MOI UNIVERSITY

SCHOOL OF ENGINEERING

Department of Civil and Structural Engineering

Telephone: +254 – 53 - 43620 **PO BOX 3900**

Fax +254 43242 **ELDORET**

PRESENTED BY:

NAME: **REG. NO**:

GODFREY OCHIENG AGORO CSE/71/03

COURSE CODE: CVS 590

COURSE TITLE: PROJECT

PROJECT TITLE

INVESTIGATION OF THE USE OF QUARRY DUST AS A SUBSTITUTE OF RIVER SAND IN CONCRETE MIXES.

SUBMITTED TO: MR. EVANS KHADAMBI

THIS REPORT IS SUBMITTED AS A PARTIAL FULFILLMENT FOR THE AWARD OF THE DEGREE OF BACHELOR OF TECHNOLOGY IN CIVIL & STRUCTURAL ENGINEERING

2007/2008 ACADEMIC YEAR

DECLARATION

I, GODFREY OCHIENG AGORO, do hereby declare that this is my original work and to the best of my knowledge has not been submitted for a degree award in any educational institution.

Signature ………………………….. Date ………………………………

GODFREY OCHIENG AGORO

D.C.S.E Student

CERTIFICATION

I, MR.KHADAMBI, hereby certify this report and approve it for examination.

Signature ………………………….. Date ………………………………

MR.KHADAMBI,

Project supervisor.

DEDICATION

To my beloved Dad Jack, mum Grace, Brother Collins, Sisters Emily and Cynthia.

ACKNOWLEDGEMENTS

The preparation of this research was a result of both direct investigations and wide ranging consultations involving a number of people.

While one cannot mention everybody, I would like to specifically record and express my deep gratitude and sincere appreciation to the following: The present project report concerns the use of quarry dust as a substitute for river sand. The project would have not been successful without the efforts of specific people.

I am most grateful to my supervisor, Mr. Khadambi, for his support, encouragement and ability to guide me through the various questions that have arisen during the project.

All technicians at the Department of Civil and Structural Engineering have contributed many valuable discussions and pieces of advice. In particular, I would like to thank Mr. Agesa and Mr. Swara for availing different materials towards this project leading my work to new frontiers.

ABSTRACT

Introduction

Common river sand is expensive due to excessive cost of transportation from natural sources. Also large-scale depletion of these sources creates environmental problems. As environmental, transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete industry needs to be found. Since up to approximately 80 percent of the total volume of concrete consists of aggregate, aggregate characteristics significantly affect the performance of fresh and hardened concrete and have an impact on the cost effectiveness of concrete [Hudson,1999].

Except for water, [Quiroga, 2003] aggregate is the most inexpensive component of Portland cement concrete. Conversely, cement is the most expensive component and, typically, is responsible for about 60 percent of the total cost of materials. Paste, cement plus water, is the part of concrete that produces shrinkage, heat generation, and durability problems although, at the same time, is the element that fills aggregate voids, the glue that keeps aggregates together after hardening and the element that provides workability to the mix in fresh concrete.

To date we have had numerous questions regarding the fine aggregate requirements that influence the properties of concrete mixes. The questions have dealt primarily with the composition of the material and the volumetric requirements. While this research seeks to address these matters, it appears that some confusion still exists. This research is to give guidance on the various issues regarding the use of quarry dust as a substitute for river sand.

Both full replacement and partial replacement of river sand with quarry dust will be investigated. This will be done by mixing of both quarry dust and river sand to determine the best gradation that produces the highest compressive strength. The Mix design has been developed using British Standard Design approach for both conventional concrete and quarry dust concrete. Tests are to be conducted

on concrete cubes to study the strength of concrete made of quarry rock dust and the results were compared with the natural sand concrete.

In order to fulfill the objectives, this research seeks to establish be benefits of using quarry dust over river sand .It is well known that Compressive strength and workability are the single most important properties of concrete. This research goes further to investigate Properties of concrete such as durability and soundness and how they are affected by the substitution of river sand with quarry dust.

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

1. VMA Voids in Mineral Aggregate
2. OPC Ordinary Portland Cement
3. MSSV Magnesium Sulphate Soundness Value
4. SSD Saturated, Surface Dry
5. BSI British Standard Institutions
6. IS Indian Standards
7. NaCl Sodium Chloride
8. ICAR International Center for Aggregates Research
9. MSA Maximum size of aggregate

TABLE OF CONTENTS

CHAPTER ONE

1.0 INTRODUCTION

River sand has been widely used in Eldoret as a construction material for the manufacture of concrete. Quarry dust as a waste product from crusher operations, is considered by most construction sites as non-marketable .and non-environmentally friendly material.

The overall economy of the concrete greatly depends on the cement content of the particular mix. Different researchers have established that the replacement of natural sand with crushed stone sand can result in savings in cement.

Replacement of a portion of natural sand with Quarry dust in the production of concrete is recommended only if the gradation of the resulting fine aggregate mixture conforms to the specified standards.

In concrete, fine and coarse aggregates constitute about 80% of the total volume (Prabin, 2005). It is, therefore, important to obtain the right type and good quality aggregates at site. The aggregates form the main matrix of the concrete mixes. Most of the aggregates used in Eldoret as fine aggregates are river sand. Fine aggregates used for concrete should conform to the requirements for the prescribed grading zone as per BS: 882 – 1982. The stone particles comprising the sand should be hard and sound. .

Aggregate characteristics of shape, texture, and grading influence workability, finishability, bleeding, pumpability, and segregation of fresh concrete and affect strength, stiffness, shrinkage, creep, density, permeability, and durability of hardened concrete. Construction and durability problems have been reported due to poor mixture proportioning and variation on grading [Lafrenz, 1997].

Fine aggregates should also not be covered with deleterious materials like clay lumps and should be clean. They should not contain organic or chemically reactive impurities. Natural or river sand may not conform to all the above requirements and may have to be improved in quality by washing, grading and blending.

1.1 STUDY AREA

Eldoret town lacks the available deposits of river sand hence relying on deposits from Kisumu, Pokot and River Nzoia. This makes the market value of river sand to be higher compared to that of Quarry dust.

The uses of quarry dust are also relatively few in the Eldoret region. There is also a perception that since quarry dust is a waste product it is inferior to sand but this may not be the case.

1.1.1 Experimental Significance

River sand is becoming a very scarce material. The sand mining from our rivers have become objectionably excessive. It has now reached a stage where it is killing all our rivers day by day. Hence sand mining has to be discouraged so as to save the rivers of our country from total death. Environmental pressure, costs and a shortage of river sand has made it necessary for an alternative in this type of deposit in developing countries to be used.

In this work, an attempt has been made to study the effects of using quarry dust as a substitute for river sand, its strengths, its weaknesses and the overall effectiveness when the river sand is replaced with Quarry dust in construction activities. In the context of the depletion of natural sand, what the study suggests will certainly give an impetus to the construction scenario of not only Eldoret town but our country in general.

This study, incorporating the extended use of quarry dust, is directed towards exploring the possibility of making effective use of the discarded quarry dust in concrete.

1.1.2 Materials and Methods

The cement used for the investigation is Ordinary Portland Cement (OPC). The fine aggregates used in this study were natural sand and quarry dust. The natural sand conforming to different grading zones according to BS 882:1992 was used in the study. The Quarry dust was collected from Sirikwa Quarry.

Cement

All concrete mixes are incorporated the same variety of ordinary portland cement.

Table 1: Chemical Composition for the Ordinary Portland Cement.

Chemical components	**Values(%)**
Silicium Dioxide(SiO_2)	20.04
Aluminium Oxide(Al_2O_3)	5.61
Ferrite Oxide(Fe_2O_3)	3.27
Calcium Oxide(CaO)	63.01
Magnessium Oxide(MgO)	2.49
Sulphur trioxide(SO_3)	2.26
Chloride(Cl)	.0006

Source: *Fırat University, Technical Education Faculty, TURKEY*

The coarse aggregates used were of 20 mm . The aggregates used were of consistent quality and its constituents were assured to be free from the deleterious constituents.

Through out the work, the concrete mix proportions were determined by thorough mix design procedures taking into consideration the physical properties of the constituents.

Emphasis was laid on the quality, strength, durability and economy of the concrete.

1.2 OBJECTIVES

1. To establish the benefits of using quarry dust over river sand
    - Compressive strength
    - Workability
    - Durability
    - Economic considerations
2. To establish why most construction sites in Eldoret prefer river sand to quarry dust.

1.3 PROJECT JUSTIFICATION

Conventionally, concrete is a mixture of cement, fine aggregate, coarse aggregate and water. The fine aggregate usually used is river sand, which is fast becoming a rare and expensive commodity. Dredging the river beds, leads to problems like bank erosion, lessened quality of sand and making concrete uneconomical and less durable. Now is the time for us to think of an alternative to natural sand. In this study an attempt was made to evaluate the different types of concrete mixes involving the use of different mix proportions of quarry dust and sand, its strengths, its weaknesses and the overall effectiveness when the river sand is replaced by quarry dust above products in construction activities. The possibility of controlled use of quarry dust in concrete was also examined in this study.

1.4 PROBLEM STATEMENT

Quarry dust can be used effectively as a substitute for river sand. Both partial replacement and full replacement of river sand should be made in order to investigate if the quality of concrete can be improved. This includes the properties of concrete such as strength, workability and durability.

1.5 HYPOTHESIS

An alternative should be found to be able to cater for the dwindling sand resources here in Kenya.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 BACKGROUND INFOMATION

Aggregates have long been regarded simply as 'inert fillers' in concrete there to provide bulk and economy. A 1931 monograph on cements and Aggregates stated that' The coarse and fine aggregates in concrete are simply inert fillers used to reduce the cost' and went on to say that the type of course aggregate has relatively small effect on the strength of concrete, provided it is sound(Baker, 1931). This view has unfortunately prevailed up to the present time among engineers.

We now know that fine aggregates can have very profound influences on the physical and mechanical properties of hardened concrete. Different aggregate types may interact differently with the matrix and these differences may be technically important depending on the magnitude of the influence. On occasions, improvements in strength induced by use of different aggregates may be economically important, by permitting significant reductions in cement content. Whether engineers can exploit such effects will depend on geographical proximity of different fine aggregates sources to a construction site and their cost. Technical and economical exploitation is possible where fine aggregates are derived from dedicated quarries producing a rock type of assured consistency.

