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Effect of manufactured sand on the durability characteristics of concrete

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Abstract: Concrete is the most sought after material due to increase in construction activities and infrastructural developments. Availability of natural sand is decreasing thereby increase in the cost of construction. In the present work undertaken, an attempt has been made to give an alternative to natural sand. Optimization of replacement of natural sand with manufactured sand in concrete, durability studies such as water absorption, rapid chloride permeability test, sorptivity, acid resistance, alkaline resistance, impact resistance and abrasion resistance of M40 and M50 grades of concrete have been studied with manufactured sand as fine aggregate and compared the results with the conventional sand concrete. The results shows that there is an increase in the durability properties up to 70 % level of replacements of sand with manufactured sand as fine aggregate and for 100 % use of manufactured sand also gives the better durability than the conventional sand concrete.

Keywords: Admixtures, durability, rapid chloride permeability test, sorptivity, Manufactured sand.

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1 Introduction: In India, currently has taken major initiative on developing the infrastructures such as elevated corridors, major power plants, express ways, metro rail systems, and rail over bridges, etc to meet the requirements of the globalization. In the construction activities, concrete plays a major role and heavy quantity of concrete is used. River sand is the constituent to be used, for production of concrete is now become vital .Due to the cost and conveyance of river sand is more, and thereby increase in cost of construction , and hence an alternative material for natural river sand has been studied in this present work. The alternative sand used in this work is manufactured sand, which is manufactured with crushing the granite boulders with vertical shaft impact crusher. The Durability of the concrete is the ability to resist weathering action, Chemical attack or any other process of deterioration. The durability properties of the concrete is examined and discussed in this paper. Ilangovan et al. [1] shows that the use of quarry rock dust as fine aggregates is possible for full replacement of natural river sand. The drying shrinkage strains of quarry rock dust concrete shows large to that of conventional sand concrete. The durability of the concrete with quarry rock dust concrete under sulphate and acid is higher to that of conventional concrete, the depth of water penetration for quarry rock dust concrete is 10 mm and for natural sand concrete 15.8 mm, the water absorption for quarry rock dust concrete is 3.8 % and for natural sand concrete is 2.6 %. Sahu et al. [2] reported that the increase in compressive strength, flexural strength, split tensile strength, durability tests when natural sand replaced with 40 % by quarry rock dust. Ilangovan and Nagamani [3, 4] shows that the natural sand with quarry dust as full replacement in concrete is possible with proper treatment of quarry dust before use to concrete construction. Perumal and Sundararajan [5] reported that the effect of partial replacement of cement with silica fume on the strength and durability characteristics of high performance concrete, the concrete with silica fume showed higher acid resistance, sea water resistance, abrasion resistance and impact resistance. The surface of water absorption and sorpvitity is 1.95 % and 0.0505 mm/min.$^{0.5}$ respectively which is lesser than the value suggested by the Taywood Engineering Ltd., for good concrete. Muthupriya et al. [6] showed the strength and durability of high performance concrete with use of mineral admixtures in concrete enhances the durability properties and strength properties of concrete Pavia and E. Condrel [7] reported that the durability of OPC versus GGBS concrete on exposure to silage effluent, the significant rise in capillary suction, water absorption and permeability over the course of the time, and concrete used to build silos undergoes severe chemical attack over the life time Guptha S. M. [8] reported that the concrete with silica fume shows better acidic resistance, alkaline resistance and thereby loss of weight loss is very low compared with the control mix concrete. Jayeshkumar Pitroda et al. [9] experimentally evaluated and reported that the sorptivity and water absorption of the concrete with partial replacement of cement by the thermal Industry waste (fly ash). The water absorption and sorptivity of M25 (fly ash) concrete is lower than M40 Grade concrete. The water absorption is found to be 1.59 % for M 25 and 0.65 % for M40 concrete and sorptivity found to be 2.32 mm/min$^{0.50}$ for M25 and 1.74 mm/min$^{0.50}$ for M40 with respective natural sand concrete. Jayeshkumar Pitroda et al. [10] reported that the durability of concrete with partial replacement of Cement by paper industry waste (hypo sludge) the water absorption and sorptivity of M25 paper industry waste concrete is higher than water absorption and sorptivity of M40 grade concrete. The percentage decreases in water absorption is found to be 1.13 % for M25 and 1.52% for M40 and the sorptivity is found to be 2.32 mm/min$^{0.50}$ for M25, and 4.56 mm/$^{min0.50}$ for M40 with respective concrete mix concrete. Shyam Prakash [11] investigated and reported that the manufactured sand is used as fine aggregates in ready mixed concrete for M20 and M25 Grade concretes and satisfied the requirements of manufactured sand and strength properties with admixtures. In this present study the durability properties of manufactured sand concrete of Grade M40 and M50 grade concrete were studied and compared the results with the conventional sand concrete. The objective of the present work is to investigate the durability characteristics for concrete of grade M40 and M50 by replacing 0 % to 100 % of natural sand with manufactured sand at the incremental increase of 10 % using super plasticizer, also an attempt is made to find out the optimum replacement level of manufactured sand for better durability characteristics of the concrete.

