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Experimental study on the Influence of Mogadishu Manufactured Sand on the Engineering Properties of Concrete.

Masters Thesis

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DECLARATION AND APPROVAL

This thesis is my original work. I also affirm that to the best of my knowledge; this has not been presented for a degree in any other university.

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ABSTRACT

Due to the increasing demand for sand for construction activities across the world including Mogadishu Somalia, natural sand resources are growingly used up and its price is becoming increasingly high. This study aimed to research the influence of Mogadishu manufactured sand on the engineering properties of concrete. Manufactured sand refers to fine aggregate which is less than 4.75mm. In this research, Mogadishu Manufactured sand was refined from the crushed limestone rock as a replacement for river sand. The overall objective of the study was to evaluate the influence of Mogadishu manufactured sand on the engineering properties of concrete; the specific objectives were to examine the properties of plastic and hardened concrete; to investigate the durability of concrete with Mogadishu manufactured sand. The study used manufactured sand incomplete and complete replacement for natural sand. The replacement level were 0% (pure river sand), 25%, 50%, 75% and 100% for constant water-cement ratio for all mixes. The basic aggregate tests considered were sieve analysis for fine and coarse aggregate, specific gravity, and water absorption was also done. Design mix of class 30 concrete having mix amount for both natural and manufactured sand was considered for the workability test (slump test and compaction factor test). The splitting tensile strength test and compressive strength test for 28 and 56 days was done. The study, in addition, considered durability testing by exposing the concrete to sodium chloride, magnesium sulphate and sulphuric acid. Then final assessment was done to determine how these chemicals affected the concrete after 28 and 56 days of immersion. It was found that the slump and compaction factor values of the concrete mix with Mogadishu manufactured sand decreased compared to that of conventional concrete. Concrete with Mogadishu manufactured sand significantly improves the strength properties of the concrete by up to 25%. This was attributed to the presence of micro fines in the manufactured sand generated from limestone rock. When exposed to sulphuric acid, magnesium sulphate and sodium chloride, the durability of concrete with manufactured sand were improved as compared to that of normal concrete with river sand. Hence from the experimental investigations, it is concluded that Mogadishu manufactured sand can be partially utilized as fine aggregate in concrete production of construction activities.

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LIST OF ABBREVIATIONS

ACI: American0Concrete0Institute

ASTM: American0Society for Testing0of0Materials0

BS: British0Standard

CA: Coarse Aggregate

DoE: Department of the Environment

FI: Flakiness index

Fig.: Figure

ISC: Intermediate strength concrete HSC: High strength concrete

Kg/m^3: Kilogram per meter cube

Kg: Kilo gram KN: Kilo Newton

LAA: Los Angeles Abrasion

lt: liter

M: meter

m^3: meter cube

mm: millimeter

MOPC: Mossoro Ordinary Portland cement MPPC: Mugher Portland Pozzolana cement FM: Fineness Modulus

MPa: Mega Pascal

M-S: Manufactured Sand

N-S: Natural Sand

NSC: Normal0strength0concrete

OPC: Ordinary0Portland0cement

PPC: Portland Pozzolana0Cement

PSD: Particle size distribution Gm.: gram

SSD: Saturated Surface Dry

W/C: Water to0cement0ratio

FA: Fine0aggregate

M.S: Manufactured sand

R.S: river sand

CHAPTER 1

INTRODUCTION

1.1 Background

Concrete is the most widely used material in the construction industries globally. It is made up of cementitious material, fine and coarse aggregate, and water (Mallum et al., 2020). It also regarded as most consumed construction material across the world including Mogadishu Somalia. Because of its adequate durability to cost ratio, easy to replace, and can be moulded into any required shape (Mallum et al., 2020; Xiao et al., 2021). Concrete, either plain, reinforced or prestressed, must be strong sufficient to support all applied loads throughout its expected life. Other important characteristics include waterproof (watertight), durability, and minimum quantity of shrinking and cracking (Zimar et al., 2017). In building construction and infrastructural development, concrete is important and a large amount of concrete is being used. Hence, the high demand for concrete resulted in high consumption of fine aggregate (river sand), which constitutes about 30% to 35% of concrete mix ratio (Nagpal et al., 2013).

Across the world the use of natural sand by the construction sector has grown significantly resulting in the rapid depletion of river beds which are the natural sources of sands. The scarcity or insufficient supply of excellent quality sand has resulted in a significant price increase, which has an impact on building costs. (Agrawal et at., 2017). This prompted academics and experts on the construction industry to look for a suitable material that is environmentally acceptable and can be utilized successfully in construction practices as an alternative material while lowering concrete production costs (Sivanarayana et al., 2014). However, one possible alternative material is manufactured sand. Manufactured sand is typically made by breaking stones of different sizes into a VSI crusher for crushing, resulting in superior quality and constant gradation. Manufactured sand produced from the above process are generally more angular and they have a rougher surface texture as defined in Is 383-1970 under clause 20. The shape and texture of manufactured sand depends mainly on (i) the type of crusher (ii) the ratio of the size of material fed into the crusher to the size of the finished product (reduction ratio) and (iii) the parent rock which manufactured sand refined from (Ayodele et al., 2015).

In this regard, river sand is the major natural deposit of fine aggregates in our nation. Nonetheless, the extensive construction activities in Mogadishu, Somalia is resulting to insufficiency and cost increase of the natural sand in the country. Furthermore, the aggregate and also concrete sectors are currently dealing with a spreading public recognition related to the environmental effect of their activities. One possible alternative product that can be utilized as substitute for natural sand is the use of manufactured sand.

Many studies (Chougule et al., 2020; Nadimalla et al., 2019; Zimar et al., 2017; Kavitha et al., 2017; Woode et al., 2015; Shanmugavadivu et al., 2020; Manguriu, et al., 2013), have examined the influence of complete or partial replacement of river sand in concrete on concrete properties using manufactured sand. Some of them demonstrated that completely replacing of manufactured sand with river sand can improve concrete's engineering properties while others indicate that partial replacement resulted an improvement of engineering properties of concrete. However, these studies did not define the parent rock which the manufactured sand was derived from. The engineering properties of manufactured sand depend on the source of its raw material, dust or powder content in the manufactured sand, hence selection of rock is very important for obtaining quality fine aggregate (Manguriu et al., 2013). Also durability studies were limited. Therefore, this study is unique because it refers to the influence of Mogadishu manufactured sand which is refined from limestone rock on the plastic and hardened concrete when replaced with Natural River sand and in addition when it is further exposed to chemical attacks such as sulphuric acid, magnesium sulphate and sodium chloride.

1.2 Problem statement.

With the world-wide decline in the availability of construction sands along with the environmental pressures to reduce extraction of sand from rivers, the use of manufactured sand as a replacement is increasing. With the ban on sand mining implemented by different states, and with the increasing demand for river sand for construction works, many civil engineers have expressed the need to promote use of manufactured sand in the construction industry (Elavenil et al., 2013). As the demand for Natural River sand is surpassing the availability, has resulted in fast depletion of natural sand sources (Susanti et al., 2018). Manufactured sand is the answer to this problem especially when some states have already banned the use of river sand for construction. This sand has been defined well in IS 383-1970, under clause 2.0. There is a need to study shape characteristics of manufactured sand, the effect of micro fines on concrete characteristics such as workability, compressive strength, tensile strength and durability of concrete.

The choice of fine aggregate, whether it is manufactured or natural sand, can greatly impact the fresh properties of concrete. There are two main sources of sand in Mogadishu: Natural sand which is obtained from El'man area in the North of Mogadishu and manufactured sand which is usually obtained by crushing lime stone rocks. Due to the booming of construction activities in Somalia's capital, natural sand resources are increasing getting depleted. Due to this depletion, the cost of natural river sand is becoming increasingly high. So it is time when manufactured sand will take a considerable factor in concrete production. There is scanty literature on studies conducted in Mogadishu in relation to the suitability of manufactured sand on engineering properties of concrete. With the lack of data on this subject and booming construction activities in Mogadishu, local and international construction companies in Mogadishu are engaging in research activities on the suitability of manufactured sand based on compressive strength, tensile strength, workability and durability of concrete. Also, previous studies showed that manufactured sand has an influence on the compressive strength, workability and tensile strength of concrete. After revisiting those studies, it is noted that there was much different results variation on compressive strength, tensile strength and workability of concrete from country to country due to row material of the rock in which manufactured sand refined from, the equipment used to crush and the process of crushing (Vijaya et al., 2015). This is why those results are not able to be localized for Mogadishu in particular as the results vary. It also noted that durability has not been adequately studied. Therefore, This study evaluated the suitability of manufactured sand on engineering properties of concrete by testing workability, compressive strength, and tensile strength of concrete in addition to the testing of the durability of normal strength of concrete in Mogadishuishu, Somalia.

1.3 Objectives of the study

1.3.1 Overall Objective

The overall objective of the study is to evaluate the influence of Mogadishu Manufactured sand on the engineering properties of concrete.

1.3.2 Specific Objectives

1. To assess the influences of Mogadishu manufactured sand on the properties of plastic and hardened concrete.

2. To investigate the durability of concrete containing Mogadishu Manufactured sand

1.4 Research Questions

1. How does Mogadishu Manufactured sand influence the properties of plastic and hardened concrete?
2. How does Mogadishu Manufactured sand influence the durability of concrete?

1.5 Justification of the Study.

The findings of the study will be used as a reference for the application of manufactured sand concrete both in the local and international construction activities industry in Mogadishu, Somalia. Workability, compressive, tensile strength, and durability of concrete made with Mogadishu manufactured sand were compared to other global and regional studies.

1.6 Scope of Work

The aim of this study was to obtain workability, strength (compressive and tensile), and durability of C30 concrete by replacing natural sand with Mogadishu manufactured sand in concrete production. The replacement levels were 0% (pure sand), 25%, 50%, 75% and 100% for constant water-cement ratio for all mixes. The experimental, work started collecting the river sand and Mogadishu Manufactured sand from the local market of Mogadishu, Somalia. The basic tests on aggregate, workability, compressive strength, splitting tensile strength test, and durability tests were done. For the basic aggregate tests sieve analysis for both fine and coarse aggregate, specific gravity and water absorption was conducted. For workability, the slump and compaction factor tests were done. For strength, the compressive strength and splitting tensile strength at 28 days and 56 days were conducted. Finally, the sulphate attack, chloride attack, acid resistance, and water absorption was assessed for a durability point of view.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter addresses the history of manufactured sand in General and also in the study area that is Mogadishu Somalia, its properties, how it relates to workability, compressive strength, tensile strength and durability of concrete and previous studies that have been done that are either similar, contradicting and the research gaps in each of them.

2.2 Concrete and its Properties

Concrete is a composite material or man-made rock that is made up of aggregate pieces (fine and coarse aggregate) bonded together by a binding substance in the presence of water. It is the most often used building material. Concrete is made up of aggregate, cement, and water. Mortar is the mixture consisting of fine aggregate (sand), cement and water; the difference from concrete is the absence of coarse aggregate in mortar. Aggregate is granular material like sand, gravel, crushed stone, and demolition waste that is mixed with cement to produce concrete or mortar. Aggregate can be divided into fine or coarser aggregate. Fine aggregate Particles are less than 4.75 mm, while coarse aggregates are larger than 4.75 mm. Cements are adhesive compounds that have the capacity to bind solid matter particles into a compact whole. (Soroka, 1979).

2.2.1: Constituents of Concrete

2.2.1.1: Aggregates.

Aggregates were originally thought to be used as a filler in concrete to minimize the quantity of cement needed. However, it is now well understood that the type of aggregate used in concrete has a significant impact on the plastic and hardened state properties of concrete. Aggregate can form 80% of the concrete mix so their properties are important to the properties of concrete. Heavyweight, standard weight, lightweight, and ultra-lightweight aggregates are the four kinds of aggregates. However, only normal weight and lightweight aggregates are used in most concrete practices. The other types of aggregates are used for specialized applications such as nuclear radiation shielding and thermal insulation (Neville, 1986).

Classification of Aggregates.

1) Fine aggregate often called sand (BS 882; 1992) not larger than 5mm in size.

2) Course aggregate, which comprises material at least 5mm in size.

Originally, all-natural aggregate particles formed a part of a large mass. This might have been fractured by natural processes of weathering and abrasion or artificially by crushing. As a result, many aggregate qualities are wholly dependent on the parent rock. E.g. chemical and mineral composition, petrological character, specific gravity, hardness, strength, physical and chemical stability, pore structure and colour. On the other hand, the aggregate has several characteristics that the parent rock does not: Absorption, particle shape and size, and surface texture. All of these characteristics have a significant impact on the quality of concrete, whether it is fresh or hardened

2.2.1.1.1: Aggregate Properties

A wide range of concrete can be produced economically to suit different requirements by selecting different sizes and kinds of aggregates, as well as varying aggregate to cement ratios. The following are some of the most important aggregate qualities that determine concrete performance:

Particle Shape and Texture

Roundness measures the relative sharpness or angularity of the edges and corners of a particle. Roundness is controlled largely by the strength and abrasion resistance of the parent rock and by the amount of wear to which the particle has been subjected. In the case of crushed aggregate, the particle shape depends not only on the nature of the parent rock but also on the type of crusher and its reduction ratio, i.e. the ratio of the size of material fed into the crusher to the size of the finished product. Particles with a high ratio of surface area to the volume are also of particular interest for given workability of the control mix.

Elongated and flaky particles are departed from equidimensional shape of particles and have a larger surface area and pack in an isotropic manner. Flaky particles affect the durability of concrete, as the particles tend to be oriented in one plane, with bleeding water and air voids forming underneath. The flakiness and elongation tests are useful for the general assessment of aggregate but they do not adequately describe the particle shape. The presence of elongated particles in excess of 10 to 15% of the mass of coarse aggregate is generally undesirable, but no recognized limits are laid down (Neville, 1986).

The surface texture of the aggregate impacts its connection to the cement paste and, in the case of fine aggregate, also effects the water demand of the mix. The form and surface texture of aggregate have a significant impact on concrete strength. In the case of high-strength concrete, the impacts of shape and texture are very important.

Fine aggregate shape and texture have a considerable impact on the water requirement of the mix made with the given aggregate. If these properties of fine aggregate are expressed indirectly by its packing, i.e. by the percentage voids in a loose condition, then the influence on the water requirement is quite definite. The influence of the voids in coarse aggregate is less definite. The flakiness and shape of coarse aggregates have an appreciable effect on the workability of concrete (Neville, 1986).

Bond of Aggregate

The strength of concrete is influenced by the bond between aggregate and cement paste, although the nature of that bond is unknown. Bond is to the interlocking of the aggregate and the hydrated cement paste due to the roughness of the surface of the former. A rougher surface, such as that of crushed particles, results in a better bond due to mechanical interlocking; a better bond is not usually obtained with softer, porous, and minor logically heterogeneous particles. Bond is affected by the physical and chemical properties of aggregate. For the good development of bonds, it is necessary that the aggregate surface be clean and free from adhering clay particles (Neville, 1986). The determination of the quality of the bond of aggregate is difficult and no accepted tests exist. Generally, when the bond is good, a crushed specimen of normal strength concrete should contain some aggregate particles broken right through, in addition to the more numerous ones pulled out from their sockets. An excess of fractured particles might suggest that the aggregate is too weak (Neville, 1986).

Strength of Aggregate

Concrete's compressive strength cannot be much greater than that of the aggregate it contains. If the aggregate under test leads to a lower compressive strength of concrete, and in particular if numerous individual aggregate particles appear fractured after the concrete specimen has been crushed, then the strength of the aggregate is lower than the nominal compressive strength of the concrete mix. Such aggregate can be used only in the concrete of lower strength. The influence of aggregate on the strength of concrete is not only due to the mechanical strength of the aggregate but also, to a considerable degree, to its absorption and bond characteristics. In general, the strength of aggregate depends on its composition, texture and structure. Thus a low strength may be due to the weakness of constituent grains or the grains may be strong but not well knit or cemented together.

2.2.1.2: Cement

Cement is a key to infrastructure industry and is used for various purposes and also made in many compositions for a wide variety of uses. Cements may be named after the principal constituents, after the intended purpose, after the object to which they are applied or after their characteristic property. Cement used in construction are sometimes named after its commonly reported place of origin, such as Roman cement, or for their resemblance to other materials, such as Portland cement, which produces a concrete resembling the Portland stone used for building in Britain. The term cement is derived from the Latin Word Cementum, which is meant stone chippings such as used in Roman mortar not-the binding material itself (Britannica, 2001). Cement, in the general sense of the word, is described as a material with adhesive and cohesive properties, which make it capable of bonding mineral fragments in to a compact whole. The first step of reintroduction of cement after decline of the Roman Empire was in about 1790, when an Englishman, J. Smeaton, found that when lime containing a certain amount of clay was burnt, it would set 9 under water. This cement resembled that which had been made by the Romans. Further investigations by J. Parker in the same decade led to the commercial production of natural hydraulic cement.

Joseph Aspdin, an English mason, made an important advance toward the manufacture of dependable hydraulic cement in 1824. His product was called Portland cement because it resembled a building stone that was quarried on the Isle of Portland off the coast of Dorset, UK. Until the end of the nineteenth century, large quantities of this cement were exported to many parts of the world. The first factories for Portland cement outside the British Isles were opened in France in 1840, Germany in 1855, The United States in 1871 and in Ethiopia in the twentieth century.

Chemical Compounds of Portland Cement.

The raw material used in the manufacture of Portland cement comprises four principal compounds. These compounds are usually regarded as the major constituents of cement and listed below:

Tricalcium Silicate, C3S hardens rapidly and is largely responsible for initial set and early strength development. The early strength of Portland cement concrete is higher with increased percentages of C3S.

Dicalcium Silicate, C2S hardens slowly and contributes largely to strength increase at ages beyond one week.

Tricalcium aluminate, C3A liberates a large amount of heat during the first days of hardening. It also contributes slightly for early strength development. Cements with low percentages of this compound are especially resistant to soils and waters containing sulphates.

Concrete made of Portland cement with C3A contents as high as 10.0%, and sometimes greater, has shown satisfactory durability, provided the permeability of the concrete is low.

Tetracalcium aluminoferrite, C4AF reduces the clinkering temperature. It acts as a flux in burning the clinker. It hydrates rather rapidly but contributes very little to strength development.