Some alternative materials have already been used as an alternative of natural sand. For example, fly ash, slag, and limestone and siliceous stone powder can be used in

concrete mixtures as a partial replacement of natural sand. Similarly, quarry waste fine aggregate could be an alternative of natural sand. It is a byproduct generated from quarrying activities involved in the production of crushed coarse aggregates. Quarry waste fine aggregate, which is generally considered as a waste material, causes an environmental load due to disposal problem. Hence, the use of quarry waste fine aggregate in concrete mixtures will reduce not only the demand for natural sand but also the environmental burden. Moreover, the incorporation of quarry waste fine aggregate will offset the production cost of concrete.

In brief, the successful utilization of quarry waste fine aggregate will turn this waste material into a valuable resource. Unfortunately, limited research has been conducted to explore the potential utilization of quarry waste fine aggregate in concrete mixtures. This study has used quarry waste fine aggregate in concrete mixtures as a partial and full replacement of natural sand. In addition, this study has examined the effect of the use of quarry waste fine aggregate on compressive strength, durability of hardened concrete.

2.1 EARLY HISTORY OF THE USE OF QUARRY DUST.

For centuries, construction aggregates or crushed stone, sand and gravel have been sold commercially for residential and commercial building construction. These materials have fundamentally improved mankind's security, safety and mobility and enhanced the quality of life. During the Greek and Roman periods, sand, gravel and volcanic rock and dust were used to make concrete-like material for use in building. Some of these structures remain standing to this day. In ancient times, a form of concrete was made from a conglomerate of gravel and broken stone with sand and lava. Vitruvius, a Roman architect and engineer, and Pliny, a Roman scholar, designed cisterns from this material for storing large amounts of water. It was not unusual for Roman roads to be made of broken stone, and some of those roads still carry traffic today. In medieval Europe, castles and cathedrals were built by stonemasons of various types of stone.

2.2.1 Advantages and disadvantages of Quarry dust

The research and development carried out on Quarry dust in countries currently using it show that Quarry dust has the following advantages and disadvantages:

2.2.1.1 Advantages of quarry dust use

1. Quarry waste fine aggregate, which is generally considered as a waste material, causes an environmental load due to disposal problem. Hence, the use of quarry waste fine aggregate in concrete mixtures will reduce not only the demand for natural sand but also the environmental burden.
2. Moreover, the incorporation of quarry waste fine aggregate may offset the production cost of concrete.
3. In brief, the successful utilization of quarry waste fine aggregate will turn this waste material into a valuable resource.
4. The main advantage of quarry dust is the consistency in its quality both in gradation and lack of contaminants.

2.2.1.2 Disadvantages of quarry dust harvesting

1. Large dump trucks used to carry aggregate may increase traffic, affect road safety, create dust and increase road maintenance requirements.

2. By their nature, aggregate operations disturb the land, and the appearance of the site from adjacent areas may be unattractive.

3. Extraction of aggregates requires the removal of vegetation and the exposure of soils and can alter storm water drainage patterns. This exposed soil may pick up sediment if not managed properly.

4. Storm water flowing across exposed soils can pick up fine clays and silt which, if not managed properly, will negatively impact offsite water quality. Quarry rock may have acid generating capabilities.

2.2 AGGREGATE CHARACTERISTICS

Aggregate characteristics have a significant effect on the behavior of fresh and hardened concrete. The impact of some particle characteristics on the performance of concrete is different for microfines, fine and coarse aggregates as well as the characterization tests required for each of these fractions.

The main characteristics of aggregate that affect the performance of fresh and hardened concrete are:

• Shape and texture
• Grading
• Absorption
• Mineralogy and coatings
• Strength and stiffness
• Maximum size
• Specific gravity
• Soundness
• Toughness

2.3 GENERAL REQUIREMENTS FOR FINE AGGREGATES

(Source American standards AM 33 section 800)

The fine aggregates consists of natural sand or, subject to approval, other inert materials with similar characteristics, or combinations having hard, strong, durable particles

2.3.1 SPECIFIC REQUIREMENTS

2.3.1.1 Deleterious Substances:

A. Deleterious Substances: The amount of deleterious substances should not exceed the following limits by dry weight:

Clay lumps.. 0.5%

Coal and lignite................................... 0.3%

Shale and other materials having a
specific gravity less than 1.95............ 1.0%
Other deleterious substances (such as
alkali, mica, coated grains, soft
and flaky particles)............................ 1.0%

The maximum amount of all deleterious substances listed above should not exceed 2.0 percent by dry weight.

2.3.1.2. Soundness

This is a term used to describe the ability of an aggregate to resist excessive changes in volume as a result of changes in physical conditions .Lack of soundness is thus distinct from expansion caused by chemical reactions between the aggregate and the alkalis in the cement.

The physical causes of large or permanent volume changes of aggregates are freezing and thawing, thermal changes at temperatures above freezing point and altering wetting and drying.

Aggregate is said to be unsound when volume changes, induced by the above causes result in deterioration of the concrete .This may range from local scaling and so-called pop-outs to extensive surface cracking and to disintegration over a considerable depth, and can thus vary from no more than impaired appearance to a structurally dangerous situation.

Unsoundness is exhibited by porous flints and cherts especially the light weight ones with a fine textural pore structure.

A British test on soundness of fine aggregates is prescribed in BS 812: part 121:1989.This determines the percentage of aggregate broken up in consequence of five cycles of immersion in a saturated solution of magnesium sulphate alternating with oven drying When the fine aggregate is subjected to five cycles of the magnesium sulfate soundness test, the weighted loss should not exceed ten percent by weight.

A satisfactory soundness record for deposits from which material has been used in concrete for five years or more, may be considered as a substitute for performing the magnesium sulfate soundness test.

2.3.1.3 Effect of Absorption

Aggregate porosity may affect durability as freezing of water in pores in aggregate particles can cause surface popouts [Popovics, 1998; Helmuth, 1994]. However, Forster [1994] states "that relationship between absorption and freeze-thaw behavior has not proven to be reliable." Nevertheless, absorption can be used as an initial indicator of soundness. Furthermore, aggregates with low absorption tend to reduce shrinkage and creep [Washa, 1998].

2.3.1.4 Organic Impurities:

Fine aggregates should be free from injurious amounts of organic impurities. Aggregates subjected to the colorimetric test for organic impurities and producing a color darker than the standard number 3 should be rejected. Should the aggregate show a darker color than samples originally approved for the work, it shall not be used until tests have been made to determine whether the increased color is indicative of an injurious amount of deleterious substances.

2.3.1.5 Grading of fine aggregates

One of the most important factors of producing workable concrete is good gradation of aggregates. A good gradation implies that a sample of aggregates contains all standard fractions of aggregates in the required proportion such that the sample contains minimum voids. A sample of the well graded aggregate containing minimum voids will require minimum (Shetty) paste to fill up the voids in the aggregates. Minimum paste will mean less quantity of cement and less quantity of water which will further mean increased economy, higher strength, lower shrinkage and greater durability. Blending of fine aggregate is allowed at times to correct the gradation.

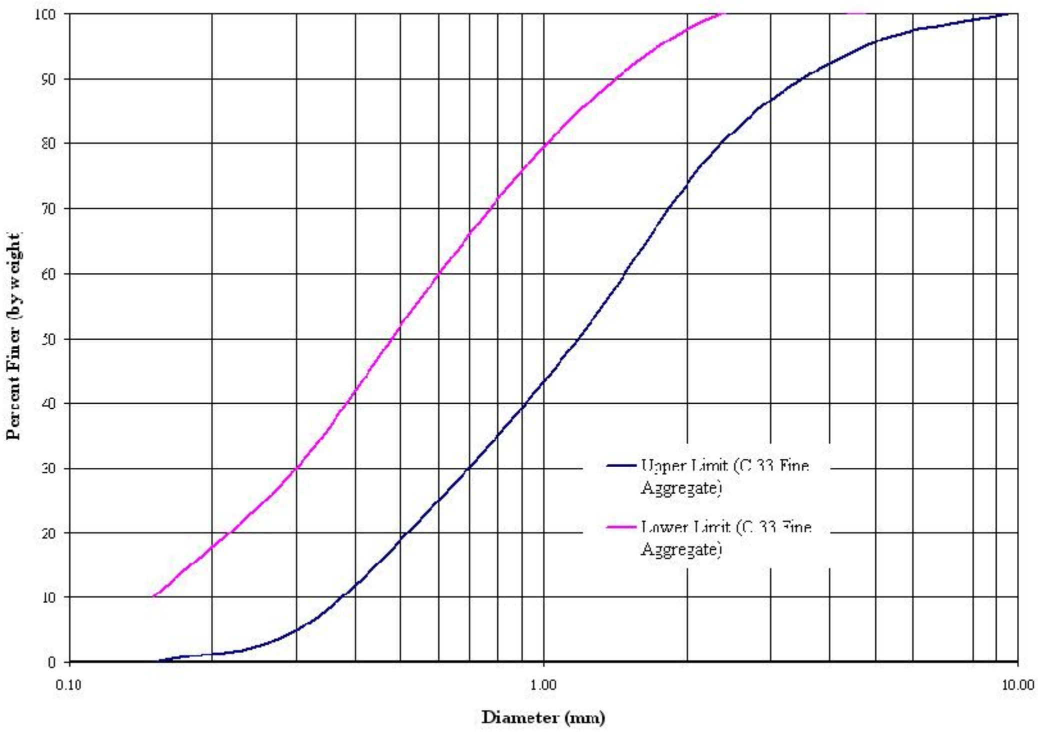


Figure 1: LIMITS FOR GRADATION CURVES FOR FINE AGGREGATES
Source: American Standards

.

CEMENTATION PROPERTIES OF QUARRY DUST

It has been established (P. V. Beresnevich, 1975) that the self-adhesion of rock dusts greatly depends on the particular type of dust, the moisture content, and the degree of compaction. With an increase in the compaction and moisture content of the rock (up to a specific value), self-adhesion of the particles increases.

A quantitative assessment (P. V. Beresnevich, 1975) was also made of the self-adhesion force for fields of magnetite and oxidized hornfels, shales, and limestones, and their specific gravity. It was found that the specific gravity of dust from a rock surface decreases with an increase in self-adhesion.

