ASSESSMENT OF RUBBERIZED CONCRETE AS A CONSTRUCTION MATERIAL IN MARINE ENVIRONMENT

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ABSTRACT: - This research aims at solving two major crises which we are facing in recent years; firstly the scarcity of fine aggregate is becoming a major issue nowadays as the extraction causes the morphological changes in river bed, in some cases substrata are being removed and ultimately grain sizes are affected and also recently the government has banned the extraction to a greater limit and secondly waste rubber which forms a substantial part of the world's solid waste as mostly rubber wastes are not being eliminated due to shortage of waste land. The objective would be to replace the fine aggregate in the concrete mix with crumbed rubber in some specific percentage and to study the effects of this concrete in their strength and durability. The project is focused on marine environment as 70% of earth is occupied by oceans and the sea water has some adverse effect on concrete like Corrosion of embedded reinforcement, Loss of strength due to carbonation effect of concrete, Occurrence of sulphate attack on concrete and reinforcement, Erosion and abrasion of concrete surface due to constant high sea winds and waves, Minor cracks due to salt crystallization which led to reduced durability and life of structure also the life time of a concrete structure in normal environment ranges between 50-100 years where as in marine environment it ranges in between 15-40 years.

Keywords: crumbed rubber, corrosion, carbonation, marine environment

INTRODUCTION: -

a) Waste management of rubber:

Waste Rubber contributes to the major part of world's solid waste. Due to increasing number of vehicles, the tyres of the vehicles having a limited life span are soon amounted in world's solid waste. Industries contribute about 9kg of waste rubber per year which are not recyclable and has to be land filled which led to environmental and health threat. Due to their shape, they occupy larger area and thus need to be put in productive use. Rubber wastes are used in the form of crumbed rubber. Crumbed rubber is a material produced by shredding and commutating used tires. The long-term objective is to find a means to dispose the crumbed rubber in Portland cement concrete and still supply a final product with good engineering properties. Crumb rubber, or the powder rubber will replace the fine aggregate i.e., sand in concrete mix. Tests have been carried out for the percentage of replacements of sand by crumb rubbers. In this research the maximum replacement allowed is 20%.

b) Effect of sea water:

The effects of sea water on concrete may conveniently be examined by considering, first, the factors characteristic of the sea-water exposure that can affect concrete; second, the elements of the specific concrete involved that may be affected by these factors; third, the consequences of the interaction of sea water with the concrete; and, finally, the precautions that should be taken to avoid undesirable performance of the concrete due to its interaction with sea water.

1. **Permeability is the key to durability**.

Deleterious interactions of serious consequence between constituents of hydrated Portland cement and seawater take place when seawater is not prevented from penetrating into the interior of a concrete. Typical causes of insufficient water tightness are poorly proportioned concrete mixtures, absence of properly entrained air if the structure is located in a cold climate, inadequate consolidation and curing, insufficient concrete cover on embedded steel, badly designed or constructed joints, and micro cracking in hardened concrete attributable to lack of control of loading conditions and other factors, such as thermal shrinkage, drying shrinkage, and alkali aggregate expansion. It is interesting to point out that engineers on the forefront of concrete technology are becoming increasingly conscious of the significance of permeability to durability of concrete exposed to aggressive waters. For example, concrete specifications for offshore structures in Norway now specify the maximum permissible permeability directly.

2. **Type and severity of deterioration may not be uniform throughout the structure**

