UNIVERSITY OF NAIROBI

Department of Civil and Construction Engineering

FINAL YEAR PROJECT

TITLE:
INVESTIGATION ON THE ENGINEERING PROPERTIES OF COARSE AGGREGATE LOCALLY AVAILABLE IN GARISSA COUNTY

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This project is submitted in partial fulfillment of the requirement for the award of the degree of Civil Engineering.

2014
DECLARATION

I, Omar Bashir Salah, do declare that this report is my original work and to the best of my knowledge, it has not been submitted for any degree award in any University or Institution.

Signed______________________________________________ Date ____________

Omar Bashir Salah.

CERTIFICATION

This project has been submitted for examination with my approval as the candidates’ University supervisor.

Signed______________________________________________ Date ____________

S.S.Miringu
DEDICATION

First, I would like to dedicate this research project to Almighty God who has blessed me and brought me to this point.

Secondly, I dedicate this research work to my mum and my dad, and all my family members. Their undying commitment to my education and unwavering support throughout this course has been a true revelation. May the Lord bless you all abundantly.
ACKNOWLEDGEMENTS

My sincere thanks go to my supervisor Engineer S.S. Miringu immense support, encouragement and positive criticism during the project and report writing without whom this work couldn’t have been realized. Also I would like to thank the Civil Engineering staff members and my colleagues who guided and assisted me in accomplishing this research work.

In addition, I would greatly like to thank my family and friends who stood by my side throughout my studies, and anyone else whose input facilitated my life throughout college.
ABSTRACT

One of the development goals of Kenya’s Vision 2030 is to provide affordable housing to all people. This can only be achieved by using locally available coarse aggregates in concrete production. In Garissa County, the locally available coarse aggregate which is quartz has been identified and over sometime has been used in construction as building block. Over time, as streams and seasonal rivers cut down into Tana River, they leave behind large flat terraces, usually made up of sand and gravel. These terraces are often our main source of aggregate. There are no studies carried out to be establish the properties of these aggregates which may pave way for their use in large scale project too. Therefore, the main objective of this project is to determine the physical properties these aggregates and their suitability in concrete production.

This locally available aggregates in Garissa County has a specific gravity of 2.62 which confirms that indeed they are quartz. They are smooth and hard, having Aggregate crushing value of 26.8%. From there smooth texture is clear these aggregates have travelled long distance and are transported through water bodies.
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1.0 INTRODUCTION

Garissa County is a County in the former North Eastern Province of Kenya. It is located between 0°27’25”S 39°39’30”E / 0.45694°S 39.65833°E. The County has a total population of 623,060 and covers an area of 44,170 KM$^2$. It is a 330km drive from Nairobi City. The Tana River that rises at the Aberdare Mountains West of Nyeri+ flows through the county.

1.1 PREVIEW

The construction industry in Kenya is one of the key factors of economic growth and is growing at a very high rate. Despite the high growth in the construction sector, demand for better housing in Kenya is quite high with over 80% of Kenyans living in unsatisfactory housing. This is an indication that the country is yet to be developed as suggested in vision 2030 document of government of Kenya.

Vision 2030 of the republic of Kenya, one of the aspects highlighted is the provision of affordable housing and good infrastructure.

As much as the economy of the construction is to be considered, the engineer’s responsibility is to ensure that the structural strength of any construction is not compromised. Due to diversification of construction works throughout the country’s expenses, it will be much economical to the locally /available materials within a given area.

In order to minimize construction costs, natural materials should be used as much as possible. Every endeavor should be made to use the cheap local materials before considering the importation of material from some distance. It is therefore of prime importance to make a complete inventory of all available materials, such as stone, gravel and sand at the investigation stage.

Aggregate is the most abundant geological resource available, and it is just as well, because we use a lot of it. One kilometer of two-lane highway uses 18,500 tonnes since so much material is used in construction, it is not surprising that the greatest cost associated with aggregate is for transporting it. Suitable aggregate deposits are not found everywhere; searching for local aggregate resources is a very important task.
In Garissa County, the locally found coarse aggregate which is quartz has been identified and over sometime has been used in the construction as building block. Over time, as streams and rivers cut down into the landscape, they leave behind large flat terraces, usually made up of sand and gravel. These terraces are often our main source of aggregate.

Quartz is the mineral that quartzite is composed of. Quartzite is the metamorphic rock produced from the application of heat and/or pressure on the sedimentary rock Sandstones.

The name quartzite implies not only a high degree of hardness, but also high quartz content. Quartzite generally comprises greater than 90% percent quartz, and some examples, containing up to 99% quartz, and are the largest and purest concentrations of silica in the Earth's crust. Although quartz-rich sandstone can look similar to quartzite, a fresh broken surface of quartzite will show breakage across quartz grains, whereas the sandstone will break around quartz grains. Quartzite also tends to have a sugary appearance and glassy luster. The varieties of colours displayed by quartzite are a consequence of minor amounts of impurities being incorporated with the quartz during metamorphism.

This aggregate locally found in Garissa County has a specific gravity of 2.62 which confirms that indeed they are quartz. They are smooth and hard, having Aggregate crushing value of 26.8%. From there smooth texture is clear these aggregates have travelled long distance and are transported through water bodies.

Concrete is one of the major elements of construction and is a mixture of cement, sand, ballast and water which over time hardens to form a rock member. Coarse aggregate or ballast is any solid particle that is mixed with other materials to form concrete. Concrete has to be made of material which can be produced cheaply so that no narrow limits can be imposed on aggregate. Strength of concrete depends on the use of high-quality aggregates.
Coarse aggregates are those that will pass through a screen with 75mm diameter holes but not pass through a sieve with 1/4-inch diameter holes. After extracting them, they may be crushed and blended to meet certain specifications, including size.

To ensure aggregates from these sources are of high quality to produce well-performing concrete, they should be tested against certain specifications such as:

Sieve analysis

Ten percent fines value

Aggregate crushing value

Aggregate impact value

Specific gravity and Water absorption

1.2 PROBLEM STATEMENT
Concrete is the most important building material used in construction industry globally. Concrete production has become expensive over the years due to an increase in demand for housing. This has led to an increase in prices of aggregates and cement.

One of the development goals of Kenya’s Vision 2030 is to provide affordable housing to all people especially in slums and shanties. This may be achieved by using locally available coarse aggregates in concrete production.

Thus from economical point of view, the provision of the locally available aggregates to be used in concrete production will help in lowering the cost of construction of housing units (low cost housing) for human dwelling and the construction period since the aggregates will not be transported from other regions.

The use of locally available in Garissa County for small scale projects, mainly domestic, is increasing. There are no studies carried out to be establish the properties of such aggregates which may pave way for their use in large scale project too.

1.3 OBJECTIVES
- To investigate the suitability of locally available coarse aggregates for use in concrete.
- To determine the physical properties of coarse aggregate locally found in Garissa County
- To determine the comprehensive strength of concrete cube whose coarse aggregate constitute locally found aggregate.

1.4 SIGNIFICANCE OF THE STUDY
According to the final report of Kenya vision 2030, —to adequately provide shelter for the projected population of 60 million by 2030, and assuming the household size of 5 members per household, the projected housing demand for the country would be more than 12 million quality dwelling units by the year 2030. Furthermore, more than 60 per cent of Kenyans will be living in urban areas by the year 2030—. To achieve this objective of providing quality houses to Kenyans by the year 2030 and in order
to minimize construction costs, every endeavor should be made to use the natural materials and cheap local materials before considering the importation of material from some distance. It is therefore of prime importance to make a complete inventory of all available materials, such as stone, gravel and sand at the investigation stage.

Currently Garissa County imports aggregates which make construction very expensive. The findings of this research will confirm the suitability of this locally available aggregate as a construction material. This will reduce the cost of construction since locally found aggregate is cheaper than imported aggregate especially due to reduced transportation cost.

This will also add to the existing body of knowledge from which other researchers may base their studies.
CHAPTER 2

2.0 LITERATURE REVIEW

2.1 CONCRETE

Concrete is a mixed product of various component materials mixed together in a predetermined order, quantity and quality so as to form one solid component used in construction. The major components which form concrete are water, cement, sand, ballast. This component materials are mixed together to come up with a uniform mix called wet concrete which over time solidifies to form a rock hard element taking the shape over which it is placed on while it was wet. This is then called hardened concrete and commonly forms part of structures.\(^{(4)}\)

To produce exceptional concrete, it is extremely important to have a smooth gradation of material from rock down to the finest particles. Ideally, it is best to have as much volume as possible filled with strong, durable aggregate particles, with enough paste to coat every particle. Also, voids should not be present in the paste unless they are specifically provided as microscopic entrained air bubbles to provide durability in freeze-thaw environments.

In real life, though, economics and local material availability dictate the quality of materials used. The result is that excess voids often exist between the aggregate particles that must now be filled by paste and air. The challenge becomes producing an appropriate amount of the best possible quality paste, so that the resulting hardened paste will fill the excess voids with durability and strength approaching that of the aggregates.

2.1 CONSTITUENTS OF CONCRETE

2.1.1 AGGREGATE

Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone-like solids, used in construction. Aggregate may be natural, manufactured or recycled.

2.1.1 CLASSIFICATION OF AGGREGATES

Aggregates may be broadly classified as natural or artificial, both with respect to source and method of preparation\(^{(4)}\).

Natural aggregate deposits, called pit-run gravel, consist of gravel and sand are the product of weathering and the action of wind or water, they can be readily used in concrete after minimal processing. Natural gravel and sand are usually dug or dredged from a pit, river, lake, or seabed. Crushed stone is produced by crushing quarry rock, boulders, cobbles, or large-size gravel. Crushed air-cooled blast-furnace slag is also used as fine or coarse aggregate. The aggregates are usually washed and graded at the pit or plant. Some variation in the type, quality, cleanliness, grading, moisture content, and other properties is expected. Close to half of the coarse aggregates used in Portland cement concrete in Kenya are gravels; most of the remainder are crushed stones. Naturally occurring concrete aggregates are a mixture of rocks and minerals. A mineral is a naturally occurring solid substance with an orderly internal structure and a chemical composition that ranges within narrow limits. Rocks, which are classified as igneous, sedimentary, or metamorphic, depending on origin, are generally composed of several minerals. For
example, granite contains quartz, feldspar, mica, and a few other minerals; most limestone consist of calcite, dolomite, and minor amounts of quartz, feldspar, and clay. Weathering and erosion of rocks produce particles of stone, gravel, sand, silt, and clay.

