank you for everything…

INDEX

INTRODUCTION:

This paper examines the inclusion of public interest evaluations in competition law, generally and further specifically as it regards Merger Analysis. Reference will be made to the Competition Act[1] (the Act) and to case law- so as to graphically illustrate examples where public interest considerations have, or at least should, substantially influenced decisions made by competition authorities. The basis of this paper will be to examine whether public interest in the general sense[2] will enhance consumer welfare, and in the specific sense[3] whether its consideration enhances the stated economic goals of income and wealth distribution with the overarching goal of realising economic growth and development.

Before a definition of competition law is given, there needs to be an understanding of how this particular law functions in tandem with the national competition policy that underlies it. 'Competition Policy...lays out the parameters of the relationship between the state and economic citizens and between economic citizens themselves, in a manner somewhat akin to the way the constitution regulates the relationship between the state and the individual citizens and between individual citizens themselves.'[4]In developed countries, 'The underlying purpose of antitrust policy is to prevent monopolisation, promote competition, and achieve allocative efficiency.'[5]The need for competition law to stem from this competition policy is further explained here to be as a result of the rapid expansion of markets, both domestically - as a result of globalisation and reduction in barriers to trade, and internationally as well[6].

'National competition law can be defined as a set of rules and disciplines maintained by governments relating either to agreements between firms that restrict competition or to the abuse of a dominant position. A major objective of competition law in most jurisdictions is efficient resource allocation, and thereby the maximisation of national welfare, by ensuring that the competitive process is not distorted or impeded through the abuse of dominant

[1]Act 89 of 1998, as amended.
[2]Regarding section 2 of the Act.
[3]Regarding section 12A(3)
[4]*Competition Policy in South Africa, Where has it come from and where is it going?,* The Investment Analysts society of Southern Africa, www.iassa.com (Accessed 10November 2011)
[5]C.R. McConnell and S. L. Brue, *Economics: Principles, Problems and Policies* (McGraw-Hill), International edition, 19th ed, at 598.
[6]Ibid

positions...or competition restricting agreements between competitors that are detrimental to social welfare.'[7]

This definition, by the inclusion of "social welfare", shows that there are considerations in the competition legislation of developing countries that include considerations not only of a purely efficiency driven nature[8] – i.e.: public interest considerations, that form part of the machinery created to accomplish the mission to secure national welfare. These other considerations include the use of this specialized legislation by governments to attain national economic goals of growth, efficiency and social welfare. This is where the realm of public interest employs itself, that is to say, to have regard to the other stated needs of society at times where a certain transactions or conduct is undertaken by a firm in the market. The effects that result are dictated, by public interest, to consider external factors that are affected directly by the transaction/conduct[9]. Therefore public interest considerations are a species of legal regulation of a market that are non-efficiency motivated. This regulation is mandated by the Legislature in South Africa as per policy created by the Executive[10] and which is executed practically by the Judiciary[11].

The public interest factors are not applied in a vacuum[12]. They need to be applied regarding specific conduct or transactions. The consideration of these issues is a form of regulation of market function by Organs of State. The competition authorities do not investigate firms at random to see whether they are complying with these specific public interest standards. They are instead considered at times where conduct is reported and brought to the attention of the competition authorities, or in times where a merger is being evaluated. There exist other legislations that exist to address matters of which public interest relates to. Regarding matters that involve employment[13] and black economic empowerment[14] legislation exists with more 'teeth' that governs these matters[15].

[7]Bernard Hoekman and Peter Holmes, *Competition Policy, Developing Countries and the WTO*, (Blackwell Publishers Ltd 1999), at page 875.
[8]As per the antitrust policy of developed states defined immediately above.
[9]See Merger section below.
[10]The Minister of Trade and Industry. Herein referred to as "the Minister".
[11]Through the Competition Tribunal (herein referred to as "the Tribunal") and the Competition Appeal Court. The Competition Commission is a body akin to the National Prosecuting Authority which forms part of the Executive.
[12]As case law evidences ad nauseum.
[13]The Labour Relations Act 66 of 1995; Employment Equity Act 55 of 1998; Basic Conditions of Employment Act 75 of 1997.

Therefore the public interest tests will be engaged in times where either anti-competitive conduct by a firm in the market occurred, and/or in times where transactions between firms (sizeable enough to fulfil a Ministerial determined threshold) can be reasonably assumed to impact on the market thereby warranting its investigation. Mergers fall within the genus of these transactions, as according to the cited definition of competition law above, competition restricting practices is the overarching family to which merger transactions belong. Public interest analysis regarding any investigation into such a transaction or to conduct that is deemed anti-competitive is undertaken after the 'competition enquiry'[16] has been completed by the relevant competition authority[17].

There exists a problem with these 'non-efficiency goals' from the outset as they encompass economic considerations linking macroeconomic principles of economic growth, to microeconomic ones of efficiency, social welfare and equity. This is a complex problem as in its application, the question arises of whether the Judiciary of a country is the medium that is best suited to address these matters. This argument will augment the consideration of whether public interest should be encompassed within the ambit of competition legislation.

Some are of the opinion that public interest has no impact on competition[18] whilst others vehemently adhere to the opinion that public interest indeed has a secured reservation to a place in competition legislation. In this paper I intend to prove my hypothesis that public interest (as a form of market regulation) does indeed have a warranted and deserved place in competition legislation, whose existence is further required because of the historical and restrictive nature of political/governmental regulation of national economies of past regimes.

---

[14]Broad Based Black Economic Empowerment Act 53 of 2003, that seeks to increase opportunities for previously disadvantaged South Africans to participate in the national economy. Herein after referred to as "the BEE Act".

[15]This application of other legislation regarding matters to which public interest is linked, is to be understood in terms of the rationale for the creation of these legislations. See Merger Section below for a discussion on policy rationales for these legislative enactments.

[16]Regarding matters of efficiency (which is always the subject of the first enquiry) and/or the suspected breach thereof, an investigation into whether the conduct offends this efficiency criteria by examining whether the conduct and its effects substantially lessens or prevents competition, as encoded in Section 2(a) and (b). Regarding mergers, the same analysis is undertaken, as encoded in Section 12A(1) and (2) of the Act.

[17]This procedure has not always been adhered to, as was the case in *MediCross HealthCare Group (Pty) Ltd /Prime Cure Holdings (Pty) Ltd* (11/LM/Mar05) [2005] ZACT 66.

[18]Tracy Hancock, *Public Interest Consideration Best Left to Other Agencies?* Merger and Acquisitions. PUBLISHED 02-04-2010.

In terms of these opinions, with specific reference to mergers, I view it in a different light. There are copious amounts of legal texts which state ad nauseum that public interest is not a criteria that has ever been practically used to disallow a merger that has in fact been discovered to be pro-competitive, or vice versa. In terms of this contention, I fully concur as it is evident there has never been a case which was decided solely on public interest grounds. The Judiciary has relied on findings that the public interest matters are not 'substantial' enough to offset the anti-competitive effects, even though there has been no definition in the Act of what exactly is to be regarded as such. However I do not believe that this is the area in which public interest is in reality employed.

The non-efficiency goals of the Act are to promote social and consumer welfare, in a manner that regards equity as a factor[19]. It is further deemed to be a regard that is had, in a manner that is conducted separately from the regard given to efficiency considerations. Therefore as a starting point, prohibited mergers will not be discussed, as they have been prohibited on the grounds they were found to be anti-competitive, and as stated have to date never been saved by public interest considerations. Upon examining the approved mergers, it will be seen that the approvals were subject to conditions[20]. It is in these conditions that the public interest and the goals stated in the Preamble of the Act are given a forum to be addressed and where they are realised. It is through these conditions, made with respect to a balancing act between the needs of the merged entity and the needs of the affected areas/people, that economic development, economic growth, and income and wealth distribution are furthered.

To surmise, there are three main questions addressed in this paper, namely:

(1) Whether there is any merit in the argument for free markets and against governmental regulation or whether the diametrically converse argument is to be preferred;
(2) Should the need for regulation exist, then to what degree is this market regulation desirable and practically conducted? Evidence of the practical degree of its application will be evidenced by the case law that will be discussed hereunder[21];

[19] The manner in which this is conducted in terms of the economic policies that are applicable, will be discussed below.
[20] Which I regard as being a regulation of the behavior of the players that exist within the market, and therefore of the market itself.
[21] *Shell South Africa (Pty) Ltd v Tepco Petroleum (Pty) Ltd* 66/LM/Oct01; *Mittal Steel et al v Harmony Gold Mining Company et al* 70/CAC/Apr07; and *Wall-Mart Stores Inc and Massmart Holding Limited* 73/LM/Nov10.

(3)Finally, regarding Merger transactions, should public interest be a sufficiently convincing criteria to contribute to a decision regarding whether the transaction will be prohibited, or conditionally/ unconditionally allowed? Furthermore, how these conditions are implemented, and how their importance is understood in terms of economic rationale that guides them.

CHAPTER ONE– Understanding Competition Policy

In order to enforce the social welfare goals, that are the rationale behind the creation of public interest policy, competition law is the selected mechanism for addressing such matters. Competition law is the machine employed so that the State can guide the market to work in a certain fashion, namely: The realisation of traditional goals of competition whilst simultaneously encouraging the market to function as freely and as openly as possible, according to a more beneficial and socially responsible standard. This machinery was selected as it is the one with the thinnest barrier between the Organs of State and the actual market, as it further provides for specialised forums where these two forces are able to interact. In these forums the government has the ability to regulate the markets structure and its activities, to a certain degree. The degree and need of such regulation will be understood via a comparison between two diametrically extreme forms of market systems, discussed hereunder.

The Preamble:

Competition legislation is South Africa is to be interpreted first and foremost in accordance with its Preamble, whose ideologies are to underlie the understanding of the provisions of the sections that follow it. The Preamble which makes reference to economic discriminatory practice that was perpetrated by the past regime on racial policy that permeated the political core of Apartheid South Africa.

Effectively, there were two separate economies in existence during Apartheid[22]. The economic players, able to navigate and exploit the totality of the national economy, were the minority group of the State who had at their disposal the most opportunities and capital to grow and to benefit as its exclusive participants. The majority of the nation's citizens were not afforded access to such interaction and the effects of this legally sanctioned blockade are

[22]Hartzenberg T, *Competition Policy and Enterprise Development: The Role of Public Interest Objectives in South Africa's Competition Policy*, (August 2004), at 6.

still being felt today. This segregation of a distinct and substantial sect of the population relegated them to the lower echelons of society where they were kept at a lower standard of living with no prospects of escaping and substantially hindering their economic development and growth albeit their desire to participate existed.

The wording of the Preamble was carefully selected to include descriptive and emotionally charged words such as 'unjust', to convey the severely immoral basis on which the Apartheid economic policy was enacted and surgically implemented, so as to depict to the reader the gravity of the degree of change that is now required in order to ameliorate these past 'injustices'. Within it, there is a call for effective administrative bodies to ensure the continued existence of this 'new' competition policy which in its mandate includes the promotion of enhanced mobility and access to all markets by all South Africans without political reservations. The call is for consideration to be had to the rights and needs of all participants in the market at all levels, with the ultimate goal of securing positive economic growth and consumer welfare increases by strategically encouraging greater product choice and international commercial interaction. It is from this template of interpretation that the Act will be read therefore giving the reader an understanding of the magnitude of importance that the public interest provisions are to be afforded.

The goals of the Act, are listed in Section 2, which state that the purpose of the Act "...is to promote and maintain competition in the Republic in order –

(a) To promote the efficiency, adaptability and development of the economy;
(b) To provide consumers with competitive process and product choices;
(c) To promote employment and advance the social and economic welfare of South Africans;
(d) To expand opportunities for South African participation in world markets and recognise the role of foreign competition in the Republic;
(e) To ensure that small and medium-sized enterprises have an equitable opportunity to participate in the economy; and
(f) To promote a greater spread of ownership, in particular to increase the ownership stakes of historically disadvantaged persons...."[23]

[23]I have not included the following sub-provisions of section 2 as they are not related to the argument being made in this paper.

Sub-sections (a) and (b) include the main goals of any competition law throughout the world[24], whilst sub-sections (c) to (f) list the additional equity and distributive objectives which are a continuation of the spirit of the Preamble. More specifically, they were incorporated into the Act as defined goals in an attempt to prevent the effects of these injustices from surviving into South Africa's democratic era and thereafter hindering the progress that was and is desperately needed[25].

These public interest provisions are considered with regard to the effects that specific conduct or transactions occurring within the market would have, and are given attention (after the competition efficiency considerations have been addressed) in the form of a balancing test[26]. The public interest enquiry is to be conducted separate from the efficiency enquiry[27].

Equity concerns are further incorporated into the Preamble and the need for this will be elucidated with reference to the needs of developing countries.

The public interest provisions that are listed in section 2 of the Act will be discussed in relation to the needs of developing countries in chapter 3, so as to give substance to the argument for their existence. Regarding the discussion on mergers refer to chapter 4.

CHAPTER TWO– Economics: Market Models

There exist various market models, each with their own proponents and critics. Against the inclusion of public interest sections in Antitrust Legislation, reference will be made to proponents of the free market system, which postulate that the core nature of the market is

[24]These goals form the primary evaluation in any competition matter. Should the conduct that is being investigated be a merger, an abuse of dominance, cartel behaviour etc, be contrary to the promotion of efficiency and who offend against the competitive process through any disruption at all.

[25]This is therefore an indication that the Act has some politically charged rationale behind its creation, in that equity and justice as driving forces have been incorporated into the interpretation and therefore intended application of this legislation.

[26]Specifically regarding a merger evaluation, a determination will need to first be made as to whether the merger will 'substantially prevent or lessen competition'. Thereafter there will be an investigation based on the representation of the merging parties as well as other investigations by the Competition Commission that will evaluate whether there are any 'technological, efficiency or other pro-competitive gains' that will result as a direct consequence of the merger. This forms the competition efficiency enquiry into the specific merger transaction. The final part of the balancing test is to see whether the public interest provisions of the Act (in s12A(3)) are affected. Ideally this final analysis should be conducted regardless of the outcome of the efficiency analysis, and the result of this public interest enquiry should be regarded in the determination of the outcome of the decision to allow or refuse the transaction- in theory at least.

[27]M Brassey (ed), Competition Law, (Lansdowne: Juta, 2002), at 275. Albeit this applies to consideration of public interest in merger analysis, the same rationale applies to public interest considerations in the general sense as well.

self regulatory and as a result it will thus adjust itself and reach an equilibrium point befitting the markets needs at that time. This is said to occur as a pure consequence that free competition (and all that this entails) has on the market. Conversely, there exist arguments that in a market setting prevalent- specifically- in most developing countries, the preferred market policy regime is to be a planned market structure, or a command economy. The rationale that the protagonists of this ideology rely on is that there are other, closely linked, tangential national needs that are to be addressed through this form of legislation that is the one which is most closely suited to addressing such matters.

(I) Free-price mechanism:

(a) The basic economics of a free market system:

'A free price system or free price mechanism ... is an economic system where prices are set by the interchange of supply and demand, with the resulting prices being understood as signals that are communicated between producers and consumers which serve to guide the production and distribution of resources.'[28]'The private ownership of resources and the use of markets and price to co-ordinate and direct economic activity characterize the market system…each participant acts in his or her own self-interest…(and) seeks to maximise its satisfaction or profit through its own decisions regarding consumption or production…'[29].

'Basic to the faith that a free economy best promotes the public weal, is that goods must stand the cold test of competition; that the public acting through market's impersonal judgement, shall allocate the Nation's resources and thus direct the course its economic development will take.'[30] Of course the national market forces will define and develop the economy, bringing with it growth and prosperity to various industries, and this force is said to be solely governed by the decisions of consumers, as evidenced by these 'signals'. The extreme application of free market systems would lead to pure capitalism[31].

