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# Strength and Durability of Fiber Reinforced High Performance Concrete Using Marine Sand

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**Abstract :** This paper generalized the result of study on Marine sand based High performance concrete The Land Reclamation and Development Board (Sri Lanka) plans to popularize the use of sea sand as a substitute to river sand. According to the experts in the global construction trade, Sea sand is being used in the construction industry in the Asian Region and some leading European countries. This study is to experiment the suitability to use beach/sea sand as a substitute for river sand as fine aggregate for concrete. The attempt has been made to find the various results by using sea sand and polypropylene fiber with normal concrete of $M_{60}$ grade with maintaining the water cement ratio of 0.32. The objective of this study is to develop concrete with good strength and to protect the rebar against corrosion due to intruded chlorides from the environment or intermixed chlorides from Marine sand by using calcium nitrate. So that durability will be reached. For this purpose, the experiment is carried out on $M_{60}$ grade of concrete using marine sand, 3.5% of calcium nitrate and different percentages (0%, 0.5%, 1%, 1.5% and 2%) of polypropylene fiber to the weight of cement. Higher grade concrete is produced by adding polypropylene fiber and calcium nitrate.
**Keywords :** Calcium nitrate, Durability, High Performance Concrete, Marine Sand, Polypropylene fiber.

## Introduction

The boom in the construction sector is a direct result of economic growth. This fast growth leads to severe competition for resource rights of fine aggregate and coarse aggregate from riverbeds. This results in unlawful mining of river beds for river sand which in turn causes environmental problems. Due to this scarcity of river sand, the contractors are mixing sea sand[1,3,4] with river sand.

Over-exploitation of river sand to meet the demand has led to various harmful consequences such as increase in the depth of the river bed, lowering of the water table, and salinity interference into the rivers. Because of these environmental problems, there is a necessity to restrict river sand mining especially at vulnerable locations. As a remedial measure, the government imposes various restrictions on the mining of river sand with consequent increases in prices. Not only has this inconvenienced the users directly, but also indirectly impacted on the overall stability of the construction industry owing to related increases in construction prices. This study is a basic practical study on the compressive strength of concrete made by using sea sand as a replacement to fine aggregate[9,10]. In this the fine aggregate was replaced by sea sand in various percentages.

**Materials**

The concrete mix has been designed for $M_{60}$ grade as per ACI 211.4R- 08 specified concrete grade involves the economical selection of relative proportion of cement, fine aggregate (marine sand), coarse aggregate and water. Although compliance with respect to characteristics strength is the main criteria for acceptance it is implicit that concrete must also have desired workability in the fresh state the impermeability and durability[2,5] in hardened state.

Mix design on recommended guide line is really a process of making an initial guess at optimum combination of ingredients and final mix proportion is obtained only on the basis of further trial mixes. For compressive strength, the following characteristics are chosen from American code (ACI 211.4R- 08) for $M_{60}$ grade concrete.

I. Required compressive strength to the field at 28 days- 60N/mm$^2$
II. Maximum Size of aggregate
III. Degree of quality control
IV. Type of exposure

The test data determined from the materials are at table 1

**Table 1.Properties of Materials used**

| S.no | Name of the material | Properties of material | Result | |
|---|---|---|---|---|
| 1 | OPC 53 grade | Specific gravity | 3.13 | |
| | | Fineness modulus | 3.6% | |
| | | Consistency | 32% | |
| | | Initial setting time | 30 min | |
| | | Final setting time | hrs | |
| 2 | Fine aggregate | Comparison | River sand | Marine sand |
| | | Specific gravity | 2.54 | 2.73 |
| | | Fineness modulus | 4.83 | 3.46 |
| | | Bulk density | 1782.46kg/m$^3$ | 1700.12kg/m$^3$ |
| 3 | Coarse aggregate | Specific gravity | 2.63 | |
| | | Water absorption | 0.56% | |