Table 2.1 CLASSIFICATION OF NATURAL AGGREGATES TO ROCK TYPE  (BS 812: Part 1:1990)

<table>
<thead>
<tr>
<th>Basalt group</th>
<th>Granite group</th>
<th>Schist group</th>
<th>Aplite group</th>
<th>Gabbro group</th>
<th>Quartzite group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andesite</td>
<td>Gneiss</td>
<td>Flint</td>
<td>Chert</td>
<td>Gritstone集团</td>
<td>Hornfels group</td>
</tr>
<tr>
<td>Basalt</td>
<td>Granite</td>
<td>Schist</td>
<td>Limestone group</td>
<td>Dolomite group</td>
<td>Group</td>
</tr>
<tr>
<td>Basic</td>
<td>Granodiorite</td>
<td>Grit</td>
<td>Dolomite group</td>
<td>Limestone group</td>
<td>Basic</td>
</tr>
<tr>
<td>Porphyrite</td>
<td>Granulite</td>
<td>Sandstone</td>
<td>Arkose</td>
<td>Marble</td>
<td>Diorite</td>
</tr>
<tr>
<td>Diabase</td>
<td>Pegmatite</td>
<td>Tuff</td>
<td>Rhyolite</td>
<td>Gabbro</td>
<td>Gneiss</td>
</tr>
<tr>
<td>Dolerite</td>
<td>Quartz-diorite</td>
<td>Granite</td>
<td>Rhyolite</td>
<td>Gabbro</td>
<td>Gabbro</td>
</tr>
<tr>
<td>Epidiorite</td>
<td>Syenite</td>
<td>Granite</td>
<td>Rhyolite</td>
<td>Gabbro</td>
<td>Peridotite</td>
</tr>
<tr>
<td>Lamprophyre</td>
<td>Flint group</td>
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<td>Rhyolite</td>
<td>Gabbro</td>
<td>Picrite</td>
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<tr>
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<td></td>
<td></td>
<td>Rhyolite</td>
<td>Gabbro</td>
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Artificial aggregates, Recycled concrete or crushed waste concrete, is a feasible source of aggregates and an economic reality, especially where good aggregates are scarce. Conventional stone crushing equipment can be used, and new equipment has been developed to reduce noise and dust.

The alternative, always used in the manufacture of good quality concrete, is to obtain the aggregates in at least two size groups, the fine and coarse aggregates generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete’s freshly mixed and hardened properties, mixture proportions, and economy. Fine aggregates generally consist of natural sand or crushed stone with most particles size not larger than 5 mm (3/16 in.) according to BS 882:1992. Coarse aggregates consist of one or a combination of gravels or crushed stone with particles predominantly larger than 5 mm (3/16in.).(4)

Aggregates must conform to certain standards for optimum engineering use: they must be clean, hard, strong, durable particles free of absorbed chemicals, coatings of clay, and other fine materials in amounts that could affect hydration and bond of the cement paste. Aggregate particles that are friable or capable of being split are undesirable. Aggregates containing any appreciable amounts of shale or other shaly rocks, soft and porous materials, should be avoided.

2.1.1.2 ROCK
In geology, a rock is a naturally occurring solid aggregate of one or more minerals. The earth is composed of rocks that have been formed over hundreds of millions of years. The Centre of the earth is composed of a core of solid material, which is believed to be made up of nickel and iron. A number of layers (some composed of liquid material called magma, make up the structure of the earth the outermost layer being called the crust. The earth’s crust varies a great deal in thickness ranging from about 65 km under mountains, to as little as 5 km under some oceans; it is the earth’s crust, which is the source of rocks used by mankind. Rocks have been used by mankind throughout history. From the Stone Age rocks have been
used for shelter and tools. The minerals and metals we find in rocks have been essential to human civilization.\(^{(2)}\)

Rocks are geologically classified according to characteristics such as mineral and chemical composition, permeability, the texture of the constituent particles, and particle size. These physical properties are the end result of the processes that formed the rocks. Over the course of time, rocks can transform from one type into another, as described by the geological model called the rock cycle. These events produce three general classes of rock: igneous, sedimentary, and metamorphic rocks.

Igneous rock is formed through the cooling and solidification of magma or lava. This magma can be derived from partial melts of pre-existing rocks in either a planet's mantle or crust. Typically, the melting of rocks is caused by one or more of three processes: an increase in temperature, a decrease in pressure, or a change in composition. Igneous rocks are divided into two main categories: plutonic rock (intrusive) and volcanic (extrusive). Plutonic or intrusive rocks result when magma cools and crystallizes slowly within the Earth's crust. Example of this type is granite. Volcanic or extrusive rocks result from magma reaching the surface either as lava forming minerals such as pumice or basalt.

Sedimentary rocks are formed by sedimentation of particles at or near the Earth's surface and within bodies of water. Before being deposited, sediment was formed by weathering and erosion in a source area, and then transported to the place of deposition by water, wind, etc. examples of sedimentary rocks are sandstones, shale...etc.

Metamorphic rocks are formed by subjecting any rock type sedimentary rock, igneous rock or another older metamorphic rock to different temperature and pressure conditions than those in which the original rock was formed. This process is called metamorphism; meaning to "change in form". The result is a profound change in physical properties and chemistry of the stone. The original rock transforms into other mineral types or else into other forms of the same mineral.

Depending on the structure, metamorphic rocks are divided into two general categories foliated and nonfoliated. The name of the rock is then determined based on the types of minerals present. Schists are foliated rocks that are primarily composed of lamellar minerals such as micas. Other varieties of foliated rock include slates, phyllites, and mylonite. Examples of non-foliated metamorphic rocks include marble, soapstone, and serpentine. This branch contains quartzite—a metamorphosed form of sandstone.

### 2.1.1.3 SANDSTONES

Sandstone is a sedimentary rock formed from cemented grains that may either be fragments of a pre-existing rock. The cements binding these grains together are typically calcite, clays, and silica. Most sandstone is composed of quartz and/or feldspar because these are the most common minerals in the Earth's crust. Like sand, sandstone may be any colour, but the most common colors are tan, brown, yellow, red, gray, pink, white and black. Since sandstone beds often form highly visible cliffs and other topographic features, certain colors of sandstone have been strongly identified with certain regions.

Sandstone has been used for domestic construction and house wares since prehistoric times, and continues to be used. Sandstone was a popular building material from ancient times. It is relatively soft, making it easy to carve. It has been widely used around the world in constructing temples, cathedrals, homes, and other buildings. It has also been used for artistic purposes to create ornamental fountains and statues.
Some sandstone are resistant to weathering, yet are easy to work. This makes sandstone a common building and paving material.

Compositional differences, both of the sand grains and the matrix, sandstone give rise to different rock names under the general heading of ‘sandstone’, such as quartzite, greywacke, gritstones, and arkoses. If sandstone is buried and undergoes sufficient heat and pressure and temperature it will metamorphosis into Quartzite.

2.1.1.4 QUARTZITE AND QUARTZ
Quartz is the mineral that quartzite is composed of, Quartzite is the metamorphic rock produced from the application of heat and/or pressure on the sedimentary rock Sandstones. Quartz is the second most abundant mineral in the Earth's continental crust, after feldspar. It is made up of a continuous framework of SiO$_4$ silicon–oxygen tetrahedra, with each oxygen being shared between two tetrahedra, giving an overall formula SiO$_2$.

![Fig 2.1; crystal structure of quartz](image)

The name quartzite implies not only a high degree of hardness, but also high quartz content. Quartzite generally comprises greater than 90% percent quartz, and some examples, containing up to 99% quartz, and are the largest and purest concentrations of silica in the Earth's crust. Although quartz-rich sandstone can look similar to quartzite, a fresh broken surface of quartzite will show breakage across quartz grains, whereas the sandstone will break around quartz grains. Quartzite also tends to have a sugary appearance and glassy lustre. The varieties of colours displayed by quartzite are a consequence of minor amounts of impurities being incorporated with the quartz during metamorphism.
2.1.1.5 SAND AND GRAVEL
Sands and gravels are defined on the basis of particle size rather than composition. Sand and gravel deposits are accumulations of the more durable rock fragments and mineral grains, which have been derived from the weathering and erosion of hard rock mainly by glacial and river action, but also by wind.

The properties of gravel, and to a lesser extent sand, largely depend on the properties of the rocks from which they were derived. However, water action is an effective mechanism for wearing away weaker particles, as well as separating different size fractions. Most sand and gravel is composed of particles that are durable and rich in silica (quartz, quartzite and flint). Other rock types, mainly limestone, may also occur in some land-won deposits including deleterious impurities such as lignite, mudstone, chalk and coal.

Processing of sand and gravel for concrete aggregate consists of washing and scrubbing to remove clay, separation of the sand fraction, grading the gravel into different sizes, sand classification and dewatering, and crushing of oversize gravel to produce smaller more saleable material. Crushing is now a common feature at many sand and gravel operations and is necessary to maximise saleable product. The washing process removes fines (silt and clay). The ‘fines’ content of a sand and gravel deposit is an important parameter in determining the viability of a deposit. Fines should not be greater than 25% for silt but less for clay as it is more difficult to remove. Gravel containing clay, for constructional fill, may be produced ‘as dug’.

2.1.1.6 CRUSHED ROCK
Crushed rocks are obtained from a quarry by drilling and blasting the bedrock. The material is then transported to the processing plant where, after removal of the fine material, it is subjected to crushing and screening a number of times. The crushing imparts to the rock particles an angular shape. It is unusual for these materials to be washed. Due to the processing requirements, crushed stone is more expensive to produce than sands and gravels.
2.1.2 CHARACTERISTICS OF AGGREGATES

2.1.2.1 Grading

The proportions of the different sizes of particles making up the aggregate are found by sieving and are known as the 'grading' of the aggregate: the grading is given in terms of the percentage by mass passing the various sieves. Continuously graded aggregates for concrete contain particles ranging in size from the largest to the smallest; in gap-graded aggregates some of the intermediate sizes are absent. Gap-grading may be necessary in order to achieve certain surface finishes. The sieves used for making a sieve analysis should conform to BS 410 or BS EN 933-2. The tests should be carried out in accordance with the procedure given in BS 812 or BS EN 933-1.

An aggregate containing a high proportion of large particles is referred to as being 'coarsely' graded and one containing a high proportion of small particles as 'finely' graded.

![Image of particle sizes](image)

**Fig. 2.3. Range of particle sizes found in aggregate for use in concrete**

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>Percentage by mass passing BS sieves for nominal sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Graded aggregates</td>
</tr>
<tr>
<td></td>
<td>40mm to 5mm</td>
</tr>
<tr>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>37.5</td>
<td>90-100</td>
</tr>
<tr>
<td>20</td>
<td>35-70</td>
</tr>
<tr>
<td>14</td>
<td>25-55</td>
</tr>
<tr>
<td>10</td>
<td>10-40</td>
</tr>
<tr>
<td>5</td>
<td>0-5</td>
</tr>
<tr>
<td>2.36</td>
<td>-</td>
</tr>
</tbody>
</table>
### Table 2.3: Grading limits for sand (from BS 882: 1992)

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>Percentage by mass passing BS sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overall limits</td>
</tr>
<tr>
<td></td>
<td>course</td>
</tr>
<tr>
<td>10mm</td>
<td>100</td>
</tr>
<tr>
<td>5mm</td>
<td>89-100</td>
</tr>
<tr>
<td>2.36mm</td>
<td>60-100</td>
</tr>
<tr>
<td>1.18mm</td>
<td>30-100</td>
</tr>
<tr>
<td>600 µm</td>
<td>15-100</td>
</tr>
<tr>
<td>300 µm</td>
<td>5-70</td>
</tr>
<tr>
<td>150 µm</td>
<td>0-15*</td>
</tr>
</tbody>
</table>

*increased to 20% for crushed rock sand except when they are used for heavy-duty floors

There are several reasons for specifying grading limits and nominal maximum aggregate size; they affect relative aggregate proportions as well as cement and water requirements, workability, pump ability, economy, porosity, shrinkage, and durability of concrete. Variations in grading can seriously affect the uniformity of concrete from batch to batch. Very fine sands are often uneconomical; very coarse sands and coarse aggregate can produce harsh, unworkable mixtures. In general, aggregates that do not have a large deficiency or excess of any size and give a smooth grading curve will produce the most satisfactory results.