Some are of the opinion that 'Since prosperity and decent employment are promoted by, and only by, real economic freedom in free market economies...'[32], that there is zero need

[28] http://en.wikipedia.org/wiki/Free_price_system
[29] McConnell and Brue, *op. cit.* note 5, at 33.
[30] *Times-Picayune Publishing Co v United States*, 345 US 594 (1953) at 605.
[31] McConnell and Brue, *op. cit.* note 5, at 33.
[32] Leon Louw, *Economic Freedom Defined*, http://freemarketfoundation.com/ShowArticle.asp?ArticleType=Publication&ArticleID=1746

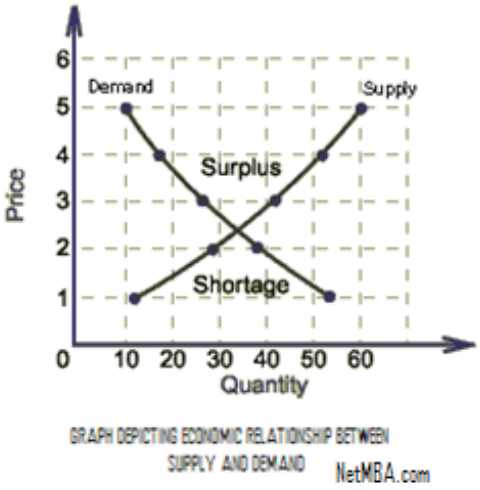
for market regulation[33]. That regardless of the surrounding circumstances that are present in any given nation, at any given time, market forces will prevail and settle the market at an equilibrium that is beneficial, and will put the growth of the economy onto the path that will result in the closest attainment of Pareto Equilibrium[34]. This school of thought believes that any state '…interference will disturb the efficient working of the market system.'[35]

The basic market model used herein focuses on Supply by Producers and Demand by Consumers. The supply will be affected solely by the amount of demand that there is for a good in the market, as there is no rationale to supply a good that has zero demand.

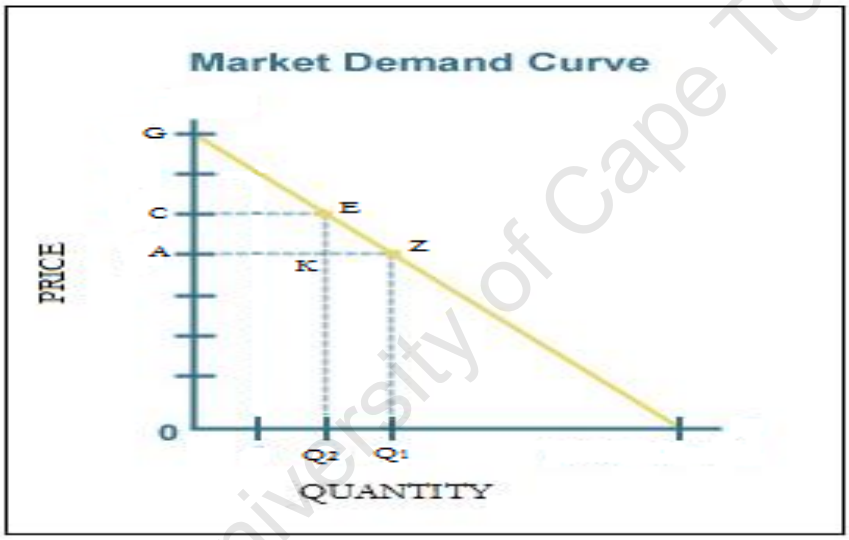
However the demand of a good will be determined by looking at factors of the good provided in that market. The main determining factor for the demand of the good will always be its price, in tandem with the utility that the good can provide. Further considerations would be the substitutability of the good which is closely linked with the price elasticity (or price inelasticity as the case may be) of demand function for that good. In a free market system, the factors that are considered are 'pure' and therefore free from any consideration regarding governmental regulation. Again, such regulation would include public interest considerations.

A graphical representation of the relationship between demand and supply in a market, as well as a representation of the demand curve will be provided to better understand the market forces at play in a free market economy.

[33]This is laissez-faire capitalism.
[34]Rachel Jafta & Johann van Eeden, *The Economics of Competition Policy*, Paper for the Free Market Foundation Competition Policy Round Table, (Econex) 30 June 2011, at 7, with reference to Reekie, W.D. (1999). The Competition Act, 1998: An Economic Perspective. South African Journal of Economics, 67(2): 257-288
[35]McConnell and Brue, *op. cit.* note 5, at 33.



The intersection of the curves indicates the point where the demand of a good by consumers equals the supply provided by producers, and is a representation of the point when the market is in a general equilibrium. This is a crucial point because it affects the relationship between the goods/services that a consumer demands with, in this case price, the opportunity cost the consumer is willing to sacrifice to gain the utility from obtaining the product.



The Pareto Optimum position that is desired to be reached is where the cost of producing a good is equal to the cost of the revenue received for the good. It is the point in a market where by the increase of one unit of production by one party thus increasing their position in the market, the corollary effect will not be that another party in the market is consequently worse off as compared to their situation before this additional unit was produced/consumed. 'Pareto efficiency is a minimal notion of efficiency and does not necessarily result in a socially desirable distribution of resources: it makes no statement about equality, or the overall well-being of a society.'[36]

[36] http://en.wikipedia.org/wiki/Pareto_optimum

Economically speaking, competition law aims to maintain the market at this equilibrium thereby preventing unit prices increasing and unit output[37] decreasing, in an attempt to allow for the market to attain Pareto Optimality whilst at the same time being aware of the fact that the conditions for the market will never exist for this to occur.

On the demand graph above, at price A the supplier is a price taker, which therefore means that the market is more sensitive to the needs of consumers. This therefore will be the Pareto Optimal price as the degree of harm that could be inflicted on a consumer at this point is negligible.

'...an economic market is determined in order to identify an equilibrium price....'[38] Should there be a Shortage then the Seller would increase prices and demand would decrease accordingly until a new equilibrium would be reached. However this new equilibrium would be further away from the Pareto Optimum, as there are still demands in the market for the good however due to the characteristics of the good (specifically its higher price) the consumers do not regard the opportunity cost of paying over the amount demanded by the Seller, as being equitable to the unchanging utility derived from consumption of that good. In a few words, the definition of Pareto Optimality is not fulfilled because while the seller is better off at charging this higher price and reducing output, consumers gain an ill-related cost to consumption utility from the opportunity cost they sacrifice in purchasing the good. What would solve this dilemma would be where the supplier either increases the supply of the good, or in terms of competition, where more producers would enter that market thereby increasing the price elasticity of demand in that market as a result of an increase in the substitutability of the goods and thus driving prices in the market down whilst at the same time increasing output. Therefore in a sense the public interest ground of Section 2(e) is a Regulation designed to aid market conditions to exist that mirror the requirements of a free market economy, in an attempt to attain perfect competition.

The Demand Curve graph will depict where the Pareto Optimum level of production will be for a market, assuming that it is a free market. The conditions for a free market are largely the same for when a market will be considered perfectly competitive.

[37] Quantitatively and qualitatively

[38] *Trends in South African Competition Law,* Webber Wentzel Attorneys, (14 June 2004), http://www.webberwentzel.com/wwb/content/en/page1874?oid=3111&sn=Detail&pid=1874

'A market economy will be perfectly competitive if the following conditions hold:

(i) Sellers and buyers are so numerous that no-ones actions can have a perceptible impact on the market place, and there is no collusion amongst buyers and sellers

(ii) Consumers register their subjective preferences among various goods and services through the market transactions at fully known prices. (*In addition it is a homogenous product*)

(iii) All relevant prices are known to each producer, who also knows all input combinations technically capable of producing any specific combination of outputs and who makes input-output decisions solely to maximise profits

(iv) Every product has equal access to all input markets and there are no artificial barriers to the production of any product.'[39]

(aa) The law as understood in terms of the free market system:

The Chicago Jurisprudential School states that efficiency is the only consideration that is to be had in the market. No other considerations are to be had when deciding to regulate the market. They are of the opinion that "...the law becomes less effective the more its true purpose is mixed up with other objectives."[40]

The argument of: 'Why "competition and its regulation"? Why not view competition...as the antithesis of regulation and celebrate it for that reason, as the triumph of market forces over administrative intervention.'[41] The reason for regulation, albeit skeletal regulations in terms of this schools' contentions, is that the requirements for a perfect market simply do not exist.

(i) In the real world, dominant firms exist in the market[42] whose actions are definitely felt in the market. The amount of Sellers and Buyers in the market is affected by historical and other extenuating factors.

(ii) Products are not homogenous. In markets, there may be a general function of a good. However due to innovation there are characteristics that will make a good within this narrow market segment stand out from the rest. For arguments sake let's use the example of a market for plastic bottles. They may be made of thick

[39]P Areeda & L Kaplow, *Antitrust Analysis: Problems, Texts, Cases,* (1997) 6 Para 107.
[40]M Brassey *op. cit.* note 5, at 1.
[41]*Supra* note 4.
[42]Dominance of a firm will exist in a stand alone fashion should the firm have sufficient market power by itself, however it can also result in the same effect should collusion between sellers occur. The extreme case of this dominance will be a monopoly, therefore it is able to charge prices as it sees fit.

plastic for rugged use, or thin plastic for those that are environmentally friendly. They may have screw tops, or nozzles that are mechanically controlled or pressure controlled. The possibilities are endless.

(iii) There is never symmetrical information in a market between all the producers and on the part of the consumer.

(iv) The barriers to entry for the access of a product to a market are inter-related to the issue of the number and specifically the size of certain firms in a market.

In terms of the Act, this would be in fulfilment of Section 2(a) and (b), which are purely focused on efficiency considerations and considerations that would provide the consumer with greater choices (i.e.: For there to be increased suppliers in the market as explained above). This form of 'regulation' is not contrary to the contentions of the Chicago School because it exists to aid the process of free markets, only when such assistance is needed. 'Although a free-trade stance...greatly reduces the scope for anti-competitive practices to be sustainable, it does not imply that the need for competition law disappears.'[43] Competition law here is restricted to ensuring that firms do not act in a manner that would substantially prevent or lessen competition.

It is then from this economic construction that the relevant authorities are able to investigate whether there exist excess profits, thereby providing a basal point that can be compared against to see whether a firm with market power behaving in an exclusionary and anti-competitive manner, and thereby acting in a manner that is not efficient. I am not talking here about State authorities acting as price setters in a market as this would be a drastic regulation completely at odds with the principles of a free market economy, but rather that this is a factor that could aid them to determine whether there has been a perpetration of exclusionary conduct or whether post transaction there would be too great a concentration of market power in a single entity that would avail that entity of opportunities to act in a competitively reprehensible manner. In a word, it allows State to ensure the efficiency of the market, acting in accordance with natural market function alone.

The implications that are brought due to the fact that the market will never be perfect, is that government is tasked with creating laws that will attempt to reduce the disparity between

[43]B Hoekman *op. cit.* note 7, at 883.

a Pareto Optimality and the actual reality of the market. This would be done by legislation that includes the requirements for a competitive market to be codified, and then somehow enforced. However this is obviously impossible.

The market forces of demand and supply discussed above function in terms of collecting and interpreting the market signals. Where there is a high price it would indicate that there is a shortage of supply and a surplus of demand. In terms of competition, this would attract new firms to that market sector in as it is appealing due to the high demand that exists in that market, all other factors equal[44]. Should more firms be introduced to this market[45] that would mean that the proportionate share of the market held by the already existing firms will decrease accordingly – and therefore the dominance of certain firms would be mitigated, consumers would have a greater choice of like products, product innovation would be encouraged in attempts to differentiate between competitors – thus increasing the quality of products provided, excess profits held by the already existing firms will decrease, etc. Once equilibrium between demand and supply is reached[46] then there would be no more profit incentive for the firm to continue to increase supply[47]. At this point, the consumer's needs and wants are able to be satisfied and the opportunity cost of obtaining this product and the linked utility that the consumption of this product would bring is reasonable and viable for the consumer to undertake. However these numerous and non-exhaustive benefits are only able to be realised should the market be perfect, and this understanding is related more to the genus of essential facilities as compared to its relation to general tradable products.

On the other hand, '...as resources become more scarce the price increases, which signals to consumers to reduce consumption thereby ensuring that the quantity demanded does not exceed the quantity supplied. It is in this way that the free price system persuades consumers to ration dwindling resources.'[48] This highlights the self regulating abilities of the market.

The matter of public interest is not addressed in this market system. I believe however, that the inherent failure of this market model is that it fails to take into account extenuating circumstances that are present in the market and that cannot be assumed away when using such models based on the pretence of a perfect market. This pretence does not include

[44]Barriers to entry are low; as are initial capital investment costs; resources available are not scarce; etc.
[45]Or should existing firms increase production.
[46]Graphically represented by the intersection of the 2 curves in the graph provided.
[47]*Supra* note 38.
[48]Supra note 28.

considerations of historical discrimination and the effect that it has in terms of cementing possible market players in the most disadvantageous position.

(b) Planned Economies:

The idea of this method of thinking is that 'Constraints are necessary before freedom can be achieved'[49].

'A planned economy is "an economic system in which the government controls and regulates production, distribution, prices, etc."'[50]

The reason for State intervention in the form of market regulation has numerous rationales. "The justification for central planning is that the consolidation of economic resources can allow for the economy to take advantage of more perfect information when making decisions regarding investment and production."[51]

A rationale for regulation comes from the fact that the modus operandi of firms includes primary aspirations to further their own interests- in the form of profits- within the market exclusive of any considerations that would impede the realisation of these goals. This is the ideal situation of a firm, to provide their product at cost price plus a profit percentage and to maximise their return. The reason for regulation is to reduce such actions that are contrary to the interests of the market, as the effects of exclusionary and anti-competitive conduct is borne by society, with the qualification to do so in a manner that would satisfy all parties.

These are considerations that Governments need to address because the protection of society is one of their primary tasks. It is under this guise that governments defend their stance on the adoption of this economic policy. However, the guise of beneficial outcomes is simply a mirage. It is a fleeting illusion conjured by the promises of leaders of a future Utopia, but one which has no overall intention to be allowed to materialise, at least not for society at large[52]. This is particularly true for emerging markets/developing countries that are stricken with issues of poverty, cronyism, and corruption[53].

---

[49]Brassey, *op. cit* note 27, at 4, with reference to D Neven, P Papandropoulos and P Seabright *Trawlings for Minnows* (1998) 1.

[50]http://en.wikipedia.org/wiki/Planned_economy with reference to Dictionary.com Unabridged (v 1.1). Random House, Inc.

[51]Ibid.

[52]Ibid, on the discussion of The Peoples Republic of China's transition from a planned economy to a market economy.

[53]Fox, Eleanor M., *Economic Development, Poverty, and Antitrust: The Other Path,* (2007). New York University Law and Economics Working Papers. Paper 102. (http://lsr.nellco.org/nyu_lewp/102)

On the matter of state owned monopolies - i.e.: Communism[54] – which is the extreme form of state regulation of markets, 'There is...widespread recognition that where, as a result of government policy, market forces do not operate and where regulation is ineffective, the services that we receive are expensive and inefficient.'[55] Should a State move from a communistic policy to a capitalistic one, extreme caution must be taken so as to allow for the transition to traumatise the market to the smallest degree. In situations where governments have reduced market regulation post recognition of the detrimental effects regulation has, they realised '…that what the retreating states left was a vacuum…that was not filled by a benign invisible hand pointing in the direction of efficient outcomes, but one that was rather filled by private concentrations of economic power, if anything less able and willing to promote economic efficiency and consumer welfare…(which resulted in) an environment that was not only extremely hard for those obliged to live and work in it, but one that was extremely unattractive to investors and, so at odds with the basic requirements for dynamic competition and economic growth.'[56]

Every firm exists to further its own position in the market. A firm that abuses its position in a way that increases barriers to entry is in line with the firm's aspirations to further itself and realise a maximum return, as with fewer competitors comes a greater percentage of market share and a greater incentive to increase a price charged beyond the acceptable level. This occurs as a result of substitutability and price elasticity of demand functions having been reduced. Regardless of the actions of the firm the harmful effect is again shouldered on society and on the consumer. Therefore regulation is important to increase the permeability and mobility of the market, according to both schools of economic thought promoting either free markets or regulated ones, state that consumers and the economy will always benefit with more competition in the market. Public interest as a regulation addresses this issue specifically in Section 2(c) and (e) of the Act.

In the past South African competition regime, 'Practically, once the (*Competition)*Board had made a ruling to the effect that an acquisition was not in the public interest, the Minister did not override that finding and would proceed to prohibit the merger.'[57]

[54] McConnell and Brue *op. cit.* note 5, at 33.
[55] *Supra* note 4.
[56] *Supra* note 4.
[57] Brassey, *op. cit* note 27, at 231.

