

CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT:
ASSESSMENT OF DEMAND AND SUPPLY OF RECYCLED
MATERIALS IN THE WESTERN CAPE

**A Dissertation Presented To the Department of Construction Economics
and Management**

Faculty of Engineering and the Built Environment

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of B.Sc. Honours in Construction Management**

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ABSTRACT

Concern for environmental degradation has been a motivating factor in the efforts to reuse or recycle construction and demolition waste. The intention is not only to reduce environmental desecration, but also to recycle the construction and demolition waste into potential building materials to be reused elsewhere. This study investigated the supply and demand of recycled construction materials in the Western Cape, and aimed to determine the perception held by important stakeholders about these materials.

A Case study was conducted on Malans Quarries Recyclers in order to determine the supply of raw materials (construction and demolition waste) reaching the recycling plant; the supply of recycled materials to the end user (consumer); and the recycling process that takes place. A sample of fifteen respondents from a variety of large, medium and small construction contractors, as well as consultants and civil engineering companies, completed a questionnaire to determine the demand for and perceptions about these materials.

A qualitative analysis of the case study results revealed that poor waste management plans implemented on construction and demolition sites have affected the quality, supply and price of recycled materials. In addition to this it was also revealed that the negative perceptions regarding recycled materials were the major barriers to creating an established secondary market. Inadequate knowledge and experience were major contributors to resistance to change of perceptions.

The qualitative analysis of the results of the questionnaires showed that the majority of respondents still preferred to use primary materials over recycled materials. However, it appears that the gap between respondents who prefer to use primary materials, and those who utilize recycled materials, has narrowed in comparison to results obtained in previous studies. It seems that there may be more usage of recycled materials in the future.

The results also revealed that tax cuts, could be a good economic incentive to encourage the use of recycled material. The questionnaire results also revealed that the majority of the respondents believed that landfill taxes were not effective in discouraging the illegal dumping of waste, and that the lack advertisements, and difficulties in obtaining recycled materials played a crucial role in the under-use of recycled materials.

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TABLE OF CONTENTS	Page
Abstract.....	i
Declaration.....	ii
Acknowledgements.....	iii
Table of contents.....	iv
List of figures.....	vii
List of tables.....	viii
CHAPTER 1: INTRODUCTION.....	1
1.1 Introduction.....	2
1.2 Background.....	2
1.3 Research focus.....	7
1.4 Justification of research report.....	7
1.5 Problem statement.....	7
1.6 The Hypothesis.....	8
1.7 Objectives.....	8
1.8 Methodology.....	8
1.9 Research limitations.....	9
1.10 Organization of the research report.....	9
1.11 Chapter summary.....	10
CHAPTER 2: LITERATURE REVIEW.....	11
2.1 The source of construction and demolition waste.....	12
2.2 The current construction and demolition waste status in South Africa.....	14
2.2.1 <i>Main drivers for change</i>	14
2.2.2 <i>Construction and demolition waste</i>	14
2.2.3 <i>Quantities of construction and demolition waste produced</i>	15
2.2.4 <i>The need for waste management</i>	16
2.3 The extent to which construction and demolition waste is recycled.....	17

2.3.1	<i>Definition</i>	17
2.3.2	<i>Material availability for recycling process</i>	17
2.3.3	<i>The advantage of recycling construction and demolition waste</i>	19
2.3.4	<i>Recycling of construction and demolition waste in United Kingdom</i>	20
2.3.5	<i>Recycling of construction and demolition waste in Brazil</i>	21
2.3.6	<i>Recycling of construction and demolition waste in EU</i>	22
2.3.7	<i>Recycling of construction and demolition waste in the USA</i>	23
2.3.8	<i>Recycling of construction and demolition waste in Japan</i>	24
2.4	The extent to which recycled materials are utilized worldwide.....	24
2.5	Examining the secondary market.....	28
2.5.1	<i>Introduction</i>	28
2.5.2	<i>Competition</i>	28
2.5.3	<i>Allocation of resources</i>	29
2.5.4	<i>Market constraints</i>	29
2.5.5	<i>Market Development</i>	31
2.5.6	<i>Stimulating secondary markets</i>	31
2.5.7	<i>Setbacks for the development of secondary materials in SA</i>	32
2.5.8	<i>Possible solution for SA</i>	33
2.5.9	<i>Chapter summary</i>	36
CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY		37
3.1	Introduction.....	38
3.2	Research strategy.....	38
3.2.1	<i>Quantitative research</i>	38
3.2.2	<i>Qualitative research</i>	39
3.3	Techniques for data collection.....	39
3.3.1	<i>Surveys</i>	39
3.3.2	<i>Questionnaires</i>	40
3.3.3	<i>Interviews</i>	40

3.3.4	<i>Case studies</i>	41
3.3.5	<i>Triangulation</i>	41
3.4	Choice of research method.....	42
3.4.1	<i>Source of information</i>	42
3.4.2	<i>Reason for selection</i>	42
3.5	Methodology.....	43
3.6	Structure of the questionnaire.....	44
3.7	Question appraisal to ensure that it would work as intended.....	46
3.7.1	<i>Editing</i>	46
3.7.2	<i>Pilot study</i>	46
3.7.3	<i>Question testing</i>	47
3.8	Structure of the case study.....	47
 CHAPTER 4: ANALYSIS OF RESULTS		49
4.1	Introduction.....	50
4.2	The Malans Quarries Company-Case study.....	50
4.3	Case study discussion	57
4.4	Results and discussion of the questionnaire.....	63
 CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS		88
5.1	Introduction.....	89
5.1.1	Chapters Summaries.....	89
5.2	Testing of the hypothesis.....	90
5.3	Achievement of the research objectives.....	91
5.4	Conclusions.....	91
5.5	Recommendations.....	93
 REFERENCES		95
 APPENDICES		101

LIST OF FIGURES

<i>Figure 1a</i> The flow of material on a recycling plant.....	51
<i>Figure 1</i> Percentage scores for respondents on question 1.....	63
<i>Figure 2</i> Percentage scores for respondents on question 2.....	64
<i>Figure 3</i> Percentage scores for respondents on question 3.....	66
<i>Figure 4</i> Percentage scores for respondents on question 4.....	68
<i>Figure 5</i> Percentage scores for respondents on question 5.....	69
<i>Figure 6</i> Percentage scores for respondents on question 6.....	70
<i>Figure 7</i> Percentage scores for respondents on question 7.....	72
<i>Figure 8</i> Percentage scores for respondents on question 8	73
<i>Figure 9</i> Percentage scores for the respondents on question 9.....	75
<i>Figure 10</i> Percentage scores for the respondents on question 10.....	76
<i>Figure 11</i> Percentage scores for the respondents on question 15.....	83

LIST OF TABLES

Table 1a <i>Composition of Waste Components for Different Types & Sizes of Construction Sites</i>	3
Table 1b <i>Summary of Construction Waste Disposal in Landfills in South Africa</i>	16
Table 1c <i>Percentage Scores for Respondents on Question 11</i>	78
Table 2 <i>Percentage Scores for Respondents on Question 12</i>	79
Table 3 <i>Percentage Scores for the Respondents on Question 13</i>	81
Table 4 <i>Percentage Scores of the Respondents on Question 14</i>	82

CHAPTER 1: *INTRODUCTION*

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1. Introduction

This chapter presents a brief background on the research topic, and the research proposal which outlines the following: research focus, justification for the research report, problem statement, hypothesis, research objective, methodology, and the structure of the research report.

1.1 Background

1.1.1 Construction waste

Construction waste is a by-product of construction industry activities such as construction, renovation and demolition. It also results from damage to property at the hands of natural disasters such earthquakes, wars, and floods. Construction and demolition (C&D) waste, building rubble, and construction debris are other terms used to refer to construction waste. For the purpose of this study, the term construction waste shall include all types of waste material generated on the construction and demolition site.

International studies have found the construction industry to be a generally wasteful sector (Ekanayake & Ofori, 2000). It is estimated that up to 15% of material delivered to a construction site ends up in landfills. Considering that the construction industry contributes a significant amount to the GDP and development of any country, the waste levels highlighted above represent lost opportunities, particularly in terms of employment creation, economic growth, prolonged use of finite natural resources and preservation of habitable ecosystems that support a better life for all.

Macozoma (2001) posits that the South African construction industry generates about 5 to 8 million tons of construction and demolition waste per annum. This waste results from domestic and industrial construction activities. Over one million tons of construction and demolition waste ends up in landfills annually, of which, a large proportion consists of concrete and masonry rubble and a small proportion is timber, steel, metal, glass and plastic.

1.1.2 Composition of construction and demolition waste

Obtaining reasonably accurate figures for the composition of construction waste has so far been elusive. The Building Research Establishment (BRE) center for waste and recycling has been gathering detailed statistics on waste arising from different types and sizes of construction sites. The details of six of these sites are illustrated in Table 1, below:

Table 1a *Composition of Waste Components for Different Types & Sizes of Construction Sites* (Hurley and Hobbs, 2001)

Waste Group	Office A %	Housing B %	Housing C %	Leisure D %	Housing E %	Restaurant F %	Ave %
Concrete	2	18	0.5	3	10	0	5.6
Ceramic	2	0	0	0	11	4	11.1
Insulation	9	0	2	1	9	1	3.7
Plastic	4	17	37	4	5	10	12.8
Packaging	47	8	22	49	9	32	27.8
Metal	6	3	0.5	3	1	0	2.3
Plaster & Cement	10	1	0.5	3	2	0	2.8
Miscellaneous	11	18	13	15	19	7	13.8
Timber	8	33	25	3	15	20	17.3
Total	100	100	100	100	100	100	100

The miscellaneous category accounts for typical waste on site, ranging from sofas to plants, tyres and glass. Almost half of all material waste was found to be due to timber pallet usage on-site. It should be noted that this table does not represent the gold standard for the composition of construction and demolition waste found on a construction site. It merely serves the purpose of highlighting the *general* construction and demolition waste composition on site.

1.1.3 Re-use and recycling

Lawson et al. (2001) also found that the rate at which construction and demolition waste are recycled and re-used in the European Union countries varies from five percent (5%) to ninety five percent (95%). A good example is the Netherlands - this country has an 80% recycling rate for construction waste. This is due to strict governmental legislation and good waste management planning.

According to Lawson et al. (2001) there is growing evidence that previous studies underestimated the amount of construction and demolition waste being recycled or re-used in the United Kingdom. Landfill tax has contributed to a large increase in the number of fixed and mobile crushing and recycling sites. Some of these inert waste recycling sites are experiencing a shortage of waste materials.

Recycling and re-use of construction waste plays a vital role in reducing the usage of energy, reducing the requirement land for landfills, as well as the reduction of extraction of natural resources. The energy required to extract raw materials and convert them into a final product is very high in relation to the energy required for recycling (Thormark, 2001). For example the energy used in recycling aluminium is far less than that required to produce it from raw materials. There are however, several barriers to recycling, other than technical difficulties. These include economic, geographic, legal, social, temporal and informational barriers (Thormark, 2001). In addition, recyclers have difficulty selling their products because of the limitations imposed by standards and specifications for building construction and the traditional engineers who are generally unwilling to explore innovative materials. The public perception of secondary material forces recyclers to sell their products at a lower price than otherwise (Macozoma, 2001).

The recycling and re-use of materials is attractive since it puts material waste back into the production cycle. In other words, part of the un-used materials on site is accounted for, and the other part may be used to provide materials to disadvantaged communities to

build their homes (Habitat, 2001). This is a major promoter of sustainable construction and sustainable development.

In order to make the construction industry sustainable, the industry needs to minimize waste disposal. One way of achieving this is through recycling. Since rubble is under-recycled and constitutes a high proportion of waste in South Africa, it rolls back the gains in sustainable construction. A market for secondary materials is required to encourage the recycling of rubble.

Recycling, recovery and re-use have a great contribution to make to construction and demolition waste minimization. The biggest challenge thus far is the establishment of a viable secondary construction materials market.

1.1.4 Quality of recycled products

The quality of recycled products refers to the physical and chemical characteristics of these recycled products. The physical characteristics of these recycled products include, durability and aesthetic appeal, while the chemical characteristic includes, the chemical reaction that will result when this recycled product comes into contact with other products. This can be best illustrated using an example of the chemical reaction between recycled mortar and bricks. The bond between the bricks will depend on the quality of the recycled mortar.

The quality of recycled products is dependent on the quality of construction and demolition waste supplied to the recycling plant. In order to achieve better quality of the recycled products, construction waste needs to be properly managed. The construction and demolition waste generated from the site must be separated at the source. This means that the masonry rubble, etc. should be placed separately from the concrete rubble, etc. This also applies to timber, metal and glass, where each by-product should be placed separately. The separation of construction and demolition waste not only plays a vital role in ensuring that the construction and demolition waste remains uncontaminated, but it

also reduces the cost that the recycler would have to spend in separating the waste. This reduction of cost will assist the recycler to deliver the product at a lower price and be competitive.

The lack of implementation of a good waste management plan on the construction site has played a vital role in the supply of poor quality construction and demolition waste to the recycling plant which in turn, has resulted in poor quality recycled products. In addition to this, lack of research on ways to improve the quality of recycled products has also contributed the poor quality of recycled products. Lack of understanding of what causes the poor quality of recycled products has resulted in a negative perception about the products among engineers, consultants and contractors. These negative perceptions have influenced the client's decision to use or not to use recycled products.

1.1.5 The extent to which recyclable materials are used

The steel industry has, for many years, been aware of the environmental and economic impact of waste from the construction and demolition process. Demolition contractors have extensive experience in recycling steel, both from structures (beams and columns) and reinforcements (Hobbs & Hurley, 2001).

Barros et al. (1998) propose that construction waste can be separated into main components at the construction site or at a sorting facility, depending on its composition. They further state that waste composed mainly of stone material can be directly shipped to a crushing facility where it will be crushed into recyclable aggregates. Most of the construction and demolition debris are crushed and used in the construction of road layers (Barros, Dekker & Scholten, 1998).

Malans Quarries is a company based in Cape Town that has been a supplier of materials used in the civil and building construction industry. The company deals with the crushing of construction rubble to produce sand, which is then supplied to contractors (Hale, 2001). An example of Malans Quarries recycling project is the Westlake Office

Development. Eighty percent of the material used in the road infrastructure was crushed rubble from demolished buildings on this site. Malans Quarries are currently investigating the possibility of manufacturing concrete aggregates from construction waste (Hale, 2001).

1.2 Research Focus

This research will investigate whether the development of recycling and re-use of construction and demolition waste material is dependent on the demand for secondary material in construction industry.

1.3 Justification of the Research Report

The construction industry has not responded to recycling needs to an appreciable scale. Perhaps it is waiting for greater landfill pressure, economic incentives or restrictive legislation before acting. But one thing is clear. The problem will not go away unless research is done to understand the root cause for under-recycling of rubble in the industry. In addition the construction industry utilizes millions of tons and generates huge quantities of waste. This is not sustainable. To bring the waste back into a reusable condition it is necessary to recycle materials. The extent of recycling in the Western Cape is not known and has not been documented. This project conducted basic research in this area, which is all the justification that was needed for doing this research project.

1.4 Problem Statement

The problem that will be addressed by this research can be summarized as follows:

In order to make the construction industry sustainable, the industry needs to minimize waste disposal. One way of achieving this is through recycling. Recycling would foster sustainability.

1.5 The Hypothesis

The hypothesis to be tested in this research may be stated as:

Low levels of recycling construction and demolition waste are not caused by inadequate demand for recycled materials.

1.6 Objectives

The objectives of this research were to:

- Conduct a detailed literature review that would:
 - Examine the amount of construction and demolition waste that is dumped in the landfills.
 - Examine the extent to which construction and demolition waste is recycled and re-used.
 - Examine the demand for secondary material in the construction industry.
- Determine quantities of construction and demolition waste supplied to the recycling plant
- Determine quantities of recycled materials supplied to the end user
- The perception about recycled materials by individuals

1.7 Methodology

For a systematic collection and compilation of basic data, the following were carried out:

- Literature Survey: a comprehensive literature survey was undertaken to obtain background information on the topic. Relevant literature on construction and demolition waste, waste management, and recycling and re-use of construction and demolition waste materials, quality of secondary materials and demand for secondary materials in the construction industry was examined. However, there

were limited sources of literature on secondary materials in the South African construction industry.

- One case study was carried out and questionnaires were sent to 25 construction companies of different size classifications. The random sample was selected from general contracting construction companies in Cape Town.
- Interviews and questionnaires with producers and suppliers of secondary materials to determine the difficulties they are faced with, if any, were conducted

1.8 Research Limitations

Data collection was limited to the Western Cape and has a time limitation

1.9 Organization of the Research Report

It is proposed that the thesis is structured as follows:

Chapter Two: A review of the literature: The literature regarding the sources of construction and demolition waste, the situation of construction and demolition waste in South Africa, recycling of construction and demolition waste, and the secondary market was reviewed and discussed.

Chapter Three: Research methodology and design. This chapter presents the research methodology that was followed as well as the research design.