#### 2.1.2.2 Particle Shape and Surface Texture

A broad classification of aggregates on the basis of shape and shape is presented in table 2.4 and 2.5 as given by BS 812: Part 1:
Table 2.4: Particle shape classification of aggregates according to BS 812: Part 1: 1990; with examples

<table>
<thead>
<tr>
<th>Classification</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rounded</td>
<td>Fully water-worn or completely shaped by attraction</td>
<td>River or seashore gravel; desert, seashore and wind blown sand</td>
</tr>
<tr>
<td>Irregular</td>
<td>Naturally irregular, or partly shaped by attrition and having rounded edges</td>
<td>Other gravels; land or dug flint</td>
</tr>
<tr>
<td>Flaky</td>
<td>Material of which the thickness is small relative to the other two dimensions</td>
<td>Laminated rock</td>
</tr>
<tr>
<td>Angular</td>
<td>Possessing well-defined edges formed at the intersection of roughly planar faces</td>
<td>Crushed rocks of all types; talus; crushed slag</td>
</tr>
<tr>
<td>Elongated</td>
<td>Material, usually angular, in which the other two dimensions</td>
<td></td>
</tr>
<tr>
<td>Flaky and elongated</td>
<td>Material having the length considerably larger than the width, and the width considerably longer than the thickness</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.5: Surface texture classification of aggregates according to BS 812: Part 1: 190 with examples

<table>
<thead>
<tr>
<th>Group</th>
<th>Surface Texture</th>
<th>Characteristics</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Glassy</td>
<td>Conchoidal fracture</td>
<td>Black flint, vitreous slag</td>
</tr>
<tr>
<td>2</td>
<td>Smooth</td>
<td>Water-worn, or smooth due to fracture of laminated or fine-grained rock</td>
<td>Gravels, chert, slate, marble, some rhyolites</td>
</tr>
<tr>
<td>3</td>
<td>Granular</td>
<td>Fracture showing more or less uniform rounded grains</td>
<td>Sandstone, oolite</td>
</tr>
<tr>
<td>4</td>
<td>Rough</td>
<td>Rough fracture of fine or medium-grained rock containing no easily visible crystalline constituents</td>
<td>Basalt, felsites, porphyry, limestone</td>
</tr>
<tr>
<td>5</td>
<td>Crystalline</td>
<td>Containing easily visible Crystalline constituents</td>
<td>Granite, gabbro, gneiss</td>
</tr>
<tr>
<td>6</td>
<td>honeycombed</td>
<td>with visible pores and cavities</td>
<td>Brick, pumice, Brick, pumice, expanded clay</td>
</tr>
</tbody>
</table>

Effect of the shape and surface texture of aggregate:

The shape and surface texture of aggregate, especially of fine aggregate, have a strong influence on the water requirement of the mix. More water is required when there is a greater void content of the loosely-
packed aggregate. Generally, flakiness and shape of the coarse aggregate have an appreciable effect on the workability of concrete. The workability decreases with an increase in the angularity number.

2.1.2.3 Bulk Density (Unit Weight) and Voids
The bulk density or unit weight of an aggregate is the mass or weight of the aggregate required to fill a container of a specified unit volume. The volume referred to here is that occupied by both aggregates and the voids between aggregate particles. Void contents range from about 30% to 45% for coarse aggregates to about 40% to 50% for fine aggregate. Angularity increases void content while larger sizes of well-graded aggregate and improved grading decreases void content. Methods of determining the bulk density of aggregates and void content are given in BS 812 part 2.

The bulk density depends on how densely the aggregate is packed and it follows that, for a material of a given specific gravity, the bulk density depends on the size distribution and shape of the particles: particles all of one size can be packed to a limited extent, but smaller particles can be added in the voids between the larger ones, thus increasing the bulk density of a packed material.

2.1.2.4 Relative Density (Specific Gravity)
The specific gravity of an aggregate is the mass of the aggregate in air divided by the mass of an equal volume of water. An aggregate with a specific gravity of 2.50 would thus be two and one-half times as heavy as water. Each aggregate particle is made up of solid matter and voids that may or may not contain water. Since the aggregate mass will vary with its moisture content, specific gravity is determined at a fixed moisture content. Four moisture conditions are defined for aggregates depending upon the amount of water held in the pores or on the surface of the particles. These conditions are shown in Fig. 5 and described as follows:

*Damp or wet*—Aggregate in which the pores connected to the surface are filled with water and with free water also on the surface.

*Saturated surface-dry*—Aggregate in which the pores connected to the surface are filled with water but with no free water on the surface.

*Air-dry*—Aggregate that has a dry surface but contains some water in the pores.

*Oven-dry*—aggregate that contains no water in the pores or on the surface.

The volume of the aggregate particle is usually assumed to be the volume of solid matter and internal pores. Two different values of specific gravity may be calculated depending upon whether the mass used is an oven-dry or a saturated surface dry mass.
2.1.3 SAMPLING OF AGGREGATES

A sample is a small portion of a larger volume or group of materials such as a stockpile, batch, carload, or truckload about which information is wanted. Sampling is the process of obtaining samples. The properties of the sample are presented as evidence of the properties of the larger unit from which it is taken. Samples should show the true nature and conditions of the materials which they represent. They will be drawn from points known to be representative of the probable variations in the material. At the laboratory the main sample will be reduced to the quantity required for testing. There are two ways of reducing the size of a sample each essentially dividing it into two similar parts of the same portion. These are:

2.1.3.1 Riffling

The sample is split into two halves using a riffler (Riffle box). This is a box with a number of parallel vertical divisions, alternate ones discharging to the left and to the right. The sample is discharged into the riffle box over its full width and the two halves are collected into the boxes at the bottom of the chutes on each side. One half is discarded and riffling of the other half is repeated until the sample is reduced to the desired size.
2.1.3.2 Quartering
The main sample is thoroughly mixed (and in case of fine aggregates, it is damped in order to avoid segregation). The aggregate is heaped into a cone and then turned over to form a new cone. This is repeated twice, the material always being deposited at the apex of the cone so that the fall of particles is evenly distributed round the circumference. The final cone is flattened and divided into quarters. One pair of the diagonally opposite quarters is discarded and the remainder forms the sample for testing. If it is still too large, it can be reduced further by quartering. Care must be taken to include all fine material in the appropriate quarter.

2.1.2 CEMENT
Portland cement is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar, and plaster. It consists of a mixture of oxides of calcium, silicon and aluminum. Portland cement and similar materials are made by heating limestone (a source of calcium) with clay, and grinding this product (called clinker) with a source of sulphate (most commonly gypsum). The manufacturing of Portland cement creates about 5 percent of human CO₂ emissions.

2.1.2.1 Production of Portland cement
There are three fundamental stages in the production of Portland cement:

1. Preparation of the raw mixture
2. Production of the clinker
3. Preparation of the cement

The chemistry of cement is very complex, so cement chemist notation was invented to simplify the formula of common oxides found in cement. This reflects the fact that most of the elements are present in their highest oxidation state, and chemical analyses of cement are expressed as mass percent of these notional oxides. The raw materials for clinker production hence cement are as follows:

- Limestone-high and low grade
- Shale
- Iron ore
- Coal- (fuel)
- Pozzolana
- gypsum

2.1.2.2 Clinker
The intermediate product produced through pyro-processing is called clinker, hourly samples are drawn for clinker analysis. Clinker is the major component of cement. Depending on clinker addition level two types of cement are produced i.e. Ordinary Portland Cement (OPC) and Portland Pozzolana Cement (PPC). Kenyan standard allow clinker usage to a minimum of 65% for the production of PPC. Clinker quality determines the quality of the cement.
2.1.3 WATER
Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and allows it to flow more easily. Less water in the cement paste will yield a stronger, more durable concrete; more water will give an easier-flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure.

Hydration involves many different reactions, often occurring at the same time. As the reactions proceed, the products of the cement hydration process gradually bond together the individual sand and gravel particles, and other components of the concrete, to form a solid mass.

2.1.4 ADMIXTURES
Chemical admixtures are materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixture.

In normal use, admixture dosages are less than 5% by mass of cement and are added to the concrete at the time of batching/mixing.

The most common types of admixtures are:

- Accelerators that speed up the hydration (hardening) of the concrete. Typical materials used are Calcium chloride and sodium chloride.
- Retarders that slow the hydration of concrete and are used in large or difficult pores where partial settling before the pour is completely undesirable. A typical retarder is table sugar, or sucrose.
- Air entrainments that add and distribute tiny air bubbles in the concrete, which will reduce damage during freeze-thaw cycles thereby increasing the concretes durability. however, entrained air is a trade off with strength as each of air may result in 5% decrease in compressive strength.
- Plasticizers (water reducing admixtures) that increase the workability of plastic or “fresh” concrete. Allowing it to be placed more easily, with less consolidating effort.
- Super plasticizers (high-range water reducing admixtures) are class of plasticizers which have fewer deleterious effects when used to significantly increase workability. Alternatively, plasticizers can be used to reduce the water content of a concrete (and have been called water reducers due to this application) while maintaining workability. This improves its strength and durability characteristics.

Uses of admixtures include:

- To increase workability without changing water content
- Reduce water content without changing workability
- Adjust setting time
- Reduce segregation and/or bleeding
- Improve pumpability
- Accelerate the rate of strength development at early ages
- Increase strength
- Improve potential durability and reduce permeability
 Reduce the total cost of the materials used in the concrete and to compensate for poor aggregate properties.

2.2 FRESH CONCRETE
This is the concrete before placement in any mould without compaction or just after placing the concrete before initial setting.

2.2.1 Properties of fresh concrete

2.2.1.1 Workability
Workability is defined as that property of freshly mixed concrete or mortar that determines the ease and homogeneity with which it can be mixed, placed, compacted, and finished.

Significance of Workability
Workability is an important property of fresh concrete because it affects the quality of several aspects of the construction process, including finishing. Workability is also a measure of uniformity. The benefits of good workability are often associated only with fresh concrete, in terms of the amount of mechanical work required to place and consolidate the concrete without segregation. However, good workability provides indirect benefits to the hardened concrete as well, because full consolidation (density) is easier to achieve. Workable mixtures that allow adequate consolidation greatly reduce the presence of large voids in the concrete, which can otherwise significantly reduce concrete strength. Also, poor workability can make finishing difficult; causing tearing of the surface that can lead to cracking. Requirements for workability will vary according to the techniques being used in the field. Therefore, contractors should be allowed to select their own workability requirements and to impose variability limits for quality assurance purposes.