2.2.1.2.1: Types of Cement

2.2.1.2.1.1: Ordinary Portland Cement

Ordinary Portland (Type-I) cement is suitable for general concrete construction when there is no exposure to sulphates in the soil. The standard requires that it is made from 95 to 100 percent of Portland cement clinker and 0 to 5 percent of minor additional constituents. Minor additional constituents are one or more of the other cementitious materials or filler. Filler is defined as any natural or inorganic mineral material other than a cementitious material (Neville, 1986). Variations in its composition may produce a difference of up to ±20 % in the compressive strength of concrete that is made with it, but uniform results are obtainable by drawing cement from one source of supply (Austin, 2002).

2.2.1.2.1.2: Portland Pozzolana Cement

Portland Pozzolana cement is manufactured by blending 10-30 percent by weight of pozzolanic material with Portland cement; either by simple mixing or by inter grinding with cement clinker. The calcium hydroxide liberated during the process of hydration of the cement combines slowly with the pozzolana to give it cementitious properties, thereby contributing to water tightness and long, continued gain in strength of the concrete.

Portland pozzolan cement is particularly suitable for use in mass concrete structures (such as in dams and bridge piers), where low heat of hydration is desired; hydraulic structures of all kinds where water tightness is important; structures subject to attack from groundwater, sea 12 water or diluted industrial wastes; and underwater construction where concrete is deposited by the bucket. A pozzolan may be used as a partial replacement of the fines of sand, without a reduction of cement content, where high early strength is required (Austin, 2002).

2.2.1.3: Water

Water is a key ingredient in the manufacture of concrete. Water used in concrete mixes has two functions: the first is to react chemically with the cement, which will finally set and harden, and the second function is to lubricate all other materials and make the concrete workable (Austin, 2002). Although it is an important ingredient of concrete, it has little to do with the quality of concrete (Mindess, 2003). One of the most common causes of poor-quality concrete is the use of too much mixing water. Fundamentally "the strength of concrete is governed by the nature of the weight of water to the weight of cement in a mix, provided that it is plastic and workable, fully compacted, and adequately cured" (Austin, 2002). It has been said that there is much more bad concrete made through using too much good quality water than there is using the right amount of poor-quality water. The rule of thumb for water quality is "if you can drink it, you can work concrete with it". A large fraction of concrete is made using municipal water supplies. However, good quality concrete can be made with water that would not pass normal standards for drinking water (Mindess, 2003).

2.2.1.4: Admixtures

Admixtures are materials other than cement, aggregate and water that are added to concrete either before or during its mixing to alter its properties such as workability, curing temperature range, setting time or colour. These days a mix without admixture is an exception. Admixture is a chemical product which is added to the concrete mix in quantities not larger than 5% by mass of cement during mixing or during an additional mixing operation prior to the placing of concrete, for the purpose of achieving a specific modification to the normal properties of concrete (Neville., 1986). Admixtures are capable of imparting considerable physical and economic benefits with respect to concrete production. It is an established fact that the use of admixtures results in concomitant savings, for example, in the cost of labour required to effect compaction and in improving durability without the use of additional measures (Neville, 1986).

2.2.2: Properties of Fresh Concrete

The engineering properties of concrete can be divided to two, namely: properties of fresh concrete and properties of hardened concrete. The properties of fresh concrete are those that affect concrete's ability to transport, handle, place and finish. For hardened concrete to be strong and durable, fresh concrete must satisfy the following:

- It must be easily mixed and transported.
- It must be uniform throughout a batch and between batches.
- It must flow adequately to fill casting forms.
- It must be easy to be compacted fully without excessive energy.
- It must not segregate during placement and compaction.
- It must be able to be finished properly, either by troweling or within the formwork.

The properties of fresh concrete that influence the overall strength and durability are: workability, segregation, and bleeding

2.2.2.1: Workability

Workability relates to the consistency of concrete and can be defined as the ability of concrete to flow freely in formwork without segregation. The more workable concrete is the easier for it to be transported, placed and finished without segregation. The level of concrete workability needed depends on the type of structure, placement and compaction. Concrete that needs to be placed in a high reinforced congested area has to be more workable than in the case of mass concrete. Compaction helps in eliminating entrapped air and to overcome the friction between individual particles in the concrete.

The main factor affecting concrete workability is the water content of the mix. Other factors are: aggregate size and characteristics, cement content, cement type, and admixture. The higher the water content, the higher the concrete consistency. Concrete mixtures with high consistency are vulnerable to segregation (non-uniform mix) and bleeding (appearance of water on the surface of the concrete after consolidation), while mixtures with too low a consistency will be difficult to place and compact. Highly wet mixes can lead to the separation of coarse aggregate from the rest of concrete (Chandel, 2014). The consistency of a dry mix can be improved by adding a water-reducing admixture. The workability of mortar can be assessed through flow test while the most universal method of assessing concrete workability is by measuring its consistency through a slump test.

2.2.2.1.1: Methods of Improving Workability of Concrete

The following are some of the ways through which the workability of concrete can be improved:

i. Increasing water/cement ratio
ii. Using larger aggregate
iii. Using well-rounded and smooth aggregate instead of irregular shape
iv. Using non-porous and saturated aggregate
v. With addition of air-entraining mixtures
vi. Adding appropriate admixtures.

Slump Test can be used to find out the workability of concrete. Slump test has been used extensively in site work to spot variants in the uniformity of mix of offered percentages. It works on the site to detect the variants of products being fed to the mixer. A rise in a slump might mean that the dampness content of aggregate has actually enhanced or an adjustment in the grading of the aggregate, such as the deficiency of great aggregate. Excessive or reduced slump provides a prompt caution and also enables the mixer driver to fix the scenario. The examination is done according to BS 1881- 102:1983 which explains the resolution of the slump of cohesive concrete of tool to high workability. The depression test is sensitive to the consistency of fresh concrete. The examination stands if it produces a real slump, this being a slump in which the concrete continues to be substantially undamaged and also balanced.

2.2.2.2: Segregation

Segregation is the separation of concrete constituents within the mix so that their distribution is no longer uniform, which can be due to differences in the specific weights of the constituents (Soroka, 1979). This can be aggravated by careless handling and the use of inadequate methods of transporting and placing. Placing concrete at a high distance and velocity may result in segregation. Factors contributing to segregation are (Khayat, 1999): large maximum particle size (>25 mm), large proportion of large aggregate, high specific gravity of coarse aggregate, decreased amount of fines (sand or cement), increased irregular shape or rough texture, and mixes that are too wet or too dry. Segregation can be partly overcome by careful handling.

2.2.2.3: Bleeding

Bleeding is a form of segregation that involves the rise of water onto the surface of cast concrete as the solid materials settle to the bottom. Mild bleeding is normal for good concrete, it prevents drying out, prior to complete hydration but excessive bleeding is deleterious to the concrete structure. Concrete becomes porous, weak, and non-durable, as a result of excessive bleeding. A weak wearing surface will 32 be formed if bleed water is re-mixed during finishing (Neville, 1981). Bleeding water may accumulate beneath large aggregate or underneath reinforcing steel, generating weak zones and reducing bond. Plastic shrinkage may also result if the bleeding water evaporates more than bleeding rates, rapidly such as in hot or dry weather. In this case, paste at the surface does not adequately hydrate causing dusting and reduced durability of the wearing surface (Khayat, 1999). Laitance is the external manifestation of bleeding, which is caused by rising of water in the internal channel within concrete, carrying along cement and fine particles in concrete and depositing them in the form of scum on the concrete surface (Chandel, 2014), resulting in weak, porous and soft surface that is prone to dusting. Bleeding can be reduced by modifying the mix in the following ways:

- Increasing the cement fineness or using pozzolans or other finely divided extenders.

- Increasing the rate of hydration by using cements with high alkali contents or high C3A contents.
- Using air entrainment admixture (quite effective).
- Reducing the water content (provided adequate workability is maintained).

2.2.3: Properties of Hardened Concrete

2.2.3.1: Tensile and Compressive Strength

The strength of hardened concrete is an important parameter for concrete design; it indicates the concrete's ability to resist stress. Strength is considered as the foremost property of concrete, but in some practical cases other properties like durability and impermeability may be more important even though strength indicates the overall view of concrete quality and most other properties improve with strength. The strength of mortar has important influence on concrete strength. Hydration reactions that occur when water is added to cement, result in the formation of calcium silicate hydrate (CSH) gel, which is responsible for strength development in mortar and concrete.

Different forms of strength measurements can be determined by subjecting the concrete to compressive, tensile and shear tests. Out of these aforementioned tests, compressive strength is the most commonly used concrete design parameter. According to Addis (1994), the relationship between tensile and compressive strengths does not have a specific pattern, because the factors affecting strength do not affect tensile and compressive strength to the same degree.

2.2.4: Concrete Durability.

The durability of concrete is defined as its ability to be serviceable and withstand environmental conditions without major deterioration throughout its design period. The environmental effect can be as a result of natural occurrences, weathering, abrasion, exposure to high temperature, ingress of chemicals, and gases. Serviceability can be affected by internal causes like alkali-aggregate reaction, sulphate attack, and other damage mechanisms, volume changes within the concrete components, and permeability. Durable concrete must be dense and impermeable to liquids and gases. It should possess high intrinsic resistance to external penetration of ionic species such as sulphates and chloride (Osborne, 1999). Durability of concrete is of great concern to researchers because it determines length of the life of concrete structures. Many structural failures can be traced to concrete of poor durability. Enhancing concrete durability has been widely discussed in a number of publications (Tarun et al., 1994; Osborne, 1999; Bai et al., 2002; Canan, 2003; Courard et al., 2003; Tsivilisa et al., 2003). One of the important factors that have gained the attention of researchers in improving concrete durability is the use of cement extenders or pozzolans in concrete mixtures. It was reported by Ha-Won and Seung-Jun (2007), that the durability of concrete is directly related to the type, size, and quantity of pores present. Due to pore refinement caused by addition of most cement extenders in concrete, decrease in final permeability, reduction in sorptivity, higher resistance to sulphate attack, and reduction in carbonation depth of blended samples have been reported (Banthia, 1989).

2.2.4.1: Sulphate Attack

Sulphate attack is one of the most aggressive environmental factors that affect the long-term durability of concrete structures. It can result in cracking, expansion and deterioration of concrete structures (Nabil, 2006). Sulphate attack is the reaction of sulphate ions with calcium hydroxide and calcium aluminate 43 hydrate to form ettringite and gypsum, these products are voluminous and lead to expansion, cracking, deterioration, and deformation of concrete structures (Torri et al., 1995; Nabil, 2006; Sideris et al., 2006; Salah, 2007) when formed after concrete has hardened. Sulphate attack can also lead to leaching of calcium compounds, degradation of calcium silicate hydrate (C-S-H), and overall deterioration of cement paste matrix (Nabil, 2006). One of the most severe conditions for durability of concrete is the sulphate or acid environment caused by industrial wastes or chemical residues at reclaimed grounds (Hanifi & Orhan, 2006).

Quite a number of studies have been done on investigating ways of increasing concrete resistance to sulphate attack through the incorporation of extenders (pozzolans) in mortars and concrete mixes (Torri et al., 1995; Osborne, 1999; Rodriguez-Camacho and Uribe-Afif, 2002; Courard et al., 2003; Nabil, 2006). Consumption of calcium hydroxide produced during hydration by cement extenders and less presence of C3A due to reduced quantity of cement content when the extender is incorporated (Rodriguez Camacho and Uribe-Afif, 2002; Salah, 2007), can help in increasing the resistance of concrete to sulphate attack.This emanates from reduction in gypsum and ettringite formation within the cementitious system. Deterioration of concrete as a result of sulphate attack can be in form of internal attack due to sulphate content of the cement, and external attack due to exposure of concrete to sulphate environment. Both forms of sulphate attack are manifested by the expansion and cracking of concrete.

According to Omar (2002), the formation of gypsum and ettringite are functions of sulphate attack. Gypsum formation results in eating away of hydrated cement paste, which is characterized by softening of cement matrix and causes a reduction in the cross-sectional area of the structural component and strength, due to loss of cohesiveness of the cement hydration products.

Also, ettringite product, tricalcium-sulfo aluminate hydrate formation results in expansion and cracking, when reactive hydrated aluminate phases are attacked by sulphate ions.

2.2.4.2: Acid Resistance of Concrete

One of the most important characteristics of structural structures is acid resistance (Ganesan et al., 2015). Acidic conditions, such as groundwater, acid rain, and industrial effluents, are often exposed to structural concrete elements (Koushkbaghi et al., 2019). As a result, acid resistance of concrete members is a critical characteristic in an aggressive environment. The durable concrete resists chemical and physical attacks which lead to deterioration of concrete. Leaching, sulphate attack, and acid attacks are a few of the attacks to enlist. Also, water which is an important ingredient of water may consist of many chemical impurities like chlorides, sulphates, and various salts. This leads to the deterioration of concrete which depends on the concentration of chemicals in water (Ajeet, et al., 2017). The rate of deterioration depends mainly on the concentration of the chemicals in water, the time of exposure and the chemical resistance of concrete (Asma et al., 2014). Liquids with a pH value less than 6.5 affect concrete but if the pH value is below 4.5 the attack is very severe (Meeravali et al., 2014). Sulphuric acid is prone to more danger since it involves acid and sulphate attacks both.

2.2.4.3: Chloride Resistance of Concrete.

The chloride ion is a typical aggressive substance that triggers the corrosion process of steel reinforcement and further causes deterioration, shortening the service life of structures (Xiao et al., 2021). Concrete structures in coastal and snowy regions are generally subjected to chloride attacks and steel corrosion often occurs due to the penetration of chloride ions (Yamato et al., 2020). To reduce future maintenance costs, concretes are required to have a high resistance to chloride ingress. Such concretes would have a denser structure and achieve excellent durability in various environments.

2.3 Manufactured Sand

The amount of aggregate in concrete has a direct and far-reaching impact on its quality and cost (Belay, 2006). Due to the booming of the construction industry in the world including Mogadishu –Somalia, natural sand resources are increasingly getting depleted and its cost is becoming increasingly high (Omar et al., 2020). Therefore, its time when manufactured sand takes a considerable factor in concrete production. Manufactured sand is manufactured in vertical shaft impact crushers (VSI – crushers) in three steps viz crushing, screening and washing. The VSI Crusher has a plant capacity of 400 tons per hour. The rocks are crushed into aggregates then fed into rotopoctors to crush the aggregate into the sand to the required shape and size as fine aggregates, then the screen is done to eliminate the fine, micro-fine and dust particles by washing the aggregates using the water jet. The end product is satisfied all the requirements of IS 383 – 1989. The sand obtained using VSI Crushers is durable, angular in shape, clean, and required particle size distribution (Cepuritis et al., 2015).

2.3.1 Properties of Manufactured Sand

Sand particle shape is determined by its formation history. Because of the cumulative effect of multiple collisions and abrasion, natural sand tends to be round and smooth. Rock crushing produces manufactured sand, which produces grains with distinct particle shapes that are dependent on the parent rock composition, fracture mode coordination number, and reduction ratio during crushing. Crushing tends to result in angular, sharp-edged particles (Vijaya et al., 2015). The shape and texture of crushed sand particles could lead to improvements in the strength of concrete due to better interlocking between particles. However, manufactured sand has more fines compared to natural sand. Fines in M-sand are usually smaller size fractions of crushed aggregate, whereas fines in natural sands can be clays or other harmful particles. In the case of manufactured sands, the fines are usually made up of rock dust rather than silts and clays (Zhang et al., 2020). Due to the presence of high fines content, the M sand has a significant influence on the water demand and the workability of the mortar.

2.3.2 Effect of Manufactured Sand on the Engineering Properties of Concrete

2.3.2.1 Effect of M-Sand on Workability

Mane and Joshi (2017), studied strength and workability of concrete with manufactured sand. In their study Workability of mixes was determined using slump, compaction factor, flow table, Vee-Bee test having same water cement ratio for all mixes as per I.S.1199-1959. It was observed that any percentage replacement of natural sand to manufactured sand will reduce the workability. The round shape and smooth surface texture of natural sand reduces the inter particle friction in the fine aggregate component so that the workability is higher in natural sand.

Manufactured sand particles are angular in shape and their rough surface texture improves the internal friction in the mix. Because of that the workability is reduced. They concluded that when replacement of Natural sand by 60% manufactured sand is done, results in producing the concrete of higher shear and compressive strength as compared to reference mix. The replacement of Natural sand with manufactured sand will help in conserving the natural resources of sand and maintain the ecological balance of the nature. However, this research is based in India and cannot be generalized. Hence the need to study Mogadishu manufactured sand and how it affects workability.

2.3.2.2 Effect of M-Sand on Compressive Strength

Zimar et al. (2017), studied effect of manufactured sand as a replacement for fine aggregates in concrete. The main objective of the study was to explore the possibility of using MS in concrete structures with grade of 20. Experimental studies on compressive strength development of concrete with manufactured sand (CMS) were carried out. The conventional river sand was replaced with 0%, 30%, 50%, 70% and 100% by the MS in concrete mixtures and test cylinders were cast for each percentage. The CMS cylinders were tested after 7 and 28 days of curing. Results indicated that river sand can be entirely replaced by MS however; water reducing admixtures need to be added as required. Further, the compressive strength of the concrete with MS was exceeded that of the concrete with natural sand at the same w/c ratio. In contrast, slump values gradually decrease with the increasing of MS in concrete due to the higher angularity of the manufactured sand particles. However, (Zimar et al., 2017), limit their study to manufactured sand in India and the results therefore cannot be generalized as properties of manufactured sand differ from region to region. In addition, they do not highlight how manufactured sand influences durability and the exposure of the same to chemical attacks such sulphuric acid, Magnesium sulphate and Sodium Chloride. This research therefore aims to answer these gaps.

2.3.2.3 Effect of M-Sand on Durability of Concrete.

Chougule and Mulla (2020) contend that as result of ban on natural sand obtained from river there is deficiency of fine aggregate used in construction industry. As a replacement for the river sand the crushed stone sand is used nowadays. They made summaries on the findings done by various researches that include (Mane et al., 2017), who conducted a study about Crushed Stone Dust as Fine Aggregate in Cement Concrete. In their study, the nominal mixes were prepared for grades M-20 and M-30 of cement concrete as per Indian Standards codes using natural sand (NS) and replacement of NS sand to crushed stone dust (CSD) in different proportions. In each case proportion the slump cone test, compaction factor test, density test, compressive strength test and Ultra-sonic pulse velocity test were carried out. The results of the study showed that, the strength properties of cement concrete using crushed rock sand is higher and homogeneous to the conventional concrete. Rajput concludes that crushed stone dust can be used as readily available solid waste as an alternative to natural sand in cement concrete construction work and it can reduce the cost of material and construction cost and can helpful to mend the environment issues.