2.4 CONTAMINATION OF FINE AGGREGATES

Both fine and course aggregates should be free from impurities and deleterious substances which are likely to interfere with the process of hydration, prevention of effective bond between the aggregate and the mix. Impurities sometimes reduce the durability of the aggregate.

Generally, fine aggregates obtained from natural sources are likely to contain organic impurities in the form of silt and clay. Quarry rock dust does not normally contain organic materials. But it may contain excess of fine crushed stone dust. Course aggregate stacked in the open and unused for along time may contain moss and mud in the lower level of the stack.

Sand is normally dredged from river beds and streams in the dry season, when the river bed is dry or when there is not much flow in the river. Under such situation along with the sand, decayed vegetable mater, humus, organic mater and other impurities are likely to settle down. But if sand is dredged when there is good flow of water from very deep bed the organic matter is likely to be washed away at the time of dredging. The organic matter will interfere with the setting action of cement and also interfere with the bonding characteristics with aggregates. The presence of moss of algae will also result in entrainment of air in the concrete which reduces its strength.

Sometimes excessive silt and clay contained in the fine or course aggregate may result in increased shrinkage or increased permeability in addition to poor bond characteristics. The excessive silt and clay may also necessitate greater water requirements for a given workability.

2.4.1 Clay and silt

The quantity of clay, fine silt and fine dust are determined by sedimentation method. In this method a sample of aggregate is poured into a graduated measuring jar and the aggregate is nicely rodded to dislodge particles of clay and silt adhering to the aggregate particles. The jar with the liquid is completely shaken so that all the clay and silt particles get mixed with water and then the whole jar is kept in undisturbed condition. After a certain time interval the thickness of the layer of sand and silt particles over the fine aggregate particles will give a fair idea of the percentage of clay and silt content in the sample of aggregate under test. The limits of deleterious materials as given in IS 383-1970 in table 5

Table 2: Limits for deleterious materials

Sr No.	Deleterious substances	Method of test	Fine aggregate percentage by weight	Fine aggregate percentage by weight	Fine aggregate percentage by weight	Fine aggregate percentage by weight
			Uncrushed	Crushed	Uncrushed	Crushed
(i)	Coal and lignite	IS: 2386(Part II) 1963	1	1	1	1
(ii)	Clay lumps	IS: 2386(Part II) 1963	1	1	1	1
(iii)	Materials finer than 75-micron IS sieve	IS: 2386(Part I) 1963	3	15	3	3
(iv)	Soft fragments	IS: 2386(Part II) 1963	-	-	3	-
(v)	shale	IS: 2386(Part II) 1963	1	-	-	-
(vi)	Total percentages of all deleterious materials(except mica) including Sr. No (i) to (v) for column 4,6 & 7 and Sr No.(i) and (ii) for column 5 only		5	2	5	5

Source : Indian standards IS 383: 1970

2.4.2 Sodium chloride in fine aggregates

Fine aggregates from tidal river or from pits near the sea shore will generally contain some percentage of NaCl. The contamination of aggregates by salt will affect the setting properties and the ultimate strength of concrete. NaCl being hygroscopic, will cause efflorescence and unsightly appearance. Opinions are divided on the question whether the NaCl contained in aggregates would cause corrosion of reinforcement. But studies (Shetty)have indicated that the usual percentage of NaCl generally contained in fine aggregates will not cause corrosion in any appreciable manner. However, it is good practice not to use sand containing more than 3 per cent.

The presence of mica in the fine aggregate has been found to reduce considerably the durability and compressive strength of concrete and further investigations are underway to determine the extent of the deleterious effect of mica. Other deleterious materials include injurious quantities of flaky particles, soft shales, organic matter, clay lumps, moisture and other foreign matter.

2.5 ALKALI AGGREGATE REACTION

For a long time aggregates have been considered as inert materials but later on particularly , after 1940's it was clearly brought out that the aggregates are not fully inert. Some of the aggregates contain reactive silica, which reacts with alkalis present in cement i.e. sodium oxide and potassium oxide.

In the US it was found for the first time that many failures of concrete like pavement, piers and sea walls could be attributed to the alkali-aggregate reaction. Since then a systematic study has been made in this regard and now it is proved beyond doubt that certain types of reactive aggregates are responsible for promoting aggregate-alkali reaction.

The types of rocks which contain reactive constituents include traps, andesites, rhyolites, siliceous limestones and certain types of sandstones. The reactive constituents may be in the form of opals, cherts, chalcedony, volcanic glass, zeolites etc.

The reaction starts with attack on the reactive siliceous minerals in the aggregates by the alkaline hydroxide derived from the alkalis in the cement. As a result, the alkalis silicate gels of unlimited swelling type are formed. When the conditions are congenial, progressive manifestation by swelling takes place which results in disruption of concrete with the spreading of pattern cracks and eventual failure of concrete structures. The rate of deterioration may be slow or fast depending on the conditions. There may be cases where concrete may become unserviceable in about a years time.

Factors promoting the alkali aggregate reaction

I. Reactive type of aggregate
II. High alkali content in cement
III. Availability of moisture
IV. Optimum temperature conditions

2.6 EFFECT OF SHAPE AND TEXTURE OF FINE AGGREGATE

Shape and texture of fine aggregate have an important effect on workability of fresh concrete and have an effect on strength and durability of hardened concrete. In fact, the effects of shape and texture of fine aggregate are much more important than the effects of coarse aggregate. Equant (cubical) or spherical particles have less specific surface area than flat and elongated particles. Consequently, cubical or spherical particles require less paste and less water for workability [Shilstone, 1999; Dewar, 1992].

Flaky and elongated particles as shown in figure 2.1 negatively affect workability, producing very harsh mixtures. For a given water content these poorly shaped particles lead to less workable mixtures than cubical or spherical particles. Conversely, for given workability, flaky and elongated particles increase the demand for water thus affecting strength of hardened concrete. Spherical or cubical particles lead also to better pumpability and finishability as well as produce higher strengths and lower shrinkage than flaky and elongated aggregates [Shilstone, 1990].

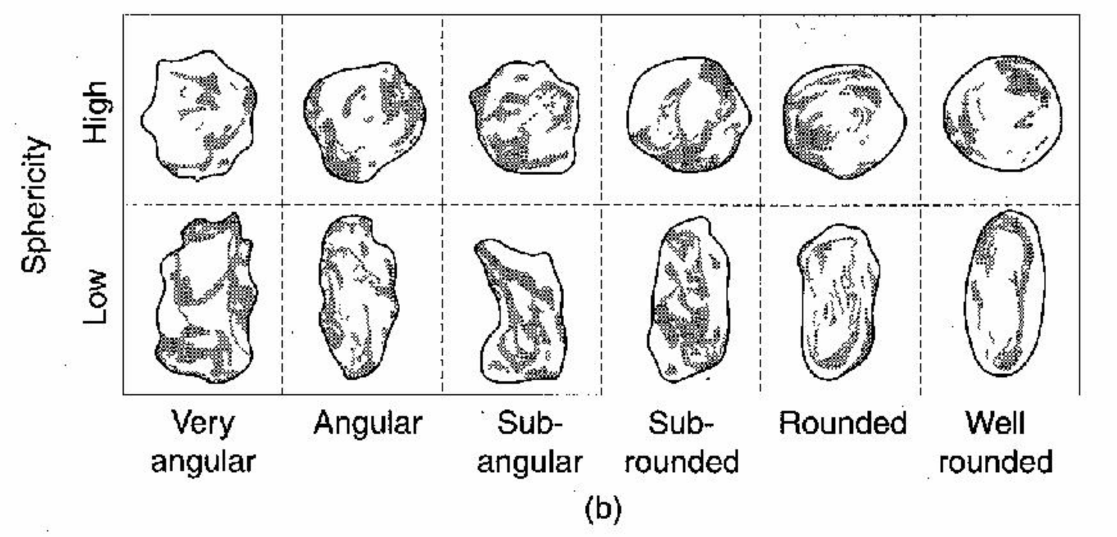


Figure 2.1:Visual Assessment of Particle Shape measurements of sphericity and roundness

Source: International Center for Aggregates Research (ICAR)

According to Hudson [1997], regarding specific surface, Murdock's Surface Index indicates that particles between 4.75 mm (No. 4) and 150 μm (No 100) appear to be the most critical; consequently particle shape will have more impact in this range. On the other hand, according to Shilstone [1990], shape has a major effect. According to the Compressible Packing Model [de Larrard, 1999] the effect of packing density has increasing importance for smaller sizes.

Angularity affects the voids content. In fact, angular particles tend to increase the demand for water as they have higher void content than round particles. Research by Kaplan [1959] indicates that compressive and flexural strengths of concrete seem to depend on angularity: angular particles tend to increase strengths. Surface texture has an effect on workability but it is not as important as grading and shape [Galloway, 1994]. Rough aggregate tends to increase the water demand for given workability. Surface texture affects particle-packing efficiency, since rough particles have higher void content; the impact of surface texture on concrete behavior becomes more important as particles get smaller [Hudson, 1999].

On the other hand, surface texture has a significant effect on strength, as rough surfaces enhance the bond between particles and paste, thus increasing strength, particularly flexural strength [Galloway, 1994].Penetration of the aggregate by cement slurry is conducive to good bond, but the porosity implied by very high penetrability may involve low tensile and shearing strength of the aggregate, with the loss in strength of the concrete. ”According to some investigators, fine aggregates with very low absorption generally develop lower strength bonds and produce less durable mortars than those with slightly higher absorption.

The interrelation between bond and absorption may account in part for the poor correlation between the durability of concrete and absorption, because the strength of bond increases as absorption increases, whereas the durability of concrete tends to decrease as absorption increases. Thus, the absorption characteristics of aggregates alone cannot be considered a reliable indication of bonding characteristics, for capillaries of extremely small size may not permit penetration of the slurry into the aggregate particles but may permit considerable penetration of water. From the standpoint of durability and bond, penetrable voids of very small size are the least desirable [Dolar-Mantuani, 1983; Ahn, 2000].

