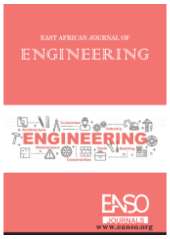

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Original Article

Experimental Study on the Influence of Mogadishu Manufactured Sand on the Engineering Properties of Concrete

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Mogadishu Manufactured Sand (MMS), Workability, Compressive, Splitting Tensile Strength, Durability.

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 in incomplete or complete replacement for natural sand. 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 up to 25% replacement and reduces as replacement increases. This was attributed to the presence of micro fines in the Mogadishu manufactured sand generated from limestone rock. When exposed to sulphuric acid, magnesium sulphate, and sodium chloride, the

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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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INTRODUCTION

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 sand. The scarcity or insufficient supply of excellent quality sand has resulted in a significant price increase, which has an impact on building costs [1]. This motivated academics and experts in the construction industry to search for a suitable material that is acceptable to the environment and can be effectively used in construction practices as an alternative material while reducing production costs [2]. 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 [3].

In this regard, river sand is the major natural deposit of fine aggregates in Somalia. Nonetheless, the extensive construction activities in Mogadishu, Somalia is resulting to insufficiency and cost increase of the natural sand in the country. One possible alternative product that can be utilized as a substitute for natural sand is the use of manufactured sand. The engineering properties of manufactured sand on concrete are determined by a number of factors including the rock from which the manufactured sand is crushed, the manufacturing process, and dust particles of the manufactured sand [11]. There have been studies conducted in the past that are related to the current study. They are discussed below in order to provide contextual and conceptual gaps.

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As a study conducted by [4] in India determined the impact of manufactured sand as partially and fully replacement of fine aggregate in concrete. 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 the corporation of 100% and 55% of M- sand can be advised to use as fine aggregate to enhance the strength of Concrete. In addition, [5] studied the effect of manufactured sand as a replacement for fine aggregates in concrete in Sri Lanka. The results showed that manufactured sand has 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. [6] determined the effect of partial replacement of natural sand with manufactured sand on the strength of concrete in Accra, Ghana. The findings revealed that 50% of manufactured sand obtained the maximum compressive strength. 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. In addition, a study conducted by [7] on the effect of manufactured sand in concrete in Ethiopia. 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%. [8], conducted a study on partial replacement of natural river sand with crushed rock sand in concrete production. The results 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).

Those studies [3,4,5,6,7,8] 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 the engineering properties of concrete. However, these studies did not define the parent rock which the manufactured sand was derived from. While the engineering properties of manufactured sand depend on the source of its raw material. 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.

MATERIALS AND METHODS

The basic aggregate, workability, compressive strength, splitting tensile strength and durability tests of concrete with MMS were done. For the basic aggregate tests; sieve analysis for fine aggregate, specific gravity and water absorption was conducted. For workability, the slump and compaction factor tests were done. For strength, the compressive and splitting tensile strength at 28 days and 56 days were conducted. Finally, the sulphate attack, chloride attack, acid resistance tests were done from a durability point of view at 28 and 56 days.

Both river and manufactured sand were obtained from the local market of Mogadishu, Somalia. Coarse aggregate is crushed limestone. Cement was ordinary Portland cement of class 42.5. Magnesium

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sulphate solution ($MgSO_4$), at 5% concentration, Sulfuric acid solution (H_2SO_4) at 5% concentration and sodium chloride (NaCl) at 3% concentration was obtained from Nairobi's Industrial Area.

Physical Properties of Concrete

Table 1: presents the tests conducted with the standard test methods

N.O	Tests	Standard
1	Sieve Analysis	BS 882 – 1992
2	Specific Gravity	BS EN 1097 - 6: 200
3	Water Absorption	BS EN 1097 - 6: 200

Table 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% MMS	27	3375000	0.091125	219	55	55	110
25% MMS	27	3375000	0.091125	219	55	55	110
50% MMS	27	3375000	0.091125	219	55	55	110
75% MMS	27	3375000	0.091125	219	55	55	110
100% MMS	27	3375000	0.091125	219	55	55	110

Study of Concrete Properties

Workability, compressive strength, split tensile strength, and durability tests were done in order to investigate the properties of concrete with and without Mogadishu-manufactured sand. A constant water/cement ratio of 0.47 was used. For workability slump test was done according to BS EN 12350-2. For a sample size of 150 x 150 x 150 mm cubic for different replacements. Compaction factor test was done by dividing mass of partially compacted concrete with that of fully compacted concrete. Compressive strength test was to BS EN 12390-3 with a similar sample size of slump test. In addition, splitting tensile strength test was done to BS EN 12390-6. 300 x 150 mm cylinder moulds were used.

