

PROPERTIES OF CONCRETE MADE WITH MANUFACTURED SAND (M- SAND) AS FINE AGGREGATE REPLACEMENT: A REVIEW

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ABSTRACT

Concrete is a composite material constitute of cement, aggregate, and water. About 75 % of the concrete mixture composed of aggregate. Based on the literature It is estimated that the world utilization of sand is more than 40 billion tons per annum, the need for natural sand for concrete production will be high in the future. Many attempts are made to study the effect of partial and full replacement of natural sand by manufactured sand as fine aggregate. The use of manufactured sand in concrete has shown better performance in concrete properties. The properties of Manufactured sand (M-sand) concrete such as workability, compressive strength, flexural strength, split tensile strength, durability and micro-structure are highlighted. From the review of the literature, it can be said that the use of manufactured sand as a fine aggregate replacement will serve as a better alternative for the river sand. The utilization of manufactured sand can help in reducing the pressure on natural resources due to excessive sand mining from river beds.

Keywords: Manufactured sand, Mechanical properties, Durability, Micro-structure.

1 INTRODUCTION

Concrete is an essential material used in Building construction industries all over the world for the development of infrastructures such as buildings, industrial structures, highways, and bridges. Construction industries are the largest consumers of sand for concrete. The developing countries use an alarming amount of concrete for project execution due to urbanization. The growth of industries and major construction projects emerges as a result of the urbanization and first-class development and this requires more concrete to be used in construction industries. Concrete is a composite material made up of cement, aggregate, and water. About 35% of concrete mix composed of sand [1]. The sand used for concrete production is extracted from the river bed, this will result in serious ecological problems and depletion of natural sand which has become a major concern to the environment and the society [2]. The deep pits dug in the river bed will lead to bank slide, loss of vegetation on the bank of the rivers and exposing the intake well of water supply scheme and hence disturb the aquatic life which in turn affects agriculture due to lowering of the underground water table [3]. River sand is a non-renewable resource and the mining activities of the material cause depletion of natural sand and therefore affect the environment, these issues prompt higher authorities to come with a restriction on the lifting of the natural sand. Some countries like China, Indonesia, and Cambodia have banned the sand exports and India has banned the mining of the sand from river bed completely, this makes the river sand to be scarce and costly. The restriction and banning of the mining activities have made the construction industries look for a suitable alternative to river sand [4]. Because of the scarcity of river sand, research is needed for the suitable substitute of fine aggregate although alternative materials have been used in concrete as partial replacement of sand e.g. dune sand, quarry dust, foundry sand, offshore sand, washed soil (filtered sand), construction demolishing waste, slag sand, process crushed rock fines, etc. Many researchers used local materials in concrete as a sand replacement such as used sand, ceramic tile sand, and bottom ash, etc. The availability of those materials in larger quantity is restricted to some areas and not in all places and most parts of the world quarrying activities are carried out [5]. According to previous research manufactured sand is found to be a viable alternative

for fine aggregate replacement. Manufactured sand is produced by crushing rock into aggregate, screening the aggregate to remove dust and then wash to eliminate fine particles. The size of M-Sand is less than 4.75 mm and It has a cubical shape in addition to ground edges with a required gradation and physical properties such as shape, smooth texture and consistency thus making it a better and suitable for construction. The physical properties of sand provide greater strength to concrete by reducing segregation, bleeding, honey combing, voids, and capillary. The required grade of sand for the given purpose helps the concrete fill voids between coarse aggregates and making it more compact and denser, hence increase strength [6].

1.1 Properties of M-Sand for concrete construction

The following are the properties of M-Sand

- 1) **Durability:** Manufactured Sand is produced from selected good quality of granite making it having required physical and chemical properties for construction of concrete structures. This property helps the manufactured sand concrete to withstand severe environmental condition.
- 2) **High strength:** Because of the physical properties that M-Sand possess such as shape, smooth surface texture and consistency, when use in concrete production improves greater strength.
- 3) **Less construction defects:** Defect arises during construction such as segregation, bleeding, honey combing and voids in concrete get reduce by utilization of M-Sand as it has optimum initial and final setting time and excellent fineness.
- 4) **Economy:** The use of M-Sand has improved durability, strength, reduce Segregation, permeability, and decrease post-concrete defects therefore, it is proving to be economical as a construction material replacing river sand.
- 5) **Eco-friendly:** Utilization of M-Sand prevent dredging of river beds that causes environmental problems such as ground water depletion, water scarcity, treat to the safety of bridges, dams etc.

1.2 Advantages of M-Sand

- 1) It is well graded in the required proportion.
- 2) It does not contain an organic and soluble compound that affects the setting time and properties of cement, thus the required strength of concrete can be maintained.
- 3) No impurities such as clay, dust and silt coatings.
- 4) Required properties of sand are obtained.
- 5) Modern machines are used to produce M-Sand to ensure required grading zone for the sand.

1.3 Disadvantages of M-sand

- 1) Workability issues
- 2) Larger proportion of micro fines.

1.4 General requirement of M-Sand

- 1) All the sand particles should have higher crushing strength.
- 2) The surface texture of the particles should be smooth.
- 3) The edges of the particles should be grounded.
- 4) The ratio of fines below 600 microns in the sand should not be less than 30%.
- 5) There should not be any organic impurities.
- 6) Silt in the sand should not be more than 2% for crushed sand.
- 7) In M-Sand the permissible limit of fines below 75 microns shall not exceed 15%.

1.5 Manufactured sand process

- 1) Crushing of stones into aggregate by vertical shaft impacting crusher (VSI) then fed to Roto pactor to crush aggregate into the sand to required grain sizes.
- 2) Screening: - Screening is done to remove dust particles.
- 3) Washing: - the sand is then washed with water to eliminate very fine particles present and hence it can be used in concrete construction. [7].