The degree of workability required for proper placement and consolidation of concrete is governed by the type of mixing equipment, size and type of placing equipment, method of consolidation, and type of concrete.

Workability is affected by Water Content, aggregates, entrained Air, time and temperature, cement, supplementary Cementitious Materials, admixtures

2.2.1.2 Segregation
Segregation is the tendency for coarse aggregate to separate from the mortar in a concrete mixture, particularly when the mixture is being transported or compacted.

Significance of Segregation
Segregation results in part of the batch having too little coarse aggregate and the remainder having too much. The former is likely to shrink more and crack and have poor resistance to abrasion, while the latter may be too harsh for full consolidation and finishing. The result is that effectively a number of different concrete mixtures are being placed as shown in the figure 2.6.
Segregation is especially harmful in placing concrete for pavement, as it results in problems such as strength loss, edge slump, spalling, blistering, and scaling.

Segregation tends to decrease with increasing amounts of fine materials, including cement and supplementary cementitious materials, in the system. At the other extreme, poor mixture proportioning with excessive paste can also lead to segregation.

2.3 HARDENED CONCRETE
This is a concrete that is in a solid state and has developed certain strength. Reaction continues with time and produced hard, strong and durable solid material.

2.3.1 Properties of hardened concrete

2.3.1.1 Modulus of Elasticity and Poisson’s Ratio

Definition
The modulus of elasticity (E), or stiffness, of concrete is a measure of how much the material will deflect under load and indicates risk of cracking. Poisson’s ratio is a measure of deflection that is perpendicular to the load.

Significance of Modulus of Elasticity
The modulus of elasticity (E) parameter is used in the structural design of the pavement and for modeling the risk of cracking. Strictly defined, the modulus of elasticity is the ratio of stress to corresponding strain for loads up to about 40 percent of the ultimate strength as shown in the figure below. (Dynamic modulus is the response of concrete to dynamic rather than static loading. The dynamic modulus of concrete is normally about 10 percent higher than the static modulus.)

Poisson’s ratio is a measure of the deflection that is perpendicular to the direction of the load. A common value used for concrete is 0.20 to 0.21, but the value may vary from 0.15 to 0.25 depending on the aggregate, moisture content, concrete age, and compressive strength. Poisson’s ratio is generally of little
Modulus of elasticity increases with an increase in compressive strength and is influenced by the same factors that influence strength.

It is primarily affected by the modulus of elasticity of the aggregate and by the volumetric proportions of the aggregate in concrete. If an aggregate has the ability to produce a high modulus, then the highest modulus in concrete can be obtained by using as much of this aggregate as practical while still meeting workability and cohesiveness requirements.

**Figure 2.7: Generalized stress-strain curve for concrete**

**2.3.1.2 Shrinkage**

Shrinkage is a decrease in length or volume of the concrete due to moisture loss. Starting soon after mixing and continuing for a long time, concrete shrinks due to several mechanisms. Because concrete shrinkage is generally restrained in some way, concrete almost always cracks. Uncontrolled cracks that form at early ages are likely to grow due to mechanical and environmental stresses that would otherwise be of no concern. Therefore, minimizing uncontrolled early shrinkage cracking can prolong the service life of the concrete.

**Factors Affecting Shrinkage**

- Autogenous shrinkage is the amount of chemical shrinkage that can be measured in a sample. (Chemical shrinkage occurs because the volume of the hydration products of cement occupies less space than the original materials.) Autogenous shrinkage is normally insignificant in concrete with a high water-cementitious materials (water/cement) ratio, but it becomes important when the water/cementm ratio is below 0.40. The difference is observed as microcracking in the matrix. (A water/cementm ratio below about 0.40 is not recommended for slip form paving, although some States have had success with ratios as low as 0.37.)
- Concrete shrinks as moisture is lost from the system, largely due to evaporation.
Plastic shrinkage occurs before the concrete sets and is primarily due to loss of moisture from the surface of fresh concrete. It can result in plastic cracking in the surface.

Drying shrinkage occurs after the concrete has set. If the shrinkage is restrained, drying shrinkage cracking will occur. Drying shrinkage may also be reduced by avoiding aggregates that contain excessive amounts of clay in their fines. Quartz, granite, feldspar, limestone, and dolomite aggregates generally produce concretes with low drying shrinkages.

The most important controllable factor affecting drying shrinkage is the amount of water per unit volume of concrete. Total shrinkage can be minimized by keeping the water (or paste) content of concrete as low as possible. The higher the cement contents of a mixture, the greater the magnitude of likely drying shrinkage. The paste content can be minimized by keeping the total coarse aggregate content of the concrete as high as possible while achieving workability and minimizing segregation.

2.3.1.3 Temperature Effects

The reaction of cement with water (hydration) in concrete mixtures generates heat. Monitoring the temperature is a useful means of estimating the degree of hydration of the system. In turn, the temperature of the concrete will influence the rate of hydration (strength development) and the risk of cracking.

An optimal temperature for freshly placed concrete is in the range of 10 to 15°C (50 to 60°F), and it should not exceed 30 to 33°C (85 to 90°F). Problems associated with high concrete temperatures include increased water demand to maintain workability, decreased setting time, increased danger of plastic shrinkage cracking, reduction in the effectiveness of the air-void system, increased risk of incompatibility, and lower ultimate strength. During the winter, the primary danger is that low temperatures may slow hydration, and thus strength gain, and in extreme cases may permanently damage the concrete if it freezes early in its life.

Other thermal effects that may be of interest include solar reflectance, specific heat, and thermal diffusivity. These properties affect the amount of solar energy absorbed by concrete, the corresponding temperature change of the concrete, and the rapidity with which the concrete dissipates this temperature to its surroundings.

Effects on Hydration

The rate of hydration of concrete is significantly accelerated with increasing temperatures and slowed at lower temperatures, affecting placement and consolidation due to early stiffening, as well as the timing of saw cutting. The early strength of a concrete mixture will be higher with an elevated temperature, but the strength may be lower at later ages than the same mix kept at a lower temperature. All chemical reactions are faster at higher temperatures; therefore, setting times will be reduced as the temperature of the concrete rises. With increasing temperature, the potential for an imbalance in the cementitious paste system will be exacerbated, possibly leading to problems with unexpected stiffening of the mixture before the mixture can be consolidated. It has been observed that water may be added to such a mix to restore workability, but with the effect of reducing strength and durability. Water should not be added to the mix in excess of the specified maximum water-cement ratio.
2.3.1.4 Strength and Strength Gain

Definition
Strength is a measure of the ability of concrete to resist stresses or forces at a given age.

Significance of Strength and Strength Gain
Strength is the most commonly measured property of concrete and is often used as the basis for assessing concrete quality. This is partly because strength measurements give a direct indication of concrete’s ability to resist loads and partly because strength tests are relatively easy to conduct. The age at which a given strength is required will vary depending on the need. Contractors may want early strength (rapid strength gain) may be in order to put construction traffic on the pavement, while the owner may be interested only in the strength at a later age. The rate of strength development will also influence the risk of cracking.

Concrete is generally strong in compression, meaning it can resist heavy loads pushing it together. However, concrete is much weaker in terms of tension, meaning that the concrete is relatively weak in resisting forces pulling it apart.

The concrete’s compressive strength is typically much greater than the compressive stresses caused by the load on the slab. However, the tensile strength is only about 10 percent of the compressive strength. Most slab failures are in flexure rather than in compression. Consequently, the flexural stress and the flexural strength (modulus of rupture) of the concrete are used in pavement design to determine required slab thickness. Slab failures after the first few weeks are often due to a loss of support under the slab, which results in excessive stresses.

Another key strength parameter of concrete is fatigue, or the concrete’s ability to carry repeated loading and unloading. Under fatigue, a small crack develops in the concrete that then grows with every cycle.

2.3.1.5 Compressive Strength
Generally considered in the design of most concrete mixes.

Strength properties of concrete in a structure is usually estimated using test performed on small samples, made from fresh concrete as it is placed in the structure, which are cured in the laboratory in a standard manner. (Cube test)

Compressive strength can be affected by the quantity of cement, amount of water, types of ingredients, mix proportions, curing, temperature, age, size and shape of specimen and test conditions

Effects of the Type and Amount of Cement
Alteration of the quantity and makeup of the paste by varying the amounts and water will give concretes with different compressive strength.

Rate of hydration is not same for all type of cement.

Effects of Aggregate
Strength of concrete improves with increase in the fineness modulus of the fine aggregate. A higher number of fineness modulus means a coarser gradation.
Increase in fineness modulus, the surface area of particles goes up, requiring less mixing water at the same consistency.

Decrease in amount of water improves the compressive strength of concrete.

Larger maximum size coarse aggregate with lower water requirement can produce strong concrete. Reduction in water/cement ratio improves the strength of concrete.

Using larger aggregate without decrease in amount water decreases the compressive strength. Strength of concrete could also be affected by the type and size of coarse aggregate.

Angular and rough surface texture particles granite aggregates may contribute to an increment in compressive strength of up to 20% compared to concrete made with river gravel at the same water/cement ratio.

**Effects of Water Ratio**
The water/cement is the ratio between the weight of water and cement in a concrete mix. For proper hydration, water/cement ratio should be 0.4. In practice, water/cement 0.55-0.65, for workable concrete.

Increase in amount of mixing water, while keeping the cement content constant would lead to increase in the void content and the concrete strength drops. Increase water lead to decrease of concrete strength.

**Influence of Voids**
Increase in water content increase the voids in concrete, lowering the durability, water tightness and compressive strength.

Good dense concrete requires a sufficient amount of cement to achieve strength, suitable gradation to minimize the void content and proper consolidation to remove air bubbles trapped within the mass.

Amount of water should just be enough to guarantee the hydration of all cement grains. Any excess water in the mix (water that doesn't participate in hydration process) increases the amount of voids that will be filled with air or water depending on moisture content.

Increase in voids, diminishes the quality of concrete.

A good quality concrete need to be considered on the following aspects during concrete making sufficient amount of cement, Well-graded aggregate, ample compaction and minimum mixing water.

**Benefits of Curing**
Concrete ripen and grow stronger with age and curing. The strength of properly cured concrete at 1 day after mixing is about 10-15 % of its 28 day strength. At 7 days, it is about 50-60 percent.

Improvement in strength of concrete beyond a year is small.

Increase of water temperature, either at mixing stage or during curing, augments the rate of gain in strength.
CHAPTER 3

3.0 EXPERIMENTATION

3.1 MATERIALS

3.1.1 Aggregate
The tests on the coarse aggregate locally found in Garissa in determining their properties were done in accordance to BS812-1992.

