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Determination of Mechanical Properties of Rubberized Concrete in Marine Environment

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***Abstract**: With an objective of saving the environment by providing crumb rubber as an alternative to natural fine aggregate this paper presents a study carried out to find the mechanical properties of rubberized concrete. Rubberized concrete is made up of waste rubber from vehicle tyres and other rubber waste which otherwise is left out polluting the environment. In this paper, 7.5% of crumb rubber (obtained by shredding the vehicle tyres) as an alternative to fine aggregate and 7.5% of fly-ash as an alternative to cement is added with other ingredients of concrete to produce an eco-friendly concrete which can be used economically and effectively for construction along the coastal areas. Various properties like workability, compressive strength, split tensile strength, and flexural strength was carried out on concrete specimens exposed to the natural marine environment along the coast of Visakhapatnam, Andhra Pradesh. The total exposure of concrete specimen was about 150 days, and various specimens were tested at 7, 28, 90, 120 and 150 days, respectively. The test results showed that with a slight compromise in strength, the workability of concrete and resistance to the effect of seawater on the strength of concrete significantly improved with the addition of crumb rubber and fly-ash.*

***Index Terms**: Compressive strength, fly-ash, marine environment, Rubberized concrete, split tensile strength.*

I. INTRODUCTION

About 70% of Earth is occupied by oceans and only 30% is land [2]. With increasing population and industrialization and land being limited, construction has already reached the far ends of mainland and is being extended along the coastal areas and even projecting into the sea. The most widely used construction material is concrete which unfortunately has a lower durability and reduced life time when exposed to marine environment. The entire coastal region of Indian peninsula is exposed to corrosive and extreme environment. It has become a challenge to safeguard the structures situated in and around the coastal areas and a number of researches are being done worldwide to increase the life and durability of concrete in such harsh environment.

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Deterioration of concrete in marine environment is mainly due to sulphate attack, corrosion of steel due to chloride ingression, carbonation of concrete etc. But these mechanism doesn't occur on its own. These problems occur due to the combined effect of moisture absorption, temperature variation, alternate wetting and drying condition, continuous exposure to abrasion due to sand in sea water etc. The sea water contains dissolved salts, the typical salt content is 3.5% by weight (35 gm/litre) and the principal ions present are Na^+, Mg^{2+}, Cl^-, and $(SO4)^{2-}$[1].

Compounds	Concentration (gm/l)
NaCl	23.5
$MgCl_2$	5.0
Na_2SO_4	3.9
$CaCl_2$	1.1
KCl	0.66
$NaHCO_3$	0.20
KBr	0.10
H_3BO_3	0.026
$SrCl_2$	0.024
NaF	0.003

Table 1: Average composition of Seawater [1]

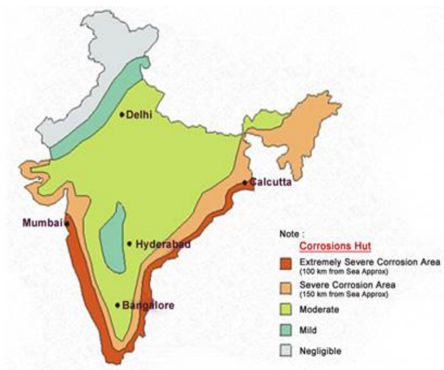

Fig-1: Corrosion map of India [3]

II. LITERATURE REVIEW

Many research is being carried out worldwide to solve the problem of salinity effect on concrete. Several authors have put forward their views on how to adopt sustainable development techniques without hampering the environment and also by utilizing various waste materials in the concrete mix. Various number of researches and articles were studied, and their conclusion was drawn before conducting the present study. Here are the highlights of some of the significant research work in this area. F.M.