Chapter Four: Reporting, discussion and interpretation of the findings and a comparison of empirical research findings with the literature is undertaken.

Chapter Five: Conclusion and Recommendations from the findings. This chapter tests the hypothesis and concludes the research report. It also draws recommendations for future research from the conclusions.

1.10. Chapter Summary

This chapter presented a background on the research topic, stated the research hypothesis, and outlined the research objectives. It also highlighted the methodology that was followed in the collection of the data. The chapter to follow will presents a review of the literature on the research topic.

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CHAPTER 2: *LITERATURE REVIEW*

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2.1.The Source of Construction and Demolition Waste

2.1.1. Introduction

Building construction has traditionally been a linear process consisting of sourcing of raw materials, followed by the processing of these raw materials into the final product. This is known as the construction phase. The resulting by-product of construction processing is known as construction waste. Traditionally, the assumption was that there is an unlimited supply of raw materials that provide the input for processing and that there is a bottomless pit or landfill that absorbs the waste (Macozoma, 2002). However this is not the case, since the supply of resources is in fact limited and there is no such bottomless pit (Macozoma, 2002).

Literature suggests that reduction of materials extraction, minimization of construction and demolition waste, and the recovery of such waste for secondary use, could be a useful solution, to the problem of environmental degradation caused by extraction and dumping of excess or waste material.

2.1.2. Life cycle of materials in building construction

According to Macozoma (2002) the life cycle of materials in construction reveals a number of deficiencies that contribute to the construction industry's poor performance. This wastefulness span throughout the various phases of the building life can be given as follows:

Virgin material extraction: These are resources with scarce availability, which require the extraction of much earth for the withdrawal of only a limited amount of material. In addition, high energy consumption rates, emissions to the environment, and disturbance of ecosystems, contribute to the abuse of the environment.

Manufacturing of materials and products: The manufacture of virgin materials is responsible for the high energy consumption rates, emissions to the environment and the use of packaging materials that end up as waste on construction sites.

Construction process: The design of buildings, labour practices and construction method are some factors, which contribute to the generation of waste on the construction site. In addition, poor materials handling, human error and inadequate waste management planning during the construction phase, influence the generation of waste.

Operation and maintenance: Once the construction process is complete, the building will still require some kind of maintenance from time to time. Some of the inefficiencies associated with this include, energy performance, renovation without planning for materials recovery, and adaptability of buildings to different users.

Demolition: Many buildings which are demolished have not reached the end of their design life. Instead, they are demolished because they do not meet the current client's needs. Lack of building flexibility, lack of design for deconstruction, and demolition without planning for recovery of useful material, are the main shortfalls (Macozoma, 2002).

2.2. The Current Construction and Demolition Waste Situation in South Africa

2.2.1. Main driver for change

The South African construction and demolition waste situation is different from that of developed countries. The main drivers for change in construction and demolition waste management practiced in developed countries include: The reduction of natural resources, the scarcity of land for development of new waste disposable facilities, and the need to preserve the environment and natural ecosystem. South Africa does not have these problems however prevention strategies have been adopted (Macozoma, 2001).

The main drivers of change in construction and demolition waste management practices in South Africa include: The loss of resources resulting from the wasteful practices of the construction industry that has contributed to the industry recession in the past decade (Macozoma, 2001); Increases in environmental degradation, resulting from increases in illegal dumping of construction and demolition waste; Concerns related to energy consumption levels of the construction industry; Increases in waste management costs, particularly waste transport and disposal; and The need to create employment opportunities.

2.2.2. Construction and demolition waste

According to the Council for Scientific and Industrial Research (CSIR, 2001) the South African construction industry has been found to generate approximately 5-8 million tons of construction and demolition waste per annum. This waste results from residential building, dense housing projects and high rise residential and non-residential dwellings.

Construction and demolition waste is generated during activities such as new construction, renovation and demolition. Over one million tons of construction and

demolition waste end up in landfill sites in South Africa per annum. A large proportion of construction and demolition waste is reused both on and off site. A smaller proportion is recycled into secondary materials. The bulk of the waste that is not recorded is dumped illegally in open areas. Waste which is recovered is utilized in high level application such as, road construction building and formed layer.

Construction and demolition waste contributes in the range of 15-30 percent (%) of the total amount of waste that is disposed of in landfill sites in most countries (McDonald & Smithers, 1996). McDonald and Smithers (1996) also claim that this figure increases to approximately 40% when taking into consideration the amount of construction and demolition waste generated. This indicates that construction and demolition waste makes for a large part of the total waste stream of a country.

2.2.3. Quantities of construction and demolition produced in different provinces in South Africa

The record keeping and control of construction and demolition waste entering landfill sites throughout South Africa in general is not of a high calibre. In Table 1a below, the estimates of the total quantities of construction and demolition waste disposed of in the different provinces in South Africa, are reported (Macozoma, 1999).

Table 1b *Summary of Construction Waste Disposal in Landfills in South Africa*

Province	Total construction and demolition waste received in landfills (tons per annum)	Illegal Dumping
Western Cape	200000	Extensive
Kwazulu-Natal	375 000	Extensive
Gauteng	560 000	Extensive
Eastern Cape	64 000	Extensive
Mpumalanga	Minimal	Extensive
North West	Minimal	Not available
Northern Cape	Minimal	Not available
North province	Minimal	Not available

Gauteng has the highest amount of construction and demolition waste reaching the landfills, while the Eastern Cape has the lowest recorded amount that is received annually in landfill sites. It is quite clear that illegal dumping is a serious problem in open areas in South Africa. The extent to which construction and demolition waste is dumped illegally is extremely high throughout the provinces. The reasons behind illegal dumping seem to be: avoiding transportation costs, waste handling costs and landfill taxes.

2.2.4. The need for waste management

A number of developed countries have realized the need to manage their construction and demolition waste stream efficiently. This reduces the quantity of waste that is generated and disposed of in landfills annually. Many countries have, or are in the process of, developing legislation (e.g. landfill taxes), aimed at controlling the disposal of construction and demolition waste in landfill sites. However landfill taxes, in many cases, have tended to encourage illegal dumping of construction and demolition waste.

To discourage this, government is looking for ways to promote the use of recycled materials. One key method of achieving this is through the establishment of a secondary materials market. In order for a secondary market to be viable, government needs to promote the use of secondary materials, provide an enabling environment for secondary materials supply and production, as well as help to stimulate the demand for recycled materials and products (Macozoma, 2001).

2.3.The Extent to Which Construction and Demolition Waste is Recycled

2.3.1. Definitions

The term *recycling* refers to the processing of raw waste materials to produce secondary materials suitable for use in building and construction activities (Macozoma, 2002).

The term *re-use* refers to the direct use of recovered construction and demolition waste materials in building and construction activities, without any kind of artificial processing of the material waste (Macozoma, 2002).

2.3.2. Material availability for the recycling process

Quantities of raw materials: A recycling plant must be situated in an area where construction and demolition activities are taking place. The distance from these sites to the recycling plant should be as short as possible so as to reduce transportation costs.

The quality of construction and demolition waste: The quality of construction and demolition waste brought to the recycling plant will determine the cost of recycling. Recycling of waste would not be feasible if the construction and demolition waste were contaminated, since the cost of pre-recycling would be high

and the rate of recovery of the products would be low, thereby increasing the operating costs. Such circumstances would be unfavorable for the recycling process.

Removing contaminants: In order to produce good quality recycled materials, it is essential to separate out different types of materials from the debris before it enters the crusher (recycling plant). The best place to start this separation is on demolition and construction sites. Wooden fixtures, windows, plumbing and wiring can be removed and recycled separately before the rest of the structure is demolished. It is predominantly vital to exclude materials which could contaminate the debris. The levels of impurities have to be controlled when recycling construction and demolition waste in order to ensure that the finished recycled materials have consistent strength and durability. (Macozoma, 2000)

Quality controls: The primary requirement for provisions of good quality recycled materials and products, is input control for materials (construction and demolition waste) received at the recycling plant. Each load of unprocessed material received at the plant should be inspected and if accepted, placed in a stock pile designated for the various grades of recycled materials to be produced.

(Macozoma, 2002)

Location: The location of the recycling plant plays a vital role in determining the success of a business. In the case of a fixed recycling plant, the distance from the construction and demolition site should be as short as possible.

Storage: Construction and demolition activities are limited. It is important for recyclers to stockpile the raw materials when the material is available. The stockpile will ensure that the recycling plant operates continuously. The constant operation of a recycling plant during the downturn phase of the construction industry (no supply of material) will guarantee the supply of secondary materials in the market. This guarantee is vital in order to establish a positive perception of the secondary materials, by the engineers (consumer). The area where the recycling plant

is located should therefore allow an additional space for stock piling the raw materials (Macozoma, 2000).

2.3.3. The advantage of recycling construction and demolition waste

According to Patel (2002) the following are the reasons for developing recycling of construction and demolition waste:

- **Compliance with policy, legislation and regulation**

Most countries have tough policies and regulations regarding the generation of waste. Companies that take the route of recycling or using recycled materials could effectively avoid costs such as tipping fees and government fines.

- **Elimination of illegal and unauthorised dumping**

Recycling of construction and demolition waste would discourage illegal and unauthorised dumping of these materials. The main reason that underlies the illegal dumping of waste is the cost associated with the disposal of the waste and various individuals avoid these high costs of disposal via illegal dumping. Recycling of these materials could provide monetary incentives to these individuals and, as a consequence, discourage illegal dumping.

- **Controlling costs**

Costs associated with the transportation of waste, tipping fees and wastage of materials can be recovered when the construction and demolition waste is recycled or re-used. Organizations that deal with recycling of construction and demolition waste offer payment in return for good quality (recoverable waste) waste materials.

- Conservation of natural resources

Recycling of construction and demolition waste ensures that materials are put back in the materials cycle. Closing the materials cycle loop would conserve natural resources as well as reduce the dependency on virgin materials. This is vital for achieving sustainable construction.

- Reduction of waste volumes to landfills

Land is scarce and the more that landfills are filled the less land there will be available in future. In order to prolong the life of a landfill the amount of waste disposed needs to be reduced. Recycling of waste would trim down the amount of waste reaching the landfill thereby increasing the life of the landfills.

- Use less energy in material

The amount of energy needed to produce recycled products is less than the energy used to produce similar products. For example, recycling aluminium products saves large amounts of energy.

- Reduction of environmental harm

Excess dumping of waste in landfills, illegal dumping of waste and excessive extraction of natural resources would harm the environment. As previously mentioned, recycling reduces the amount of waste disposed of, and this would reduce the environmental degradation.

2.3.4. Recycling of construction and demolition waste in the United Kingdom

In the United Kingdom (UK) the construction and demolition waste is seen as a potential source of raw material. The utilization of construction and demolition waste reduces the reliance on primary aggregate, thus lowering the environmental impact of construction. The Environment Agency of England and Wales conducted a survey to

provide an estimate of the quantity of construction and demolition waste generated annually. Approximately 70 million tons of construction and demolition waste was generated, 5 million tons of which was recovered (approximate 9.2%) was revealed by the estimate. In 1995 the UK Government White Paper *Making Waste Work* set targets for increasing the use of waste and recycled materials as aggregates to 30 million tons per annum by 2006. In order to achieve this, incentives were introduced for the purpose of encouraging the use of recycled materials. The tax on disposal of waste material to landfills, imposed as a “green” taxation measure in 1996, was an economic incentive to increase the recycling of construction and demolition waste.

Lawson et al. (2001) ascertained that the UK government had set targets ensuring that 60% of new developments should be located on brownfield sites. The problem that the developers were faced with was that the land was contaminated. No guidelines on how to classify whether waste is contaminated or not, were available. This problem was solved when the Building Research Establishment (BRE) and the University of Manchester developed a risk assessment methodology for contamination of construction and demolition wastes.

There is growing evidence that the amount of construction and demolition waste which is recycled has increased by a significant amount as a result of the introduction of landfill taxes. The number of fixed and mobile crushing and recycling plant sites has also increased. A survey, which was carried out by McGrath (2001) revealed that the number of recycling sites increased from 100 in 1994, to 400 in 2000.

2.3.5. Recycling of construction and demolition waste in Brazil

In 2000 a survey conducted revealed that the city of Salvador, Brazil generates 1700 tons of construction and demolition waste daily. The government realized that something had to be done to prevent the degradation of the environment caused by excessive waste dumping in landfills. Thus the government passed a policy of reduction of construction and demolition waste.

The municipal waste company of Salvador (LIMPURB) created a “Construction and demolition waste program”. The main objective of this program was to correct the environmental degradation caused by illegal disposal of construction and demolition waste. The company identified the reason for illegal dumping as the distance from the construction and demolition site to the landfills. Decentralization of construction and demolition waste reception and disposal was introduced. To achieve this, a number of strategically located areas were prepared to receive those waste materials. These areas were (and still are) called construction and demolition Waste Disposal Sites (WDS), and construction and demolition Waste Disposal Bases (WDB). WDS receive waste from small generators and are placed next to construction and demolition waste generator areas. WDS have the capacity to accommodate up to two meter cube (2m³) of construction and demolition waste per day. The waste is then transferred from the WDS to the WDB, which is located near a recycling plant. Each plant is capable of processing at least 200 tons of construction and demolition waste daily. The decentralization of the disposal of construction and demolition waste, guarantees the supply of construction and demolition waste to the recycling plants (Carneiro, Brum, Costa, Sampaio, Alberte, & Viera, 2000).

2.3.6. Recycling of construction and demolition waste in European Union

One hundred and eighty (180) millions tons of construction and demolition waste are produced in the European Union each year. The rate of recycling of construction waste varies between 5% to 95%, in different Member States (Paulo, 2000; Dorsthorst & Hendriks, 2000).

The Netherlands has drawn up a national “Building site waste” plan, comprising actions aimed at banning the landfilling of recoverable waste. As a result of these measures, approximately 95% of the construction and demolition waste is recycled and re-used.

In Denmark, municipalities are responsible for the collection of the construction and demolition waste. In addition to this, the authorities have introduced specific regulations which govern the sorting of construction and demolition waste. The pre-sorting of construction and demolition waste will have the effect of increasing the quality of raw materials reaching the recycling plant, as well as a resultant decrease in processing costs.

2.3.7. Recycling of construction and demolition waste in the United States Of America (USA)

According to a survey conducted by the US Environment Protection Agency (1998), it was found that 20-30 percent of construction and demolition waste was recovered for either re-use or recycling purposes. The re-use and recycling of construction and demolition waste plays a fundamental role in reducing the amount of waste reaching landfills. The correlation between increases in tipping fees and the move towards alternative waste handling options is responsible for the increase in the number of recycling facilities. In 1996, there was an estimated 1800 recycling facilities in the United States of America. This number doubled in the next two years to 3500 facilities in operation in 1998. (Macozoma, 2001)

The success of waste minimization through waste reduction, recovery and recycling has been controlled by the close network that institutions have kept in an effort aimed towards reducing the amount of waste generated and disposed of in landfills in the US. In addition, the government has been very supportive financially, technically and with infrastructure (Macozoma, 2001).

2.3.8. Recycling of construction and demolition waste in Japan

In Japan, 45 percent of waste generated from construction and demolition of buildings as well as civil construction ends up in landfill sites. In addition to this, almost all of the remaining construction and demolition waste is illegally dumped. Illegal dumping of construction and demolition waste occurs as a perpetuator to avoid high transportation costs and landfill taxes. To improve the current situation the government of Japan has passed a new law controlling the deconstruction process and encourages the recycling of construction and demolition waste. The law was enacted in 2000. It has five main parts, namely:

- Requirement for selective dismantling and recycling
- Action to promote recycling and demolition
- Regulation of the contract between the owner and the dealer
- The establishment for a registration system to demolition dealers
- The setting of objectives concerning recyclers

This law has played a vital role in encouraging the development of recycled materials and reduction of construction and demolition waste (Nakajima & Futaki, 2001).

2.4. Worldwide Utilization of Recycled Materials

2.4.1. Masonry and concrete waste

Masonry and concrete waste generated by construction and demolition activities can be crushed into fine and course aggregate. The fine and course recycled aggregate are utilized in the production of blocks, road construction and the production of mortar.

i. Production of soil-cement blocks

The fine recycled aggregate can be mixed with cement to produce soil-cement blocks. Fabrication of blocks using recycled aggregate as a raw material reduces the environmental impact of such wastes and provides low-cost construction materials.

ii. Road construction

Recycled aggregate is used in the construction of the base and sub-base layers of roads. Using recycled aggregate in the flexible-granular bases and sub-bases of roads consumes large amounts of recycled materials.

iii. Hardcore (Building construction)

Recycled aggregate is also utilized as hardcore filling in building construction provided that the grading of the recycled aggregate is checked to suit the condition of the soil.

iv. Granular material for drainage

Recycled aggregates are also used for providing drainage layers.

v. Production of mortar and concrete

Mortar and concrete can be produced using recycled aggregates instead of primary aggregates. Recycled aggregates are produced when the construction and demolition waste (consisting mainly of rubble) is crushed by a recycling plant into fine and course aggregate. Fine recycled aggregate can be used to produce mortar and course recycled aggregate can be used to produce non-structural concrete. However the utilization of recycled aggregate in structural concrete might reduce mechanical performance and durability of concrete. For this reason the possibility of re-using recycled aggregates in alternative ways should be examined (Moriconi et al, 2002).