Fig 3.1: sample of sieved local aggregate

3.1.2 Cement
Portland cement satisfying BS12:1991 and KS-18-1: 2000 of average strength 32.5N/mm² will be used. Cement not being a variable item in the experiments; it will be obtained from the lab.

3.1.3 River sand
Also not being a variable element in the experiments, one source will be maintained in order to eliminate the effects of the fine aggregates on strength.

3.2 LABORATORY TESTING OF PROPERTIES OF AGGREGATES
The tests were carried out in accordance with the procedure given in BS 812-1992.

3.2.1 Particle size distribution

Introduction
The sieves used for making a sieve analysis should conform to BS 410. The tests were carried out in accordance with the procedure given in BS 812.

Objective
I. To determine the particle size distribution of specified aggregates.
II. To draw grading curves for the aggregates specified.

Apparatus
1) A set of Sieves of different sizes.
2) Balance or scale.
Procedure

1) The test sieves were arranged from top to bottom in order of decreasing aperture sizes with pan and lid to form a sieving column.
2) The aggregate sample was then poured into the sieving column and shaken thoroughly manually.
3) The sieves were removed one by one starting with the largest aperture sizes (top most), and each sieve shaken manually ensuring no material is lost. All the material which passed each sieve was returned into the column before continuing with the operation with that sieve.
4) The retained material was weighed for the sieve with the largest aperture size and its weight recorded.
5) The same operation was carried out for all the sieves in the column and their weights recorded.
6) The screened material that remained in the pan was weighed and its weight recorded.

Calculations

1) Record the various masses on a test data sheet.
2) Calculate the mass retained on each sieve as a percentage of the original dry mass.
3) Calculate the cumulative percentage of the original dry mass passing each sieve down to the smallest aperture sieve.
3.2.2 Ten Per cent Fines Value (TFV)
This test gives a measure of the resistance of an aggregate to crushing and is applicable to both weak and strong aggregates. The ten percent fines value test is sensitive and give true picture of difference between more or less weak aggregate. The standard test is made on aggregate passing a 14.0mm test sieve and retained on a 10mm BS test sieve.

Objective

I. To determine the relative measure of the resistance of an aggregate to crushing under gradually applied compressive load.

Apparatus

1) An open ended steel cylinder of nominal 150mm internal diameter with plunger and base plate.
2) Round ended steel tamping rod 16mm Ø and 600mm long.
3) A weighing balance.
4) BS Test sieves 14mm, 10mm and 2.36mm.
5) A compressive testing machine capable of applying 400KN, at a uniform loading rate.
6) A cylindrical metal measure of internal dimensions; 115mm Ø by 180mm deep.

Procedure

1) The surface – dry aggregate was sieved through 14mm and 10mm sieves and the material retained on 10mm sieve adopted for test. The retained material was placed in the cylindrical measure and its weight of aggregate determined and recorded as Wt (A).
2) The cylinder of the test apparatus was put in position and the test sample placed in three layers each layer being subjected to 25 strokes of the tamping rod.
3) The surface of the aggregate was then leveled and the plunger inserted and ensured it rested horizontally on the surface of the aggregates.
4) The apparatus with the test sample and plunger were then placed in position between the platens of the testing machine and loaded at a uniform rate to the required load.
5) After loading the crushed material was removed from the cylinder and sieved through 2.36mm sieve. The fraction passing the 2.36mm sieve was then weighed and recorded as Wt (B).

Calculations and expression of results

Calculate the force F (in kN), to the nearest whole number, required to produce 10% of fines for each test specimen, with the percentage of material passing in the range 7.5% to 12.5%, from the following expression:

\[ 10\% \text{ Fines value} = \frac{14f}{m + 4} \]

Where

- \( f \) is the maximum force (in kN)
- \( m \) is the percentage of material passing the 2.36mm test sieve at the
maximum force.

3.2.3 Aggregate crushing value

Objective

I. To determine the relative measure of the resistance of an aggregate to crushing under gradually applied compressive load.

Apparatus

1) An open ended steel cylinder of nominal 150mm internal diameter with plunger and base plate.
2) Round ended steel tamping rod 16mm Ø and 600mm long.
3) A weighing balance.
4) BS Test sieves 14mm, 10mm and 2.36mm.
5) A compressive testing machine capable of applying 400KN, at a uniform loading rate.
6) A cylindrical metal measure of internal dimensions; 115mm Ø by 180mm deep.

Procedure

1) The surface – dry aggregate was sieved through 14mm and 10mm sieves and the material retained on 10mm sieve adopted for test. The retained material was placed in the cylindrical measure and its weight of aggregate determined and recorded as Wt (A).
2) The cylinder of the test apparatus was put in position and the test sample placed in three layers each layer being subjected to 25 strokes of the tamping rod.
3) The surface of the aggregate was then leveled and the plunger inserted and ensured it rested horizontally on the surface of the aggregates.
4) The apparatus with the test sample and plunger were then placed in position between the platens of the testing machine and loaded at a uniform rate to the required load.
5) After loading the crushed material was removed from the cylinder and sieved through 2.36mm sieve. The fraction passing the 2.36mm sieve was then weighed and recorded as Wt (B).

Calculation and expression of results

Calculate the aggregate crushing value (ACV) expressed as a percentage to the first decimal place, of the mass of fines formed to the total mass of the test specimen from the following equation

\[ ACV = \frac{M_2}{M_1} \times 100\% \]

Where

\( M_1 \) is the mass of the test specimen (in g);
\( M_2 \) is the mass of the material passing the 2.36 mm test sieve (in g).
3.2.4 Aggregate Impact value

This test was used to determine the relative measure of resistance of the aggregate to sudden shock or impact. In some aggregates, it differs from its resistance to slow compressive load. The standard aggregate impact value test was made on aggregate passing a 12.70mm and retained 9.52mm BS test sieve.

Objective

I. To determine the resistance of the aggregates to sudden impact

Apparatus

1) An aggregate impact testing machine with steel cup 100mm Ø and 50mm deep.
2) BS test sieves sizes 14mm, 10mm and 2.36mm.
3) A standard measure 75mm Ø and 50mm deep.
4) A metal tamping rod 10mm Ø and 225mm long rounded at one end.

Procedure

1) The aggregate for the test was sieved through 14mm and 10mm. The retained material on 10mm sieve was used for the test.
2) The weight of the aggregate required to fill the steel cup was measured and recorded as Wt (A) and placed in the cup fixed firmly in position on the bases of the impact machine. 25 blows of the tamping rod were then applied.
3) The sample in the cup was then subjected to 15 blows by allowing the hammer to fall freely.
4) The crushed aggregate was then sieved on a 2.36mm sieve and the weight passing the sieve determined and recorded as Wt (B).

Calculation and expression of results

Calculate the aggregate impact value (AIV) expressed as a percentage to the first decimal place, of the mass of fines formed to the total mass of the test specimen from the following equation:

\[ AIV = \frac{M_2}{M_1} \times 100\% \]

Where

- \( M_1 \) is the mass of the test specimen (in g);
- \( M_2 \) is the mass of the material passing the 2.36 mm test sieve (in g).

3.2.5 Specific gravity and water absorption

Specific gravity is used in the calculation of quantities but the actual value of the specific gravity is not a measure of its quality.

Objectives
I. To determine the relative and apparent specific gravities for the specified coarse and fine aggregates.

II. To determine water absorption for the aggregates.

Apparatus

1) A weighing balance accurate to 0.01g.
2) Test sieve with mesh apertures 10mm as specified.
3) Thermometer accurate to 0.1°C.
4) A drying oven capable of maintaining temperatures of 110°C and above.
5) A wire basket preferably 3mm mesh, 200mm diameter and 400mm height.
6) A water tight tank containing water at 22±3°C.
7) A dry absorbent cloth.

Procedure for coarse aggregates

1) Approximately 2Kg of a representative sample of aggregate retained on a 10mm test sieve was taken.
2) The sample was thoroughly washed with water to remove dust on the surface of the grains.
3) This was followed by soaking in water at 22±3°C for 24 hours.
4) The specimen was removed from water, shaken off and rolled in large absorbent cloth until all the visible films of water were removed. Large particles were wiped individually.
5) The sample was weighed and recorded as W_{SD}.
6) The samples was then placed in a wire basket, immersed in water at room temperature and tapped to remove entrapped air on the surface and between the grains and weighed the sample while immersed. This weight was recorded as W_{W}.
7) The sample was removed from water; dried in a drying oven to a constant weight at a temperature of 105°C – 110°C. and cooled to room temperature, weighed and recorded as W_{D}.

Expression of results

Relative density on an oven-dried basis = \frac{D}{A - (B - C)}

Relative density on a saturated and surface-dried basis = \frac{A}{A - (B - C)}

Apparent relative density = \frac{D}{D - (B - C)}

Water absorption (percent of dry mass) = \frac{100(A - D)}{D}

Where

A is the mass of saturated surface-dry sample in air (g)
B is the mass vessel containing sample and filled with water (g)
C is the mass of vessel filled with water only (g)
D is the mass of oven dry sample in air

3.2.6 Bulk density

Objective

I. To determine the bulk density
II. To determine the percentage of permeable voids

Apparatus

I. A cylinder of 350mm diameter 300mm thickness, 0.03m³ nominal volume fitted with handle, water tight and protected against corrosion.
II. Balance accurate to 50g
III. Steel rod 16mm diameter by 600mm long and rounded at one end

Procedure

1. The container is filled to about one third with the aggregate.
2. The tamping rod is allowed to fall freely from height of 50mm above the surface of aggregate to give blows.
3. Two similar quantities of aggregate are added to fill the container.
4. The container is filled to over flow and tamping rod is rolled across the container to obtain smooth surface flush with the top.

Calculation and expression of results

Weight of aggregate + container = \( M_1 \)

Weight of container = \( M_2 \)

Weight if aggregate \( M_3 = M_1 - M_2 \)

Volume of container = \( V \)

Bulk density \( D = \frac{M_3}{V} \)

3.3 Design of concrete mixes

This is the process of selecting the correct proportions of cement, fine and coarse aggregate, water and sometimes admixtures to produce concrete having the properties specified and desired i.e. workability, compressive strength, density and durability requirements by means of specifying the minimum or maximum water/cement ratio.

The approach to be adopted for specifying mix parameters will be reference to the weights of materials in a unit volume of fully compacted concrete. This approach will require the knowledge of expected density
of fresh concrete which depends primarily on the relative density of the aggregate and the water content of the mix. This method will result in the mix being specified in terms of the weights in kilograms of different materials required to produce 1m$^3$ of finished concrete.

Due to variability of concrete strengths, the mix must be designed to have higher mean strengths than the characteristic strength. The difference between the two is the Margin. The margin is based on the variability of concrete strengths from previous production data expressed as a standard deviation.

3.3.1 Department of Environment (DoE) mix design
The concrete mix design was done in five stages:-
STAGE 1: Selection of Target Water/Cement (WATER/CEMENT) ratio

STAGE 2: Selection of free – water content.