It has been seen that both the free and the planned market models have their pros and cons. However neither is suitable in its entirety to be implemented into the economy of a developing country in a 'plug and play' fashion, especially not in the South African economy. The drafters of competition policy in South Africa realised that '…markets led o economic outcomes superior to those attainable through administrative direction of the economy; but (also) that in order to realise their considerable promise, markets had to be subject to effective regulation.'[58]

CHAPTER THREE – The Needs of a Developing Country

The situation of the economic growth of developing countries is a sensitive and elastic one. South Africa's history is distinctive in the sense that the discrimination that existed within the nation was not only sanctioned, but legally enforced by the government. When the country was liberated from the claws of institutionalised racist policy, it was deemed necessary to implement other policies to counteract the (specifically) economic discriminatory policy, whose purpose was to promote and enforce economic disparity and limit opportunities for market participation by an identifiable market segment. Even though the method of implementation of such discrimination was unique, the effects produced are not uncommon in other countries. 'High levels of concentration are common...Markets are small, consumers are not well informed of their rights, and capacity to effectively implement competition policy and law is scarce. Challenges of unemployment...as well as a history of excessive government regulation and adverse effects on competition are also common to many developing countries.'[59]

In a developing country, consumer's income is statistically lower than in developed countries[60]. As a result there is a decreased amount of national saving and increased expenditures- expenditures made with little available resources to begin with. There are broadly two types of goods in an economy:

(i) Consumption goods, which are purchased and used by consumers to satisfy their needs. Should there be any surplus in earnings post consumption of these goods, there is generally an increase in savings and investment.

[58] *Supra* note 4.
[59] Hartzenberg *op. cit.* note 22, at 4.
[60] Debraj Ray, *Development Economics,* Princeton University Press, Princeton New Jersey (1998), at 10-22.

(ii) With this capital, capital goods are bought that are then used in the increased or more efficient production and supply of further goods[61]. This increase also brings with it more employment opportunities.

The cycle grows and grows with every increase in investment and as a consequence, simplistically, economic growth and development is promoted. This vital cycle is however premised upon the requirement that there are sufficient citizens earning monies above levels that satisfy their needs in terms of consumer goods, and therefore there is a sufficient level of savings pooling from which to invest and continue the cycle through to its next progression of capital goods purchases. 'Economic growth is positive when investment exceeds the amount necessary to replace depreciated capital, thereby allowing the next periods cycle to recur on a larger scale.'[62]

At the end of the day it is the consumer who through their actions and economic decisions, further the economy and stimulate growth[63]. The Act was created to include provisions that would protect the consumer from certain kinds of harm[64] that amount to either an abuse of dominance by a firm that holds sufficient market power, or by exclusionary conduct. The effect of these conducts is that there would be an unnecessarily and unjustifiably increase in expenses incurred by the consumer, whose expense is inflicted on the consumers income thereby reducing savings equivalently. Should this regulation of such conduct of producers in the market not exist, then the result would be that firm (that for argument sake has market power and therefore whose conduct is able to have an appreciable effect on the market) would be in a position to abuse it to the detriment of the consumer. Without regulation there would further be no forum to address and prevent this oppressive behaviour, market dominance would be a high probability[65] which would then result in barriers to entry being high and market forces subsequently being sand-bagged out and prevented from engaging. Pareto optimality would never be realised, and the result would be that social welfare would be injured if not destroyed. Should the product that the hypothetical firm in question produce hold a price inelastic characteristic, the consumer will then need to

[61]Ibid at 51.
[62] Ibid, at 54.
[63]Ibid.
[64]*Competition Commission v Pioneer Foods (Pty) Ltd,* (15/CR/Feb07, 50/CR/May08) [2010] ZACT 9 (3 February 2010)
[65]This is to be understood in terms of the call from free-market system promoters which are in favour of deregulation of the market. As a result of South Africa's history and the subsequent democratic regime, regulation is vital, lest the situation as described above with reference to footnote 56 materialize.

spend more on these goods. As a result there will be less expenditure in other industries, which translates into economic growth effectively being severely retarded and as a conjoined consequence social welfare and economic efficiency will be unattainable. This is however an extreme view, which would only exist – if ever – in the short term. Nonetheless the example is useful to explain the far-reaching and damaging effects that are associated with lack of regulation regarding the conduct of firms.

Therefore the market will need to be regulated in a manner that has more goals in mind as compared to a free market economy so as to prevent harm to the consumer and further to society as a whole. There is clearly a need for regulation, as a developing country is in a position that has its origin on the back foot as it were. Such regulation however needs to exist at a point where '…the optimal amount of regulation is that at which the marginal benefit and marginal cost (of said regulation) are equal….The task is deciding on the right amount.'[66]

Factors affecting economic growth and development, and whose rationale formed part of the basis for its inclusion in public interest provisions enshrined in section 2 and 12A(3) of the Act, include matters relating to the equity and fairness. 'We cannot speak of development without a serious consideration of the problem of inequality.'[67]

Regulations in terms of mergers and the rules that state the transaction needs to be investigated upon surpassing stated thresholds is a form of preventative and forward looking market protection mechanism.

The argument against a free market system is found inherently in its characteristics that due to signals being sent by consumers and producers in the market, the allocation of resources will be generated in a manner that would have the overall effect of directing the growth path of the economy. In a developing country that has scarce resources a free market will not accurately direct the most beneficial economic growth path. Many economists that agree with free market systems argue that through efficiency, equity will eventually be reached. The problem is exactly that. Equity will be reached as theory dictates, however the time that it will materialise may be far too long. It is not plausible for a new democratic government, that has recently prevailed over a past oppressive system (be it Apartheid or any

[66]McConnell and Brue *op. cit.* note 5, at 79.
[67] Debraj Ray *op. cit.* note 60, at 169.

other oppressive past regime, with which numerous developing countries are riddled), to at that point indicate to the population that efficiency will be the main driving factor in their new economic policy and that equity shall be disregarded due to complications in its application. According to Kuznets inverted U model, what will initially result through a purely efficiency driven economic policy will be a deterioration in the economic standing of the poorest and a bolstering of such standing of the richest. Even though this will be temporary and income distribution will begin to rise once per capita levels increase beyond a certain point, this is not an argument that the population with such a history will accept. Civil unrest is almost certain to result which would collapse the economy even further. This contention would be an argument in favour of market regulation specifically in the form of public interest.

However, where there is a situation of an over concentration of regulation, where states have reduced their interference in a previously controlled market by "...withdrawing from the economy...they quickly discovered that what the retreating states left behind was a vacuum...filled by private concentrations of economic power, if anything less able and willing to promote economic efficiency and consumer welfare...."[68] This is then a testament to the fact that a decrease in governmental regulation of the previously heavily regulated market needs to be done in a fragile balance, (that is, not to interfere too much and not to leave it completely free) because the common result would be resultant inefficiencies and harm to socio-economic interest of the consumer.

Therefore there cannot be a complete assimilation of either market system into an economy because the immediate effects would be harmful, and the inherent characteristic of dominant firms in the market would be to incubate their practices in an attempt to ensure continued benefits flowing to them.

On a discussion regarding the origins of competition policy, national law reflects and addresses goals that are peculiar to that nation, "...but what they had in common was that they all responded to a growing recognition, first, that markets led to economic outcomes superior to those attainable through administrative direction of the economy; but, second that, in order to realise their considerable promise, markets had to be subject to effective regulation."[69]

[68] *Supra* note 4.
[69] *Ibid.*

Governmental market regulation in developing countries that is enshrined in its competition law policies should be aimed to increase mobility and access to the market whilst simultaneously making strides to attaining the overarching and broader goal of national economic growth and development with the idea to enhance social welfare[70].

Regulation is required in terms of varying degrees. Regarding essential facilities, "...the demand here is for stronger, more effective regulation rather than further deregulation. There is, in other words, widespread recognition that where, as a result of government policy, market forces do not operate and where regulation is ineffective, the services that we receive are expensive and inefficient."[71]

I view the Apartheid policies as being to a degree akin to a State monopoly as it were. This is seen in light of the segregation of the economic market. Whites were allowed to participate freely and to the exclusion of all other segregated people. Therefore when the markets opened and this 'state regulation' fell away, I believe that should the market have been made free and open as it was, yet further left to fend for itself and auto-correct as the proponents of Free market systems believe[72], the result may have been too similar for comfort to the resultant vacuum relating to privatization of markets as discussed above.

There are different types of market participation of course. South Africa was seen to have two different domestic markets during Apartheid which merged with democracy. Previously disadvantage people were now able to freely act as producers and consumers, however they were confronted with a difficult hurdle to overcome when it came to market participation in a role of a producer or competitor. The only means to ameliorate this predicament is through regulation. Regulation that is not focused on efficiency alone, but also to have regard to what has been termed 'public interest' so as to allow for the market to be permeated by all members of society with some market players being afforded a degree of heightened protection, ideally for a limited period- whose duration is not currently determinable. This raises questions of who will decide when this period has ended or whether it will end in stagnated steps or decisively on the fulfilment of criteria that are also to be decided without certainty. This matter will not be addressed, as the current fact is that some form of regulation in South Africa's economy is required.

[70]Fox, *op cit* note 53. This is the so called "Other Path" that the author elucidates in her article.
[71]*Supra* note 4.
[72]The Chicago School on Jurisprudential Competition thought.

The reason for the inclusion of the public interest grounds listed in the Preamble of the Act as well as in sections 2(c) and (f), as well as in 12A(3)(b) and (c), is to empower courts to aid the market in functioning in a manner that results are as near to Pareto Optimal as possible.

The problem that the economic free market model fails to take heed of is the fact that in a country where there has been rampant yet calculated discrimination against a sector of the consumers in a market, there cannot be reliance on market forces to self regulate after a political change in climate has occurred. I feel that a free market system would be efficient should all the 'players' in the market start on equal footing. Not equal in the sense that they have exactly the same resources available to them or that they have the exact same opportunities, but rather that on average these factors are at least similar.

With the history South Africa has, the position of the white minority was advantageously secured through the actions of the Apartheid government. It is not rationale or possible to believe that post 1994, previously disadvantaged people could, as a result of now being freely able to equally participate in the economy inclusive of all the benefits that such participation entails, be able to begin to participate at a competitive level. The resources that they have are no-where near those of the previously advantaged members of the market, neither is their knowledge, expertise, or accessibility to and mobility in said market.

As a result of these factors, regulation is not only desired it is inherently required. There can be no other medium to attain a satisfactory equilibrium where the constitutional principle of equality is realised. There is an argument that in time the regulation is to diminish accordingly so as not to allow for a situation where benefits of market regulation are unduly imposed in a manner that would accord an unfair advantage, and thereby defeating the principle purpose of the regulation.

However this is a matter that will need to be decided in the future, and in order to get to the place in which a decision is capable of consideration, policy previously created by government must reach a certain stage of fruition – particularly in the spheres of realising certain levels of the economic goals of development, efficiency and social welfare. "Policy statements related to economic efficiency and consumer benefits provide for flexibility in interpretation. References to adaptability and development of the economy, extend beyond an

interpretation of economic efficiency in a static welfare state, to incorporation of dynamic considerations including market entry, firm mobility and innovation."[73]

A form of regulation which has occurred recently is the enactment of the Consumer Protection Act[74] which will allow consumers to bring complaints against firms in a market for conduct that is not in line with its provisions. This has the effect of giving more power to the consumer to help State Agencies like the Competition Commission to investigate questionable conduct. This has the effect of increasing the scope and ability of government to regulate the dealings of firms so that it will ensure that this Section 2 will be better addressed.

Exemptions to the applicability of the Act are enshrined in section 10 of the Act. These apply should the stated requirements be satisfied. These exemptions provide the necessary wiggle room for courts to apply the law in matters that are not clearly black and white, which ties into the degree of regulation of the market that needs to be imposed. "A particular reason for consideration of an exemption application is 'ensuring economic stability'."[75]

Dave Lewis '...argues that the high levels of poverty and inequality need to be addressed urgently and this requires that all the country's policies be directed towards addressing these problems...'[76] . He further states that '…in a country like South Africa, while we, the Competition Authorities, may well understand the pitfalls in balancing competition and the public interest, we equally recognize that a competition statute that simply ignored the impact of its decisions on employment or on securing greater spread of black ownership, would consign the act and the authorities to the scrap heap.'[77] In an attempt to understand how Organs of State envisage the furtherance of these non-efficiency goals, development economics is a useful tool. 'Ultimately, economic inequality is the fundamental disparity that permits one individual certain material choices, while denying another individual those very same choices.'[78]

[73]Hartzenberg, *op. cit.* note 22, at 13.
[74]Act 68 of 2008.
[75]Hartzenberg, *op. cit.* note 22, at 14.
[76]Jafta & van Eeden *op. cit.* note 34, at 13 with reference to, A Lewis, D. *Competition Regulation: The South African Experience.* (2000) Paper presented at the ISCCO Conference, Taipei.
[77] Jafta & van Eeden *op. cit.* note 34, at 14 with reference to, Lewis, D. *The Role of Public Interest in Merger Evaluation*. (2002) Presented to the ICN, Naples.
[78] Debraj Ray *op. cit.* note 60, at 170.

In terms of any of the public interest provisions that are designated to regard matters of employment and securing greater spreads of black ownership generally[79], or specifically[80] so as to understand the effects that a change in market structure would have, regard is to be had to income distribution economics. It is useful in that it provides theories that can be transposed to understand how an economy is performing at any moment in time with regard to its strive to attain minimal levels of disparity across classes and overall, to highlight areas that require attention so as to attain satisfactory economic growth and development. Income distribution has been defined as a measure of '...how a nation's total GDP is distributed amongst its population...(and it) has always been a central concern of economic theory and economic policy... (Furthermore its) Important theoretical and policy concerns include the relationship between income inequality and economic growth.'[81] The arguments made were based on the use of per capita income values in varying countries and the rationale for its usage is based on particular studies that '…express the idea that per capita income is a powerful correlate of development, no matter how broadly we conceive it.'[82] 'Saving rates are severely affected at low levels of income; so is the capacity to do useful work.'[83]

A survey indicated that '...the poorest 40% of the population earn on average, around 15% - perhaps less – of overall income, whereas the richest 20% earn around half the total income.'[84] Furthermore, 'savings rates are severely affected at low levels of income; so is the capacity to do useful work.'[85] As a result of this decrease in savings, comes further harm in that poverty, malnutrition and education all take a savage beating. In order to give some useful understanding to the concept and the results that inequality brings, information about '(a) how endowments were distributed and (b) what kind of economic interaction occurred in the "previous period"…'[86] must be available. '…the goal is to see how a given past influences the future…'[87] 'It is common place to see enormous wealth coexisting with great poverty…It isn't that such inequalities do not exist in the developed world –they do- but

[79]In terms of the Section 2 understanding of it.
[80]In terms of the Section 12A(3)(b) and (c) understanding of it.
[81]http://en.wikipedia.org/wiki/Income_distribution
[82]Debraj Ray *op. cit.* note 60, at 30-31.
[83] Ibid, at 197.
[84]Debraj Ray, *op. cit.* note 60, at 22. Further, at 25, figure 2.6 on page 23 indicates the inverted U hypothesis of Kuznets, which illustrates the use of per capita income as an indicator for income distribution. This model illustrates that 'At higher levels of per capita income, economic gains tend to be distributed more equally – the poorest quantiles now gain in income share.'
[85]Debraj Ray *op. cit.* note 60, at 197, as previously mentioned at 25 with specific regard to middle income states.
[86]Debraj Ray *op. cit.* note 60, at 198.
[87]Ibid.

coupled with the low average income in developing countries, these disparities result in an outcome of visible poverty and destitution[88],

Regarding the graph depicting Kuznets hypothesis[89], it '…indicates the possibility that as economic growth proceeds, it initially benefits the richest groups in society more than proportionately… At higher levels of per capita income, economic gains tend to be distributed more evenly.'[90] Using the Tunnel Theory[91] with regard to the progress of economic development, poses a grim prospect of acceptance. Seeing as the richer segments of society benefit first and inequality will rise, post Apartheid this would mean that the suppressed members of the population will be exposed to further inequality and that they will observe previously advantaged people benefit further. The only way that this dissatisfaction can be bearable is when the hypothetical individual's levels of tolerance are high as he is of the expectation that soon he will also benefit. However, '…increased inequality may not be tolerated at all if the perceived link between the growing fortunes of others and the individual's own welfare is weak or non-existent. The greater the extent of segregation to begin with, the higher the possibility of this outcome.'[92]

'If growth and equity in income distribution are considered to be the two principal objectives of the process of economic development, the development strategy has to be devised by keeping in mind the social and political context.'[93]

There are of course other factors that contribute to the development and growth of a nation, which are factors termed human development. Matters such as the education policy of a government, life expectancy and infant mortality rates. In a country like South Africa there is not a good education system with poor literacy levels. Thereafter there is the issue of aids that plagues this country – whose incidence is increasing and which has a direct effect on life expectancy rate . This severely hampers the growth and development that is attainable by the State. Education has been deemed to be the best tool available to combat this plague. However per capita income is still closely correlated to these other factors, even though

[88] Ibid, at 18.
[89] Ibid at 198.
[90] Ibid at 25.
[91] Ibid at 200.
[92] Ibid at 201.
[93] Ibid.