**Table 2.Specification of Specimens**

| Specimen | Explanation |
|---|---|
| MIX RS | Conventional mix using river sand + 1% SP |
| MIX SS | Conventional mix using sea sand + 1% SP |
| MIX 1 | Concrete mix using SS + 0.5% PF + 1% SP + 3.5% CN |
| MIX 2 | SS + 1% PF + 1%SP + 3.5% CN |
| MIX 3 | SS + 1.5% PF + 1%SP + 3.5% CN |
| MIX 4 | SS + 2% PF + 1%SP + 3.5% CN |

**Mix Designs**

- Grade of concrete = M60
- Code used = ACI 211.4R- 08
- Maximum size of aggregate = 12.5 mm
- Specific gravity of cement = 3.134s
- Specific gravity of Sea Sand = 2.73
- Specific gravity of C.A = 2.63

| Water | Cement | Fine Aggregate | Coarse Aggregate |
|---|---|---|---|
| 501.19 $l/m^3$ | 155.37 $kg/m^3$ | 616.98 $kg/m^3$ | 1302 $kg/m^3$ |
| 1 | 0.32 | 1.23 | 2.59 |

Sea sand (SS) is used as the fine aggregate, polypropylene fiber (PF) is varied from 0.5%-2%, calcium nitrate[8] (CN) and superplastizier (SP) are kept in constant of 3.5% and 1% respectively as Shown in table 2.

## Experimental Works

### A Slump test

Workability is defined as the ability or case with which the concrete is handled, t ransported and placed in the form with minimum loss of homogeneity. In the present study, workability was determined using slump cone test for the concrete using sea sand. The slump test was performed as per IS 1199- 1959, the slump test is the most well-known and widely used test to characterize the workability of fresh concrete.

### B Compressive Strength

Compressive strength of a material is distinct to the value of uniaxial compressive stress reached when the material fails completely. In this investigation, the cube specimen of size 150mm x 150mm x 150mm were cast, cured and tested in accordance with BIS: 516 – 1959 (method of test for test of concrete). The testing was done on compressive testing machine of 2000kN capacity. The machine has a facility to control the rate of loading with a control valve. The machine has been calibrated to the required standards. The plates were cleaned: oil level was checked and keep ready in the all respects of testing. After 28 days of curing, cube specimen were removed from the curing tank and cleaned to wipe of the surface water. The specimens were transferred on to the swivelling head of the machine such that the load is applied centrally. The top plate was bought in contact with the specimen by rotating the handle. The oil pressure valve was closed and the machine was switched on. The maximum load to failure at which the specimen breaks and the pointer starts moving back was noted. The test was repeated for three specimen and average value was taken as the compressive strength.

### C Split Tensile Strength

The objective of this is to find the splitting tensile strength of the concrete cylinders. This cones under indirect tension test methods. The test was carried out by placing a cylinder specimen horizontally between the loading faces of the compressive testing machine and the load was applied until failure of the cylinder, along the vertical diameter. A concrete cylinder of size 150mm diameter and 300mm height was subjected to the action of the compressive forces along two opposite edges. The test was conducted using compressive testing of 200kN capacity. The cylinder was subjected to the compression near the loaded region and length of the cylinder is subjected to uniform tensile stress.

Horizontal Tensile Stress = $2P/\pi DL$

Where, P = Compressive load on the cylinder.
L = Length of cylinder.
D = Diameter of cylinder.

### D Water Absorption

This test is done to know the relative porosity or permeability characteristics of the concrete. The test is carried out after 28 days of moist curing. The concrete specimens used for this test are 150 mm X 65 mm size cubes. The percentage absorption [6] is calculated using Eq. below.

Absorption (%) = $(W_2 - W_1)/W_1 X100$
Where, $W_1$=weight of concrete specimen after complete drying at 105C
$W_2$= final weight of surface dry concrete specimen after immersion in water at least 24 hours

The concrete specimens are first dried for 24 hours at 105C in oven. The concrete specimens are removed from the oven and weighed which is considered as initial weight $W_1$. They are immersed in water again for 24 hours.