1.6 Use of manufactured sand

Manufactured sand can be used in the following application

- 1) Concrete production as fine aggregate
- 2) Block and bricks masonry
- 3) Concrete pavement
- 4) Plastering

2 REVIEW OF LITERATURES

2.1 Physical and Chemical Properties of Manufactured Sand

2.1.1 Physical properties

Physical properties of manufactured sand such as shape, smooth surface textures, and consistency make it the best sand suitable for construction. These physical properties provide greater strength to the concrete by reducing segregation, bleeding, honeycombing, voids, and capillary. The specific gravity of manufactured sand is between 2.46 - 2.80 depending upon the source. The physical properties of manufactured sand are shown in table 1.

Table 1. Physical properties of manufactured sand

Physical properties	Rajput et al., (2018)	Shen et al., (2017)	Ding, et al, (2016)	Saravanan, et al., (2016)	Nanthagopalan & Santhanam, (2011)	Sugapriya, et al., (2017)
Specific gravity	2.8	-	-	2.45	2.65	2.65
Bulk density	-	1505	1550	1556	1857	-
Water absorption (%)	5.31	-	0.7	1.0	1.00	-
Fineness modulus	2.49	2.7-2.8	3.34	3.54	-	4.26

2.1.2 Chemical properties

Manufactured sand composed of elements such as Si, Al, Ca, Mg, Na, K, and Fe. Although the sources of the stone play a vital function in respect to the element present. Table 2 shows the studies on the composition of elements from different authors.

Table 2. Chemical Properties of manufactured Sand

Chemical composition (%)	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	Na ₂ O	K ₂ O	MnO
(Shen et al., 2018)	65.89	12.54	1.17	1.99	1.76	1.19	5.65	-
Angelin & Kishore, (2015)	62.48	18.72	6.54	2.56	4.83	-	3.18	-

2.2 Proportion of Manufactured Sand in Concrete

M-sand are used in concrete mix as fine aggregate to replace river sand either partially or fully because of the scarcity of quality aggregate as a result of depletion of natural resources which emerges due to mega trend development and urbanization. The use of manufactured sand caught the attention of industries as fine aggregate is in higher demand and it is depleting. The physical properties of manufactured sand such as shape, smooth surface texture and consistency, when use in concrete production improves greater strength [7]. Manufactured sand is used in various application such as concrete mix, block making, pavement concrete etc. as reported by some authors. [8] explored the use of manufactured sand as a fine aggregate replacement along with glass fiber and Fly ash. The strength and durability properties of M20 and M30 were studied using a water-cement ratio of 0.32. Findings reveal that the workability of manufactured sand concrete decreases, which could be as a result of the fine particle associated with the M-sand. The workability of manufactured sand aggregate will be improved by the used of superplasticizer. [9] assessed the influence of manufactured sand characteristics in strength and abrasion resistance of pavement cement concrete. Based on the study, it was discovered that the increment in manufactured sand increases the compressive strength, flexural strength and improved the abrasion resistance. Similarly, the result disclosed that the performance of manufactured sand concrete in strength and abrasion resistance is found to be higher compared to conventional concrete and the crushing value is low. The increase in the surface roughness and decrease of crushing value and Los Angeles abrasion value improved the abrasion resistance of manufactured sand pavement cement concrete. [10] studied the physical and mineralogical properties of manufactured sand and the influence of its characteristics on the strength and workability of concrete. It was experimentally proven that the compressive and flexural strength of concrete was higher than the conventional concrete, this could be as a result of the angular shape of the manufactured sand that has a positive effect on the aggregate interlock and hence, result in significant improvement in the bond between the cement and aggregate particles. The use of 100 % manufactured sand is viable. [11] investigated the effect of replacing fine aggregate with manufactured sand and quarry dust in concrete with dissimilar curing condition. the curing method used are gunny sack, air-shade, membrane curing and sprinkled water. It was observed that the compressive and tensile strength properties were higher in self-curing with Super Adsorbent Polymer (SAP) 0.3 %. The result indicated that air shade curing has the least strength value compared to other types of curing.

2.3 Sieve Analysis

Table 3. Result of sieve analysis of manufactured sand by different authors

S/N	Author	Sieve	River Sand	Manufactured Sand	Fine aggregate grading Limits (ASTM C33)
1.	Saravanan et al., (2015)	4.75mm	98	97.20	95-100
		2.36mm	96	93.62	80-100
		1.18mm	82.10	65.86	50-85
		600 μ	59.67	53.51	25-60
		300 μ	15.84	21.60	5-30
		150 μ	4.14	7.60	0-10
2.	Shanmugapriya et al., (2017)	4.75mm	97	99.2	95-100
		2.36mm	92.2	93.6	80-100
		1.18mm	77	56.6	50-85
		600 μ	52.2	38.6	25-60
		300 μ	10.6	18.4	5-30
		150 μ	2	7.4	0-10
3.	Vijaya B et al., (2015)	4.75mm	100.00	100	95-100
		2.36mm	95.60	90.7	80-100
		1.18mm	86.00	66.2	50-85
		600 μ	56.20	39.8	25-60
		300 μ	17.70	25.50	5-30
		150 μ	3.10	9.90	0-10
4.	Priyanka et al.,	95-100	95-100	95-100	95-100

	(2016)	80-100	80-100	80-100	80-100
		50-85	50-85	50-85	50-85
		25-60	25-60	25-60	25-60
		5-30	5-30	5-30	5-30
		0-10	0-10	0-10	0-10
5.	Kulkarni & Joshi, (2017)	4.75mm	93.80	93.70	95-100
		2.36mm	85.20	83.30	80-100
		1.18mm	75.70	70.60	50-85
		600 μ	42.30	43.40	25-60
		300 μ	15.10	12.90	5-30
		150 μ	6.90	5.10	0-10