'…per capita income, or even the equality of its distribution, does not serve a unilateral guarantee of success in 'human development'…(however) per capita GDP still acts as a fairly good proxy for most aspects of development…'[94]

'Recent literature in economics has emphasized the fact that investment in education and training that raises the skills embodied in labour is no less an investment. Skills may not be tangible objects like machinery, but they contribute to increased production just as any piece of machinery does. The act of training and education may be aptly termed investment in human capital.'[95] This then forms the rationale upon which most conditions regarding mergers, as they affect employment, are premised.

In terms of the ability that a South African firms have to become internationally competitive, one needs to have regard to what the comparative advantage is of this developing country. 'It is clear that, on the whole, developing countries do rely on primary product exports, whereas the opposite is true for the developed countries.' [96] This however is dangerous as such goods are traded in a highly fluctuating market and so there is not a method to foresee changes in levels of demand. This would lead to wasting of economic products[97].

There needs to be some sort of regulation of the emerging markets. This is abundantly clear. However what is also as clear is that public interest concerns needs to be incorporated into such regulation. Should the market be left alone to self regulate, the chance exists that the previously disadvantaged will remain as such and that the rich will continue to benefit from the position they once enjoyed as a result of their previously advantageous economic situatedness[98]. Each country has specific and unique national interests that are peculiar to them. Accordingly, the national interest as codified in legislation will reflect steps taken in meeting these objectives. "Major challenges to sustainable development in South Africa are employment and black economic empowerment. Explicit reference to these factors is thus to

[94] Debraj Ray *op. cit.* note 60, at 29.
[95] Ibid, at 53.
[96] Ibid, at 39.
[97] Some goods can be stored and their sale effectively postponed till such time where demand for them once again exists. However some goods are of the inherent nature that they need to be sold soon after their production. These goods will therefore pose a problem of wasting, an example of which is in the agricultural industry where products may be perishable. If the agricultural industry is a core export industry in this hypothetical state, then demand for the goods (or lack thereof) severely affects the ability for that state to attain any measure of economic growth.
[98] In South Africa such a position was, as a result of Apartheid protection, enjoyed by the white minority.

be expected in a significant area of policy and law such as competition and in some sense provides a balance of considerations in the challenge to develop a set of complimentary policies and laws to facilitate enterprise development and the achievement of broader socio-economic objectives."[99] Their achievement is aimed to be fulfilled by the public interest criteria in the Act.

CHAPTER FOUR– Mergers & the Public Interest

OVERVIEW

In terms of both anti-competitive conduct[100] and mergers[101], the two key factors that are considered before any investigation is initiated are: what is the defined market[102]; and then whether the firm has market power[103] in said market. This is classically the point of departure in any merger evaluation. However it is to be noted that this applies to the efficiency tests – the 'competition' analysis- and that in the consideration of public interest tests, the scope of same is much broader[104]. Public interest is a machine of political and economic origin, which is engaged in the niche of law that has access to powers of regulation over market activity – to some degree or another.

Mergers, sometimes referred to in terms of the genus of business activity termed concentrations, occur in one of two ways. Either two or more companies join all assets and liabilities between them respectively[105] to form a new entity, or where one company (the target company) is incorporated into another company (the acquiring company). 'Whilst a firm may build market power through unilateral conduct, the easiest way for a firm to establish or to enhance market power is by acquiring or merging with other firms.'[106] Market power and efficiencies are therefore the main incentives that drive firms to consider merging.

[99]Hartzenberg, *op. cit.* note 22, at 17.
[100]That involves section 7 abuse of dominance matters.
[101]Regarding section 12 and 12A matters.
[102]If the market is defined too widely then the effect of the merger on said market will be diminished, whilst if the market is defined too narrowly then the effect will be unrealistically magnified.
[103]Should the firm not have market power then their actions are negligible as market forces of price elasticity of demand and substitutability will be engaged to auto-correct the consequences of this conduct.
[104]However there are instances where 'competition' considerations and public interest ones overlap. Lawrence Reyburn: Philip Sutherland and Katharine Kemp *Competition Law of South Africa,* (LexisNexus Butterworths Durban) Service Issue 14 (October 2011) at 10-5.
[105]Wholly or partially.
[106]Brassey, *op. cit* note 27, at 224.

The importance of mergers is to be analysed in terms of the consequences they bring[107]. 'There must be a causal link between the merger and the anti-competitive effects on a market.'[108]In the end, the anti-competitive effects of a merger are evidenced in terms of efficiency considerations, and again – public interest is a broader consideration than the efficiency segment of the evaluation. Regardless, the same rationale holds true for the consideration of the public interest probes in a merger evaluation – namely, the effects that substantially affect the public interest need to have a connection to the transaction being evaluated. The courts have repeatedly in their '...previous decisions indicated that (they) do not exercise (their) public interest determinations in a void.'[109]

There exist three classes of mergers, namely horizontal[110]; vertical[111]; and conglomerate, '...which in that order, attract decreasing levels of concern.'[112] Furthermore these classes are subdivided into large, medium and small mergers – which in South Africa are classed as such in terms of parameters established by the Minister of Trade and Industry. Horizontal mergers are said to be the form of mergers that attract most attention and therefore scrutiny.

The subdivisions of the classes of merger being large, medium or small exist for a reason. Upon surpassing the stated thresholds[113], the merging parties will need to follow the

[107]'Merger law focuses less on anti-competitive conduct and more on the structure of the market....(with) the aim to prevent anti-competitive results' Sutherland & Kemp *op. cit.* note 104, at 8-7.
[108]Sutherland & Kemp *op. cit.* note 104, at 10-8. With reference to *Santam Ltd/Guardian National Insurance Co Ltd* 14/LM/Feb00, and a few other cited cases listed in footnote 57.
[109]*Distillers (South Africa) Ltd v Bulmer (SA) (Pty) Ltd* 2002 (2) SA 346 (CAC), para 232: With reference to *Unilever Plc and other/Robertson's Foods (Pty) Ltd and others* 55/LM/Sep01 para 43; and *Shell/Tepco* Supra note 21, para 58.
[110]Involve firms '...selling identical or similar products in the same geographic area thereby eliminating competition between the two firms... *(and)* result in the elimination of competition between competing firms.... Brassey, *op. cit* note 27, at 225. (*Word inserted*) Horizontal mergers, due to the fact that they occur within the same market segment, they have the potential to deliver efficiencies and innovation in that market that would tremendously benefit the consumer. With this benefit, the roll on effect is that the other competitors in the market will have to evolve technologically and therefore innovate their products/services in their attempts to remain competitive. This further benefits the consumer as the result, ideally, would be that the products on the market increase in range and quality to suit whatever need the consumer may harbour at that time.
[111]Their most common justification that the firm (integrating forward or backwards) is doing so primarily to fulfil '...its desire to minimise transaction costs and cure principal-agent problems.' Dr. Roger Van der Burgh & Dr. Peter D. Camesasca, *European Competition Law and* Economics: Chapter 9- Eileen Reed *Concentrations and Merger Control,* at 350.
[112]Brassey, *op. cit* note 27, at 225. Vertical mergers are said to be ones that occur in the same supply chain and are usually undertaken for efficiency rationales so that the acquiring firm can streamline its business activities and reduce costs. Conglomerate mergers are described to be mergers of firms that operate in different markets that seemingly have no connection to the competition that exists in either of the markets.
[113]As discussed in s11 of the Act.

procedural steps of the Act and notify the Commission of their intention to merge[114]. This notification[115] procedure has been created so as to firstly aid the Competition Authorities to remain involved and informed of activities of firms within markets they are tasked to safeguard (as it is impossible to constantly monitor every firms activities within the national territory) and further to aid the Competition Authorities to qualitatively focus their attention on transactions with the greatest impact. Seeing as the Commission is a government agency it has limited resources and therefore cannot afford to investigate every single matter. These thresholds apply to both efficiency tests as well as to public interest ones, as they are designed to indicate the degree to which importance is to be attributed to them in terms of their ability to noticeably affect the markets function and its structure.

Mergers have as their economic consequence a 'structural change'[116] within the defined market as there is a decrease in competition within that market segment due to one of the firm's from that market essentially disappearing. 'A concentration implies that firms integrate their operations more completely and permanently than was the case under *a* contractual setting....'[117]This fact highlights the gravity of this form of transaction. A merger cannot be undone at a later stage via judicial interference, as is the case with a cartel for example. On an examination of the economic effects that would occur should a firm exit the market for any other reason besides merging with another competitor, it will be evidenced that market forces will engage themselves and the market will find a new equilibrium following the loss of one of its producers. The loss of a producer in a market, besides the competition concerns[118], will have effects that will be felt on the different links of the supply chain involved in that market as well as on interrelated industries, society, and the nation's productivity as depicted internationally.

[114]As discussed in s13 – with regard to small mergers; and s13A - with regard to intermediate and large mergers; of the Act.
[115]As per the parameters set out in Section 13 of the Act, read together with GN 254 and GG22025 of 2 February 2001.
[116]E. Reed *op. cit.* note 102, at 349
[117]Ibid. The comparison of the effects of a merger are further extended to one between mergers and cartels. The inherent difference between cartels and mergers is that due to the core characteristic nature of cartels, they are self destructive as they are based on the trust of parties that are by virtue of this association, dishonest.
[118]The market share that was held by that firm will be distributed, albeit potentially unequally, amongst the remainder of the competitors within that market on the basis of the other firms by virtue of existing in the same market producing substitute goods. However, when a firm merges (specifically horizontally), *all* of its market share (and market power) is absorbed into the new merged entity, which then has the consequential effect that the merged entity increases its market share and power singularly, to the exclusion of all the other firms within the same supply chain link.

Note however that '...merger law "Is not, or not only, about pre-emptively preventing a merged entity from abusing its dominant position in the future; it is also about maintaining a market structure that is capable of delivering the benefits that follow from competition."'[119]However the effects of the merger in terms of public interest are more far reaching than merely loss of a player in that industry. s12A(1)(a)(ii) states the importance of public interest considerations- namely, that after the efficiency enquiry has been completed there needs to be further enquiry into the effects born from the merger that will follow.

Should the efficiency test fail it is stated that a merger can still be allowed if it is able to be '…justified on substantial public interest grounds.'[120] It was held[121] that there is a possibility that the public interest grounds can within themselves also produce opposing views, and as a result the '…net public interest effect of a merger must be determined….A procedure for dealing with such situations has been developed (*where either*): Every public interest ground asserted must be viewed in isolation to determine whether it is substantial; (*or*) If more than one contradictory public interest ground is found to be substantial, then the competition authority must attempt to reconcile them; (*or*) If no reconciliation is possible, then the conflicting aspects must be balanced and a net conclusion must be reached.'[122] It is against this backdrop of positive gains that a merger can bring (or of course the corollary negative harms) that public interest tests need to be employed in a comparative manner.

The analysis of these transactions has as a unique characteristic the fact that it is carried out before the transaction or the effects thereof actually occur[123]. 'Based on the information and the data available prior to a concentration, competition authorities need to project its impact on a given market structure, which will only become fully established after the transaction has been implemented.'[124] The events that will occur as a factual cause to the merger therefore need to be considered and ascertained using reasonable foresight based on economic and empirical evidence[125]. 'Antitrust authorities must predict the future by looking

[119]*Distillers/Bulmer* Supra note 109, at 358, referred to Sutherland & Kemp *op. cit.* note 104, at 8-8.
[120]S12A(1)(a)(ii) and s12A(1)(b) of the Act.
[121]*Harmony Gold Mining Co/Gold Fields Ltd* 93/LM/Nov04, and *Distillers Corporation (SA) Ltd/Stellenbosch Farmers Winery Group Ltd* 08/LM/Feb02 at par 214-217.
[122]Sutherland & Kemp *op. cit.* note 104, at 10-93 and 10-94 respectively, as confirmed in Supra note 121, Para 219.
[123]*Medicross/Prime Cure Holdings* Supra note 17, at 62ff.
[124]E. Reed *op. cit.* note 102, at **349**
[125]Some jurisdictions utilise economic formulae to ascertain the effects that mergers would have on the competition within that market. One of these formulae is the Herfindahl–Hirschman Index**.**

at the past and current situations in a market. Research and economic tools are useful for making these predictions, but they never create absolute certainty and adequate data sometimes will not be available.'[126] The evaluation of this form of common business activity, I view to be a regulation of the market by Organs of State. Whether I feel it to be a necessary regulation, will be illuminated to the reader below after consideration of the reasons for aforementioned regulation.

Mergers form an integral part of everyday economic activity. As a result of this they cannot be classed and dealt with as a per se prohibition that are listed in section 4(1)(b) of the Act. This is regardless of the fact that the effects of the merger may well be such for which this per se prohibition was designed to protect against. It was for this reason that mergers are no longer regarded as a per se prohibition in the antitrust legislation of the United States of America, whereas in the past this species of transaction was in fact forbidden[127]. Mergers are transactions that can, broadly, either have as a sine-qua-non of their conclusion: a beneficial result due to the efficiencies they produce; or a detrimental result due to the harm they cause. It is for the existence of these efficiencies that a merger cannot be a per se prohibition as benefits to society would be foregone should mergers be disallowed outright. In the old antitrust legislation of the United States of America, the prohibition of this form of transaction was too heavy a regulation of the market's activities. This was an example of regulation devised to protect the goals of the antitrust legislation however in application the reality was that it worked against the attainment of these goals. Whenever there are decisions being made by people who are not aware of the intentions, but moreover the effects of certain conduct, the consequence can rarely be desirable.

Section 12A(3) of the Act lists the public interest criteria that are to be regarded in times of the evaluations and the disputes regarding such transactions. It reads as follows:

[126]Sutherland & Kemp *op. cit.* note 104, at 10-6. This shows that the forward looking analysis of the consequences of a merger is not an exact science, and therefore this form of regulation is in essence an educated guess on what the result of the merger will be. With such guesses, there is an inherent flaw that the predictions are incorrect and therefore the decision to allow or prohibit the merger could then also be the incorrect decision. This is not a consequence that can be reversed and therefore the decision on the matter is considered cautiously. As was stated in *Medicross/Prime Cure Holdings* Supra note 17, '…the competition authority must still justify its findings on the facts before it.'

[127]http://en.wikipedia.org/wiki/Sherman_Antitrust_Act.

'When determining whether a merger can or cannot be justified on public interest grounds, the Competition Commission or the Competition tribunal must consider the effect that the merger will have on-

(a) A particular industrial sector or region;
(b) Employment;
(c) The ability of small businesses, or firms controlled or owned by historically disadvantaged persons, to become competitive; and
(d) The ability of national industries to compete in international markets.'

Each of these factors will be analysed in depth below, referring to economic rationale behind the inclusion of these specific public interest criteria, and to case law in order to see how the Judiciary has had regard to the application of these criteria.

There is a need to disclose all information by the merging parties to the competition authorities so that a specific determination can be made. Further the competition authorities sometimes require additional assistance and there are provisions or the Minister to intervene in merger matters and make representations to the court. Generally speaking should the competition authorities have minimal information asymmetry regarding the relevant aspects of the merger, they would therefore be in a position to rule more fairly and speculate less[128]. Reluctance to be forthcoming with all relevant information is however the norm, as by withholding certain information from the courts could have the possibility to secure future untold profits. The safeguard to this however lies in criminal regarding matters of perjury and fraud, with delictual matters relying on the doctrine of estoppel should for example an affected party suffer harm due to some or other aspect of the transaction. The point is that this is a dynamic field of law with effects of such transactions being far reaching and touch on a multitude of issues which have forums to address any issues that arise. With full disclosure, the amount of conditions placed on the entity, which are deemed to be a form of regulation of the markets, would be more accurately representative of the needs of society that the judgement of the Judiciary will affect, and therefore aid government to attain a degree of regulation that is not too little, not too much, but is just right.