2.4.2. Timber waste

Construction timber waste is in the form of timber pallets, crates, cable drums and formwork. The majority of this waste can be re-used or recycled into secondary materials. However, formwork materials have a greater possibility of contamination, due to their contact with oil and concrete.

Timber recycling is now a common path for a large amount of untreated timber waste generated in construction and demolition sites. The virgin feedstock which was used traditionally in the manufacturing of wood panels is now replaced with recycled fiber in chipboard (Hobbs & Hurley, 2001).

According to (Lohman, 1991) timber from demolished buildings can be utilized to manufacture wood-chip concrete by injecting cement grout into the voids of compacted wood-chips in moulds. However the mechanical properties of the wood-chip concrete does not tolerate structural construction but can be utilized in non-structural construction.

2.4.3. Metal waste

Steel reinforcement from demolished concrete is usually separated from the rubble on the site and sold as scrap to recycling plants. There is a tendency to re-use old reinforcement bars. This growing demand has proved lucrative enough for the demolition contractors to employ full-time workers, whose jobs are to straighten out the tangled mass of distorted and twisted rebar for use again as reinforcement steel in concrete for new buildings

2.4.4. Glazing

The main incentives for recycling glass from demolition sites are to cut energy costs and to reduce the impact on the surrounding environment due to quarrying of raw material. Glass can be recycled into a number of materials: it can be substituted for quartz of feldspar in the manufacturing of high-strength porcelain sanitary ware; it can also utilized in the production of mineral wool which is utilized in production of insulation products; and crushed glass can be used in concrete mixing as a substitute for aggregate. In the USA glass granules are used to fabricate bricks which can be consumed in the construction process.

2.4.5. Plastics

There is an over-abundance of waste plastic, which is becoming more difficult to dispose of in landfills because of stricter environmental regulations. Waste plastic can be shredded and used as fillers in other materials such as concrete.

According to Elias-Ozkan and Duzgunes (2000) the use of granulated polymeric (plastic) waste materials as aggregate and fillers in masonry mortar and outdoor plaster is not only a method of recycling plastic but also a technique which results in the following advantages for mortars and plaster: low thermal conductivity; low bulk density; low wear of mixing and pumping equipment due to the lesser hardness of the polymers compared to mineral aggregates.

2.4.6. Asphalt

Asphalt is almost exclusively placed right back in the hot mix to be replaced on the road again. Recycling asphalt is a well-established industry throughout North America. A very large and established industry exists that recycles asphalt exclusively, and it is estimated that more than 150 million tons are recycled annually (www.cdrecycling.org/history.htm).

Asphalt paving materials are recovered from demolished roads. The recovered asphalt is recycled for both asphalt binder and for the aggregates.

2.4.7. Gypsum

Since Gypsum is a difficult material to recover from wallboards at demolition and construction sites, most countries have banned this material from landfills due to its contamination effect on the environment. Canada is an example of one of these countries.

2.5. Examining the Secondary Market

2.5.1. Introduction

Secondary construction materials markets consist of suppliers, industries and end consumers of the secondary materials and products that are sourced from recovered construction and demolition waste (Macozoma, 2001). Secondary construction materials markets have the potential to absorb construction and demolition waste that is fabricated. The incorporation of these wastes by the secondary market reduces the amount of waste reaching landfills and/or being illegally dumped. The benefit of establishing a self-sustaining secondary market not only decreases environmental degradation caused by the construction industry, but creates job opportunities, revenue streams and unveils new economic opportunities, while addressing the problems relating to construction performance and waste management practices (Macozoma, 2001).

The biggest challenge faced in the recycling of construction and demolition waste, is the location of the market that will absorb the secondary materials. The extent to which the secondary materials will be absorbed will depend upon the public demand for these materials, their quality and performance, their price in comparison with virgin materials, and the supply of these secondary materials.

2.5.2. Competition

In situations where competition is high, the secondary material price is regulated by the market condition. Recyclers have little or no power to control the market price. The competition can exist between secondary materials and virgin materials. In such a case, the supplier for virgin materials can decide to lower the price of these materials, thereby discouraging the consumer from buying secondary materials. Competition among recyclers also allows for the price of secondary materials to be slashed. This situation has the following advantage and disadvantage. The advantage

of having competition among recyclers is that the quality of secondary materials will improve and the production process will be efficient. On the other hand, the disadvantage of competition among recyclers is that the selling price of secondary materials is decreased. This decrease in price will reduce the profit margin, which will reduce the incentive for the recycler to invest in research and to find new innovative ideas.

2.5.3. Allocation of resources

A fair amount of resources must be allocated to find new opportunities for expanding markets. It is vital for any recycling plant to uncover innovative marketing techniques that will attract potential clients. It is also important that future trends of secondary materials be closely followed, and that research into innovative ideas for the recycling of construction and demolition waste be conducted.

2.5.4. Markets Constraints

According to Patel (2002) the following factors hinder the development of a secondary market:

- Low cost of primary materials

There are many suppliers who deal with primary materials. As a result of this the competition that exists among primary materials suppliers is fierce. Companies that want to survive must offer their products at lower price. This has therefore lowered the price of primary materials over the years. Various recycling plants cannot compete with such prices, thus creating barriers for establishing a market.

- **High capital costs for processing**

The amount of capital that is needed to establish a recycling plant is high. Due to the high risk and unstable markets of recycled materials, the majority of investors find it unattractive to invest an enormous amount of capital in such products.
- **Environmental concerns**

The process of recycling construction and demolition waste generates dust and noise. These factors have forced authorities to not grant permission to process construction and demolition waste on sites and in residential areas. This has resulted in increases in costs such as transport, and has discouraged the manufacturing of recycled materials.
- **Perception of standards and specifications**

The perception that recycled materials are inferior because they are produced from waste, together with the specification criteria of materials used in construction (which do not take into account recycled materials) are the main barriers for establishing a secondary market.
- **Irregular and uncertain flow of materials**

In order for a market to be established there must be a demand for the product as well as a supply of the products. Due to the fact that the recycling of construction and demolition waste is dependent on the construction and demolition activities taking place in the area, it is difficult for the recycler to guarantee the supply of recycled materials to the market to satisfy the demand. The irregularity and uncertainty of the flow of recycled materials to the end user has created a barrier for establishing a secondary market.

2.5.5. Market development

The following factors are fundamental to the development of a secondary market:

- Technology development

Technology development in relation to the recycling process is a key factor towards establishing a stable secondary market.

- Changing the perception

In order for a secondary market to develop and sustain itself, the way in which people perceive recycled materials needs to change. The negative perceptions that exist throughout important stakeholders in the industry need to change.

(Patel, 2002)

2.5.6. Stimulating secondary markets

According to Patel (2002) the following factors can be used to stimulate the secondary markets:

- Restriction or bans

Imposing restrictions or banning the disposal of recoverable construction and demolition waste is an approach to stimulate a secondary market. This approach forces the parties responsible for generating waste to recycle the construction and demolition waste generated on site.

- Subsidies for recycling businesses

The cost of establishing a recycling plant is high. In addition to this the cost of running the plant is also high. The government can offer financial incentives in the form of subsidies for recycling business which will encourage entities to

establish recycling plants and increase the supply of recycled materials to the end-user. This would stimulate the secondary market.

- Enforce waste management plans

The quality of the recycled materials depends on the quality of input (construction and demolition waste received). The quality of recycled materials is a key factor in developing the demand for these materials. By enforcing effective waste management plans on construction and demolition sites a decrease in waste as well as an increase in the quality of recoverable construction and demolition waste would result. Therefore by enforcing effective waste management plans on site the quality of recycled materials is enhanced.

- Education and training

Education and training in respect of recycled materials are the most important factors to be considered when attempting to stimulate the secondary market. The negative perceptions about recycled materials that exist among stakeholders are due to inadequate knowledge and experience regarding these materials. Thus by providing education and training the awareness among these stakeholders would increase.

2.5.7. Setbacks to the development of secondary materials in South Africa

Standards and specifications: South African standards and specifications have not taken into account the use of alternative construction and secondary materials. The main factor contributing to this is the negative perception of the secondary materials, among the clients, designers and contractors. None of the mentioned parties are ready to use secondary materials, since they are not familiar with the risks involved. Many are also unaware of the research that is currently taking place in the field of secondary materials. The few standards regarding secondary materials that do exist in South Africa involve, technical testing of materials to

determine durability. This approach takes time and has a cost implication which discourages the use of secondary materials (Macozoma, 2001).

Market dynamics: The South African secondary market is not well established (Macozoma, 2000). A problem exists in getting the raw materials from the construction demolition sites to the recyclers. There is also no incentive for the contractor to dump the construction and demolition waste on recycling plant sites. Authorities are sensitive and unwilling to grant permission for construction and demolition waste recycling on demolition sites, naming noise and dust as their reason. The recyclers have difficulty selling secondary materials because of the limitations imposed by the standards and specifications for building, as well as the negative perceptions traditionally held by engineers, who are generally unwilling to explore new materials in the market. Funding for recycling plants, and quality assurance are still the main setbacks faced by recyclers in South Africa.

Incentives: There is no mechanism that will encourage the separation and the recycling of construction and demolition waste.

Inadequate awareness: Lack of awareness of the potential opportunities for using recycled materials and the lack of resources, are factors contributing to inadequate marketing of recycled materials. There is a need for marketing and sales support.

2.5.8. Possible solutions

Government support: This is probably one of the most important stakeholders that can support the development of a self-sustaining secondary construction materials market. Government support can include partnerships, financial support, technical support, legislative support and infrastructure.

- **Partnerships:** Construction and demolition waste affects more than just the waste management sector. It is quite clear that an integrated approach is required. In order to attain adequate interaction among designers, contractors, clients and recyclers (Macozoma, 2001). Partnerships with private sectors and communities will enhance the interaction that is critical for the development of the secondary materials market.
- **Financial Support:** Starting up a new construction and demolition waste recycling plant requires a large amount of capital (Kibert et al, 2000), as recycling plants are very expensive. Financial assistance is not only needed at the initial stages of the company but also in the expansion of the markets. For instance, the market appears to be ready for expansion but is stagnated by the companies' lack of resources (financial resources). In addition to this, the recycler will need extra capital to cover the start-up costs. The government can offer assistance in the form of financial support through sponsorship of demonstration projects, as well as reducing or removing taxes on recycling plants and materials in attempt to lower the market price of secondary materials.
- **Technical support:** The government can support the recyclers through the involvement of government staff in research teams or by participation in deconstruction projects.
- **Legislative support:** The government is capable of exercising its power to draft new laws. The new laws passed by parliament could aim to discourage disposal of useful construction and demolition waste in landfills and promote the use of secondary materials. For example, in the Netherlands, the government had banned the disposal of any useful construction and demolition waste, and, as a result of this action, the rate of recycling construction and demolition waste increased to ninety five percent (95%) – the highest in the world. The government can also increase landfill taxes

known as “green tax”, which will discourage the disposal of construction and demolition waste. However this may encourage illegal dumping of construction and demolition waste. What the government could do, is reduce or remove the taxes related to the recycling process and offer tax exemption to clients who use secondary materials. The government could also increase the tax on virgin materials. This will all serve to promote the use of secondary materials.

- **Infrastructure support:** The government can provide infrastructure support to construction and demolition waste recyclers by offering state laboratories as well as the use of state equipment (Macozoma, 2001).

Standards and specifications: According to Macozoma (2001) there is a need to move from prescriptive specifications, as they have been shown to limit innovation in secondary material use. Macozoma (2001) suggests that the appropriate form of specification is a performance-based specification. This kind of specification details only the performance aspects of a particular material and not its composition. This will undoubtedly give opportunity to the utilization of secondary materials. Ongoing research and development is needed with reference to the type and methods of testing in order to ensure that all materials are tested on merit and accommodated by specifications where appropriate.

Incentives: Variable cost pricing should be introduced as a substitute for flat rate pricing. Variable cost pricing has been introduced in a number of countries to increase the marginal cost of waste disposal, to expose waste generated to real cost of waste disposal, and to create an incentive for people to recycle waste. Pricing mechanisms which can be used for encouraging the recycling of construction and demolition waste include: average pricing, two-tier pricing and marginal pricing. The average pricing of construction and demolition waste is a process whereby the total price for the year is calculated and shared among parties who are directly involved in the generation of waste. The two-tier mechanism for pricing involves two stages for pricing. The first stage includes a flat fee that is established up to certain level,

afterwhich the price is raised by a considerable amount in second stage. Through marginal pricing, the waste is priced per unit of waste dumped. These pricing mechanisms can be used to promote recycling and minimization of construction and demolition waste. Since the greater the waste generated the higher the cost will be (Macozoma, 2001).

The government can create business opportunities by injecting funds into programs that will encourage the use of secondary materials and also provide areas where high quality construction and demolition waste can be disposed of for free. The free disposal of high quality waste will act as an incentive to promote a waste management plan of construction and demolition waste on site. The high quality construction and demolition waste which has been disposed of will also provide incentives for the creation of more recycling plants, since raw materials are easily available and their quality is high, resulting in end products of a better quality.

2.6 Chapter Summary

This chapter reviewed the literature on the following topics: sources of construction and demolition waste, the current status of construction and demolition waste in South Africa, the extent to which recycled materials is recycled, and the market barriers in establishing a self-sustaining secondary market. The chapter to follow will discuss the research design and the methodology used in this dissertation.

CHAPTER 3: *RESEARCH DESIGN & METHODOLOGY*

University of Cape Town

3.1 Introduction

In the previous chapter it was found that the extent of recycling of construction and demolition waste was affected by the negative perceptions of important stakeholders in the construction industry, namely the consultants, engineers, architects, construction managers, and project managers, whose advice could improve or increase the usage of recycled materials in construction.

This chapter outlines research methods used in data collection and presents a description and justification of the research method. The data collection procedure is clearly defined, and the structure of the research questionnaire and the case study are explained.

3.2 Research strategy

In broad terms, there are two types of research approaches, namely quantitative and qualitative research. Deciding which research method to select depends on the purpose of the study and the type and availability of the information required.

3.2.1 Quantitative research

Quantitative research is defined as an inquiry into a social or human problem, based on testing a hypothesis or a theory composed of variables, measured with numbers, and analyzed with statistical procedures, in order to determine whether the hypothesis or the theory held is true (Creswell, 1994). Quantitative research is selected in the following situations:

- To pull together realistic evidence and study the relationship that exists between these facts in order to test a particular theory or hypothesis.
- To uncover facts about a concept, question or an aspect.

3.2.2 Qualitative research

Qualitative approaches seek to gain insight and to understand perceptions of the world, either as an individual or as a group. In qualitative research, the beliefs, understanding, and opinions of people are investigated. The data collected may be unstructured, at least in its raw form, but will tend to be detailed and hence rich in content and scope. The information collected in qualitative research can be classified into two categories of research, namely, exploratory and attitudinal.

- **Exploratory research**

Exploratory research is used when the amount of knowledge about the topic is inadequate. The method for collecting the information is normally interview-based. The purpose of exploratory research is intertwined with the need for clear and precise statements of the recognized problem.

- **Attitudinal research**

Attitudinal research is used to instinctively evaluate the opinion, view or the perception of a person, towards a particular object. The method used for gathering this kind of information is by questionnaires.

3.3 Techniques for data collection

There are a number of techniques that are used for collecting research data. These include surveys, questionnaires, interviews, case studies and triangulation.

3.3.1 Surveys

Surveys are used to gather data from a relatively large number of respondents within a limited time frame. There are two types of surveys:

- **Descriptive survey:** The aim of this survey is to answer questions such as, 'how many, who, where and when?' It entails counting the number of respondents with certain opinions towards a specific object. (Riley et al, 2000)
- **Analytical survey:** The objective of this survey is to establish the relationship and association between the objects of the researcher questionnaire.

(Gillham, 2000)

3.3.2 Postal Questionnaires

Postal questionnaires are probably the most widely used data collection technique for conducting surveys. Postal questionnaires have been widely used for descriptive and analytical surveys. Types of questions which occur in these questionnaires take the form of open-ended or close-ended questions. Open-ended questions are designed to enable the respondents to answer in full. Closed-ended questions have a set number of responses as determined by the researcher (Melville, 1996).

3.3.3 Interviews

Interviews may be structured on three different levels, namely unstructured, structured and semi-structured. One type of research may require the combination of all three forms while other types may require only one form.

Types of interviews:

- **Unstructured interview:** This form of interview uses open-ended questions. The questions are often pitched at a very general level so that the researcher can observe the direction in which the interviewee chooses to take their response. It is usually conducted within a qualitative research framework.
- **Structured interview:** In this form of interview the questions are presented in the same order and with the same wording to all interviewees. The

interviewer will have full control over the questionnaire throughout the entire interview process.