2.4 Fresh Properties of Manufactured Sand Concrete

2.4.1 Workability

Workability of fresh concrete is measured by either slump cone test, compacting factor test, vebe test or flow table test. The workability of manufactured sand concrete generally requires higher water/cement ratio for attained the desired slump due to the high angularity of the M-sand particles however the workability will be improved by the use of admixtures such as superplasticizer. [3] checked the effect of using manufactured sand as a partial replacement of natural sand in concrete. The slump value of concrete with manufactured sand has 35 mm at 0.45 water-cement ratio while the conventional concrete has 40 mm and at 0.50 water-cement ratio the slump value of manufactured sand is 40 mm while conventional concrete has 50 mm so the workability of manufactured sand concrete is lower than the conventional concrete.[3] studied the effect of manufactured sand concrete on the strength properties and workability of concrete with water-cement ration 0.45 using fine aggregate replacement level 0,20,40 and 60 %. The slump value of concrete with manufactured sand is 80 mm and the conventional concrete is 80 mm. Studies suggest that the increase in percentage replacement of fine aggregate decrease the workability of the concrete except for the concrete that contains 40 % manufactured sand as fine aggregate which is equal to the conventional concrete both of the concretes having the slump value of 85 mm. [12] evaluated the impact of utilizing manufactured sand as a partial replacement in ultra-high-performance concrete. Increase in the replacement of natural sand decreases the slump value of manufactured sand concrete compared to conventional concrete. The decrease in the workability of concrete with manufactured sand as fine aggregate was 11.7 % when the replacement is 50 % and this is a result of the surface properties and particle size distribution of manufactured sand. Literatures indicated that the use of manufactured sand decreases the workability of concrete and it has been further noticed that the higher the replacement level of natural river sand by manufactured sand the lower the workability of the manufactured sand concrete although the workability of M-sand could be adjusted by the use of superplasticizer.

Table 4. workability of fresh concrete using different method by various authors

Author	Slump (mm)		Compaction Factor		Vebe Time (second)		Flow Table	
	Conventional Concrete	M-sand						
Shinde et al., (2016)	105	105	0.97	0.96	-	-	-	-
Yajurved et al., (2016)	50	37	0.91	0.89	9.2	13.1	-	-
Kulkarni & Joshi, (2017)	98	75	0.91	0.84	7.1	10.1	48	32
Ritesh et al., (2018)	60	56	0.91	0.91	8.2	8.65	-	-
Suresh & Revathi, (2017)	50	40	-	-	-	-	-	-

2.5 Hardened Properties of Manufactured Sand Concrete

2.5.1 Compressive strength

Compressive strength of concrete is the capacity of the concrete material to withstand the applied load, in other word it is the resistance offered by the concrete block before yielding to the applied load. [13] investigated workability and strength properties of high-performance concrete using manufactured sand as fine aggregate with 0, 25 %, 50 %, and 75 % replacement of natural sand by manufactured sand. Superplasticizer (SP 100) was of 0 %, 1 %, and 1.3 % was used. The result reveals that the compressive strength of concrete containing manufactured sand increases as the percentage replacement of M-sand increase with 1.3 % superplasticizer (SP) compared to conventional concrete. The percentage increase in compressive strength is 27.55 and 12.78 % at the age of 7 and 28 days respectively. The optimum percentage replacement of natural sand by manufactured sand is 50 % with 1.3 % SP. [14] assessed the strength properties of concrete with manufactured sand as fine aggregate, various replacement level of 20, 40, 60, 80, and 100 % manufactured sand by natural sand was used with silica fume as cement replacement using a proportion of 5 %, 7.5 %, and 10 % and the water-cement ratio of 0.32 and platinum B233 as super-plasticizer. it was inferred that a 7-day strength of concrete with 100 % M-sand had better performance with 7.5 % silica fume and a slight decrease was observed with concrete having 10 % silica fume and manufactured sand. results disclosed that manufactured sand concrete with 80 % natural sand replacement with 7.5 % silica fume had the highest strength at 28 days with the maximum compressive strength of 19.7 % compared to conventional concrete. [15] revealed that the compressive strength of self-compacting self-curing concrete (SCSCC) with fly ash and manufactured sand (m-sand) is found to be comparable with the conventional concrete. Study shows that the use of M-sand as a fine aggregate replacement with fly ash and water reducing admixture Glenium improved the properties of the concrete, the compressive strength of Manufactured sand concrete was 20.70 N/mm² at 7 days and 34.12 N/mm² at 28 days. Findings indicate that manufactured sand concrete has about 3 % higher strength than the conventional concrete. [16] reported the strength properties of concrete with ground granulated blast furnace slag (GGBS) 10, 20, 30, 40 % and manufactured sand (M-sand) 10 to 50 %. The compressive strength of concrete mix having 10 % ggbs and 50 % M-sand exhibited higher strength with an increase of 5.66 % at 56 days compared to conventional concrete. The authors discovered that manufactured sand concrete satisfied the requirement of fine aggregate using concrete grade M40. [17] Studied the effect of manufactured sand in concrete grade M20 using 0, 30, 50, 70, 100 % manufactured sand as a fine aggregate replacement with a water-cement ratio of 0.58. it was observed that the compressive strength of concrete significantly increases when the natural sand is completely replaced with M-sand. Result disclosed that the increase in the compressive strength of manufactured sand concrete at 28 days was 26.9 Mpa about 10.2 % higher compared to conventional concrete. [18] experimented on the strength characteristics of re-tempered concrete made by manufactured sand to study the effect of re-tempering concrete on the compressive strength with the addition of retarder 0.2 %, 0.4 % and 0.6 % at a re-tempering time from 15 to 90 minutes of concrete grade M20. Compressive strength of concrete without retarder shows maximum strength at a re-tempering time of 45 minutes while the concrete with 0.2 % retarder show target compressive strength up to the re-tempering time of 60 minutes. The other two with 0.4 % and 0.6 % both show target compressive strength up to 90 minutes. [19] studied the properties of high-performance concrete with manufactured sand as a fine aggregate replacement using a proportion of 0, 25, 50, 75, and 100 % of natural sand with the M-sand. Admixtures such as silica fume and superplasticizer were used to produce a concrete grade M60. The optimum percentage replacement of natural sand by M-sand was 75 %. The compressive strength of manufactured sand concrete having 75 % sand replacement is 70.90 N/mm² while conventional concrete has about 69.36 N/mm². [5] the strength properties of concrete with 50 % manufactured sand show better performance with compressive strength of 67.34 N/mm² which is about 7.85 % higher than the conventional concrete. The concrete grade M40 with 50 % natural sand replacement by manufactured sand show improved performance in the compressive strength of concrete with 0.40 water-cement ratio. The investigation reveals that the percentage replacement of 60, 70, 80, 90 and 100 % natural river sand by M-sand decreases compressive strength of concrete at 28 days. They noticed that concrete become harsh with the increase in percentage replacement. [20] Investigated an experimental study on the effect of replacing 100 % natural sand by manufactured as fine aggregate. It was observed from the experiment