STAGE 3: Determination of cement content

STAGE 4: Determination of total aggregate content

STAGE 5: Selection of fine and coarse aggregate content

STAGE 6: Mix proportioning

3.3.2 Trial mixes

3.3.2.1 Production of trial mixes
The main objective of making trial mixes is to check whether or not the particular aggregates or cement selected for use will behave as anticipated. Adjustments may be made to the original mix proportions, if necessary, will differ according to how much the results of the trial mixes differ from the design values. Based on these, the courses of actions which may be contemplated are;

I. To use trial mix proportions in the production of mixes.
II. To modify the trial mix proportions slightly in the production of mixes.
III. To prepare further trial mixes incorporating major changes to the mix proportions.

The mix design method adopted gave the weights in Kg of the different materials required to produce one cubic metre of compacted concrete. The batch weights for the trial mix were obtained directly by multiplying each of the constituents contents by the volume of the mix required. For instance, in the special mix 1;

5 cubes of 150 mm each were required

Volume of 1 cube; $0.15m \times 0.15m \times 0.15m = 0.003375m^3$

Volume of mix required; $5 \times 0.003375m^3 = 0.027m^3$

Trial mixes were prepared in accordance to the requirements of BS 1881 – 108: 1983 and BS 1881 part 125 which allow the use of aggregates in any of the four moisture conditions;

(i) Oven – dry conditions.
(ii) Air – dried conditions.

(iii) Saturated surface – dry conditions.

(iv) Saturated by soaking in water for at least 24 hours.

The aggregates used were first brought to saturated surface – dry condition by addition of water of the required amount for absorption by the aggregate as specified in BS 1881 – 125:1983.

### 3.3.2.2 Adjustment to mix proportions

During the mixing process of the trial mixes, adjustments to the water contents were done by inspection of the workability of the mix. Initially, a small proportion of the mix water (approximately 10% of the initially designed value) was withheld as the mixing process continued. When by visual assessment of the workability, the mix required addition of water; water was added with great care. Furthermore, when at the designed water content, the workability of the mix appeared below that required, additional water was added to until the required workability was achieved.

### 3.4 Testing the properties of fresh concrete

#### 3.4.1 Workability

Two alternative methods were used to determine workability; Slump test which is more appropriate for higher workability mixes and the compacting factor test which is particularly appropriate for mixes which are applicable to mixes compacted by vibration.

#### 3.4.2 Slump test BS 1881: Part 102

**Introduction**

Slump test has been used extensively in site work to detect variations in the uniformity of mix of given proportions. The test was done according to BS 1881 – 102:1983 which describes the determination of slump of cohesive concrete of medium to high workability.

**Objective**

1) To determine slump of fresh concrete mix.

**Apparatus**

1) A standard mould which is a frustum of a cone complying with BS 1881 – 102: 1983.
2) A standard flat base plate preferably steel.
3) A standard tamping rod.
4) Standard graduated steel rule from 0 to 300mm at 5mm intervals.
5) A scoop approximately 100mm wide.

**Procedure**

1) The inside surfaces of the mould were cleaned and oiled to prevent adherence of fresh concrete on the surfaces.

2) The mould was the placed on the base plate and firmly held.
3) The cone was then filled with fresh concrete in three layer with each layer compacted with 25 strokes of the tamping rod.

4) After filling the mould, the top surface was struck off by means of rolling action of the tamping rod.

5) Immediately after filling, the cone was slowly and carefully lifted.

6) Immediately after removal of the mould the slump of the unsupported concrete was measured and recorded.

3.4.3 Compacting factor test

Introduction

This is the degree of compaction measured by the density ratio that is the ratio of density actually achieved in the test to the density of the same concrete fully compacted.

Objective

To determine the workability of concrete mix by compacting factor method

Apparatus

1) Compacting factor apparatus
2) Weighing balance
3) Standard rod
4) A scoop approximately 100mm wide
5) A trowel or a float

Procedure

1) The inside surfaces of the hoppers and the cylinder were cleaned, dried and oiled to reduce friction between the hopper surfaces and the concrete.
2) The upper hopper was then filled with concrete mix, the concrete being placed gently so that no work is done on concrete.
3) The door of the hopper was then released so that the concrete fell on to the lower hopper.
4) The door of the lower hopper was released so that the concrete fell on to the cylinder. Excess concrete was then cut by a trowel or a float. Concrete adhering to the cylinder outside surfaces were then removed.
5) The weight of the concrete in the cylinder was then weighed. This gave the weight of the partially compacted concrete.
6) Using the same cylinder, the concrete was then re-filled in three layers, each layer vibrated to achieve full compaction. The concrete was then weighed. This gave the weight of fully compacted concrete.

Calculations

Compacting Factor = $\frac{\text{weight of partially compacted aggregate}}{\text{weight of fully compacted aggregate}}$
3.5 Testing the properties of hardened concrete according to BS 1881

3.5.1 Determination of compressive strength-cube test

3.5.1.1 Casting of cubes
The specimens were cast in iron moulds generally 150mm cubes. This conforms to the specifications of BS 1881 – 3:1970. The moulds surfaces were first cleaned and oiled on their inside surfaces in order to prevent development of bond between the mould and the concrete. The moulds were then assembled and bolts and nuts tightened to prevent leakage of cement paste.

After preparing trial mixes, the moulds were filled with concrete in three layers, each layer being compacted using a poker vibrator to remove as much entrapped air as possible and to produce full compaction of concrete without segregation. The moulds were filled to overflowing and excess concrete removed by sawing action of steel rule. Surface finishing was then done by means of a trowel. The test specimens were then left in the moulds undisturbed for 24 hours and protected against shock, vibration and dehydration at a temperature of 20 ± 3°C.

3.5.1.2 Curing of cubes
Curing may be defined as the procedures used for promoting the hydration of cement, and consists of a control of temperature and of the moisture movement from and into the concrete. The objective of curing was to keep concrete as nearly saturated as possible, until the originally water – filled space in the fresh cement paste was filled to the desired extent by the products of hydration of cement. The temperature during curing also controls the rate of progress of the reactions of hydration and consequently affects the development of strength of concrete. The cubes were placed in a curing pond/tank at a temperature of 20 ± 2°C for the specified period of time.

Before placing cubes into a curing tank they must be marked with a water proof marker. Details to be marked on the cubes are mainly; type of mix, date of casting, duration for curing and crushing day.

3.5.1.3 Compressive Test
After curing the cubes for the specified period, they were removed and wiped to remove surface moisture in readiness for compression test. The cubes were then placed with the cast faces in contact with the platens of the testing machine that is the position of the cube when tested should be at right angles to that as cast. The load was applied at a constant rate of stress of approximately equal to 15 N/mm² to failure. The readings on the dial gauge were then recorded for each cube.
Fig3.3: Compressive test machine (Manually loaded through hydraulic system) before and after crushing.
CHAPTER 4

4.0 RESULTS AND ANALYSIS

4.1 Particle size distribution

Table 4.1 Sieve analysis for the coarse aggregate results

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>Retained mass (mm)</th>
<th>Percentage retained %</th>
<th>Cumulative pass %</th>
<th>Lower spec. limit</th>
<th>Upper spec. limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0</td>
<td>0.0</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>37.5</td>
<td>0</td>
<td>0.0</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>995</td>
<td>29</td>
<td>100</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>14</td>
<td>1280</td>
<td>39</td>
<td>71</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>10</td>
<td>680</td>
<td>20</td>
<td>32</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>370</td>
<td>11</td>
<td>12</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>0.075</td>
<td>50</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>total</td>
<td>3375</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig4.1; coarse aggregate grading curve
### Table 4.2 Sieve analysis for the fine aggregate results

<table>
<thead>
<tr>
<th>Pan mass (gm)</th>
<th>Initial dry sample mass + pan (gm)</th>
<th>Initial dry sample mass (gm)</th>
<th>Fine mass (gm)</th>
<th>Fine percent (%)</th>
<th>Acceptance Criteria (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>133</td>
<td>562</td>
<td>429</td>
<td>4</td>
<td>0.9</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>Retained mass (g)</th>
<th>Percentage retained</th>
<th>Cumulative pass %</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>0</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>4.76</td>
<td>14</td>
<td>3.3</td>
<td>96.7</td>
</tr>
<tr>
<td>2.36</td>
<td>15</td>
<td>3.5</td>
<td>93.2</td>
</tr>
<tr>
<td>1.18</td>
<td>46</td>
<td>10.6</td>
<td>82.5</td>
</tr>
<tr>
<td>0.6</td>
<td>112</td>
<td>28.1</td>
<td>56.4</td>
</tr>
<tr>
<td>0.3</td>
<td>148</td>
<td>34.4</td>
<td>21.9</td>
</tr>
<tr>
<td>0.15</td>
<td>76</td>
<td>17.7</td>
<td>4.2</td>
</tr>
<tr>
<td>0.075</td>
<td>14</td>
<td>3.3</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>425</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

**Fig 4.2; Fine aggregate grading curve**

[Diagram of fine aggregate grading curve]
### 4.2 Specific gravity (SG) and water absorption

**Table 4.3 specific gravity and water absorption results**

<table>
<thead>
<tr>
<th>Saturated surface dried,</th>
<th>=579g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submerge weight</td>
<td>=359g</td>
</tr>
<tr>
<td>Saturated surface dried SG</td>
<td>$\frac{579}{579-359} = 2.63$</td>
</tr>
<tr>
<td>Oven dried weight,</td>
<td>=578.9g</td>
</tr>
<tr>
<td>Oven dried S.G/apparent S.G</td>
<td>$\frac{578.9}{579-359} = 2.63$</td>
</tr>
<tr>
<td>Water absorption</td>
<td>$\frac{579-578.3}{578.3} = 0.121%$</td>
</tr>
</tbody>
</table>

### 4.3 Bulk density

**Table 4.4 Bulk density results**

<table>
<thead>
<tr>
<th>Weight of aggregate + can</th>
<th>=7130g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of can</td>
<td>=2570</td>
</tr>
<tr>
<td>Weight of aggregate</td>
<td>=4560g</td>
</tr>
<tr>
<td>volume</td>
<td>=2700cm$^3$</td>
</tr>
<tr>
<td>Bulk Density</td>
<td>$\frac{4560}{2700} = 1.69,g/cm^3 = 1690,kg/m^3$</td>
</tr>
</tbody>
</table>
### 4.4 Ten Per cent Fines Value (TFV)

**Table 4.5 Ten percent fines value results**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum force applied, $f$</td>
<td>=370kN</td>
</tr>
<tr>
<td>Weight passed, $M_2$</td>
<td>=816g</td>
</tr>
<tr>
<td>Weight retained, $M_3$</td>
<td>$=M_2+M_3=2228g$</td>
</tr>
<tr>
<td>Total weight of sample, $M_1$</td>
<td>=3044 g</td>
</tr>
<tr>
<td>Percentage of material passing, $m$</td>
<td>$=\frac{M_2}{M_1}\times100% = \frac{816}{3044}\times100% =26.8%$</td>
</tr>
<tr>
<td>Ten percent Fines value</td>
<td>$=\frac{14f}{m+4} = \frac{14\times370}{26.4+4} =160kN$</td>
</tr>
</tbody>
</table>