The findings of (Rajput 2018) are similar to that of who conducted a study about evaluation of characteristics strength of concrete using crushed stone dust as fine aggregate. The suitability of crushed stone dust waste as fine aggregate for concrete was assessed by comparing its basic properties with that of conventional concrete. Two basic mixes were selected for natural sand to achieve M25 and M30 grade concrete. The equivalent mixes were obtained by replacing natural sand by stone dust partially fully. The test result indicated that crushed stone dust waste can be used effectively used to replace natural sand in concrete. In the experimental study of strength characteristics of concrete using crushed stone dust as fine aggregate it was found that there is increase in compressive strength.

(Parjeen &Kavita2018), also studied Durability Properties of Manufactured Sand in Concrete. Mixes were evaluated for durability properties of manufactured sand in concrete by partially replaced with natural sand with by three proportions (ie 25%, 50%, 75%). They conclude that the durability properties of concrete can be improved by partial replacement of Msand for fine aggregate. M-sand can be used as partial replacement for the natural sand. Chloride ion penetration and water absorption are decreased as the percentage of M- sand is increased up to optimum level. The optimum percentage of replacement of natural sand by M-sand 75%. In 25% of replacement we get least chloride ion penetration. Comparing to M sand we get low chloride ion penetration. Hence using the M-sand will increase the life of the structure. In 75% of replacement we get less water absorption. ϖ The dwindling sources of natural sand and its high cost could encourage the adoption of M-sand by 75% replacement of natural sand.

From these studies (Williams et al., 2019), conclude, durability studies are not sufficient to come to any conclusive statements regarding cracks or expansion etc. so there is future scope in this area that should be considered in forthcoming researches to get a sound research base. This informs the scope of this study on the influence of Manufactured sand on durability of Concrete in relation to Mogadishu manufactured sand, exposure to chemical attacks and the science of how properties of Manufactured sand influence the engineering properties of plastic and hardened concrete and their resultant effect on durability.

Conceptual framework

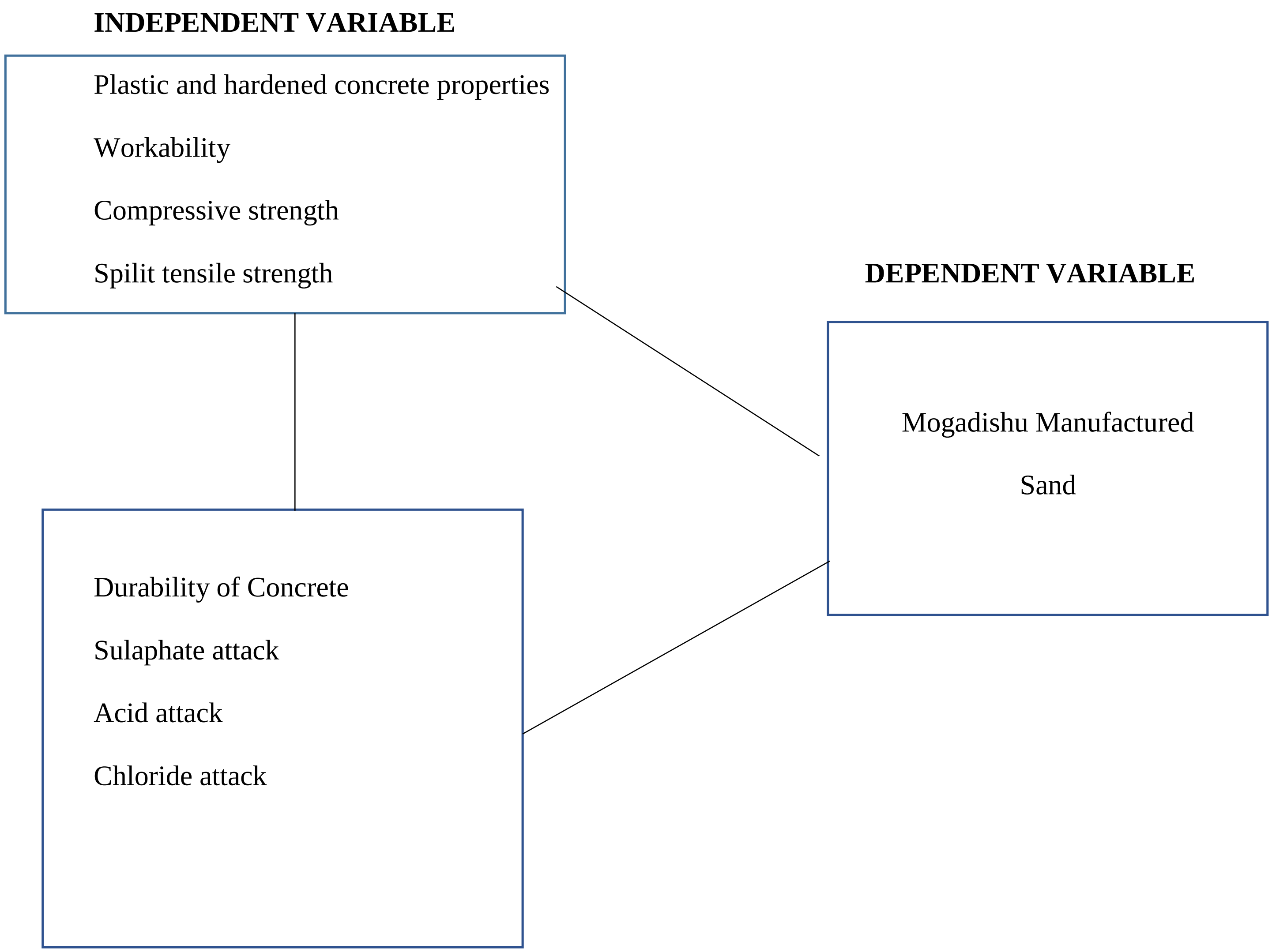

Figure 2.1: Conceptual Framework

2.4 Summary of Literature review and Knowledge Gap

Here is a list of some of the global and regional studies that have been conducted.

1. A study was conducted by Chougule and Mulla (2020) on strength and durability aspects of crushed stone sand in India. In this study, different researches that have been conducted about engineering properties of crushed stone with different years were analyzed and combined (2019, 2018, 2017, 2016, 2010). Different grades of concrete were used in the studies, each with its own set of standards and replacement levels. The findings of the study indicated that the compressive strength of crushed stone sand varies depending on its raw material and

percentage in concrete. Furthermore, the researchers concluded that durability studies are insufficient to make any conclusive statements and that more research is needed.

2. As a study conducted by Nadimalla et al. (2019), in India determined the impact of manufactured Sand (M-Sand) as partially and fully replacement of fine aggregate in concrete. In the research Ordinary Portland Cement (53 grade) was used as per IS: 8112-1989. The river sand was collected from the Mangalore local area which is excavated from riverbeds while manufactured sand was collected from the manufacturing plant situated in Mangalore. The workability of concrete, Compressive Strength test, Flexural strength test, and Impact Test Results were carried out. The results showed that, manufactured sand properties are similar to river sand, M-sand is slightly coarser as compared to river sand. By 100% and 55% incorporation of M sand by river sand concrete can achieve higher flexural strength and compressive strength of concrete at 7 days, 28 days, and 90 days. It was thus concluded that in incorporation of 100% and 55% of M sand can be advised to use as fine aggregate to enhance the strength of Concrete.
3. A study was conducted by Zimar et al. (2017), about the effect of manufactured sand as a replacement for fine aggregates in concrete in Sri Lanka. The commercial Portland Ordinary cement of the grade of 52.5 (P.O 52.5) was used in the study. Slump test and compressive strength test were conducted in accordance with the specifications ASTM C143 (ASTM, 2015) and ASTM C39 / C39M-17b (ASTM, 2017) respectively. The replacement level was 0% (pure sand), 30%, 50%, 70%, 100% (rock sand). The results showed that river sand samples had an average specific gravity of 2.63, while manufactured sand samples had an average specific gravity of 2.79. The average water absorption of manufactured sand was 0.60%, while the average water absorption of river sand was 0.35%. Manufactured sand shows poor workability in the concrete compared to the river sand. In terms of compressive strength, the values reveal a gradual increase of strength when the river sand was replaced by the manufactured sand. The highest compressive strength was observed when MS was 100% in concrete higher than when natural sand was 100% in concrete.
4. Kavitha and Partheeban (2017) investigated the durability properties of manufactured sand in concrete in India. Chemical admixtures are used to enhance the properties of concrete and mortar in the plastic and hardened state. Water absorption test, Rapid chloride Permeability test, and Water Absorption Permeability Test with replacing river sand to the manufactured

sand were carried out. It was established that partial replacement of manufactured sand improved the durability properties of concrete compared to the natural river sand.

5. Woode et al., (2015), determined the effect of partial replacement of natural sand with manufactured sand on the strength of concrete in Accra, Ghana. The natural sand was obtained from pits in the Greater Accra region of Ghana while manufactured sand was derived from gneiss rocks of the Basin Granitoid formation in Ghana. The compressive strength of concrete was carried out using a 2000KN capacity compressive strength test machine at a constant loading rate. The results showed that 50% of manufactured sand obtained the maximum compressive strength. Then the strength decreased as manufactured sand increased. It was thus concluded that partial replacement of natural sand with manufactured sand is, therefore, suitable if it is ensured that the level of fresh biotite is minimal in the manufactured sand.
6. A study conducted by Shanmugavadivu et al., (2020), on the effect of manufactured sand in concrete in Ethiopia [59]. The mix design was prepared for M20 grade concrete using river sand and manufactured sand as fine aggregate. The slump cone test and compaction factor test were used to evaluate the workability of the concrete. It was established that the workability of the concrete is reduced with the increase in the percentage of manufactured sand. The Compressive and tensile strength of the concrete is increased with the increase in the percentage of manufactured sand. The study concluded that natural river sand can be replaced with manufactured sand at most 100%.
7. Manguriu et al. (2013) conducted a study on partial replacement of natural river sand with crushed rock sand in concrete production.

   The nominal mixes were prepared using C20 grade of concrete as per British Standards using natural sand (NS) and replacement of NS sand to Crushed Rock Sand (CRS) in different proportions. In each case proportion, the slump cone test, compressive strength, indirect tensile strength, and flexural strength test was carried out. The results of the study show that the mechanical properties of crushed rock sand depend on the source of its raw material hence the selection of quarry is very important for obtaining quality fine aggregate. The results concluded that 0 to 60 % CRS resulted in strength values above that of the design (20 N/mm2). However, the best results were achieved with 20 % CRS. The replacement of natural river sand can therefore made up to 60%.

2.5 Knowledge Gaps of the Research

Mogadishu is the capital city of Somalia along the coast of the Indian Ocean. Due to the booming of construction activities in Somalia's capital, a huge quantity of concrete is consumed by the construction industry. Conventional concrete is produced using natural sand as fine aggregate. Natural sand resources are increasingly getting depleted. Due to this depletion, the cost of natural river sand is becoming increasingly high. Nowadays local and international companies of construction are engaging in using manufactured sand as partially or fully replacing with river sand. Mogadishu manufactured sand is produced by crushing the coral reef rock from the El'man area in the North of Mogadishu and Jazeera along the cost of the Indian Ocean. The rock quarried is mostly coral reef, which is the only available geometrical locally. The coral rock is either limestone or sandstone (Omar Shire, 1978). The rocks are crushed into aggregates then fed into rotopactors to crush the aggregate into the sand to the required shape and size as fine aggregates.

This study sought to determine the influence of Mogadishu manufactured sand on the engineering properties of concrete. However, there are research limitations conducted on the influence of Mogadishu manufactured sand on the engineering properties of concrete in Mogadishu, Somalia. Compared to those studies conducted in India (Zimar et al., 2017); Sri Lanka (Kavitha& Partheeban 2017) ; Ethiopia (Shanmugavadivu et al., 2020); Ghana (Woode et al., 2015) ; and Kenya (Manguriu et al., 2013), showed that manufactured sand influences the compressive strength, workability, and tensile strength of concrete. Because the engineering properties of manufactured sand differed from country to country or even city to city due to differences in row material (rock), manufacturing process, and powder or dust content in the manufactured sand, the results of those studies on how manufactured sand influences the engineering properties of concrete were different. Some of them demonstrated that completely replacing manufactured sand with river sand can improve concrete's engineering properties. While others are engaged in partial replacement, concrete strength will be developed. Therefore, this study investigated the suitability of manufactured sand prior to their applications in constructions in Mogadishu- Somalia. The results were compared to other studies conducted on the global and regional perspective and talked about the science behind how those results differ from one another. It was also noted that the durability of concrete partially or completely replaced with manufactured sand had not been adequately investigated. This is because, the science of how manufactured sand influences the engineering properties of concrete and how acid, sulphate, and chloride attack concrete with and without manufactured sand is limited. In addition, there has been no comparison of the effects of sulphuric acid, magnesium sulphate, and sodium chloride on concrete durability for both river and manufactured sand which has been covered in this particular study.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

The chapter presents materials and methods for executing the objectives of the study. It outlines the procedures for preparing and collecting samples from the market. The basic aggregate, workability, compressive strength, splitting tensile strength and durability of concrete with Mogadishu manufactured sand was done. For the aggregate, sieve analysis for both fine and coarse aggregate, specific gravity and water absorption was conducted. For workability, slump and compaction factor tests were done. For strength, the compressive strength at 28 days and 56 days and splitting tensile strength at 28 days and 56 were conducted. Finally, the sulphate attack, chloride attack, acid resistance and water absorption was done for a durability point of view at 28 and 56 days.

3.2 Sample Preparation

Fine aggregate to be used as both river and manufactured sand was obtained from the local market of Mogadishu, Somalia. Coarse aggregate is crushed limestone. Cement was ordinary Portland cement of class 42.5. Magnesium sulphate solution ($MgSO_4$), at 5%concentration, Sulfuric acid solution (H_2SO_4) at 5%concentration, sodium chloride (NaCl at 3%concentration was obtained from the industrial area.

3.3 Physical Characterization Tests

Both natural river sand and manufactured sand were analyzed for particle size distribution. The specific gravity of river sand and manufactured sand was determined. Under the physical properties of fine aggregate, water absorption of natural and manufactured sand is also investigated. Finally, coarse aggregate particle size distribution, specific gravity, and water absorption were determined. These were carried out at the University of Nairobi's civil engineering laboratories and entailed the following.

Table 3.1: Tests on Aggregates

N.O	Tests	Standard
1	Grading of aggregate	BS 882-1992
2	specific gravity	BS EN 1097 – 6: 200
3	Water absorption	BS EN 1097 – 6: 200

3.3.1 Grading For River Sand and Manufactured Sand.

Particle size distributions of river sand and manufactured sand were determined by Sieve analysis to establish in accordance to BS 882-1992. A sample of natural river sand and manufactured sand was graded by shaking a nest of stacked sieves, with the largest sieve size at the top so that the material retained on each sieve represents the fraction coarser than the sieve in question but finer than the sieve above. After shaking the material through nested sieves, material retained and passed of 14mm, 10mm, 4.7mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm,0.15mm, 0.0755mm was weighed and calculated for both river sand and Mogadishu manufactured sand. The mass retained on each sieve was expressed as a percentage of the total mass of a sample. The cumulative percentage passing each sieve was calculated as shown in tables A.1 and A.2 respectively. On a standard semi-log graph, the grading curve: percentage (%) passing was plotted against particle diameter, along with the upper and lower limits of the adopted fine aggregate grading curve envelope. Sand that fell outside of this envelop was considered less quality than other sand that fitted into zone 2 grading of B.S 882- 1992. The sum of cumulative percentage weight retained in each sieve was divided by 100 to determine the Fineness modulus of natural and manufactured sand. The main goal of calculating the fineness modulus was to see how it affects the engineering properties of concrete with or without Mogadishu manufactured sand.

3.3.2 The Specific Gravity of Manufactured Sand and River Sand.

The specific gravity of collected Mogadishu manufactured sand and river sand samples were determined using the Apparatus shown in figure 3.1in accordance with BS EN 1097 – 6: 200.

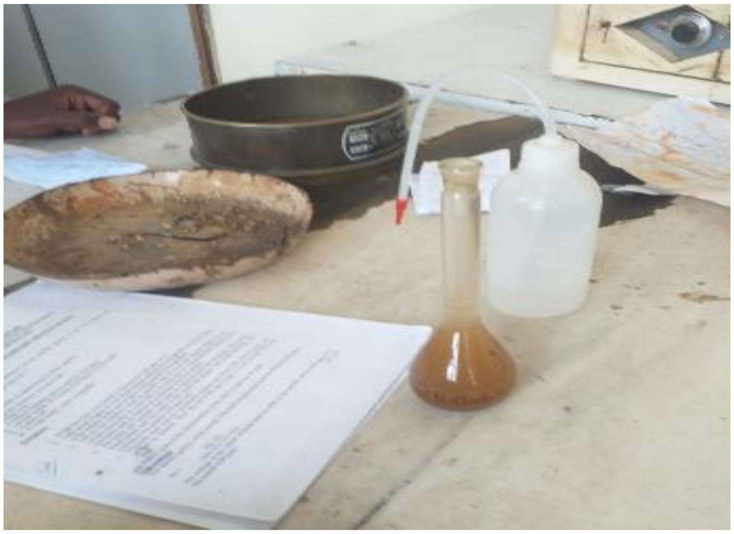

Figure 3.1: Apparatus of Specific Gravity

The weight of the empty bottle, Weight of bottle + sand, Weight of bottle + sand +water, Weight of bottle + water were determined for both river sand and Mogadishu manufactured sand. These values are then used to calculate the specific gravity of Mogadishu manufactured sand and natural sand. The evaluated values are in tables A.3 and A.4 respectively. Finally, the effect of specific gravity on the engineering properties of concrete was determined.

3.3.3 Water Absorption of Manufactured Sand and River Sand

A sample of Mogadishu manufactured sand and river sand was used to determine the water absorption in accordance with BS EN 1097 – 6: 200. Saturated surface dried of sand weight (W1), Dry weight of sand (W2) for both river sand and Mogadishu manufactured sand were determined. The percentage of water absorption of Mogadishu manufactured sand and river sand was calculated by dividing the weight of water by the dry weight of sand and multiplying by 100. The result obtained from the test is given in table A.5 and A.6. Finally, the implication of the results was determined.

3.4 Study of Concrete Properties

Workability (slump and compaction factor tests), compressive strength, split tensile strength, and durability tests were tested to investigate the behavior of concrete properties with and without Mogadishu manufactured sand.