- **Semi-structured interview:** This form of interview is more formal than the unstructured interview in that there are a number of specific topics around which to build the interview.

(Foddy, 1993).

3.3.4 Case studies

Case studies are used when exhaustive analyses of an entity, a group of individuals, or a particular project are sought. The conclusion drawn will not be generalized but, rather, related to one particular event. This is because the case studies which focus on one aspect of a problem. There are three types of case study designs.

Types of case studies

- **Descriptive case study:** This type of case study is analogous to the concept of the descriptive survey, except that it is applied in.
- **Analytical case study:** This type of case study is analogous to the concept of the analytical survey, with the exception that it is applied on detailed cases.
- **Explanatory case study:** This type of case study is based on the theoretical approach to the problem. It explains causality and tries to show linkages among the objectives of the case study.

3.3.5 Triangulation

Triangulation is the use of two or more research methods to investigate the same thing. A questionnaire is utilized to generalize. Thus a representative sample of respondents would assist the researchers to understand the general strength of the finding from the

particular case study and would serve to aid understanding of its unique and generally appropriate features.

(Fellows & Liu, 1997).

3.4 Choice of Research Method

The choice of research method will be determined by the type of information that needs to be captured. The discussion that follows identifies specific information needs of this research and the appropriate research method selected.

3.4.1 Sources of information

This research project aimed to investigate the perceptions that various individuals in the construction industry have regarding recycled construction materials. In order to capture information related to these perceptions, one needs to study the demand and supply that exists for recycled materials. The demand for recycled materials will be governed by the perceptions held among the consumers of these materials. It can also be used to identify precisely what these perceptions are. However to ensure this, other factors should also be examined, including, the supply of recycled materials, specifications and standards for recycled materials, quality of recycled materials, and built-in incentive mechanisms used to encourage the use of recycled materials. It is therefore necessary to use a case study to capture information regarding the supply of recycled materials and a questionnaire to capture information regarding the demand for these materials.

3.4.2 Reason for selection

The research strategy selected for this research report includes a quantitative as well as a qualitative component. The reason for selecting both strategies is due to the fact that information to be collected from the case study conducted, as well as the various perceptions held regarding recycled materials, cannot be quantified. In contrast to this, information gathered through use of questionnaires can be statistically analyzed and quantified using percentages and a ranking scale.

The survey technique chosen for data collection for this research report was 'Triangulation'. The rationale for selecting this technique was that, two techniques were necessary for collecting the data. The first technique utilized was 'a case study' while the second technique was a 'questionnaire'.

3.5 Methodology

The respondents were telephonically contacted and asked if they were willing to participate in the study by completing a questionnaire. The questionnaire (Appendix A) was either hand-delivered or delivered via facsimile to all willing respondents. Questionnaires that were hand-delivered were returned immediately after completion to the researcher, while those delivered via facsimile were faxed back to the researcher. These two techniques of delivering the questionnaires were selected, in order to increase the respondent hit rate. Prior surveys conducted of a similar nature revealed a low rate of response (i.e. 37%).

The questionnaire survey was conducted throughout the Western Cape Region. Questionnaires were sent to companies rather than individuals. The firms were randomly selected using the Professional Directory, Yellow Pages and Master Builders Booklet.

The total survey size amounted to twenty-five (25) firms, comprising large, medium, and small construction contractors, civil engineers and consultants. This diverse sample was necessary to achieve a wide spectrum of the perceptions surrounding recycled materials.

A total of sixteen questionnaires were returned, of which fifteen were suitable for analysis. This constituted a response rate of sixty four percent (64%) which is considered acceptable for a survey of this nature.

Malans Quarries Company, a recycling company in Bellville, was selected for a case study, because it is a well established recycling company in South Africa. Malans Quarries Company was the first recycling company to be established in the Western Cape

Region. It has been operating for more than ten years and it is expanding as a business. Due to the vast knowledge and experience the company has to offer in terms of recycling construction and demolition waste, it was selected among the three construction and demolition waste recycling companies in the Western Cape Region for this case study.

The case study was conducted on one of three Malans Quarries Company recycling plants in the Western Cape Region. The particular recycling plant studied was selected because it is currently *dominant* among the three. The information was captured by observation and a personal interview with the recycling plant manager and the director of Malans Quarries Company.

3.6 Structure of the Questionnaire

The questionnaire was divided into seven sections. Each section was designed to capture the required information (discussed below). Sections one to six of the questionnaire were in the form of a ranking scale. The respondents were required to select one out of four responses provided, namely: strongly agree, agree, disagree, and strongly disagree, to answer each question. Each response selection was based on the experience, knowledge, and skill of the respondent. The last section of the questionnaire consisted of a series of open-ended questions. The open-ended questions were designed to allow the respondent the freedom to add any further relevant information. The additional information provided by the respondent was constrained within boundaries set by the researcher. The pre-setting of such boundaries was necessary to avoid responses containing irrelevant information.

Section one: This section pertained to the quality of recycled materials. Some authors have argued that the quality of recycled material is poor, while others argue that the quality of recycled materials is good provided that specifications are followed. Thus, the aim in designing this section of the questionnaire was to determine the perceptions held by consumers regarding the durability and performance of recycled materials used in construction, so as to clarify the contradiction that exists in the literature.

Section two: This section was comprised of questions regarding the availability of recycled materials. The literature revealed that recycled materials were not well advertised and they are not readily available. This section of the questionnaire aimed to determine the ease of obtaining recycled materials by the consumer. It was thus designed to capture information regarding the availability of recycled materials in the Western Cape.

Section three: This section attempted to establish whether an incentive mechanism would help to encourage the utilization of recycled materials in construction, since the literature stated that reduction in taxes and/ or tax exemption encourages the use of recycled materials.

Section four: This section was aimed at capturing information regarding the South Africa Bureau of Standards (SABS) in relation to the utilization of recycled materials in construction activities. While the literature suggested the use of performance-based testing over traditionally used perception testing for assessing the performance standard of recycled materials, this section of the questionnaire also aimed to capture the perceptions of the respondents regarding assessment of recycled materials using performance-based measuring.

Section five: This section investigated the role of the pre-design phase (i.e. briefing stage) of construction and whether or not it had any influence over the utilization of recycled materials.

Section six: This section was subdivided into two sub-sections. The first sub-section investigated the reasons why some companies do not use recycled materials. The second sub-section investigated the reason why companies did utilize recycled materials, as well as the quantity utilized, and the application of these materials.

3.7 Questionnaire appraisal to ensure that it would work as intended

It was critical that the questions presented in the questionnaire worked as intended. For this reason the following procedure was followed in the questionnaire appraisal.

3.7.1 Editing

The topic, as well as the information that was required about the topic and reason for coveting this information was clearly defined for the respondents. Hypothetical issues were avoided to ensure that the questions asked were relevant to the respondents. Care was taken to ensure that the questions asked were not biased in any way, but were instead, generated from questions arising in previous studies. Layman's terms were used to describe questions to make certain that respondents comprehended them.

3.7.2 Pilot study

A pilot study was conducted on a small sample of respondents drawn from the target sample population. The purpose of this pilot study was to uncover aspects of the questionnaire that were likely to result in ambiguities amongst respondents in the main study, as well as to discover whether or not the respondents interpreted each question as intended. The respondents of the pilot study were systematically asked the following questions by the researcher:

- “Did any of the questions make you feel uncomfortable?”
- “Were any questions repeated?”
- “Which (if any) question(s) was (were) misinterpreted by you?”
- “Were there any sections where you felt that you would have liked the opportunity to say more?”

3.7.3 Question testing

A small sample of respondents drawn from the target sample population was used for question testing. Three techniques were used in question testing. The first technique used was to ask the respondents to rephrase the questions in their own words. The second approach was a double interview, while the last approach was to ask the respondents to think aloud as they answered each question.

- Asking the respondent to rephrase the questions in their own words enabled the researcher to identify the understanding of the question by the respondent.
- Double interview: This procedure entailed presenting each question that was selected for testing to the respondents in the normal way. After each question was answered, a sequence of questions designed to uncover the respondent's interpretation of the key concepts was posed.
- Asking the respondents to think aloud as they answered each question: This approach rests on the principle of having respondents think aloud as they are formulating answers to the questions selected for in-depth investigation. The respondents were asked to write their thoughts down. This information was examined and utilized in formulating the final questionnaire.

3.8 Structure of the Case Study

The case study was designed to capture information regarding the supply of raw materials (construction and demolition waste) to the recycling plant, the recycling process that takes place on a recycling plant and the supply of recycled materials to the customer (contractor). The case study was divided into the following three parts:

Part one: This part of the case study dealt with the supply of raw materials (construction and demolition waste) to recycling plant. It identified the different

suppliers of raw materials to the plant, the procedure taken to check the quality of the raw materials received, as well as the quantity of raw materials received annually.

Part two: This part dealt with the technical aspects of running of the recycling plant. That is, the type of plant used, the capacity of the plant and production techniques applied.

Part three: This part of the case study dealt with the supply of recycled material to the consumer (contractor). The following themes were investigated: the quantity of material sold, feedback from customers (who have utilized the materials), marketing strategies of the company and setbacks faced by the recycling company.

University of Cape Town

CHAPTER 4: *RESULTS & DISCUSSION*

University of Cape Town

4.1 Introduction

This chapter presents the case study conducted at Malans Quarries Company. It also presents an analysis of the case study and the results of the questionnaires.

4.2 The Malans Quarries Company – Case Study

The aim of this case study is to investigate the supply of raw material (construction and demolition waste) reaching the recycling plant; the recycling process that takes place, and the supply of recycled materials to the end user (consumer).

4.2.1 Background

Malans Quarries is a company based in Cape Town that was originally a transport company dealing with the transportation of civil engineering materials. Later the company involved itself in the mining of natural gravel crushings and establishment of sand mines. In 1996, with the demolition of the old Power Station at Paarden Island, it was decided that material from the site be re-utilized for the planned development on the same site. However, the development did not occur. For this reason Malans Quarries entered into the business of crushing the demolition waste from the old Power Station and selling it commercially as recycled aggregates. The company now has recycled aggregates (Crushed rubble), sand supplies, quarrying and gravel supplies as its core business. Consequently since 1996, the company has crushed more than 1,200,000 m³ (cubic meters) of demolition and construction waste and sold it to engineering contractors and brick manufacturers.

4.2.2 Operation of the plant

The construction and demolition waste is loaded into a dump truck by an excavator. From there the material is put into the bin of a crushing plant. The construction and demolition waste is then fed into the primary jaw of the crushing plant. The rubble then

passes on a conveyor belt under a rotary electromagnet. The electromagnet is used for removing metal objects entrapped in the recycle. The crushed rubble passes through a row of hand pickers who remove contaminated particles. The secondary jaw crusher is then used to crush the rubble to the required size. This crushed rubble then passes through a screen. The oversized material re-enters the system and passes through the secondary jaw crusher once again. The diagram below illustrates the operation process of the recycling plant.

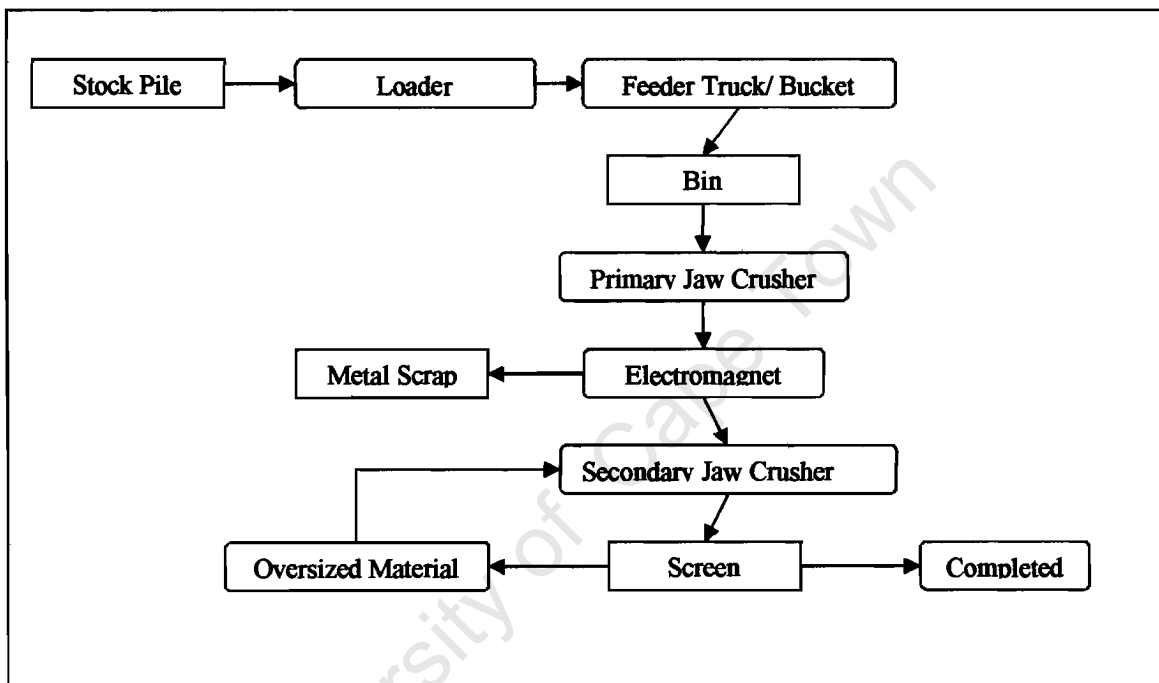


Figure 1a The flow of material on a recycling plant

4.2.3 The supply of raw materials

The main suppliers of raw materials for the recycling plant (crushing plant) in Malans Quarries are construction contractors, civil contractors, and demolition contractors. The quantity and quality received from these suppliers differ. Obviously the quantity received will be greater from the demolition contractor in comparison to that received from the construction contractor.

The construction contractors who supply the raw materials are mainly large construction firms, namely Murray and Roberts, WBHO, etc....

Power construction, Encor Civils, and Brink and Heath Civils, are some of many civil contractors who supply raw materials to the recycling plant. In addition to the civil and construction contractors, Ross Demolishers and Bradis Demolition Company also supply raw materials.

Assessment of raw material quality

Malans Quarries Company has a simplified method of assessing the quality of construction and demolition waste (raw materials) delivered to the recycling plant. The method which is used to assess whether the quality of raw material is appropriate or inappropriate is based on judgments made by experienced personnel. Before the construction and demolition waste is off-loaded from the truck, the material is visually checked by experienced employees, and the decision regarding the rejection or acceptance of the raw materials to be stock piled, is made, based on the perceptions of this employees, who draw from their knowledge and expertise. Despite the fact that Malans Quarries does not have any sophisticated method of testing the quality of the raw materials received by the suppliers it has managed to provide excellent quality recycled materials by implementing this simple quality checking method.

Sorting of the raw materials

The construction and demolition waste materials need to be sorted before they can be recycled. A high proportion of sorting takes place before the materials reach the recycling plant. Most of the sorting takes place on the construction and demolition sites, however the extent to which construction and demolition waste is sorted on site will be determined by the waste management plan implemented. Well-organized waste management plans will reduce waste contamination. Malans Quarries is faced with the additional costs of landfill taxes (Appendix B) transporting contaminated waste (i.e.

paper, plastics). Such costs could be avoided, if the suppliers had better waste management plans in place. It is vital for a recycling company to cut down its costs so as to provide reasonably priced recycled materials in comparison to virgin materials.

Quantity of raw materials received

Malans Quarries receives approximately two hundred thousands tons (200 000) of construction and demolition waste annually. Due to the highly unpredictable nature of construction and demolition waste supply, Malans Quarries have adopted a system of building up stockpiles of raw materials. The stockpiles ensure a continuous supply of raw materials, in addition to a guaranteed supply of recycled materials to its customers.

The composition of materials received

The raw materials received from the supplier at Malans Quarries generally consist of a mixture of concrete and masonry rubble as well as small traces of metal, plastic, wood and paper. The concrete and masonry rubble is mixed with excavation rubble. The mixing of the rubble makes the recycled materials better binding. The mixed raw materials are stock piled after which no separation of different elements is done (i.e. keeping concrete rubble separate from the masonry rubble).

4.2.4 The supply of recycled materials to the end user

The main clients that Malans Quarries supplies with recycled materials are construction contractors, civil contractors and brick manufactures. The contractors include:

- Power Construction
- Martin & East Civil
- Encor Civils
- Quideon Contractors

The above named contractors are the main clients for the company, but are not the only clients, as many others have not been named here.

Projects utilizing recycled aggregate supplied by Malans Quarries

The following are some examples of projects where Malans Quarries have supplied recycled aggregate:

- Century City, Ratanga Junction, and Grand West Casino where recycled aggregate was used as a sub-base for the parking lots.
- The Cape Town International Conventional Center where Malans Quarries supplied the recycled aggregate G-5 as a sub-base and G-7 as a layer below the sub-base. The recycled aggregate supplied were used for the access roads and parking lots. The quantity of recycled aggregate supplied was approximately 2850 tons.
- Westlake Office Development where 80% of the materials used in the road infrastructure was crushed demolition waste from the demolished buildings on site.