For example, with a concrete cylinder the section that always remains above the high-tide line will be more susceptible to frost action and corrosion of embedded steel. The section that is between high- and low-tide lines will be vulnerable to cracking and spalling, not only from frost action and steel corrosion but also from wet-dry cycles. Chemical attacks due to alkali-aggregate reaction and seawater cement paste interaction will also be at work here. Concrete weakened by micro cracking and chemical attacks will eventually disintegrate by action and the impact of sand, gravel, and ice; thus, maximum deterioration occurs in the tidal zone. On the other hand, the fully submerged part of the structure will only be subject to chemical attack by seawater; since it is not exposed to subfreezing temperatures there will be no risk of frost damage, and due to lack of oxygen there will be little corrosion. It appears that progressive chemical deterioration of cement paste by seawater from the surface to the interior of the concrete follows a general pattern. The formation of aragonite and bicarbonate by CO2attack is usually confined to the surface of concrete, the formation of bruise by magnesium ion attack is found below the surface of concrete, and evidence of ettringite formation in the interior shows that sulphate ions are able to penetrate even deeper. Unless concrete is very permeable, no damage results from chemical action of seawater on cement paste because the reaction products (aragonite, brucite, and ettringite), being insoluble, tend to reduce the permeability and stop further ingress of seawater into the interior of the concrete. This kind of protective action would not be available under conditions of dynamic loading and in the tidal zone, where the reaction products are washed away by wave action as soon as they are formed.

3. **Corrosion of embedded steel is, generally, the major cause of concrete deterioration in reinforced and prestressed concrete structures exposed to seawater, but in low-permeability concrete this does not appear to be the first cause of cracking.** Based on numerous case histories, it appears that cracking corrosion interactions probably follow the route diagrammatically illustrated in Figure3. Since the corrosion rate depends on the cathode/anode area, significant corrosion and expansion accompanying the corrosion should not occur until there is sufficient supply of oxygen at the surface of the reinforcing steel (i.e., an increase in the cathode area).

   This does not happen as long as the permeability of steel-cement paste interfacial zone remains low. Pores and micro cracks already exist in the interfacial zone, but their enlargement through a variety of phenomena other than corrosion seems to be necessary before conditions exist for significant corrosion of the embedded steel in concrete. Once the conditions for significant corrosions are established, a progressively escalating cycle of cracking corrosion– more cracking begins, eventually leading to complete deterioration of concrete.

c) Why maritime environment is taken?

- 70% of earth is occupied by oceans. All the countries as well as off-shore structures are subjected to impact of chemical and physical deterioration due to saline water and wind.
- Reduced durability and life of structure is noted in these areas. Life time of a concrete structure in normal environment ranges between 50-100 years where as in marine environment it ranges in between 15-40 years
- To increase life time special alloy steels and high strength concrete with various admixtures are incorporated in these areas which ultimately leads to increase in cost of the structure.

- Greater depth of cover is provided for reinforcements which increases the size and weight of concrete structures.

d) Major problems with marine environment

- Corrosion of embedded reinforcement
- Loss of strength due to carbonation effect of concrete
- Occurrence of sulphate attack on concrete and reinforcement
- Erosion and abrasion of concrete surface due to constant high sea winds and waves
- Minor cracks due to salt crystallization

OBJECTIVE: -

- Check for compressive strength of rubberized concrete
- Check for sorptivity
- Check for water absorption
- Check for impact strength
- Compare normal concrete cubes with rubberized concrete cube

LITERATURE REVIEW: -

- **Tushar R More, Pradip D Jadhao and SM Dumme** In their study the aim was to study of waste tyre as partial replacement of fine aggregate to produce rubberizes concrete in M25 grade of mix. Different partial replacement of crumb rubber i.e., 0%, 3%, 6%, 9% and 12% by volume of fine aggregate are casted and tested for flexural strength and split tensile strength. The result shows that there is a reduction in all type of strength for crumb rubber mixture, but crumb rubber content concrete become more lean due to increase in partial replacement of crumb rubber as fine aggregate ie.,3%, 6%, 9% and 12%. Flexural strength of concrete decreases with 3% replacement of sand and further decrease in strength with the increase in percentage of crumb rubber. For split tensile strength decreases with 3% replacement of sand and further decrease in strength with the increase in percentage of crumb rubber. This is mainly due to lower bond strength between cement paste and rubber tyre aggregate
- **Prof. M. R. Wakchaura and Mr. Prashant. A. Charan**In this study they did partial replacement of fine aggregate as crumb rubber as 0.5%, 1%, 1.5% and 2% in M25 grade of

concrete and its effects on concrete properties like compressive strength, flexural strength were investigated. Addition to this combination of glass fiber at ratio 0.4% and 0.5% addition to the weight of cement are used to regain the reduced strength due to use of waste tyre crumb rubber particle. Results indicate that replacement of waste tyre crumb rubber particle to the fine aggregate in concrete at ratio 0.5% and 1% there is no effect on the concrete properties would occur, but there was a considerable change for 1.5% and 2% replacement ratio.