The strength and permanence of the bond between the cement and aggregate are functions not only of the surface texture, but also of the chemical characteristics of the aggregate. The integrity of bond will be lost if chemical reactions, such as that between high-alkali cement and reactive aggregates, subsequently take place. On the other hand, some types of chemical superficial interactions between the aggregate and the cement paste may be beneficial in effecting a more intimate and stronger union. Since natural sands are often rounder and smoother than manufactured sands, natural sands usually require less water than manufactured sands for given workability. However, workable concrete can be made with angular and rough particles if they are cubical and they are well graded. Manufactured sands that do not have cubical shape and that are very rough may negatively affect workability or water demand and should be avoided [Hudson, 1999]. Bleeding is significantly affected by angular, flaky, and elongated particles. As a result, crushed aggregates tend to increase bleeding, as they tend to increase the water demand [Washa, 1998; Kosmatka, 1994]. However, this could be counteracted by proper grading. Durability is also affected by shape and texture since durability is associated with low water content.

2.7: THE USE OF QUARRY DUST IN ROAD CONSTRUCTION.

Concrete pavements (specifically, Portland cement concrete) are created using a concrete mix of Portland cement, gravel, and quarry dust. The material is applied in a freshly-mixed slurry, and worked mechanically to compact the interior and force some of the thinner cement slurry to the surface to produce a smoother, denser surface free from honeycombing as shown in figure 3.

Figure 2.2: Concrete road under construction

Concrete pavements have been refined into three common types:

This are

1. Jointed plain (JPCP)
2. Jointed reinforced (JRCP)
3. Continuously reinforced (CRCP).

The one item that distinguishes each type is the jointing system used to control crack development.

Quarry dust is widely used in the construction of concrete roads because it comes from the quarry which is meant to produce the course aggregates that is used in road construction. River sand is rarely used in the construction of concrete roads and this might be due to the economic and durability factors that have been taken into consideration.

Concrete roads have a large number of advantages over bituminious ones. These advantages include:

- **Fuel Saving:** Concrete roads are rigid pavements, which do not deflect under loaded trucks, unlike bitumen pavements. Hence load carriers require less energy when travelling on concrete roads (since no effort is expended in getting out of deflection 'ruts'). Trials carried out in the USA by the Federal Highway Administration and in India by the Central Road Research Institute, have shown that laden goods carriers consume 15-20% less fuel on concrete roads as compared to bituminious ones. Considering the fact that a considerable amount of our country's goods traffic moves by road, construction of a nation-wide network of concrete roads could thus save us hundreds of shillings worth of foreign exchange now being spent on importing petroleum products.

- **Long Maintenance-Free Life:** Concrete roads have a life of 40 years or more, compared to 10 years for bituminious ones. In addition, concrete roads require almost no maintenance, whereas bituminious ones need frequent repairs due to damage by traffic, weather, etc.

- **Resistance to Weather, Oil Spills, etc.:** Concrete roads are neither damaged by rain (being waterproof), nor softened and distorted by heat. They also do not lose their binder due to leakage of oil from vehicles. Hence they remain damage free under most adverse conditions.

- **Economy in use of materials:** For the same traffic load conditions, concrete pavements are thinner than bituminious ones. Where the load bearing capacity of the soil is poor, a bituminious pavements may have to be made more than one-and-a-half times thicker than a concrete one. Concrete roads thus use less aggregates, which are in short supply or difficult to procure in many places.

- **Use of Indigenous Materials:** Concrete roads use cement, which is manufactured from indigenously available materials like limestone, of which a plentiful supply is available. Bituminious roads need bitumen, which is obtained from imported crude oil (since Indian crude contains almost no bitumen). Besides which, availability of crude oil both in Kenya and abroad is likely to reduce in the near future , thus jeopardising bitumen supplies required to repair existing bituminious roads.

Concrete roads, however, have one disadvantage vis-a-vas bituminious ones, in that they are initially costlier to construct. However, with the price of bitumen going up steadily, and the use of quarry dust in making concrete mixes for pavements now being accepted, the relative cost of these two types of pavements could become quite comparable.

When life-cycle costs are considered (as recommended by the BIS, for all competing technologies), concrete pavements with their long life and negligible maintenance, come out invariably superior to bituminious ones.

2.7 PROPERTIES OF CONCRETE

2.7.1 Strength of concrete

Strength of concrete is commonly considered the most valuable property, although in many practical cases, other characteristics, such as durability and permeability, may infact be more important. Nevertheless, strength usually gives an overall picture of the quality of concrete because strength is directly related to the structure of the hydrated cement paste. Moreover the strength of concrete is almost invariably a vital element of structural design and is specified for compliance purposes.

There are two classical theories of hardening or development of strength of cement. That put forward by Le La Chatelier in 1882 states that the products of hydration of cement have a lower solubility than the original compounds.

In engineering practice, the strength of concrete at a given age and cured in water at a prescribed temperature is assumed to depend primarily on two factors only

1. The water cement ratio
2. The degree of compaction

When concrete is fully compacted, its strength is taken to be inversely proportional to the water cement ratio. It may be recalled that the water/cement ratio determines the porosity of the hardened cement paste at a given stage of hydration. Thus the water cement ratio and the degree of compaction both affect the volume of voids in concrete

For a given concrete mix, the strength that may be developed by a workable, properly placed mixture of cement, aggregate and water is influenced by

1. Ratio of cement to mixing water
2. Ratio of cement to aggregate
3. Grading, surface texture, shape, strength and stiffness of aggregate particles
4. Maximum size of the aggregate

2.7.1.1 Testing of hardened concrete

The most common of all tests on hardened concrete is the compressive strength test, particularly because it is an easy test to perform and particularly because many, though not all of desired characteristics of concrete are quantitatively related to its strength. But mainly because of the intrinsic importance of the compressive strength of concrete in structural design. Although invariably used in construction, the compressive strength test has some disadvantages. The strength test may be affected by a number of factors. This includes

1. The variation in type of specimen
2. Specimen size
3. Type of mould
4. Curing
5. Preparation of end surface
6. Rigidity of the testing machine
7. Rate of application of stress

For this reasons, testing should follow a single standard Compressive strength tests on specimens treated in a standard manner which includes full compaction and wet curing for a specified period to give results representing the ***potential*** quality of concrete.The concrete in the structure may be inferior due to inadequate compaction, segregation or poor curing. These effects are of importance if we want to know when the formwork may be removed.

2.7.2 Workability

Concrete which can be readily compacted is said to be workable, but to say merely that workability determines the ease of placement and the resistance to segregation is too lose a description of this vital property of concrete(Neville 2000). Furthermore, the desired workability in any particular case would depend on the means of compaction available. Likewise workability suitable for mass concrete is not necessarily suitable for thin, inaccessible or heavily reinforced sections. For this reasons workability should be defined as a physical property of concrete alone without reference to the circumstances of a particular type of construction.

The aggregate characteristics, texture, shape, and size distribution play a major role in the workability of concrete.

2.7.2.1 Need for sufficient workability

Workability has so far been discussed merely as a property of fresh concrete. It is however, also a vital property as far as a finished product is concerned because concrete must have a workability such that compaction up to maximum density is possible with a reasonable amount of work or with the amount that the engineer is prepared to put in under given conditions.

The need for compaction becomes apparent from a study of the relationship between the degree of compaction and the resulting strength. It is convenient to express the former as a density ratio, i.e. a ratio of the actual density of the given concrete to the density of the same mix when fully compacted .Likewise the ratio of the strength of the concrete that is partially compacted to the strength of the same mix when fully compacted can be called the strength ratio.

.

2.7.2.2. Factors affecting workability

The main factor affecting workability is the water content of the mix, expressed in kilograms of water per cubic meter of concrete .It is convenient, though approximate, to assume that for a given type and grading of aggregate and workability of concrete, the water content is independent of the aggregate/cement ratio or of the cement content of the mix.

If the water content and other mix proportions are fixed, workability is governed by the maximum size of the aggregate, its grading, shape and texture. In particular, the higher the water/cement ratio, the finer the grading required for the highest workability.

2.7.2.3 Measurement of workability

Unfortunately there is no acceptable test which will measure directly the workability of a concrete mix(Neville 2000). Tests used to measure workability include

1. Slump test
2. Compacting factor test
3. The Vebe test

2.7.3 Durability of concrete

It is essential that every concrete structure should continue to perform its intended functions, that is maintain its required strength and serviceability, during the specified or traditional expected service life. It follows that concrete must be able to withstand the process of deterioration for which it can be expected to be exposed. Such concrete is said to be durable.

Within limits, the less paste at a constant water-cement ratio, the more durable the concrete [Shilstone, 1994].It is worth adding that durability does not mean an indefinite life, nor does it mean withstanding any action on concrete. Moreover it is nowadays realized, although it is not so in the past that, in many situations, routine maintenance of concrete is required.

There is an assumption that strong concrete is durable concrete. It is now known that for many considerations of exposure of concrete structures, both strength and durability have to be considered explicitly at the design stage.

2.7.3.1 Causes of inadequate durability

Inadequate durability manifests itself by deterioration which can be due either to external factors or to internal causes within the concrete itself. The various actions can be physical, chemical or mechanical.

Mechanical damage is caused by impact, abrasion or erosion. The chemical causes of deterioration include the alkali-silica and alkali-carbonate reactions which is external chemical attack occurs mainly through the action of aggressive ions, such as chlorides, sulphates or of carbon dioxide as well as many natural and industrial liquids and gases.

The physical causes of deterioration include effects of high temperature or the difference in thermal expansion of the aggregate and of the hardened concrete.

2.7.4 Abrasion of concrete

Under many circumstances, concrete surfaces are subjected to wear. This may be due to attrition by sliding, scraping or percussion. In the case of hydraulic structures, the action of hydraulic materials carried by water leads to erosion

Resistance of concrete to abrasion is difficult to assess because the damaging action varies depending in the exact cause of the wear and no one test procedure is satisfactory in evaluating all the conditions.

2.7.5 Effect of maximum size of aggregates in concrete

Maximum size of aggregate, MSA, influences workability, strength, shrinkage, and permeability. Mixtures with large maximum size of coarse aggregate tend to produce concrete with better workability, probably because of the decrease in the surface [Washa, 1998]. There is an optimal maximum size of coarse aggregate that produces the highest strength for a given consistency and cement content [Popovics, 1998], [Washa,1998]. For example, in high-performance concrete (HPC) with low water-cement ratio and high cement content, a high value of MSA tends to reduce strength. This can be explained by the observation that bond with large particles tends to be weaker than with small particles due to smaller surface area-to-volume ratios. Mixtures with coarse aggregate with large maximum size tend to have reduced shrinkage and creep [Washa, 1998]. Finally, for a given water-cement ratio, the permeability increases as the maximum size of the aggregate increases [Helmuth, 1994].