### 4.5 Aggregate impact value (AIV)

**Table 4.6 Aggregate impact value results**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight passed, $M_2$</td>
<td>=119g</td>
</tr>
<tr>
<td>Weight retained</td>
<td>=547g</td>
</tr>
<tr>
<td>Total weight, $M_1$</td>
<td>=666g</td>
</tr>
<tr>
<td><strong>AIV</strong></td>
<td>$=\frac{M_2}{M_1}\times100% = \frac{119}{666}\times100% =19%$</td>
</tr>
</tbody>
</table>

### 4.6 Aggregate crushing value (ACV)

**Table 4.7 Aggregate crushing value results**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight passed, $M_2$</td>
<td>=816g</td>
</tr>
<tr>
<td>Weight retained</td>
<td>=2228g</td>
</tr>
<tr>
<td>Total weight, $M_1$</td>
<td>=3044g</td>
</tr>
<tr>
<td><strong>ACV</strong></td>
<td>$=\frac{M_2}{M_1}\times100% = \frac{816}{3044}\times100% =18%%$</td>
</tr>
</tbody>
</table>
4.7 FRESH CONCRETE

4.7.1 WORKABILITY RESULTS
The tests were carried in two batches.

1. Slump test

Table 4.8 Batch 1 and 2 slump test results

<table>
<thead>
<tr>
<th>Batch 1.</th>
<th></th>
<th>slumps</th>
</tr>
</thead>
<tbody>
<tr>
<td>before</td>
<td>30</td>
<td>25.5</td>
</tr>
<tr>
<td>slump</td>
<td>30</td>
<td>25.5</td>
</tr>
<tr>
<td>4.5cm=45mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Batch 2.</th>
<th></th>
<th>slumps</th>
</tr>
</thead>
<tbody>
<tr>
<td>before</td>
<td>30</td>
<td>25.2</td>
</tr>
<tr>
<td>slump</td>
<td>30</td>
<td>25.2</td>
</tr>
<tr>
<td>4.8cm=48mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Compacting factor (CF)
Compacting Factor = $\frac{\text{weight of partially compacted aggregate}}{\text{weight of fully compacted aggregate}}$

Table 4.9 Batch 1 and 2 Compacting factor results

<table>
<thead>
<tr>
<th>Batch 1.</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Partially compacted weight</td>
<td>10.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fully compacted weight</td>
<td>12.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compacting Factor</td>
<td>0.84</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Batch 2.</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Partially compacted weight</td>
<td>11.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fully compacted weight</td>
<td>13.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compacting Factor</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.8 HARDENED CONCRETE

4.8.1 COMpressive STRENGTH TEST

Table 4.10; 7day concrete cube compressive test results

<table>
<thead>
<tr>
<th>Test cube no.</th>
<th>Cube size (mm)</th>
<th>Age in days</th>
<th>Weight (kg/m$^3$)</th>
<th>Applied load (kN)</th>
<th>Comprehensive strength(N/mm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC1</td>
<td>150×150×150</td>
<td>7</td>
<td>2317</td>
<td>407</td>
<td>18.1</td>
</tr>
<tr>
<td>LC2</td>
<td>150×150×150</td>
<td>7</td>
<td>2305</td>
<td>415</td>
<td>18.4</td>
</tr>
<tr>
<td>LC3</td>
<td>150×150×150</td>
<td>7</td>
<td>2315</td>
<td>395</td>
<td>17.5</td>
</tr>
<tr>
<td>LC4</td>
<td>150×150×150</td>
<td>7</td>
<td>2315</td>
<td>425</td>
<td>18.8</td>
</tr>
</tbody>
</table>
Table 4.11; 14 day concrete cube compressive test results

<table>
<thead>
<tr>
<th>Test cube no.</th>
<th>Cube size (mm)</th>
<th>Age in days</th>
<th>Weight (kg/m$^3$)</th>
<th>Applied load (kN)</th>
<th>Comprehensive strength (N/mm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC5</td>
<td>150×150×150</td>
<td>14</td>
<td>2317</td>
<td>520</td>
<td>23.1</td>
</tr>
<tr>
<td>LC6</td>
<td>150×150×150</td>
<td>14</td>
<td>2310</td>
<td>515</td>
<td>22.8</td>
</tr>
<tr>
<td>LC7</td>
<td>150×150×150</td>
<td>14</td>
<td>2315</td>
<td>510</td>
<td>22.6</td>
</tr>
<tr>
<td>LC48</td>
<td>150×150×150</td>
<td>14</td>
<td>2315</td>
<td>528</td>
<td>23.4</td>
</tr>
</tbody>
</table>

fig4.3; 7 day concrete cube compressive test results

fig4.4; 14 day concrete cube compressive test results
Table 4.12: 28day concrete cube compressive test results

<table>
<thead>
<tr>
<th>Test cube no.</th>
<th>Cube size (mm)</th>
<th>Age in days</th>
<th>Weight (kg/m³)</th>
<th>Applied load (kN)</th>
<th>Comprehensive strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC9</td>
<td>150×150×150</td>
<td>28</td>
<td>2317</td>
<td>605</td>
<td>26.8</td>
</tr>
<tr>
<td>LC10</td>
<td>150×150×150</td>
<td>28</td>
<td>2305</td>
<td>580</td>
<td>25.7</td>
</tr>
<tr>
<td>LC11</td>
<td>150×150×150</td>
<td>28</td>
<td>2317</td>
<td>628</td>
<td>26.0</td>
</tr>
<tr>
<td>LC12</td>
<td>150×150×150</td>
<td>28</td>
<td>2315</td>
<td>595</td>
<td>26.4</td>
</tr>
</tbody>
</table>

![28day compressive strength](chart.png)

*fig4.5; 28day concrete cube compressive test chart*

Table 4.13: average 7, 14, 28 days concrete cube compressive strength

<table>
<thead>
<tr>
<th>Days</th>
<th>Average compressive strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>18.2</td>
</tr>
<tr>
<td>14</td>
<td>23.0</td>
</tr>
<tr>
<td>28</td>
<td>26.2</td>
</tr>
</tbody>
</table>
**fig 4.6; average 7, 14, 28 days concrete cube compressive strength line graph**

**fig 4.7; comparing 0.4 and 0.5 water/cement ratio compressive test strength**
CHAPTER 5

5.0 DISCUSSION OF THE RESULTS

5.1 Particle size distribution

It should be noted that at the outset that there is no one ideal grading curve but a compromise is aimed at.

The results for the sieve analysis test on the locally found coarse aggregates are shown in table 4.1 and figure 4.1. The grading curve (figure 4.1) for the aggregates falls within the lower and upper limit of the grading requirement for aggregate from natural sources BS 882 (1992). However, the grading curve shows reasonable fallout from the gradation limit and a significant portion of the curve is below the lower limit requirement above sieve 37.5 and 50mm which means it is 'coarsely' graded. This implies that the coarse aggregate has greater voids to be occupied by greater fines to achieve reasonable workability. Hence the aggregates are suitable for construction work.

The results for the sieve analysis test on the fine aggregates are shown in table 4.2 and figure 4.2. The grading curve for the aggregates falls within the lower and upper limit of the grading requirement for aggregate from natural sources BS 882 (1992). This implies that the aggregates are suitable for construction work.

The main purpose of grading is to determine whether or not a particular grading is suitable to produce a workable mix. In the first instance, grading is of importance only in so far as it affects workability, because strength is independent of the grading. However, high strength requires a maximum compaction with a reasonable amount of work, which can only be achieved with a sufficiently workable mix. In fact, there are no ideal grading requirements because of the main influencing factors on workability; the surface area of the aggregate which determines the amount of water necessary to wet all the solids, the relative volume occupied by the aggregate, the tendency to segregate and the amount of fines in the mix.

5.2 Specific gravity (SG) and water absorption

Specific gravity (SG)

Specific gravity is used in the calculation of quantities but the actual value of the specific gravity is not a measure of its quality. However in the case of mass construction such as gravity dams, a minimum density of concrete is essential for the stability of the structure.

From the result table 4.3, both the saturated surface dried SG and apparent specific gravity are found to be equal, 2.63 which confirm that the aggregates are indeed quartzite type. The saturated surface dried SG is easily determined and it is used for calculations of yield of concrete and of the quantity of aggregate required for a given volume of concrete. The apparent specific gravity of aggregate depends on the specific gravity of the mineral of which the aggregate is composed and also on the amount of voids.

The majority of natural aggregates have specific gravity of between 2.6 and 2.7.

Water absorption

This is test is determined by measuring the increase in mass oven-dried sample when immersed in water for 24hours.
From the table 4.3 the water absorption value is 0.121% which is less than the minimum value according to BS 882; the value should be less 2%. This can be said to mean that there is low porosity within the aggregate.

Water absorption = \((\text{saturated surface dried - oven dried weight})/\text{oven dried weight}\)

5.3 Bulk density
The bulk density of the locally found aggregate is found to be 1690 kg/m\(^3\) as shown in the result table 4.4. Bulk density the coarse aggregate is between the recommended values according to the British Standards of between 1200 – 1750 kg/m\(^3\).

For a coarse aggregate of a given specific gravity, a higher bulk density means that there are fewer voids to be filled by fine aggregate and cement \(^{(5)}\). For this aggregate it has a high bulk density therefore very few voids.

5.4 Ten Per cent Fines Value (TFV)
TFV is used to determine the relative measure of the resistance of an aggregate to crushing under gradually applied compressive load.

This test, higher numerical result denotes higher strength of the aggregate. From result table 4.5 The local aggregate has a Ten percentage fines value of 160KN which is a value higher than the minimum limiting value as stipulating in table 2 BS 882 1990 thus making it suitable for the manufacture of concrete to be used in pavement wearing surfaces and heavy duty concrete floor finishes and other concretes work.

5.5 Aggregate impact value (AIV)
This test was used to determine the relative measure of resistance of the aggregate to sudden shock or impact. In some aggregates, it differs from its resistance to slow compressive load.

The local aggregate has an Aggregate Impact value of 19% as shown at table 4.6 which is a value lower than the maximum limiting values as stipulating in table 2 BS 882 1990 thus making it suitable for the manufacture of concrete to be used in pavement wearing surfaces and heavy duty concrete floor finishes and other concrete work.

5.6 Aggregate crushing value (ACV)
To determine the relative measure of the resistance of an aggregate to crushing under gradually applied compressive load. The crushing value of this aggregate is found to be 26.8% from the result table 4.7. There is no obvious physical relationship between this crushing value and this compressive strength, but the results are usually in agreement. This is evident since the desired compressive strength of concrete under this locally found aggregate was achieved.

5.7 FRESH CONCRETE
The characteristic strength of concrete is 25N/mm\(^2\) water/cement ratio was 0.4; slump range is 30-60mm.