Durability of Concrete

Sulphate, Acid and Chloride Attack Resistance Tests

The specimens of size 150 x 150 x 150 mm were casted and cured in water for 28 days. 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 ($MgSO_4$), 5 % sulfuric acid solution ($H2SO_4$) and 3% sodium chloride (Na Cl) for the next 28 and 56 days of sulphate, acid, and chloride exposure. Then the immersed specimens were taken out from the tank of magnesium sulphate, sulfuric acid solution and sodium chloride after 28 and 56 days. The samples are weighed and tested for compressive strength and compared with

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the specimens which were not exposed to sulphate, acid, and chloride attack. Finally, the percentage of weight and compressive strength loss due to sulphate, acid and chloride attack were then calculated using this formula:

$$\text{Loss (\%) of weight or compressive strength} = \left(\frac{\text{initial}-\text{final}}{\text{initial}}\right) \times 100$$

The tests were carried out in accordance to ASTM C 1012-18b, ASTM C 1012-20, ASTM C1202-19, respectively.

RESULTS AND DISCUSSIONS

Physical Properties of Fine Aggregate

Grading for river sand and manufactured sand

Figure 1: Particle size distribution of river sand

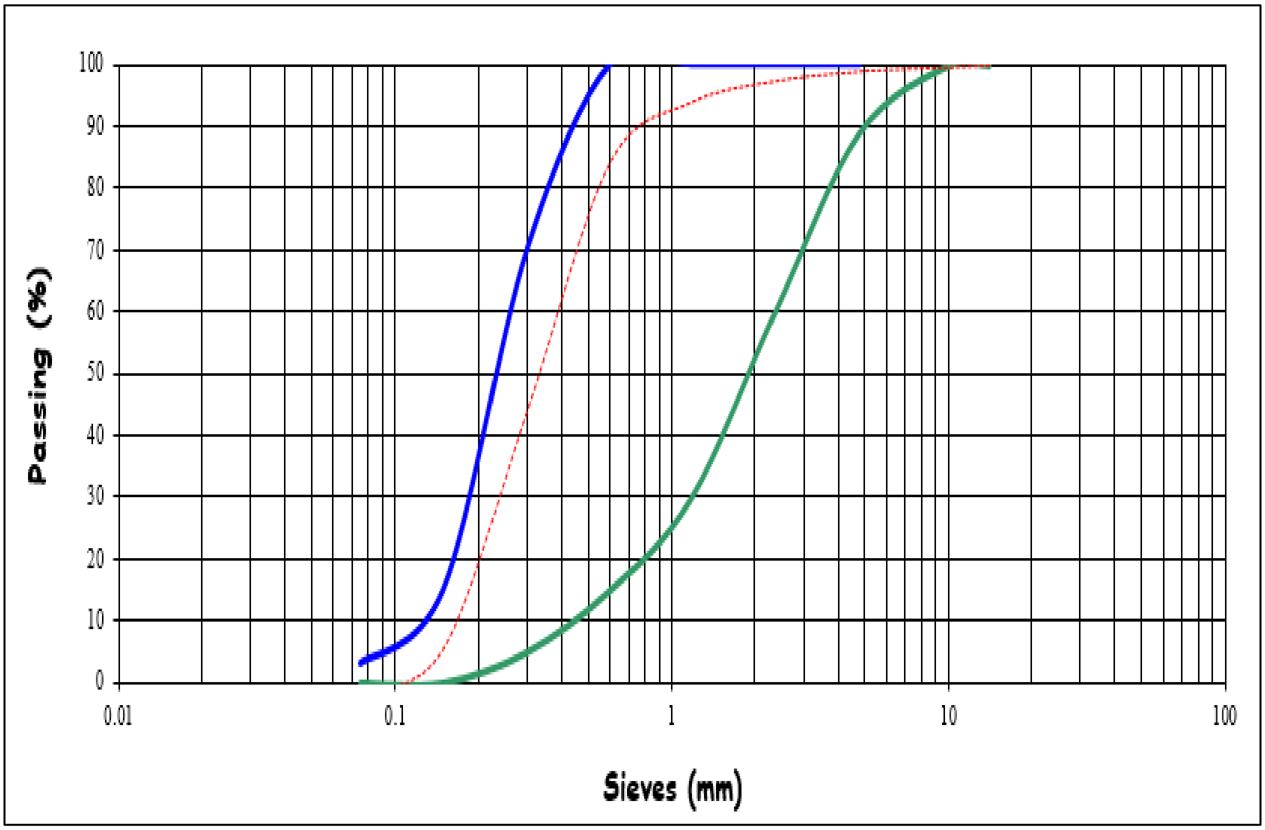

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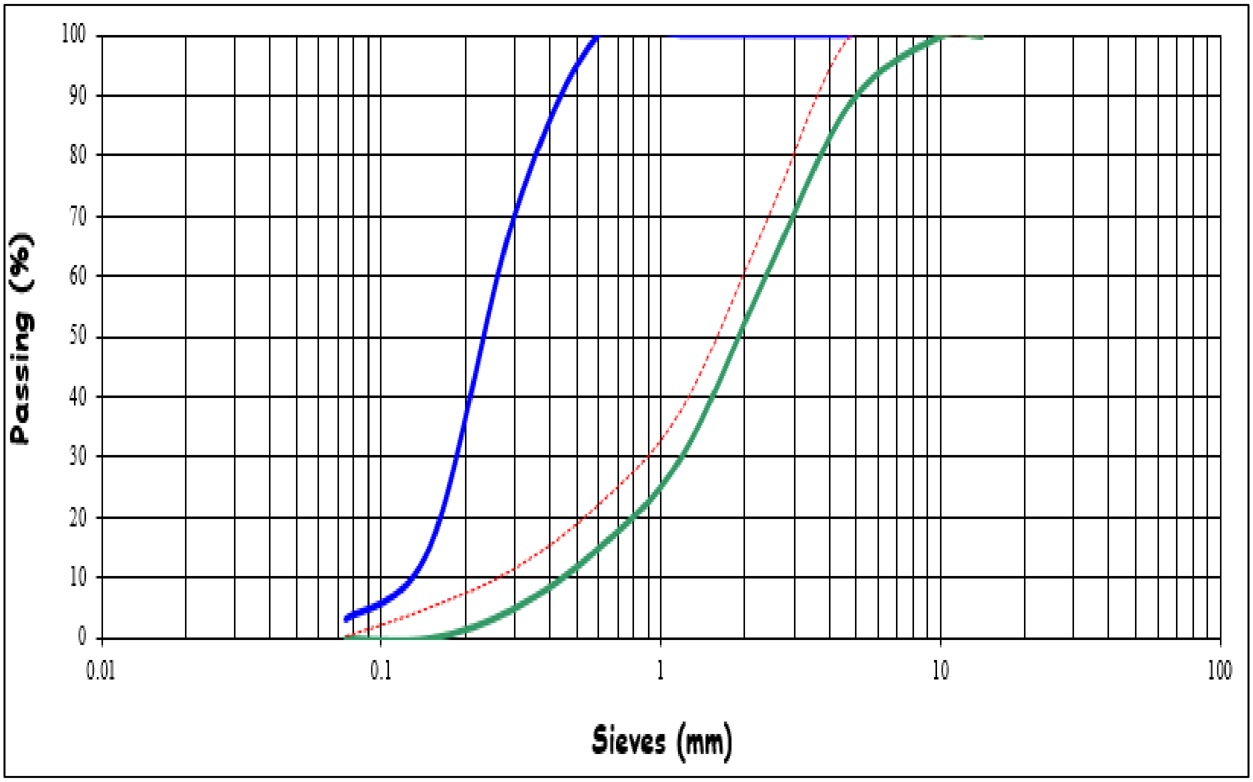
Figure 2: Particle size distribution of MMS



In terms of grading and particle size characteristics, MMS and natural sand are slightly similar and both sands fitted into zone 2 grading of B.S 882- 1992 as shown in *Figures 1* and *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. The higher value of F.M increases the compressive strength, tensile strength, and durability of concrete [9]. In totality, therefore, it is important to consider grading as physical property in studying the influence of MMS on the engineering properties of concrete.

Specific Gravity, and Water Absorption of *MMS* and River Sand

The specific gravity of ***MMS*** was 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 [10]. The higher the specific gravity, the higher the strength and durability. The findings also showed that replacing manufactured sand with natural sand can increase the compressive strength, tensile strength, and also durability of concrete.

The water absorption of MMS was 2.09% while that of river sand was 1.7%. The result also suggests that MMS has an 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.

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Properties of MMS on Concrete

Workability of Concrete

To assess the influence of MMS on concrete workability, slump and compaction factor tests were determined. The results of these tests are presented in ***Table 3*.**

Table 3: Slump and Compaction Factor

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

Table 3 shows 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 [5]. However, due to its preparation process, defects in manufactured sand include irregular particle shape, inconsistent gradation, and a high stone powder content. When compared to natural river sand, which has a smooth surface texture and rounded shape, aggregate that is more angular will require more water [11], [12], [13]). Due to that, MMS shows poor workability in the concrete compared to the river sand. As it is seen in Table 3 when the percentage of MMS 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.