Wegian et.al [6] in his study concluded that the strength after 7 and 14 days for concrete mixes mixed and cured in seawater was higher than concrete mixed and cured in fresh water.
A similar study conducted by Swati maniyal and Asutosh patil (*2015*) [7] said that the strength increased at 7 and 14 days but there was a slight decrease of about 1-4% in the 28 days strength, which was however above the target strength. Preeti Tiwari et.al [8] also concluded in their study that there was a marginal increase in strength of the concrete cast and cured in salt water as compared to concrete cast and cured in fresh water. A paper presented by Olutoge, F Adeyemi and Amusan G Modupeola [10] concluded that the strength of concrete cast and cured in seawater increased gradually for all curing period up to 90 days. However, research by Akinkurolere et.al [14] indicated that sea water is unsuitable for mixing and curing of concrete. S. Selvakumar and R. Venkatakrishnaiah [12] in their research work on Rubberized concrete concluded that crumb rubber concrete with 10% replacement gave acceptable strength, and the slight decrease in strength was mainly due to less bonding ability of crumb rubber particles. Rubberized concrete proved to be good for resistant against impact loading according to a study made by Eehab Khalil et.al [15]. The study also concluded that the main disadvantage of rubberized concrete was its decrease in compressive strength with increase in rubber content. L. Zheng, X. Sharon and Y. Yuan [5] posted in their research work that the compressive strength, static modulus of Elasticity and dynamic modulus of elasticity of rubberized concrete decreased with increase in the amount of rubber content. They also concluded that the Brittleness Index of rubberized concrete remained less than that of normal concrete. Also in a different study by the same group indicated that the damping ratio of rubberized concrete increased considerably with an increase of rubber content. This proved to be beneficial for the use of rubberized concrete in seismically active regions. Topcu and Avcular [9] in their research work concluded that the use of rubber chips in concrete could significantly improve the ductility property of concrete. Fattuhi and Clarke [13] suggested the application of rubberized concrete in non-load bearing structures and to structures where considerable resistance to impact or vibration damping is required. Ruizhe Si et.al [11] reported that the durability performance of rubberized mortar and concrete with NaOH solution treated rubber particles increased considerably as compared to rubberized concrete without treated rubber particles

III. SIGNIFICANCE OF PRESENT RESEARCH

As the salinity of sea water, quality of material, construction techniques and practices etc. vary from country to country, hence many of the above studies cannot be directly compared with the Indian conditions. Hence there was a need of study along Indian coasts with which further researches would be compared. Also being a developing country India needs to manage and utilize its waste for sustainable development. On average India produces about 15 lakh M.T of tyres each year. In recent years tyre production is increasing by about 4-5% every year. Currently, 75-80% of scrap tires are buried in landfills or disposed of in the open ground. Only 25% of these scrap tyres go for the actual recycling process.

Thus rubberized concrete can open an eco-friendly way of disposing of these scrap tyre wastes by converting them into crumb rubber and utilizing it into concrete as a construction material.From the previous research work, it was evident that no research has been carried out on the effect of seawater or effect of marine environment on properties of rubberized concrete. Moreover from the previous studies, it was found that rubberized concrete with fine crumb rubber particles proved to be effective in decreasing the permeability of concrete, increased resistance to impact loading, good shrinkage and cracking resistance, good freezing and thawing resistance, better resistance to heat and sound insulation, etc. So keeping in mind these advantageous properties this paper aims at determining the feasibility of rubberized concrete as a construction material along the Indian coastline. This paper deals with the mechanical strength properties of rubberized concrete and the effect of the marine environment on them.

IV. EXPERIMENTAL INVESTIGATION

A. Materials:

a) ***Cement****:* The cement used was PPC (Portland pozzolona cement) of 53 grade conforming to IS 1489. Table 2, gives the detail specification of the cement.

b) ***Coarse aggregate***: crushed stone aggregate of maximum size 20 mm and minimum size 12mm in the mix ratio of 25% and 75% respectively were used. The aggregates were in accordance to IS 383-1970.

c) ***Fine aggregate*****:** The fine aggregate (sand) used in the study was obtained from river banks of river Sarada in Visakhapatnam. The grading zone of sand used is zone II as per Indian standards. The specific gravity of sand was 2.63

d) ***Water*****:** clean tap water was used for the mixing of concrete. The water used was free from suspended impurities and chemical substances.

e) ***Crumb Rubber*****:** The crumb rubber was obtained by shredding of waste used vehicle tyres. Table 3, gives the detail specification of crumb rubber. For this study the shredded crumb rubber particles were directly obtained from Enar Rubber Reclamation factory situated in Jamshedpur, Tatanagar.

f) ***Salt Water*****:** Sea water was directly taken from the sea coast of Visakhapatnam. The curing of concrete specimen was done directly by placing the specimens along the sea coast. The average salinity of the sea water was found to be about 3.5%

g) ***Fly-ash*****:** The fly-ash was obtained from the nearby thermal power plant. Fly-ash used was of type –F. The size of the particle of fly-ash is 0.1µm - 150 µm.

B. Mix proportion:

The mix design used in this study was M30 as it is the most common mix adopted for all types of construction along coastal areas and off-shore structures. The mix ratio was calculated to be as 1:1.81:3.37 (Cement: Fine aggregate: Coarse aggregate) along with water- cement ratio of about 0.42%. The fine aggregate was replaced by crumb rubber. The replacement was 7.5% by weight of fine aggregate.

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Also, the cement quantity was replaced by about 7.5% of fly-ash by weight.

