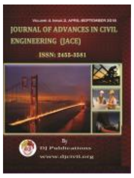
Journal of Advances in Civil Engineering, Vol. 4(2) 2018, pp. 8-14



RESEARCH ARTICLE

Behavioural Study on Treated Sea Sand as a Fine Aggregate in Concrete

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Received- 4 February 2018, Revised- 20 March 2018, Accepted- 3 April 2018, Published- 13 April 2018

ABSTRACT

In developing countries like India, the need of the essential construction material particularly sand is getting increased; but the availability of source of the sand is very less. The over collection of river sand from river beds affects our ecological cycle directly or indirectly and so instead of river sand, sea sand that is enormously present in nature at sea shores has become common. Only if the concrete has natural aggregates, the strength and durability would be enhanced. In the current scenario, most of the building agencies and MNC companies adopt artificial sand in their projects. Sea sand is less expensive and reduces the overall construction cost, which also helps to protect river sand from being destruction. It is validated using spectroscopy results that incorporation of sea sand adds strength to the structure and can be preferred for any construction purpose.

Keywords: Natural aggregates, Sea sand, Durability, Construction cost, Spectroscopy results.

1. INTRODUCTION

To avoid scarcity of river sand, this project aims to use sea sand as a fine aggregate in concrete batching. Many researchers say that using sea sand as a replacement for river sand would reduce the bonding between cement and sand because of enormous amount of silt content present in the sea sand. To avoid this problem and to attain well graded grain size, this project aims to partially add M-sand instead of river sand. So hereby we take 25% of sea sand, 25% of M-sand and 50% of river sand.

Many engineers are afraid that the chloride present in sea sand might generate corrosion in Reinforced Cement Concrete (RCC) elements; but though it cannot be completely arrested, it can be controlled to some extend by means of proper treatment of sea sand. In construction industry, in order to avoid corrosion, a few kinds of steels like stainless steel, epoxy coated steel and fiber reinforced polymer steels are used, and certain chemicals like acrylic solutions are used as a coating over the steel bars that hold the development of electro chemical reaction and reduce the level of chloride ion immersion into concrete surface [1].

1.1. Origin of the sea sand

At the time of ice age, the sea water level was 120 m lower than today. Day by day due to the movement of tectonic plates, the level has increased and 4000 years ago, the process has ended and the beaches are formed. A main constituent in sea sand is quartz (SiO_2), generally formed by volcanic eruptions. SiO_2 is extremely hard in nature and do not consist of any carbon content in it. Additionally, sea sand also contains calcite ($CaCO_3$), which has carbon atom. Its advantages are as follows,

- It is more rounded or cubical like river sand
- Available as natural deposit
- Contains no organic contaminant or silt
- Abundantly available
- Can be mined at a low cost

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Double blind peer review under responsibility of DJ Publications
https://dx.doi.org/10.18831/djcivil.org/2018021002

2. LITERATURE REVIEW

To form concrete by using sea sand, many experts say that if the sea sand is collected from 10 km away from the shore area, then the amount of chloride become less and the collected sand can be adoptable to develop the standard quality concrete [2]. Apart from concrete work, the sea sand may also be used for other constructional works like reclamation and filling during the highway project works. As per the American concrete institute and American coastal department, each individual uses 200 kg of sand annually. So next to water and cement, the need for sand is essential, particularly in civil industry. In the construction industry, 1/3 part is occupied by fine aggregate in the total concrete volume, and without it, concrete production is less possible. The amount of moisture content present in sea sand is nearly about 10% of weight of the total sea sand. It affects the mix ratio while developing the concrete mix design. Hence moisture level must be considered and has to be eliminated from sea sand using water elimination devices like hot air oven. If concrete is considered as an element, then the property of concrete is mainly based upon the constituents present in the concrete. In this project, sea sand is considered as a fine aggregate for concrete formation. So the properties of concrete like shrinkage, creep, unit weight, young's modulus, surface friction, thermal properties, etc. depend on the sea sand properties. Hence it is necessary to focus on material study apart from elemental study.

[3] A recent survey has informed that Cochin port trust, plans to dredge out 70,000 m^3 of sand slurry daily and 8 Mt of sand annually. Shell content reduces workability and strength, whereas chloride content reduces durability and strength. So these two components must be eliminated from sea sand to attain better quality concrete. If we construct a structure using steel RCC, then the chloride content in cement must be limited to 0.1% (As per IS 456:2000). If the limit exceeds, then it destroys the alkaline coating present in the steel surface leading to the formation of rust due to increase in the volume of steel reinforcement. Thus, the reinforcement loses its stability, which automatically makes the entire element to lose its load bearing capacity. Finally the entire system collapses indicated by certain warning. The sea sand containing free chloride ion would be washed away by keeping it under natural rainfall for a period of 1 year. But this is not suitable for the sea sand in which the chloride ions are physically or chemically bounded with it. In such cases, an additional requirement is needed. It has been established through the process of wet sizing and attrition scrubbing, in which the amount of chloride can be reduced from 500 ppm to 100 ppm.