2. **Materials and methods**

Materials used

2.1 Cement: Ordinary Portland cement, 53 grade confirming to IS: 12269-1987 [12] is used. The Physical and chemical properties calculated and measured by the standard test conducted as per IS Code and were tabulated in Table (1).

2.2 Coarse aggregate: Crushed blue granite stone confirming to graded aggregates of nominal size 20 mm confirming to IS: 383-1989 [13], with specific gravity of 2.70 and fineness modulus of 6.72 is used. The physical properties were calculated, and tabulated in Table (2).

2.3 Fine aggregates:

Natural river sand: Locally available natural river sand at Karur confirming to Grading zone II of IS: 383-1989 with specific gravity of 2.60 and fineness modulus 3.44 is used as fine aggregates. The physical properties were calculated and tabulated in Table (2).

Manufactured sand: Manufactured sand is manufactured in vertical shaft impact crushers (VSI – crushers) in three steps viz crushing, screening and washing. The VSI Crusher having the plant capacity of 400Tons per hour.The granite boulders are crushed into aggregates then fed into rotopactors to crush the aggregate into sand to the required shape and size as fine aggregates, then 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 are durable, angular in shape, clean and required particle size distribution. The sand used in this work is from vertical shaft impact crushers at Salem (SRC M sand). The physical properties confirming to IS: 383-1989 with specific gravity of 2.45 and fineness modulus of 3.54 is used as fine aggregates for replacement of conventional sand. The physical properties calculated are tabulated in Table (2).

2.4 Water: The water used for the present study is free from acids, organic matters, suspended solids, alkalis and impurities present have adverse effect on the strength and durability of concrete. Potable water with the pH value of 7.00 confirming to IS: 456-2000 **[14]** is used for concrete specimen making and curing the specimens as well.

2.5 Chemical admixtures: Super plasticizer (or) high range of water reducing admixtures are used to improve the workability and durability of concrete. Commercially available Super Plasticizer produced and supplied by Cera-Chem (Pvt) Ltd, Chennai, Ceraplast 300 RS(G) is used in this present investigation.

Table (1): Physical and chemical properties of cement (OPC 53 Grade).

Sl No.	Property / Composition	Result
1.	Specific gravity	3.15
2.	Standard consistency	31%
3.	Initial setting time	33
4.	Final setting time	385
5.	Compressive strength 7 days 28 days	 43.50MPa 57.50MPa
6.	Silicon dioxide ($Si0_2$)	19.85%
7	Aluminum Oxide (Al_2O_3)	5.65%
8.	Ferious oxide (Fe_2O_3)	5.20%
9.	Calcium oxide (CaO)	62.55%
10.	Magnesium oxide (Mgo)	0.91%

Table (2): Physical properties of course and fine aggregates.