- **Dr. B. Krishna Rao** in this investigation he did casting and testing of cubes, cylinders, and prisms for M20 grade of concrete and added 5% and 10% of rubber fiber by volume of concrete. There the specimens are tested for compression, split tensile and flexural strength. The test results were done and noted that due to addition of rubber fiber, strength of concrete decreases, but as observing ductility is improving. Hence it is used for medium grade of concrete. The various rubberized concrete mixes were designed in accordance with standard mix design procedure for normal concrete with grade of M20. As expected, the target strength was not achieved for the mixes incorporating rubber fiber.
- **Er. Yogender Antil** The primary objective of their investigation is to study the strength behaviors i.e., compressive strength and flexural strength of rubberized concrete with different volume of crumb rubber. Parameter to be varied in Investigation is volume variation of crumb rubber. The proposed work is aimed to study the effect of volume variation of crumb rubber on the compressive strength, flexural strength and slump test. So, they founded that strength of modified concrete is reduced with an increase in rubber content. The Flexural strength of the concrete decreases about 69% when 20% of sand is replaced by crumb rubber. The compressive strength of the concrete decreases about 37%when 20% of sand is replaced by crumb rubber. So overall large percentage of crumb rubber the lower the compressive strength and flexural strength as compared to conventional concrete.
- **Sulagno Banerjee, Aritra Mandal, Dr. Jessy Robby** the aim of their investigation was studies on mechanical properties of tyre rubber concrete. In their study they made a concrete of M25 grade by replacing 5%, 10%, 15%, 20% and 25% of tyre concrete with coarse aggregate and compared with regular M25 grade concrete. The properties of fresh concrete and flexural strength of hardened concrete were identified. So, they concluded that flexural strength decreases in concrete. In 7 days', flexure strength, there is not much variation seen between conventional and rubberized concrete. So, there was not much difference in strength of rubberized and conventional concrete.
- **Nithiya P and Portchejian G** It this research paper the mix design was done as per IS:10262-2009 to achieve the target strength. The concrete mixes were made by replacing fine aggregate with 5%, 10%, 15% and 20% for M20 grade concrete. So, they founded that compressive strength decreases with the replacement of crumb rubber increased and 5%

replacement of crumb rubber proves exceptionally well in compressive strength and tensile strength. It also gives more strength at 28th days for 5% replacement for M20 grade of cement and split tensile strength decreases at the maximum at the maximum of 25% when crumb rubber is replaced up to 10% of fine aggregate. Thus, by replacing fine aggregate by crumb rubber safeguards the environment.

METHODOLOGY:

1. Artificial marine environment

Artificial sea water is used for laboratory testing such as evaluating the deleterious effects on concrete surfaces and structures, electronic components, test for oil contamination and detergency evaluation and for oceanographic, biochemical and forensic purposes, etc., where a reproducible solution simulating sea water is required. The effect of marine flora and fauna are excluded. In this experiment artificial sea water is required as the rubberized as well as the normal concrete cubes will be cured in water for particular day's gaps.

1.1. Quantity of chemical proportions

The proportions are as per IS: 8770 – 1978.

COMPOUND	CONCENTRATTION (G/L)
Sodium Chloride (NaCl)	23.5
Magnesium Chloride (MgCl)	5.0
Sodium Sulphate (Na_2SO_4)	3.9
Calcium Chloride ($CaCl_2$)	1.1
Potassium Chloride (KCl)	0.66
Sodium Bicarbonate ($NaHCO_3$)	0.20
Potassium Bromide (KBr)	0.10

Boric Acid (H_3BO_3)	0.026
Strontium Chloride ($SrCl_2$)	0.024
Sodium Fluoride (NaF)	0.003

2.3. Solutions

Amount of sea water required for the completion of this test is 90 liters. The compounds are mixed with 90 liters of normal water as per the proportions written in IS:8770 – 1978 as mentioned above.