C. Methodology:

Three batches of concrete were cast. One batch is made of normal M30 grade concrete, one batch is made of M30 grade concrete with 7.5% replacement of fine aggregate with crumb rubber. Another batch of M30 grade concrete is made up by 7.5% replacement of cement with type-1 fly-ash and 7.5%replacement of fine aggregate with crumb rubber. Workability of concrete was tested for the three types of batches. It was found that concrete with crumb rubber and fly-ash gave higher workability and hence further tests were carried out on two batches, one normal concrete and other with 7.5% crumb rubber and 7.5% fly-ash as replacement for fine aggregate and cement respectively. **Table-2** shows the detail of different types of batches. Three types of specimen were used and the mixing of concrete was done with normal tap water whereas curing was done in the marine environment by placing the specimen along the sea coast within the tidal range. The specimens were kept for curing for a total of 150 days and various samples were tested at ages of 7 days, 28days, 90days, 120 days and 150 days.

Table 2: Types of batches prepared.

Batches	Notation	Replacement
Type 1	NC	No replacement
Type 2	RC	7.5 % crumb rubber
Type 3	RCF	7.5% crumb rubber and 7.5% fly-ash.

D. Specimens:

Three types of specimen were used in this research namely, Cube, cylinder and prism specimens. Cube specimen used had dimensions of 150mm x 150mm x 150mm and were used to find the compressive strength at different ages. The cylinder specimen had dimensions of 150mm diameter and 300mm height, and were used for determining the split tensile strength test of concrete. Prism specimen of dimension 500mm x 100mm x 100mm were used to find flexural strength of concrete.

E. Tests conducted:

The tests conducted in this research were as follows:

a) Workability tests
b) Compressive strength test
c) Split tensile strength test
d) Flexural strength tests

F. Tests Results and Discussions:

Both normal and rubberized concrete specimen were tested after their designated curing period. The results obtained are discussed in detail.

a) Workability Tests:

From the tests result it was noted that workability increased with addition of rubber content and also slightly with the addition of fly-ash in concrete. The workability tests were carried out by compaction factor tests as per IS: 1199 – 1959. The results are shown by graphical representation in Fig:7.

b) Compressive strength tests:

Compressive strength of concrete decreased with addition of crumb rubber and fly-ash. However, with only 7.5% replacement of crumb rubber the decreased strength was still under the acceptable limits. Also with the increase in curing period under sea water up-to 90 days of curing there was not much decrease in strength but after 120 days and 150 days curing a certain decrease in strength was noted. The results are shown in Fig: 4-6.

c) Split tensile strength:

Split tensile strength was carried out on a cylindrical specimen of 150 mm dia and 300 mm height. The test was conducted as per IS 516-1959 at 7, 28 and 90 days. The result showed that addition of crumb rubber led to reduction of tensile strength both in normal and marine environment. The result is shown in Fig: 3.

d) Flexural strength:

Flexural strength of concrete was carried out on a prism specimen of dimension 100 x 100 x 500 mm. The test results were tabulated as shown below. The result is shown in Fig: 2