SlNo.	Property	Course aggregate	Msand	Natural Sand
1.	Specific gravity	2.70	2.45	2.60
2.	Bulk density	1510	1556	1460
3.	Water Absorption (%)	0.45	1.00	1.15
4.	Moisture constent	0.85	1.15	1.10
5.	Fineness particles Less than 0.075 mm(%)	-	5.30	4.14
6.	Finess modules	6.72	3.54	3.44
7	Impact value	12.50	-	-
8	Sieve analysis	-	Zone-II	Zone -II

2.6 Mix design:

The concrete for the grades M40 and M50 is designed using the specifications IS:10262-2009 **[15]**, IS:456-2000, SP:29 **[16]**, by considering good degree of quality and moderate exposure conditions to achieve desired target strength and durability. The mix proportions were measured by means of weight ratio and the unit of the mix proportions are in terms of kilogram (kg).The mix Designations are for 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% are denoted as M1, M2, M3, M4, M5, M6, M7, M8, M9, M10 and M11 respectively

3. Test specimens and test procedures:

The concrete cube specimen of size 150 x 150 x 150 mm were used as a test specimen to conduct the water absorption test, Acid resistance, Alkaline resistance test and cylindrical specimen of size 100 mm diameter and 200 mm height for impact resistance, 100 mm x 100 x 100 mm size concrete cubes for abrasion resistance test and 100 mm diameter 50 mm thickness cylinders for sorptivity test were casted and cured for the respective number of days for the tests. The ingredients of concrete were mixed properly in concrete mixer machine till the uniform consistency was achieved. The specimen were properly compacted well on a vibrating table and then properly cured before the sample is taken out from the curing tanks and the samples were properly cleaned and dried to atmosphere temperature so as to get the most accurate results.

3.1 Durability tests:

3.1.1 **Water absorption test**: Water absorption test is conducted as per ASTM C 642-97 **[17]**, by oven drying method. The concrete cube specimens are kept immersed in water for 28days for curing. Then the specimen was taken from the curing tank and air dried in atmosphere to remove the surface moisture then the initial weight of the sample in taken as W_1, the final weight of the specimen W_2 is noted after oven dried at 110 ^oC to 24 hours and allowed to cool at room temperature. Figure (1) shows the experimental setup of the water absorption test.

Figure (1): Experimental setup of the water absorption test.

3.1.2**: Rapid chloride permeability test:** The influence of Chloride ion penetration were assessed using the RCPT test as per ASTM C-1202 **[18]**. The concrete specimen of size 100 mm x 50 mm is casted properly and cured for 28 days, 90 days and 180 days for the test. The specimen were connected to 60 V, DC electrical potential for 6 hours with one head is immersed in 0.5 N sodium chloride solution and the other end in immersed in 3 % sodium hydroxide solution. The charge passed through this cell in coulombs for concrete specimen were determined and used to evaluate the chloride ion penetration values of the specimen and compared the results with standards. Figure (2) shows the rapid chloride permeability test setup.

Figure (2): Rapid chloride permeability test setup.

3.1.3. **Sorptivity**: The sorptivity of the concrete specimen for M40 and M50 grade concrete of size 100 mm diameter and 50 mm thickness cylindrical specimen is calculated as per ASTM C – 1585 **[19]**. In this present experimental study, the test for sorptivity was conducted on the specimen by immersing them in water and measuring the gain in mass at regular interval of 30 minutes duration over the period of 2 hours. Figure (3) shows the sorptivity test set up used in the experimental studies.

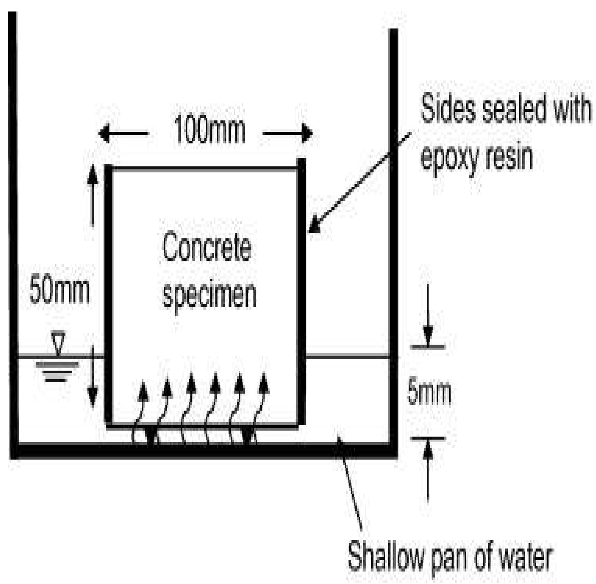

Figure (3): Sorptivity test set up.