that the compressive strength of concrete with manufactured sand has a strength of 53 Mpa. the study reveals that the manufactured sand concrete has about 7.5 % higher strength compared to conventional concrete. the use of 100 % manufactured sand as fine aggregate is possible. [21] evaluated the compressive strength of concrete with partial replacement of natural sand with manufactured sand having a replacement of 20,40,60,80, and 100 % and the water-cement ratio of 0.5 was used for the mix. The result of the experiment disclosed that manufactured sand can be used as a fine aggregate replacement. It was observed from the literature that the compressive strength of manufactured sand concrete is higher than the conventional concrete. [22] carried out research on the properties of concrete with manufactured sand and fly ash using percentage replacement of natural river sand in order 0,20,40,60,80, and 100 %. It was discovered from the experiment that the use of manufactured sand along with fly ash improved the compressive strength of concrete. The strength increase in manufactured sand concrete was 14.27 % at 100 % river sand replacement by the manufactured sand. It has been confirmed based on the above literature that the manufactured sand can be used as fine aggregate replacement and can perform better than the conventional concrete in-terms of compressive strength and it was also noticed that when manufactured sand is used along with admixture (mineral and chemical) complete replacement of the river sand is viable with an improve strength in all curing age.

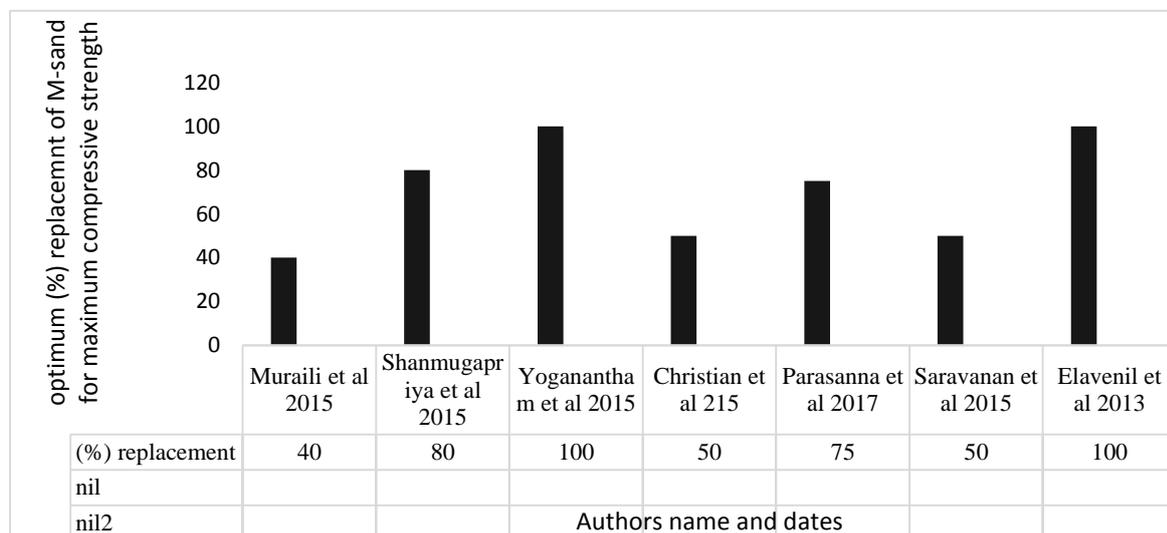


Figure 1. Optimum percentage replacement of M-sand by various researchers for compressive strength.

2.5.2 Split tensile strength

It is a method of determining the tensile strength of concrete using a cylinder which splits across the vertical diameter. It is an indirect method of testing the tensile strength of concrete through the application of the compressive load and this developed tensile stresses and make the concrete specimen crack and split. [23] studied the tensile strength development of manufactured sand and the influence of water-cement ratio and the stone powder on the tensile behaviour of manufactured sand. The use of manufactured sandstone powder is reported to have a beneficial effect on the tensile strength of the concrete. It was observed that the growth of the tensile strength of manufactured sand was rapid within 28 days and slow after 28 days which might be as a result of the effect of the amount of stone powder in the manufactured sand and the water-cement ratio. The long-term tensile strength was beneficial within 13 % of the stone powder and with no less than 0.45 water-cement ratio. The content of stone powders up to 9 % was also beneficial when the water-cement ratio was lower than 0.45. [24] examined the effect of using manufactured sand as fine aggregate and silica fume as a partial replacement of cement by 7.5 % with a water-cement ratio of 0.32. The replacement ratio of M-sand was 10,20,30,40,50,70 %. Result reveals that the used of 60 % M-sand and 7.5 % silica fume shows a greater improvement in split tensile strength of about 8 % higher than the conventional concrete and this is as a result of the shape and proper gradation of the M-sand fine aggregate. Based on the result, the authors concluded that M-sand can be used as a viable alternative to natural sand in high-performance concrete