3.4.1 Concrete Cube Moulds Preparation.

Before the concrete mixing operation, the 150mmx150mmx150mm metal molds were cleaned and lightly lubricated. The lubricant served as a release agent, allowing hardened samples to be easily removed.

3.4.2 Procedure for Mixing of Class 30 concrete

For each durability and compressive strength tests, 3 cubes were done. The total cubes of each replacement level were 27.

Table. 3.2: Mix Design Calculation

Sand replacements %	No of sample	Volume of each cubic (mm^3)	Volume of total (mm3)	Total mass of concrete (kg)	Sand (kg)	Cement (kg)	C.A (kg)
0% rock sand	27	3375000	0.091125	219	55	55	110
25% rock sand	27	3375000	0.091125	219	55	55	110
50% rock sand	27	3375000	0.091125	219	55	55	110
75% rock sand	27	3375000	0.091125	219	55	55	110
100% rock sand	27	3375000	0.091125	219	55	55	110

The density of plain concrete was assumed to 2400 $^{kg}/_{m^3}$ the dimensions of the cubes are 150mm x 150mm x 150mm metal cube molds.

$$= 0.15 \times .0.15x0.15 = 3.375 \times 10^{-3}m^3 \quad \text{……….Equation 3.1}$$

$$3.375 \times 10^{-3} m^3 \times 27 = 0.091125 m^3$$ ....Equation 3.2

$$2400 {}^{Kg}/_{m^3} \times 0.091125 = 219 Kg$$ ....Equation 3.3

For Class 30 ratio is 1:1:2

1. Cement $= \frac{1}{1+1+2} \times 219 = 55 kg$......Equation 3.4
2. Sand $= \frac{1}{1+1+2} \times 219 = 55 kg$.........Equation 3.5
3. Course aggregate $= \frac{2}{1+1+2} \times 219 = 110\ kg$...Equation 3.6
4. Water cement ratio $= 55 \times 0.47 = 26\ litres$....Equation 3.7

For all of the mixtures, a constant water/cement ratio of 0.47 was used.

Table 3.3: Replacement Level of Mogadishu Manufactured Sand With River Sand

Sand replacements (%)	Total mass of concrete (kg)	River Sand (kg)	Rock Sand (kg)	Cement (kg)	C.A (kg)
0% rock sand	219	55	0	55	110
25% rock sand	219	41.25	13.75	55	110
50% rock sand	219	27.5	27.5	55	110
75% rock sand	219	13.75	41.25	55	110
100% rock sand	219	0	55	55	110

3.4.3 Workability.

To determine the workability of concrete, this experimental study, slump, and compaction factor tests were conducted.

3.4.3.1: Slump Test

The concrete slump test is a method of determining the workability of fresh concrete. The slump cone, is 300 mm high with an open base of 200 mm diameter and a smaller opening of 100 mm diameter at the top. The test procedure began with dampening the mould and base plate and placing them on a level surface. With the mould being held firmly onto the base plate, the mould was filled up in three layers, each being compacted with 25 strokes of the steel tamping rod of 16mm diameter and 110 cm length, the tamping being evenly distributed After the top layer had been compacted, the surface of the concrete was struck off by a sawing and rolling motion of the tamping rod.

The spilled concrete was then removed from the base plate and the mould was raised by a steady uplift. The difference between the height of the mould and that of the highest point of the slumped test specimen was measured using a straight edge and recorded as the slump value. The slump test was undertaken to procedures outlined in BS EN 12350-2

Figure 3.2: Slump Test Apparatus

3.4.3.2: Compaction Factor Test.

The fresh concrete was placed in the upper hopper of the compaction factor test apparatus Figure 3.3 and then allowed to drop into the lower hopper to bring it to a standard state before dropping it further into the cylinder. The concrete in the cylinder was then streamed and the mass of concrete in the cylinder was measured, (m1). The concrete in the cylinder was then compacted and more added to fill the cylinder with compacted concrete whose mass is also measured, (m2). The compaction factor is calculated as the ratio of the two masses.

$$\text{Compaction Factor} = \frac{mass\ of\ partially\ compacted\ concrete(M1)}{mass\ of\ fully\ compacted\ concrete\ (M2)} \ldots \text{ Equation 3.8}$$

3.4.4 Casting and Compaction.

After tests on the fresh concrete were done, specimens for strength tests were made. This involved remixing the fresh concrete and filling 150mm$\times 150mm \times 150mm$ steel cube moulds and 150mm diameter by 300mm high concrete cylinder moulds in layers and vibrating using a vibrating table. The excess concrete above the upper edge of the mould was removed using steel trowels and the surface was carefully levelled. Then, the cube was stored undisturbed for about 24 hours at room temperature. At the end of this period, the mould was stripped and the cube was further cured in water for 28 and 56 days.

Figure 3.4: Preparation of Concrete Specimens

Figure 3.5: Compacting of Concrete Cubes for Strength Tests

3.4.5 Compressive Strength of Concrete.

The effect of Mogadishu manufactured sand on the compressive strength at 28 and 56 days was done as shown in Table 3.4

Table 3.4: Compressive Strength of Concrete at 28 and 56 Days.

N	Replacement level	Cubic size	Number of sample	Grade of concrete	Days	
1	0% manufactured sand	$150\times 150\times 150\ mm$	6	C30	28	56
2	25% manufactured sand	$150\times 150\times 150\ mm$	6	C30	28	56
3	50% manufactured sand	$150\times 150\times 150\ mm$	6	C30	28	56
4	75% manufactured sand	$150\times 150\times 150\ mm$	6	C30	28	56
5	100% manufactured sand	$150\times 150\times 150\ mm$	6	C30	28	56
Total samples at 28and 56 days $=$ 30 cubic samples						

The capacity of a material or structure to withstand axially directed pushing forces is known as compressive strength. The compression testing machine that was used for this exercise, which had a capacity of 2000kN. Part of the test machine is shown in figure 3.6.

The testing procedure entailed wiping excess moisture from the specimen's surface first. The sample's mass was measured to the nearest gram. Similarly, all of the bearing surfaces on the testing machine were wiped clean to remove any loose grit. The samples were placed in the center of a compression testing machine, and a load was applied at a rate 6.80 KN/second.

The maximum load at failure and corresponding compressive strength of the 30 cubic samples was read from the compressive machine and the type of failure assessed.

The concrete compressive strength test was carried out according to the procedures outlined in BS EN 12390-3.

Figure 3.6: Compressive Strength Testing Machine

The compressive strength can thus be expressed as,

$$COMPRESSIVE\ STRENGTH =) \frac{\text{CRUSHING LOAD (N}}{Area\ of\ cube\ (mm2)} \text{.......Equation 3.9}$$

3.4.6 Splitting Tensile Strength of Concrete

The effect of Mogadishu manufactured sand on the tensile strength at 28 and 56 days was conducted as shown in Table 3.5

Table 3.5: Splitting Tensile Strength of Concrete at 28 and 56 Days.

1. N.O	Replacement level	Cylinder size	N. of sample	Grade of concrete	Days	
1	0% manufactured sand	300 x150mm	4	C30	28	56
2	25% manufactured sand	300 x150mm	4	C30	28	56
3	50% manufactured sand	300 x150mm	4	C30	28	56
4	75% manufactured sand	300 x150mm	4	C30	28	56
5	100% manufactured sand	300 x150mm	4	C30	28	56
Total samples at 56 days = 20 cubic samples						

The principle of the tensile splitting test is such that the cylindrical specimen is subjected to a compressive force applied to a narrow region along its length. The resulting orthogonal tensile force causes the specimen to fail in tension. The (300 x150mm Cylinder) was used as an experimental test of splitting tensile strength. The test was carried out in accordance to BS EN 12390-6.

The 28-day old concrete cylinder was removed from the curing bath and placed on its side in a compression testing machine and loaded across its vertical diameter. Plywood strips were inserted at the interfaces of cylinder and steel loading platens to ensure an even loading over the length of the cylinder.

The tensile stress was calculated using this formula $= \frac{\mathbf{2P}}{\mathbf{3.142LD}}$ **…..**Equation 3.10

Where:

P = Failure load,

L = Length of cylinder

D = Diameter of cylinder.

3.4.7 Durability of Concrete

Finally, the sulphate attack, chloride attack, acid resistance and water absorption was done for durability point of view at 28 and 56 days.

3.4.7.1: Sulphate Attack Resistance Test

The effect of Mogadishu manufactured sand on the Sulphate attack resistance at 28 and 56 days was conducted as shown in Table 3.6.

Table 3.6: Immersing Concrete in Magnesium Sulphate for 28 and 56 Days.

1. N.O	Replacement level	Cubic size	N. of sample	Grade of concrete	Curing Days before chemicals	Immersing days with chemicals	
1	0% manufactured sand	$150\times 150 \times 150\ mm$	6	C30	28	28	56
2	25% manufactured sand	$150\times 150 \times 150\ mm$	6	C30	28	28	56
3	50% manufactured sand	$150\times 150 \times 150\ mm$	6	C30	28	28	56
4	75% manufactured sand	$150\times 150 \times 150\ mm$	6	C30	28	28	56
5	100% manufactured sand	$150\times 150 \times 150\ mm$	6	C30	28	28	56
Total samples at 28 and 56days $=$ 30 cubic samples						28+28=56 days	56+28=84days

The exposure solution was magnesium sulphate solution (MgSO4), at 5%concentration. In order to make a 5% solution. Each 100 gram contains solution 95 grams of water and 5 gram of magnesium sulphate powder (Cang & Bao 2017).

Water required to immersed the 2 sample was **11.5 liters**

11.5litre convert to gram= $11.5 \times 1000 grame \ = 11500 gram$….Equation 3.11

11500grame $= \times$

100gram $= \quad 5 gram$

575grame of magnesium sulphate powder and were diluted to one liter of distilled water.

Figure 3.7: Magnesium Sulphate Powder (Left) and Samples Exposure 5% Magnesium Sulphate Solution (Right).

By immersing the specimens in a sulphate solution, the sulphate resistivity of concrete was investigated. The test was carried out with conventional concrete and concrete replacing fine aggregate with 0%, 25% 50%, 75% and 100% of Mogadishu manufactured sand. The specimens of size 150x150x150mm were casted and cured in water for 28 days as shown in Table 3.6 after 28 days of curing the specimens were removed from the curing tank and their surfaces were cleaned to remove weak reaction products and loose materials from the specimen.

The specimens were weighed before being immersed in a 5 % magnesium sulphate solution ($MgSO_4$) for the next 28 and 56 days of sulphate exposure. Then the immersed specimens were taken out from the tank of 5% magnesium sulphate after 28 and 56 days. The samples are weighted and tested for compressive strength and compared with the specimens which were not exposed to sulphate attack. Finally, the percentage of weight and compressive strength loss due to sulphate attack were then calculated using this formula:

Loss percentage (%) $of\ weight\ or\ compresive\ strenth$

$= (\frac{\text{initial}-\text{final}}{\text{initial}}) \times 100$ ………………………. Equation 3.12

Initial$=$ $compresive\ strenth\ or\ weight\ of\ the\ sample\ before\ immersed\ in$ 5% magnesium sulphate solution ($MgSO_4$).

Initial$=$ $compresive\ strenth\ or\ weight\ of\ the\ sample\ after\ \ immersed\ in$ 5% magnesium sulphate solution ($MgSO_4$).

The test was carried out in accordance to ASTM C 1012-18b.

3.4.7.2: Acid Attack Resistance Test

The effect of Mogadishu manufactured sand on the Acid attack resistance at 28 and 56 days was conducted as shown in Table 3.7

Table 3.7: Immersing Concrete Sulfuric Acid for 28 and 56 Days.

N.O	Replacement level	Cubic size	N. of sample	Grade of concrete	Curing Days before chemicals	Immersing days with chemicals	
1	0% manufactured sand	$150\times 150 \times 150\ mm$	6	C30	28	28	56
2	25% manufactured sand	$150\times 150 \times 150\ mm$	6	C30	28	28	56
3	50% manufactured sand	$150\times 150 \times 150\ mm$	6	C30	28	28	56
4	75% manufactured sand	$150\times 150 \times 150\ mm$	6	C30	28	28	56
5	100% manufactured sand	$150\times 150 \times 150\ mm$	6	C30	28	28	56
Total samples at 28 and 56days $=$ 30 cubic samples						28+28=56 days	56+28=84days

The normal exposure solution was (H_2SO_4) Sulfuric acid solution at 5%concentration. In order to make a 5% solution. Each 100 gram contains solution 95mlof water and 5 ml of Sulfuric acid solution

Water required to immersed the 2 sample was **11.5 liters**

11.5litre convert to ml$= 11.5 \times 1000ml = 11500ml$……..Equation 3.13

11500ml $= \times$

100ml $= 5ml$

575ml of Sulfuric acid solution.

The test was carried out in accordance to ASTM C 1012-20.

Figure 3.8: Samples Exposure 5 % Sulfuric Acid solution (H_2SO_4)

Concrete's acid resistance was investigated by immersing specimens in a 5% sulfuric acid solution (H_2SO_4). The test was carried out according to the procedures outlined. The test was carried out with conventional concrete and concrete replacing fine aggregate with 0%, 25% 50%, 75% and 100% of Mogadishu manufactured sand. The specimens of size 150x150x150mm were casted and cured in water for 28 days as shown in Table 3.7 after 28 days of curing the specimens were removed from the curing tank and their surfaces were cleaned to remove weak reaction products and loose materials from the specimen.

The specimens were weighed before being immersed in a 5 % sulfuric acid solution (H_2SO_4) for the next 28 and 56 days of acid exposure. Then the immersed specimens were taken out from the tank of sulfuric acid solution after 28 and 56 days. The samples are weighted and tested for compressive strength and compared with the specimens which were not exposed to Acid attack. Finally, the percentage of weight and compressive strength loss due to Acid attack were then calculated using this formula

Loss percentage (%) of weight or compressive strength

$= (\frac{\text{initial}-\text{final}}{\text{initial}}) \times 100$ **Equation 3.14**

Initial compresive strenth or weight of the sample before immersed in (H_2SO_4) Sulfuric acid solution at 5%concentration

Initial = compresive strenth or weight of the sample after immersed in (H_2SO_4) Sulfuric acid solution at 5%concentration.

3.4.7.3: Chloride Attack Test

The effect of Mogadishu manufactured sand on the chloride attack resistance at 28 and 56 days will be conducted as in shown Table 3.8

Table 3.8: Immersing Concrete in Sodium Chloride for 28 and 56 Days.

N.O	Replacement level	Cubic size	N. of sample	Grade of concrete	Curing Days before chemicals	Immersing days with chemicals	
1	0% manufactured sand	$150\times 150\times 150\ mm$	6	C30	28	28	56
2	25% manufactured sand	$150\times 150\times 150\ mm$	6	C30	28	28	56
3	50% manufactured sand	$150\times 150\times 150\ mm$	6	C30	28	28	56
4	75% manufactured sand	$150\times 150\times 150\ mm$	6	C30	28	28	56
5	100% manufactured sand	$150\times 150\times 150\ mm$	6	C30	28	28	56
Total samples at 28 and 56days = 30 cubic samples						28+28=56 days	56+28=84days

The exposure solution was sodium chloride at 3% Na Cl concentration. In order to make a 3% Na Cl solution. Each 100 gram contains solution 97 grams of water and 3 grams of Sulfuric acid [66].

11.5litre convert to gram= $11.5\times 1000 grame\ = 11500 gram$

11500grame $=\ \times$

$100gram \quad = \quad 3gram$

345grame of sodium chloride powder and were diluted to one liter of distilled water.

Concrete's chloride resistance was investigated by immersing specimens in a 3% sodium chloride (Na Cl). The test was carried out according to the procedures outlined ASTM C1202-19. The test was carried out with conventional concrete and concrete replacing fine aggregate with 0%, 25% 50%, 75% and 100% of Mogadishu manufactured sand. The specimens of size 150x150x150mm were casted and cured in water for 28 days as shown in table 3.8. After 28 days of curing the specimens were removed from the curing tank and their surfaces were cleaned to remove weak reaction products and loose materials from the specimen.

The specimens were weighed before being immersed in a 3% sodium chloride (Na Cl) for the next 28 and 56 days. Then the immersed specimens were taken out from the tank of sodium chloride after 28 and 56 days. The visual appearance of specimens was analyzed. The samples are weighted and tested for compressive strength and compared with the specimens which were not exposed to Acid attack. Finally, the percentage of weight and compressive strength loss due to Acid attack were then calculated using this formula.

Loss percentage (%) of $\text{weight or compressive strenth}$

$$= \left(\frac{\text{initial} - \text{final}}{\text{initial}}\right) \times 100 \qquad \textbf{Equation 3.5}$$

Initial$=$ $\text{compresive strenth or weight of the sample before immersed in sodium}$ chloride at 3% Na Cl concentration

Initial$=$ $\text{compresive strenth or weight of the sample after immersed in sodium}$ chloride at 3% Na Cl concentration.

3.4.7.4 Water Absorption Test.

Absorption testing is a popular method of determining the water-tightness of concrete. A water absorption test, such as BS 1881-122: Testing Concrete: Method for Determination of Water Absorption, measures the amount of water that penetrates into concrete samples when submersed

Moisture penetration is one of the factors affecting the durability of concrete. Concrete as a porous material which can allow water to migrate through it, corroding steel reinforcement, bringing in harmful chemicals. So, it is a predominant factor to be determined to assess the quality of concrete.

For water absorption test, cube specimen of size of 150 mmx150 mm x150mm was casted and immersed in water for 28 days. The specimens were oven dried for 24 hours at the temperature of 110°C until the mass becomes constant and again weighed at room temperature.

%water absorption = $\frac{W1-W2}{W2} \times 100$. **Equation 3.6**

CHAPTER 4

RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents the results and discussions of different mixes of both river sand and Mogadishu manufactured sand concrete.

4.1 Physical Properties of Fine Aggregate.

The physical properties of fine aggregates referred to in this research include particle size distribution (grading) for fine aggregate, specific gravity, and water absorption for both river and manufactured sand collected from Mogadishu, Somalia.

4.1.1 Grading For River Sand and Manufactured Sand

In this research, the grading curve of manufactured sand and river sand obtained from Mogadishu was plotted on charts of 4.1 and 4.2 as shown below.