Quantity of recycled materials sold

Approximately two hundred thousand tons (200 000) of recycled materials are produced and sold annually. When compared with the amount of raw materials received before recycling, the amount of recycled materials sold annually is approximately equivalent.

Application of recycled materials

The most common applications of these recycled materials are as follows:

- G-5: This type of recycled material is used in road construction or parking as a sub-base.
- G-4: This type of recycled material is also used in road construction or parking as a base-course.
- G-7: This type of recycled material is used in brick manufacturing.

These materials are however, not limited to road and parking construction. They have other applications too, for example, some of these materials are used in the manufacturing of bricks.

4.2.5 The perception of the consumer from the supplier's point of view

Malans Quarries have been supplying recycled materials for more than six years. The response that the company has received from the customers in terms of the quality of recycled materials has been that the materials supplied are good, and that no traces of defect or failure have been acknowledged (Appendix C). However, the company is still faced with the problem that some consulting engineers continue to hold negative perceptions about the recycled materials, disallowing the use of these materials. The reason given by these consulting engineers has been that the materials are inferior in quality. However when consulting engineers were asked to provide evidence to support their argument, it was found that their argument had no basis.

Frequently asked questions of first time buyers

The two most common questions that are asked by first time buyers of recycled materials include:

- Do the materials conform to standards specifications?
- Are the materials inferior to virgin materials?

Marketing barriers

The main problem faced by Malans Quarries in terms of marketing the recycled materials is the negative perception that exists in people about these materials. They hold the belief that because recycled materials are produced from recycled waste they must be inferior in quality. The consultants' failure to accept these materials is the main problem faced by all recyclers.

Malans Quarries have developed a marketing strategy that can help to create new markets. The strategy focuses on manipulating the price of recycled materials. The company has seen what a reduction in price of the recycled materials can do to the market for these materials. The company conducted an experiment to test this price manipulation strategy, by lowering the price of recycled materials to 20% less than virgin materials. In so doing, they noticed an increase in the demand for these materials. As the demand for these recycled materials increased, the negative perceptions (inferior quality) about these materials, previously held by some consultants, reduced.

Malans Quarries also used academic institutions for research and development of recycled materials in terms of improving the quality and process methodologies to be implemented. Continuous improvements in recycled materials will lead to better markets in the future.

4.3 Case Study Discussion

4.3.1 Introduction

Two particular tactics were used in the analysis of the data obtained from the case study conducted, namely, pattern matching and time series analysis. The pattern matching technique involved comparing the observed processes to the theory derived processes, while the time series analysis technique was used where the interaction of tasks across timelines was analyzed. The discussion to follow will include considerations of the following themes: raw materials delivered to the recycler, sorting of the raw materials, the supply of recycled materials to the end user, and the perceptions of the consumer from the supplier's perspective.

4.3.2 Raw materials delivered to the recycler

Large construction companies, civil engineering companies and demolishing companies were found to be responsible for maintaining the supply of raw materials to the recycling plant, and the quantity of raw materials delivered was dependent on the stage of construction that each of these companies was at. For example, during the demolition and excavation stages of construction, the quantity of raw materials delivered was reported to be at its highest, whereas during the finishing stages, raw materials supplied to the recycling plant was generally at its lowest.

The case study revealed the interesting finding that small contractors did not contribute to the supply of raw materials to the recycler. In the Western Cape, the number of small contractors is much higher than that of large contractors. However, these small contractors mainly engage in renovation contracts where a high percentage of waste is generated from renovation activities. Additionally, because the total waste generated consists mainly of small batches of waste, the majority of these batches either, end up at landfill sites, or are illegally dumped.

Furthermore, a large number of small contractors, particularly in the Western Cape, may not prioritize the implementation of waste management plans. In such instances, waste generated may be contaminated, with many different types of waste materials mixed together, as it may not be economically viable to transport small quantities of waste produced. Therefore, potentially recoverable waste may not be re-usable or recyclable.

The establishment of a decentralized system for collecting construction and demolition waste would increase the supply of raw materials to the recycler as well as discourage illegal dumping. Such a decentralization technique has been utilized in Brazil and in Denmark (Carneiro et al, 2000), and the literature suggests that these decentralization techniques have proved to be a success. However, in order for the decentralization technique to sustain itself a demand for recycled materials is necessary.

One decentralization technique is currently being implemented in South African by the paper recyclers, “Sappi”. This company has established small stations where waste paper is collected. These stations are located in prime areas where waste paper is generated (i.e. schools, copy shops and offices). Introducing an equivalent technique in the construction industry in the Western Cape, may assist in increasing the supply of raw materials to the recycler.

Another finding revealed in the case study was that the annual amount of raw materials (construction and demolition waste) received by Malans Quarries’ recycling plant was approximately two hundred thousand tons. In comparison to the amount of waste reported to be generated annually (Macozoma, 1999), the amount of waste received is proportionally small. In addition, the literature suggests that in the Western Cape two hundred thousand tons of construction and demolition is dumped in landfills annually. However, inadequate record keeping has resulted in difficulties quantifying the exact amount of waste received in these landfills (Macozoma, 2001). It is also important to remain cognizant of the fact that the two hundred thousand tons of waste reported to be dumped in landfills annually, excludes all waste being illegally dumped. Even so, two hundred thousand tons of waste reaching the landfill sites, is still a large amount of waste

to merely discard. Deficient waste management implementation may have contributed to this excessive amount of waste dumping in landfills.

4.3.3 Sorting of the raw materials

The literature states that sorting of construction and demolition waste is fundamental to the development of the quality of recycled materials, where this quality is dependent on the quality of the raw material input. Countries like Denmark have noted the importance of sorting construction and demolition waste. In such countries, the authorities have introduced specific regulations which govern the sorting of construction and demolition waste, where the pre-sorting of construction and demolition effectively increases the quality of raw materials reaching the recycler. Since the recycler has little control over the quality of raw materials received at the recycling plant, the recycler accepts all raw materials that meet the standard set by the recycler. In addition, the recycler has the option of rejecting the raw materials judged to be below the set standard, or accepting these materials and bearing the cost of separating recoverable waste from the rest of the waste. In conducting the case study on Malans Quarries it was found that recyclers did not accept any raw materials judged to be below standard, thus leaving the contractors with no other option but to dump all the rejected materials in landfills.

Had effective waste management plans been implemented on the construction and demolition sites, prevention of this large quantity of poor quality raw materials dumped in landfills may have been possible. Effective management of waste would have ensured that recoverable waste was kept separate from non-recoverable waste, and if the recoverable materials were further sorted out into different components (i.e. wood, glass, concrete, masonry), the likelihood of their quality remaining of an appropriate standard would have been high. Furthermore, through implementation of effective waste management plans, additional revenues to the contractor and the recycler would have been ensured, in that contractors would have received income for the materials supplied to the recycler, while the recycler would have profited from sales of high quality recycled products (i.e. a 'win-win' situation).

The results of the case study verified the technique Malans Quarries utilized to inspect raw materials before accepting them for recycling. Because construction and demolition waste brought to the recycling plant generally consisted of a mixed variety of materials, conducting any technical testing on these materials, (e.g. hydraulic testing of concrete rubble) was not possible. Therefore, the technique used by Malans Quarries was based on a visual examination of the raw materials, which may have been inefficient, in that such a technique allows for much variability in subjective judgments of the standard of the raw materials.

Once more, had appropriate waste management plans been implemented on the construction and demolition sites, where waste generated was classified according to recoverable use, technical testing may well have been possible.

The case study also revealed that additional costs were incurred by Malans Quarries for removing contaminated waste from the recycling plant and transporting it to landfill sites. These costs were reported to increase the overhead cost of the recycling plant. Given that the competing advantage of recycled materials over primary materials is the 'price', it is vital for the recycling plant to avoid any unnecessary sundry costs, since any additional costs would have a severe impact on the demand for recycled materials.

4.3.4 The supply of recycled materials to the end user

The case study revealed that the quantity of recycled materials sold annually was approximately two hundred thousand tons, which was equivalent to the amount of raw materials received annually, implying that recycled materials are utilized in the Western Cape. However the case study also revealed that in comparison to primary materials, the amount of recycled materials used in the Western Cape is extremely small.

Through the case study it was found that Malans Quarries supplied secondary materials as well as primary materials yet, the amount of primary materials supplied in one month

was equivalent to the amount of recycled materials supplied in an entire year. It was also reported that a number of consultant engineers refused to utilize recycled materials, stating 'inferior quality' of these materials as their reason for refusal. Negative perceptions held by consultants regarding secondary materials may also have contributed to this excessive difference in the demand for primary versus secondary materials. Previous literature on the topic revealed a similar pattern, although the reason for refusal suggested by the literature included the fact that *inadequate knowledge* and *awareness* of recycled materials played a vital role in prolonging the negative perceptions among various consultants.

The recycled material sold by Malans Quarries was reported to be used primarily in road construction, with G-4 and G-5 being the recycled materials most commonly produced. The reason stated for this was that these materials could be easily tested before being employed in road construction. In addition to this road construction is not as complex as the construction of buildings, where risks are high and unfamiliar to consultants. The literature has suggested that this risk factor has played a major role in discouraging the use of recycled materials in other construction activities (Lima, 2000), and this suggestion was confirmed through the case study.

The case study did however highlight the fact that more consultants and constructors are experimenting with the use of recycled materials, than in the past. This was evident in the other applications of these materials, that were reported, including application in parking lot construction (which is similar to road construction), as well as brick manufacturing. These other application patterns reveal a positive trend for the development of recycled materials. However the transformation towards the utilization of recycled construction materials is slow.

4.3.5 The perceptions of the consumer from the supplier's perspective

The literature proposed that the negative perceptions held by various individuals created a market barrier for recycled materials (Macozoma, 2001). This was confirmed in the case study, where the recycler reported that the biggest challenge for establishing a sustainable secondary market was to persuade the consultants that recycled materials could be utilized in construction without affecting the quality of the end product.

Malans Quarries have successfully implemented a particular strategy to assist in the persuasion of the consultants who previously disagreed to utilize recycled materials, to make use of recycled materials. This implies that resistance by various individuals to the utilization of recycled materials is not based on the actual performance of these materials, but rather on the lack of awareness and knowledge regarding recycled materials.

Serious marketing is required to spread the awareness concerning the use of recycled materials. Many recyclers have insufficient resources available; this has played a role in hindering the development of recycled materials in the Western Cape. Macozoma (2001) suggests that government support is needed in order to spread awareness of recycled materials.

4.4 Results and Discussion of the Questionnaire

4.4.1 Introduction

The following section presents the results and analysis of the questionnaire.

4.4.2 Section one of the questionnaire

This section aimed to determine the perceptions held by consumers regarding the quality of recycled materials, in terms of durability and performance. Three questions were presented in this section of the questionnaire. The first question was designed to gather information regarding whether the respondents thought that recycled materials could be a substitute for primary material. The second question was included to determine the respondent's perceptions regarding the performance of recycled materials, and the third question was incorporated to investigate the perceived gap between recycled materials and primary materials, in terms of usability.

4.4.2.1 Question 1: Can recycled materials replace primary materials?

Figure 1 below depicts the distribution of responses from all respondents to question 1 of the questionnaire, in terms of percentages.

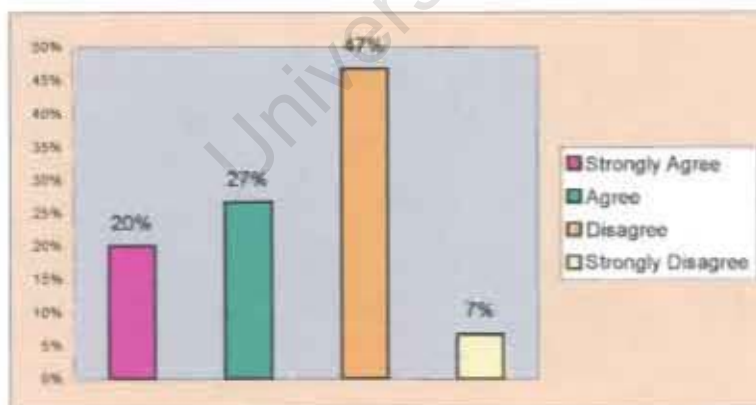


Figure 1 Percentage scores for respondents on question 1

With reference to Figure 1, twenty percent (20%) of respondents strongly agreed, twenty seven percent (27%) agreed, forty seven percent (47%) of the respondents disagreed and seven percent (7%) strongly disagreed, that recycled materials could replace primary materials.

A gap was noted between respondents who agreed versus those who disagreed that recycled materials could be used in situations where primary materials are currently being applied in construction activities (forty seven percent of the respondents disagreed, while twenty seven percent of the respondents agreed). The majority of respondents seemed to prefer to utilize primary materials in construction activities. Previous studies have demonstrated similar results (John & Zordan, 2001). However the divergence between the respondents who agreed and disagreed (47% vs. 54%) appears to have narrowed over time. This pattern implies that more individuals are leaning towards the use of recycled material in construction activities where such materials may be utilized as a substitute for primary materials.

4.4.2.2 Question 2: Are recycled materials durable?

Figure 2 below depicts the distribution of responses from all respondents to question 2 of the questionnaire, in terms of percentages.

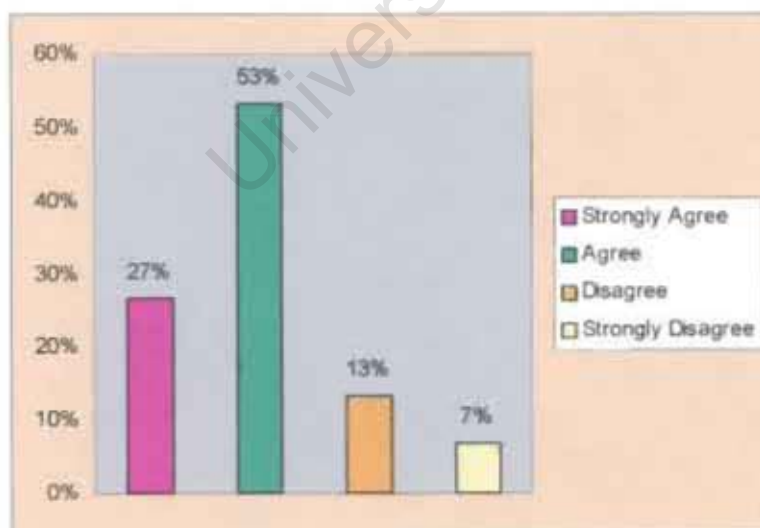


Figure 2 Percentage scores for respondents on question 2

Analysis of Figure 2, revealed that twenty seven percent (27%) of respondents strongly agreed, fifty three percent (53%) of the respondents agreed, thirteen percent (13%) disagreed and seven percent (7%) strongly disagreed, that recycled materials were durable.

On enquiring about the perceived durability of recycled materials, an interesting finding was observed. While eighty percent (80%) of the respondents perceive recycled construction materials to be durable, only twenty percent (20%) oppose this. This was in contrast to the literature which suggested that the majority of respondents perceived recycled construction materials to be inferior in quality to primary materials (Macozoma, 2001). The differences in the findings of previous studies and the current study may have been attributed to factors such as increasing awareness regarding the benefits of using these recycled materials, in terms of lower prices and reduction of ecological degradation, as well as increasing awareness of the actual risk involved in using recycled materials in comparison to that of primary materials. This finding that increased awareness has a positive effect on the individual's perceptions of the durability of recycled materials reiterates the findings of the case study at Malans Quarries. The effort made by recyclers to promote awareness through conducting workshops and demonstrations to various individuals, has appeared to have resulted in more positive perceptions of recycled materials, which in turn promotes further spread of awareness, by competing contractors.

4.4.2.3 Question 3: Is the quality of recycled material equivalent to that of primary materials?

Figure 3 below depicts the distribution of responses from all respondents to question 2 of the questionnaire, in terms of percentages.

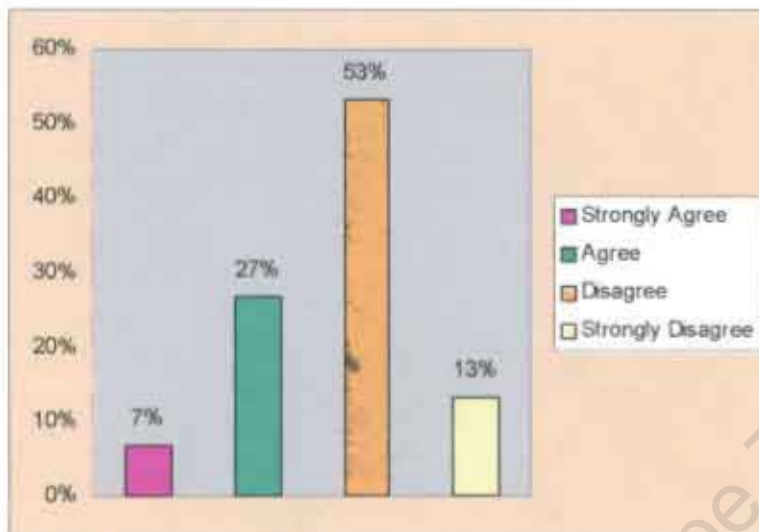


Figure 3 Percentage scores for respondents on question 3

With regards to Figure 3, the perceptions of respondents regarding whether or not the quality of recycled and primary materials are equivalent, are shown. Seven percent (7%) of respondents in the survey strongly agreed, twenty seven percent (27%) agreed, fifty three percent (53%) of the respondents disagreed and thirteen percent (13%) strongly disagreed.