2.4. Preparation of solution

Stock Solution A - Dissolve the indicated amounts of the following salts in water and dilute to a total volume of 10 liters. Store in well- stoppered glass container:

- Magnesium chloride ($MgCl_2.6H_2O$) 5335 g
- Calcium chloride ($CaCl_2$) Anhydrous 550 g
- Strontium chloride ($SrCl_2.6H_2O$) 21 g

Stock Solution B - Dissolve the indicated amounts of the following salts in water and dilute to a total volume of 10 litres. Store in well- stoppered glass container:

- Potassium Chloride (KCl) 660 g
- Sodium bicarbonate ($NaHCO_3$) 200 g
- Potassium bromide (KBr) 100 g
- Boric acid (H_3BO_3) 26 g
- Sodium Fluoride (NaF) 3 g

2.5. Preparation of sea water

Amount of compounds in solutions required for 90 litres of sea water are described as follows

Solution A		**Solution B**	
Magnesium chloride	48015 gm	Potassium chloride	5940 gm

Calcium chloride	4950 gm	Sodium bicarbonate	1800 gm
Strontium chloride	189 gm	Potassium bromide	900 gm
		Boric acid	234 gm
		Sodium fluoride	27 gm

1. **Concrete mix**

A-1 STIPULATIONS FOR PROPORTIONING:

a) Grade designation: M30
b) Type of cement: OPC-43 grade conforming to IS 8112
c) Max nominal size of aggregates: 20 mm
d) Min cement content: 260 kg/m^3
e) Max water cement ratio: 0.42
f) Workability: 100 mm (slump)
g) Exposure condition: very severe (for RC)
h) Method of concrete placing: pumping
i) Degree of supervision: good
j) Type of aggregate: crushed angular aggregate
k) Max cement content: 450 kg/m^3

A-2 TEST DATA FOR MATERIALS:

a) Specific gravity of cement: 3.15
b) Specific gravity of1. Fine aggregate 2. Coarse aggregate: 2.74
c) Water absorption 1. Fine aggregate: 1.0 2. Coarse aggregate: 0.5%
d) Free surface moisture: Nil (for coarse and fine aggregates)
e) Sieve analysis:

1. Coarse aggregate:

IS sieve size (mm)	Analysis of coarse aggregates fraction	% of different fractions

	I	II	I 60%	II 40%	Combined 100%
20	100	100	60	40	100
10	0	71.20	0	28.5	28.5
4.75	-	9.40	-	3.7	3.7
2.36	-	0	-	-	-

2. Fine aggregate:
   Conforming to grading zone II of Table-4 of IS 383.

A-3 Target strength for mix design:

$F_{ck}' = f_{ck} + 1.65S$

Where, f_{ck}'= Target avg compressive strength at 28 days

F_{ck}= Characteristic compressive strength at 28 days

S= Standard deviation

From Table I, standard deviation, S= 5N/mm^2

Therefore, f_{ck}'= 30+1.65x5 = 38.25 N/mm^2

A-4 Selection of water cement ratio:

Max w/c ratio = 0.42

Adopted w/c ratio = 0.42, 0.42 <= 0.42, hence ok

A-5 Selection of water content:

From table 2, max water content for 20 mm agg = 186 litres (for 25-50 mm slump range)

Water content for 100 mm slump = 186 + 6/100 x 186 = 196 litres

A-6 Calculation of cement content:

w/c ratio = 0.42; cement content = 197/0.42 = 469 kg/m^3; For very severe exposure conditions min. cement content is 260 kg/m^3;469 kg/m^3> 260 kg/m^3, hence ok

A-7 Proportion of volume of coarse and fine aggregates content:

From table 3, volume of coarse aggregate corresponding to 20 mm size and fine aggregate (zone II) for w/c ratio of 0.5 = 0.62

Present w/c ratio = 0.42

Corrected volume of coarse aggregate for the w/c ratio of 0.42 = 0.635

For pump able concrete these values should be reduced by 10%

Therefore, vol of coarse agg = 0.635 x 0.9 = 0.5

Vol of fine agg = (1-0.57) = 0.43

A-8 Mix calculation:

The mix calculation/ unit volume of concrete

a) Vol of concrete = 1 m^3
b) Vol of cement = (mass of cement)/ (specific gravity of cement) x 1/1000
   = 469/3.15 x 1/1000
   = 0.148 m^3
c) Vol of water = (mass of water)/(specific gravity of water) x 1/1000
   = 197/1 x 1/1000
   = 0.197 m^3
d) Vol of all in aggregate = [a-(b+c)]
   = [1-(0.148+0.197)]
   = 0.655 m^3

e) Mass of coarse aggregate = ex vol of coarseagg x spc gravity of coarse aggregate x 1000
= 0.655 x 0.57 x 2.74 x 1000
= 1023 kg

f) Mass of fine aggregate = ex vol of fine aggregate x spc gravity of fine aggregates x 1000
= 0.655 x 0.43 x 2.74 x 1000
= 772 kg

A-9 Mix proportions:

- Cement = 469 kg/m^3
- Water = 197 litres
- Fine aggregates = 772 kg/m^3
- Coarse aggregates = 1023 kg/m^3
- Water cement ratio = 0.4

RESULT

COMPRESSIVE STRENGTH TEST:

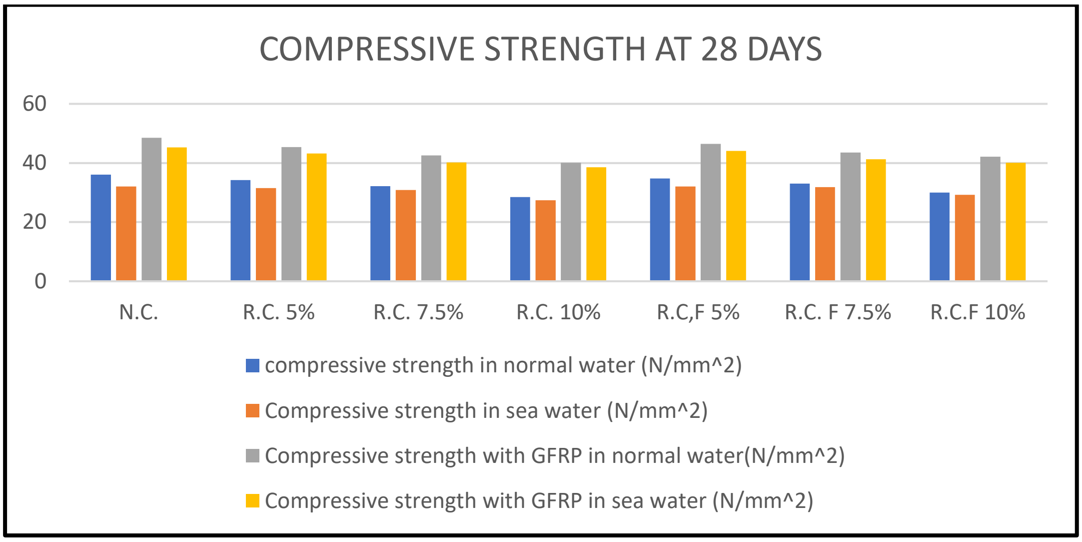

Figure17: Graph for type of concrete versus compressive strength

CONCLUSION: - Rubberized concrete is found to be slightly weak than the normal concrete which can be concluded. With addition of fly ash its strength increases slightly. Thus, we can say the long-term strength of both normal concrete and rubberized concrete is same under marine environment. GFRP sheets help in increasing the resistance and thus can be used as long-term materials for joints in beams and columns.

