Study on sea sand as a partial replacement for fine aggregate

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ABSTRACT

Sand researches around the world are in continuous search for the alternatives of sand. Fine aggregate is an important constituent of concrete and is required in large quantities. Generally, river sand is used as fine aggregate. Due to the increase in the utilization of concrete in construction sector, the need for river sand has been increased enormously. Hence, the abundant sea sand can be used as an alternative of river sand partially.The sea sand samples before (samples A and C) and after mineral extraction were utilized to replace for fine aggregate. The mineral extracted chiefly includes ilmenite, zircon, rutile, sillimanite and super garnet was confirmed by an analytical technique Energy-dispersive X-ray analysis (EDXA). Physical properties of these sands were recorded. Results reveal that the angle of internal friction (Ø) was high and low in sample A and C, but an opposite trend was observed for specific gravity. Except sample D, remaining samples belong to grade II size. Concrete cubes were laid for M35 grade concrete with the combinations of the above samples. The fine aggregate proportion from the design mix was replaced partially by 20% of sea sand. Compressive strength test and pull out test and the behaviour of concrete were conducted on the various soil specimens and the results were tabulated. The strength tests were conducted at 7, 14 and 28 days of water curing. Compressed strength, band strength as well the weight $kg^{-1}$of the concrete did not affected by replacement of either sample A (10%) or sample B (20%). Proposed replacement is economically cheaper. Considering laboratory studied, we recommended to utilized sea sand for partial replacement for fine aggregate.

Keywords: Fine aggregate, sea sand, minerals, concrete, strength

1. INTRODUCTION

Fine aggregate is one of the important constituents of concrete and mortar in construction industry (Mehta and Monteiro, 1993). River sand is becoming a scarce material. Sand mining from our rivers has become objectionably excessive. It has now reached a stage where it is killing our rivers day by day. As natural sand deposits have become depleted near some areas of metropolitan growth, the use of alternatives to sand as a replacement for fine aggregate in concrete is receiving increased attention. As a solution for this, various alternatives are explored and used in many parts of the world. They include: manufactured sand (M sand) (Sudha et al., 2016), processed quarry dust, Sea sand (Chandrakeerthy and De, 1994; Dolage et al., 2013; Sai Deepak and Tirupathi Naidu, 2015; Kumar et al., 2016; Subashini et al., 2016), Dune sand (Al-Harthy et al., 2007), Copper slag sand (Al-Jabri et al., 2009; Mithun and Narasimhan, 2016), Fly ash (Rafieizonooz et al., 2016), bottom ash (Singh, Malkit, and Rafat Siddique, 2016), pond ash, powered glass, aluminium saw mill waste and construction demolition waste etc (Satish Kumar *et al.,* 2016).

Literature reveals that sea sand has been recommended and usable for the construction purposes (Newman , 1968; Limeira *et al.,* 2011; Huiguang et al., 2011; Sukumaran et al., 2010; Sai Deepak and Tirupathi Naidu, 2015; Subashini et al., 2016). Earlier literature study revealed that the partial replacements of fine aggregate by sea sand in percentages of 20%, 40%, 60%, 80% and 100% resulted in successive reduction in the characteristic compressive strength of concrete (Kumar *et al.,* 2016). Further, it was stated that 20% replacement was found to be effective and gained more strength compared to the other percentages.Hence this effective percentage of 20% was chosen and mixed with 80% of river sand (Sai Deepak and Tirupathi Naidu. 2015). This paper reports the experimental study which investigated the influence of 20% replacement of river sand with sea shore sand and mineral extracted sand separately. These results are compared with those of 100% river sand.

The alternative we have chosen for our project is sea sand, the reason being it is available in abundance. Our project deals with the use of sea sand both before and after mineral extraction and comparing their test results with river sand. The ultimate objective of this research is to study the practical utilization of sea sand as fine aggregate partially and to study the properties of mineral extracted sea-shore soil. It also includes thedetermination of the strength of concrete with sea sand, as fine aggregate as partial replacement.