Even though the literature suggested that the properties of recycled materials are similar to those of primary materials utilized in the construction process, the majority of respondents disagreed (66% in total). Quality testing of recycled construction materials has been regularly conducted for a number of years (Collins, 2000). The results yielded from experimental testing of these materials have indicated that recycled materials have similar properties to primary materials, provided that the recycling process is done under specification, and where necessary, additional materials may be supplemented to improve the properties of recycled materials. In accordance with this, the case study revealed that

Malans Quarries undertakes to produce recycled materials according to the specifications set out, as well as to test the materials before they are supplied to the consumer. Therefore, once again, inadequate awareness and knowledge by users may have been the rationale behind the fact that the majority of respondents perceived recycled materials as the 'second best' option.

4.4.2.4 Summary

The results of the survey revealed that the majority of respondents preferred primary materials over recycled materials. The majority of the respondents were opposed to suggestions of recycled material having comparable properties to primary materials. However most agreed that recycled materials are durable and can be used in construction. Thus overall, the perceptions held by various individuals, regarding recycled materials appears to have remained negatively skewed (i.e. continued resistance towards recycled materials due to negative perceptions).

4.4.3 Section two of the questionnaire

This section aimed to determine the availability of recycled materials in terms of how easily accessible recycled materials are to the consumer. This section was comprised of three questions. The first question was designed to determine the extent to which recycled materials are advertised, and the second and third questions were aimed at investigating perceptions held regarding the infrastructure in place for consumer's easy access to these materials.

4.4.3.1 Question 4: Do suppliers of recycled materials advertise their products effectively?

Figure 4 below depicts the distribution of responses from all respondents to question 4 of the questionnaire, in terms of percentages.

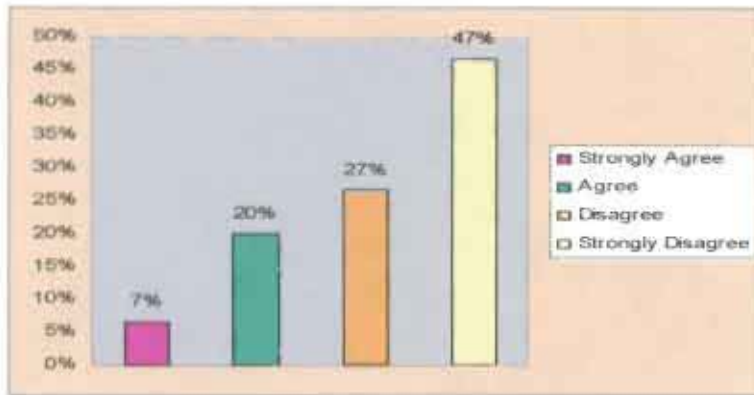


Figure 4 Percentage scores for respondents on question 4

With reference to Figure 4 above, seven percent (7%) of respondents in the survey strongly agreed, twenty percent (20%) agreed, twenty seven percent (27%) disagreed and forty seven percent (47%) strongly disagreed, that suppliers of recycled materials advertise their products effectively.

The majority of respondents (74% in total) disagreed that the suppliers of recycled materials in the construction industry advertise their products effectively. The literature supported this finding and it suggested that the most likely factor contributing to the inadequate marketing of recycled construction materials was a lack of resources, for example, administration and financial resources (Macozoma, 2001). It is vital for any recycling plant to market their products. In order to achieve this, it is necessary to allocate a fair amount of resources to advertising and innovation.

In relation to this, the case study revealed that the strategy currently being employed by Malans Quarries is based on the presentation, promotion and marketing of their recycled materials to selected companies. Due to the negative perceptions regarding recycled materials, held by many consumers, Malans Quarries felt that it was necessary to

convince those selected companies that the quality of the products they supplied met the set standards and that they were not defective. Nationwide advertising campaigns would perhaps not have been persuasive enough and may have required a significantly larger amount of resources, thus rendering company visits more cost effective in the short term. The finding that the majority of respondents, in the Western Cape, held the perception that suppliers did not advertise their products effectively may have been attributed to the fact that only a small number of companies have been approached by Malans Quarries to date.

4.4.3.2 Question 5: Do suppliers of recycled materials offer a delivery service?

Figure 5 below depicts the distribution of responses from all respondents to question 5 of the questionnaire, in terms of percentages.

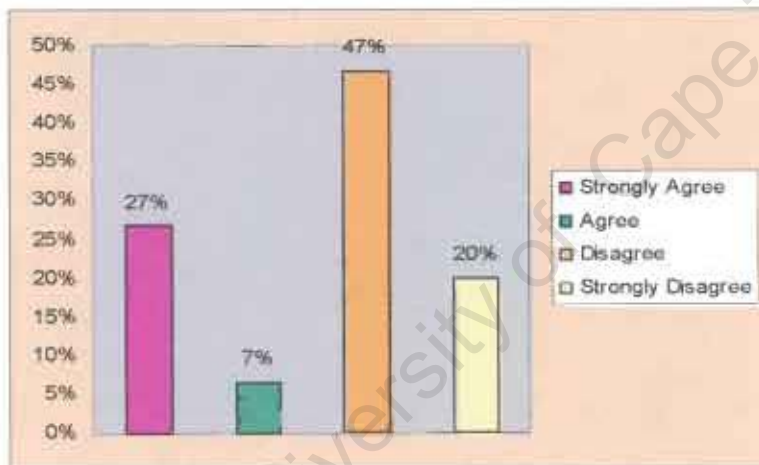


Figure 5 Percentage scores for respondents on question 5

As depicted in Figure 5, twenty seven percent (27%) of respondents in the survey strongly agreed, seven percent (7%) agreed, forty seven percent (47%) disagreed and twenty percent (20%) strongly disagreed, that suppliers of recycled materials offer a delivery service.

The results illustrate the interesting finding that the majority of the respondents disagreed, that suppliers offered delivery services. However, this was in contrast to what

was reported in the case study, which revealed that the supplier (Malans Quarries) did offer a delivery service for recycled materials ordered. Perhaps these respondents disagreed on the basis of the fact that they have not yet been exposed to the products and services offered by Malans Quarries in particular, as well as the fact that their general knowledge and awareness regarding recycled materials and their delivery may have been lacking.

4.4.3.3 Question 6: Are recycled materials easily accessed by the consumers?

Figure 6 below shows the distribution of responses from all respondents to question 6 of the questionnaire, in terms of percentages.

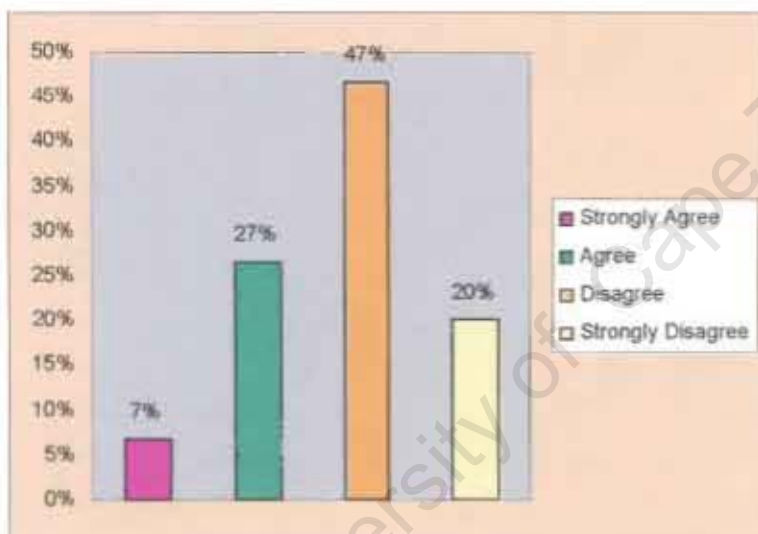


Figure 6 Percentage scores for respondents on question 6

With respect to Figure 6, seven percent (7%) of respondents in the survey strongly agreed, twenty seven percent (27%) agreed, forty seven percent (47%) disagreed and twenty percent (20%) strongly disagreed, that recycled materials are easily accessible to the consumer.

The majority of the respondents disagree that recycled materials are easily accessed. Inadequate awareness by consumers regarding the availability of recycled materials is perhaps a factor that may be contributing towards the difficulty in obtaining recycled

materials. The finding in Figure 4 above, that the majority of respondents did not agree that suppliers advertised their products effectively shows that there is insufficient information reaching potential consumers, concerning recycled materials.

Another factor that may be contributing to the difficulty in accessing recycled materials is the supply of recycled materials. Since there are only four suppliers of recycled materials in the Western Cape, the possibility exists that they are not able to feed the construction industry with sufficient quantities of materials. It is however vital to keep in mind the fact that recyclers depend on the availability of raw materials (construction and demolition waste), in order to produce their recycled materials, where the availability depends on the number of demolition and construction activities taking place.

4.4.3.4 Summary

To summarize the findings of section two of the questionnaire, most of the respondents were opposed to the fact that recycled materials are well advertised. Additionally, the majority of respondents revealed that recycled materials are difficult to access.

4.4.4 Section three of the questionnaire

This section attempted to establish whether incentives, such as reduction in taxes and/or tax exemptions, would help to encourage the utilization of recycled materials in construction, as suggested by the literature. Four questions were presented in this section. The first question was designed to determine the perceptions held by respondents regarding landfill taxes. The remaining questions were included to evaluate whether the implementation of tax incentives by the government would encourage and increase the utilization of recycled materials, in the Western Cape.

4.4.4.1 Question 7: Do high landfill taxes encourage illegal dumping of construction and demolition waste?

Figure 7 below shows the distribution of responses from all respondents to question 7 of the questionnaire, in terms of percentages.

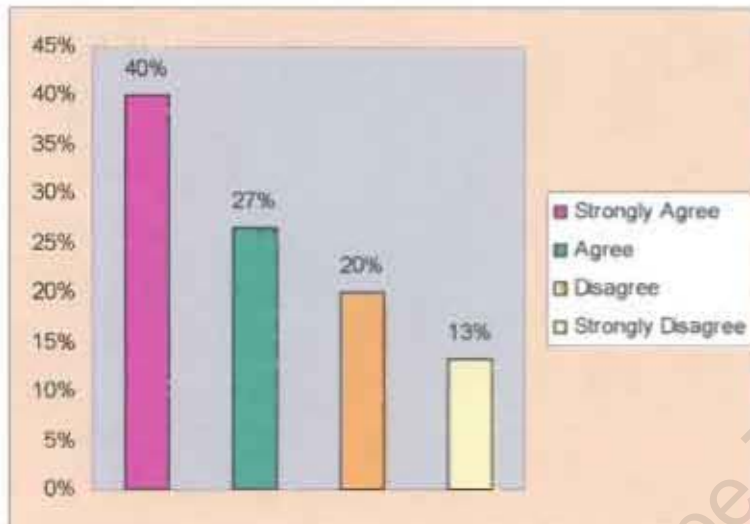


Figure 7 Percentage scores for respondents on question 7

Forty percent (40%) of the respondents strongly agreed that high landfill taxes encourage the illegal dumping of waste. Twenty seven percent (27%) agreed, while twenty percent disagreed and thirteen percent strongly disagreed.

The majority of respondents (67% in total) agreed that high landfill taxes have encouraged the illegal dumping of construction and demolition waste in the Western Cape. However, the literature proposed that landfill tax was introduced to *discourage* the dumping of recoverable waste and encourage recycling. This concept has been enforced by most first world countries (i.e. United States of America, European Union), and has proven to be effective (Lawson, et al., 2001).

There is growing evidence that the amount of construction and demolition waste which is recycled has increased by a significant amount as a result of the introduction of landfill taxes. The number of fixed and mobile crushing and recycling plant sites has also

increased. A survey, which was carried out by McGrath (2001) revealed that the number of recycling sites in the United States of America, has increased from 100 in 1994, to 400 in the year 2000. However, landfill taxes have not been successfully enforced in the Western Cape. Instead of discouraging the disposal of recoverable waste, these taxes have encouraged illegal dumping of construction and demolition waste, in attempt to evade additional transportation and tax costs. The fact that illegal dumping of construction waste in the Western Cape has been allowed to continue may be attributed to factors such as insufficient preventative measures taken by the authorities, as well as the availability of large undeveloped areas which provide a favourable environment for easy illegal dumping of the waste. Such open areas of land are scarce in first world countries since they are fully developed, and the only available sites for dumping of waste are the allocated dumping sites. Thus, the authorities in these countries can effectively enforce landfill taxes to encourage recycling by discouraging disposal of recoverable waste.

4.4.4.2 Question 8: Will reducing taxation on recycled materials encourage the use of these materials?

Figure 8 below shows the distribution of responses from all respondents to question 8 of the questionnaire, in terms of percentages.

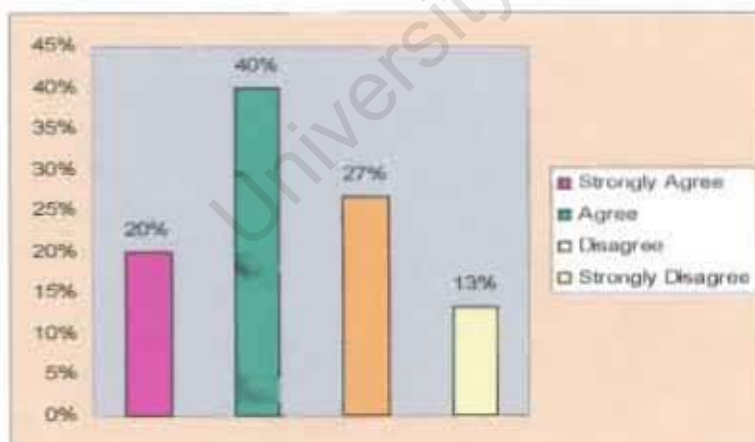


Figure 8 Percentage scores for respondents on question 8

With reference to Figure 8, twenty percent (20%) of respondents in the survey strongly agreed, forty percent (40%) agreed, twenty seven percent (27%) disagreed and thirteen percent (13%) strongly disagreed.

In total, 60% of the respondents agreed that reducing taxes on recycled materials would encourage the increased utilization of these materials, and the literature revealed similar trends. Macozoma (2001) suggested governmental (financial) support, to encourage the use of recycled materials. Macozoma (2000) stated that if governments reduced taxes on recycled materials the selling price of these materials would be indirectly reduced. By lowering the price of recycled materials, the demand for these materials would most likely increase. The case study revealed that the South African government was not entirely convinced that reducing the taxation on recycled materials would necessarily lower the selling price thereby increasing the demand for recycled materials. However, the government was reported to have volunteered land for all those various individuals interested in establishing a recycling plant as an incentive to increase recycling.

In the Netherlands the government implemented the reduction of the taxation on recycled materials and in order to compensate for this, they increased the taxes on primary materials, which could easily be substituted by recycled materials. This successfully resulted in the increased consumption of recycled materials in the construction industry (Dorsthorst & Hendricks, 2000).

The concept of shifting costs from recycled materials to primary materials to compensate for loss of revenue by the government may however, not work in Western Cape, since the supply of recycled materials is still small and not enough to feed the entire provincial construction industry. Furthermore, by decreasing the cost of recycled materials, the demand for these materials would increase, but the supply in the Western Cape would remain constant. In terms of economic laws of supply and demand, increased demand for products of a limited supply results in increased prices (Brue & McConnell, 1999). Thus, this increased cost of recycled materials, in addition to the increased price of primary

materials, due to compensation taxes, may result in increases in the cost of construction thereby affecting the economy of the country.

4.4.4.3 Question 9: Would the use of recycled materials be encouraged if the South African Government offered Income Tax exemption as an incentive for the purchasing of these materials?

Figure 9 below depicts the distribution of responses from all respondents to question 9 of the questionnaire, in terms of percentages.