in the construction industry. [25] Investigated the study of concrete with partial replacement of dolomite as cement replacement and Manufactured sand as a fine aggregate replacement using concrete grade M25. The fine aggregate replacement was 10,20,30,40, and 50 % and dolomite replacement was 10 % by weight of cement. the split tensile strength of concrete with dolomite and manufactured sand shows a promising strength when the percentage replacement of M-sand is 40 %. The optimum percentage replacement was 40 % M-sand and 10 % dolomite which gives higher split tensile strength of 4.93 N/mm² at 28 days and the conventional concrete was found to be 3.53 N/mm². It was discovered that all the concrete containing M-sand show better performance compared to conventional concrete. [26] verified the effect of replacing natural sand by manufactured sand on the concrete properties. The percentage replacement of natural sand by manufactured sand is in order of 0,45,50,55, and 100 % using 0.55 as a water-cement ratio. The result depicts that the split tensile strength increased with increase in Manufactured sand. They further disclosed that the optimum percentage of manufactured sand replacement is 55 % with about 12.07 % increase in strength compared to the strength of the conventional concrete. It was concluded that the split tensile strength of M-sand concrete show better performance in all replacement level than the conventional concrete. [27] demonstrated that, the addition of manufactured sand as fine aggregate in concrete improved split tensile strength for M40 grade of concrete. The result indicated that 60 % M-sand replacement greatly improved the split tensile strength having a value of 4.87 Mpa that has about 20 % higher in strength compared to conventional concrete. The improved split tensile strength is due to the manufacturing process of M-sand and this result in reduced surface area and better parking that contributed to better binding with the cement. [16] reported an experimental investigation on the strength and durability characteristics of high-performance concrete using ggbs as cement replacement and M-sand as a fine aggregate replacement with superplasticizer (SP430). The result indicated that the split tensile strength of M-sand concrete has a beneficial effect on the properties of concrete. It was revealed that the optimum percentage replacement of natural sand by manufactured sand gives higher splitting tensile strength. It was noticed based on the above literature, the partial replacement of natural sand by manufactured sand is more beneficial to split tensile strength of concrete as indicated in figure 2 below.

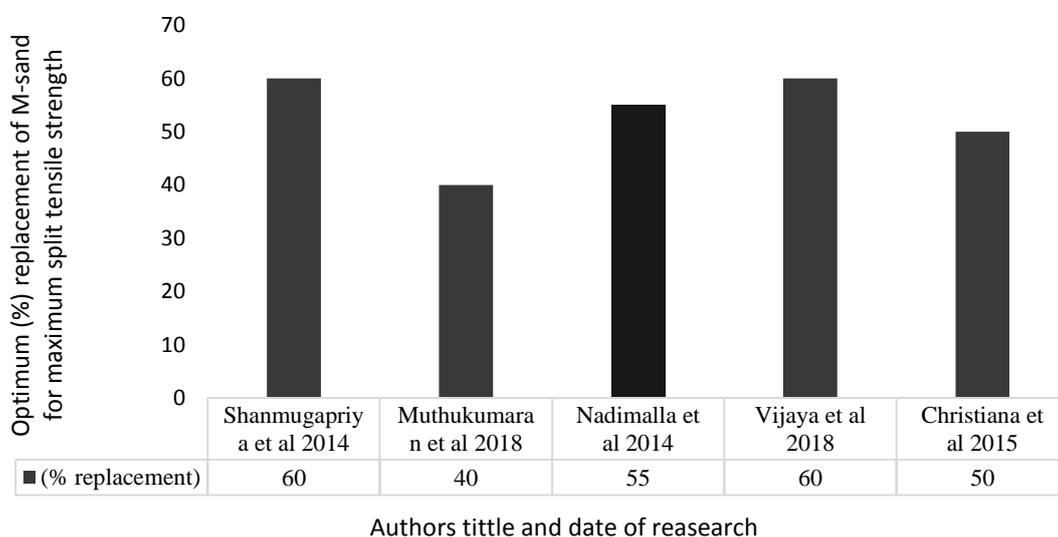


Figure 2. The optimum percentage replacement of M-sand by various researchers for split tensile strength

2.5.3 Flexural strength

Flexure test of concrete block: Can be defined as the resistance offered by the concrete block just before it yields in a flexure test. [28] investigated the effect of high-performance concrete containing Manufactured sand as fine aggregate and steel fiber at 28 days. Manufactured sand was used to replaced natural sand with different percentage using 30,40,50 and 60 %. The result revealed that manufactured sand concrete has better performance in all replacement compared to conventional