2. Materials and methods

The sea sand samples were collected from Kuthenkuly (8.2162° N, 77.7803° E), Tirunelveli district of Tamil Nadu, India. Sample A which is yellowish white in colour was collected from the beaches. Sample C which is black in colour is collected from the shore where the progression of wave is high. The samples A and C were processed and after mineral extraction the extracted soil sample is Sample B. This Sample B is mixed with the local barren lands and the sample so obtained is Sample D. Sample A and sample C (before mineral extraction) and sample B and sample D (after mineral extraction). The mineral composition of the sand was analysed by Energy-dispersive X-ray analysis (EDXA). Composition of Concrete

Cube are: 1) standard (river sand -100%), 2) test material 1 [sample A (10%), sample C (10%), river sand (80%)], 3) test material 2 [sample B (20%) and river sand (80%)], and test material 3 [sample D (20%) and river sand (80%)]. An OPC 43 grade Chettinad cement was used for this study. The physical properties of the cement used ere found based on the respective IS a code is presented in Table 1.In addition, chemical composition, consistency, initial setting and final setting times were recorded. 20% of these samples were mixed with 80% of river sand and the sieve analyses testes were carried out with standard protocol (BIS Standard). They were casted into concrete cubes of M35 grade concrete. After 7, 14 and 28 days of water curing, the concrete cubes were tested for compressive strength test and pull out test with standard procedures as mentioned below. Aggregates are used in concrete to provide economy in the cost of concrete. They act as filler only. These do not react with cement and water.But there are properties or characteristics of aggregate which influence the properties of resulting concrete mix is presented in table 1. Two types of sand were used in the study. In the first case, the ordinary river sand used in concrete production was used. In the second case, sea sand before and after mineral extraction was used for the study. They were subjected to sieve analysis, specific gravity test

Sieving is performed by arranging the various sieves one over the other in the order of their mesh openings the largest aperture sieve being kept at the top and the smallest aperture sieve at the bottom. A receiver is kept at the bottom and a cover is kept at the top of the whole assembly. The soil sample is put on the top sieve and the whole assembly is fitted on a sieve shaking machine. The amount of shaking depends upon the shape and the no of particles. At least 10 minutes of shaking is desirable for soils with small particles. The portion of the soil sample retained on each sieve is weighed. The percentage of soil retained on each sieve is calculated on the basis of the total mass of the soil sample taken (1-5 kg) using the following formula:

Fineness modulus = Sum of cum. % of aggregate retained upto 150mm / 100

According to Indian Standard Code IS: 460-1962 (Revised), the sieve number is the mesh width expressed in mm for large sizes and in microns for small sizes.

To design the concrete mix, specific gravity of aggregate is essential one, it is necessary for calculation of yield of concrete or the quantity required for a given volume of concrete.

Specific Gravity = Weight of solid material excluding pores / Weight of an equal volume of gas free distilled water

Specific Gravity = $(W_2 – W_1) / (W_2 – W_1) - (W_3 – W_4)$

where,

W_1 = empty weight of specific gravity bottle

W_2 = Weight of 1/3 fine aggregate in the bottle

W_3 = Weight with full water + coarse aggregate

W_4 = Weight with full water only

Furthermore, physical properties such as colour, angle of internal friction (Ø) (AIF) and aapparent cohesion (c) (AC) of the sea sands was recorded as per (Reference).

The mix design for the control specimens was done based on IS: 10262-1982. The water to cement ratio taken was 0.4. The compressive strength and bond strength of concrete depends on the properties of the materials used in the concrete. In general the various requirements of concrete are strength, workability and economy. Based on the physical properties of the materials used in the concrete mix design was done. For the present study two trial mixes with different proportioning were laid and the one with better economy and workability was selected for the study is presented in table 2.

2.1 Properties of Concrete

2.1.1 Slump Cone Test for fresh concrete

Concrete is placed as per mix design. The freshly concrete is filled in a clean slump cone in four successive layers. 25 tamping is given for each layer properly before adding another layer. Excessive concrete is strike off with a trowel from the top of the mould after the final layer has been tamped. The cone is then removed immediately by raising it slowly and carefully in the vertical direction. The settlement or subsidence (slump) i.e., difference between the height of the slump mould and the highest point of the subsidized concrete cone] in cone measured as soon as it comes to stop.

2.1.2 Hardened concrete

2.1.2. a Cube Compressive Strength Test

For cube compression testing of concrete, 150 mm cubes were employed. All the cubes were tested in saturated condition, after wiping out the surface moisture. For each mix 2 cubes were tested at the age of 7 days, 14 days and 28 days of curing using 400 tonne capacity compression testing machine as per BIS:516-1959. The tests were carried out a uniform stress after the specimen has been centered in the testing machine. Loading was continued till the dial gauge needle just reverses its direction of motion. The reversal in the directions of motion of the needle indicates that the specimen has failed. The dial gauge reading at that instant was noted, which is the ultimate load. The ultimate load divided by the cross sectional area of the specimen is equal to the ultimate cube compressive strength.