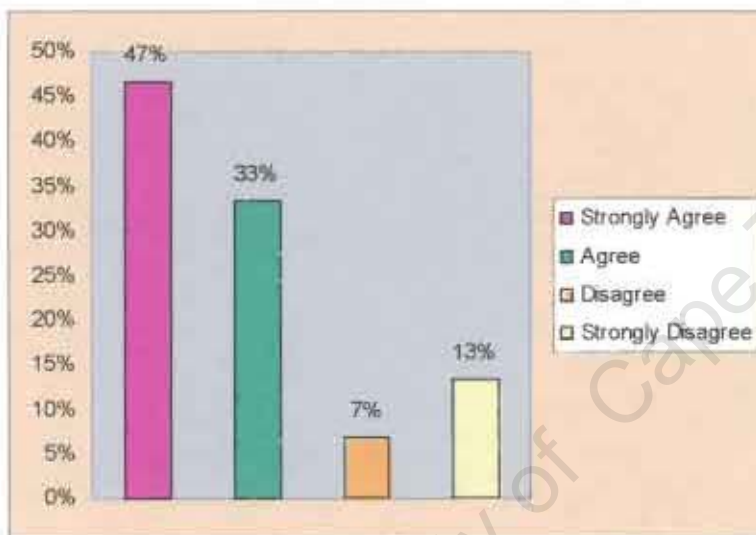


Figure 9 Percentage scores for the respondents on question 9

With respect to Figure 9, forty seven percent (47%) of the respondents strongly agreed, thirty three percent agreed (33%), seven percent (7%) disagreed, and thirteen percent (13%) strongly disagreed, that the use of recycled materials would be encouraged if the South African Government offered income tax exemption as an incentive for the purchasing of recycled materials.

There was an overwhelming response of respondents in favour of income tax exemption, where eighty percent (80%) of the respondents agreed that they would use recycled materials if the government offered tax reductions or exemptions on these materials. Similarly, the literature has demonstrated the influence that the government

has towards establishing a sustainable secondary market (Macozoma, 2001). Therefore, tax exemptions on recycled materials would be an ideal incentive for encouraging the use of recycled materials as well as minimizing the amount of construction and demolition waste disposed.

4.4.4.4 Question 10: Do landfill taxes have a significant impact on the operating cost of your company?

Figure 10 below depicts the distribution of responses from all respondents to question 10 of the questionnaire, in terms of percentages.

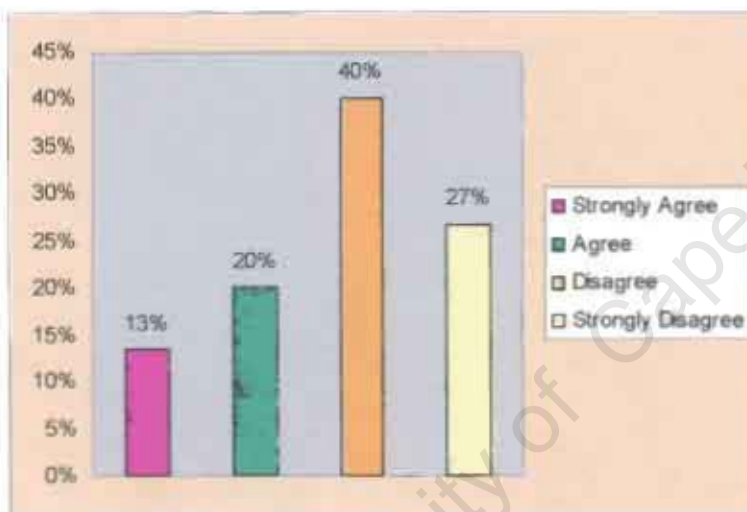


Figure 10 Percentage scores for the respondents on question 10

In relation to Figure 10, thirteen percent (13%) of the respondents strongly agreed, twenty percent (20%) agreed, forty percent (40%) disagreed, and twenty seven percent (27%) strongly disagreed, that landfill taxes have a significant impact on the operating cost of the company.

The majority of respondents in the sample (67% in total) disagreed that landfill taxes have a significant impact on the operating cost of their company. This finding is in contrast to the literature which suggests that landfill taxes paid by companies have a negative impact on the operating costs, in terms of increasing these costs. Companies

that are attempting to decrease their operating cost will have no other option but to minimize the waste generated on site through implementation of good waste management plans, thereby increasing the recycling of waste. Perhaps all those respondents who disagreed that landfill taxes significantly impact operating costs were employed by companies which applied good waste management plans on the site. Since it is common practice that landfill sites do not charge a fee for disposal of uncontaminated waste, the operating costs of the companies at which the majority of the respondents were employed were most probably not perceived as being significantly impacted by landfill taxes as a result of the company's implementation of a good waste management plan.

Yet another factor that may have contributed to the respondents' disagreement, that landfill taxes significantly impact the operating costs of their companies, may be that most of these companies outsource the waste removal from the site to specialized subcontractors (i.e. Wasteman), where the cost of this service is transferred to the project client as priced in the tender document.

4.4.4.5 Summary

The results of this section of the questionnaire indicated that fewer respondents disagreed that landfill taxes encourage illegal dumping of construction and demolition waste, than those who agreed. The majority of respondents supported the idea of introducing financial incentives as a tool to encourage the utilization of recycled materials. Most of the respondents did not consider landfill taxes as a significant cost to the operation of their company.

4.4.5 Section four of the questionnaire

This section attempted to capture the perceptions of the respondents regarding the South African Bureau of Standards (SABS) in relation to the utilization of recycled materials in construction activities. There were two questions presented in this section. The first question was aimed at capturing the perceptions held by the respondents regarding the role of the SABS, and the second question was designed to capture perceptions regarding benchmarks against which to measure recycled materials.

4.4.5.1 Question 11: Does the SABS play a vital role in discouraging the use of recycled materials?

The following table presents the percentages of responses to the above question.

Table 1c Percentage Scores for Respondents on Question 11

Strongly agree	Agree	Disagree	Strongly Disagree
23 %	33%	13%	27%

With reference to Table 1c, twenty three percent (23%) of the respondent strongly agreed, thirty three percent (33%) agreed, thirteen percent (13%) disagreed, and twenty seven percent (27%) strongly disagreed, that the SABS plays a vital role in discouraging the use of recycled materials.

From the results on the survey, respondents generally perceived that the SABS did play a role in discouraging the use of recycled materials. The literature showed similar findings suggesting that South African standards and specifications have not taken into account the use of alternative construction and secondary materials, and the few standards regarding secondary materials that do exist in South Africa involve the technical testing of these materials to determine their durability (Maozoma, 2001). Thus, in the current study, this may have been a factor, perceived by the respondents, to have discouraged the use of recycled materials, since such an approach tends to be time-consuming and may have cost implications, in terms of increasing costs, due to laboratory and testing fees.

The literature also suggested that there is a need to shift from prescriptive to performance-based specifications, since prescriptive specifications have been traditionally based on the properties of virgin materials, and have thus been shown to limit the utilization of secondary materials (Macozoma, 2001). If secondary materials in the Western Cape were standardized according to performance-based specifications, where detail on the performance of the materials, and not their composition was obtained, then perhaps the utilization of secondary materials would have increased.

4.4.5.2 Question 12: Would the selection of the recycled materials to be used in construction be easier if all recycled materials had a specific benchmark against which to be measured?

The following table presents the percentages of the responses to the above question.

Table 2 *Percentage Scores for Respondents on Question 12*

Strongly agree	Agree	Disagree	Strongly Disagree
80%	7%	13%	0%

In relation to Table 2, eighty percent (80%) of the respondents in the sample strongly agreed, seven percent (7%) agreed, thirteen percent (13%) disagreed, and none of the respondents strongly disagreed, that the selection of recycled materials would be easier if all recycled materials were referenced against a specific benchmark.

The results of the survey indicated that the majority of the respondents agreed (87% in total) were in agreement benchmarks against which to measure recycled materials would contribute to their ease in selection of these materials. Similarly, previous literature has suggested that ongoing research into and the development of standardized methods of evaluating recycled materials is necessary to ensure that all materials are tested based on their merit and according to a specified level of reference.

Effective waste management plans and the implementation of these could perhaps be a vital component towards establishing this system of benchmarking of recycled materials, since the quality of recycled materials is dependent on the quality of raw materials received at the recycling plants. By implementing effective waste management plans on construction and demolition sites, the quality of construction and demolition waste (raw materials) delivered to the recyclers would be high in standard which would assist in creating a good foundation for establishing and developing a benchmark system.

4.4.5.3 Summary

In section four of the questionnaire, the majority of respondents agreed that by creating benchmarks against which to measure recycled materials the utilization of these materials would be encouraged. In addition the majority agreed that the SABS discourages the use of recycled materials.

4.4.6. Section five of the questionnaire

This section set out to investigate the role of the pre-design phase (briefing stage) in the construction process, by means of three questions. The first question aimed to determine the perceptions of the respondents, as to whether the briefing stage in the construction process had an influence on the utilization of recycled materials. The second question explored the respondent's views regarding the role of the client in determining the type of materials used, while the last question delved into whether the respondents thought that the knowledge and experience of the design team influenced the choice as to whether recycled materials were selected for construction.

4.4.6.1 Question 13: Does the briefing stage in the design phase influence the choice to or not to utilize recycled materials in construction?

The following table presents the responses to the above question.

Table 3 Percentage Scores for the Responses to Question 13

Strongly agree	Agree	Disagree	Strongly Disagree
33%	53%	13%	0%

In respect of Table 3, thirty three percent (33%) of the respondents strongly agreed, fifty three percent (53%) agreed, thirteen percent (13%) of the respondents disagreed, while none of the respondents strongly disagreed, that the briefing stage in the design phase had an influence over the choice of utilizing recycled materials in construction.

These results revealed that the majority of respondents agreed that the briefing stage plays a crucial role in deciding whether to use recycled materials in a project. This is not surprising since during this stage the client requests information regarding the options available. Literature has proposed that during the briefing stage the client is informed by the consultant regarding the material options available, and John & Zordan (2001) found that in most cases, the option of using recycled materials is not availed as a result of the fact that the consultant may be unfamiliar with recycled materials.

However in cases where the client is experienced, the client may recommend the use of recycled materials, as was revealed in the case study, where major projects that took place in the Western Cape over the past few years incorporated the use of recycled materials upon recommendation of the client as well as the consultant. Such projects include the Cape Town International Conventional Center, Grand West Casino and Century City/Canal Walk Shopping Center.

4.4.6.2 Question 14: Does the client play a crucial role in determining the type of material used in construction?

The table below presents the percentages of the responses to the above question.

Table 4 Percentage Scores of the Respondents on Question 14

Strongly agree	Agree	Disagree	Strongly Disagree
67%	33%	0%	0%

Sixty seven percent (67%) of the respondents strongly agreed that client plays a crucial role in determining the type of material used in construction. Thirty three percent (33%) agreed and none of the respondents were opposed to this.

All of the respondents agreed that the client plays a crucial role in determining the type of materials to be used in the project. This is perhaps because experienced clients may influence contractors to utilize recycled materials in the project. However, although the literature is in agreement that the client may have an influence over the contractor with regard to the utilization of recycled materials many clients have failed to communicate effectively (Macozoma, 2001). A possible reason for this may be the client's resistance to change due to the perceived risk involved. Most clients are not familiar with the risk involved in utilization of recycled materials, and as was detailed in the case study, these clients maintain that if primary materials are capable of achieving the required outcome, why substitute them, especially since there are no incentives for clients to change their traditional techniques.

The government of Japan had realized how important the client can be in encouraging recycling and waste minimization. In the year 2000 the government of Japan enacted a law aimed at encouraging the recycling of construction and demolition waste. This law had five main components. One of these components regulated the contract between the client and the contractor, in terms of enforcing the utilization of recycled materials where

appropriate (i.e. where primary materials could be substituted by recycled materials). This law has been successful, in that the recycling rate in Japan has increased (Nakajima & Futaki, 2001).

4.4.6.3 Question 15: Does the knowledge and experience of the design team influence whether recycled materials are selected for construction?

Figure 11 below depicts the distribution of responses for all respondents for question 15 of the questionnaire, in terms of percentages.

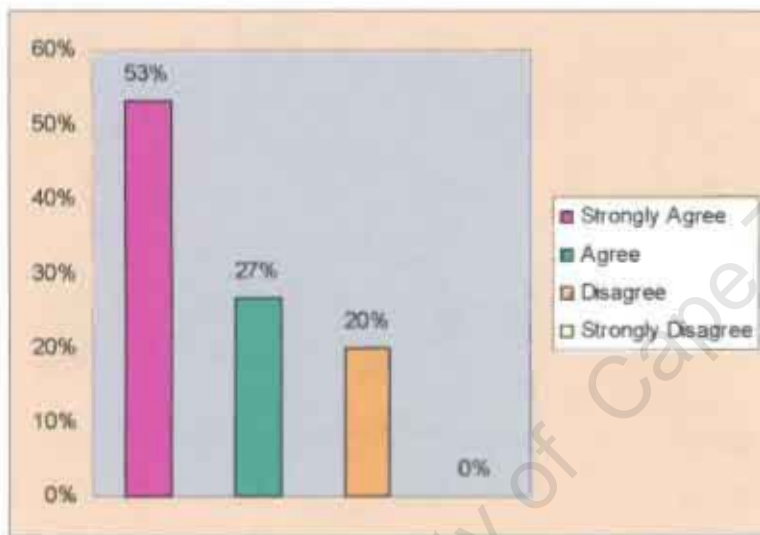


Figure 11 Percentage scores for the respondents on question 15

With regards to Figure 11, fifty three percent (53%) of the respondents strongly agreed, twenty seven percent (27%) agreed, twenty percent (20%) disagreed, and none of the respondents strongly disagreed that the selection of recycled materials for construction was influenced by the knowledge and experience of the design team.

The results reveal that the majority of the respondents in the survey (80% in total) agreed that the experience and the knowledge of the design team were part of factors that influenced the selection of recycled materials in a construction project. The literature shows a similar trend in that inadequate knowledge and experience of using recycled materials by various consultants has created a barrier towards the utilization of these

materials (Macozoma, 2002). Awareness on the utilization of recycled materials is a key tool towards establishing a sustainable secondary market. Informing the client and consultant on both financial and environmental benefits of using the recycled materials may help to increase the knowledge of the design team. The more familiar the consultant is with the risk involved and how to manage it, the more likely it is that the consultant will utilize recycled materials.

4.4.6.4 Summary

The briefing stage plays a vital role in deciding whether recycled materials are utilized in construction. The majority of respondents asserted that the client plays a crucial role in the decision as to whether or not to use recycled materials. The knowledge and experience of the design team on recycled materials were also factors that were perceived to influence the choice between the utilization of recycled materials and primary materials.

4.4.7 Section six of the questionnaire

This section was subdivided into two subsections each containing open-ended questions. The first section investigated the rationale behind companies not utilizing recycled materials. The second subsection was completed by only those respondents who were employed at companies which regularly utilized recycled materials. This subsection aimed to investigate why these companies chose to utilize recycled materials, the quantity utilized, as well as the application of these materials.

4.4.7.1 Reasons for not utilizing recycled materials

The main reason reported in the questionnaire by construction firms for not utilizing recycled materials was that the consultant did not specify that these materials were to be used, and construction firms have traditionally had little say as to which materials are to be used in construction activities. Furthermore, construction firms do not wish to expose themselves to any further risk, by utilizing materials that were not specified.

The literature and findings on the questionnaire as well as in the case study are in agreement that the negative perceptions held by consultants, regarding recycled materials, are a major factor preventing the utilization of these materials. Many consultants are unaware of the research into the development and improvement in the quality and standard of secondary materials that is currently taking place in the field. As previously discussed, the few standards regarding secondary materials that do exist in South Africa involve time-consuming and expensive technical testing of these materials to determine their durability (Macozoma, 2001).

An interesting finding was revealed in the case study and confirmed by the responses to the questionnaire, was that the majority of respondents (Figure 2) agreed that recycled materials are durable. According to studies conducted by Macozoma (2002), the majority of consultants believe that the quality of recycled materials is substandard. However, the case study in the current study revealed that consultants in the Western Cape did not have strong evidence to support this claim. In addition, some consultants who had previously resisted the utilization of these materials changed the perceptions that they held regarding recycled materials when they realized the cost saving that could be achieved when selecting these materials over primary materials. Additionally, much research has been conducted over the years to determine recycled materials durability. Recyclers are continuously looking for ways to further improve the standard of recycled materials. The case study revealed that for more than ten years Malans Quarries has supplied recycled materials to different projects. All these projects have been successful, indicating that the standard of recycled materials is adequate.

Inadequate knowledge regarding recycled materials and lack of experience in utilization of these materials by various consultants may have played a crucial role in perpetrating the negative perceptions that exist among various individuals regarding the quality of these materials. The case study findings as well as Macozoma (2001) suggest that in order to establish a sustainable secondary market, awareness should be amplified concerning the potential opportunities for using recycled materials.

4.4.7.2 Reason for utilizing recycled materials

The survey revealed that the sole factor that appeared to motivate companies to use recycled materials in construction activities as a substitute for primary material was the price difference between these materials. The selling price of recycled materials is generally lower than that of primary materials, and the case study revealed that companies which opt to use recycled materials decrease their operating cost by twenty percent (20%). The lower cost of recycled materials may thus be used as a means to encourage the use of recycled materials, as was observed in the case study at Malans Quarries when the company lowered the selling price of recycled materials, which resulted in an increase in the demand for these materials.