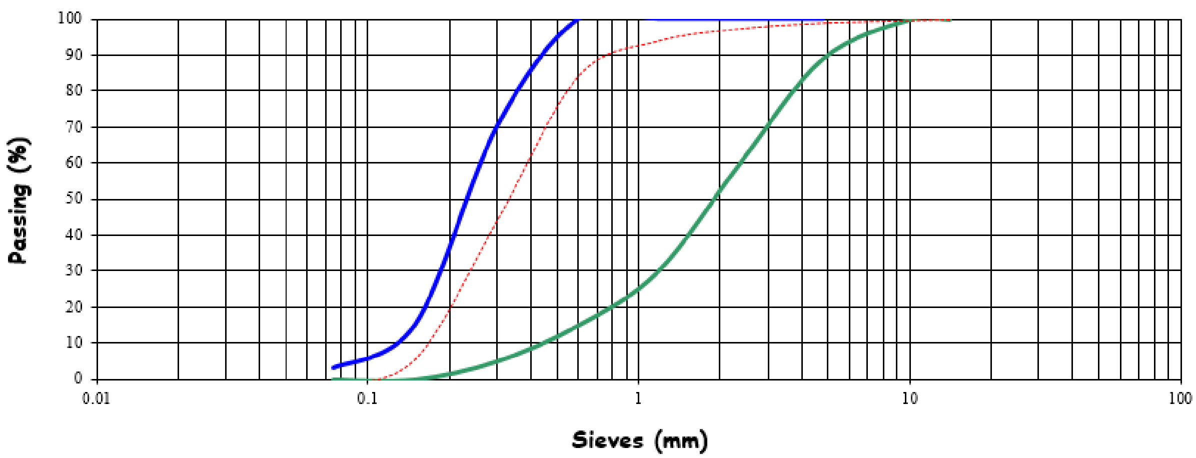

Figure 4.1: Particle Size Distribution of River Sand.

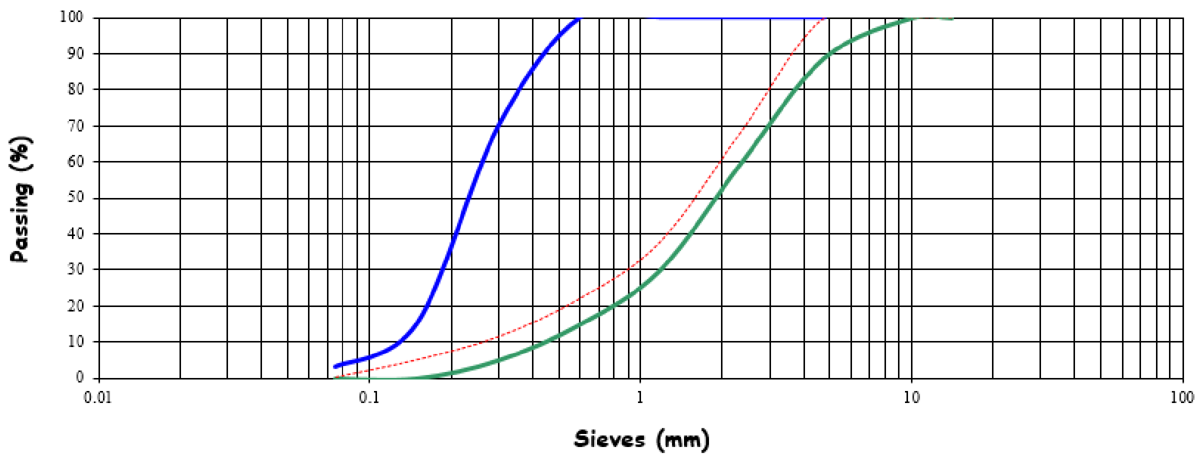

Figure 4.2: Particle Size Distribution of Manufactured Sand

It is observed that for both river sand and manufactured sand a normal S- curve is obtained which shows well-graded aggregates. In terms of grading and particle size characteristics, Mogadishu manufactured sand and natural sand are slightly similar and both sands fitted into zone 2 grading of B.S 882- 1992 as shown in figures **(**4.1 and 4.2). In addition, from the sieve analysis test the river sand and manufactured sand fineness value were 2.77 and 3.5 respectively. This shows that manufactured sand has coarser particles then river sand. However, fines modulus effects the engineering properties of concrete. The higher value of F.M increases the compressive strength, tensile strength and durability of concrete. While it decreases workability of concrete and it needs more water (Purwandito et al., 2017). In cases where replacement of fine aggregates is being undertaken, grading both river sand and manufactured sand is required (Thamilselvi 2016). In totality, therefore, it is important to consider grading as physical property in studying the influence of Mogadishu manufactured sand on the engineering properties of concrete.

4.1.2 The Specific Gravity of Manufactured Sand and River Sand.

In this research, the specific gravity of the collected M-sand and R- sand samples were determined. The specific gravity of manufactured sand was determined to be 2.62 while that of river sand was 2.53. The specific gravity of manufactured sand was dependent on the parent rock and the process of manufacture. The specific gravity of aggregates indirectly measures their density; hence it is the most essential parameter of the strength or quality of the aggregates (Czinder & Török 2021). The higher the specific gravity, the higher the strength and durability, this is because low specific gravity means porous, weak, and absorptive material. The findings from this research also showed that replacing manufactured sand with natural sand can increase the compressive strength, tensile strength, and also durability of concrete. This is due to the fact that manufactured sand has higher specific gravity than river sand. Therefore, partial replacement of manufactured sand with river sand is good to achieve better engineering properties of concrete.

4.1.3 Water Absorption of Manufactured Sand and River Sand

A sample of manufactured sand and river sand from Mogadishu, Somalia was used to determine the water absorption. The result obtained from the test are given in Tables 4.5 and 4.6 The water absorption rate for manufactured sand is determined to be 2.09% while that of river sand is 1.7%. The water absorption rate for manufactured sand and river sand is within the acceptable limits of not more than a 3% water absorption rate. According to BS 8007, aggregates should comply with either BS 882 or BS 1047 and have absorption as measured in accordance with BS 812-2, the water absorption rate of sand should not exceed 3%.

The result also suggests that Mogadishu manufactured sand has higher water demand than natural river sand. This is due to the irregular particle shape and high stone powder content in the manufacturing process. As a result, replacing manufactured sand with river sand is less suitable in terms of concrete workability, and it improves the compressive, tensile strength and durability of concrete in relation to the water absorption rate.

4.1.4 Grading Of Coarse Aggregate

The particle size distribution test was carried out on coarse aggregates and the results are as shown below.

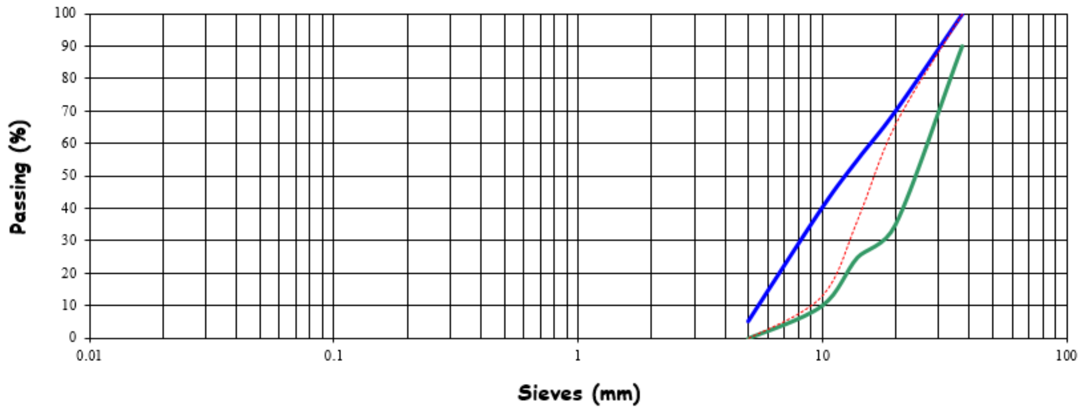

Figure 4.3: Particle Size Distribution of Course Aggregate.

Figure 4.3 depicts the average particle size distribution of coarse aggregate that passes through or is retained on each sieve, from the smallest particle to the largest particle size. So, the cumulative percentage passing and acceptance criteria of the grading curve of the coarse aggregate were used in accordance with BS: 882:1992 within the limit of 40 mm to 5 mm. Consequently, the results indicate that the percentage of coarse aggregate passing through the sieves complies with BS 882:1992.

Therefore, the distribution of different grain sizes influences the engineering properties of the coarse aggregate, such as surface texture, size and shape, voids, and absorption, which affect the workability, strength, and durability of the concrete. This finding concurs with a study by Ajamu and Ige (2015) that concluded that coarse aggregate size is directly proportional to the slump of fresh concrete with a constant water ratio and that the compressive strength of a concrete increases with an increase in coarse aggregate size.

4.1.5 Specific Gravity of Course Aggregate

From the test, specific gravity values of 2.51, 2.57 and 2.67 were achieved. Specific gravity is the weight of a given volume of aggregates relative to the water of an equal volume of water thus a higher value implies stability of a structure built using these aggregates. A lower value would imply low density which may be attributed to the presence of deleterious material in the aggregates which are lighter and not supposed to be in the concrete mix. Low specific gravity generally indicates porous, weak and absorptive materials, whereas high specific gravity indicates materials of good quality. The specific gravity of major aggregates falls within the range of 2.6 to 2.9. Specific gravity values are also used while designing concrete mixes.

4.1.6 Water Absorption of Course Aggregate

From the results, the water absorption of course aggregate was 2.3%.

Test in BS 812 Part 120 is limited to aggregates with water absorption <3.5%. Water absorption may be defined as the difference between the weight of very dry aggregates and the weight of the saturated aggregates with surface dry conditions. The minute holes formed in rocks during solidification of the molten magma, due to air bubbles, are known as pores. Rocks containing pores are called porous rocks. Depending upon the amount of moisture content in aggregates, it can exist in any of the 4 conditions.

Very dry aggregate (having no moisture), Dry aggregate (contain some moisture in its pores), Saturated surface dry aggregate (pores completely filled with moisture but no moisture on the surface) and Moist or wet aggregates (pores are filled with moisture and also having moisture on the surface).

4.2: Workability of Concrete

To assess the influence of Mogadishu manufactured sand on concrete workability, slump and compaction factor tests were used to determine the workability of concrete. Results of these tests are presented in Table A.9, Figures 4.4, and 4.5 as shown below.

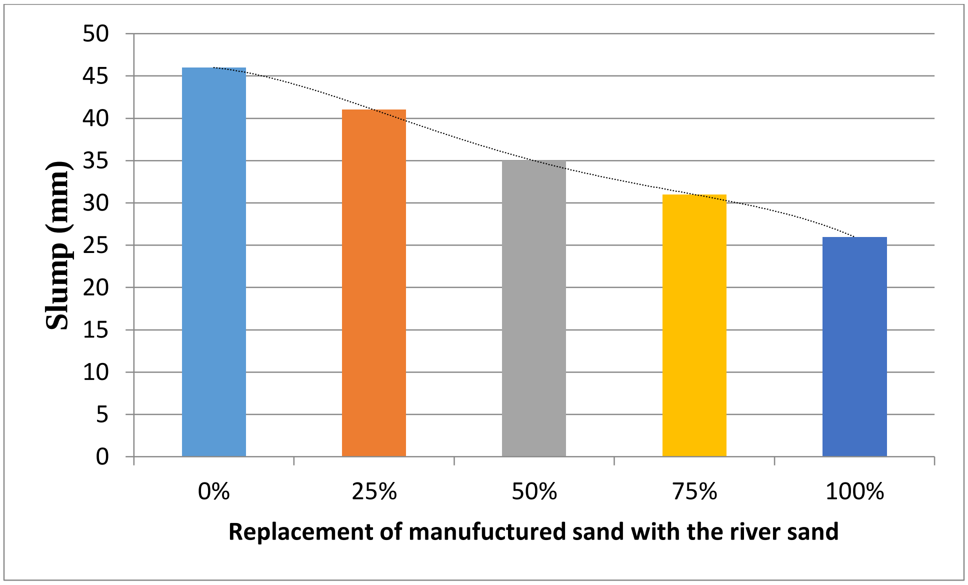

Figure 4.4: Slump Result of Class 30 Concrete with Different Percentages of Replacement of M-Sand

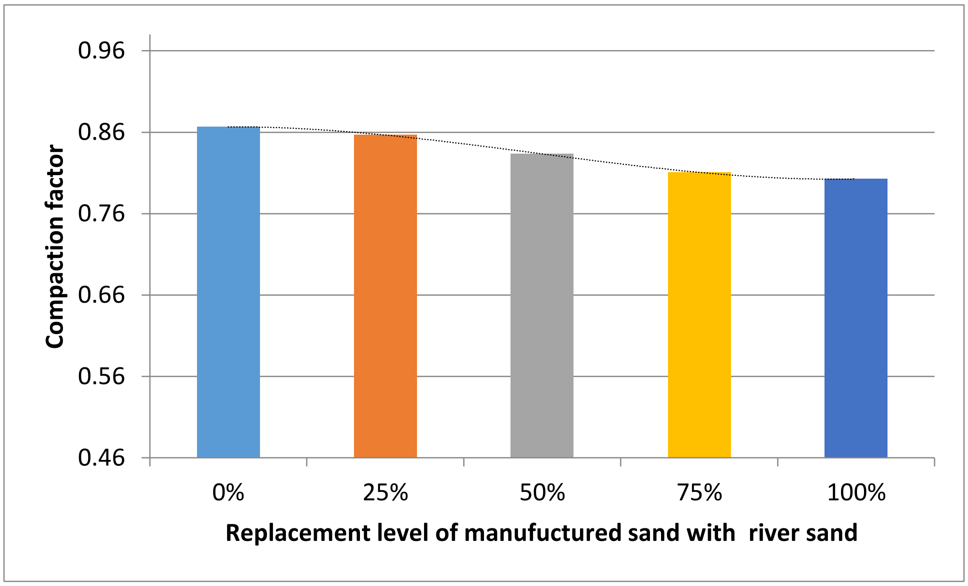

Figure 4.5: Compaction Factor Result of Class 30 Concrete with Different Percentages of Replacement of M-Sand

Figures 4.4 and 4.5 presented, slump and compaction values with a constant water-cement ratio (0.47). At 0% manufactured sand, slump values were 46mm. For 25% manufactured sand the slump decreased to 41mm. further at 50% manufactured sand, 75% manufactured sand, and 100% the slump values continued to decline to 35, 31, and 26 respectively. The 0% pure sand compacting factor value was 0.87. The values decreased to 0.86 at 25% manufactured sand. At 50%, 75% and 100 % manufactured sand the values continued to decline to 0.84, 0.81, and 0.80 respectively. The results show that 0% (pure sand) was higher workability compared to others for both slump and compaction factor values. It is clear that manufactured sand requires more w/c ratio than river sand hence concrete does not give adequate workability with an increase of manufactured sand.

The particle size distribution of aggregate, the shape of aggregate, the surface texture of aggregates, and the water-cement ratio all have a direct impact on the workability of concrete [(Zimar et al., 2017). However, due to its preparation process, defects in manufactured sand include irregular particle shape, inconsistent gradation, and a high stone powder content. These weaknesses also prompt performance differences between manufactured sand and river sand concrete (workability, mechanical properties, and durability), (Elavenil et al., 2013; Pilegis et al., 2016; Jadhav & Kulkarni 2012). When compared to natural river sand, which has a smooth surface texture and rounded shape, aggregate that is more angular will require more water.

Due to that, Mogadishu manufactured sand shows poor workability in the concrete compared to the river sand. As it is seen from Figures 4.4 and 4.5 when the percentage of Mogadishu manufactured sand increases from 0% to 100% the slump values and compaction factor of the fresh concrete decrease from 46 mm to 26 mm, 0.87 to 0.80 respectively. This implies that concrete with manufactured sand has less workability compared to conventional concrete.

The results concur with that of (Vijaya et al., 2015), who conducted a study about the strength and workability of concrete with manufactured sand and found that at 0% replacement (pure river sand) slump values was 98mm and compaction factor value was 0.910, at 20% replacement, the slump and compaction factor (C.F) decreased to 90mm and 0.893 respectively while at 40% replacements, the slump and C.F values continued to decline to 87mm and 0.899 respectively. (Mane et al., 2017) also noted that at 60%, 80% and 100% the slump and compacting factor values further declined to 85mm, 80mm, 75mm and 0.885, 0.857, 0.840 respectively (Vijaya et al., 2015), The results imply that any percentage replacement of natural sand to manufactured sand will reduce the workability. The round shape and smooth surface texture of natural sand reduce the antiparticle friction in the fine aggregate component so that the workability is higher in natural sand. Manufactured sand particles are angular in shape and their rough surface texture improves the internal friction in the mix. Because of that, the workability is reduced. Likewise, in a study on the effects of manufactured sand on compressive strength and workability of concrete (Vijayaraghavan & Wayal 2013), established that at 100% natural sand (0% manufactured sand), the slump value was 125mm, at 50% natural sand + 50% manufactured sand slump values decreased to 100mm while at 100%manufactured sand (0% natural sand) the slump values drastically declined to 34. This is an implication that the workability of concrete will reduce with increasing percentage of manufactured sand to concrete. In addition, Su and Gurunathan (2010). in a study on the effect of m-sand from various sources on the workability of the concrete foundation that the workability of the fresh concrete improved constantly according to the increasing water-cement ratios ranging from 0.4 to 0.5 with a successive interval of 0.05 and that manufactured sand of various sources had a greater effect over the workability of the concrete.

From these results, it can be concluded that concrete produced using manufactured sand has poor workability then conventional concrete. But its angularity it will improve the strength (compressive, tensile) and durability of concrete. The use of manufactured sand in construction activities around the world, including Mogadishu, requires the participation of water-reducing admixtures and plasticizers as part of their quantities, in order to improve the workability of concrete for whatever manufactured sand is used. Adding concrete workability enhancer admixtures to manufactured sand presents a research opportunity and a potential research gap.

4.3 Compressive Strength of Concrete

Results of this test is presented in Figure 4.6 as shown below.