2.1.2. b Pull Out Test

A pull out test measures the force required to pull out from the concrete a specially shaped rod whose enlarged end has been cast into that concrete. The stronger the concrete, the more is the force required to pull out. The ideal way to use pull out test in the field would be to incorporate assemblies in the structure. These standard specimens could then be pulled out at any point of time. The force required denotes the strength of concrete. Another way to use pull out test in the field would be to cast one or two large blocks of concrete incorporating pull out assemblies. Pull out test could then be performed to assess the strength of concrete. Pull-out tests were carried out using the Universal Testing Machine by changing the position of the cube. Cube was placed in such a manner that pull-out test can be performed effectively. The length of reinforcement was increased to 500 mm where 150 mm was embedded in the cube. The bars were passed through the hole present in the deck and then clamped at the jaws present at the top. Hence proper tensile forces were transferred uniformly through the cube.

After completion of curing period of cubes, they were attached to the UTM machine. The reinforcing bar was held by the jaws present on the middle deck. Before loading, the system was brought in equilibrium by adjusting the distance between the upper deck and middle deck with the help of Non-Loading motor. This was done to nullify the effect of self-weight of the cube. The rate of loading of UTM was set to 2250 kg/min. Then loading was started and recording of loads was carried out. The machine automatically stops when no resistance is offered by the specimen to the tensile force being applied i.e. when specimen has failed. After completion of test, samples were removed from the test setup, and physical verification of crack and type of slip were observed. The pull-out load is then converted into bond stress based on the embedment length and reinforcing bar diameter.

Stoical analyses

Sieve size between river sand alone and along with sea sand combinations were subjected to One-way analysis of variance and its significant was expressed at 5% using SPSS software.

3. RESULTS AND DISCUSSIONS

3.1 Physical properties of Cement

In the present study an Ordinary Portland chettinad Cement (brand name) (OPC 43 grade- conforming to BIS:12269-1987) was used. The physical properties of the cement tested according to Indian Standard procedure confirms to the requirements of IS:12269 and the physical properties are: specific gravity (3.04), initial (85 minutes) and final (165 minutes) setting times and standard consistency is 30%. Chemically the chettinad Cement consists of $3CaO.SiO_2$, $2CaO.SiO_2$, $3CaO.Als.O_3$ and $4CaO.AlO_3Fe_2O_3$ confirming BIS: 4031-1988 and BIS: 4032-1985 standard. The consistency of the cement was 30%.

3.2 Physical property of Sea sand

Sample A which is yellowish white in colour was collected from the beaches. Sample C is black in colour which is collected from the shore where the progression of wave is high. The samples A and C were processed and after mineral extraction the extracted soil sample is Sample B which is also light yellow. This Sample B is mixed with the local barren lands and the sample so obtained is Sample D and hence it is red in colour. Sample A and sample C (before mineral extraction) and sample B and sample D (after mineral extraction).

3.3 Elemental composition by Energy Dispersive X-Ray Spectroscopy (EDXA)

SiO_2 was found to be in abundance in all the four samples. Despite the presence of SiO2 in all the samples, silica was found to be predominant in sample A, Titanium was found to be predominant in Sample B, Calcium was found to be predominant in Sample C and Aluminium was found to be predominant in Sample D (Table 3). Sillimanite was found to be 3.6% in sample C which acts as a good resistance to spalling, thermal shock and chemical corrosion. It also provides high mechanical strength and low thermal expansion.

3.4 Sieve Analysis

River sand consists of more fine sand (76.0%), than medium sand (23.0%) and coarse sand (1.0%). Its fineness modulus is 2.924. Sample A + sample C + river sandsample consists of more percent of medium sand (63.3%), followed by fine sand (20.7%), coarse sand (4.4%) and clay and silt (1.0%) (Figure 1). However, sample B + river sand sample consists of more percent of fine sand (74.85%) followed by medium sand (22.15%), clay and silt (2.0%) and coarse sand (1%) (Figure 2). Similarly, the sample D + river sand sample consists of more percent of fine sand (72.55%) followed by medium sand (23.0%), clay and silt (2.45%) and coarse sand (2%) (Figure 3). But invariably all samples lies in zone- III as per BIS code 383-1970. One-way analysis of variance between river sand alone and along with sea sand combinations were insignificant (df3,12; F= 0.01; p= 0.998550).