concrete. It was discovered that the optimum percentage of flexural strength was 8.6 N/mm² at 28 days with 50 % natural sand replacement and 1 % steel fiber. [14] proposed an experimental study on the strength and durability properties of manufactured sand concrete along with silica fume 5 %. The proportion of the natural river sand replacement by M-sand is 0,20,40,60,80 and 100 %. The strength of the concrete was observed to have higher flexural strength than the conventional concrete and this could be attributed due to the presence of Manufactured sand and silica fume resulting in a denser matrix. The maximum percentage increase in flexural strength of concrete containing M-sand is 14 % higher than the conventional concrete. The optimum percentage of natural sand replacement with manufactured sand is 100 %. [29] studied on the high-performance concrete M50 grade containing ground granulated blast furnace slag (GGBS) and manufactured sand with 0.37 water-cement ratio along with water-reducing admixture to increase the workability. The authors confirmed that partial replacement of natural sand by manufactured sand improved the flexural strength of concrete compared to the conventional concrete mix. The use of 50% GGBS and 40 % manufactured sand gives a maximum flexural strength of 6.85 N/mm² which is about 12 % higher than the conventional concrete at 28 days. [30] investigated the strength and durability properties of concrete by replacing natural sand by manufactured sand and fly ash. The replacement level of manufactured sand is 0,20,40,60, and 80%. The result revealed that the use of manufactured sand improved the flexural strength of concrete which indicated that the optimum is 60 % natural sand replacement. It was concluded that the flexural strength of concrete with manufactured sand is 7.14 Mpa and the conventional concrete is 4.97 Mpa. [31] according to the study, it was verified that the use of manufactured sand along with supplementary cementitious materials increase the flexural strength of concrete compared to the conventional concrete. The replacement of natural sand in proportion of 0,10,20,30,40,50,60,70,80,90 and 100 % by manufactured sand was made to ascertain the performance of M-sand as fine aggregate replacement. The optimum percentage replacement of natural sand by manufactured sand is 60 %. It was noted that the flexural strength of manufactured sand concrete is 7.89 Mpa which is higher than the conventional concrete. [32] evaluated the strength characteristics of pavement quality concrete mixes using GGBS and manufactured sand. It was verified that manufactured sand concrete enhances the flexural strength of concrete and can be used in pavement quality concrete mixes. The result indicates that the higher flexural strength is between 12-14 % compared to conventional concrete. The optimum percentage replacement for fine aggregate and cement are 100 % manufactured sand and 20 % GGBS and this gives strength of 6.10 Mpa at 28 days with an increase of about 13.03 % higher than the conventional concrete. [33] explored on the flexural behavior of manufactured sand concrete and fly ash using replacement level of manufactured sand 0, 30, and 40 %. The result indicated an increase in flexural strength of manufactured sand concrete with a strength of 8.10 N/mm² at 56 days while the conventional concrete has 5.4 N/mm². It can be deduced from the research work; the flexural strength of manufactured sand concrete has better performance in all replacement level than the conventional concrete.

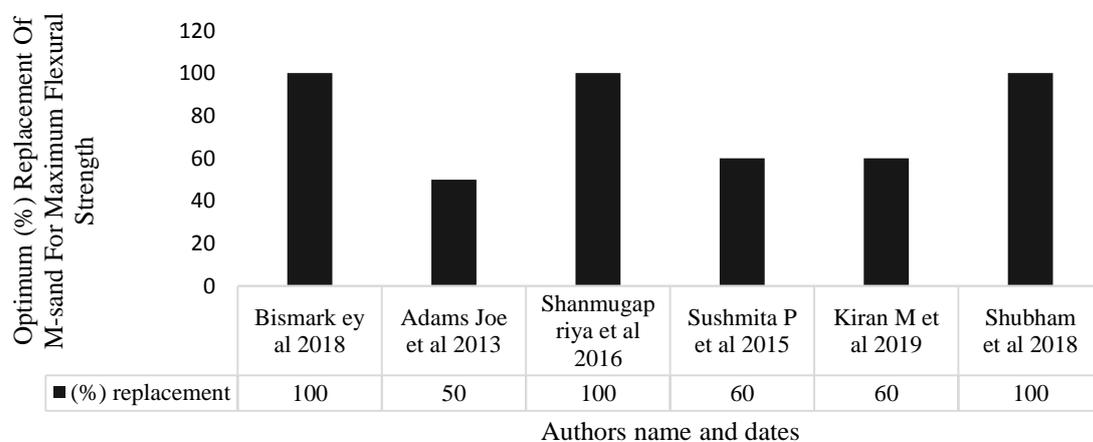


Figure 3. The optimum percentage replacement of M-sand by various researchers for flexural strength

2.6 Durability Properties of Manufactured Sand Concrete

2.6.1 Water absorption and Sorptivity

Water absorption and sorptivity are used to determine the amount of water absorbed under specified conditions. Water absorption means the capacity of a sample to hold water while water sorptivity is the rate at which the sample fills the sample, although both the terms measure the same thing. It simply measures the water drawn in under suction and is intended to determine the susceptibility of an unsaturated concrete to the penetration of water. [34] examined the durability properties of concrete with manufactured sand and basalt fiber using 12 mm length of the fiber with 0.1 % to 0.3 % and manufactured sand 50 and 60 %. The workability of the concrete mix was adjusted with superplasticizer SP340. Six different mixes were used to assess the water absorption capacity of the M-sand with basalt fiber. The result revealed that the concrete with a combination of 50 % M-sand and 1 % basalt fiber absorbs less amount of water compared to conventional concrete. [35] described an experiment on the strength and durability of manufactured sand using concrete grade M30, M40, and M50 with 0 to 100 % manufactured sand as fine aggregate replacement. The reduction in sorptivity was observed with an increase in grade of concrete in the presence of manufactured sand. It was also noted that the higher-grade of concrete show a lower initial rate of absorption and secondary rate of absorption for the same proportions of the natural sand and M-sand.