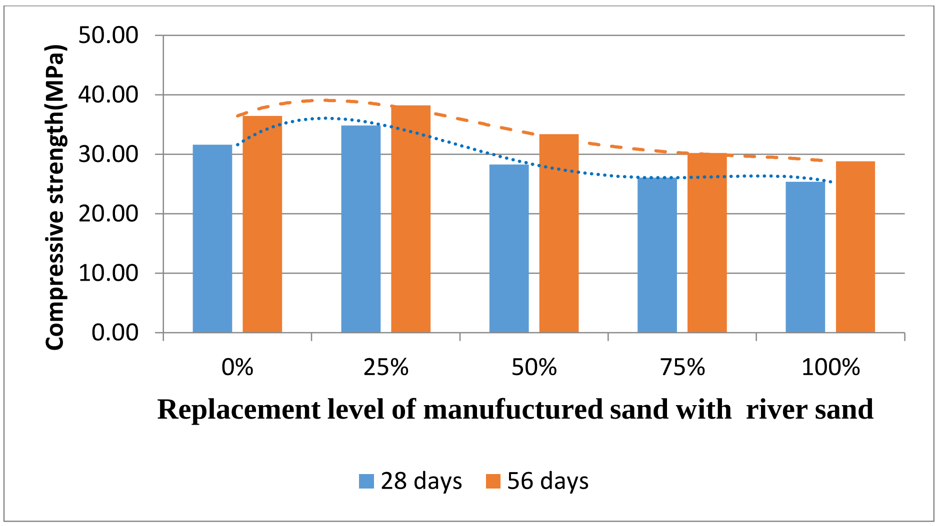

Figure 4.6: Compressive Strength at Various Percentage Replacement at 28 days and 56 Days.

At 28 days of curing, the compressive strength of pure river sand concrete was 32 MPa, increasing to 34.815 MPa at a 25% replacement level (75 per cent river sand/25 percent manufactured sand) at the same time. However, further addition of manufactured sand into river sand at 28 days curing period resulted in a consistent decline in the compressive strength of concrete to 28.3MPa, 26MPa, 25.4MPa for 50%, 75%, and 100% replacement levels respectively. At 56 days of curing period of concrete, the compressive strength of pure river sand was 36.43MPa. The compressive strength increased to 38.24MPa at 25% replacement level (75% river sand/25% manufactured sand). This is the highest level of compressive strength of concrete, implying that at a 56-day curing period. The compressive strength of concrete in the replacement level 50%, 75%, and 100% at the 56-day treatment period resulted in a continuous decline of the compressive strength of concrete to 33.4MPa, 30.23MPa, 28.776 MPa respectively.

The result shows a significant improvement in the compressive strength of concrete up to 25% replacement with M-sand. This is attributed to the irregular-shaped particles of the manufactured sand which tend to enhance the soil properties and improve bonding and interlocking between particles (aggregate and cement) resulting in high strength (Pilegis et al., 2016; Mamaru 2020). Furthermore, the compressive strength of concrete is reduced as the percentage of manufactured sand replacement increases. Due to an increase in the contribution of irregularly shaped particles from manufactured sand, this change in strength is expected to increase as the percentage of manufactured sand increases. This may be due to Mogadishu manufactured sand containing more micro fines and high stone powder content than natural river sand. The presence of micro-fines in concrete will almost certainly affect its workability and strength. It reduces workability and may result in weak bonds between coarse aggregates and cement paste and resultant weak concrete compressive strength. To confirm this claim, more research may be required in Mogadishu manufactured sand.

The results concur with (Zhang et al., 2020), in a study on the effect of manufactured sand as a replacement for fine aggregates in Concrete who found that the values reveal a gradual increase of the strength when the river sand was replaced by the manufactured sand. Compressive strengths of samples changed between 19.3 MPa and 21.0 MPa for 7 days curing time. The highest compressive strength, 21.0 MPa was observed when MS was 100% in concrete and it was 8.8% higher than when natural sand was 100% in concrete. The research also found that in 28 day of curing, the highest compressive strength was obtained for the 100% MS made concrete which is 26.9 MPa, 10.2% higher than 100% natural sand made concrete. It was concluded that the main reason for the strength increment with MS is the excellent bonding between coarse and fine aggregates as it is attributed by the formation of water-cement gel in the matrix. Similar observations were made by (Nadimalla et al., 2020; Shanmugapriya & Balaji 2016), found that compressive strength increases by the manufactured sand of 5% to 10% compared to natural sand for grade 40 concrete. However, (Dilek 2015). In a study about Experimental Investigation on the Strength and Durability Properties of Concrete Using Manufactured Sand observed that the compressive strength, split tensile strength and flexure strength of concrete is improved by partial replacement of M-sand for fine aggregate. In addition to that compressive strength, split tensile strength are increased as the percentage of M-sand is increased up to a maximum level of 60%. The experimental results revealed that the M-sand replaced concrete have 20% more compressive strength up to 60% replacement of M-sand and further increase in the percentage of M-sand reduced the strength.

The implication from the study findings is that 25% replacement of Mogadishu manufactured sand with river sand increases the compressive of concrete. Hence, partially replacements are recommended in construction activities. However, in order to improve the strength of concrete with Mogadishu the screen is done to eliminate the, micro-fine, and dust particles that lead the strength to be weak by washing the Mogadishu manufactured sand using the water jet.

4.4 Splitting Tensile Strength of Concrete

Results of this test is presented in Figure 4.7 as shown below.

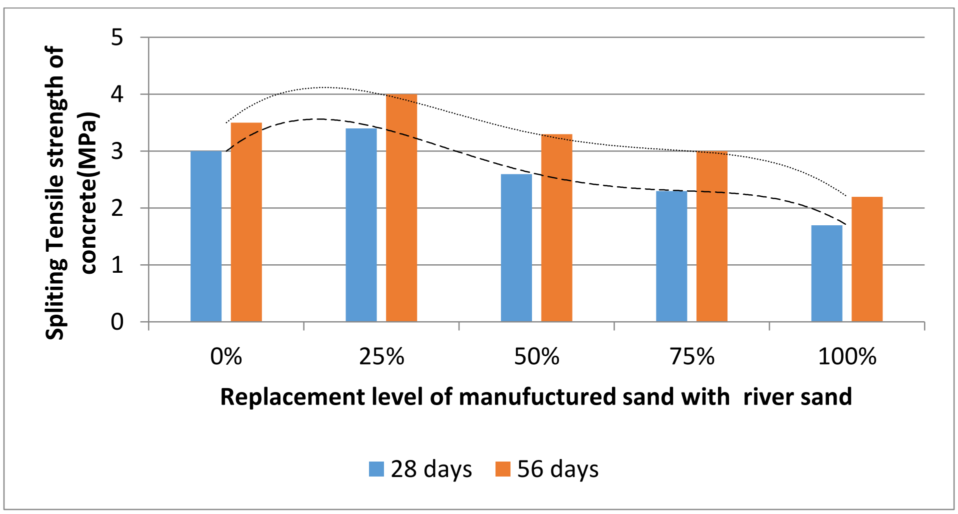

Figure 4.7: Splitting Tensile Strength of Concrete at 28 days and 56 Days.

Results showed that the tensile strength of concrete made of pure river sand (control 0%) at 28 days was 3MPa. However, tensile strength of concrete rose to 3.4MPa after making the concrete in the mixture of 75% pure river and 25% manufactured sand. There after there was a decline in tensile strength of the concrete at replacement level 50%, 75% and 100%.

For pure river sand (control 0%), the tensile strength of concrete was 3.5MPa at 56-day period. The tensile strength rose to 4MPa when the concrete was made in the mixture of 75% pure river and 25% manufactured sand in the same time period. There was decline in the tensile strength of the concrete at replacement level 50%, 75% and 100%.

Based on the tensile results of the concrete, the results imply that splitting tensile strength of concrete was strongest at 25% replacements (75% river sand and 25% manufactured sand) both 28 and 56 days. Also, the splitting tensile strength of concrete was weakest at 100% manufactured sand for both 28 and 56 days. Also it has been observed that the splitting tensile strength of concrete with replacement of natural sand by manufactured sand goes increasing up to 25% replacement level. The science and implication of this is similar to the compressive strength test.

A study by (Vaishali & Dhanalakshmi 2018). On the effect of manufactured sand on mechanical properties of concrete found that on comparing the tensile strength results of Karur manufactured sand concrete with the conventional concrete, it showed 7%, 11.9% and 12.15% higher tensile strength than conventional concrete for 7 days, 14 days and 28 days. (Vijaya et al., 2015) on study about Comparative study on the strength and durability properties of concrete with manufactured sand concluded that the split tensile strength of concrete increased by 28%, 20% and 9% for M30, M40, and M50 grade concrete when compared with conventional concrete up to 60% replacement of M-sand with river sand.

4.5 Durability of Concrete.

durable concrete is that which resists the forces in that environment that tend to cause it to deteriorate prematurely without requiring excessive effort for maintenance. The research concludes that durable concrete must possess properties appropriate for the environment (Taylor et al., 2013). Specifying durable concrete begins with identifying exposure conditions. Therefore, the durability of concrete is its ability to perform satisfactorily in the exposure condition to which it is subjected over an intended period of time with minimum maintenance. This implies its ability to withstand weathering action, chemical attack, or any other process of deterioration (Vijayaraghavan, & Wayal 2013). Durability has become one of the most important considerations in building design and construction in recent years. Concrete is susceptible to chemical attacks such as acid, sulfate, and chloride, because of its alkaline nature. The socioeconomic losses associated with infrastructure deterioration due to chemical attacks exceed billions of dollars all around the world.

With the increasing demand for manufactured sand for construction activities in several regions across the world including Mogadishu, it is important therefore to assess how manufactured sand influences the durability of normal strength concrete under different exposure conditions. In this research, the aim is to study the effect of manufactured sand on the durability of concrete in terms of acid, Sulphate, and chloride resistance by exposing the concrete specimens to Sulphuric acid (H_2SO_4), 5% magnesium sulfate ($MgSO_4$) solution, and 3% sodium chloride (Nacl) for 28 and 56 days. Which are the exposure conditions in Mogadishu and whose research is not yet explored. Parameters evaluated included weight changes, and compressive strength changes before and after immersing the concrete into the chemical.

4.5.1: Acid Attack.

A series of tests were conducted to study the effect of Mogadishu manufactured sand on the durability of concrete in terms of acid resistance by exposing the concrete specimens to a 5% Sulphuric acid (H_2SO_4), solution for 28 and 56 days. Parameters evaluated included weight changes and compressive strength changes before and after immersing the concrete in the chemical.

4.5.1. 1: Change in Mass Under Sulfuric Acid.

Test on variations in the mass of concrete after soaking the specimen in the sulphuric acid solution, for 28 and 56 days as a percentage of the mass before and after exposure were done. The change in mass of the concrete exposed to the sulphuric acid is shown in Figure 4.8

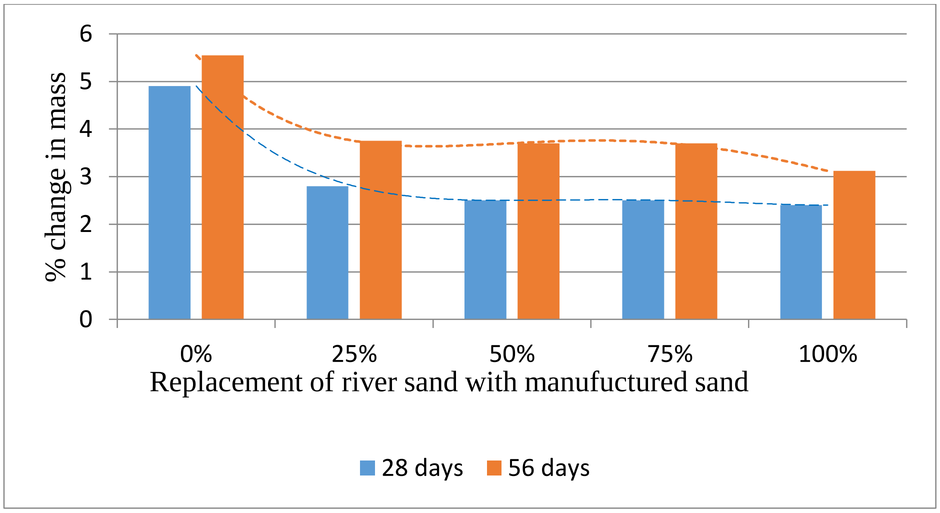

Figure 4.8: Percentage Change in Mass Under Sulfuric Acid.

Mass change for pure river sand concrete (0% manufactured sand) under sulfuric acid treatment, the % loss in mass change was 4.94 at a 28-day exposure period. The percentage loss in mass of the concrete made of 75% pure river and 25% manufactured sand was 2.8% in the same exposure period. However, the percentage loss in mass of the concrete made of 50% pure river and 50% manufactured sand decreased to 2.5% in the same exposure period. Thereafter, the percentage loss in mass of the concrete was 2.5% and 2.4% at 75 %and 100% replacement of manufactured sand as shown in figure 4.8. Also, the figure is shown in the 56-day treatment period, the percentage loss of mass for pure river sand (control 0%) was 5.55%. At 75% percent pure river sand and 25% manufactured sand; there was a loss of 3.75% in the mass of the concrete. Percentage loss of mass for concrete at exposure levels 50% and 75% was the same at 3.7% loss.100% Manufactured sand percentage loss of mass was 3.12% in the 56-day treatment period.

The results thus imply that percentage loss of mass is highest in pure river sand and lowest in concrete made-produced using 100% manufactured sand exposed to sulphuric acid-treated for both 28 and 56 days. It is therefore notable that the loss of weight is reduced as the manufactured sand replacement increase under Sulphuric acid immersion for both 28- and 56-day treatments. Meaning that manufactured sand is more resistant to Sulphuric acid attacks than conventional sand. This is because of the denser particle packing and silt-free nature or lesser impurity of manufactured sand compared to river sand (Mamaru 2020).

It is clear that the weights of concrete are decreased in chemical solutions such as sulphuric acid, since concrete is an alkaline substance, many of its components readily react with Sulphuric acid. Due to these reactions between sulphuric acid and cement, the concrete microstructure becomes weak, cement paste is lost, and the size of the specimen reduces (Ayodele & Ayeni 2015). These observations are consistent with the findings of (Irico et al., 2020), who concluded that the loss of weight of concrete cubes in H_2SO_4 medium is due to ettringite formation. That is, Sulphuric acid attacks on Ca (OH)s and form CaSO4 which is leached out of concrete easily. The calcium silicate hydrate reacts with H2SO4 to form fragile silica gel which is easily destroyed by external physical forces. The calcium sulphate formed by initial reaction can proceed to react with calcium aluminate phase in cement to form voluminous calcium sulpho aluminate (ettringite) which can cause expansion, cracking, loss of weight & strength and disintegration of concrete. The results concur with (Vijaya et al., 2015), who found that the percentage weight loss due to sulphate attack was

1.8 % for conventional concrete and 1% for manufactured sand replaced concrete. (Joel M & Mbapuun 2016).study indicated no loss of weight in the specimens in the initial 7 days but recorded percentage weight loss that increased progressively till 56 days.

The implication of the study is that Sulphuric acid attacks and reduces the weights of the concrete produced using both natural and manufactured sand. However, the effect of sulfuric acid, is higher for river sand concrete compared to manufactured sand concrete. Thus, during construction, the use of manufactured sand concrete is more suitable in environments that experience acid, including Mogadishu – Somalia compared to river sand concrete so as to maintain the structural integrity of a building.

4.5.1. 2: Change in Compressive Strength Under Sulfuric Acid.

Results of this test is presented in Figure 4.9

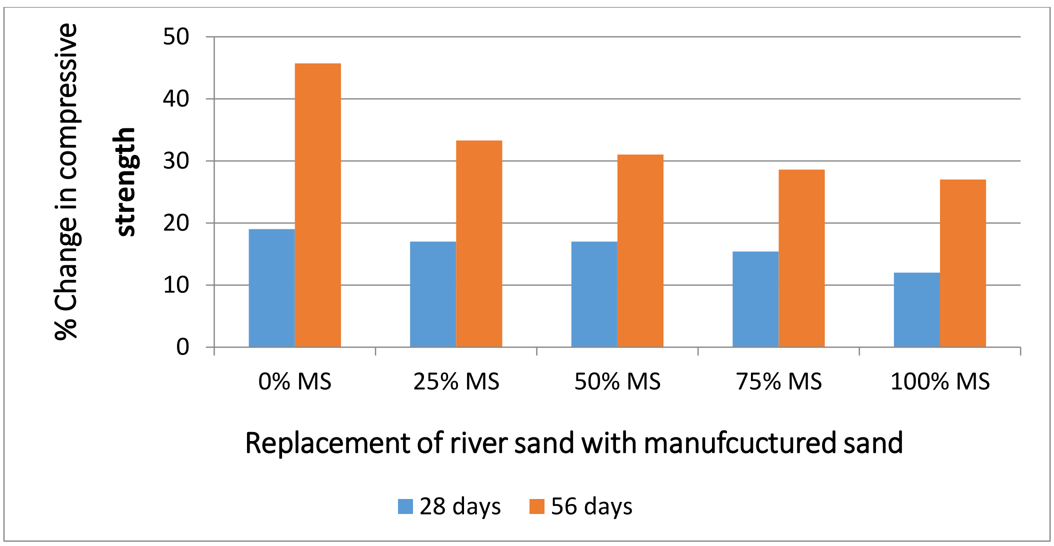

Figure 4.9: Loss of Compressive Strength Under Acid Attack

The percentage loss of compressive strength of concrete exposed to sulphuric acid for 28 days at 0%, 25%, 50%, 75% and 100% replacement level was 19%, 17%, 17%, 15.4%, and 12% respectively as shown figure 4.9. The results depict a decreasing loss of compressive strength of concrete based on the replacement level. There is a high loss of compressive strength of concrete for pure river sand exposed to sulfuric acid for 28 days and the smallest loss of compressive strength of concrete for manufactured sand in the same period. Figure 4.9 also, shows for concrete made of pure river sand exposed to sulfuric acid for 56 days, there is loss of compressive strength by 45%. The compressive strength loss of the concrete continues to fall in the replacement level 25%, 50%, 75% and lowest at 100% was 33.3%, 31%,28.6%,27% respectively.

The inference derived from this results is that compressive strength loss is greatest for concrete made of pure river sand and lowest for concrete made of manufactured sand after immersion in sulphuric acid, solution for both 28- and 56-days treatment periods.

It is noticed that the compressive strength losses are lesser in manufactured sand and it is least for the optimum proportion of 100% of manufactured sand when compared to the concrete with natural river sand. This implies that manufactured sand increases the durability of concrete under acid attack than river sand. The explanation for this is due to the better interlocking of aggregate in manufactured sand concrete.