5.7.1 WORKABILITY RESULTS
Two methods were used to determine workability that is the amount of useful work necessary to obtain full compaction. The methods used were slump test and compacting factor test. Slump test does not measure directly workability but has been widely used in site work to detect variations in the uniformity of mix of given proportions. Slump test is sensitive to consistency of fresh concrete.
The tests were carried in two batches.

**Slump test**

For a WATER/CEMENT ratio of 0.4 the obtain slump from the two batches was 50mm and 48mm from table 4.8, which are within the desired range of mix design, 30-60mm slump. According to table 5.1 the workability is medium. This high workability or slump under water/cement ratio of 0.4 is because of the smooth and rounded surface of the aggregate. This aggregate requires less amount of paste to coat its surface and thereby leave more paste for lubrication so that interactions between aggregate particle during mixing is minimized. The particle shape and surface texture of coarse aggregate influence the properties of freshly mixed concrete more than the properties of hardened concrete. Rough-textured, angular, elongated particles require more water to produce workable concrete than do smooth, rounded, compact aggregates.

**Table 5.1 description of workability and magnitude of slump** \(^{(5)}\).

<table>
<thead>
<tr>
<th>Description of workability</th>
<th>Slump mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>No slump</td>
<td>0</td>
</tr>
<tr>
<td>Very low</td>
<td>5-10</td>
</tr>
<tr>
<td>Low</td>
<td>15-30</td>
</tr>
<tr>
<td>Medium</td>
<td>35-75</td>
</tr>
<tr>
<td>High</td>
<td>80-155</td>
</tr>
<tr>
<td>Very high</td>
<td>160 to collapse</td>
</tr>
</tbody>
</table>

**Compacting factor**

From table 4.9 the compacting factor from the two batches are 0.84 and 0.85 this conforms to slump test that the concrete produced by the aggregate has a medium Workability as shown in table 5.2. Unlike the slump test, variations in the workability of dry concrete are reflected in a large change in the compacting factor, i.e. the test is more sensitive at the low workability end of the scale than at high workability.

**Table 5.2 description of workability and compacting factor** \(^{(5)}\).

<table>
<thead>
<tr>
<th>Description of workability</th>
<th>Compacting factor</th>
<th>Corresponding slump mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>0.78</td>
<td>0-25</td>
</tr>
<tr>
<td>Low</td>
<td>0.85</td>
<td>25-50</td>
</tr>
<tr>
<td>Medium</td>
<td>0.92</td>
<td>50-100</td>
</tr>
<tr>
<td>high</td>
<td>0.95</td>
<td>100-175</td>
</tr>
</tbody>
</table>
5.8 HARDENED CONCRETE

5.8.1 COMPRESSIVE STRENGTH

After studying the grading and relative densities of the aggregates were studied. The mix ratio and water/cement ratio adopted for the study was 1:2:3.4 and 0.4 respectively. The target mean strength at 28 days was 25N/mm$^2$. Twelve concrete cubes (150mm x 150mm x 150mm) were cast of which four were crushed at each maturity age namely; 7, 14, and 28 days.

Tables 4.10, 4.11, and 4.12 as well as chart 4.3, 4.4, and 4.5 shows the result of cube crushing at 7, 14, and 28 days respectively.

Compressive strength of concrete is the capacity of the concrete cubes to withstand axially directed pushing forces. When the limit of compressive strength is reached, materials are crushed. Therefore, it is that value of uniaxial compressive stress reached when the material fails completely.

The table 4.13 shows the average compressive strength at each maturity age namely; 7, 14, and 28 days. It was observed that the compressive strength increases with age at curing. The compressive strengths were observed to increase from day 0 to day 28 reaching or exceeding the target mean strength of 25N/mm$^2$. At 7th day it was generally observed that the concrete cubes had already attained 67% percent of the 28th day compressive strength and by 14th day, the cubes had already attained 85% of the 28th day strength. This is well shown in figure 4.6.

The compressive strength of concrete depends on the water to cement ratio, degree of compaction, ratio of cement to aggregate, bond between mortar and aggregate, and grading, shape, strength and size of the aggregate. Concretes which are required to provide strength, hardness, durability, imperviousness and resistance to chemicals must be as dense as possible and this requires a low water:cement ratio, this was evident when you compare the trial mix design strength which water/cement ratio was 0.5.

From figure 4.7, this locally found aggregate which are uncrushed and smooth gave highest strength with low water/cement ratio of 0.4 as compared to water/cement ratio of 0.5. This strength is increasing and has not yet reached constant strength as compared to stress- strain curve of BS8110 part 1. The strongest of the concrete are obtained by using a workable aggregate with the lowest water:cement ratio which enables the mix to be thoroughly compacted by mechanical means.
CHAPTER 6

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The objectives of the project were achieved; the entire stated tests were performed according to the prescribed methodology according to British Standards accorded to them. The hypothesis statement was proved right that actually this coarse aggregate locally found in Garissa County can find major application in concrete production.

The suitability of any aggregate for a particular purpose depends principally on its physical and mechanical properties. This locally found coarse aggregate has a physical properties which meet or are within the standard limiting values as stipulating in BS 882 1990 thus making it suitable for the manufacture of concrete and their application in construction work.

The compressive strengths were observed to increase from day 0 to day 28 reaching or exceeding the target mean strength of 25N/mm². From figure 4.7 and 4.8, this locally found aggregate which are uncrushed and smooth gave highest strength with low water/cement ratio of 0.4 as compared to water/cement ratio of 0.5. The particle shapes of aggregate with satisfactory gradation, uncrushed aggregates affect the strength of concrete mainly by affecting the cement paste. With proper cement content, uncrushed or smooth and rounded aggregate would require a low water/cement ratio as possible in order to achieve the target mean strength. If proper mix design procedure is done with proper content of the other concrete materials, this coarse aggregate can produce concrete of high strength as per the design mix.

Apart from the physical requirement, the economical aspects must not be forgotten. Concrete has to be made of materials which can be produced cheaply.

6.2 RECOMMENDATION

According to the laboratory results obtained, I would like to recommend the use of this coarse aggregate locally found in Garissa County in production of concrete and housing construction. Since these aggregates were uncrushed or smooth and rounded, they would require a low water/cement ratio as possible and a proper cement content in order to achieve the target mean strength.

I would like to recommend further research on the behavior of the locally obtained aggregates in concrete by conducting the following test

1. Test for strength in tension; both flexural strength tests and splitting tension test.
2. Pull-out tests.
APPENDIX;
CONCRETE MIX DESIGN (Based on the procedure given by the Department of Environment –
Transport and Road Research Laboratory, London)

CONCRETE MIX DESIGN TABLE

<table>
<thead>
<tr>
<th>Stage</th>
<th>Item</th>
<th>Reference/Calculation</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.1</td>
<td>Characteristic strength</td>
<td>Specified</td>
</tr>
<tr>
<td>1</td>
<td>1.2</td>
<td>Standard deviation</td>
<td>Fig. 3</td>
</tr>
<tr>
<td>1</td>
<td>1.3</td>
<td>Margin</td>
<td>C1</td>
</tr>
<tr>
<td>1</td>
<td>1.4</td>
<td>Target mean strength</td>
<td>C2</td>
</tr>
<tr>
<td>1</td>
<td>1.5</td>
<td>Cement type</td>
<td>Specified</td>
</tr>
</tbody>
</table>
| 1     | 1.6  | Aggregate type: coarse Aggregate type: fine | | ………Uncrushed……… 
|       |      |                        |        | ………Uncrushed…………………… |
| 1     | 1.7  | Free water/cement ratio | Table 2, Fig 4 | ………0.4….. |
| 1     | 1.8  | Max. water/cement ratio | Specified | ………0.5……………… |
| 2     | 2.1  | Slump or V-B | Specified | Slump...30-60.........mm or V-B.........s |
| 2     | 2.2  | Max. aggregate size | Specified | ...20........mm |
| 2     | 2.3  | Free water content | Table 3 | …180........kg/m³ |
| 3     | 3.1  | Cement content | C3 | …180..÷...0.4.=...450...kg/m³ |
| 3     | 3.2  | Max. cement content | Specified | |
| 3     | 3.3  | Min. cement content | Specified | |
| 3     | 3.4  | Modified water/cement ratio | | ……………………… |
| 4     | 4.1  | Relative density of aggregate | | ………2.62……… |
### 4.2 Concrete density

Fig 5

\[ \text{Concrete density} = 2400 \text{ kg/m}^3 \]

### 4.3 Total aggregate content

C4

\[ \text{Total aggregate content} = 2400 + 180 + 450 = 1770 \text{ kg/m}^3 \]

### 5 Grading of fine aggregate

BS 882

Zone \( \ldots 2 \ldots \)

### 5.2 Proportion of fine aggregate

Fig 6

\[ \text{Proportion of fine aggregate} = 45 \% \]

### 5.3 Fine aggregate content

C5

\[ \text{Fine aggregate content} = \frac{45 \% \times 1770}{100} = 796.5 \text{ kg/m}^3 \]

### 5.4 Coarse aggregate

C5

\[ \text{Coarse aggregate} \]

\[ \text{Fine aggregate content} = \frac{45 \% \times 1770}{100} = 796.5 \text{ kg/m}^3 \]

\[ \text{Coarse aggregate} = 1770 - 796.5 = 973.5 \text{ kg/m}^3 \]

### Quantities

<table>
<thead>
<tr>
<th>Cement (kg)</th>
<th>Water (kg)</th>
<th>Fine Aggregate (kg)</th>
<th>Coarse Aggregate (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>180</td>
<td>795</td>
<td>975</td>
</tr>
</tbody>
</table>

### Per trial mix of \( \ldots \text{m}^3 \)
Figure 5  Estimated wet density of fully compacted concrete

Figure 6  Recommended proportions of fine aggregate for BS 882 grading zones 1, 2, 3 and 4

16
Figure 6 (continued)

Figure 6 (continued)
<table>
<thead>
<tr>
<th>Shump (mm) or V-B (s)</th>
<th>0 - 10</th>
<th>10 - 30</th>
<th>30 - 60</th>
<th>60 - 180</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;12</td>
<td>150</td>
<td>180</td>
<td>205</td>
<td>225</td>
</tr>
<tr>
<td>10</td>
<td>180</td>
<td>205</td>
<td>230</td>
<td>250</td>
</tr>
<tr>
<td>Uncrushed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crushed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>135</td>
<td>160</td>
<td>180</td>
<td>195</td>
</tr>
<tr>
<td>Uncrushed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crushed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>115</td>
<td>140</td>
<td>160</td>
<td>175</td>
</tr>
<tr>
<td>Uncrushed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crushed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
REFERENCES

1) Department of Geology, University of Nairobi.

2) John A Franklin and Maurice B Dusseault (1978); Rock Engineering; Mc Craw Int. Publishers.


8) BS 812: Part 1; Classification of natural aggregates.

9) BS 812: Part 2; Method of testing aggregates.

10) BS 882; part 2; Specification for aggregates from natural sources of concrete.

11) BS 1881; part 2; Tests on Concrete.