[128] *Mondi Ltd and Kohler Cores and Tubes/Competition Tribunal* [2003] 1 CPLR 25 (CAC) 33.

(a) A Particular Industrial Sector or Region:

First and foremost, there needs to be an examination of the wording of the subsection. 'The term "industrial sector" should be interpreted widely to include any sector of economic activity.'[129] This therefore highlights the recognition that a concentration transaction has far reaching effects[130] that are not isolated to the specific market[131] in which the merging firms operate.

To understand the effects that a merger will have on a sector of the market there obviously needs to be an investigation done on the structure of that market niche and the environment in which it exists. The market determination methods used to indicate market power of a firm that are used in South Africa include analysis' that use Concentration Ratios and the Herfindahl-Hirshmann Index, that are based on the structure of the market in relation to the number of competitors that function within that market[132]. However, the public interest factor in s12A(3)(a) refers to having a broader regard to the effects of the merger on an industry and/or region, and does not specifically deal with the market within which the firms exist because the efficiency test covers this determination sufficiently.

In *Iscor Ltd/Saldanha Steel (Pty) Ltd*[133], it was held that should the merger be prohibited the resultant adverse public interest effects would be egregious[134]. Saldanha Steel was a firm that was notoriously in financial difficulty as a result of global market fluctuations and conditions which were further compounded by domestic trade policy alterations[135]. The fact that the firm provided the fiscal injection required to stimulate economic growth and development in the region placed the Tribunals consideration of the merger in a precarious position[136]. 'There is evidence that the Saldanha Steel plant is a vital part of the town's economic life. If the plant was to be shut down…for a period this would not only have a substantial impact on the employees of the plant who would be retrenched, but also on all the

[129]Sutherland & Kemp *op. cit.* note 104, at 10-95.
[130]Specifically where the transaction is incidental to other industrial sectors and region's.
[131]Which is understood to be at any point in the supply chain of the same industry.
[132]Sutherland & Kemp *op. cit.* note 104, at 10-17.
[133]67/LM/Dec01 at par 143-147.
[134]As was the case in *Tiger Brands Ltd/Langberg Foods International Ashton Canning Co (Pty) Ltd,* 46/LM/May05 at Para 142, where it was evidenced that '…Ashton is heavily dependent on the canning firms since it is an economically troubled area that offers little hope for unskilled labour.' The unskilled labour came mainly from seasonal workers that were employed by the thousands in the area for this industry. The merger would affect employment which would therefore affect the surrounding region.
[135]Ibid, Para's 17-35.
[136]Ibid, Para 144.

firms and individuals in the West coast region whose livelihoods are so dependent on the plants functioning.'[137] This then indicates that this public interest criteria has regard for firms that exist not within the same supply chain. Saldanha Bay is situated within a the deepest and sheltered South African bay in the Western Cape[138] and is therefore perfect for a port to be operational there safe from the dangers of open waters. The local economy is strongly dependant on the steel industry and the harbour[139], and the development of the region into the modern harbour that it is today was as a result of the steel industry and the necessity to export steel from Sishen in the Northern Cape[140]. One of the biggest industries in South Africa is the production of steel from iron ore, which is connected directly to Saldanha by the Sishen-Saldanha Railway Line[141]. As a result, Iscor built a railway line to Saldanha where it set up a production plant to refine the ore into a final product that could be sold domestically or exported and as a result of the geographic situation of the plant[142], transportation costs are reduced and more jobs were created. This therefore stimulated the economy in the region from the production plant, the port, the transportation industry, and the shipping industry and all the intermediaries that it entails, to name but a few. Should this merger not have been approved the local economy may well have collapsed and the area may well have been reduced to idle capital. This would not only have impacts on the local economy but further on the steel industry as transportation costs would have increased to deliver the goods to other areas for exportation. This increase in production costs would have a negative impact on the ability of this vital South African industry to remain internationally competitive.

In *Harmony Gold Mining Co Ltd/Gold Fields Ltd*[143], the merger was to take place in a sector of industry upon which the South African economy relies heavily, that is to say the gold mining sector. It was alleged by an economic expert witness[144] that the merged entity would fail as a result of the poor management that the acquiring firm has suffered and that the risk posed to the economy was therefore 'systematic' and great. However this was held to be an extreme and improbable result that was consequently disagreed with. The opinion of the Tribunal was that should the merger occur then the 'stronger' target company could actually have a beneficial effect on the 'weaker' acquiring company and this would therefore help

[137] Ibid, Para 145.
[138] http://ports.co.za/saldanha-bay.php
[139] http://en.wikipedia.org/wiki/Saldanha_Bay
[140] http://ports.co.za/saldanha-bay.php
[141] http://en.wikipedia.org/wiki/Sishen-Saldanha_Railway_Line
[142] Which is the areas comparative advantage.
[143] 08/LM/Feb02
[144] Ibid, at para 63, whose 'expertise' was in Para 74-75 rejected by the Tribunal.

attain a positive public interest result[145]. This was therefore in effect an argument in favour of the merger as opposed to against it. In addition, should the merged entity fail as alleged probable by this expert, it was stated by the Tribunal that the assets would be sold off in liquidation proceedings as is the case in normal business activity, and bought up at a discounted rate which would then in all probability be used in the same industry and the economy in this market segment would continue to function[146]. It was held that there are market forces, in the form of stakeholders and interested parties of an entity, which would engage themselves to not idly stand by whilst the firm is 'driven into the ground'[147]. This therefore shows that the public interest tests cannot be used, as the target firm desired, to circumvent the natural and positive application of market forces in an attempt to attain a preferred judicial and binding decision. Public interest is by definition a regulation of the market for the overarching non-efficiency goals that are stated to possess the force of law. However this is not an instance of a command economy where organs of state dictate in which manner a market will function based on its own, unjustifiable, opinion.

In *Tongaat-Hulett Group Ltd/Transvaal Suiker Bpk*[148], there was a proposed merger in the sugar production industry. This industry is said to be extremely volatile as it is a residual market that is heavily regulated due to the fact that world prices are customarily below the average production cost of the sugar, as incurred in the producing countries[149]. It was held in terms of the public interest analysis that the merger would not have a substantial pro-competitive or pro-public interest impact on the industry. The firm[150] that was wanting to merge into the acquiring firm[151] averred that its exit from the market would provide for the creation of smaller firms because THS states that it intends to sell 8000Hectres of land. This intended sale of the land is stated as being directed specifically to previously disadvantage individuals, and so would aid in the economic development of the regions concerned and their respective local communities as well[152]. 'However these benefits are not sufficiently substantial to countervail the negative impact of the merger on competition, nor is it at all clear that they will not occur in the absence of the merger… the merger will have no impact, one way or another, on the ability of South African firms to play a positive role in the

[145]Ibid, at para 71.
[146]Ibid, at para 64.
[147]Ibid, at para 73.
[148]83/LM/Jul00 par 39-41.
[149]*Tongaat-Hulett/Transvaal Suiker* Supra note 148, para 18.
[150]The firm cited TSB
[151]the firm cited THS
[152]Mpumalanga.

region.'[153]

In *Nasionle Pers Ltd/Education Investment Corporation Ltd*[154], the proposed merger was to occur in the education industry that is held to be a core industry that is profoundly important and linked to the development of the nation. The Tribunal held '…we are bound to accord the education sector a stature reserved for few others….there is no question that the impact of monopolistic practices in the private education sector will reverberate more powerfully on the economy and society than would similar practices in most other sectors.'[155]Conditions were imposed onto the merging parties to protect this industry. Of the conditions that relate to this subsection is that a divestment of an identifiable segment of the merged entity occur, so as to stabilize the existence of competition within this important market and prevent possible abuses[156]. Furthermore the new company will be required for a period of two years to aid the Department of Education in discovering and aiding in the implementation of schemes to improve capacity in public education[157].

In the large merger in *Wal-Mart Stores Inc/Massmart Holdings Limited*[158], one of the conditions that were imposed was 'the merged entity must establish a program aimed exclusively at the development of local South African suppliers, including SMEs, funded in a fixed amount of R100 million to be contributed by the merged entity and expended within three (3) years from the effective date of this order. This program will be administered by the merged entity, advised by a committee established by it and on which representatives of trade unions, business including SMMEs, and the government will be invited to serve. The merged entity must report back to the Competition Commission annually, within one month of the anniversary of the effective date, about its progress. In addition the merged entity must establish a training programme to train local South African suppliers on how to do business with the merged entity and with Wal-Mart.'[159]

This condition is an indication of how the Tribunal considered the possible effects that the merger would have on the industrial sector and region. It is an attempt to blunt the trauma that would be felt from the merger, having regard in its assessment of the known past

[153] *Tongaat-Hulett/Transvaal* Supra note 148, para 114.
[154] 45/LM/May03
[155] Ibid, Para 47.
[156] Ibid, at Para 52.
[157] Ibid, at Para 55.
[158] 73/LM/Nov10
[159] 73/LM/Nov10 Order of Court, at Para 3.

practices of Wal-Mart, namely that it is a corporate giant with international sourcing connections that are second to none. The ability that Wal-Mart has to procure products from abroad was a cause for concern that was raised at both the Tribunal and the Appeal hearings. It is an illustration of the fact that efficiencies brought through a merger as a result of procurement of goods of a certain quality and at a lower price are attractive as it boosts consumer welfare in terms of choice available and at a price cheaper than normal. However it is further an illustration that there are problems with such efficiencies that are in conflict with other needs of a state, namely the protection of the local economy and the local industry. To blunt the effects that this merger would have on local suppliers, the condition incorporates a fiscal investment in the region which is to be used in a manner that improves the industry and allows capital for a degree of innovation so as to remain competitive. Furthermore there is a sub-condition that suppliers are to be afforded training from Wal-Mart so as to be capable of trading with the entity. Consumers are to benefit from such transactions in their capacity as such, therefore increasing their utility per unit of consumption and further with a wider range of choices so as to maximize said utility in the consumption being in line with their individual preferences. However, looking at the bigger picture for a moment, local producers would suffer as their product would essentially be exposed to international competition, where perhaps other States have better comparative advantage in producing those items. There are however other safeguards in place that exist to protect the possibility that goods are imported at unfair prices[160].

(b) Employment:

The basis for the inclusion of this is the same for the rationale used to include this public interest goal in section 2(e) of the Act. Namely, to ameliorate wealth and income distribution throughout the nation.

Unemployment rates are of serious concern to government as they have a direct link to the productive efficiency of a nation, as labour is one of the nation's most key resources[161]. Unemployment has numerous consequences, of which a strong link has been established

[160]GATT 1994, Article VI – The anti-dumping provisions which need to have their criteria proved before their enforcement.
[161]McConnell and Brue *op. cit.* note 5, at 26.

empirically to connect this status to an increase in the levels of crime and vagrancy[162]. Crime and vagrancy affect the economy negatively and is a massive problem in South Africa. Economic growth and development is severely stunted by these activities and is therefore prevented from growing at a positively steady pace. As a result, employment levels are of concern to government and should therefore be incubated from forces that could possibly affect its levels negatively. Currently the reported unemployment levels in South Africa is quoted at 25%[163], while some of the poorer regions of the country report higher levels of unemployment[164]. 'With unemployment or productive inefficiency, the economy would produce less…'[165].

South Africa has a very large unskilled labour force. Employment allows for a forum in which skills are able to be learned and for these skills to be applied. Employment offers the channel through which households are able to have the tools to improve their standard of living and through which further educational opportunities could be availed to the next generation so that their subsequent lives will be improved. This is of course in the scenario where income is utilised in this manner. Labour is an important factor of production, and the skills held by the labour force are an indication as to what the potential ceiling of economic growth is at any given moment. With more skilled labour, productive efficiency rises. However 'With unemployment or productive inefficiency, the economy would produce less…'[166]. Therefore levels of employment are to be fiercely protected and unemployment levels are to be combated and constrained from growing. However in terms of this public interest criteria, 'In many cases, the problem of job losses can be addressed by imposing conditions.'[167]

[162] http://www.ncjrs.gov/App/Publications/abstract.aspx?ID=108423, Steven D Levitt, *Alternative Strategies for Identifying the Link Between Unemployment and Crime*, Journal of Quantitative Criminology, Vol. 17, No. 4, December 2001, (2001) Plenum Publishing Corporation, at 377.

[163] http://www.statssa.gov.za/keyindicators/keyindicators.asp as per the third quarter of 2011, and previously it has been hovering around this level for a few years. This level of unemployment has been compared similarly to the levels of unemployment that existed in the United States of America during the time of the Great Depression.

[164] http://www.fin24.com/Economy/SA-unemployment-rate-among-worlds-highest-20110504, quoting Mpumalanga as having levels of 42.5%.

[165] McConnell and Brue *op. cit.* note 5, at 29. Refer to production possibilities curve at same, for a graphical illustration of this.

[166] McConnell and Brue *op. cit.* note 5, at 29. Refer to production possibilities curve at same, for a graphical illustration of this.

[167] Sutherland & Kemp *op. cit.* note 104, at 10-97 with reference to *Cherry Creek Trading 14 (Pty) Ltd/Northwest Star (Pty) Ltd* 52/LM/Jul04, Para 17-22; and *Multichoice Subscriber Management (Pty Ltd/Tiscali* 72/LM/Sep04 at par 82.

The public interest in merger evaluation regarding employees, is centred mainly on procedural rights '…allowing employees to receive timeous information about mergers that often affect them deeply.'[168] However there is another benefit to this public interest application in that it affords competition authorities to '…protect levels of employment through conditions…(as there is) a powerful link between direct employment loss and a restructuring initiative like a merger…'[169]. Only employment that is proved to be affected by the merger transaction will be considered in terms of this subsection, be it job losses or jobs saved[170].

In *Tongaat-Hulett Group Ltd/Transvaal Suiker Bpk*[171], it was averred by the merging parties that the merger would result in the creation of 3000 additional jobs as a direct result of the sale of portions of arable farm land that was at the time being used by TSB for the cultivation of sugar cane[172]. However as stated above[173], it is unsure that this would not have occurred regardless of the transactions existence. Should the merger not have taken place then the additional result would be that the target firm would fail, as per the parties allegations, and there would arise an opportunity for its assets and operations to be procured by other interested parties. This could be either other firms, or new firms. Particularly in the areas where the target firms properties are situated, either another firm would purchase it and therefore employment opportunities would be created, or previously disadvantaged persons could enter the market through buying the property in addition to securing employment[174].

In *Harmony Gold Mining Co Ltd/Gold Fields Ltd*[175], there was a concern regarding the loss of jobs as a result of the merger with particular attention paid to the different consequences that arise from retrenchments to the class of the skilled labour force and the unskilled labour force. The Tribunal, upon a recommendation of the Commission that was

[168]Sutherland & Kemp *op. cit.* note 104, at 10-96.
[169]Ibid, with the latter quote originating in *Daun et Cie AG/Kolosus Holdings Ltd* 10/LM/Mar03 at par 126.
[170]Sutherland & Kemp *op. cit.* note 104, at 10-97. *Schumann Sasol (South Africa) (Pty) Ltd/ Price's Daelite (Pty) Ltd* 23/LM/May01 at Par 76 where it was stated that it is unknown that PD will fail and should it do so the employees positions may be protected as a result of new entrants buying out portions of the failed company and restoring a percentage of these jobs. Further it was held that should the merger be allowed that it would relocate PD to Sasolburg and this would result in the retrenchment of the current employees.
[171]83/LM/Jul00 par 39-41.
[172]*Tongaat-Hulett /Transvaal Suiker* Supra note 148, Para 113.
[173]Ibid, Para 114.
[174]In terms of s5(f) of the BEE Act, previously disadvantaged people are able to apply to have government aid them in their economic endeavours. This therefore limits the amount of risk that they will be exposed to and further, through their business plan being assessed, their prospects of success is increased.
[175]08/LM/Feb02

further revised, imposed a condition that the retrenchments would be limited to a certain amount. Furthermore, interestingly, the retrenchments were to be effected solely in managerial and supervisory categories. This is interesting as it is this group of employees that will be able to procure other employment positions with a greater ease than unskilled labour[176]. This order therefore had the effect of satisfying the need of the merged entity to reduce production costs by removing employee's that generally earn higher salaries[177] than unskilled labour and further forced the entity to streamline its operations as its business practice already is known to do[178]. The Tribunal stated that it is not interested in the decisions the acquiring firm makes in terms of running its business activities, but merely stated that should the firm make decisions to retrench, that it would be limited to the conditions imposed on the merger. Simultaneously, the needs of unskilled labour that would find it more difficult to secure other employment will be kept in their positions[179]. A further consideration is that the firm with a void in its managerial echelon would now have to increase the skill level of some of its lower echelon employees in order to fill this gap as it is unlikely that the firm would fire people already employed in these positions and thereafter hire others to fill them[180]. It is uncertain whether this occurred however the mere possibility of it indicates a further beneficial outcome to the transaction. In addition the affect that a merger has on employment is limited to exactly that, namely as a factual cause of the merger. The Tribunal is not concerned with job losses that occur in an industry that is following the general trend that exists, which is to say that this public interest criterion is not applicable to usual business trends in an industrial sector but is limited to considerations of effects related to a merger transaction[181].