A study on the effects of manufactured sand on compressive strength and workability of concrete [14] established that at 100% natural sand (0% manufactured sand), the slump value was 125 mm, at 50% natural sand + 50%, manufactured sand slump values decreased to 100 mm 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. Mane et al. (2017) also noted that at 60%, 80%, and 100%, the slump and compacting factor values further declined to 85 mm, 80 mm, 75 mm and 0.885, 0.857, 0.840 respectively [15]. The results imply that any percentage replacement of natural sand to manufactured sand will reduce the workability.

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.

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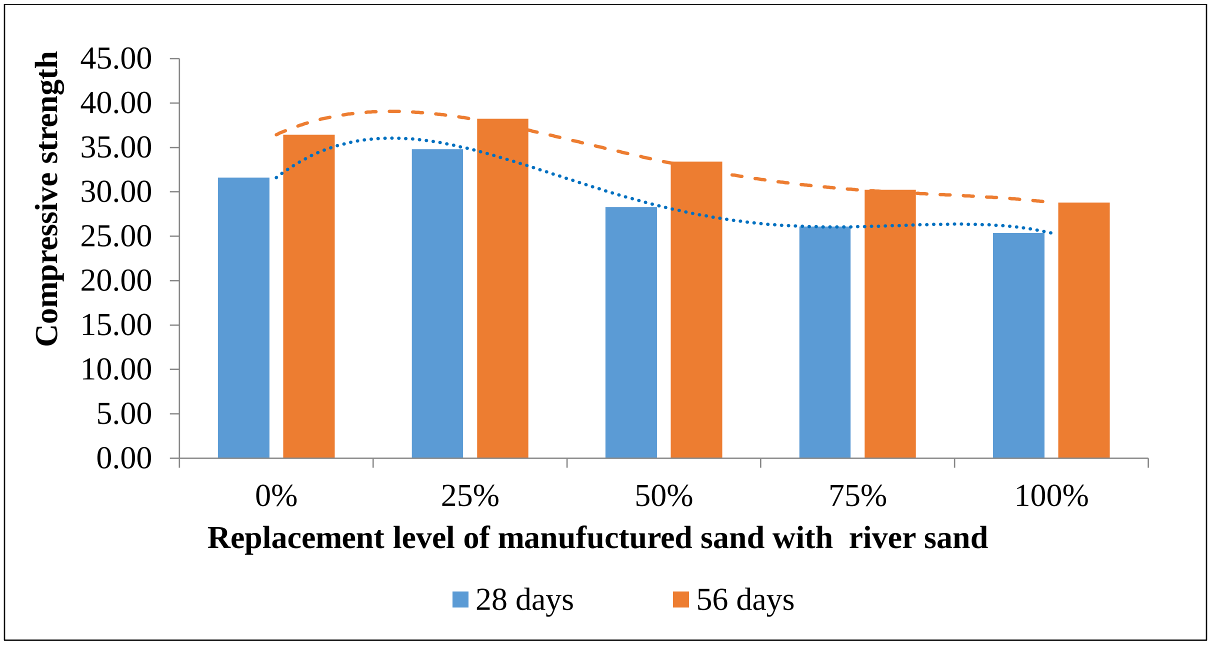
Compressive Strength of Concrete.

Figure 3: 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 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 28.3 MPa, 26 MPa, 25.4 MPa for 50%, 75%, and 100% replacement levels respectively. At 56 days of curing period of concrete, the compressive strength of pure river sand was 36.43 MPa. The compressive strength increased to 38.24 MPa at 25% replacement level of MM. 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 33.4 MPa, 30.23 MPa, 28.776 MPa respectively.

The result shows a significant improvement in the compressive strength of concrete up to 25% replacement with MM-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 [12, 16]. Furthermore, the compressive strength of concrete is reduced as the percentage of MMS 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 MMS 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 MMS.

The results concur with [4] 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