3.1.4. **Acid resistance**: The acid resistance test was conducted for the concrete cube of size 150 x 150 x 150mm size. The initial dry weight of sample is weighed and the value is W_1. Subsequently, concrete specimen immersed in water diluted with 5 % sulfuric acid by weight of water for acid resistance test for 28 days, 56 days, and 90 days. The strength of sulfuric acid is verified continuously during the period of the test. Subsequent to curing in sulfuric acid solution for pre-determined days, the samples were taken out and weighed, and the weight is noted as W_2. The percentage loss of weight is then calculated. Figure (4) shows that acid resistance test setup.

Figure (4): Acid resistance test setup.

3.1.5. **Alkaline resistance**: The alkaline resistance for the concrete sample for M40 and M50 was experimentally conducted for the concrete cube of size 150 mm x 150 mm x 150 mm.The initial weight of specimen is taken as W_1 then sample at 5% sodium sulfate solution for 28 days, 56 days, and 90 days. The pH value of sodium sulphate solution is properly maintained at 12 for the complete duration of the test. For the test the specimen is taken from the solution and washed properly with tissue paper and kept in atmosphere for constant weight, then weighed the specimen and the weight is noted as W_2. The percentage of weight loss due to sulphate attack/alkaline attack is then calculated and presented. Figure (5) shows that alkaline resistance test setup.

Figure (5): Alkaline resistance test setup.

3.1.6. **Impact resistance test**: As per ACI Committee 28-89 **[20]**, the impact resistance of the concrete sample of size 100 mm dia meter x 64 mm thickness were carried out using drop weight hammer testing machine. The specimen were kept on the base plate and centered. A drop weight of 45 N was used to apply as impact load. The number of blows required by dropping a hammer at a height of 457 mm to cause initial and the final failure of concrete samples were recorded. The test was conducted for the conventional sand concrete, 100% manufactured sand concrete and the optimal replacement of concrete and reported.

3.1.7. **Abrasion resistance**: As per ASTM C-944-99 **[21]**, the abrasion resistance of concrete specimen of size 100 mm x 100 mm x 100 mm was carried out using the abrasion testing machine. This abrasion of concrete surface may occur due to abrasion by sliding, scraping or the action of abrasion materials carried out by water. Generally Abrasion resistance is an important factor in highway rigid pavements, bridges etc. Test was conducted by allowing the testing machine to rotate for 300 revolutions by keeping the speed of the machine as 30 revolution per minutes. The initial weight of specimen is W_1 and after 300 revolution the final weight is W_2 and weight loss in percentage is then calculated and reported as abrasion resistance of the concrete.

4. Results and discussions:

The test results for the durability characteristics of the concrete of Grade M40 and M50 were studied for the following durability properties and discussed. The result obtained for manufactured sand were compared with conventional sand concrete.

Water absorption: It has been observed that the water absorption for the concrete mix of M40 and M50 grade with manufactured sand concrete are lower than the conventional sand concrete Figure (6) shows the water absorption values of M40 and M50 Grade concrete at 28 days and the results shows the values of manufactured sand concrete is decreasing due to micro filter effect of the fines percent in manufactured sand.