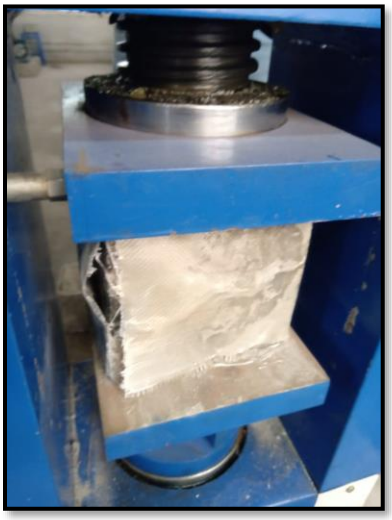

Figure 18: specimen under compressive testing machine Fig19: specimen for strength test

SORPTIVITY TEST

Sorptivity = [I÷√t]

Where,

I = [ΔW÷√ꞵ]

t = time in minutes (30 min)

ꞵ = 1000 kg/m^3

A = 150 x 150 mm^2

ΔW = (W_2 – W_1)

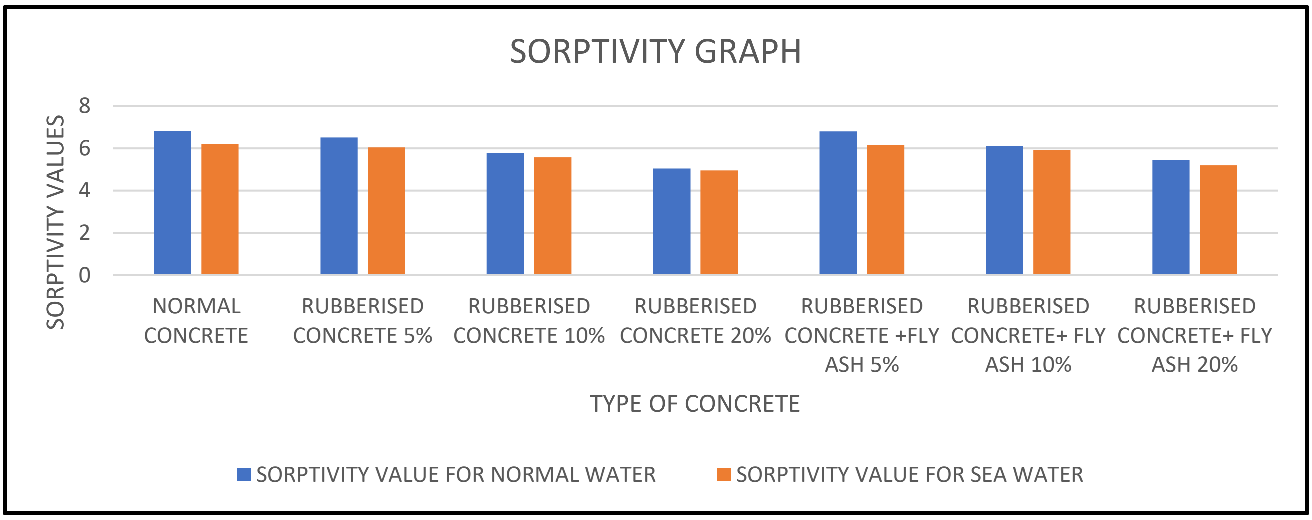

Figure 20: Graph for type of concrete versus sorptivity values

CONCLUSION: - Sorptivity of rubberized concrete shows lower value at the replacement of 7.5% of each fly ash and crumb rubber. The fly ash here can be an innovative supplementary cementitious construction material but judicious decision has to be taken by engineers. Thus, fly ash increases sorptivity.