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

For the purpose of this research work, the quarry dust samples were obtained from Sirikwa Quarry and the river sand was obtained from Kisumu. In order to achieve the aim and specific objectives made in chapter one, the use of a combination of various approaches were considered to be inevitable. These approaches included:

1. Literature review: to establish the level of current thinking and knowledge and to provide the intellectual context for the research.

2. Laboratory experimentation and testing:
This will involve the compressive strength tests , magnesium sulphate soundness and the slump tests on concrete of class 20.

3. Visits to different construction sites in Eldoret to establish the type of fine aggregates that they use and why.

3.1 LABORATORY EXPERIMENTATION AND TESTING

3.1.1 British Method of mix selection

The British method of concrete mix design, popularly referred to as the "DOE method", is applicable to normal weight concrete made with portland cement.

The DOE Method divides concrete mix design into five stages.

3.1.1.1 Mix Design Stages

The mix design is carried out according to the DOE Method in the following five stages.

Stage (I). Determine Free Water/Cement Ratio Required for Strength

Stage (II). Determine Free Water Content Required for Workability

Stage (III). Determine Required Cement Content

Stage (IV). Determine Total Aggregate Content

Stage (V). Determine Fine Aggregate Content

3.1.2 Compressive strength test

The compressive strength test is used to measure the strength of concrete. The procedure for preparation of the concrete involves taking a sample of the mix and curing it in laboratory conditions to ensure full testing strength is achieved.

The concrete should be thoroughly mixed before placing in the oiled cube. The mix is compacted in three layers, the first being about a third full, with at least 35 strokes of the tamping rod on each layer. The cube is then cured at 20°C in a controlled environment such as a curing tank. When a prescribed time has elapsed the cubes are then subjected to the ’crushing test’

3.1.3 Magnesium Sulphate soundness test

This is the repeated immersions of aggregate samples in magnesium or sodium sulphate solutions and alternating with oven. After each drying cycle, the sodium or magnesium sulphate salt rehydration precipitated in the aggregate causes expansion during the soaking cycles. This expansion is said to simulate the expansion of water upon freezing .Soundness is a general descriptor for the ability of an aggregate to resist weathering. The sulphate soundness test is designed to simulate the physical effects of freezing and thawing.

3.1.4 Slump test

The slump test is the simplest and the most commonly used test for workability The freshly mixed concrete is packed into a 300mm high cone 200mm wide at the bottom and 100mm wide at the top, which is open. The concrete is smoothed off level at the top rim of the cone and the cone is then carefully lifted so that the concrete is left unsupported. The slump is the distance that the centre of the cone top settles .In a so called true slump test the base of the concrete does not spread excessively. If the concrete collapses or shears to one side the test results will be unreliable.

Although the slump test does not measure the work needed to compact the concrete, it gives a reasonable indication of how a mix can be placed and is simple to perform. This test is only suitable for reasonably workable and cohesive mixes.

CHAPTER 4

4.0 DATA ANALYSIS AND PRESENTATION

To accomplish the objectives, the project was divided in the following four studies:

1. Sieve analysis
2. Compressive strength tests
3. Slump test
4. Magnesium sulphate soundness test

TABLE 4.1 :SIEVE ANALYSIS FOR QUARRY DUST

SIEVE SIZES	WEIGHT RETAINED	% RETAINED	% PASSING 100
2.36 mm	689	45.45	54.55
2.0 mm	104	6.9	47.65
1.18 mm	253	16.7	30.95
600 µm	245	16.7	15.25
425 µm	59.5	4.2	10.64
300 µm	49	3.2	6.85
212 µm	41	2.7	4.15
150 µm	27	1.8	2.35
75 µm	25	1.6	0.74
63µm	15	0.9	0.56
PAN	5	0.3	0.3

GRADATION CURVE FOR QUARRY DUST

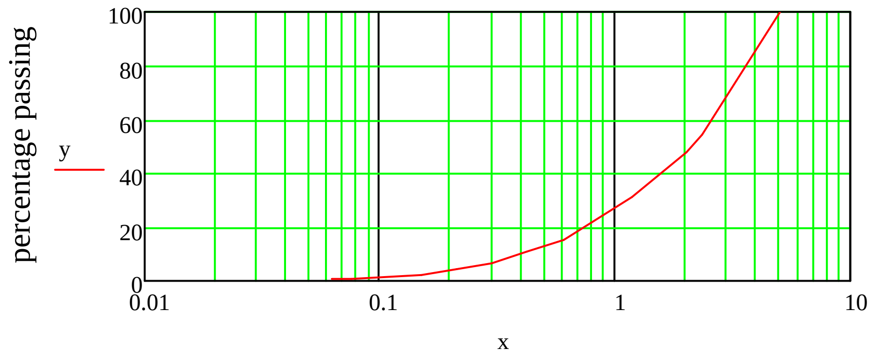


FIGURE 4.1: Gradation Curve for quarry dust

TABLE 4.2: SIEVE ANALYSIS FOR RIVER SAND

SIEVE SIZES	WEIGHT RETAINED(g)	% RETAINED	% PASSING 100
2.36 mm	168	11.2	88.8
2 mm	80	5.3	83.5
1.18 mm	327.5	21.78	61.72
600 µm	503.0	33.35	28.37
425 µm	110	7.32	18.85
300 µm	48	3.2	10.85
212 µm	105.5	7	5.75
150 µm	77	5.1	3.09
75 µm	40	2.66	1.59
63 µm	23	1.5	0.59
PAN		1	0

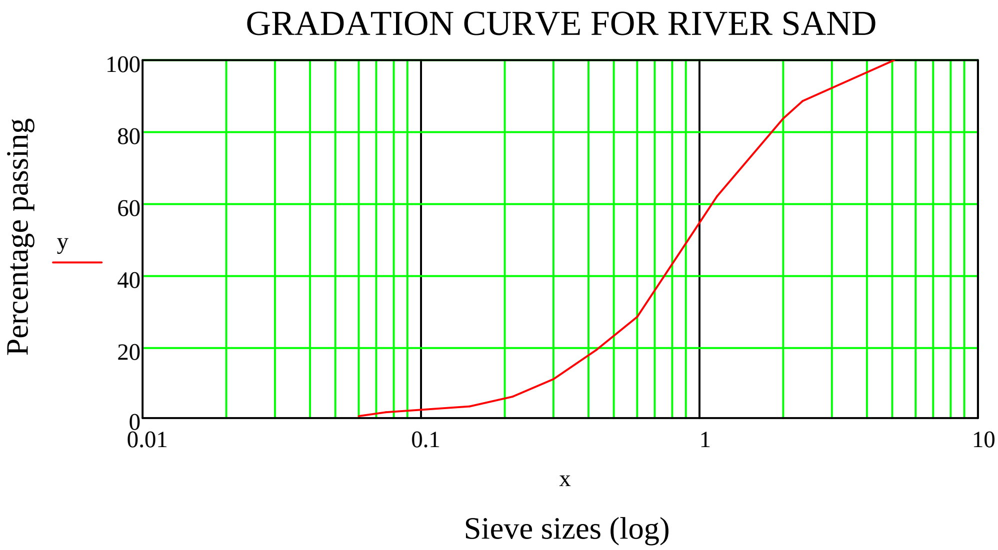
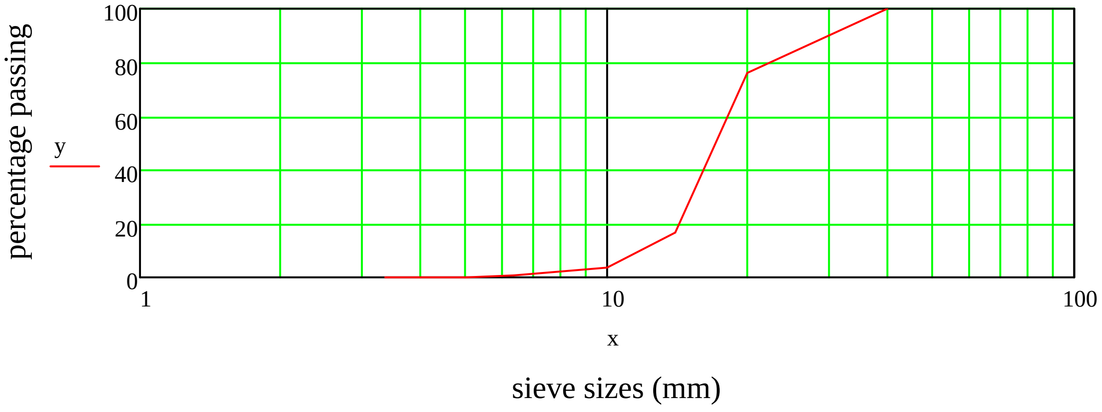


FIGURE 4.2: Gradation Curve for river sand

TABLE 4.3: SIEVE ANALYSIS FOR COURSE AGGREGATE (20mm)

SIEVE SIZES	**WEIGHT RETAINED(g)**	**% RETAINED**	**% PASSING** 100
20mm	800	23.12139	76.87
14mm	2060	59.53757	17.34
10mm	480	13.87283	3.48
6.30mm	100	2.890173	0.57
5mm	10	0.289017	0.289
3.35mm	10	0.289017	0

GRADATION CURVE FOR 20mm COURSE AGGREGATES



CONCRETE MIX DESIGN

TABLE 4.4: MIX DESIGN CALCULATION FOR CLASS 20 CONCRETE (SAND)

STEP	ITEM	REFERENCE	CALCULATIONS AND VALUES
1	Characteristic strength	Specified	Compressive 20 N/mm^2 at 28 days
	Standard deviation	Fig 3	Proportion defective = 5% 4 N/mm^2
	Margin	C1	(k= 1.64) 1.64 * 4= 6.56 N/mm^2
	Target mean strength	C2	20+6.56 = 26.56 N/mm^2
	Cement type	Specified	OPC
	Aggregate type: coarse	specified	crushed
	Aggregate type: fine	specified	natural river sand
	Free water/cement ratio Maximum free water/cement ratio	Table 2 fig 4	0.5 0.48
2	Slump	Specified	Slump 10-30
	Maximum aggregate size	Specified	20mm
	Free water content	Table 14.10	190 kg/m^3
3	Cement content	C3	190/0.48 = 395 kg/m^3
	Maximum cement content	Specified	350 kg/m^3
	Minimum cement content	specified	280 kg/m^3
4	Relative density of aggregate (SSD)	C4	2.64
	concrete density		2400 kg/m^3
	Total aggregate content		2400-190-395=1815 kg/m^3
5	Grading of fine aggregate	BS 882:1992	28% Passing 600µm sieve
	Proportion of fine aggregate	Fig 6	40%
	Fine aggregate content	C5	(1815*40/100)=726 kg/m^3
	Coarse aggregate content		1815-726 = 1089 kg/m^3

TABLE 4.5: WEIGHED RATIOS OF THE CONCRETE MIX

CEMENT	WATER	FINE AGGREGATE	COURSE AGGREGATE
395 kg/m3	190 kg/m3	726 kg/m3	1089 kg/m3

TABLE 4.6: CONCRETE RATIOS

CEMENT	FINE AGGREGATE	COURSE AGGREGATE
1	1.83	2.75

4.1.1 Preparation of Fresh Concrete:

The fresh concrete was prepared using a 50L rotating mixer. At first, the course aggregates were added into the mixer followed by the fine aggregates, then followed by the cement. The specified amount of water was then added into the mix. The entire mixing operation was completed in 5 minutes.