3.5 Specific gravity and Direct shear values

Specific gravity of the sample C was very high (4.420) than sample D (3.960), sample B (3.030), sample A (2.900) and river sand (2.660). The Shear Box Test was carried out to determine the soil shear strength parameters (cohesion "C" – AC and angle of internal friction "Ø"-AIF) of the sea san. The strength of sand is usually characterized by the peak friction angle Ø and the critical state friction angle Ø or anyone. We considered internal friction of the soil in the present study to evaluate the strength of the sea sand. AIF was high in sample A, followed by sample D, B and C. However, specific gravity and Apparent cohesion (c) was low in sample A. Except sample D all other samples were belongs to size III zone. Specific gravity of samples was almost same (Table 4).

3.6 Cube compressive strength

Results for the compressive strength of concrete cubes on 7 days, 14 days and 28 days with 20% replacement of river sand with sea sand was compared with the results of 100% river sand and are presented in table 5.From the 7 days compressive strength test results, it is observed that the variation in compressive strength is from 30.956N/mm^{2}to 38.368 N/mm^2. Considering the target mean strength, there is about 16% reduction in river sand compressive strength, 28.4% reduction in sample D compressive strength, 21.4% reduction in sample B compressive strength and 11.28% reduction in sample A+C compressive strength. Also, the compressive strength of river sand is reduced by 5% compared to the compressive strength of sample A+C.Statistical comparison between compressive strength and weight of the concrete on 7th day (df1,6; F=267.08; p <.0001), 14th day (df1,6; F=267.08; p <.0001) and 28th day (df1,6; F=267.08; p <.0001) were significant

From the 28 days compressive strength test results, it is observed that the variation in compressive strength was ranged from 39.676N/mm^{2}to 44.908 N/mm^2. However, it was only 41.7% in Japan condition (Dong et al., 2016).Considering the target mean strength, there is about 4% increase in river sand compressive strength, 8.26% reduction in sample D compressive strength, 3.5% increase in sample B compressive strength and 3% increase in sample A+C compressive strength. Also, the compressive strength of sample A+C is reduced by 0.97% compared to the compressive strength of river sand and the compressive strength of sample B is reduced by 0.48% compared to the compressive strength of river sand. However, Sai Deepak and Tirupathi Naidu (2015) reported that replacement of 20, 40, 60 and 80% sea sand the compressive strength (MPa) was 18.29, 17.15, 15.32 and 14.08% respectively. In another study, it was reported that the compressive strength of Partial River and sea sand was 19.8-19.9% (Subashini *et al.,* 2016). Compressed strength (CS) standard and 10% sample A replacement and sample B 20% replacement were almost equal. However, CR was deceased 11.66% while sample D was replace 20%. Further, the statistical comparison between compressive strength and weight of the concrete on 7th day (df1,6; F=267.08; p <.0001), 14th day (df1,6; F=277.56; p <.0001) and 28th day (df1,6; F=753.02; p <.0001) were significant. Sea sand-based congregate has been recommended in different parts of the world (Huang, 2007; Nong, 2008; Jiang et al., 2015; Li *et al.,* 2016), we also suggest to partially replace the river sand with sea sand. Further, Jianghong *et al.* (2016) suggested methodology to enhanced the durability of sea sand-based concentre.