Ponnani, the area located in Kerala at which the sea sand treatment is going successfully under large working area with lot of human resources, and the treated sea sand is transported to ready mix concrete plants. All these relevant works are done by the directorate of ports. After obtaining the ready mix concrete plants, the chemical engineers add small quantity of admixtures to remove the effect of minimum amount of chloride ion and check with the standard value, and finally the prepared concrete plants are supplied to nearby contractors. Through this activity, the Kerala government has made 2300 employment opportunities both directly and indirectly. Depending on the past ratio average of cement consumption in the country, the expected requirement of sand at 2020 will be about 600-650 Mt.

[4] The melting point of sea sand is 1722℃, but it can be reduced to 12900℃ by adding flux. Sea sand has high Safe Bearing Capacity (SBC). [5] Silica fume, blast furnace slag, fly ash can be used to improve the lifespan of sea sand concrete in which the pore volume can also be reduced by the silica fume. [6] Unwashed sea sand and water improves the density of concrete when compared to normal concrete. In addition to these added mixture, admixture consisting of calcium nitrate is also added to improve durability of sea sand concrete.

Table 1 shows the summation of these results. Corrosion rate has been delayed using epoxy-coated steel bars, stainless steel bars, and carbon fiber rods. Permeability co-efficient gets reduced due to density of microstructure. [7] 50% replacement of sea sand concrete does not affect its strength, but [8] 40% is considered to be the maximum limit. [9] Shell content size of fine aggregate does not exceed 5 mm since it causes not only corrosion but also results in efflorescence that acts as a water absorbing agent.

Table 1.Materials and their effect

Materials of sea sand concrete	Resultant effect
Silica fume	Increases the pore volume
Silica fume, blast furnace slag, fly ash	Improves the life span of sea sand concrete
Unwashed sea water and sand	Improves the density
Admixture comprising calcium nitrate	Adds durability

[10] The strength of concrete gets improved by enhancing the colloidal crystal. [11] Regression analysis determines the diffusion of chloride ion in sea sand concrete. When W/C ratio of sea sand concrete decreases, the penetration of chloride ion is also decreases. APT testing software is used to measure the durability (coefficient of permeability of chloride ion).

[12, 13] Letting the sea sand in the running water for 30 minutes is sufficient to remove maximum amount of soluble salts contained in it. [14, 15] After 28 days, wetting and drying tests are conducted alternatively using standard curing method by soaking in seawater and naturally drying it for 6 hours and 1 hour respectively at baking temperature (60°C) for 16 hours and finally allowed to cool for 1 hour. The presence of salt in seawater or sea sand concrete does not produce any effect on its impermeability. The obtained slag consist of large amount of active SiO_2 and Al_2O_3 which improves the hydration and quantity of gel formation, and reduce the porous of the concrete. Shrinkage rate is similar to both cases of ordinary and sea sand concrete. In this method, [16, 17] Accelerated surface area and porosimetry system has been used to find out the microstructure of solid element and x-ray diffractometer and thermal gravimetric/differential thermal analyzer has been used to observe the composition of concrete. [18] With respect to the increase in temperature, the mechanical properties of concrete are reduced [19] has presented that sea sand develops its early strength faster when compared to ordinary concrete. [20] has presented that the mechanical properties of concrete can be enhanced by the addition of flyash, silica fume and foundary sand.

[21] Normally, pouring concrete on steel reinforced mold produces an alkaline coating on its surface, and the alkaline coating is destroyed, when excess amount of chloride ions combines with concrete. If the amount of chloride is less, it does not stop the dissolving process, instead the time required to dissolve the alkaline coating gets extended resulting in the formation of rust which increases the volume of steel from 2 to 4 times. Element must be free from calcium carbonate because it generates structural issues. Drinking water consists of 0.2 g chloride ions. As per IS code, the maximum amount of chloride present in concrete structure is restricted to 2.5 g; in terms of RCC, the value is further reduced to 0.5 g for prestressed concrete structure, but zero chloride ion is never allowed. That is why deionized water is used for sand washing. If normal water is used for washing, it transfers 0.2 g of chlorine into sand. Several hybrid methods are used to combine the sea and river sand to form a single fine aggregate unit, which can be used as concrete. Corrosion inhibitors admixtures are also applied while preparing concrete. Some biological methods are available to mix the bacteria into sand, thereby removing maximum amount of chloride ions from sea sand. But this is considered to be an expensive one. Zinc coated rebar can also be used. Based on suitability and affordability, methods can be selected.