In addition, it may be due to the presence of fewer pores in concrete with 100 % manufactured sand which reduces the permeability of acid solution through the concrete specimens. This acid solution attacks and leaches away the calcium compounds of cement paste formed in concrete through the hydration process, as well as the calcium in the calcareous aggregate (Shanmugavadivu et al, 2014.) Furthermore, the result showed that the decrease in compressive strength of concrete with manufactured sand increases with the increase of curing age in immersed acid solution. This means the strength of manufactured sand concrete at 56 days is less than that at 28 days when exposed to sulphuric acid.

The results concur with ((Shanmugavadivu et al., 2014) in a study of Gradation of Manufactured Sand in Acid Attack of Concrete who found that the mechanism of concrete deterioration caused by sulfuric acid can be explained by the fact that the sulphuric acid penetrating into the concrete reacts with calcium hydroxide of cement hydrates and produces gypsum. The disintegration of hardened cement paste, as a result of interaction with the environment, causes a reduction in the compressive strength of concrete. Furthermore, the research found that when compared to the conventional concrete, the strength reduction due to acid attack is reduced by 10 to 20 % while using the manufactured sand. Finally concrete with manufactured sand shows high resistance to acid attack. Taku et al., 2015 also noted that an Acidic curing environment has a negative effect on the compressive, flexural and tensile strengths as well as density of concrete cured in acidic water. The research concluded that Concrete's strength deteriorates as it ages and as the percentage concentration of acid in the curing water rises.

Therefore, it can be concluded that acid attack compromises concrete strength resulting in a weaker structure and shorter life span. The use of manufactured sand concrete is therefore, more suitable in environments that experience acid conditions including Mogadishu – Somalia compared to river sand concrete.

4.5.2: Sulphate Resistance:

A series of tests were conducted to study the effect of manufactured sand on the durability of concrete in terms of Sulphate resistance by exposing the concrete specimens to a 5% magnesium sulfate ($MgSO_4$) solution for 28 and 56 days. Parameters evaluated included weight changes and compressive strength changes before and after immersing the concrete in the magnesium sulphate. The results are compared with samples before and after immersing in 5% magnesium sulphate solution ($MgSO_4$) for both 28 and 56days of different replacements of manufactured sand of class 30 concrete.

4.5.2. 1: Change in Mass Under Sulphate Attack.

Results of this test is shown in Figure 4.10

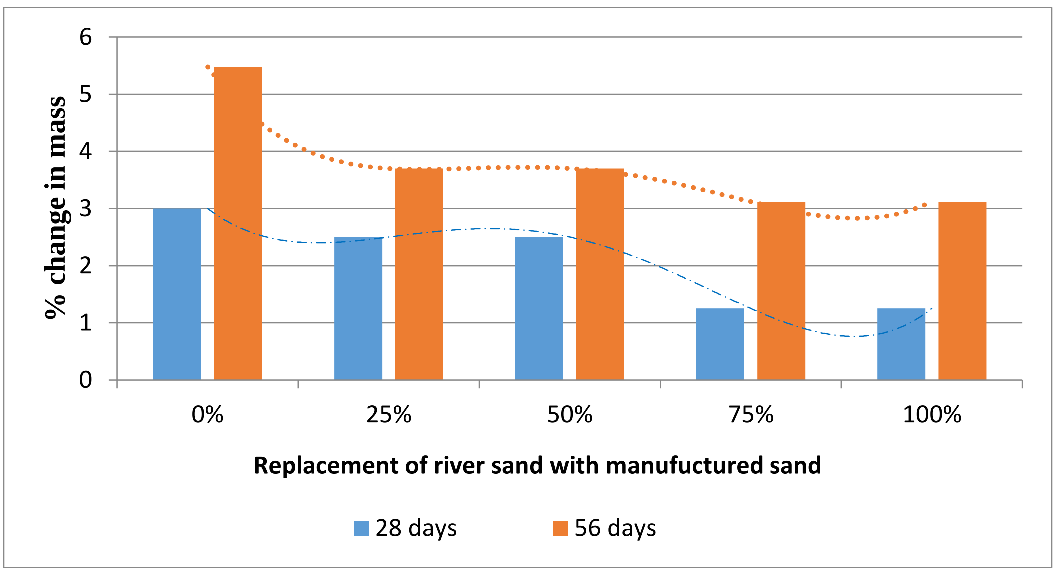

Figure 4.10: Percentage Loss of Mass Under Sulphate Attack.

As presented in figure 4.10, the percentage loss of mass under sulphate attack ($MgSO_4$) was 3% for pure river sand at the 28-day treatment period. In the replacement level 25% and 50%, the loss of mass under sulphate attack was 2.5% in both the cases. For the concrete made of 25% river sand and 75% manufactured sand, the mass loss was 1.25% which remained the same under pure manufactured sand in the same treatment period. In the 56-day treatment period, the percentage loss of mass for pure river sand (control 0%) was 5.48%. At 75% percent pure river sand and 25% manufactured sand; there was a loss of 3.7% in the mass of the concrete. There was drop in percentage loss of mass by 3.7% for concrete made of river sand and manufactured sand in the ratio 1:1. Mass loss was 3.12% for concrete mixture of 25% river sand/75% manufactured sand. Concrete made of pure manufactured sand recorded a loss of mass by 3.12% treated for 56 days.

The data shows that the greatest percentage loss of mass is more in 100% river sand and lowest in concrete with 100% manufactured sand exposed to magnesium sulphate treated for both 28 and 56 days. Reducing the weight of the specimens under magnesium sulphate is due to reaction between the concrete and magnesium sulfate ($MgSO_4$) since concrete is alkaline substances (The formation of ettringite at the early stage causes a damage to cement paste. Damage caused by sulphate attack is attributed to decalcification, which weakens the C-S-H matrix, which causes the concrete microstructures becomes week, cement paste is lost and weight of samples reduced (Reddy, et al., 2015). In terms of sand, manufactured sand is more resistant to the sulphate attach then river sand. This is due to high fines modulus of manufactured sand or coarser particles which fill voids and create better interlock between the aggregate and cement.

These findings concur with (Shanmugavadivu et al., 2018) in a study of Durability Properties of Concrete Using Manufactured Sand as Fine Aggregate, found that the weight loss due to sulphate attack is reduced as 25 – 40 % while using 70 percentages of manufactured sand. They summarized that manufactured is more resistant of durability then reviver sand. Also (Vijaya et al., 2020) found that The percentage weight loss due to sulphate attack is 1.8 % for conventional concrete and 1% for M-sand replaced concrete. Hence, the durability point of view .M-sand concrete have good resistance against sulphate attack.

The relevance of the study is that exposure of concrete to magnesium sulphate results in reduction of its mass thereby affecting its durability. This is more prone in concrete with pure river sand than that with manufactured sand. It is therefore recommended that manufactured sand be used infrastructure projects where the environmental conditions have magnesium sulphate

4.5.2. 2: Change in Compressive Strength Under Sulphate Attack.

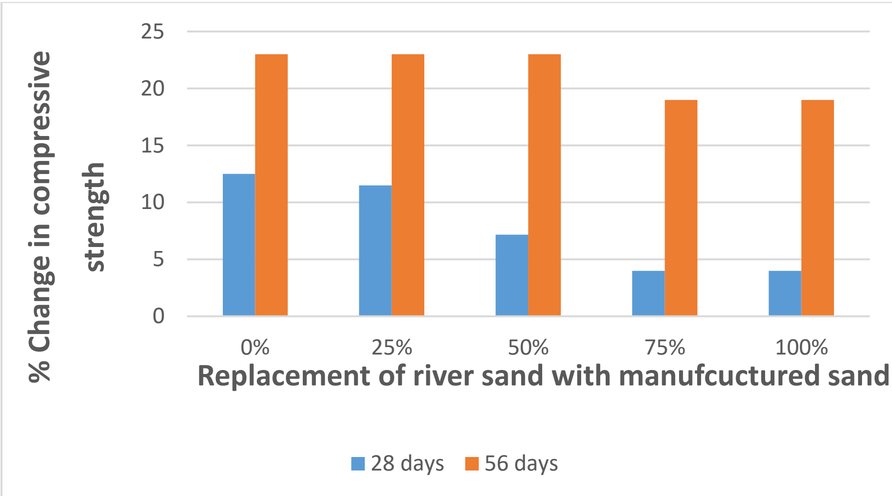

Figure 4.11: Loss of Compressive Strength Under Sulphate Attack.

Figure 4.11 presented that the percentage loss of compressive strength concrete exposed to magnesium sulphate for 28 days at 0%, 25%, 50%, 75% and 100% replacement level was 12.5%, 11.5%, 7.15%, 4% and 4% respectively. There is a higher loss of compressive strength for concrete made of pure river sand and lower for concrete made of 25% river sand/75% manufactured sand and 100% manufactured sand in the 28-day exposure period. For concrete made of pure river sand (0% manufactured), at 25% replacement and 50%, replacement the percentage loss of compressive strength was greatest at 23% and exposed to $MgSO_4$ for 56 days. For concrete made of 25% river sand/75% manufactured sand and pure manufactured sand and exposed to $MgSO_4$ for 56 days, the percentage loss of compressive strength is 19% in both experiments as presented in figure 4.11. As mention earlier the percentage loss of compressive strength is lesser the 100%manufutured sand and highest for 0% for pure river sand.

Sulfate attack is one the most aggressive and the most complex durability problems associated with concrete. The sulfate attack of concrete leads to expansion, cracking, and deterioration of many civil engineering structures exposed to sulfate environment such as piers, bridges, foundations, concrete pipes. When the attacking solution contains magnesium ion, such as in magnesium sulfate (MgSO4), it reacts with all cement compounds, including CSH, thus decomposing cement, and subsequent forming gypsum and ettringite. Concrete deterioration due to MgSO4 attack was attributed to the decalcification of C-S-H to form M-S-H, the formation of magnesium hydroxide (brucite) as well as the expansion caused by the formation of expansive salts. reduc (Vijaya &Selvan 2015) in a study on comparative study on the strength and durability properties of concrete with manufactured sand found that the compressive strength loss due to sulphate attack after 28 days of river sand are slightly more than that for concrete samples with 60% manufactured sand (Zhang, et al., 2018). However, a study by Venkatanarayanan and Rangaraju (2014) indicated that magnesium sulfates caused significant deterioration in the specimens and significant loss in compressive strength. (Oymael 2008), also found that solution with MgSO4 had relatively lower compressive strength

The significance is that in areas where structures are exposed to sulphate attack manufactured sand is more durable as compared to natural river sand. Hence manufactured sand can fully be replaced with river sand in Mogadishu- Somalia.

4.5.3: Chloride Attack

A series of tests were conducted to study the effect of manufactured sand on the durability of concrete in terms of Chloride resistance by exposing the concrete specimens to a 3% sodium chloride (NaCl) for 28 and 56days. Parameters evaluated included weight changes and compressive strength changes before and after immersing the concrete in the chemical. The results are compared with samples before and after immersing in 3% sodium chloride (NaCl) for both 28 and 56days of different replacements of manufactured sand of class 30 concrete.

4.5.3. 1: Change in Mass Under Chloride Attack

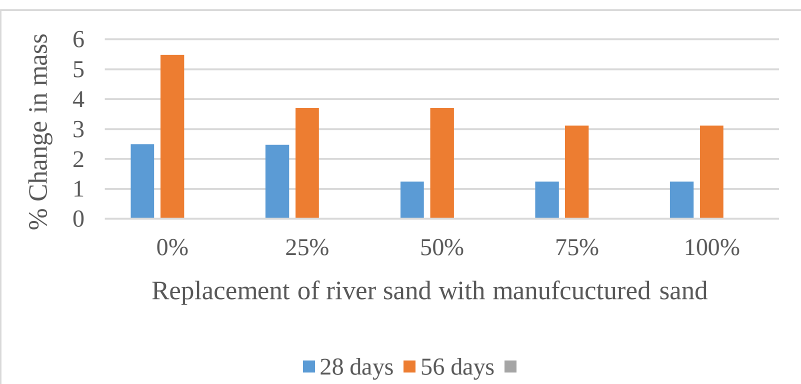

Figure 4.12: Percentage Loss of Mass Under Chloride Attack.

Figure 4.12 shows; the percentage loss of mass under chloride attack (NaCL) was 2.5 for pure river sand at the 28-day treatment period. The percentage mass loss fell to 2.47% in the 75% river sand/25% rock sand in the same period. For replacement level strength 50%, strength 75% and strength 100%, the percentage mass loss due to chloride attack was 1.25% in all the three cases after the elapse of the 28-day period. In the 56-day treatment period of in NaCL, the percentage loss of mass for pure river sand (control 0%) was 5.48%. At 75% percent river sand and 25% manufactured sand; there was a loss of 3.7% in the mass of the concrete. The percentage loss of mass was 3.7% for concrete made of river sand and manufactured sand in the ratio 1:1. Mass loss was 3.12% for a concrete mixture of 25% river sand/75% manufactured sand. Concrete made of pure manufactured sand recorded a loss of mass by 3.12% treated for 56 days.

Similarly, as for both the acid attack and sulphate attack findings, the results for chloride attack imply that the greatest percentage loss of mass is highest in pure river sand and lowest in concrete made-produced using 100% manufactured sand for both 28 and 56 days. In addition, it can be seen that the loss of weight is reducing as the manufactured sand replacement increase under chloride attacks for both 28 and 56 treatments. Meaning that manufactured sand is more resistance to chloride attacks than conventional sand. The science of this is similar to that of sulphuric acid and magnesium sulphate. The only difference is the chemical compositions and reactions to the concrete. These results concur with (Shanmugavadivu et al., 2018) on the Durability Properties of Concrete Using Manufactured Sand as Fine Aggregate found that he chloride attach is high for concrete with natural sand and it is reduced while using manufactured sand. This may be due to the grain size of the manufactured sand is coarser and the better packing is developed. From the above results, it is observed that the optimum proportion of 70 % manufactured sand gives better results. The result concurs with (Saravanan, et al., 2016) on the Effect of manufactured sand on the durability characteristics of concrete concluded that Concrete with manufactured sand shows lesser chloride ion penetrability than the conventional sand concrete, which shows that lesser permeability with manufactured sand in concrete.

In areas that have chloride exposure conditions such as Mogadishu, Somalia, the weight of the building is reduced So that, during building and construction activities, the use of manufactured sand is more suitable compared to the river sand concrete.

4.5.3. 2: Change in Compressive Under Chloride Attack

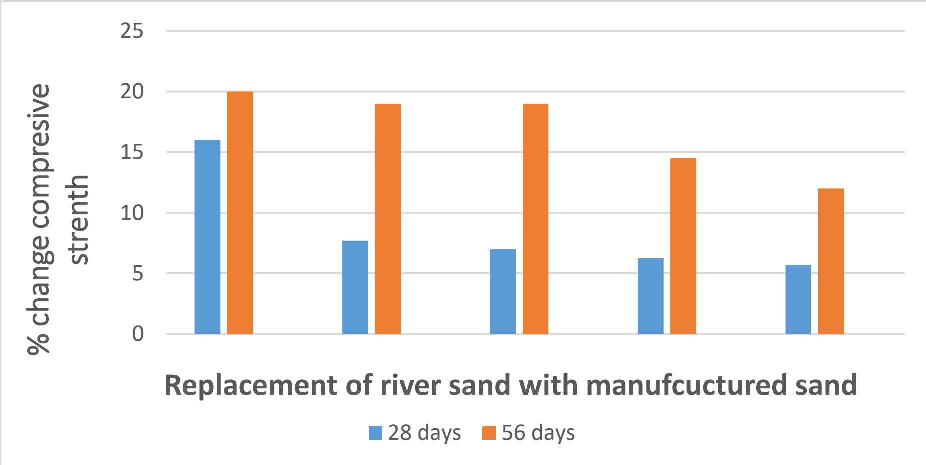

Figure 4.13: Loss of Compressive Strength Under Chloride Attack.

Figure 4.13 shows that the percentage loss of compressive strength concrete exposed to chloride attack for 28 days at 0%, 25%, 50%, 75% and 100% replacement level was 16.0%, 7.7%, 7%, 6.25%, and 5.7%, respectively.

There is a higher loss of compressive strength for concrete made of pure river sand and lower for concrete made of pure manufactured sand after exposure to NaCL. for 28 days. Further, the concrete was exposed to chloride attack for 56 days under varying levels of sand replacements. For concrete made of pure river sand (control 0%), the percentage loss of compressive strength under chloride attack was 20%. In the replacement of 25% 50%, of manufactured sand, the percentage loss of compressive strength fell to 19% in both the two tests. Percentage loss of compressive strength under-strength 75% and 100% manufactured sand fell to 14.5% and 12.5% respectively.

In summary, 100% manufactured sand has lesser loss of compressive strength compared to 100% of pure river sand after immersion sodium chloride solution for both 28 and 56 days. treatment period. It also found that compressive strength loss was reducing as the replacement level of manufactured sand increased for sodium chloride solution for 28 and 56 days of class 30 concrete meaning that manufactured sand is more resistant to durability than river sand. This is due to the rough surface and angular particles of the manufactured sand creating better interlocking between the aggregate and the hydrated cement paste. Another reason for the strength increment is that the manufactured sand has less impurities. The impurities present in the natural river sand interferes with the bond between the aggregate and the cement paste which give gap to chemicals and reduces the compressive strength of the concrete (Mamaru 2020).

The use of manufactured sand in concrete is recommended for regions that have chloride conditions as it enhances its durability thus ensuring a longer lifespan of an infrastructure project in such areas.

4.4.4 Water Absorption Test.

Water tries to fill voids between sand or soil particles. Permeability is a measure of how willing the sand or soil particles are to let water fill the spaces between them. Permeability is very important in civil engineering. Water absorption is an important parameter of concrete. If water absorption is high, then the water cement ratio is also high, and the consumption of cement is high. If the silt percentage is high in fine aggregate, then the water absorption is also high but in washed manufacture sand the silt percentage is in limit as per IS 383-: 1970. Water cement ratio depends on water absorption**.** Figure 4.19 shows the water absorption rates.