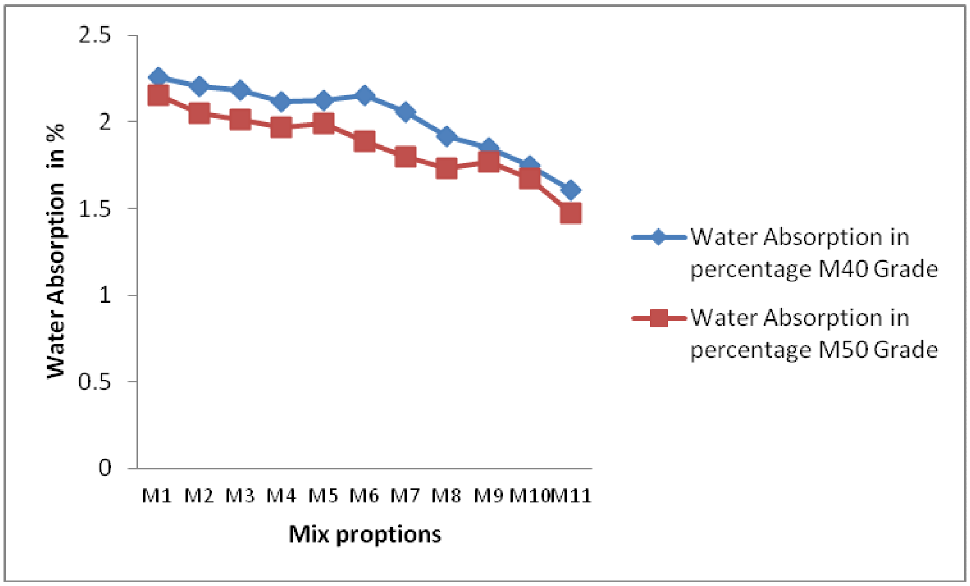

Figure (6): Water absorption test for M40 and M50 grade concrete.

Rapid chloride permeability test:

The RCPT test is performed for concrete of grade M40 and M50. The test results showed that the concrete of 28 days, 90 days and 180 days the charge passed in the concrete specimen are decreasing as the percentage of manufactured sand is increasing up to 100% replacement. The permeability of conventional sand and up to 20% replacement of sand is in moderate zone and beyond which the permeability of manufactured sand concrete shows low permeability zone for M40 concrete and for M50 concrete it shows low permeability zone in both concretes. This is due to proper particle size and fines percent in M sand; resulting the lesser the permeability of manufactured sand than the conventional sand concrete. Figure (7) shows that the RCPT values are decreasing in trend for manufactured sand than the conventional sand.

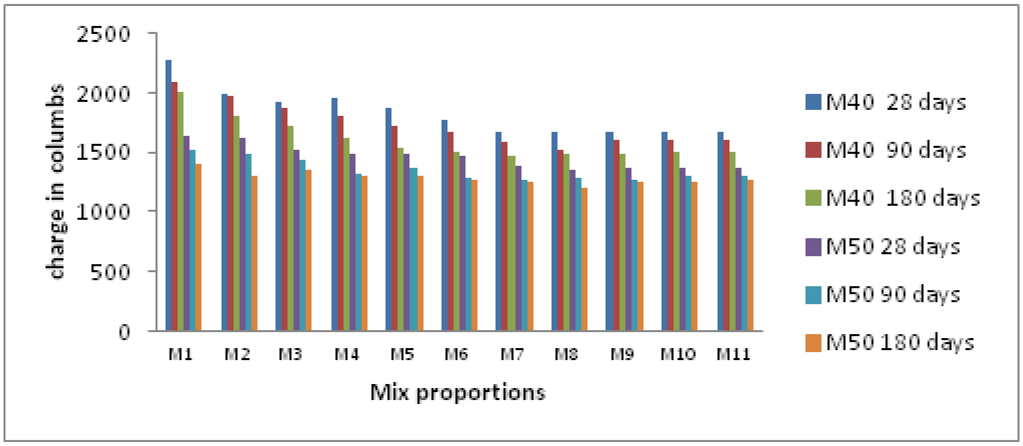

Figure (7): RCPT values for M40 and M50 grade concrete.

Sorptivity: It has been observed from figure (8) that, the sorptivity of the concrete with manufactured sand is lesser than the conventional sand concrete up to the optimum percentage of replacement of the natural sand with manufactured sand. Complete replacement of conventional sand also gives lesser value than the conventional sand concrete. Hence, our results indicate that manufactured sand has better performance in sorptivity test also.