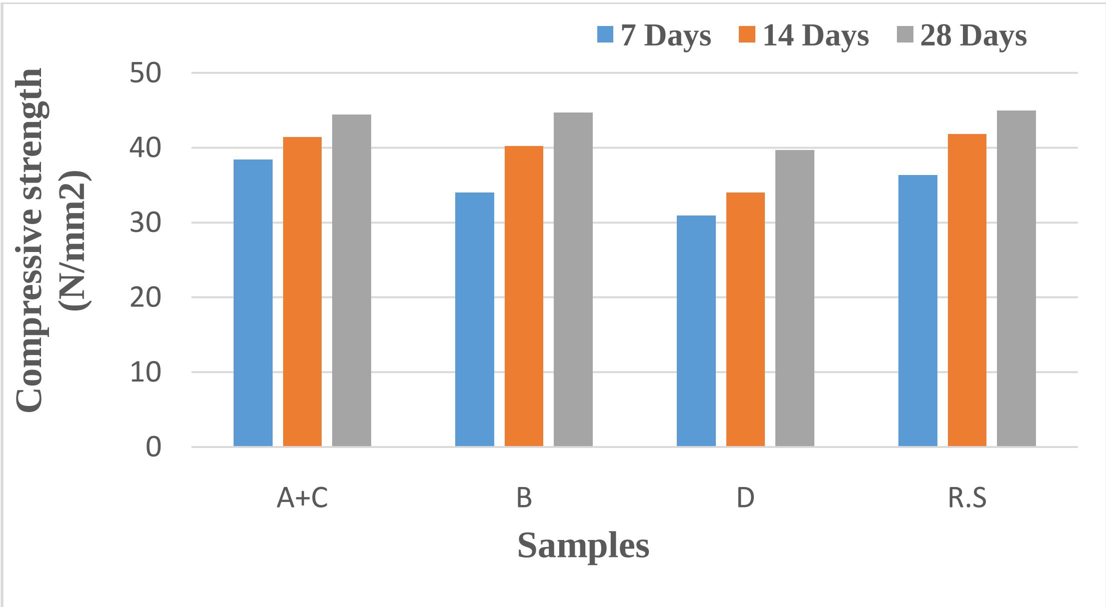

Fig 1 Compressive strength

3.7 BOND STRENGTH

Newman (1968), Limeira et al. (2011); Huiguang et al. (2011) proposed to utilize sea sand for concrete. The test results for the bond strength of concrete cubes on 7 days and 28 days with 20% replacement of river sand with sea sand was compared with the results of 100% river sand and are presented in table 6. From the 7 days bond strength test results, it is observed that the variation in bond strength is from 7.074 N/mm^2 to 7.816 N/mm^2. Considering the target strength, there is about 6.2% increase in river sand bond strength, 3.89% reduction in sample D bond strength, 2.93% increase in sample B bond strength and 4.28% increase in sample A+C bond strength. Also, the bond strength of river sand is increased by 1.80% compared to the bond strength of sample A+C.

From the 28 days bond strength test results, it was observed that the variation in bond strength was between 8.311 N/mm^2 to 9.815 N/mm^2. Considering the target strength, there is about 8.81% increase in river sand bond strength, 7.86%

reduction in sample D bond strength, 5.38% increase in sample B bond strength and 6.85% increase in sample A+C bond strength. Also, the bond strength of river sand is increased by 1.80% compared to the bond strength of sample A+C. The band strength of sea san concrete was varied between 15.03 -18.67 (Zhiqiang Dong *et al.,* 2016). Previous studied indicated that band strength is mainly controlled by the outer FRP layer (Micelli and Nanni, 2004; Robert and Benmokrane, 2010).Statistical comparison between compressive strength and weight of the concrete on 7^{th} day (df1,6; F=15.55; p = 0.007595) and 14^{th} day (df1,6; F= 16.48; p = 0.006654) were significant, but on 28^{th} day (df1,6; F=0.31; p = 0.597819), it was insignificant.