WATER ABSORPTION TEST:

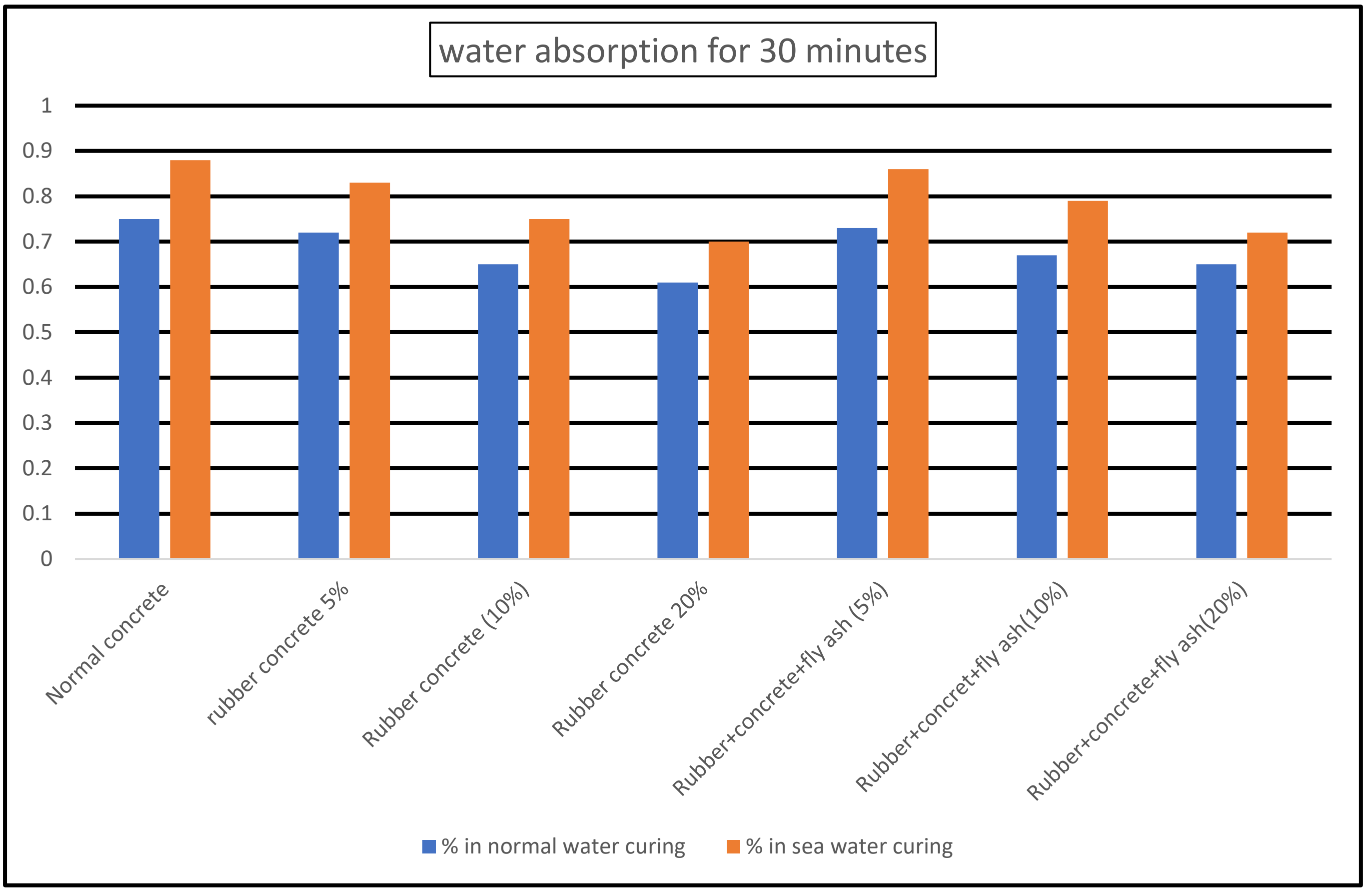

Figure 21: Graph showing type of concrete versus water absorption

CONCLUSION: - Water absorption by rubberized concrete is low compared to normal concrete in both normal as well as sea water, which can prove to be an advantageous factor because lower water absorption is beneficial for construction in marine environment.