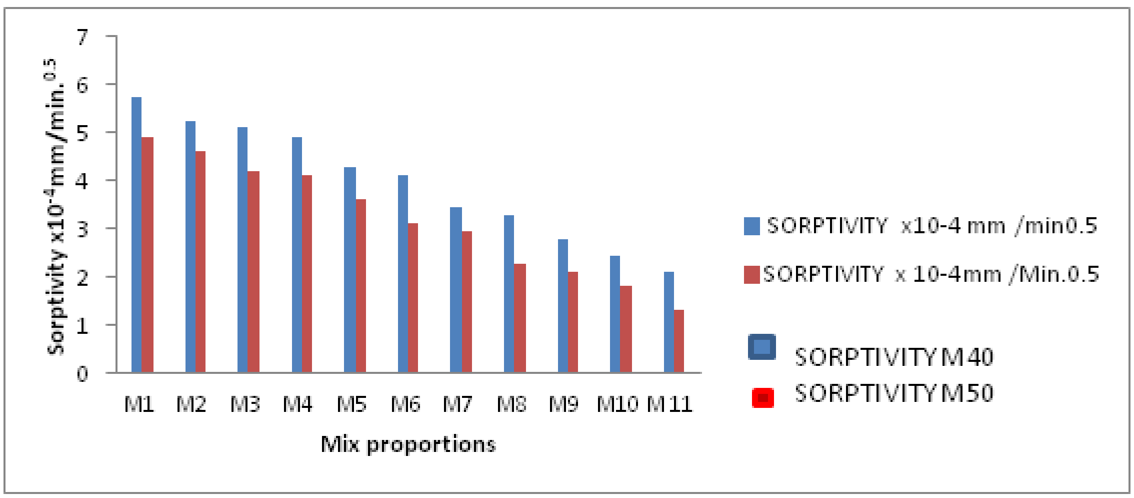

Figure (8): Sorptivity values for M40 and M50 grade concrete.

Acid resistance: The loss of weight due to sulfuric acid attack was conducted and shows that the loss of weight is lesser in manufactured sand concrete than the conventional sand concrete. Figure (4) shows that the loss of weight in concrete due to acid attack for M40 and M50 grade of concrete at 28 days ,56 days and 90 days concrete. It is observable from Figure (9) that the durability of manufactured sand concrete under acid attack is higher than the conventional sand concrete.In other words Manufactured sand concrete is more Acid resistace than the natural sand concrete.

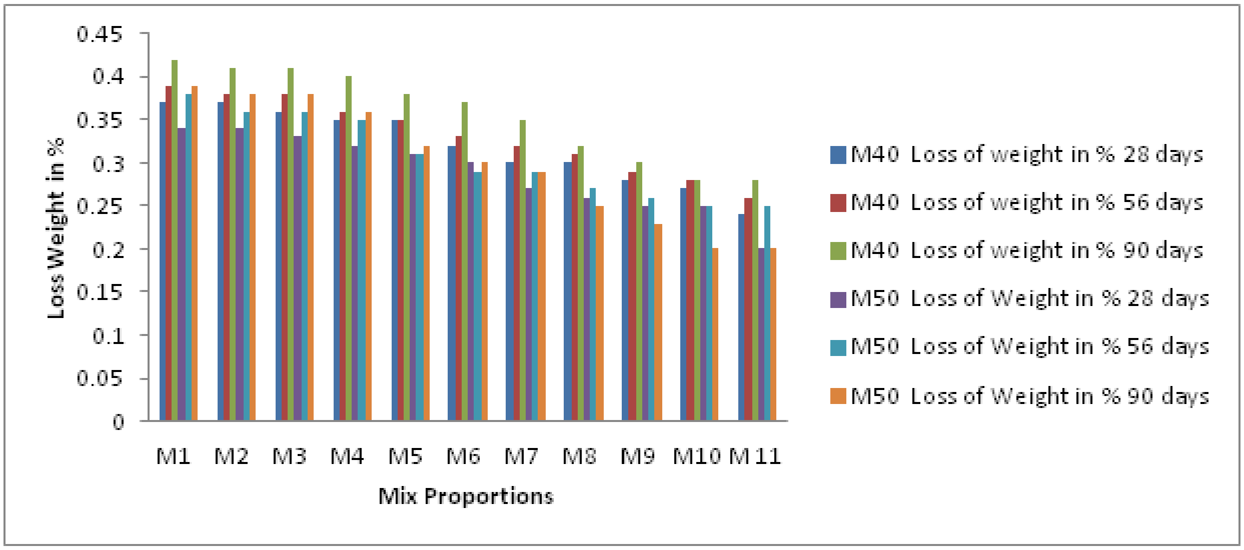

Figure (9): Acid resistance in concrete for M40 and M50 grade.