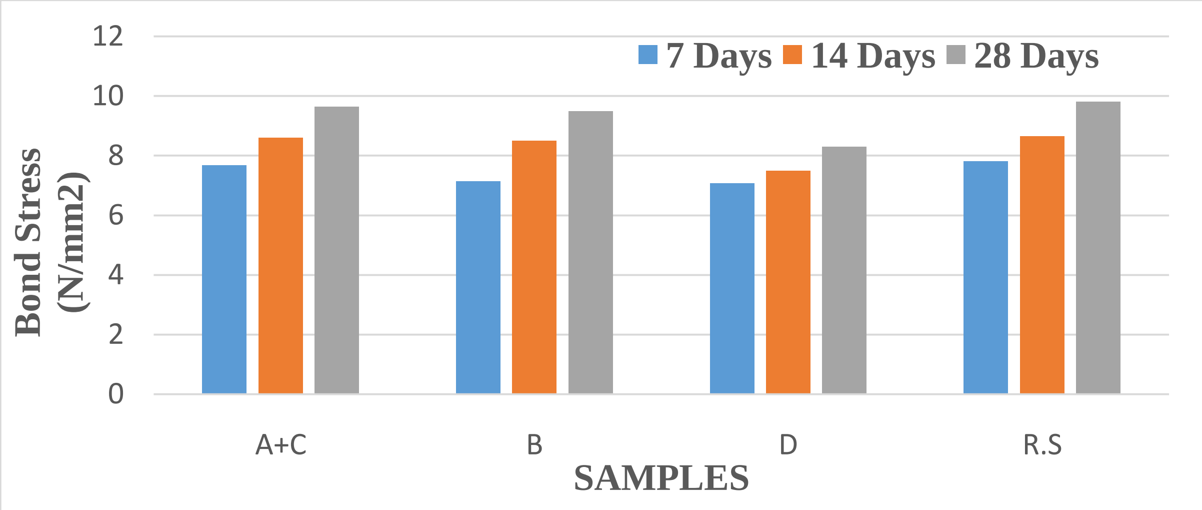

Fig 2 Bond strength

3.8 Economy

Considering the economic point of view, the cost of 1unit river sand is about Rs.5750. The total quantity of fine aggregates required for six concrete cubes is about $0.36m^3$($1m^3$= Rs.2032) which costs about Rs.731. After the 20% replacement of sea sand, the remaining 80% of river sand has a quantity of $0.29m^3$which costs about Rs.585. Hence, a reduction of about Rs.146 for $1m^3$of concrete has been obtained.

4 CONCLUSION

It was concluded from our results that 20% of the fine aggregate used in concrete production can be effectively replaced with sea sand. Overcomes the future demand in the requirement of the river sand in construction, most local sea sands are suitable for concrete production. Site locations can be found where sea sand mined can be used directly without washing. Most sea sands can be used after wasShing to remove salt contaminations. The performance of river sand was far better than sea sand.Sea sand after mineral extraction have higher strength values by 0.5% compared to the sea sand before extraction to reduce the cost. This also proves to be a good solution for the disposal of a solid waste as it is recycled without affecting the environment. Advantages proposed by Chandrakeerthy (1994) and also our observations we suggested utilizing sea sand for concrete.

5 REFERENCES

1. Al-Harthy, A. S., Halim, M. A., Taha, R., & Al-Jabri, K. S. (2007). The properties of concrete made with fine dune sand. *Construction and building materials*, *21*(8), 1803-1808.
2. Al-Jabri, K. S., Hisada, M., Al-Oraimi, S. K., & Al-Saidy, A. H. (2009). Copper slag as sand replacement for high performance concrete. *Cement and Concrete Composites*, *31*(7), 483-488.
3. Chandrakeerthy SRDeS. 1994. Suitability of sea sand as a fine aggregate for concrete production, Transactions, Institution of Engineers, Sri Lanka. 1994:93-114.
4. Chandrakeerthy, S.R.De S., 1994. Suitability of Sea Sand as a Fine Aggregate for Concrete Production. 01, P 93-114
5. Dolage, D. A. R., Dias, M. G. S. and C. T. Ariyawansa, “Offshore Sand as a Fine Aggregate for Concrete Production”, British Journal of Applied Science & Technology, 3(4): 813-825, 2013.
6. Dolage, D. A. R., Dias, M. G. S. and C. T. Ariyawansa. 2013. Offshore Sand as a Fine Aggregate for Concrete Production. *British Journal of Applied Science & Technology* 3(4): 813-825.
7. Dong, Z., Wu, G., & Xu, Y. (2016). Experimental study on the bond durability between steel-FRP composite bars (SFCBs) and sea sand concrete in ocean environment. *Construction and Building Materials*, *115*, 277-284.
8. Huang, H.X. 2007. An experimental study on the durability of sea sand concrete, Master thesis, Jinan University, Jinan, China (in Chinese).
9. Huiguang Y, Yan L, Henglin L, Quan G. 2011. Durability of sea sand containing concrete: Effects of chloride ion penetration. *Mining Science and Technology (China),*21:123-127.
10. IS 10262-2009 : Concrete mix proportioning – Guidelines
11. IS 2770 (Part 1) -1967 : Methods of testing bond in reinforced concrete (Pull-out test)