3. SCOPE OF THE STUDY

The main scope of this study is

- To concentrate on strength and durability of the concrete with replacement of 10mm fine aggregate of sea sand and 20mm coarse aggregate. In this project, the sea sand sample is taken from Vembar, Tuticorin District, and Tamilnadu, India.
- To check the behavior of sea sand in a concrete cube.
- To check the primary character of concrete element like compressive strength, water absorption, permeability of sea sand concrete cube and to compare with river sand concrete cube.

4. RESULTS & DISCUSSION

4.1. Specific gravity and fineness modulus of aggregates

Specific gravity is an important parameter during the mix design calculation of concrete. Quantity of the concrete depends mainly on the density of these constituent materials, which in turn depends on the specific gravity of the constituents. In order to achieve better quality of concrete mix it is essential to found out the specific gravity exactly. Table 2 shows the sand properties.

Table 2.Sand properties

Property	Value
Fineness modulus of River sand	2.48
Fineness modulus of Sea sand	3.80
Specific gravity of M- sand	2.60
Specific gravity of river sand	2.65
Specific gravity of sea sand	2.70
Specific gravity of coarse aggregate	2.80
Specific gravity of mixture of sand	2.65

The level of 0.1 variations in the specific gravity also leads to serious change in the total density of the materials. So care should be taken to compute the specific gravity of several aggregates and the obtained values are tabulated. Fineness modulus of aggregate gives aggregate zone, based on which the calculation can be done. As per IS code, the fine aggregate of concrete must be present in the zone II among the IV zones. Zone II satisfies the requirement of well graded size aggregate, which is used to prepare concrete. In this project, sea sand comes under zone III because of the value of fitness modulus (i.e) 3.80. By removing the fine content from sea sand and mixing with M-sand, the fitness modulus value can be changed thus changed to zone II.

4.2. Alkalinity test

As per IS code, the concrete must have a pH value of 9.5-12.5 to sustain against durability. Alkalinity test of the sand samples determines the value of pH. The obtained results show that the river sand has a pH value of 11.25, which satisfies the requirement of IS code. But untreated sea sand with a decreased pH value 8.1 does not follow the Indian codal regulations, pointing out that the acidic content of the element increases when consumed.

Increase of acidic content creates several problems to concrete structure, and hence use of untreated sea sand in RCC structure fails gradually. Similarly, the alkalinity test for the water treated and chemical treated sea sand is also performed and the value is found to be 9.5 and 10.23 respectively. Thus the results show that instead of using untreated sea sand, water washed sea sand followed by chemically treated sea sand can be used to eliminate the acidic content of the concrete structure to improve the strength and durability.

4.3. SEM ANALYSIS

Generally, Scanning Electron Microscope (SEM) image provides the surface topography of the element. This project uses these images to understand the nature of the used material and can be used to both untreated and treated sea sand. Figure 1 shows the presence of expansive salt, which must be removed and therefore the sea sand is washed with water, such that the surface is converted to a smooth layer.

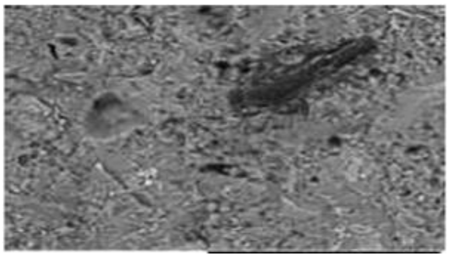

Figure 1.SEM image

This indicates that the presence of water molecule eliminates the foreign matter and durability affecting agents, thereby generating O-H bond to provide interlocking capacity for cement particles.

4.4. Chloride test

The durability of the concrete and RCC structures depends mainly on chloride present in the ingredients. According to IS 3025 (part 32), the acceptable limit for chloride content in concrete and RCC structures should not exceed 2000 ppm and 500 ppm respectively. Even the presence of 1 ppm chloride affects the durability which is impossible to remove it completely, but can be reduced by chemically treated technique using NAOH solution. The experimental value of table 4 points out that, the sea sand initially contains 1500 ppm of chloride and after washing with water, it is found to be 450 ppm. To reduce further, the chemical treatment is preferred which reduces the chloride content to 50 ppm. The types of chlorides present in sea sand are termed as free chlorides and chemically bounded and physically bounded chlorides. Free chloride can be eliminated using normal distilled water wash. Chemically bounded chloride can be removed using certain chemicals, while the physically bounded chlorides require pressure and hot condition to get removed. This project improves the lifetime of the building using sea sand with reduced chlorine content by washing with water, thereby satisfying the condition of codal provisions.