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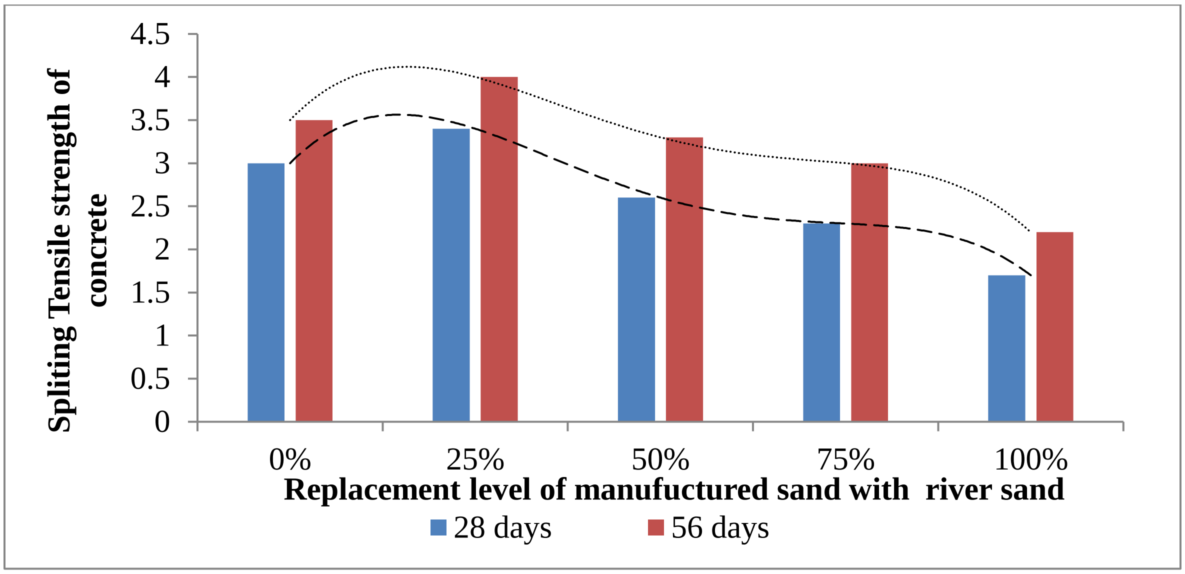
river sand was replaced by the manufactured sand. Compressive strengths of samples changed between 19.3 MPa and 21.0 MPa for 7 days curing time. The highest compressive strength, 21.0 MPa was observed when MS was 100% in concrete and it was 8.8% higher than when natural sand was 100% in concrete. The research also found that in 28 days 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.

The implication from the study findings is that 25% replacement of MMS with river sand increases the compressive strength of concrete. Hence, partially replacements are recommended in construction activities.

Splitting Tensile Strength of Concrete

Figure 4: Splitting Tensile strength of concrete at 28 days and 56 days.



Results showed that the tensile strength of concrete made of pure river sand (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. Thereafter, 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 3.5 MPa at 56-day period. The tensile strength rose to 4 MPa 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.

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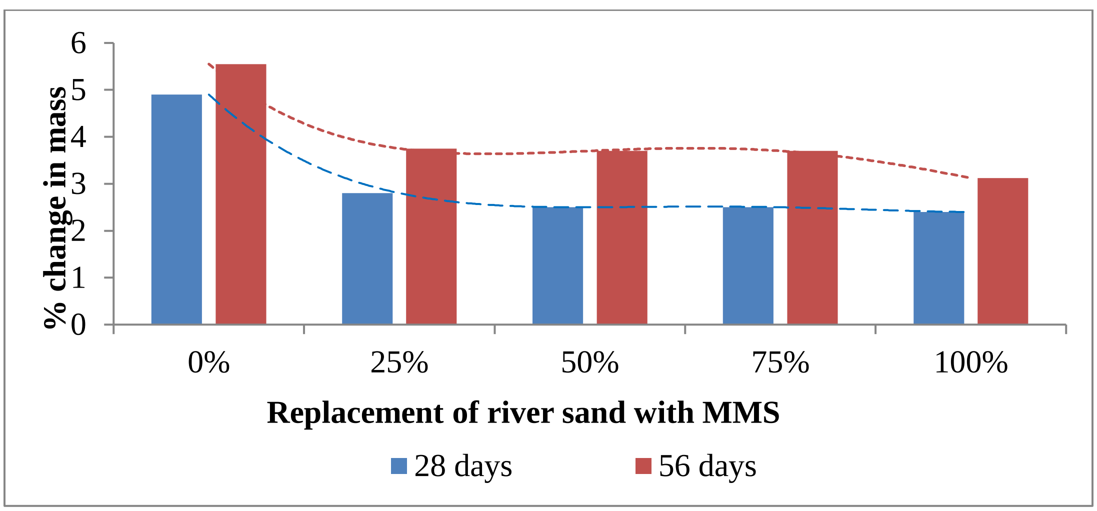
Durability of Concrete

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 [17]. 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 [14]. 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, sulphate, 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 5% Sulphuric acid (H_2SO_4), 5% magnesium sulphate ($MgSO4$) 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.

Change in Mass

Test on variations in the mass of concrete after soaking the specimen in the sulphuric acid solution, magnesium sulphate solution, sodium chloride 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 was as shown in the figures below.