**E Impact Resistance Test**

The impact strength of the concrete is important when it is subjected to sudden load or repeated impact load as witnessed in forge hammer foundations. The impact strength of concrete increases with increase in compressive strength. The apparatus used to find impact strength is shown in fig. The cylindrical mould size is 150 X 200 mm. The twelve discs of size 100 X 64 mm were cut using a diamond cutter. The discs were then subjected to drop weight. The test consisted of repeated applications of impact load in the form of blows, using a 44.5N hammer falling from 457 mm height on the steel balls of 63.5 mm diameter, placed at the centre of the top surface of the disc. Number of blows (N1) and (N2) that cause the first visible crack and failure respectively was noted as first crack strength and the failure strength of the sample. The impact energy was calculated for each concrete specimen using below equation:

Impact Energy U = $(n.\ m.\ V^2 / 2)$
Where,
V = velocity of hammer
m = drop mass
N = no of blows

**F Rapid Chloride Penetration Test**

The diffusion cell has two chambers. NaCl solution concentration 2.4M and NaOH solution concentration 0.3M are prepared. NaCl solution concentration 2.4M is filled in one chamber and in another chamber 0.3M NaOH solution is taken. The chloride ions were forced to migrate through the centrally placed vacuum saturated concrete specimen under an impressed DC voltage of 60 Volts as shown in the figure view of RCPT set up.

The procedure of this test method for measuring the resistance of concrete to chloride ion penetration has no bias because the value of this resistance can be defined only in terms of a test method. The method relies on the results from a test in which electrical current passes through a concrete sample during a six-hour exposure period. The interpretation is that the larger the Coulomb number, or the charge transferred during the test, the greater the permeability of the sample. The more permeable to the concrete, the higher the coulombs value; the less permeable to the concrete, the lower the coulombs value. The total charges passed through the cell in coulomb has been found in order to determine the resistance of the specimen to chloride ion penetration. The following formula, based on the trapezoidal rule can be used to calculate the average current flowing through one cell.

$$Q = \frac{1800}{2}(I_0+2I_{30}+2I_{60}+2I_{90}+2I_{120}+\ldots+2I_{300}+2I_{330}+I_{360})$$

(or)

$$Q = 900(I_0+2I_{30}+2I_{60}+2I_{90}+2I_{120}+\ldots+2I_{300}+2I_{330}+I_{360})$$

Where,
Q = current flowing through one cell (coulombs)
I0 = Current reading in amperes immediately after voltage is applied, and
It = Current reading in amperes at t minutes after voltage is applied

The table 3 shows the rating of chloride permeability according to ASTM C 1202-97 and Figure 1 shows the Rapid chloride permeability test setup.

**Table 3. Rating of Chloride ion permeability**

| Charge passing in coulombs | Chloride permeability rating |
|---|---|
| >4,000 | High |
| 2,000 to 4,000 | Moderate |
| 1,000 to 2,000 | Low |
| 100 to 1,000 | Very Low |
| <100 | Negligible |

**Figure 1. Rapid chloride permeability test setup**

**Table 4.Slump values of HPC mixes with River and Sea sand**

| MIX ID | Slump value in mm |
|---|---|
| MIX RS | 70 |
| MIX SS | 62 |
| MIX 1 | 58 |
| MIX 2 | 56 |
| MIX 3 | 49 |
| MIX 4 | 31 |

## Result And Discussion

### A Slump value

The workability of the concrete was mainly influenced by the water requirement at the time of mixing. For conventional concrete, it was mainly based on the maximum size of the aggregate used. When mineral admixture was added to the concrete, their physical characteristics mainly influenced the water demand as well workability of the mix. The slump value obtained for river and sea sand mixes are presented in table 4.

### B Compressive and Split Tensile Strength

The Compressive and Split Tensile Strength of High Performance Concrete with various percentage of adding Polypropylene fiber and Calcium nitrate and replacing fine aggregate River sand with Sea sand. These results are given in table 5 and figure 2.