Alkaline resistance: The loss of weight due to sodium sulphate solution is lesser in manufactured sand concrete than the conventional sand concrete. Figure (10) shows that the sulphate resistance for M40 and M50 grade of concrete. From the figure, the percentage of loss of weight has been observed that the sulphate resistance of manufactured sand concrete is lesser than the conventional sand concrete and it is inferred that the alkaline resistance of manufactured sand concrete is more durable than the conventional sand concrete.

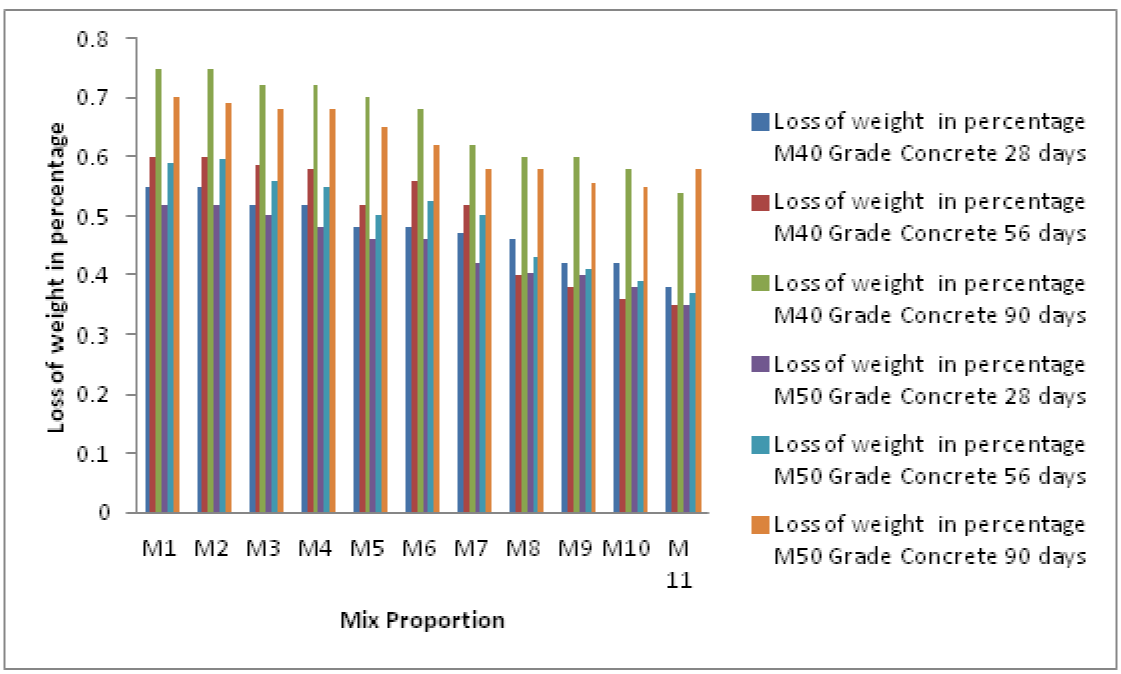

Figure (10): Alkaline Resistance for M40 and M50 Grade of Concrete.

Impact resistance:

The results shows that the average number of drops at failure from the impact resistance test for M40 and M50 grade of concrete that the mix containing manufactured sand have higher impact energy and resistance than the conventional sand concrete. Figure (11) shows that the results obtained experimental investigation of impact energy for concretes of grade M40 and M50.