Figure 5: Percentage change in mass under sulfuric acid



Mass change for pure river sand, 25%, 50%, 75%, and 100% of MMS under sulfuric acid treatment was 4.94%, 2.8%, 2.5%, 2.5%, and 2.4% respectively at a 28-day exposure period as shown in *Figure 5.* Also, the figure is shown in the 56-day treatment period, the percentage loss of mass for pure river sand (0%), 25%. 50%, 75%, and 100% of

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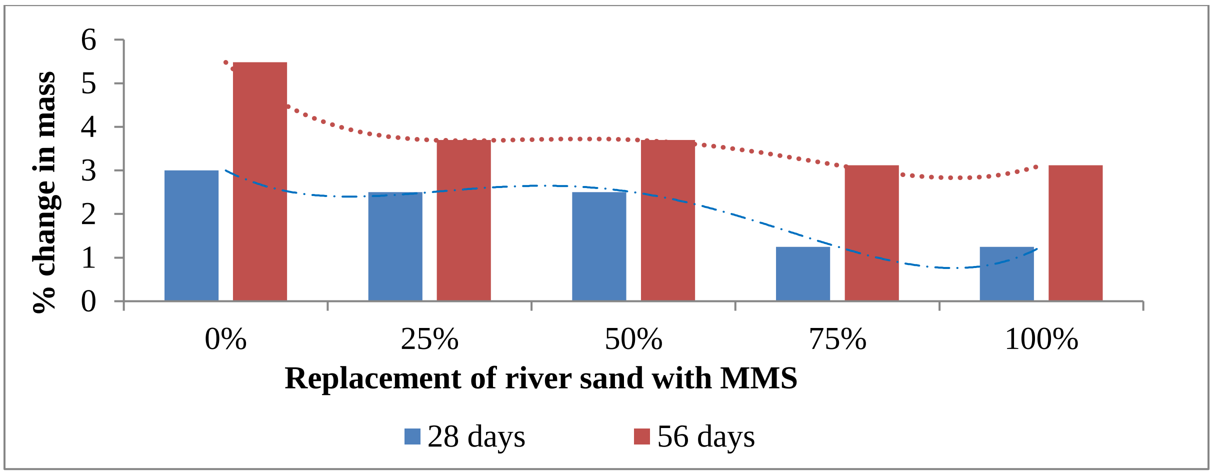
MMS was 5.55%. 3.75%, 3.7%, 3,7%, and 3.12 respectively.

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 manufactured sand has tighter particle packing and is silt-free or has fewer impurities than river sand [16]. Additionally, it is evident that concrete loses weight when exposed to chemical solutions like sulphuric acid since concrete is an alkaline material and many of its constituent parts react with the acid rather easily. As a result of these interactions between sulfuric acid and cement, the concrete microstructure deteriorates, cement paste is lost, and the size of the specimen reduces [3].

Figure 6: Percentage loss of mass under sulphate attack.



As presented in *Figure 6*, the percentage loss of mass under sulphate attack ($MgSO_4$) was 3%, 2.5%, 2.5%, 1.25%, 1.25% at the 28-day treatment period in the replacement level of 0%, 25%, 50%, 75%, 100% of MMS respectively. In the 56-day treatment period, the percentage loss of mass for pure river sand (0%), 25%. 50%, 75%. 100% of MMS was 5.48%, 3.7%, 3.7%, 3.12%, 3.12% respectively. 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 sulphate ($MgSO_4$) 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 [18]. In terms of sand, manufactured sand is more resistant to the sulphate attack than 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.

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Figure 7: Percentage loss of mass under chloride attack.

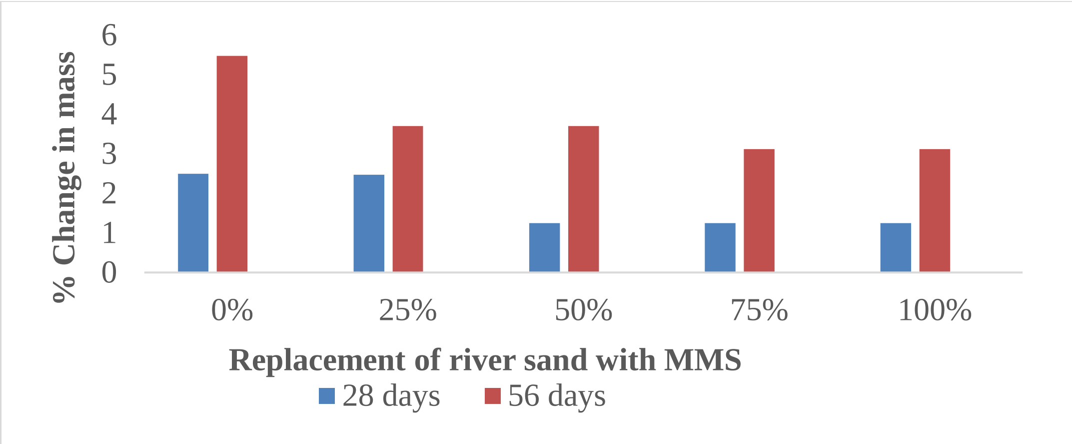

Figure 7 shows; that the percentage loss of mass under chloride attack (NaCL) was 2.5 for pure river sand and the percentage mass loss fell to 2.47%, for 25% of MMS during the 28-day treatment period. For replacement levels of 50%, 75%, and 100% of MMS, the percentage mass loss due to chloride attack was 1.25% in all the three cases after the elapse of the 28-day period. In the 56-day treatment period of NaCl, the percentage loss of mass for pure river sand (0%), 25%, 50%, 75%, 100% was 5.48%, 3.7%, 3.7%, 3.12%, 3.12% respectively. 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.