4.5. FTIR spectroscopy test

FTIR (Fourier Transform Infra-Red) spectroscopy is used to find out the organic, inorganic and polymeric substance present in the sample and it can also be used to determine the bond type present in between the particles. Figure 2 indicates that the sea sand initially consists of a gradual line with high chloride content.

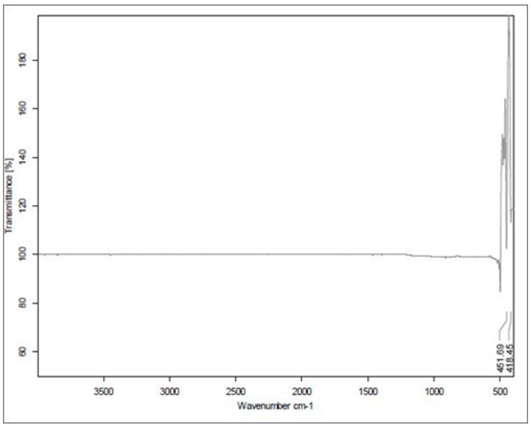

Figure 2.Spectroscopy results indicating high chloride

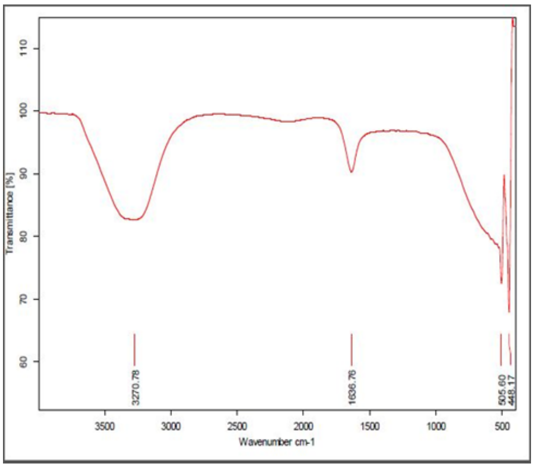

Figure 3.Spectroscopy results after water treatment

Figure 3 shows that before washing of sea sand, there is no change in the peak value, where only gradual line is formed with high chloride content. But after treatment of sea sand, 2 peaks are generated in which one peak is a strong O-H bond normally present in all binding materials and another bond is a strong C-C bond representing the generation of high negative attraction forces. High friction means high bonding strength which in turn refers to the maximum amount of impact resistance. Chemically treated sea sand also gives the values similar to the water wash. Many engineers and researchers avoid sea sand due to the poor bonding between cement and sand and because of the presence of silt content. But in case of treated sea sand, the quantity of silt content is reduced which rises to peaks formation and improve the bonds.

4.6. Organic impurity test

Constituents used for the production of concrete must be free from organic matter as the organic matter degrades the functional property of concrete. So this project has a responsibility to resolve this problem in a proper way. Based on this, chemical test is done, and the results are found that untreated sea sand gives dark colour to the solution that is not acceptable for making concrete. Water treated sea sand gives straw colour to the solution that also not suitable for most cases. But during chemical treatment, no colour is shown, i.e. zero organic matter (zero failure). Thus this project succeeds and satisfies the requirements of limits.

4.7. Silt content

The sand less than 75 micron sieve is generally said to be silt. The presence of silt content would break the bonding of cement-fine aggregate, thus lessening the structural strength.

Table 3.Silt reduction

Description	Untreated	Treated
Volume of sample, V_1 (ml)	86	97
Volume of silt after 3 hours, V_2(ml)	14	3
% silt by volume = $(V_2/V_1)*100$	16.23%	3.1%

Table 3 shows that prior to washing of sea sand, the silt content present in the sample is 16.23%, but normal washing results in the removal of the most of the silt matters and the values reduced down into 3.1%. However our code 2346 says that the maximum limit of presence of silt content in fine aggregate is 6%. So it is validated that the civil engineers encourage the application of sea sand after water treatment.

4.8. Water absorption

All fine aggregate must have water absorption property, which is limited to 2% and beyond this limit, the workability of the concrete gets affected. If the water absorption value of aggregates is not considered, the quantity of water used for concrete production is increased. In order to achieve better workability, an exact value of water cement ratio is required, which also strengthens the structure. The test results shows that before sea sand treatment, water absorption is 0.8% whereas after treatment the value is decreased into 0.5%, which indicates that the water absorbing particles are eliminated.

5. CONCLUSION

The present work validates that the addition of sea sand makes the structure more durable. Utilizing the abundantly available sea sand after water and chemical treatment reduces the overall construction cost as well. Specific gravity and fineness modulus of aggregates are tabulated. Besides, alkalinity test, SEM analysis, chloride content test, FTIR spectroscopy test, organic impurity test, silt content and water absorption analysis are also done to confirm the experimental results.

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