The discussion regarding skilled and unskilled labour is a common one. In *Tiger Brands Ltd/Langsberg Foods*[182], where the Commission '…sought to impose a condition on the merger in respect of employment loss, the gist of which is that the merging parties should set

[176]Ibid, at par 83 and 91, due to their 'marketable skills'.
[177]Ibid, at Para 77.
[178]Ibid, at Para 81.
[179]Ibid, at par 89, which states the dangers of retrenching unskilled labor forces as this could very well result in long-term unemployment.
[180]In addition this would be contrary to the Labor Legislation in South Africa.
[181]*Harmony Gold Mining/Gold Fields* Supra note 121, Para 87.
[182]Supra note 134.

up a training fund that would not only benefit the retrenched workers but any other member of the Ashton Community.'[183]

In *Telkom SA Ltd/TPI Investments (Pty) Ltd*[184], a condition for the proposed merger was that employees would not be retrenched for a stated period[185]. Due to the nature of the telecommunications industry as discussed in the case, technological innovation is frequent and therefore there is the possibility that some employees will become redundant. Due to the fact that the effects of the merger sometimes materialises well after the conclusion of the contract, this condition provides a degree of job security to the employees of the merged entity whilst simultaneously possibly not being too great of an imposition on the merged entity itself. Further a condition was imposed stating that the obligation to not retrench any employees for the stated period discussed above, could be enforced individually by the employees themselves, which therefore gave employees the right to enforce this obligation[186]. Furthermore, a condition was imposed stating that as a result of the merger the new entity that was formed to merge with Telkom had no assets and therefore there was a concern that should the enterprise fail the employees would be left without any recourse to claim what may be due to them at such time. As a result the condition imposed to protect the interests of the employees further, was that the employment obligation was extended to bind the shareholder of the firm[187]. The time constraint that was imposed onto the merger also has the direct benefit to the employee that they will within that stated time be in a position to exploit the opportunity to receive more marketable skills from the merged entity.

In *Liberty Group Ltd/Capital Alliance Holdings Ltd*[188], there was a concern that the parties had not informed the employees of the possible worst case scenario in respect of retrenchments that could be a result of the merger. The Tribunal ordered the parties to consult

[183]Ibid, Para 132. This is an indication that in the event of retrenchments, particularly of unskilled workers, in an attempt to ameliorate the common result suffered by unskilled laborers risk of long term unemployment, an investment is often requested to increase their skills and therefore aid them in making themselves more marketable as was discussed in *Distillers* Supra note 121.
[184]81/LM/Aug00.
[185]Ibid, Para 40, and further at Para 42 referring to employees that are directly connected to the transaction as there was a worry that should Telkom outsource some of its functions that retrenchments would occur within the firm as was historically evidenced to have occurred.
[186]Ibid, Para 41. This gave the employees the right to enforce the obligation where generally a court in the absence of this obligation being a condition of the transaction, may not interfere with this matter as it would be an unwarranted interference y the courts of the administration of the business activities of a firm. This gave further protection to the employees than the avenues that are always available to them in terms of labour legislation that applies to their relationship to their employers.
[187]Ibid, Para 43.
[188]04/LM/Jan05

with the employees in order to afford them the right to raise any concerns they harboured regarding the merger. This is an indication that the competition authorities enforced the right to representation of employees that were clearly affected parties to the transaction and provided them a forum in which to raise their concerns in order for these matters to be considered before a decision was made on the outcome of the proposed merger.

The failing firm rationale was invoked in *Tiger Brands Ltd/Langberg Foods*[189]*,* in an attempt to illustrate that '…Ashton will, sans merger, fail and that Langberg Food International would scale back its purchases.'[190] It was proposed by the parties that should the merger not occur then the effect on employment would be severe, as compared to the job cuts that would occur should the merger be approved. However in order to use the failing firm rationale for the merger, the firms need '…to show that there is no more preferable buyer for the merging firm, (and) under the public interest they need to show that no one else would be willing to buy Ashton if it failed.'[191] This could not be demonstrated by the parties' evidence[192]. In addition, both the aggressive negotiating tactics of Ashton during merger discussions and its consideration to buy LFI should the merger not be allowed indicated that the firm was not in a position of financial distress as represented. In fact it was found that as a result of failing to convince the Tribunal of the failing firm, it was then uncertain that any jobs would be lost should the merger not occur, but conversely jobs would be lost should it be approved[193]. In order to offset the harm to public interest, the Tribunal approved the merger subject to the condition that a sum of R2 Million would be invested to be used by the unskilled employees who lost their jobs as a result of the merger[194]. This figure as disputed by the merging parties as being too high and that it would prevent the emergence of the efficiencies that are expected to be a result of the merger. The Tribunal held that this was

[189]Supra note 124.
[190]Ibid, Para 135.
[191]Ibid.
[192]ibid, Para 136.
[193] Ibid, Para 137-143. Specifically Para 143 states that the merger will result in unskilled laborers losing their employment and therefore due to their lack of skill will find it difficult to secure alternative employment, the merger was held to '…have a substantially negative effect on employment and hence the public interest.' As opposed to the scenario that occurred in *Food and Allied Workers Union/The Competition Commission, McCain Foods and Heinz Frozen Foods* 17/AM/Mar01 at Para 30, where it was held that '…the employment consequences of prohibiting the transaction are likely to be more severe than the consequences of approving the transaction'
[194]*Tiger Brands/Langberg Foods* Supra note 124, Para 150-151, where a further subsection of the condition was that the monies would be available only to unskilled laborers who ideally would use their portions of this lump sum to receive training in some or other industry and therefore increase their opportunities to secure alternative employment. These funds are available solely to former unskilled employees whose retrenchment is 'merger specific', to the exclusion of management employees as they have a more marketable set of skills.

incorrect as the potential elucidated by the parties of the merged firm would be able to handle the monetary investment that is the condition for approval. In *Distiller's*[195]the merged company offered a reasonable package that was well beyond what the legislation regarding the matter dictates, as well as surpassed the previous practices of both of the merging firms[196]. This offer was further accepted practically unanimously. This situation is contrasted with that in *Trident Steel (Pty) Ltd/Dorbyl Ltd*[197], where it was stated that should the target firm not be allowed to merge with the acquiring firm that it would have to scale back some of its operations which would then result in many more jobs lost as compared to the small amount of managerial jobs that would be lost as a result of the merger being approved.

In *Unilever/The Competition Commission of South Africa*[198], it was stated that the number of potential job losses that were foreseeable as a result of the merger were not to be construed as substantial as there is the possibility that conditions could be imposed to offset the effects of these job losses[199]. Furthermore the tribunal held that the information regarding job losses was not to be understood as per the allegations of the merging parties that it is information of the privileged kind, which therefore means that employees not party to unions had no right to access such information[200]. The right to this information is more procedural than anything else, as employees whose status as such will be affected by a transaction are afforded a right to make representations in terms of this effect they are exposed to. The timing that such information is divulged is of supreme importance. This is regarding the fact that merger analysis is done prospectively. It will then be moot to divulge information after a decision on the matter has been already made. Regardless, it was stated categorically that '…the most powerful channel available to the unions to address employment related issues arising from the merger is the Labour Relations Act or private collective bargaining agreements where they exist.'[201] The problem that befalls competition enquiries into public interest is that there are requirements to balance interests from both sides. In terms of Labour laws, there exist no such requirement which then avails a better suited and more beneficial forum for employees and unions to address their concerns[202].

[195]*Distillers/Stellenbosch* Farmers Supra note 121.
[196]Ibid**,** Para 229.
[197]89/LM/Oct00 at Para 93
[198]Supra note 100.
[199]Ibid, Para 36.
[200]Ibid, Para 37-40.
[201]Ibid, Para 43.
[202]Ibid. This balancing act is the norm. In *Lonmin Plc/Southern Platinum Corp* 55/LM/May05, at Para 13-15 it was stated that should the merger not be allowed then the job loss would be three times higher than if the merger

In *Wal-Mart/Massmart*[203] merger, one of the conditions that were imposed was that the entity not be allowed to retrench people for a period of 3 years after the completion of the transaction[204]. This is good because it allows the employees to gain skills from this international retail giant. Further there was the concern that Wal-Mart has a reputation for de-unionising the workforce. This is not something that needs to be worried about in a public interest analysis during a merger evaluation as there are other legislations with enough teeth that are there and able to deal with this matter better than the competition authorities.

(c) The ability of small businesses, or firms controlled or owned by historically disadvantaged persons, to become competitive:

This criteria of the public interest tests that form part of the merger analysis as well as a general goal of competition law as listed in section 2 of the Act, I believe, is an attempt to rectify the injustices of the past through the use of income distribution economics. Preferential treatment has been afforded to previously disadvantaged persons that own or control firms, which is in line with the Black Economic Empowerment provisions that filter through various legislations.

South Africa was in the unique position during Apartheid in that international investment and import-export abilities were hindered as a result of many States imposing sanctions and embargoes on the country. The profits that firms were then making were then invested locally and across different industries. The repercussions of this were that the minority had a very strong hold on varying sectors of the economy which then made barriers to entry even higher. 'In *Anglo American Holdings Ltd/Kumba Resources Ltd*[205], it was suggested that this provision be interpreted widely in the light of the preamble and section 2. The apartheid economic system led to excessive concentrations in the economy, and it was one of the goals

---

was allowed. The cost of production regarding employment was alleged to be 60% of the overall costs incurred, and that through the merger in order to realize efficiency goals of the firm not more than 400 employees would be retrenched. In addition to this a quarter of the retrenched employees would be ear marked for re-employment should positions become available within the entire Lonmin Group. As a result of the target firm being in dire financial straits, the tribunal ordered that the firm instead of providing a financial investment into the area as has been seen to be the common remedy, that skills training would be afforded to retrenched employees for a period of 6 months post merger. This I believe to be a remedy that accommodates both the needs of the merged entity as well as those of the affected employees in a manner that is cost effective and not unduly unfair on either party.

[203]Supra note 21.

[204]Ibid, Para 2.

[205]46/LM/Jun02 at Para 145-170.

of the Act to promote a wider spread of ownership of economic assets by a greater number of South Africans.'[206]

What this translates into is that new firms, controlled or owned by previously disadvantaged persons found it difficult to enter into these markets. This was not only as a result of the barriers to entry, but further as a result of the poor standard of education and skills that they received, coupled with the pittance income they were paid. Therefore, by and large, there were no skills to use and no capital to invest in order to enter markets. There was therefore little chance for these entities to succeed having come from this background[207].

'The Tribunal should refrain from unnecessarily restricting the business activities of firms that are controlled by black shareholders. It should not impose onerous conditions where empowerment firms dispose of assets for good business reasons.'[208] However, the competition authorities are charged with the task of protecting the competitive process, and not certain competitors. S12A(3)(c) therefore poses a difficult scenario. This is an argument regarding the lessening of barriers to entry that exist in a market, and in terms of an efficiency argument I believe it should apply generally to all small and medium enterprises regardless of the race of the persons controlling or owning them. However, in reality, this cannot be the only method to introduce previously disadvantaged persons into the economy, and in fact it is not. According to the BEE Act[209], enterprises are encouraged by law to reorganise their structure to be more representative of the population. This method of induction of this sector of the population seems to be a better option as firms which benefitted previously as a result of the laws that protected them are now incentivised to participate in a more equitable manner. Employees therefore are afforded skills training and are provided with opportunities to learn the industry they are in and become productive members of society. This is neither here nor there regarding public interest, as this is another –seemingly more suitable forum in which to address this matter. Specifically because competition law protects the competitive process, not competitors themselves- which is precisely what this section of the Acts public interest seems to promote.

[206]Sutherland & Kemp *op. cit.* note 104, at 10-97-8.
[207] Debraj Ray *op. cit.* note 60, at 235 – Inequality begets Inequality.
[208]Ibid, at at 10-97.
[209] Supra note 14.

In *Schumann/Price's Daelite*[210], it was evidenced that should the merger be prohibited then the resultant effect would be that there is a gaping hole left in the particular market. What would then happen is that the demand in the market for the product[211] would- holding all other factors equal- remain the same, whilst supply would severely drop. This would then be a perfect opportunity for the small and medium firms that remain in the market to invest in increasing production capacity, and to innovate so as to frantically scramble to secure as much of the now shelved market share that was held by the failed firm. It would be simplest for the already existing firms in the market to earn the available market share as opposed to new firms entering the market and doing so. However the latter is also a possibility as a large firm has exited the market, which then reduces the barriers to entry into the market even more. Whatever occurs, the potential for many players to enter the market, selling homogenous goods, where prices are basically known between the producers due to the simplistic nature of the good[212], these factors bode well for an argument in favor of a free market system as this market could possibly be considered quasi-perfect. It is interesting to note that without the regulation, that is, without the judicial system intervening in this merger and prohibiting it (regardless of the reason for such prohibition), the parties would have merged, and this quasi-perfect market would not have come into existence.

In *Business Venture Investments 790 (Pty) Ltd/Afrox Healthcare Limited*[213], it was averred by the parties granting loans to the acquiring Black Economic Empowered firm concerned, that the rationale for their participation in the merger was to secure this empowerment of a company owned/controlled by previously disadvantaged persons. The IDC[214] '…is a state owned national development finance institution, mandated to promote, through its financial activities, economic growth, industrial development and economic empowerment.'[215] In line with its mandate, it granted the fiscal assistance needed by the firm to effect the transaction and to aid in furthering the goals of the Act, which was in addition to the competition enquiry producing a positive result.

[210]Supra note 170, para 75.
[211]Candles in this case.
[212]23/LM/May01 at par 77, where it was held that the poorest ranks of society consume these products, and consequently this is an indication that the products need to be cheaply made; in bulk due to their rapid expenditure; and without any need for much research and development for interested firms considering entering the market.
[213]105/LM/Dec04 at para 18
[214]Industrial Development Corporation
[215]*Business Venture/*Afrox Supra note 202,para 14.

In *Engen Limited & Others/Sasol Oil & Other*[216], the fact that there were empowerment inclusions to the transaction, was not regarded in the public interest enquiry as their inclusion is not voluntary but prescribed by the petroleum industry charter[217]. Engen was already an empowered firm, and Sasol Oil was required by industry regulation to alter its constitution so as to comply with the empowerment charter that is in effect within the industry. Therefore regardless of the merger this would have to be complied with[218].

The sale of the land in *Tongaat-Hulett/Transvaal Suiker*[219] to previously disadvantaged persons from the local community, seems to not have regarded that TSB's agricultural operations are fully artificially irrigated. As opposed to the other competitors in the market that rely mainly on rain. This would then mean an increase in costs of production for the new cane growers, and so a lesser return on their production. Economically speaking this would decrease the amount of earning that would be made in the region, which would then decrease saving and investment. This would in turn decrease the buying ability to obtain capital goods and thereafter increase production, innovate, and evolve the industry. This therefore undercuts the potential that this act of corporate social responsibility could generate for the region, and renders this undertaking to be at risk of being viewed as a purely token gesture who's supposed benefits cannot be realised. It is a token gesture because it will be difficult for these growers to become competitive. They have been given a small portion of the market and may well be regarded as subsistence farmers in the extreme. The Tribunal was of the opinion that the employment that would be created would have occurred in any case, and regardless of how it would occur, the benefits that would flow from it would not be sufficient to offset the anti-competitive effects that the transaction would produce.