12. IS 383 (1970) : Specification for Coarse and Fine Aggregates from Natural - Sources for Concrete
13. Jiang, Y., Liu, J. Z., Sun, W., Zheng, C. Y., & Wu, S. Y. 2015. Study on the properties of sea sand concrete with Fly Ash. In *Advanced Materials Research,* 1065: 1854-1857.
14. Jianghong, M. A. O., Weiliang, J. I. N., Hua ZHANG, C. X., & Jin, X. I. A. (2016). Technology for Enhancing Durability of Structures of Sea-sand Concrete and Its Application. *Journal of Chinese Society for Corrosion and protection*, *35*(6), 563-570.
15. Kumar, B. N. N., Kumar, P. K., Babu, E. R., Gopal, M., Reddy, D. S., Sreekanth, K., & Yellppa, U. 2016. An experimental study on sea sand by partial replacement of sea Sand in Concrete. IJSRST 2(2): 181-184.
16. Li, Y. L., Zhao, X. L., Singh, R. R., & Al-Saadi, S. (2016). Experimental study on seawater and sea sand concrete filled GFRP and stainless steel tubular stub columns. *Thin-Walled Structures*, *106*, 390-406.
17. Limeira J, Etxeberria M, Agullo L, Molina D. 2011. Mechanical and durability properties of concrete made with dredged marine sand. *Journal of Construction and Building Materials.* 25:4165-4174.
18. Mithun, B. M., & Narasimhan, M. C. 2016. Performance of alkali activated slag concrete mixes incorporating copper slag as fine aggregate. *Journal of Cleaner Production*, *112*, 837-844.
19. Mehta and Monteiro. 1993. *Concrete Structure, Properties, and Materials*, Prentice-Hall, Inc., Englewood Cliffs, NJ
20. Micelli, F., A. Nanni, 2004. Durability of FRP rods for concrete structures, Constr. Build. Mater. 18 (7) (2004) 491–503.
21. Newman K. 1968. Aspects of workability, strength, shrinkage and creep, sea dredged aggregates for concrete, Proceedings of a Symposium, Sand and Gravel Association of Great Britain, Buckinghamshire
22. Nong, R. 2008. The experimental study on mechanical properties of sea sand concrete components, Master thesis, Harbin Institute of Technology, Harbin, China (in Chinese).
23. Praveen Kumar P, Shareef NM, Gopalan CV. Marine sand resources in the south-west continental shelf of India. Indian Journal of Geo-Marine Sciences. 2010; 39(4):572–78.
24. Rafieizonooz, M., Mirza, J., Salim, M. R., Hussin, M. W., & Khankhaje, E. (2016). Investigation of coal bottom ash and fly ash in concrete as replacement for sand and cement. *Construction and Building Materials*, *116*, 15-24.
25. Robert, M., B. Benmokrane, 2010. Effect of aging on bond of GFRP bars embedded in concrete, Cem. Concr. Compos. 32 (6) (2010) 461–467.
26. Singh, Malkit, and Rafat Siddique. 2016. Effect of coal bottom ash as partial replacement of sand on workability and strength properties of concrete. *Journal of Cleaner Production* 112: 620-630.
27. Sai Deepak, W. and G. Tirupathi Naidu. 2015. Effect on compressive strength of concrete using sea sand as a partial replacement for fine aggregate.*International Journal of Research in Engineering and Technology* 4(6): 180-183.
28. Satish Kumar, D., Manjunath, L.R., Nataraja, M.C., Marutiram Kaza and Prasad, S.M.R. 2016. Urgent need for a new aggregate standard. *The Indian Concrete Journal* pp. 65-72.
29. Subashini,B. and Sivaranjani, G., 2016. Experimental Investigation of Sea Sand for Construction Purposes. *Indian Journal of Science and Technology*, 9(11), DOI: 10.17485/ijst/2016/v9i11/89400
30. Sudha, C., Ravichandran, P. T., Krishnan, K. D., Rajkumar, P. K., & Anand, A. (2016). Study on Mechanical Properties of High Performance Concrete using M-Sand. *Indian Journal of Science and Technology*, *9*(5). DOI: 10.17485/ijst/2016/v9i5/87262,
31. Subashini, B., G. Sivaranjani , G. Dhanalakshmi , K.Gayathri , A. Ashok Kumar , A. Srimathi and C. Revathi. 2016. Experimental Investigation of Sea Sand for Construction Purposes. *Indian Journal of Science and Technology,* 9(11), DOI: 10.17485/ijst/2016/v9i11/89400
32. Sukumaran PV, Unnikrishnan E, Gangadharan AV, Zaheer B, Abdulla NM, Kumaran K, Ramachandran KV, Hegde SV, Maran N, Bhat KK, Rao MK, Dinesh AC, Jayaprakash C, Zhiqiang Dong, Gang Wu and Yiqian Xu. 2016. Experimental study on the bond durability between steel-FRP composite bars (SFCBs) and sea sand concrete in ocean environment. *Construction and Building Materials* 115: 277–284.