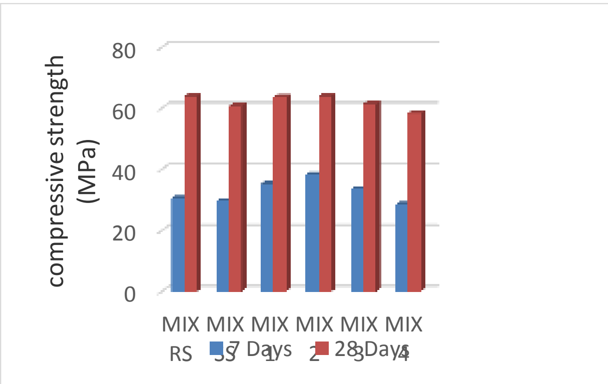


**Figure 2: Influence of Sea sand on Compressive strength of Concrete**

**Table 5. Influence of River sand and Sea sand on Compressive and Split tensile strength of HPC**

| Concrete label | Compressive Strength (MPa) | | Split Tensile Strength (MPa) | |
|---|---|---|---|---|
| | 7 days | 28 days | 7 days | 28 days |
| MIX RS | 30.5 | 64.03 | 2.91 | 4.38 |
| MIX SS | 29.67 | 60.68 | 2.57 | 4.00 |
| MIX 1 | 35.25 | 63.73 | 3.97 | 5.72 |
| MIX 2 | 38.22 | 64.05 | 3.45 | 5.20 |
| MIX 3 | 33.56 | 61.39 | 3.21 | 4.81 |
| MIX 4 | 28.51 | 58.34 | 2.50 | 3.71 |

From the test results, the compressive strength obtained for the MIX RS 28 days is greater than the MIX SS. The compressive strength for 1% of polypropylene fiber (64.05MPa) is higher than the control mix (MIX SS). The result show that for all ages, the polypropylene fiber ranging from 0.5%, 1% and 1.5% yields higher compressive strength when compared to conventional concrete mix. Beyond that there is a decrease in strength for addition 2% of polypropylene fiber as shown in figure 3.

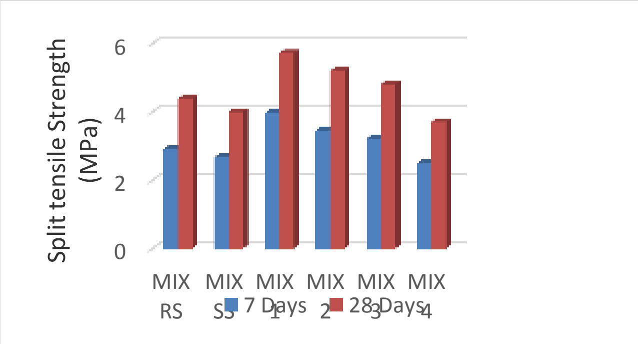


**Figure 3.Split tensile strength of sea sand based concrete**

From the test results, the Split Tensile strength obtained for the MIX RS 28 days is greater than the MIX SS. The Split tensile strength for 0.5% of polypropylene fiber(5.72MPa) is higher than the control mix (MIX SS). The result show that for all ages, the polypropylene fiber ranging from 0.5%, 1% and 1.5% yields higher tensile strength when compared to conventional concrete mix. Beyond that there is a decrease in strength for addition 2% of polypropylene fiber.

## C Test Result for Water Absorption of Concrete

From the table 6 test result it is observed that the percentage of water absorption is 1.44% for River sand and 0.70 for Sea sand. The Mix 1 has the lowest water Absorption percentage than the conventional of sea sand mix.

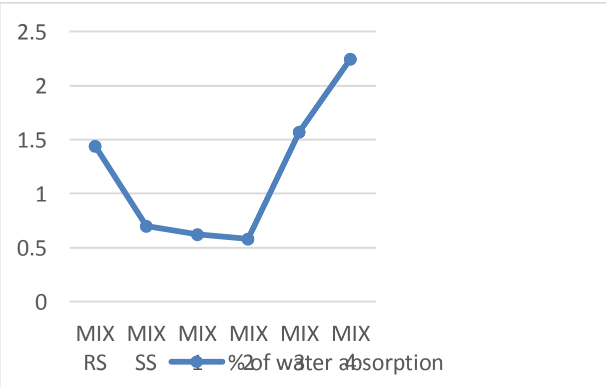


**Figure 4. Water absorption results for Sea sand**

Figure 4 gives the graphical representation of water absorption test results for Sea sand based concrete. From the result, it can observed that the percentage of water absorption is 1.4% for river sand and 0.7% on sea sand. The mix 1 has the lowest water absorption percentage than the other mixes. Compared to the river sand mixes sea sand mix has the lowest water absorption