The merger in *Shell/Tepco*[220] was approved unconditionally, and the conditions that were recommended by the Competition Commission were heavily criticised. In said criticism, it was interesting to note that the Competition Tribunal stated that 'Empowerment is not furthered by obliging firms controlled by previously disadvantaged persons to continue to exist on a life support machine.'[221] This shows the extent to which a public interest ground, in this case referring to s12A(3)(c), is to be considered and that more importantly in this

[216]101/LM/Dec04
[217]Ibid, par 130.
[218]Ibid, para 548.
[219]Supra note 148, par 39-41.
[220]Supra note 21.
[221]Ibid, Para 42.

particular merger, where the firm owned by previously disadvantaged persons cannot withstand reasonable and usual competition within their relevant market coupled with the fact that should as a result of the merger the aforementioned firm be incorporated into another competitor firm, should competition in that market be unaffected therefore the public interest grounds are not sufficient to nullify the result of the competition segment of the enquiry. Namely that there is no substantial prevention or lessening of competition as a result of the transaction due to the fact that said firm has negligible participation in that market and equally as important, the fact that should the merger not have occurred then the result would be that the firm would foreclose in any event due to the internal shortcomings that it suffered from.

I do not believe that this public interest factor should hold much weight although the rationale for its inclusion is favourable. There are other mechanisms to secure the participation of previously disadvantaged persons in the economy that I feel to be better suited to the realisation of such rationale. Through making existing firms more representative, previously disadvantaged people are available to exploit opportunities to gain knowledge in the field the pursue, whilst simultaneously not being exposed to the risks involved with entering markets with the possibility of lacking sufficient capital or knowledge to give themselves a chance to succeed. The chance for a firm to succeed is generally the same regardless of who controls it, however being a previously disadvantaged individual could in all probability further minimise the chances you have to succeed. The Broad Based Black Economic Empowerment Act I feel sufficiently dealt with this conundrum of how to include and involve previously disadvantaged persons in the economy. Further the IDC's mandate promotes such inclusion. This provision of the Act simply does not adhere to competition policy as a result of its segmentation of ownership of juristic persons being racially based to be capable of enjoying preferential treatment. I do not feel that competition law is the medium in which to effect such favourable treatment.

(d) The ability of national industries to compete in international markets:

In most cases it has been found that there is no correlation between mergers and abilities of the firms concerned to become more internationally competitive[222]. The matter regarding a firm's ability to become internationally competitive depends largely on the comparative advantage of the industry and the firm as compared to those similar industries abroad.

[222] *Distillers/Stellenbosch Farmers* Supra note 121, at para 171; *Schumann/Price's Daelite* Supra note 170, para 74.

In *Tongaat-Hulett/Transvaal Suiker*[223] the market is heavily regulated. 'The South African sugar industry is a low cost producer, well set up to compete successfully on international markets.'[224]The Tribunal held that the trade tariffs imposed on imported goods '…insulated the South African market from foreign competition…'[225], which seems to be a justifiable regulation of the market. This is because often with international competition, comes problems of products being dumped on the South African market at prices that cannot be matched by local producers. The effect of this is that international competition undercuts the domestic firm's ability to compete in its market resulting, inevitably and in the extreme, in their exit from the market. Furthermore the parties alleged that the merger would benefit the competitiveness on the international market, however this argument failed due to the fact that the size of the merging firms were not inconsequential. 'Cost competitiveness may be considerably influenced by the size of the productive units, however the merger has no direct influence on this there being no consolidation of any productive capacity.'[226]

On the other hand, there is the problem that the new entity or the acquiring company is international and therefore will increase imports into the country. Such was the concern that existed in the Wal-Mart/Massmart merger that is currently under review from the Competition Appeal Court. This would then have the effect that the region within which the entity will operate is exposed to the risk that the demand for the local goods that they produce would decrease and therefore have negative roll on effects for the entire region.

Further there needs to be an examination into the market share of Massmart, and the competitors that are within that same market.

The public interest considerations cited above (in its enactment by the Legislature, as well as in its application by the Judiciary) are understood to be a regulation of the market by Organs of State. The purpose of the inclusion of public interest goals in legislation is "...deemed to be important to ensure longer-term balanced and sustainable growth."[227]

[223] Supra note 148, para 39-41.
[224] *Ibid,* para 115.
[225] Sutherland & Kemp *op. cit.* note 104, at 10-6.
[226] *Tongaat-Hulett /Transvaal Suiker* Supra note 148, para 115.
[227] Hartzenberg *op. cit.* note 22, at 13.

CHAPTER FIVE– Legal Considerations

There is the legal issue of the fact that it is the role of the electorate to make policy and law. However it is left to the Courts to preside on the matter that involves such considerations. This is seen to be an issue because the courts are then going to have to make decisions regarding policy considerations where they are in fact not the correct democratic forum in which to make the assertion, whilst simultaneously being the only practical forum in which these matters can be addressed. The solution to this is that the courts interpret these matters in a restrictive manner. '…it is incumbent on an un-elected, administrative tribunal, principally charged with defending and promoting competition, to approach its public interest mandate with great circumspection.'[228]

An interesting consideration would be that as stated, a balance between regulated and free markets is to be obtained, and it is within the realm of the Legislature and the Executive to determine this balance. However in the restrictive interpretation by the Judiciary of the intention and policy of these two Organs of State, the resultant decision will be created through a process that actually favours a free market economy because the carefully considered balance is vitiated to a degree by this sort of interpretation being employed. One practical view of the restrictive interpretation of the Judiciary of this competition law policy is that in substance the courts favour a free market system.

"The greater the number of objectives or constraints that a competition authority is required to take into consideration, the higher the likelihood that the focus of enforcement efforts will not centre primarily on safeguarding the competitive process."[229] The courts of a State are in no position to be price setters, and have a long history of preferring to not involve themselves with commercial decisions made between parties – especially where the parties both do not agree to what the court decides. Further, due to the fact that the parties before the

[228] *Daun et Cie/Kolosus* Supra note 169, at para 124; *Unilever/Robertson Foods* Supra note 109; *Shell/Tepco* Supra note 21; and *Distell/Stellenbosch Farmers* Supra note 112.
[229] Hoekman and Holmes, *op. cit.* note 7, at 884.

court seldom are forthcoming with required information, the court is at a further disadvantage as they cannot make a decision based on all the relevant information[230].

Regarding mergers, their implications are conducted before the merger actually occurs, where the reality is that the effects of the merger can only be ascertained after the merger has been concluded (and is thus irrevocable and irreversible), the situation is always present regarding whether the correct decision was made. The underlying purpose of merger regulation is to prevent the proliferation of anti-competitive constructions that have no efficiency justifications for their existence. Sometimes the courts are not fully equipped to be making such determinations even if they have been granted the power to do this by the legislature. Without the required expertise there is a danger that a decision will be made with the intention of safeguarding and promoting competition however where the effects of the decision in question in reality negate this goal. "This is why merger regulation is so important- rather constrain through merger regulation, the rise of structures conducive to monopolistic conduct then imagine that they can be easily controlled after the fact."[231] Merging parties desire their transaction to go through with as little delay and investigation as possible so that they could maximise their potential within that market.

Additionally, matters of exclusionary conduct perpetrated by firms are difficult to bring to trial. Parties are generally not forthcoming with information because they do not want to expose their investment to the risk of losing any possible benefits that will flow from them as a result of their decision to be completely open with the information that they have and to what their intentions are. These hurdles are put in place by the parties for competition authorities to jump over, knowing full well the limited resources that these authorities have. "The competition authorities, however well intentioned, are well advised not to pursue their public interest mandate in an over-zealous manner lest they damage precisely those interests that they ostensibly seek to protect."[232]

There is an issue in merger considerations that the transaction attempts to go through with as little hindrance as possible. Regulations even though they exist for the purpose of protecting interests that will be affected by the transaction, at the same time bring negative ramifications as a result of this delay. I do not believe that the merging parties would avoid

[230] Parties are hardly forthcoming regarding information as they seek to secure future profits that would be hampered by determinations of the court having symmetrical information.
[231] *Supra op. cit.* note 4.
[232] Hartzenberg, *op. cit.* note 22, at 28.

considering a merger as a result of these 'other' regulations as a merger has its rationale cast in the furtherance of the firm's profitability. The only negative effect that I see this regulation having is that it will take more time, as compared to the significant positive effects of increased transparency, increased protection to those members of society that require it - be it consumers or other smaller firms that could risk ejection from the market as a result of not being able to compete in that market post merger; or employees that will be affected by the merger detrimentally; or previously disadvantaged persons being prevented from expanding their economic interests and activities thus relegating them to remain disadvantaged.

CHAPTER SIX– Practical Implications

'We derive some comfort from the knowledge that each of the elements of public interest that we are obliged to consider are protected and promoted by legislation and institutions specifically designed for that purpose…'[233]

In terms of the requirement to empower historically disadvantaged people in South Africa, there are other regulations besides for the Act that require compliance in order to achieve this goal[234]. Focusing on the Act however, there are cases that exist that have dealt with this. 'The role played by the competition authorities in defending even those aspects of the public interest listed in the Act is, at most, secondary to other statutory and regulatory instruments – in this case the Employment Equity Act, the Skills Development Act, and the (Empowerment) Charter itself spring to mind.'[235] This then shows what is confirmed by case law, that public interest is not a main or even an equal priority in competition law, as compared to efficiency. This however does not negate the fact that it is still to be considered. However the ramifications of the consideration are in practice blunted compared to the ordinary understanding of what was written in the Act.

In terms of the consideration of competition authorities of the public interest criteria listed in s12A(3)(a) of the Act, it is said that '…a competition authority should be conservative in addressing this aspect of public interest issue (and that) it is preferable for these problems to be regulated by other authorities.'[236] I do not believe this to be correct, as it

[233] *Daun et Cie/Kolosus* Supra note 169, at Para 124.
[234] BEE Act.
[235] Hartzenberg, *op. cit.* note 22, at 28.
[236] Sutherland & Kemp *op. cit.* note 104, at 10-96.

is the competition authority and the Tribunal which are the refereeing entities with the closest link between government and market regulation. These entities are able to access information and advice from varying professional fields, and further the Minister is afforded a right to appear at hearings so as to aid the court in its determination of the matter. The Tribunal and the Competition Appeal Court are not ordinary courts, they are specialized and presided over by officers who hold sufficient knowledge in these matters so as to tread satisfactorily in these waters. There is of course the probability that these presiding officers lack the degree of expertise required in a given matter, and could rule on matters with the intention of adhering to the law in a manner intended to inflict the minimal amount of harm onto society – which is the courts mandate, that is, to in fact protect society and its interests. In terms of mergers, this dilemma would be solved through a decrease in relevant information asymmetry, and this is left for the parties to comply.

In *Shell/Tepco*[237] it was stated that 'This case raises very important considerations in the interpretation of the public interest in the context of a merger assessment. While public interest concerns are explicitly incorporated into the merger assessment process, it is recognised that they should be interpreted very cautiously, and that the role of other policy initiatives in promoting those public interest objectives may be far more important than that of competition law.'[238]

It was reiterated that the importance of the public interest test in a merger analysis '...may lead to the prohibition of (or the imposition of conditions on) a pro-competitive merger. Or it may result in us approving an anti-competitive merger. Hence in balancing the public interest and competition we are obliged to consider whether a merger that passes muster on the competition evaluation nevertheless falls to be prohibited because of its negative impact on any of the specified public interest factors...'[239]

As noted in this case there is no guidance in the Act about how exactly to consider public interest, with the only qualification to said consideration being that it should be 'substantial'.[240]

The Tribunal further held in this case that it is reluctant to involve itself in commercial decision of firms, especially since doing so could lead the Judiciary as an Organ

[237]Supra note 21.
[238]Hartzenberg, *op. cit.* note 22, at 28.
[239]*Shell*/*Tepco* Supra note 21, at Para 37.
[240]Ibid, Para 38, with reference to s12A(1)(b).

of State to meddle in the business of private firms. The Tribunal expressed that it has no desire to assume such a role.[241]

Regarding the need for public interest to be included in competition legislation, and the use thereof, the Competition Commission stated that "...as a public authority it must be guided by the public interest, it must enforce public policy."[242] The Tribunal responded to this stating that where the Commission uses public interest as a basis for its intervention, that such intervention needs to be cautiously pursued. It was reiterated[243] that the public interest goals are secondary to the other Legislations that specifically exist to deal with related matters[244], and that the pursuit of the public interest criteria's should be conducted wearily "...least that damage precisely those interests that they ostensibly seek to protect."[245]

In *Mittal Steel/ Harmony Gold Mining*[246] , it was stated that 'The Tribunal does not function as an ordinary court. Competition proceedings involve the public interest, and under the Act, the Tribunal has an active role to play in protecting that interest. "As a result, the Tribunal conducts its proceedings in an inquisitorial manner, potentially calling its own witnesses, accepting evidence not normally admissible in a court of law, allowing a broad range of participants, and adjusting its procedures as it sees fit."[247]' Further this case highlighted the consideration of public interest to be secondary to the competition consideration[248]. South African competition law does not really focus on the protection of public interest and even though the courts are empowered to promote or refute a merger based on public interest considerations, in practice it has not yet happened[249].

In *Freeworld Coatings Limited / Competition Commission & Kansai Paint Company Limited*[250] there were very stringent conditions imposed on the merger as a result of the anti-competitive effects it produced, as well as the effects it had on public interest grounds[251]. The public interest effect that it had was that Freeworld Coatings was a local firm with exemplary BEE criteria. The fact that it would be taken over by a foreign entity, Kansai Paint Company

[241]Ibid, at Para 49.
[242]Ibid, at Para 57.
[243]Ibid, at Para 58.
[244]As per my discussion above regarding the LRA, BEE Act etc.
[245]*Shell/Tepco* Supra note 21, at Para 58.
[246]Supra note 21.
[247]With reference to Sutherland & Kemp *op. cit.* note 104, at 11-24, Para 11.4.6.1.
[248]At Para 41; and *Medicross/Prime Cure Holdings* Supra note 17, at Para 23; and *Natal Association of Pharmaceutical Wholesalers & Others/Glaxo Wellcome (Pty) Ltd & others* CT68/IR/Jum00 at para 64.
[249] Sutherland & Kemp *op. cit.* note 104, at 10-93.
[250]62/X/Oct10.
[251] Jafta & van Eeden *op. cit.* note 34, at 12-13.

Limited, was feared to have a detrimental effect on the '... "keep it local" nature of Freeworld's operations, describing it as contributing to a uniquely South African product development and commercialisation...'[252], and in an attempt to mitigate these effects the Competition Commission approved the merger subject to conditions that would serve the public interest, namely:

'The Commission further added several conditions which it believes will serve the public interest:

- No retrenchments for a period of three years following the merger
- Kansai will continue to manufacture decorative coatings for a period of ten years, and is required to establish an automotive coatings manufacturing facility in South Africa within five years
- Kansai will invest in South African research and development in decorative coatings
- Kansai will implement a BEE transaction within two years'[253]

The inclusion of the public interest relating to employment in this manner is not a novel method of addressing the public interest requirement[254], as the Tribunal believes that there are better and specialised institutions that are able to adequately address matters dealing with employment. On the matter of employment, there have been explicit provisions made regarding the inclusion of procedural rights afforded to employees and their trade union representatives[255]. In *Mittal Steel/Harmony Gold Mining*[256] there was the further contention that the employees that were not in executive/manager positions and who were ordinary labourers were to be protected more than their higher ranking colleagues because their prospect for employment should they lose their jobs as a result of the merger would impose a greater burden onto them.

In the party's submissions in the case of *Wal-Mart/Massmart*[257], it was not so much a consideration in the merger analysis of the efficiencies that the merger would or would not bring. There was empirical proof of the fact that Wal-Mart actually does benefit the consumer

[252]Ibid
[253]Ibid, at 13.
[254]*Daun et Cie/Kolosus* Supra note 169, at Para 125
[255]Section 13A states that in a time of a merger, employees &/or their representatives need to be informed of the merger so that the possible post merger ramifications can be addressed fairly and within sufficient time.
[256]Supra note 21.
[257]Supra note 21.

and therefore consumer welfare in the sense that its main selling point is that it sells products at reduced prices[258] and increased consumer choices[259].