The water absorption rate for concrete ranged between 7.7% and 6.3%

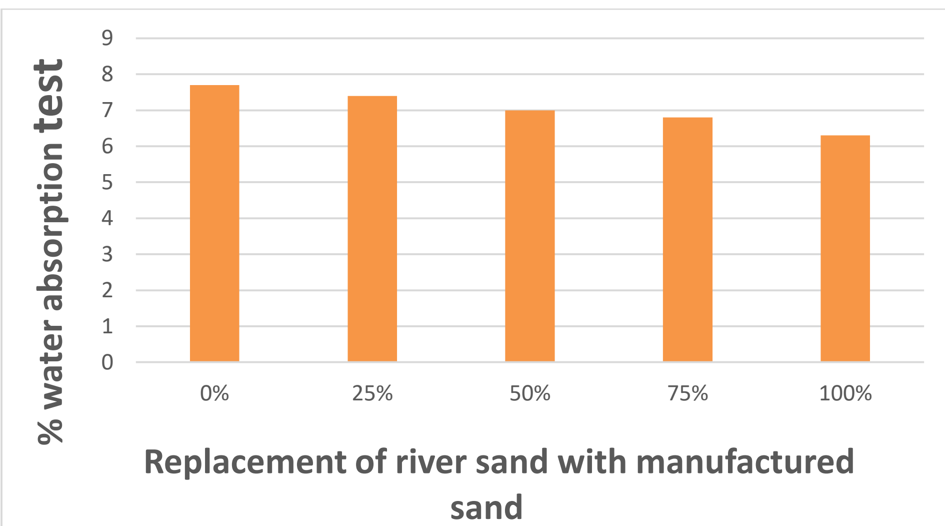

Figure 4.14: Water Absorption (%)

The water absorption rate for pure river sand is 7.7% For 75% river sand/25% manufactured sand, 50% river sand/50% manufactured sand, 25% river sand/75% manufactured sand and 100% pure manufactured sand, the water absorption rate was7.4%, 7.0%, 6.8%, and 6.3% respectively. The study by (Nadimalla et al., 2019), on durability properties of manufactured sand in concrete showed water absorption rate of 3.62%, 3.90% 3.23% for manufactured sand (M60) at 25 days, 50 days and 75 days period respectively. the result concurs with (Kavitha & Partheeban 2017), found that 75% of replacement of Manufactured Sand get low absorption of water compared to 25%, 50% of manufactured sand. Hence the manufactured sand is good for durability in terms of water absorption. This is due to the rough surface and angular particles of the manufactured sand creating better interlocking between the aggregate and the hydrated cement paste

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

This research fulfils the gap of influence of Mogadishu Manufactured sand on engineering properties of Concrete in Mogadishu- Somalia. The outcomes of the study made following conclusions;

- The properties of manufactured sand on the engineering properties of concrete depend on the parent rock of which manufactured sand refined from.
- Specific gravity and water absorption are higher for MMS than river sand.
- MMS shows higher fineness modulus compare to river sand
- The workability of concrete gradually decreases with increases of Mogadishu manufactured sand on the concrete.
- Replacing river sand with Mogadishu manufactured sand in concrete production increases the compressive and splitting tensile strength of concrete up to 25% replacement level.
- Compressive strength loss is greatest for concrete made of pure river sand and lowest for concrete made of Mogadishu manufactured sand after immersion in sulphuric acid, magnesium sulphate solution, sodium chloride solution for 28- and 56-days treatment periods. Hence manufactured sand concrete is more durable than conventional concrete.
- Weights of concrete are decreased in chemical solutions such as sulphuric acid, magnesium sulphate, and sodium chloride. Weight loss is greatest for concrete made of pure river sand and lowest for concrete made of 100% of Mogadishu manufactured sand.
- Manufactured sand concrete is less water absorption compared to the river sand.

5.2 Recommendation

5.2.1: Recommendation from This Work

It is therefore recommended that manufactured sand can replace river sand in construction activities of Mogadishu Somalia. In addition, even though the M- sand is already available in the market, there is a need to develop standards for usage of the M- sand.

5.2.2: Recommendation for Further Work

Further studies however need to be done on the long-term effects of exposure of concrete replaced with M-sand to chemicals such as sulphuric acid, sodium chloride and magnesium sulphate. In order to improve the workability of concrete produced using Mogadishu manufactured, more research is required to investigate the performance of Mogadishu manufactured sand with the addition of workability enhancer admixtures.

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APPENDIXES

APPENDIXES A: Laboratory Results of aggregate

Table A.1: Results of Sieve Analysis of River Sand.

Sieve size	Retained mass(gm)	Retained %	Cumulative % Retained	Passed percentage	Acceptance criteria	
					Min%	Max%
14	0	0.0	0	100.0	100	
10	1.4	0.2	0.2	99.8	100	
4.76	3.4	0.6	0.8	99.4	89	100
2.36	8	1.3	2.1	98.7	60	100
1.18	17	2.8	4.9	97.2	30	100
0.6	49	8.2	13.1	91.8	15	100
0.3	202	33.7	47	66.3	5	70
0.15	192	32.0	79	68.0	0	15
0.075	37	6.2	85.2	93.8	0	3
	24	4.0	--	96.0		

Table A.2: Results Sieve Analysis of Mogadishu Manufactured Sand.

Sieve size	Retained mass(gm)	Retained %	Cumulative % Retained	Passed percentage	Acceptance criteria	
					Min%	Max%
14	0	0.0	0	100.0	100	
10	0	0.0	0.0	100.0	100	
4.76	1	0.2	0.2	99.8	89	100
2.36	156	29.2	29.4	70.7	60	100
1.18	154	28.8	58.2	41.9	30	100
0.6	78	14.6	72.8	27.3	15	100
0.3	53	9.9	82.7	17.4	5	70
0.15	32	6.0	88.7	11.4	0	15
0.075	24	4.5	93	6.9	0	15
	29	5.4	--	1.5		

Table A.3: Results for Specific Gravity of Mogadishu Manufactured Sand.

No	Item	Symbol	Mass (gram)	Specific gravity
1	Weight of bottle	W1	55.6	2.62
2	Weight of bottle + rock sand	W2	70	
3	Weight of bottle + rock sand +water	W3	161.9	
4	Weight of bottle + Water	W4	153.2	

GS= $\frac{W2-W1}{(W4-W1)-(W3-W2)}$ $\frac{70.0-55.6}{(153.2-55.6)-(161.9-70.0)}$ =2.53

Table A.4: Results for Specific Gravity of River Sand.

No	Item	Symbol	Mass (gram)	Specific gravity
1	Weight of bottle	W1	56.4	2.53
2	Weight of bottle + rock sand	W2	72.6	
3	Weight of bottle + rock sand +water	W3	161.42	
4	Weight of bottle + Water	W4	151.4	

GS= $\frac{W2-W1}{(W4-W1)-(W3-W2)} = \frac{72.6-56.4}{(151.4-56.4)-(161.4-72.6)}$ = 2.62

Table A.5: Water Absorption of Mogadishu Manufactured Sand

No	List	Symbol	Mass (gram)	Water absorption (%)
1	Saturated surface dried rock sand weight:	W1	80.25	2.09
2	Dry weight of rock sand	W2	78.6	

Water absorption of Mogadishu manufactured sand= $\frac{weight\ of\ water}{weight\ of\ dry\ rock\ sand} \times 100$

$$= \frac{1.65}{78.60} \times 100 \quad = 2.09\%$$

Table A.6: Results in Water Absorption Of River Sand

No	List	Symbol	Mass (gram)	Water absorption (%)
1	Saturated surface dried rock sand weight:	W1	65.4	1.7
2	Dry weight of rock sand	W2	64.3	

$$\text{water absoption} = \frac{\text{weight of water}}{\text{weight of dry rock sand}} \times 100$$

$$= \frac{1.1}{64.30} \times 100 \quad = \quad 1.7\%$$

Table A.7: Results of Sieve Analysis of Coarse Aggregate.

Sieve size (mm)	Retained mass (gm)	% Retained (%)	Cumulative passed percentage (%)	Acceptance Criteria	
				Min(%)	Max (%)
37.5	0	**0.0**	**100.0**	**90**	**100**
20	730	**30.0**	**70.0**	**35**	**70**
14	952	**39.2**	**30.8**	**25**	**55**
10	496	**20.4**	**10.4**	**10**	**40**
5	250	**10.3**	**0.1**	**0**	**5**
2.36	2	**0.1**			
	2430				

Table A.8: Results in Specific Gravity and Water Absorption of Coarse Aggregate

Item	**Specific gravity**
Specific gravity on an oven- dried basis = $\frac{D}{A-(B-C)} = \frac{531.9}{544.5-(1480.9-1148.5)} = 2.51$	2.51
Relative density on a saturated and surface dried basis $= \frac{A}{A-(B-C)} = \frac{544.5}{544.5-(1480.9-1148.5)} = 2.57$	2.57
Apparent relative density $= \frac{D}{D-(B-C)} = \frac{531.9}{531.9-(1480.9-1148.5)} = 2.67$	2.67
Water absorption of course aggregate percent mass of aggregate $= \frac{100(A-D)}{D} = \frac{100(544.5-531.9)}{531.9} =$ 2.3%	2.3%

Table A.9: Slump and Compaction Values Versus Manufactured Sand

Replacements level	**Slump values**	**Compaction factor test**
0%	46	0.87
25%	41	0.86
50%	35	0.84
75%	31	0.81
100%	26	0.80

APPENDIXES B: Laboratory Results of compressive and splitting tensile strength of C30 concrete.

B. 1: Results of compressive strength of C30 for both 28 and 56 days

Table B.1: Results of Compressive Strength of C30 Concrete for Both 28 and 56 Days

Replacement level	Cube size	Weight of samples		Compressive strength (Mpa)	
		28 days	56days	28 days	56days
0%	150x150x150mm	8.07	8.05	32	36.43
25%	150x150x150mm	8.07	8	34.8	38.24
50%	150x150x150mm	8	8	28.3	33.4
75%	150x150x150mm	8	8	26	30.23
100%	150x150x150mm	8	8	25.4	28.8

B. 2: Results of Splitting tensile strength of C30 concrete for both 28 and 56 days.

Table B.2: Results of Splitting Tensile Strength of C30 Concrete for Both 28 And 56 Days

Replacement level	Cylinder size	Compressive strength (Mpa).	
		28 days	56days
0%	300 x150mm	3	3.5
25%	300 x150mm	3.4	4
50%	300 x150mm	2.6	3.3
75%	300 x150mm	2.3	3
100%	300 x150mm	1.7	2.2

APPENDIXES C: Laboratory Results of durability Test for C30 concrete.

C.1: Change in compressive strength under acid attack.

Table C.1: Change in Compressive Strength Under Acid Attack.

Replacement level	Compressive strength (Mpa) before immersing **Sulphuric acid (H_2SO_4)**		Compressive strength after immersing Mpa) **Sulphuric acid (H_2SO_4)**		Loss of compressive strength under acid attack (Mpa)	
	28 days	56days	28 days	56days	28 days	56days
0%	32	36.43	25.92	20	19%	45%
25%	34.8	38.24	28.88	25.5	17%	33.3%
50%	28.3	33.4	23.5	23.0	17%	31%
75%	26	30.23	22	21.6	15.4%	28.6%
100%	25.4	28.8	22.4	21	12%	27%

C.2: Change in compressive strength under sulphate attack.

Table C.2: Change in Compressive Strength Under Sulphate Attack

Replacement level	Compressive strength (Mpa) before immersing Magnesium sulphate solution (MgSO4))		Compressive strength after immersing Mpa) magnesium sulphate solution (MgSO4)		Loss of compressive strength under sulphate attack (Mpa)	
	28 days	56days	28 days	56days	28 days	56days
0%	32	36.43	28	28.05	12.5%	23%
25%	34.8	38.24	30.8	29.5	11.5%	23%
50%	28.3	33.4	26.3	25.72	7.15%	23%
75%	26	30.23	24.96	24.5	4%	19%
100%	25.4	28.8	24.4	23.33	4%	19%

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C.3: Change in compressive strength under chloride attack.

Table C.3: Change in Compressive Strength Under Chloride Attack.

Replacement level	Compressive strength (Mpa) before immersing **sodium chloride (NaCL)**		Compressive strength after immersing Mpa) **sodium chloride (NaCL))**		Loss of compressive strength **under chloride attack** (Mpa)	
	28 days	56days	28 days	56days	28 days	56days
0%	32	36.43	26.88	29.1	16%	20
25%	34.8	38.24	32.12	31	7.7%	19
50%	28.3	33.4	26.3	27.05	7	19
75%	26	30.23	24.4	25.85	6.25%	14.5
100%	25.4	28.8	23.95	25.34	5.7%	12

C.4: Change in mass under sulfuric acid

Table C.4: Change in Mass Under Sulfuric Acid.

Replacement level	Weight of the samples (kg) before immersing **Sulphuric acid (H_2SO_4)**		Weight of the samples after immersing (kg) **Sulphuric acid (H_2SO_4)**		Loss of weight under acid attack (kg)	
	28 days	56days	28 days	56days	28 days	56days
0%	8.07	8.0	7.7	7.56	4.9%	5.5%
25%	8.07	8.0	7.77	7.7	2.8%	3.75%
50%	8.0	8.0	7.8	7.7	2.5%	3.7%
75%	8.0	8.0	7.8	7.7	2.5%	3.7%
100%	8.0	8.0	7.87	7.75	2.4%	3.12%

C.5: Change in mass under sulphate attack

Table C.5: Change in Mass Under Sulphate Attack

Replacement level	Weight of the samples (kg) before immersing **Magnesium sulphate solution ($MgSO_4$))**		Weight of the samples after immersing (kg) **Magnesium sulphate solution ($MgSO_4$))**		Loss of weight **sulphate attack** (kg)	
	28 days	56days	28 days	56days	28 days	56days
0%	8.07	8.0	7.8	7.56	3%	5.48%
25%	8.07	8.0	7.87	7.7	2.5%	3.7%
50%	8.0	8.0	7.8	7.7	2.5%	3.7%
75%	8.0	8.0	7.9	7.75	1.25%	3.12%
100%	8.0	8.0	7.9	7.75	1.25%	3.12%

C.6: Change in mass under chloride attack.

Table C.6: Change in Mass Under Chloride Attack.

Replacement level	Weight of the samples (kg) before immersing **sodium chloride (NaCL)**		Weight of the samples after immersing (kg) **sodium chloride (NaCL)**		Loss of weight **under chloride attack**	
	28 days	56days	28 days	56days	28 days	56days
0%	8.07	8.0	7.87	7.56	2.5%	5.48%
25%	8.07	8.0	7.87	7.7	2.47%	3.7%
50%	8.0	8.0	7.9	7.7	1.25%	3.7%
75%	8.0	8.0	7.9	7.75	1.25%	3.12%
100%	8.0	8.0	7.9	7.75	1.25%	3.12%

APPENDIXES D: Material Breakdown

D.1: Material used for compressive strength test for both 28 and 56 days.

Table D.1: Material Used For Compressive Strength Test for Both 28 And 56 Days.

Replacement level	Test	Total sample	Cement (Kg)	Coarse aggregate (Kg)	M. sand (Kg)	R. sand (Kg)	Water $(litres)$
0	Compressive strength	6	12.15	24.3	0	12.15	6
25%	Compressive strength	6	12.15	24.3	3	9.1	6
50%	Compressive strength	6	12.15	24.3	6.0	6.0	6
75%	Compressive strength	6	12.15	24.3	9.1	3	6
100 %	Compressive strength	6	12.15	24.3	12.15	0	6
		30 samples	60.75	121.5	30.25	30.25	30

D.3: Material used for Acid attack test for both 28 and 56 days

Table D.3: Material Used For Sulphate Attack Test for Both 28 And 56 Days.

Replacement level	Test	Total samples	Cement (Kg)	Corse aggregate (Kg)	Sand (Kg)	R. sand (Kg)	Water ($litres$)	Sulfuric acid solution (liters)
0	Acid attack test	6	12.15	24.3	0	12.15	6	1.7
25%	Acid attack test	6	12.15	24.3	3	9.1	6	1.7
50%	Acid attack test	6	12.15	24.3	6.0	6.0	6	1.7
75%	Acid attack test	6	12.15	24.3	9.1	3	6	1.7
100 %	Acid attack test	6	12.15	24.3	12.15	0	6	1.7
		30 samples	60.75kg	121.5	30.25	30.25	30	8.5

D.4:

Material used for Sulphate Attack test for both 28 and 56 days

Table D.4: Material Used for Sulphate Attack Test for Both 28 And 56 Days.

Replacement level	Test	Total samples	Cement (Kg)	Coarse aggregate (Kg)	M.Sand (Kg)	R.sand (Kg)	Water $(litres)$	Magnesium Sulphate Powder (Kg)
0	Sulphate Attack test	6	12.15	24.3	0	12.15	6	1.7
25%	Sulphate Attack test	6	12.15	24.3	3	9.1	6	1.7
50%	Sulphate Attack test	6	12.15	24.3	6.0	6.0	6	1.7
75%	Sulphate Attack test	6	12.15	24.3	9.1	3	6	1.7
100 %	Sulphate Attack test	6	12.15	24.3	12.15	0	6	1.7
		30 samples	60.75kg	121.5	30.25	30.25	30	8.5kg

D.5: Material used for chloride attack test for both 28 and 56 days

Table D.5: Material Used for Chloride Attack Test for Both 28 And 56 Days.

Replacement level	Test	Total samples	Cement (Kg)	Course Aggregate (Kg)	M.S (Kg)	R.s (Kg)	Water (litres)	sodium chloride Powder (Kg)
0	Chloride attack test	6	12.15	24.3	0	12.15	6	1.0
25%	Chloride attack test	6	12.15	24.3	3	9.1	6	1.0
50%	Chloride attack test	6	12.15	24.3	6.0	6.0	6	1.0
75%	Chloride attack test	6	12.15	24.3	9.1	3	6	1.0
100 %	Chloride attack test	6	12.15	24.3	12.15	0	6	1.0

D.6: Material used for water absorption test for both 28 days.

Table D.6: Material Used for Water Absorption Test for Both 28 Days.

Replacement level	Test	T.S	Cement (Kg)	C.Ag (Kg)	M.S (Kg)	R.s (Kg)	Water $(litres)$
0	water absorption test	3	6.075	12.15	0	6.075	3
25%	water absorption test	3	6.075	12.15	1.5	4.55	3
50%	water absorption test	3	6.075	12.15	3	3	3
75%	water absorption test	3	6.075	12.15	4.55	1.55	3
100 %	water absorption test	3	6.075	12.15	6.075	0	3
		15 samples	30.4	60.75	15.125	15.125	15

D.7: Material Used for Crushing the Limestone Rock.

Figure D. 7: Material Used for Crushing the Limestone Rock

D.8: Limestone Rock

Figure D.8: Limestone Rock

D.9: Crushed Course Aggregate From Limestone Rock

Figure D.9: Crushed Course Aggregate From Limestone Rock

D.10: Mogadishu Manufactured Sand.

Figure D.10: Mogadishu Manufactured Sand.