Although environmental degradation, due to waste dumping and excessive extraction of unrecoverable resources, may also play an important role in encouraging the use of recycled materials, many companies have failed to implement their policies regarding sustainable environmental practices. In addition, literature has demonstrated that no companies are ready to use secondary materials, since they are not familiar with the risks involved. However, in the current study it appears that, the saving that companies may make by using recycled materials provides the major incentive to take the risk.

The majority of companies utilizing recycled materials apply these materials in road construction, brick manufacturing and construction of parking lots. This was confirmed by literature, as well as in both, the case study and the questionnaire, which revealed that the main application of recycled materials in the Western Cape was in road construction. Perhaps the factor that has contributed most to this application of recycled materials is the availability of recycled aggregates, specifically used in road construction, since Malans Quarries supplies more than two hundred thousand (200 000) tons of recycled aggregates annually.

Braids Recycling Company produce recycled concrete aggregate which is used in light structure concrete. Problems do however exist in the production of recycled aggregate.

One such problem includes the fact that the by product of producing recycled concrete aggregate is a fine dust which consists of almost half of the input materials. This dust cannot be recovered, consequently increasing the cost of recycling and decreasing the supply. Due to inadequate supply and cost factors many companies are not utilizing recycled concrete aggregate. The abundant supply of primary materials and competitive prices has contributed to the narrowing of the application of recycled materials to road construction and parking lots. Studies have shown that countries that reported a high rate of recycling of construction and demolition waste had many high-way constructions taking place (Lima, 2000). This implies that the high rate of recycling was due to the demand for the materials in road construction.

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CHAPTER 5: *CONCLUSIONS & RECOMMENDATIONS*

University of Cape Town

5. Conclusions and Recommendations

5.1 Introduction

This research has explored the various perceptions held by individuals (customers & suppliers) about recycled materials in terms of supply, quality, standards, and demand of recycled materials, as well as the perception held by individuals regarding the utilization of economic incentives as tools to encourage the use of recycled construction materials in the Western Cape. The Hypothesis tested by the research was stated (chapter one) as:

Low levels of recycling of construction and demolition waste are not caused by inadequate demand for recycled materials.

The methodology chosen for the research was broadly ethnographic, comprising of a thorough review of the appropriate literature, a questionnaire survey and a case study of one particular recycling plant in the Western Cape, using both qualitative and quantitative approaches.

In this chapter, a brief summary of the previous chapters is presented, followed by a section on testing of the research hypothesis. Conclusions are drawn from the research findings, and recommendations are made for practice and for future research. Finally, the evaluation of the research objective is discussed.

5.1.1 Chapter summaries

Chapter one presented the outline of the research report. Chapter two entailed a review of the literature on the following topics: source of construction and demolition waste, the current status of construction and demolition waste in South Africa, the extent to which recycled materials are recycled, as well as the market barriers in establishing a self sustaining secondary market. Chapter three outlined the research design and the methodology that was followed during the data collection. Chapter four presented and

discussed the case study conducted at Malans Quarries, as well as the questionnaire distributed to various construction consultants, engineers and contractors.

5.2 Testing of the Hypothesis

The results of the current study revealed that the majority of respondents preferred primary materials over recycled materials, even though they did consider recycled materials to be durable. This implies that the *demand* for recycled materials in the Western Cape is low in comparison to the demand for primary materials. Furthermore, the results of the case study conducted at Malans Quarries, suggested that the negative perceptions held by various individuals towards recycled materials have a significant effect on the demand for these materials.

The results further demonstrated that the majority of respondents felt that recycled materials were not well advertised, and were difficult to access. This was attributed to the fact that there are only a few recyclers operating in the Western Cape, who have limited resources, indirectly implying that the *supply* of these materials in Western Cape is low.

Upon consideration of the overall results of the study, it may be argued that one of the factors underlying the *under-recycling* of construction and demolition waste in the Western Cape is the inadequate demand for these materials.

These results are considered to be conclusive enough to disprove the hypothesis that:

Low levels of recycling construction and demolition waste is not caused by inadequate demand for recycled materials

5.3 Achievement of the research objectives

The objectives for the research included:

1. *Conduct a detailed literature review that will:*
 - *Examine the amount of construction and demolition waste that is dumped in the landfills.*
 - *Examine the extent to which construction and demolition waste is recycled and re-used.*
 - *Examine the demand for secondary material in the construction industry.*
2. *Examine the supply of construction and demolition waste to the recycling plants.*
3. *Examine the supply of recycled materials to the end-user.*
4. *Examine the perceptions held by various individuals regarding recycled materials.*

The first research objective was achieved through the meticulous literature review in chapter two, while the second and third objects were achieved through the analysis of the results of the case study at Malans Quarries. The fourth object was achieved through the analysis of the results of the questionnaire survey.

5.3 Conclusions

5.3.1 Construction and demolition waste produced

South Africa produces between 5-8 million tons of construction and demolition waste annually. This is still a small amount in comparison to other countries such as Germany which produces up to 59 million tons annually. Failure to implement sustainable processes now may lead South Africa to similar problems faced by many developed

countries in the not so distant future, including a lack of land available for landfills. The current driver for change in South Africa is to achieve sustainability, so that the amount of raw materials extracted from the environment may be reduced.

5.3.2 The supply of construction and demolition waste to the recycling plant

The main suppliers of construction and demolition waste consist of large and medium contractors. The amount of construction and demolition materials supplied by these companies is dependent on the level of construction and demolition activities taking place within the region of the recycling plant. However the amount of recoverable construction and demolition waste supplied by these companies is dependent on the effective implementation of waste management plans on site. Therefore it is fundamental to have an effective waste management plan so as to increase the supply of construction and demolition waste to the recycler, which will in turn assist in an increased supply of recycled materials.

The amount of construction and demolition waste produced by small contractors is not commonly known. The number of small contractors is generally greater than the number of large and medium contractors. Thus, the overall amount of recoverable waste collectively produced by this large number of small contractors would effectively assist in supplying recyclers on a continuous basis. It is essential for recyclers in the Western Cape to consider small contractors as significant suppliers of construction and demolition waste to their recycling plants.

5.3.3 The supply of recycled materials to the end user

The quantity of recycled materials used in the Western Cape is extremely small in comparison to primary materials, especially since inadequate knowledge and experience about recycled materials has played a vital role in the utilization of recycled materials.

5.3.4 The perception about recycled materials by various individuals

Primary materials have traditionally been preferred over recycled materials due to the fact that the risk involved in using primary materials is generally known. In addition, the price difference between primary material and recycled materials has to date, not been sufficient enough to persuade various individuals to use recycled materials. Furthermore, the following aspects have played a part in hindering the development of recycled materials in the Western Cape:

- Inadequate advertising of recycled materials
- Difficulty in obtaining recycled materials
- Landfill taxes that are ineffective
- The inadequate establishment of formal systems for measuring the standard of recycled materials
- Inadequate initiation by the clients and consultants to recommend the use of recycled materials in projects.

5.4 Recommendations

This research report has highlighted a number of obstacles in the development of the market for recycled materials in the Western Cape. In light of this, the following recommendations are made:

5.4.1 Effective waste management plans

In order to increase the supply of construction and demolition waste to the recyclers, effective waste management practices must be implemented on construction and demolition sites.

5.4.2 Decentralization of waste collection

In order for recycling plants to effectively tap into the supply of construction and demolition waste currently being produced by small contractors, decentralized construction and demolition waste collection systems must be implemented.

5.4.3 Increase awareness

More workshops on recycled materials need to be conducted in order to increase awareness among various stakeholders. The government should offer free training and education regarding the use of recycled materials in construction to all parties involved in the construction industry.

5.4.4 Economical incentives

Taxes on recycled materials and recycling plants should be reduced. In addition to this, tax reductions for all those companies who utilize recycled materials should be effected by the government. Such incentives would encourage the use as well as the production of recycled materials.

5.4.5 Further research

Further research should be conducted on establishing effective secondary markets in the South African construction industry, as well as ways of enforcing effective waste management practices in small, medium, and large contractors.

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University of Cape Town

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APPENDICES

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APPENDIX A

CONSTRUCTION AND DEMOLITION WASTE QUESTIONNAIRE

Company Name: _____

Respondent Name: _____

Contact Details: _____

Respondent's Position Held: _____

1. Can recycled materials replace primary materials in construction?

Strongly agree 1 2 3 4 Strongly disagree

2. Recycled materials used in construction are durable.

Strongly agree 1 2 3 4 Strongly disagree

3. The quality of recycled materials in relation to primary materials is equivalent.

Strongly agree 1 2 3 4 Strongly disagree

4. Suppliers of recycled materials advertise their products effectively.

Strongly agree 1 2 3 4 Strongly disagree

5. Suppliers of recycled materials offer a delivery service.

Strongly agree 1 2 3 4 Strongly disagree

6. Recycled materials are easily accessed by the consumers.

Strongly agree 1 2 3 4 Strongly disagree

7. High landfill taxes encourage illegal dumping of construction and demolition waste.

Strongly agree 1 2 3 4 Strongly disagree

8. Reducing taxation on recycled materials will encourage the use of these materials.

Kamil Delaware

Strongly agree 1 2 3 4 Strongly disagree

9. If the South African Government offered Income Tax exemption as an incentive for the purchasing of recycled materials, the use of these materials would be encouraged.

Strongly agree 1 2 3 4 Strongly disagree

10. Landfill taxes have a significant impact on the operating cost of the company.

Strongly agree 1 2 3 4 Strongly disagree

11. The South African Bureau of Standards (SABS) plays a vital role in discouraging the use of recycled materials.

Strongly agree 1 2 3 4 Strongly disagree

12. The selection of the recycled materials to be used in construction would be easier if all recycled materials had a specific benchmark against which to be measured.

Strongly agree 1 2 3 4 Strongly disagree

13. The briefing stage in the design phase influences the choice to or not to utilize recycled materials in construction.

Strongly agree 1 2 3 4 Strongly disagree

14. The client plays a crucial role in determining the type of material used in construction.

Strongly agree 1 2 3 4 Strongly disagree

15. The knowledge and experience of the design team influences whether recycled materials are selected for construction.

Strongly agree 1 2 3 4 Strongly disagree

(IF THE COMPANY IS NOT USING RECYCLED MATERIALS, PLEASE ANSWER QUESTION 17. IF THE COMPANY IS USING RECYCLED MATERIALS PLEASE COMPLETE QUESTION 18-21.)

16. What is the reason for the company for not using recycled materials?

Kamil Delaware

17. If the company is using recycled materials, who are the suppliers?

18. Where are the recycled materials used on site (e.g. Backfilling, Road construction)?

19. Why does the company use recycled materials?

20. Approximately what quantity of recycled materials is used by the company?

Please send the completed questionnaire to:

Mr. Kamil Delaware
9 Mariendahl Court, Boundary Road
Newlands
7700
Cell: 082 7284 696
Tel/Fax: 021 6898024

THANK YOU FOR YOUR CO-OPERATION

APPENDIX B

G. Disposal Tariffs for Landfills in Cape Town

38 Water Street
Cape Town 8001
P O Box 18548
Windsong 8018
Tel: +27 21 487 2718
Fax: +27 21 487 2476
E-mail: p.west@cmc.gov.za

34 Water Street
Cape Town 8001
Block 10548
Windsong 8018
Tel: +27 21 487 2718
Fax: +27 21 487 2476
E-mail: p.west@cmc.gov.za

Windsong 28
Kingsford 8009
P O Box 18548
Windsong 8018
Tel: +27 21 487 2718
Fax: +27 21 487 2476
E-mail: p.west@cmc.gov.za

**CITY OF CAPE TOWN
ISIXEKO SASEKAPA
STAD KAAPSTAD**

Mr P H Mavutsa – Head : Waste Management – CMC Administration

WATER AND WASTE DIRECTORATE
CMC ADMINISTRATION
2002-06-19

TO: ALL USERS OF THE CITY OF CAPE TOWN'S WASTE MANAGEMENT FACILITIES:

**WASTE MANAGEMENT DEPARTMENT
DISPOSAL TARIFFS FOR PERIOD 1 JULY 2002 TO 30 JUNE 2003**

GENERAL WASTE DELIVERED TO ANY COUNCIL LANDFILL SITE:

- R62.27 (Excl VAT) R70.99 (Incl VAT)* Per 1 metric ton or part thereof.
- 1 and 2 ton skips are obtainable at Municipal cash offices.
- Account facilities available by prior arrangement.

*Tariffs are based on the carrying capacity of vehicle.

GENERAL WASTE DELIVERED TO THE ATHLONE TRANSFER STATION:

(Account holders only):

- R62.27 (Excl VAT) R70.99 (Incl VAT)* Per 1 metric ton or part thereof.

*Tariffs are based on the carrying capacity of the vehicle. NOTE: No special waste allowed.

GENERAL WASTE (BASED ON ACTUAL MASS):

(Account holders only – subject to prior written application & Head Office approval):

- R71.61 (Excl VAT) R81.64 (Incl VAT)*

*Tariffs are based on actual mass per metric ton or part thereof as determined by the site weighbridge. Applicable to all disposal sites with weighbridges and transfer stations.

SPECIAL WASTE DELIVERED TO THE VISSERSHOK LANDFILL SITE ONLY – ALL SPECIAL WASTE IS SUBJECT TO PRIOR PERMITTING:

- R87.47 (Excl VAT) R111.12 (Incl VAT)* Per 1 metric ton or kilolitre or part thereof.

*Tariffs are based on actual mass^a or volume^b (as determined by the site weighbridge)

FREE DISPOSAL:

- Clean builders rubble (all loads irrespective of mass): Suitable for road construction or covering of waste, such as broken bricks, sand, stone, plaster or soil. Large items, concrete with protruding steel, paint, asbestos, tiles etc., are excluded and are subject to tariffs.
- All loads of household (non-putrescible) or garden waste up to 1 ton in privately owned vehicles (motor cars plus single axle trailers or nominal 1 ton bakkies): NOTE: commercial vehicles are excluded from free disposal.

COUNCIL WASTE MANAGEMENT FACILITIES:

- Athlone Refuse Transfer Station - Settlers Way, Athlone Tel 694-1710
- Bellville General Waste Landfill - Sacks Circle, Bellville South Tel 951-4793
- Brackenford General Waste Landfill (No Weighbridge) - Reservoir Road, Brackenford Tel 962-4713
- Coastal Park General Waste Landfill - Baden Powell Drive, Mufsonberg Tel 788-2850
- Faure General Waste Landfill (No Weighbridge) - Old Main Road, R102, Eerste River Tel 843-3114
- Swartkops General Waste Landfill - Swartkops Road, Mitchells Plain Tel 397-8077
- Viessershok General & Hazardous Waste Landfill - Frankdale Road, Viessershok Tel 567-3309
- Special Waste Permitting, Waste Management Department - 38 Water Street, 9th Floor, Cape Town Tel 487-2479
- Compost Sales, Mitchells Plain Compost Plant - Swartkops Road, Mitchells Plain Tel 397-8004
- General Enquiries, Waste Management Department - 38 Water Street, 9th Floor, Cape Town Tel 487-2477



Environment-friendly and responsible waste management

APPENDIX C

ULUNTU		INDICATOR & CBR DATA			
CLIENT: MALANS TRANSPORT		PROJECT: KOEBERG POWERSTATION		DATE: 25.02.2002	
STOCKPILE					
SAMPLE NO		U 4171			
DESCRIPTION OF MATERIAL		CRUSHED BUILDING RUBBLE		TRH 14 G 4 SPEC.	
MOISTURE CONTENT %					
SIEVE ANALYSIS	75.0 mm				
	63.0 mm				
	53.0 mm	100		100	
	37.5 mm	87		85-100	
	28.5 mm	72			
	19.0 mm	60		80-90	
	13.2 mm	50			
	4.75 mm	35		30-65	
	2.00 mm	27		20-50	
0.425 mm	18		10-30		
0.075 mm	6		5-15		
SOIL COARSE SAND		33			
MORTAR FINE SAND		48			
MATERIAL <0.075 mm		21			
SOIL LIQUID LIMIT					
CONSISTANTS PLASTICITY INDEX		NP		6 MAX	
CONSISTANTS LINEAR SHRINKAGE		0.0			
GRADING MODULUS		2.48			
MAXIMUM DRY DENSITY (Kg/m ³)		2060			
% OPTIMUM MOISTURE		8.8			
CBR DATA	MODIFIED AASHTO	COMP. MOISTURE	9.8		
		% DENSITY	100.7		
		CBR	87		
	NRB	% DENSITY	97.1		
		CBR	80		
		% SWELL	0.00		
	PROC-TOR	% DENSITY	94.3		
		CBR	54		
		% SWELL	0.00		
CBR	AT 100% MODIFIED AASHTO	94			
	AT 80% MODIFIED AASHTO	84			
	AT 60% MODIFIED AASHTO	60			
	AT 40% MODIFIED AASHTO	45			
TRH 14 CLASSIFICATION		G 4			
TBR CLASSIFICATION		A-1-a (0)			