However what the contention was regarding public interest in this matter was that Wal-Mart has a reputation of increasing imports into the country it enters. This would have the effect of decreasing the demand on local producers which would in turn threaten goals of growth in those domestic sectors[260]. However it was contended that the procurement of goods locally by Massmart was not as a result of its inability to procure goods internationally and enjoy the same benefits Wal-Mart does, due to Wal-Mart's massive contacts in the global supply chain[261]. The merger was conditionally approved, with conditions similar to those of the Kansai case. The decision was taken on appeal to the CAC and is currently pending.

The fear that economists have regarding matters being decided on in terms of public interest considerations is that, as in the Wal-Mart-Massmart merger, foreign investors will be dissuaded from investing in South Africa as they may be of the opinion that the conditions relating to their business that may be imposed on them are too stringent, and as a consequence they will invest elsewhere[262].

In terms of recorded opinions of major practitioners of competition law in South Africa[263], the negative effects of time delays in the implementation of decisions by firms that occurs when public interests are considered, where necessary, are negligible. This is because as these public interest have been included in the Act it forces them to be considered by all the parties. This I suppose could be regarded as the market regulating itself as it considers these matters beforehand so as to limit any potential delays to the process in question. Such action would be beneficial for all parties involved as the parties would decrease the time that is spent on the matter being scrutinized, and the competition authorities would not have to waste more time and money, of which both are in short supply, considering matters that it could get assistance in considering. However the reality is that should these interests not have been included, then they would not be regarded at all, and economic policies would be mere statements with even more limitations on their ability to be applied than presently exists.

[258]Ibid, at Para 20.
[259]Ibid, at Para 21.
[260]Ibid at Para 31-32.
[261]Ibid at Para 32-45.
[262] Jafta & van Eeden *op. cit.* note 34, at 14-15.
[263]T. Hancock, *op. cit.* note 18.

CONCLUSION

'…government plays a substantial role in the economy. It not only provides the rules for economic activity but also promotes economic stability and growth, provides certain goods and services that would otherwise be under produced or not produced at all, and modifies the distribution of income. The government is however not the dominant economic force in deciding what to produce, how to produce it, and who will get it. That force is the market.'[264]

'…competition authorities are unlikely to prohibit a merger that is not anti-competitive, or approve a merger that is anti-competitive, on public interest grounds…The most important effect of the public interest criteria has been that the authorities frequently approve mergers subject to conditions that protect the public interest.'[265] This is evidenced in *Glaxo Wellcome pls/Smithklin Beecham plc*[266] where it was proposed to the Tribunal that '…the merged firm allow competition by producers of generic drugs, which could be used to treat opportunistic infections in HIV/AIDS cases and anti-retrovirals for HIV.'[267] However the tribunal could not justify the condition based on any of the public interest grounds in the Act.

'From an economic perspective, (*competition)* policy should aim at safeguarding the competitive process so that firms are able to compete away any excess profits that may exist at any point.'[268], and further, that '...many specialists have recommended that developing countries pursue a broad based competition policy... (using) the key principle underlying an active competition policy stance is to rely on market forces to determine the allocation of productive resources, subject to the constraint of ensuring social equity objectives are realised as efficiently as possible, and that mechanisms exist through which attempts to create monopolies and exploitation of market power can be addressed.'[269] Therefore there should be a hybrid of regulation and reliance on market forces to attain a fragile balance needed to allow a market to work in a desirable manner, addressing all required goals.

There is definitely a need for public interest in competition legislation. This is because it is this legislation that deals with economic matters that are required to be regarded in specific instances. For example due to the forward looking nature of merger analysis, it can

[264]McConnell and Brue *op. cit.* note 5, at 33.
[265]Sutherland & Kemp *op. cit.* note 104, at 10-93.
[266]58/AM/May00 par 20.
[267]Sutherland & Kemp *op. cit.* note 104, at 10-94.
[268]Hoekman and Holmes *op. cit.* note 7, at 882.
[269]Ibid, at page 844.

be economically predicted what the possible effects the transaction would have on s12A(3) listed factors. This is the only legislation that allows such scrutiny over commercial decision prior to the transaction being recognised and therefore legally available to be implemented. It is true that there are other regulatory bodies that exist in South Africa, and abroad as well, that deal with the specific matters enshrined in this article. However they are only able to be mobilised once a breach of their provisions has occurred.

The forward looking ascertainment of the effects of the transaction is thus very useful, in an attempt to prevent possible and reasonably foreseeable harm from occurring, before it occurs.

Regarding the effects that the transaction would have on trade and industry, this public policy consideration is important for the ascertainment of how the conduct will affect government's economic goals of encouraging and nourishing national economic growth, efficiency and social welfare. The same rationale is true for the heightened protection of firms owned by previously disadvantaged persons being encouraged to participate in the economy and compete in the markets. I view this provision as being something akin to a handicap policy in golf, where firms that are exposed to higher risk of failure in their ability to participate in the market due to their historical economic disabilities, as it were, should be given a proportionate 'helping hand' to be able to participate fairly. However regarding section 2(e) and 12A(3)(c) respectively, the public interest is in conflict with competition policy itself. There are better means in which to secure the attainment of this goal, namely through the provisions of the BEE Act as it relates to concessions and charters formulated by the Executive to encourage/force the industries to which these acts relate to become representative.

The same rationale applies for domestic industries that are to be protected from international firms perverting said industries, thereby having the possible consequence of retarding national economic growth and the fulfilment of the other economic goals of efficiency (in the domestic and global consideration) and of domestic social welfare.

The reasons that public interest considerations exist is to account for the effect that decisions of players within the market have on the market itself and on intricately linked economic considerations of growth, efficiency and welfare.

The contentions that public interest considerations specifically hinder market functionality in terms of the delays that are involved with the consideration of these criteria, are ill founded as should the parties be prepared to disclose all relevant information prior to the hearing then the investigations regarding these criteria would be swifter, and consume less resources – both from the parties themselves that will be faced with extended periods in court and therefore the associated legal fees, as well as for the competition authorities that will not need to expend as much capital and time resources into the necessary investigation of the matter.

With regard to the matter of income and wealth distribution, 'the market system is impersonal and may distribute income more inequitably than society desires. It yields very large incomes to those whose labour, by virtues of inherent ability and acquired education and skills, command high wages.'[270] This is then a basis to repute the free market system as it does not take sufficient cognisance of the fact that in developing countries, there is a need to promote equity values especially where there has been a historical discrimination which is presently required to be rectified. It seems that the inclusion of equity issues in economic growth policy will hamper the speed at which desired growth rates will be realised. However according to Kuznets inverted U hypothesis, referring specifically to the fact that should pure efficiency be the only policy objective in realising economic growth, the advantaged will become more advantaged for a time and the disadvantaged will become more so. This time frame is not a matter of months or a few years, as economic growth is popularly discussed in terms of changes evident from generation to generation. This amelioration of wealth and income disparity will be seen in economic terms through a reduction in the gap between the Lorentz curve and the 45 degree line. Should this pure efficiency goal be followed, the result will be undue civil unrest. Historically disadvantaged people vote for representation with the hope that past injustices will be remedied and results will be evident within reasonable time. To expect the majority of South African citizens to suffer further post Apartheid, with representation of their own democratic choosing, is simply ludicrous and will never be accepted.

I believe therefore that public interest does indeed have a place in competition policy, as it is a form of necessary regulation of the market so as to guide growth and development in a manner that promotes social welfare and equity. The process may take longer however the

[270]McConnell and Brue *op. cit.* note 5, at 79.

results will gradually begin to be seen in each income bracket thus abating the frustrations of previously disadvantaged persons and further promoting a uniform equitable economic growth.

BIBLIOGRAPHY

TEXTS AND JOURNALS

- *Competition Policy in South Africa, Where has it come from and where is it going?,* The Investment Analysts society of Southern Africa, www.iassa.com (Accessed 10November 2011)
- C.R. McConnell and S. L. Brue, *Economics: Principles, Problems and Policies* (McGraw-Hill), International edition, 19th ed
- Bernard Hoekman and Peter Holmes*, Competition Policy, Developing Countries and the WTO*, (Blackwell Publishers Ltd 1999)
- Tracy Hancock, *Public Interst Consideration Best Left to Other Agencies?* Merger and Aquisitions. PUBLISHED 02-04-2010.
- Harzenberg T, *Competition Policy and Enterprise Development: The Role of Public Interest Objectives in South Africa's Competition Policy*, (August 2004)
- Leon Louw, *Economic Freedom Defined*, found at http://freemarketfoundation.com/ShowArticle.asp?ArticleType=Publication&ArticleID=1746
- Rachel Jafta & Johann van Eeden, *The Economics of Competition Policy*, Paper for the Free Market Foundation Competition Policy Round Table, (Econex) 30 June 2011
- Reekie, W.D. (1999). The Competition Act, 1998: An Economic Perspective. South AfricanJournal of Economics, 67(2)
- P Areeda & L Kaplow *Antitrust Analysis* (1997) 6
- M Brassey (ed), Competition Law, (Lansdowne: Juta, 2002)
- D Neven, P Papandropoulos and P Seabright *Trawlings for Minnows* (1998)
- M. Fox, *Economic Development, Poverty and Antitrust: The Other Path*, Festschrift for Professor Lawrence Sullivan, 13 SW. J. L. & Trade in Americas 211 (2007)
- A Lewis, D. (2000). Competition Regulation: The South African Experience. Paper presented at the ISCCO Conference, Taipei
- Lewis, D. (2002). The Role of Public Interest in Merger Evaluation. Presented to the ICN, Naples.
- Sutherland and Kemp, *Competition Law of South Africa* (Service Issue 11 October 2008)
- Lawrence Reyburn: Philip Sutherland and Katharine Kemp *Competition Law of South Africa,* (LexisNexus Butterworths Durban) Service Issue 14 (October 2011)

- General Agreements of Tariff and Trade (World Trade Organization) 1994
- Steven D Levitt, *Alternative Strategies for Identifying the Link Between Unemployment and Crime*, Journal of Quantitative Criminology, Vol. 17, No. 4, December 2001, (2001) Plenum Publishing Corporation.
- Dr. Roger Van der Burgh & Dr. Peter D. Camesasca, *European Competition Law and* Economics: Chapter 9- Eileen Reed *Concentrations and Merger Control*
- *Trends in South African Competition Law,* Webber Wentzel Attorneys, (14 June 2004), http://www.webberwentzel.com/wwb/content/en/page1874?oid=3111&sn=Detail&pid=1874
- Rijit Sengupta & Cornelius Dube, *Competition Policy Enforcement: Experiences from Developing Countries and Implications for Investment*, OECD Global Forum On International Investment VII (March 2008), www.oecd.org/investment/gfi-7.
- Kim Kampel, *The Role of Competition Law in Supporting SMEs*, http://www.competition-regulation.org.uk/conferences/southafrica04/kampel.pdf.
- Lesley Morphet, *South Africa: South African CompetitionLaw and Public Interest*, (17 May 2007), http://www.mondaq.com/article.asp?articleid=47176
- Vani Chetty, *The Place of Public Interest in South Africa's Competition Legislation: Some Implications for International Antitrust Convergence*, (ABA Section of Antitrust Law, 53rd Spring Meeting, Washington D.C., 30 March – 1 April 2005), http://apps.americanbar.org/antitrust/at-committees/at-ic/pdf/spring/05/aba-paper.pdf
- James Hodge, Sha'ista Goga, Tshepiso Mohloli, *Public Interest Provisions in the South African Competition Act: A Critical Review*, Competition Policy, Law and Economics Conference (2009), www.compcom.co.za/...**review**/.../**Public-Interest-Provisions**14-August-2009- 2.docx
- A. E. Rodriguez and Mark D. Williams, *The Effectiveness of Proposed Antitrust Programs for Developing Countries,* 19 N. C. J. INT'L & Com. Reg. 209.
- Debraj Ray, *Development Economics,* Princeton University Press, Princeton New Jersey (1998)

SOUTH AFRICAN LEGISLATION:

- Competition Act 89 of 1998, as amended.
- The Labour Relations Act 66 of 1995;

- Employment Equity Act 55 of 1998;
- Basic Conditions of Employment Act 75 of 1997.
- Broad Based Black Economic Empowerment Act 53 of 2003

CASES:

- *MediCross HealthCare Group (Pty) Ltd /Prime Cure Holdings (Pty) Ltd* (11/LM/Mar05) [2005] ZACT 66.

- *Shell South Africa (Pty) Ltd v Tepco Petroleum (Pty) Ltd* 66/LM/Oct01;
- *Mittal Steel et al v Harmony Gold Mining Company et al* 70/CAC/Apr07;
- *Wall-Mart Stores Inc and Massmart Holding Limited* 73/LM/Nov10.
- *Times-Picayune Publishing Co v United States*, 345 US 594 (1953)
- ***Competition Commission v Pioneer Foods (Pty) Ltd,* (15/CR/Feb07, 50/CR/May08) [2010] ZACT 9 (3 February 2010)**
- *Santam Ltd/Guardian National Insurance Co Ltd* 14/LM/Feb00
- *Distillers (South Africa) Ltd v Bulmer (SA) (Pty) Ltd* 2002 (2) SA 346 (CAC)
- *Unilever Plc and other/Robertson's Foods (Pty) Ltd and others* 55/LM/Sep01
- *Harmony Gold Mining Co/Gold Fields Ltd* 93/LM/Nov04
- *Mondi Ltd and Kohler Cores and Tubes/Competition Tribunal* [2003] 1 CPLR 25 (CAC) 33.
- *Iscor Ltd/Saldanha Steel (Pty) Ltd* 67/LM/Dec01
- *Tiger Brands Ltd/Langberg Foods International Ashton Canning Co (Pty) Ltd,* 46/LM/May05
- *Tongaat-Hulett Group Ltd/Transvaal Suiker Bpk* 83/LM/Jul00
- *Nasionle Pers Ltd/Education Investment Corporation Ltd* 45/LM/May03
- *Cherry Creek Trading 14 (Pty) Ltd/Northwest Star (Pty) Ltd* 52/LM/Jul04
- *Multichoice Subscriber Management (Pty Ltd/Tiscali* 72/LM/Sep04
- *Schumann Sasol (South Africa) (Pty) Ltd/ Price's Daelite (Pty) Ltd* 23/LM/May01
- *Telkom SA Ltd/TPI Investments (Pty) Ltd*81/LM/Aug00.
- *Liberty Group Ltd/Capital Alliance Holdings Ltd* 04/LM/Jan05
- *Food and Allied Workers Union/The Competition Commission, McCain Foods and Heinz Frozen Foods* 17/AM/Mar01
- *Trident Steel (Pty) Ltd/Dorbyl Ltd* 89/LM/Oct00
- *Unilever/The Competition Commission of South Africa*

- *Lonmin Plc/Southern Platinum Corp* 55/LM/May05
- *Anglo American Holdings Ltd/Kumba Resources Ltd* 46/LM/Jun02
- *Business Venture Investments 790 (Pty) Ltd/Afrox Healthcare Limited*105/LM/Dec04
- *Engen Limited & Others/Sasol Oil & Other* 101/LM/Dec04
- *Daun et Cie AG/Kolosus Holdings Ltd* 10/LM/Mar03 *Distillers Corporation (SA) Ltd/Stellenbosch Farmers Winery Group Ltd* 08/LM/Feb02
- *Freeworld Coatings Limited / Competition Commission & Kansai Paint Company Limited* 62/X/Oct10
- *Glaxo Wellcome pls/Smithklin Beecham plc* 58/AM/May00 par 20.

WEBSITES

- http://en.wikipedia.org/wiki/Free_price_system
- http://en.wikipedia.org/wiki/Pareto_optimum
- http://www.roylaw.co.za/home/article/trends-in-south-african-competition-law/pageid/competition-law
- http://en.wikipedia.org/wiki/Planned_economy
- http://en.wikipedia.org/wiki/Herfindahl_index
- http://en.wikipedia.org/wiki/Sherman_Antitrust_Act.
- http://en.wikipedia.org/wiki/Income_distribution
- http://ports.co.za/saldanha-bay.php
- http://en.wikipedia.org/wiki/Saldanha_Bay
- http://www.statssa.gov.za/keyindicators/keyindicators.asp
- http://www.fin24.com/Economy/SA-unemployment-rate-among-worlds-highest-20110504
- http://ports.co.za/saldanha-bay.php
- http://en.wikipedia.org/wiki/Sishen-Saldanha_Railway_Line