2.6.2 Rapid chloride penetration

A durable reinforced concrete structure is required especially when the concrete structure will be exposed to a harsh environment. Reinforced steel may get corroded through the ingress of chloride which is the most common environmental attacks that lead to the deterioration of the concrete structures and in later ages, a reduction in strength will be experience and hence the expected serviceability period of the structure will not be attained which in turn impair the aesthetic of the structure. [34] investigated the permeability properties of manufactured sand concrete with six different mixes and results indicate that concrete with 50 % M-sand and 0.1 % basalt fiber (mix 1) and 60 % M-sand and 0.2 % basalt fiber (mix 5) show low chloride permeability than the other mixes. from the experiment, it was observed by the authors that the concrete mix with 60 % M-sand and 0.2 % basalt fiber show very low chloride permeability value which indicated good permeability of the concrete. [36] established that low chloride ion permeability was observed for manufactured sand concrete whereas moderate chloride ion permeability for the natural sand. It was revealed based on the experiment conducted that the durability properties of concrete were enhanced by partial replacement of sand with 60 % of Manufactured sand and 40 % natural sand in all grades of concrete. The concrete grade M50 show low permeability than M30 and M40 grades. [37] disclosed that the durability properties of concrete with 70 % manufactured sand as fine aggregate in concrete has better performance compared to conventional concrete. The use of 100 % M-sand as fine aggregate also indicate a strength compared to conventional concrete. The rapid chloride permeability of manufactured sand has a low permeability zone for both M40 and M50 and this is due to a proper particle size of manufactured sand. [38] Assessed the durability properties of concrete with manufactured sand and natural sand using rapid chloride migration test. It was discovered that the chloride penetration depth and migration coefficient of the sample with manufactured sand is lower than the conventional concrete in the chloride-induced environment. the result shows that the quality of concrete with manufactured sand is better compared to conventional concrete. Based on the above, it was discovered that manufactured sand concrete exhibits low permeability in all grades of concrete. It can be further assumed that the use of manufactured sand in concrete will improve the permeability of concrete excellently.



Figure 4. Percentage (%) replacement of M-sand for high resistance in chloride environment by various authors

2.6.3 Carbonation

Carbonation occurs in concrete when the calcium bearing phases present are attacked via carbon dioxide from the air changing it to calcium carbonate. The presence of carbonation can be detected by means of either change in coloration or by means of indicator such as phenolphthalein. [39] worked on the impact of mineral admixture and water binder ratio on carbonation of high-performance manufactured sand concrete (HPMSC) using fly ash and silica fume. The test result disclosed that the carbonation resistance of HPMSC increased when the water-binder ratio decreases because concrete with low water binder ratio has good compactness and improved ability of concrete carbonation resistance. It was noted that when the concrete compressive strength is over 55 Mpa, carbonation resistance is higher and it was further realized that, when the water binder ratio is lower than 0.38 the impact of mineral admixtures on carbonation resistance can be neglected.

2.6.4 Sulphate attack

It is among the common types of concrete deterioration; it occurs when the concrete structure is exposed to sulphate environment. This is more pronounced when the water containing the dissolved sulphate penetrates the concrete. The sulphate ions that penetrate the concrete will then react with CH to form gypsum and ettringite which cause the concrete structure to experience expansion, loss of bond between the cement paste and aggregate and extensive cracking, as a result, the overall concrete strength will be lost. [36] experimented the strength and durability of manufactured sand using different grades of concrete M30, M40 and M50 along with fine aggregate replacement of 0 % and 60 %. The result indicated that about 1.8 % weight loss for conventional concrete with 100 % fine aggregate is due to sulphate attack and it is further said that the concrete with 60 % manufactured sand has 1 % weight loss due to sulphate attack. The optimum percentage replacement of fine aggregate is observed in M50 grade of concrete with 60 % manufactured sand compared to conventional concrete.

2.6.5 Acid attack

When acid attacks concrete it breaks down both hydrated and un-dehydrated cement compound and calcareous aggregate. Concrete vulnerability to acid attack increases as the PH of acid in contact decreases although aggression of the acid is not only because of PH value but also due to the presence of CO₂ in the reaction of the hardness of water. [36] the use of 60 % manufactured sand and 40 % natural sand in preparing concrete with three different grades M30, M40, M50 was established. The concrete was cured for 28 days and later placed in 5 % sulphuric acid to determine the resistance of the concrete with manufactured sand to acid attack. The result shows that the weight loss of manufactured sand concrete is 2.09 % and the conventional concrete has a weight loss of 2.65 % due to acid attack. It was experimentally proven that manufactured sand concrete is more resistant to acid attack compared to conventional concrete. [37] studied the effect of manufactured sand on the durability characteristics of concrete having M40 and M50 grade of concrete. It was observed that the durability of manufactured sand concrete under 5 % sulphuric acid (acid attack) is higher than the conventional concrete and the loss of weight in manufactured sand concrete due to acid attack for M40 and M50 concrete is lesser than the conventional concrete. The concrete with manufactured sand shows better resistance to acid attack compared to its counter-part conventional concrete. [24] investigated the effect of gradation of manufactured sand concrete in the acid attack using concrete grades M20, M30 and M40 grade. The percentage weight reduction was less in concrete containing manufactured sand when compared to conventional concrete, the weight loss for M30 and M40 grade is less than the M20 grade of concrete which might be as a result of low water-cement ratio used for the M30 and M40 that contributed to less porosity. The weight loss in sulphuric acid solution at 365 days is reduced at 25 to 40 % while using M-sand. The concrete with 70 % manufactured sand which is the optimum percentage replacement showed high resistance to acid attack. [40] established study on the durability properties of manufactured sand concrete having a replacement ratio of 0,20,40,60,80 and 100 % for concrete grades M20 and M30. It was observed that there is a slight decrease in compressive strength, split tensile strength and flexural strength of concrete after exposure to acid. The concrete grade M30 has shown an increase of 19.1 % higher than the conventional concrete at 60 % replacement and for M20 grade of concrete, the strength increase is 19.73% before exposure to acid. Based on the result, it was discovered that the optimum percentage replacement of fine aggregate is 60 % and the strength of the concrete after

exposure to acid showed that, the grade M20 concrete decreases more than concrete grade M30. These indicated that the grades of the concrete also play an important role in the resistance of concrete to acid attack which could be as a result of the lower water-cement ration that the M30 grade concrete (w/c- 0.45) has than the M20 grade of concrete (w/c- 0.50). Manufactured sand concrete exhibited good resistance to acid attack compared to conventional concrete.