4.1.2 Testing of Fresh Concrete:

The fresh concretes were tested for slump. The slump and slump flow were determined based on BS 1881: Part 106.

4.1.3 Preparation of Concrete:

Cube specimens were prepared from the fresh concrete. 150 mm cube specimens were cast for use in testing of compressive strength. After casting, the specimens were left in the laboratory awaiting curing. The specimens were removed from their moulds at the age of 24±2 hours and cured in water until the day of testing. The curing temperature was maintained at 20±2°C.

4.1.4 Testing of Hardened Concretes:

The hardened concrete was tested at the age of 7, 14, 21 and 28 days to determine compressive strength. The compression test was performed according to Bs 1881 Part 119: 1983

TABLE 4.7: 100% SAND MIX

	7 DAY	**14 DAY**	**21 DAY**	**28 DAY**
DATE OF CASTING	5/03/2008	06/03//2008	10/03/2008	04/03/2008
DATE OF TESTING	13/03/2008	21/03/2008	01/04/2008	02/04/2008
LOADING	350KN	530KN	560KN	600KN
COMMPRESSIVE STRENGTH	15.55 N/mm^2	23.55 N/mm^2	24.88 N/mm^2	26.67 N/mm^2

TABLE 4.8: 25% SUBSTITUTION OF SAND WITH QUARRY DUST

	7 DAY	**14 DAY**	**21 DAY**	**28 DAY**
DATE OF CASTING	5/03/2008	5/03/2008	03/03/2008	19/03/2007
DATE OF TESTING	13/03/2008	20/03/2008	25/03/2008	17/04/2007
LOADING	300KN	480KN	520KN	550KN
COMMPRESSIVE STRENGTH	13.33N/mm^2	21.33N/mm^2	22.66N/mm^2	24.44 N/mm^2

TABLE 4.9: 50% SUBSTITUTION OF SAND WITH QUARRY DUST

	7 DAY	**14 DAY**	**21 DAY**	**28 DAY**
DATE OF CASTING	5/03/2008	12/03/2008	06/03/2008	21//02/2008
DATE OF TESTING	13/03/2008	27/03/2008	27/03/2008	21/03/2008
LOADING	310KN	460KN	505KN	510KN
COMMPRESSIVE STRENGTH	13.77N/mm2	20.44N/mm^2	22.44 N/mm^2	22.66 N/mm^2

TABLE 4.10: 100% SUBSTITUTION OF SAND WITH QUARRY DUST

(QUARRY DUST)CONCRETE	**7 DAY**	**14 DAY**	**21 DAY**	**28 DAY**
DATE OF CASTING	5/03/2008	5/03/2008	03/03/2008	28/02/2008
DATE OF TESTING	13/03/2008	20/03/2008	25/03/2008	28/03/2008
LOADING	310KN	410KN	460KN	465KN
COMMPRESSIVE STRENGTH	13.77N/mm^2	18.22N/mm^2	20.44N/mm^2	20.66 N/mm^2

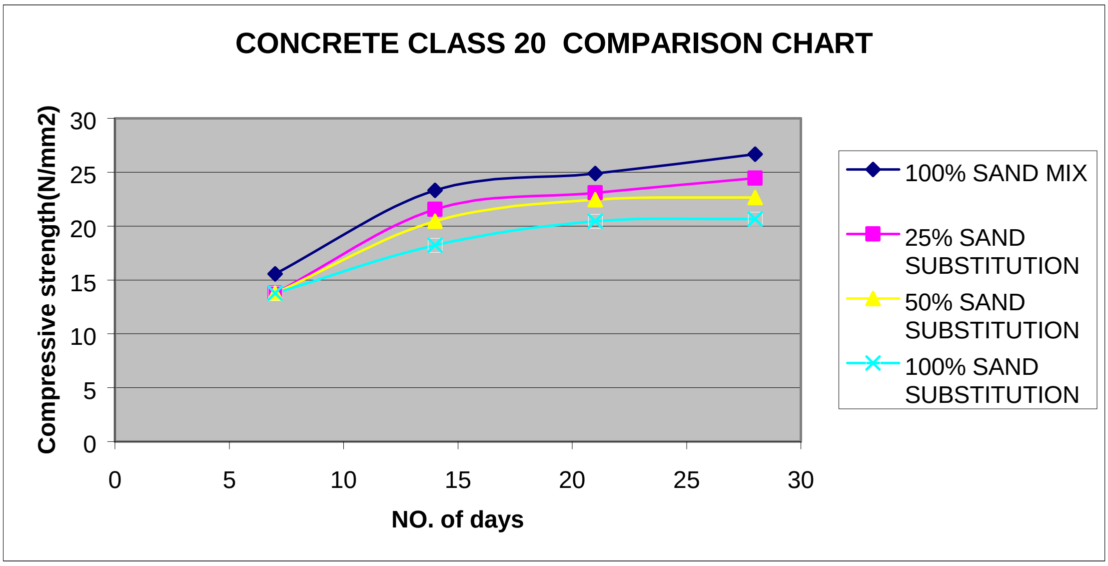


FIGURE 4.3: Comparison chart for class 20 Concrete

CONCRETE CLASS 20 AT THE SITE:

RATIO 1:2:4

TABLE 4.11: 100% SAND MIX

	7 DAY	**14 DAY**	**21 DAY**	**28 DAY**
DATE OF CASTING	15/04/2008	26/04/2008	22/04/2008	17/04/2008
DATE OF TESTING	23/04/2008	10/05/2008	14/05/200/	16/05/2008
LOADING	280KN	430 KN	525 KN	560 KN
COMMPRESSIVE STRENGTH	12.44 N/mm^2	19.11 N/mm^2	23.33 N/mm^2	24.88 N/mm^2

TABLE 4.12: 50% SUBSTITUTION OF SAND WITH QUARRY DUST

	7 DAY	**14 DAY**	**21 DAY**	**28 DAY**
DATE OF CASTING	16/04/2008	30/04/2008	24/04/2008	21/03/2008
DATE OF TESTING	24/04/2008	15/05/2008	16/05/2008	20/03/2008
LOADING	2 75 KN	400 KN	475 KN	480KN
COMMPRESSIVE STRENGTH	12.22 N/mm^2	17.77 N/mm^2	21.11 N/mm^2	21.33 N/mm^2

TABLE 4.13: 100% SUBSTITUTION OF SAND WITH QUARRY DUST

	7 DAY	**14 DAY**	**21 DAY**	**28 DAY**
DATE OF CASTING	21/04/2008	28/04/2008	16/04/2008	22/04/2008
DATE OF TESTING	29/04/2008	13/05/2008	8/05/2008	21/05/2008
LOADING	265 KN	350 KN	400 KN	410 KN
COMMPRESSIVE STRENGTH	11.77 N/mm^2	15.55 N/mm^2	17.77 N/mm^2	18.22 N/mm^2

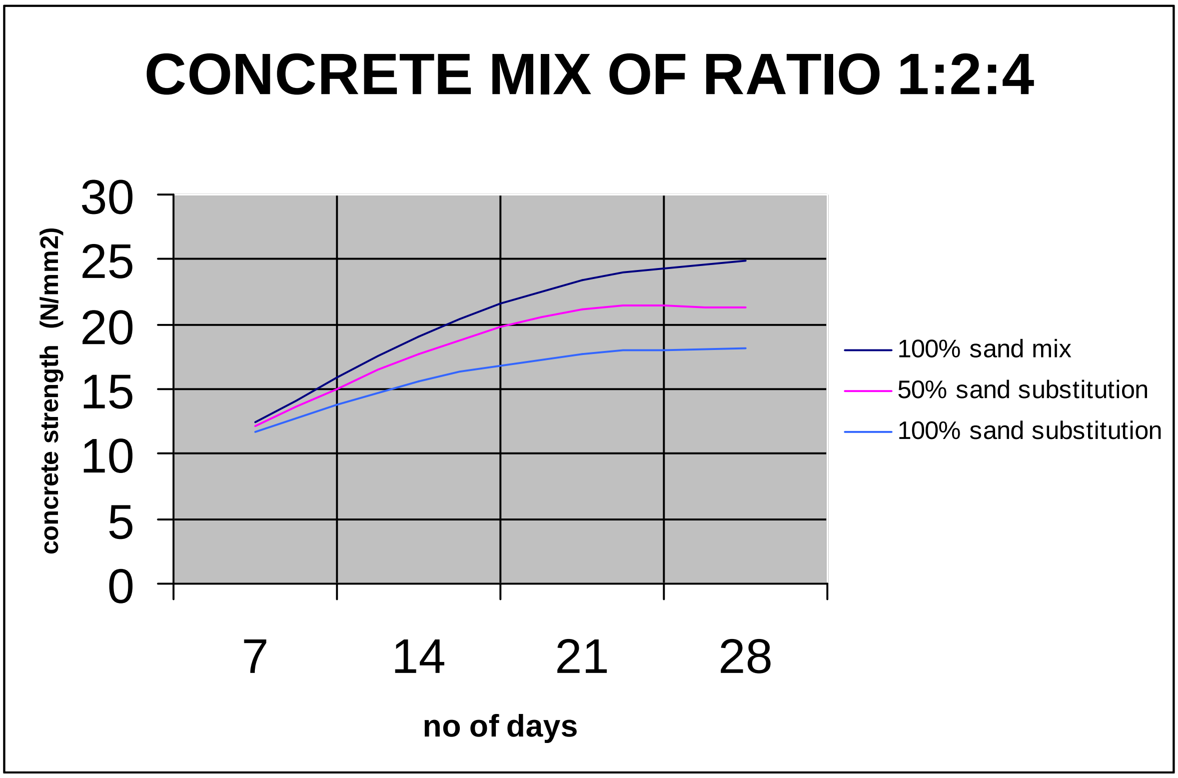


FIGURE 4.4: Comparison chart for concrete mix 1:2:4

4.3:COMPRESSIVE STRENGTH

The presence of voids in concrete greatly reduce its strength.5 per cent of voids can lower strength by as much as 30 per cent , and even 2 per cent in voids can result to a drop in strength of more than 10 per cent. This is in agreement with Féret's expression relating strength to the sum of the volumes of water and in the hardened cement paste.