**Table 6. Influence of River Sand and Sea Sand on water absorption of concrete**

| S.No | Combination | Dry weight | Wet weight | Percentage of water absorption |
|---|---|---|---|---|
| 1 | MIX RS | 8.887 | 9.014 | 1.44 |
| 2 | MIX SS | 8.877 | 8.939 | 0.70 |
| 3 | MIX 1 | 8.981 | 9.036 | 0.62 |
| 4 | MIX 2 | 8.871 | 8.946 | 0.85 |
| 5 | MIX 3 | 8.467 | 8.610 | 1.57 |
| 6 | MIX 4 | 8.289 | 8.475 | 2.25 |

**Table 7.Chloride permeability for M60 using marine sand**

| S.No | Sample | Chloride permeability (Coulombs) | Remark |
|---|---|---|---|
| 1 | MIX RS | 5582 | High |
| 2 | MIX MS | 4985 | High |
| 3 | MIX 1 | 2985 | Moderate |
| 4 | MIX 2 | 3554 | Moderate |
| 5 | MIX 3 | 3985 | Moderate |
| 6 | MIX 4 | 5661 | High |

**D Rapid chloride penetration test**

The average current flowing through the MIX 1, MIX 2 and MIX 3 specimen was within the range of 4000 as the addiction of Calcium nitrate at 3.5% gives good result as shown in table 7. If the chloride permeability decreases than the corrosion rate also decreases so the durability of the concrete increases clearly seen in figure 5.

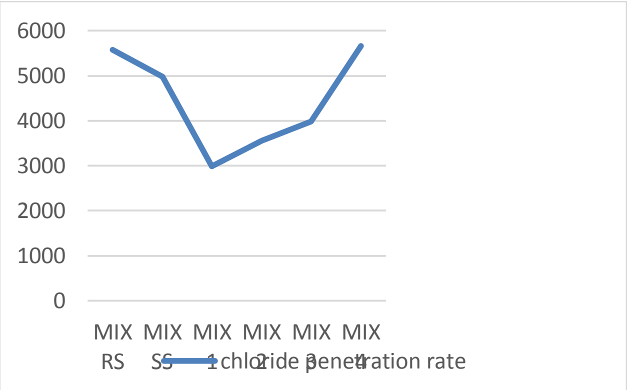


**Figure 5. RCPT value for sea sand based concrete**

## Conclusion

The following conclusions are drawn for feasibility study conducted on HPC with sea sand as fine aggregate includes,

The conclusion based on the limited observations from the present investigation on study of compressive, split tensile strength and RCPT of the concrete made using sea sand as fine aggregate as a replacement of river sand by using polypropylene fiber (0% to 2%) and constant dosage of calcium nitrate (3.5%) and super plasticizer (1%). The addition of polypropylene fiber ranging from 0.5%, 1%, and 1.5% yields higher compressive strength than the conventional concrete mix. Beyond that there is a decrease in the compressive strength of concrete by adding 2% of polypropylene fiber.

- Sea sand based HPC has 5.5% lower compressive strength when compared to its counterpart mix made of river sand
- The addition of polypropylene fiber and calcium nitrate increases the compressive strength and split tensile strength containing sea sand as a fine aggregate.
- The addition of polypropylene fiber by 1% and sea sand as a fine aggregate had shown 5.5% increase in compressive strength and at 0.5% of polypropylene fiber 42.5% increase in compressive strength when compared to the conventional concrete mix (MIX SS)
- Water absorption is found to be lower in case of sea sand mix when compared to the river sand mix.
- Due to the addition of calcium nitrate which is a corrosion inhibitor so the rate of corrosion decreases and chloride penetration also decreases for 0.5%, 1.0% and 1.5% addition of polypropylene fiber so that durability of the concrete increases.

Sea sand contributes to production for local consumption, reduces the construction and material transportation cost. On considering the distance factor, the people in and around the sea shore are suggested to use sea sand as fine aggregate instead of river sand..

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