2.7 Micro-Structural Properties of Manufactured Sand Concrete

2.7.1 XRD (X-ray diffraction)

It is a technique used to identify the compound and mineral present in the powder specimen based on the comparison of relative intensities of the peaks corresponding to a different chemical species determined at particular values of diffraction angles. [41] explored the impact of using manufactured sand (M-sand) and supplementary cementitious material. It was discovered that the use of 100 % M-sand replacement along with 30 % fly ash as cement replacement has significantly increased the total C-S-H gel. The concrete containing M-sand 100 %, silica fume 7.5 % and fly ash 15 % indicated the highest increase in concrete strength with age. Figure 1 show the XRD of M-sand 100 %, silica fume 7.5 % and fly ash 15 % as reported by [41].

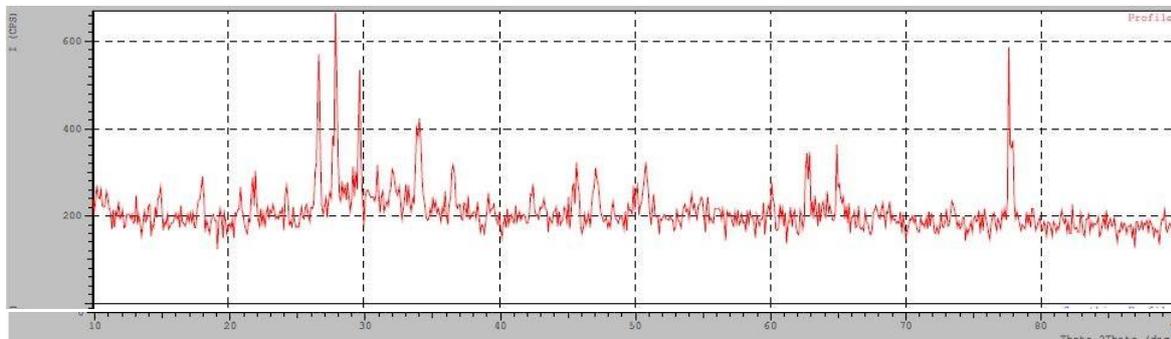
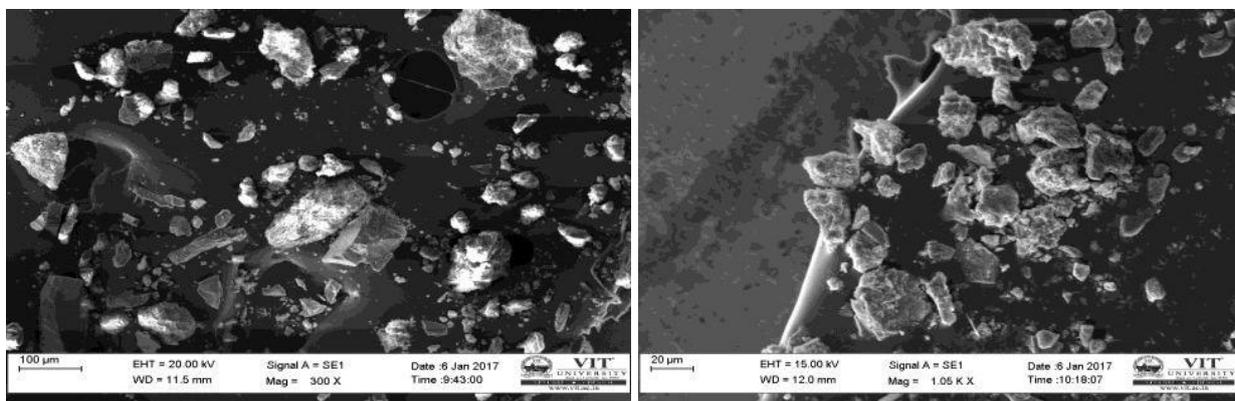


Figure 5: XRD diffraction of concrete

2.7.2 SEM (Scanning Electron Microscopy)

It is a method used to identify the morphology of the structure. [35] proposed a study on the strength and durability properties of concrete made with manufactured sand. It was observed from figure 6 that the M-sand had elongated and rough structure as compared to round and smooth surface of natural sand. The rough and elongated structure of M-sand helped in reducing the micro-cracks in the vicinity of the interfacial transition zone (ITZ). Thus, a strong bond between the cement matrix and the M-sand at ITZ was noticed as compared to that which was observed in case of natural sand as reported by [35].



a)

b)

Figure 6. SEM images of (a) M-sand (b) River sand.

3 CONCLUSION

Based on the review of different experimental studies performed by various researchers the following conclusions will be drawn:

- 1) Workability of manufactured sand concrete was observed to be lower than the conventional concrete and can be improved by the used of superplasticizer.
- 2) The addition of M-sand has significantly increased the compressive strength, split tensile strength and flexural strengths of concrete compared to conventional concrete.
- 3) It was discovered based on the literature that, manufactured sand concrete exhibits low permeability and low water absorption in all grades of concrete.
- 4) It was observed from the review literature that; the manufactured sand concrete mixes show higher acid resistance, sulphate resistance, and carbonation resistance compared to conventional concrete in all grades of concrete used.
- 5) The rough and elongated structure of M-sand helped in reducing the micro-cracks in the vicinity of the interfacial transition zone (ITZ) and as a result, a strong bond between the cement matrix and the M-sand at ITZ was noticed.

From the above findings, it is clear that the use of manufactured sand as fine aggregate replacement in concrete construction for sustainable developments is possible, and it can also be concluded that the replacement of natural sand with manufactured sand in concrete construction will be a viable solution to natural sand depletion.

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