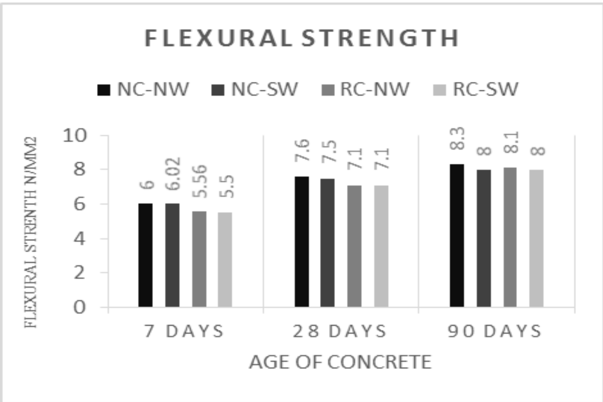

Fig 2: Flexural strength variation

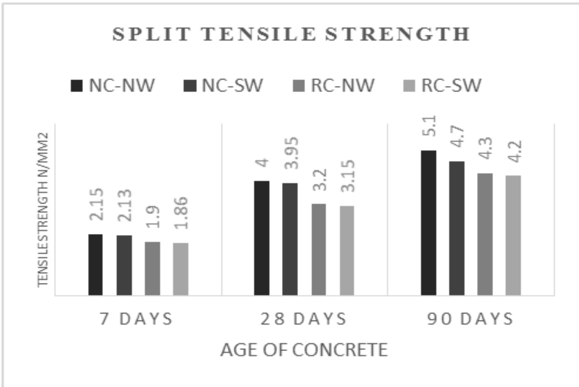

Fig 3: Split tensile strength

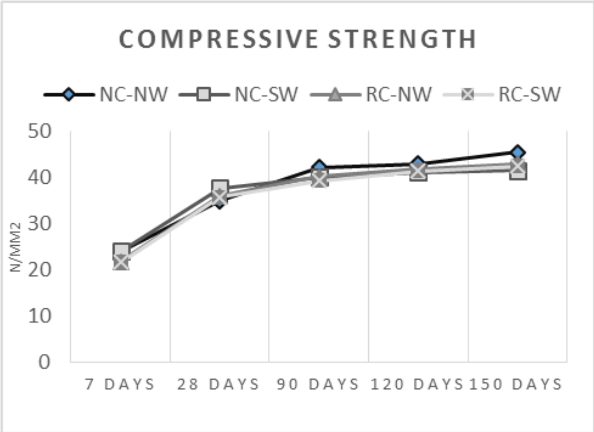

Fig 4: Compressive strength

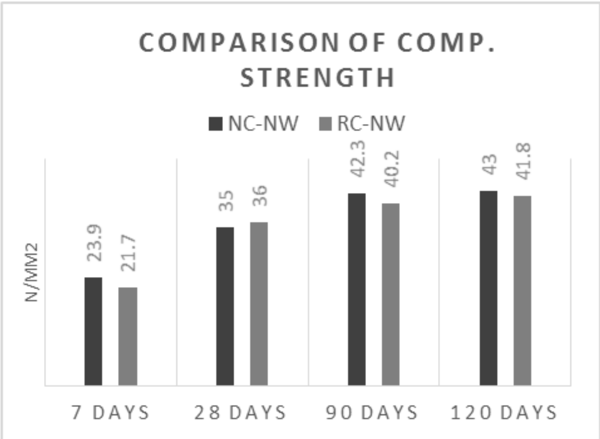

Fig 5: Compressive strength in Normal water curing

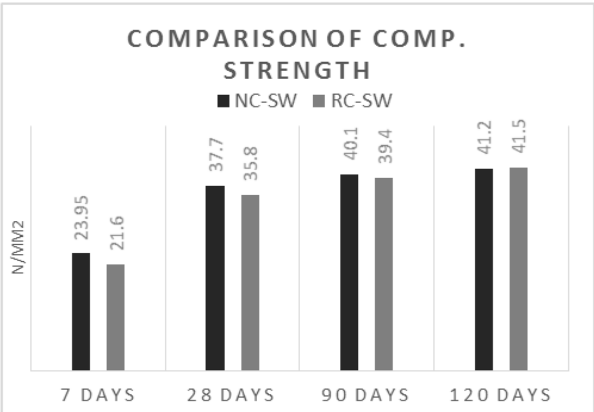

Fig 6: Compressive strength in seawater curing

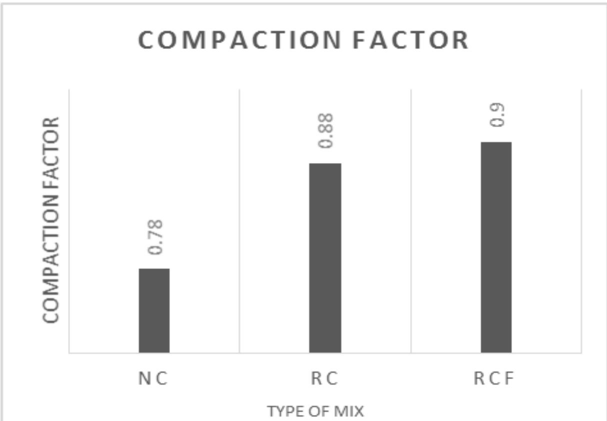

Fig 7: Workability test result

Fig 8: Casting of a batch of samples

Fig 9: Curing of some of the samples on the sea coast

Fig 10: Failure pattern of Normal concrete

Fig 11: Failure pattern of Rubberized concrete

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Fig 12(a): Failure pattern of NC and RCF in tensile test

Fig 12 (b): Failure pattern of NC and RCF in tensile test

V. CONCLUSIONS

From the present study, the following conclusions were drawn:

i. The workability of concrete increased significantly by the addition of crumb rubber. 7.5% of crumb rubber increased workability by 12.8%. Addition of fly-ash further increased the workability slightly than normal concrete. The percentage reduction in the increase of strength for rubberized concrete was less than normal concrete. After 90 days, the percentage increase in strength for normal concrete was less than rubberized concrete. This shows that rubberized concrete can be a better option for construction in coastal areas.

ii. Compressive strength of rubberized concrete was found to be slightly less than that of normal concrete, this decrease in strength can, however, be overcome by the addition of silica fume, retrofitting by GFRP and various other methods.

iii. It was noted that when curing was done in seawater rubberized concrete performed better.

iv. During compressive strength test, it was observed that normal concrete showed wide cracks and the concrete cubes disintegrated, whereas rubberized concrete failed with large number of minor hair cracks. Fig 4.2 explains the best.

v. Tensile and flexural strength of rubberized concrete were slightly less than normal concrete but even there when curing was done in sea water the percentage decrease in strength of rubberized concrete was less than that of normal concrete.

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