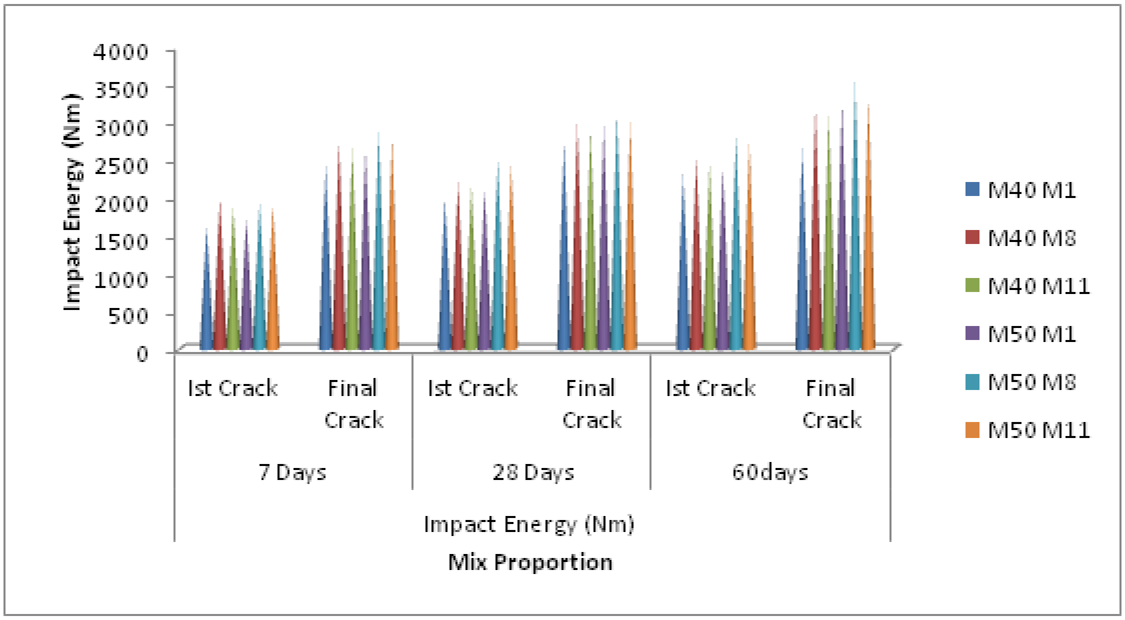

Figure (11): Impact resistance of the concrete of grade M40 and M50.

Abrasion resistance: From the Table (3) the results shows that the loss of weight due to abrasion for M40, M50 concrete grade with manufactured sand concrete is lesser than the conventional sand concrete. That is the concrete with manufactured sand is more abrasion resistance than the natural sand concrete.

Table 3. Abrasion Resistance of concrete for grade M40 and M50

Sl No.	Mix	Mix Designation	% of Where
1	M40	M1	0.20
2		M8	0.10
3		M11	0.12
4	M50	M1	0.10
5		M8	0.00
6		M11	0.00

5. Conclusions

From the above experimental data and analysis of the results shows that the increase in percentage of replacement with manufactured sand concrete improves the durability properties up to the optimum replacement. This is due to the fines and micro fines present in the manufactured sand and provide good cohesiveness for concrete. Beyond the optimum replacement also manufactured sand produces good durability than the conventional sand concrete and manufactured sand qualifies and proved the physical properties as per Indian standards and specifications, and cost of M sand is cheaper than the natural sand.

- Use of manufactured sand for concrete of grade M40 and M50, shows the lesser water absorption than conventional sand concrete and the use of lower water binder ratio resulted in impermeable concrete.

- Concrete with manufactured sand shows lesser chloride ion penetrability than the conventional sand concrete, which shows that lesser permeability with manufactured sand in concrete.
- Concrete mixes containing manufactured sand shows higher acid resistance, alkaline resistance than the conventional sand concrete. That is the loss of weight due to acid attack and alkaline attack is lesser in manufactured sand concrete than the conventional sand concrete.
- Manufactured sand concrete have more impact resistance and abrasion resistance than the conventional sand concrete.

From the above results provides strong support for using the manufactured sand as fine aggregate in concrete construction for sustainable developments, and it can also be concluded that the replacement of conventional sand with manufactured sand as 100% replacement in concrete construction is also possible by considering the above durability characteristics of the manufactured sand concrete. From the well planned and carefully performed experimental programs, the full replacement of natural sand with manufactured sand encouraged by considering the technical, commercial and environmental factors.

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