The implication of the study is that Sulphuric acid, magnesium sulphate, and sodium chloride attacks and reduces the weights of the concrete produced using both natural and manufactured sand. However, the effect of the chemicals 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, sulphate and chloride including Mogadishu – Somalia compared to river sand concrete so as to maintain the structural integrity of a building.

Change in Compressive Strength

Test on variations in compressive strength after soaking the specimen in the sulphuric acid solution, magnesium sulphate solution, sodium chloride solution for 28 and 56 days as a percentage of the compressive strength before and after exposure were done. The change in compressive strength was shown in the figures below:

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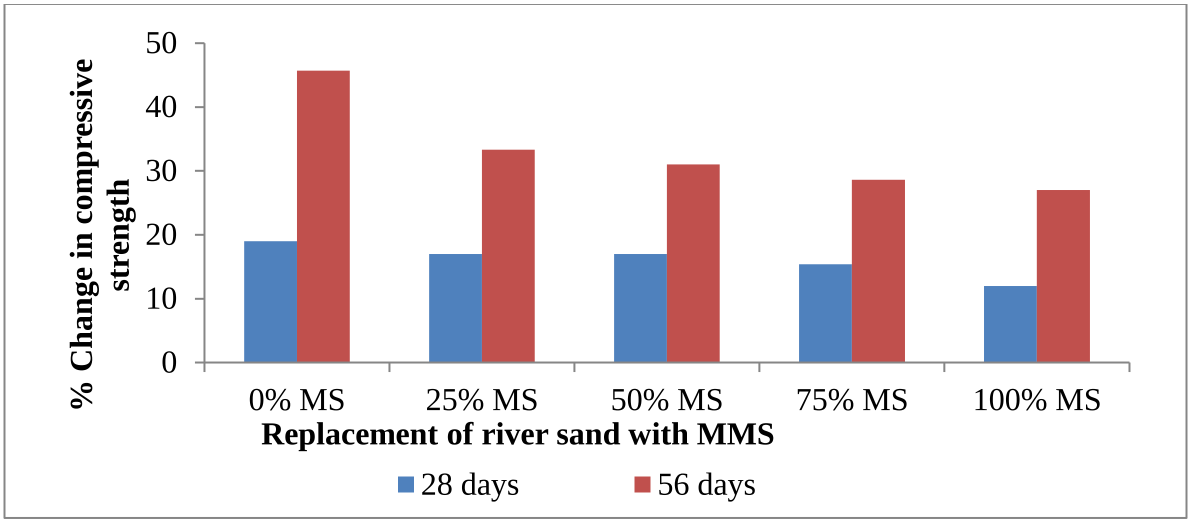
Figure 8: Loss of compressive strength under acid attack



As shown in *Figure 8*, 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. *Figure 7* 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 these 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-day treatment periods. Compressive strength losses are shown to be reduc ing as manufactured sand replacement rises. Comp ared to 100 % river sand, 100% manufactured sand loses less compressive strength. 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 [19]. 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.

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Figure 9: Loss of compressive strength under sulphate attack.