From table 4.7 TO 4.10 it is manifest that the compressive strength of concrete decreased successively with increase in quarry dust content. Also from the results of table A5 it was concluded that grading for maximum density gives the highest strength and that the grading curve of the best mixture resembles a parabola (Filler and Thompson).

Figure 4.5: Compressive strength test

Source: Prof. Huissmans laboratories

4.4 MAGNESIUM SULPHATE SOUNDNESS

4.4.1 Theoretical background

This test describes the method for determining the soundness of aggregates by subjecting the aggregate to cycles of immersion in a saturated solution of magnesium sulphate followed by oven drying. This test was done according to BS 812 Part 121:1989.

.This subjected the sample of aggregate to the disruptive effects of the repeated crystallization and rehydration of magnesium sulphate within the pores of the aggregate .The degree of degradation resulting from the disruptive effects was measured by the extent to which the material finer than 1.18mm in particle size is produced.

The Soundness test was performed on both quarry dust and river sand.

4.4.2 Apparatus

1. Test Sieves of sizes 2.36mm and 1.18mm and a woven wire 1.15mm test sieves
2. A balance of at least 500g capacity accurate to 0.05g
3. At least 2 brass or stainless steel mesh brackets for immersing aggregate specimens
4. An oven capable of being heated continuously at 105° to 110°c.
5. A density hydrometer complying with Bs 718 1979 type

4.4.3 Reagents

1. A supply of distilled or deionized water
2. Barium chloride 5% solution dissolve 5g of barium chloride in 100ml of distilled water

3. A saturated solution of magnesium sulphate ($MgSO_4.7H_2O$).

Preparation of test portions and specimens

A solution was prepared by slowly adding 1500g mass of crystalline $MgSO_4.7H_2O$ to each liter of water .During preparation the temperature was maintained at between 25-30°c and stirred thoroughly during the addition of the crystals after preparation. Lower the temperature to 20°+- 2°c and maintain at this temperature for at least 48 hours before use.

Prior to use check that the solution has achieved a density of 1.292 +- 0.008g/mL using the density hydrometer.

Procedure

1. Immerse the basket containing the specimen under the test in a container holding the saturated solution of magnesium sulphate so that the aggregate is completely immersed for a period of 17H+_ 30 mins. Suspend each basket so that there is a minimum of 20mm of solution above the specimen and 20mm separation from any salt cake accumulation or from any other basket. Cover the container holding the solution and the test specimen to reduce evaporation and to prevent ingress of foreign matter.

2. At the end of the immersion period remove the basket from the solution, cover the container and leave the basket to drain for a period of 2h+_15 min. Place the basket in the oven maintained at 105°c to 110°c for at least 24 hours

3. Remove the basket from the oven and leave to cool to lab temperature for 5H+_ 15 min.

4. Immerse the basket in the saturated solution of magnesium sulphate and repeat the process of immersion, drainage, oven drying cooling and agitation described above until 5 cycles have been completed .When the specimen has cooled after the last cycle of the test wash the aggregate in the basket with water until it is free from any magnesium sulphate Ensure that no magnesium sulphate remains by adding a few drops of barium chloride solution to a 10ml aliquot of the washing and comparing the turbidity of this with the turbidity of an equal volume of fresh tap water
5. Dry the specimen in an oven at 105° to 110°c to constant mass and allow to cool in the dessicator to cool at laboratory temperature Hand sieve the specimen on a 1.18mm sieve and record the mass (M_2) of the material retained on the sieve to the nearest 0.1g

Calculation and expression for test results

The soundness value S (in %) of each specimen was calculated from the following equation recording each value to the first decimal place.

$S=100M_2/M_1$

Where M_1 is the initial mass of the test specimen.

M_2 is the mass of material retained on the 10mm sieve at the end of the test.

The mean of the two results was calculated and the magnesium sulphate soundness value (MSSV) to the nearest whole number was obtained.

Soundness value for river sand

$S=100M_2/M_1$

Where M_1 =110g

M_2 = 90.4g

$S=\frac{100x90.4}{110}$

=82.14%

the weighted loss=100-82.18

=17.18%

Soundness value for quarry dust

$S=100M_2/M_1$

Where M_1 =110g

M_2 = 99.4g

$S=\frac{100x99.4}{110}$

=90.36%

the weighted loss=100-90.36

=9.63%

Discussion

The soundness test on aggregates can be performed using either magnesium sulphate or sodium sulphate. The British method of doing the soundness test uses only magnesium sulphate while the American method uses both sodium sulphate or magnesium sulphate. The five-cycle sulfate test with magnesium is more severe and often causes a higher loss percentage than sodium. ASTM Specification C 33 recognizes this by allowing a higher limit for magnesium.

The value of the weighed loss of aggregate in sand was 17.18%. This is compared to the weighed loss of quarry dust which was 9.63% .This shows that quarry dust can resist weathering effectively compared to river sand.

After each drying cycle, the magnesium sulfate salt re-hydration precipitated in aggregate pores causes expansion during soaking cycles. This expansion is said to simulate the expansion of water upon freezing. Soundness is a general descriptor for the ability of an aggregate to resist weathering

.

4.4.4: ASTM C 33 sulfate soundness limits — percentage loss

Coarse Aggregate — 12% loss for sodium sulfate and 18% loss for magnesium sulfate.

Fine Aggregate — 10% loss for sodium sulfate and 15% loss for magnesium sulfate.

4.5: SLUMP TEST

The slump test is the most well-known and widely used test method to characterize the workability of fresh concrete. The inexpensive test, which measures consistency, is used on job sites to determine rapidly whether a concrete batch should be accepted or rejected .The workability of the concrete mix was assessed by the slump test conducted following the Bs 1881 102 1983 standard . For this test, an inverted cone was cast in three layers; each one compacted by 25 strokes of the 5/8-in. rod. The concrete cone was then leveled at the top. The slump cone was then removed vertically then the slump height was measured using a tape measure.

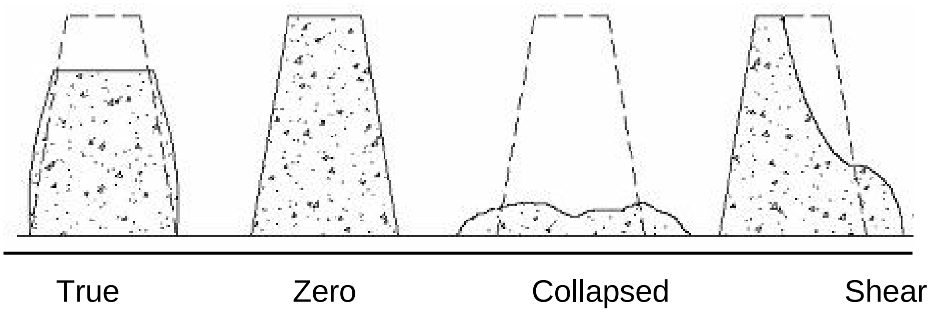


Figure 4.6: Forms of slump

TABLE 4.14: slump test results

	SLUMP HEIGHT
100% QUARRY DUST MIX	11mm
50% SAND MIX	12mm
75% SAND MIX	13mm
100% SAND MIX	15mm

4.5.1 Discussion

The aggregate characteristics, texture, shape, and size distribution play a major role in the workability of concrete. The target range for workability was 10mm to 30 mm. The low slump of the concrete made from quarry dust is a pointer to the fact that quarry dust produces concrete of low workability. However an increase in the amount of sand from the resulting blending of sand with quarry dust results to an improvement in workability of the concrete.

However, some researchers, Popovics [1994] states that the slump test does provide some information about workability and qualitative information with regard to mix cohesiveness on a “within-batch” basis. That is to say that the test offers results when comparing a sample at the front of a batch to one taken at the end of the same batch.

4.6: FINDINGS OF THE QUESTIONNAIRE

The quarry dust around Eldoret comes from three quarries namely,

1. Sirikwa quarry
2. Kaptinga quarry
3. Gituru quarry

From the questionnaire findings it was established that most construction sites around Eldoret prefer river sand compared to quarry dust in the production of concrete .This is because river sand is perceived to produce concrete having a higher compressive strength compared to quarry dust. The quarry dust was also supplied with a larger amount of particles ranging between 2mm to 5 mm and therefore making it inadequate to fill the voids in concrete to produce stronger concrete.

The amount of large particles in quarry dust also made it inappropriate for quarry dust to be used in making motar for plastering walls. The workability of concrete made with quarry dust was also found to be wanting as it is indicated by the low slump values.

However quarry dust was widely used in the making of concrete blocks. This is because , due to its cementations properties, quarry dust needs a small amount of cement to be able to form a strong bond.

CHAPTER FIVE

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The research was carried out successfully considering the stated objectives and was completed within the time frame stipulated. From the analysis and design procedures carried out in this work, several conclusions could be drawn as given below.

For a constant W / C ratio, concrete produced with river sand was 23% stronger than the concrete produced with quarry dust .This was mainly due to the capacity of river sand to be able to fill the voids in concrete better than quarry dust. However with blending of quarry dust with river sand, the difference in compressive strength was very minimal. The results indicate that quarry dust can be used effectively to replace natural sand in concrete and the use of a certain percentage of quarry dust can further enhance its quality.

The grading curve of the best mixture resembles a parabola (Filler and Thompson). The laboratory results indicate that quarry dust produced a harsher mix and formed a lower slump compared to river sand. This is because workability is governed by grading, shape and texture of the aggregates. The workability of quarry dust improved with the substitution of quarry dust with river sand.