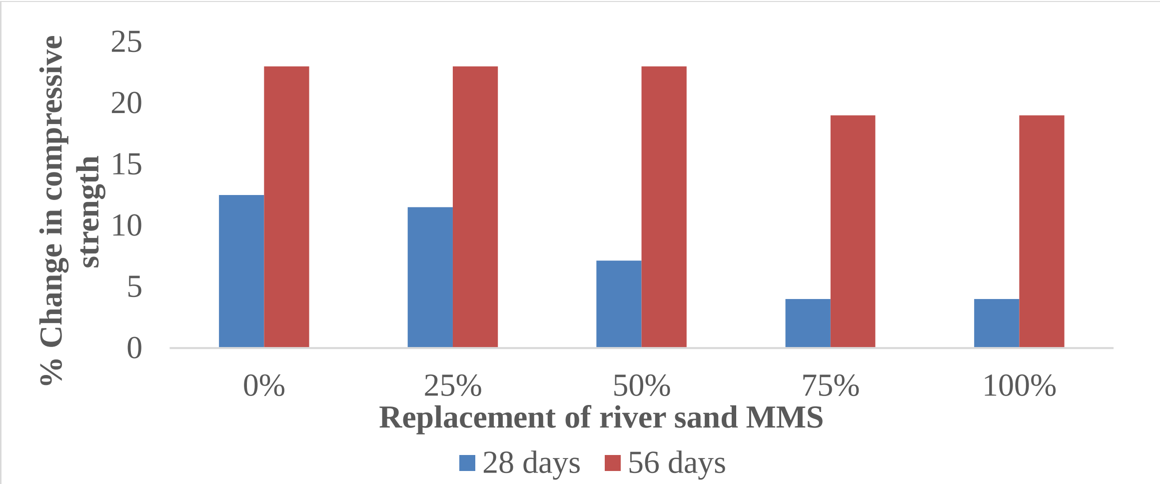

Figure 9 presented that the percentage loss of compressive strength concrete exposed to magnesium sulphate for 28 days at 0%, 25%, 50%, 75% and 100% replacement level was 12.5%, 11.5%, 7.15%, 4% and 4% respectively. There is a higher loss of compressive strength for concrete made of pure river sand and lower for concrete made of 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% when exposed to $MgSO_4$ for 56 days. For concrete made of 25% river sand/75% manufactured sand and pure manufactured sand exposed to $MgSO_4$ for 56 days, the percentage loss of compressive strength is 19% in both experiments as presented in *Figure 8*. As mentioned earlier the percentage loss of compressive strength is lesser the 100% manufactured sand and highest for 0% for pure river sand.

Sulphate attack is one the most aggressive and the most complex durability problems associated with concrete. The sulphate attack of concrete leads to expansion, cracking, and deterioration of many civil engineering structures exposed to sulphate environment such as piers, bridges, foundations, and concrete pipes. When the attacking solution contains magnesium ion, such as in magnesium sulphate (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. However, a study by [20] indicated that magnesium sulphates caused significant deterioration in the specimens and significant loss in compressive strength. [21], also found that solution with MgSO4 had relatively lower compressive strength.

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Figure 10: Loss of compressive strength under chloride attack.

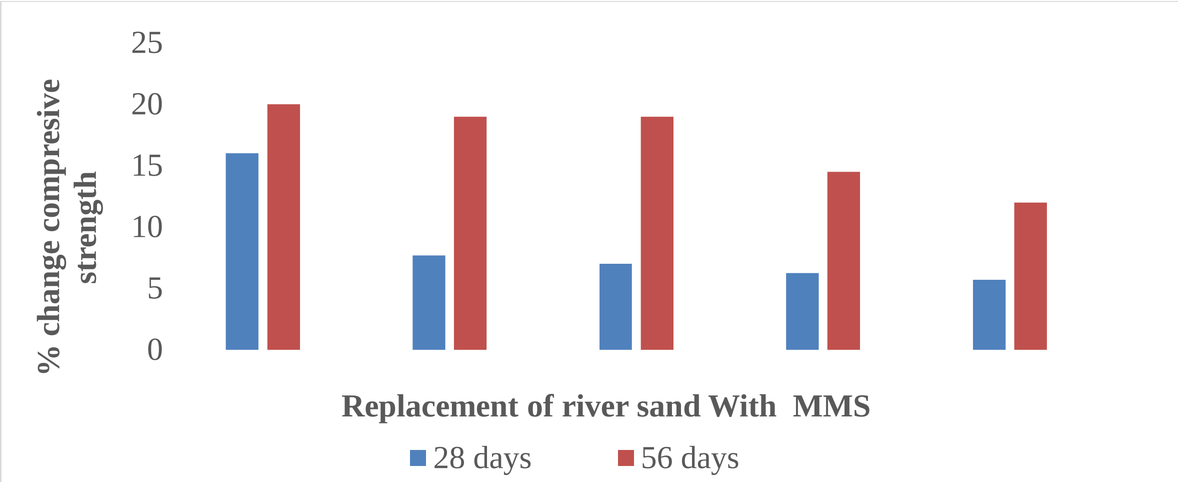

Figure 10 shows that the percentage loss of compressive strength concrete exposed to chloride attack for 28 days at 0%, 25%, 50%, 75%, and 100% replacement level was 16.0%, 7.7%, 7%, 6.25%, and 5.7%, respectively. Further, the concrete was exposed to chloride attack for 56 days under varying levels of 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 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 [16].

Therefore, it can be concluded that acid, sulphate, and chloride 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.

CONCLUSION

This research fulfils the gap of influence of MMS 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.

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- MMS shows higher fineness modulus compare to river sand
- The workability of concrete gradually decreases with increases of MMS on the concrete.
- Replacing river sand with MMS 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 MMS after immersion in sulphuric acid, magnesium sulphate solution, and 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 MMS

Recommendations

Recommendation from this Work

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

Recommendation for Further Studies

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

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