The weighted loss of river sand in the magnesium sulphate soundness test was 17.81% while the weighted loss of quarry dust was 9.63%.This shows that the concrete made from quarry dust will be more durable compared to the concrete made from river sand. Thus, it can be concluded that quarry dust can efficiently replace river sand in the concrete industry, and proper quality control while using quarry dust can result in better results.

The cost of quarry dust ranges between Ksh. 500 to Ksh. 600 per ton while the cost of river sand ranges between 1100 Ksh. to 1200 Ksh. per ton. The findings of this research indicate that the higher compressive strength and better workability of river sand in concrete outstripped the economic consideration and higher soundness value of quarry dust thus making sand to be preferred in many construction sites.

Recommendations

1. Further research should be conducted on concrete class 30 and 40 to establish if the findings conform to the results of this research.
2. The quarry dust from Sirikwa quarry has a higher soundness value compared to river sand and therefore it is recommended to be used in road construction because ,since it is more durable, it will resist abrasion effectively .
3. It is recommended that the organic test should be done on both quarry dust and river sand to determine the amount of organic content in each.
4. In the production of concrete it is highly recommended that quarry dust be blended with river sand to improve on its workability and compressive strength.

REFFERENCE

1. Blanks, R. F., Good Concrete Depends on Good Aggregate, *Civil Engineering*,122 No. 9 : 651 – 655. 1952.
2. Aggregates for concrete BS EN 12620:2002
3. Neville A. M., *Properties of Concrete*, Pearson Education Asia, 2000.
4. Neville A. M., *Properties of Aggregates*, Pitman Books Limited, 1981.
5. Shetty. M .S , Concrete Technology: Theory and Practice, S. Chand,2005
6. Klieger P and Lamond J.F ,Significance of Tests and Properties of Concrete and Concrete-Making Materials,Technology - Page 393 ,1994
7. Murdock, L. J.. The Workability of Concrete, *Magazine for Concrete Research*, 36: 135 – 144, 1960.
8. BSI, *BS 882: Specification for Aggregates from Natural Sources for Concrete*, 1992.
9. Prabin P K. , An alternative to natural sand Surface Water Division Centre for Water Resources Development and Management (CWRDM) Kunnamangalam, Calicut – 673 571
10. Building Research Establishment (BRE) Digest No 330 (revised 1991) — Alkali aggregate reactions in concrete

11. Safiuddin M. D, 1 Raman S.N. and. Zain M.F.M ,Utilization of Quarry Waste Fine Aggregate in Concrete Mixtures, Journal of Applied Sciences Research, 3(3): 202-208, 2007
12. Pedro Nel Quiroga, the Effect of the Aggregates Characteristics on the Performance of Portland cement Concrete, The University of Texas at Austin December, 2003.

13. Eric P. Koehler and David W. Fowler, ICAR Project 108: Aggregates in Self-Consolidating Concrete Aggregates Foundation for Technology, Research, and Education (AFTRE)International Center for Aggregates Research (ICAR)The University of Texas at Austin, March 2007

14. Roshazita Che Amat and Khairun Azizi M.Azizli ,Manufactured sand as a substitute for natural sand in high technology concrete, School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia,

15. BSI, BS 882: Specification for Aggregates from Natural Sources for Concrete, 1989.

16. Prof. David Manning ,Exploitation and Use of Quarry Fines,19th March 2004.

CHAPTER SIX

APPENDICES

Appendix 1:

TABLE A1:Fine aggregate gradation chart.

Sieve size	Percentage by mass passing BS sieve			
	Overall limits	Additional limits for grading		
		C	M	F
10.00 mm	100	—	—	—
5.00 mm	89 to 100	—	—	—
2.36 mm	60 to 100	60 to 100	65 to 100	80 to 100
1.18 mm	30 to 100	30 to 90	45 to 100	70 to 100
600 µm	15 to 100	15 to 54	25 to 80	55 to 100
300 µm	5 to 70	5 to 40	5 to 48	5 to 70
150 µm	0 to 15[a]	—	—	—

NOTE Individual sands may comply with the requirements of more than one grading. Alternatively some sands may satisfy the overall limits but may not fall within any one of the additional limits C, M or F. In this case and where sands do not comply with Table 4 an agreed grading envelope may also be used provided that the supplier can satisfy the purchaser that such materials can produce concrete of the required quality.

[a] Increased to 20 % for crushed rock fines, except when they are used for heavy duty floors.

TABLE A2:Course aggregate gradation chart.

Sieve size	Percentage by mass passing BS sieves for nominal sizes							
	Graded aggregates			Single-sized aggregate				
mm	40 mm to 5 mm	20 mm to 5 mm	14 mm to 5 mm	40 mm	20 mm	14 mm	10 mm	5 mm[a]
50.0	100	—	—	100	—	—	—	—
37.5	90 to 100	100	—	85 to 100	100	—	—	—
20.0	35 to 70	90 to 100	100	0 to 25	85 to 100	100	—	—
14.0	25 to 55	40 to 80	90 to 100	—	0 to 70	85 to 100	100	—
10.0	10 to 40	30 to 60	50 to 85	0 to 5	0 to 25	0 to 50	85 to 100	100
5.0	0 to 5	0 to 10	0 to 10	—	0 to 5	0 to 10	0 to 25	45 to 100
2.36	—	—	—	—	—	—	0 to 5	0 to 30

[a] Used mainly in precast concrete products.

TABLE A3: Combined gradation of both course and fine aggregates.

Sieve size	Percentage by mass passing BS sieves for nominal sizes			
	40 mm	20 mm	10 mm	5 mm[a]
50.0 mm	100	—	—	—
37.5 mm	95 to 100	100	—	—
20.0 mm	45 to 80	95 to 100	—	—
14.0 mm	—	—	100	—
10.0 mm	—	—	95 to 100	100
5.00 mm	25 to 50	35 to 55	30 to 65	70 to 100
2.36 mm	—	—	20 to 50	25 to 100
1.18 mm	—	—	15 to 40	15 to 45
600 µm	8 to 30	10 to 35	10 to 30	5 to 25
300 µm	—	—	5 to 15	3 to 20
150 µm	0 to 8[b]	0 to 8[b]	0 to 8[b]	0 to 15

[a] Used mainly in precast concrete products.
[b] Increased to 10 % for crushed rock sand.

TABLE A4: Recommended test sieves

Reccomended test sieves , mesh baskets and mass of specimens for testing aggregates outside the range 10.0mm to 14.0mm

Size fraction	Mass of test specimen	Test sieve		Mesh baskets		
	g	% Passing mm	% retained mm	Mesh size mm	Height mm	Diameter mm
Larger than 14.0mm	800-830	28.0	20.0	3.35	160	120
	600-630	20.0	14.0	3.35	160	120
10.0mm to 14.0mm	400-420	14.0	10.0	3.35	160	120
Smaller than 10.0mm	300-310	10.0	6.30	1.18	120	95
	200-210	6.30	5.0	1.18	120	95
	200-210	5.0	3.35	0.60	120	95
	200-210	3.35	2.36	0.60	120	95
	100-110	2.36	1.18	0.15	80	65
	100-110	1.18	0.6	0.15	80	65
	100-110	0.6	0.3	0.15	80	65

TABLE A5:CONCRETE WEIGHTS IN WATER AND IN AIR

	WEIGHT IN AIR(g)	WEIGHT IN WATER(g)
100% QUARRY DUST MIX	7695	4360
50% SAND MIX	7770	4400
75% SAND MIX	7798	4634
100% SAND MIX	7850	4960

TABLE A6: CONCRETE DENSITIES

-	(SAND)	50- 50 MIX	Quarry dust
WEIGHT(g)	7907	7846	7680
DENSITY(KG/m3)	2342	2324	2275

Appendix 7:Picture of a concrete cube being weighed

Appendix 8: Picture of a slump cone.

Appendix 9:

Appendix 9 :DOE method assumptions

The DOE method is based on various assumptions and requirements:

1. Mixes are specified by the weights of the different materials contained in a given volume of fully compacted concrete.

1. It is assumed that the volume of freshly mixed concrete equals the sum of the air content and of the absolute volumes of its constituent materials. The method therefore requires that the absolute densities of the materials be known in order that their absolute volumes may be calculated.
2. It is assumed that the strength of a concrete mix depends on:

    - The Free water/Cement Ratio;
    - The Coarse Aggregate Type;
    - The Cement Properties.

3. It is assumed that the workability of a concrete mix depends primarily on:
    - The Free Water Content;
    - The Fine Aggregate Type and, to a lesser degree, the Coarse Aggregate Type;
    - The Maximum Size of Coarse Aggregate.
4. It is assumed that the workability of a concrete mix depends secondarily on:
    - The Percentage of the Fine Aggregate as a proportion of the total aggregate content.
    - The Grading of the Fine Aggregate.
    - The Free water/Cement Ratio;

QUESTIONNAIRE

PROJECT TITLE: QUESTIONNAIRE ON THE USE OF SAND AND QUARRY DUST IN DIFFERENT CONSTRUCTION SITES AROUND ELDORET

General information

1. Name of respondent…………………………..…………………….………..
2. Job title(optional)…………………………………...………………………
3. Contact details(optional)………………………….…………………………

1.Which type of fine aggregates is used in this construction site

1……………………………………
2……………………………………

2. Which sources do you get your quarry dust from?

1……………………………………
2……………………………………
3……………………………………

3. Which sources do you get your river sand from?

1……………………………………
2……………………………………
3……………………………………

4. Are there any particular structural places in buildings where river sand or quarry dust is preferred

…………………………………………………………………………………………

…………………………………………………………………………………………
…………………………………………………………………………..

5. If you compare the workability of concrete made with river sand or quarry dust, which one is better?

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

6. Which classes of concrete is in use in your construction site PS. State also the ratios?

……………………………………………………………………………………
……………………………………………………………………………………
………………………………………………………………………………

7. According to you , between river sand and quarry dust which one makes stronger concrete and why?

……………………………………………………………………………………
……………………………………………………………………………………
………………………………………………………………………………

8. If you compare the cost of river sand and quarry dust, which one is more economical? Please indicate the figures

……………………………………………………………………………………
……………………………………………………………………………………

9:Do river sand and quarry dust conform to the gradation requirements of BS 882:1992

……………………………………………………………………………………
……………………………………………………………………………………

Thank you for your cooperation