Figure 22: specimens kept for water absorption

IMPACT TEST

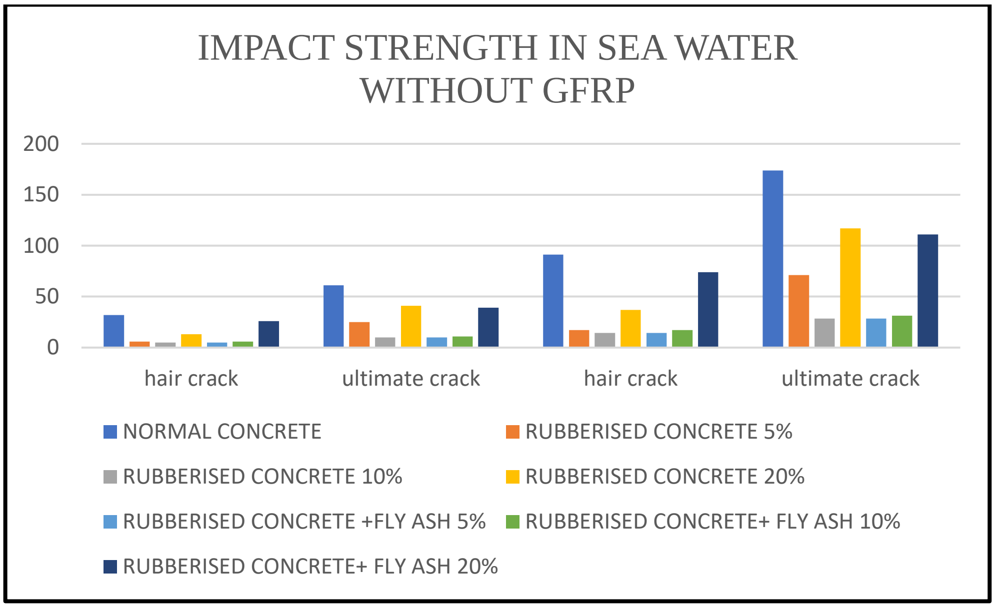

Figure 23: Graph for impact strength in sea water without GFRP

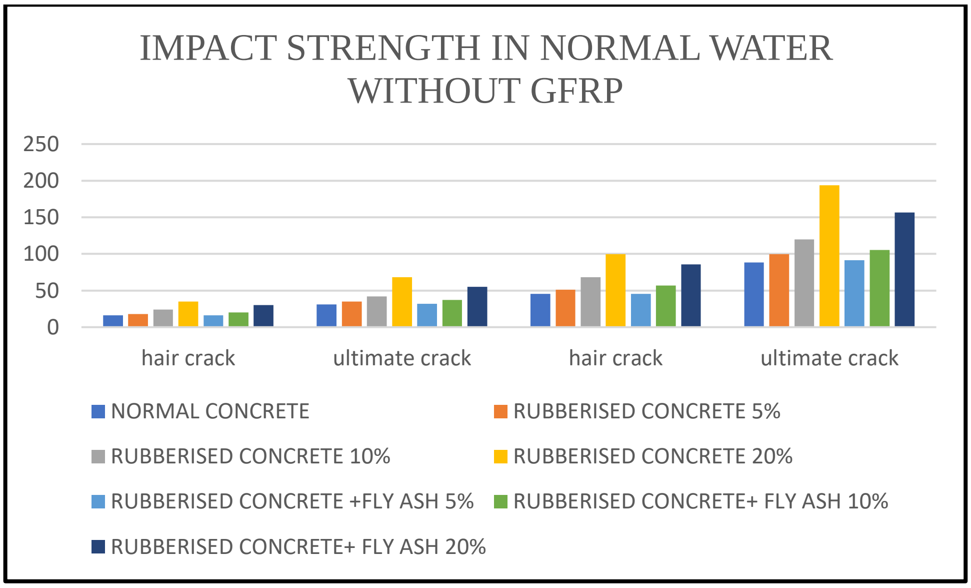

Figure 24: Graph for impact strength in normal water without GFRP.

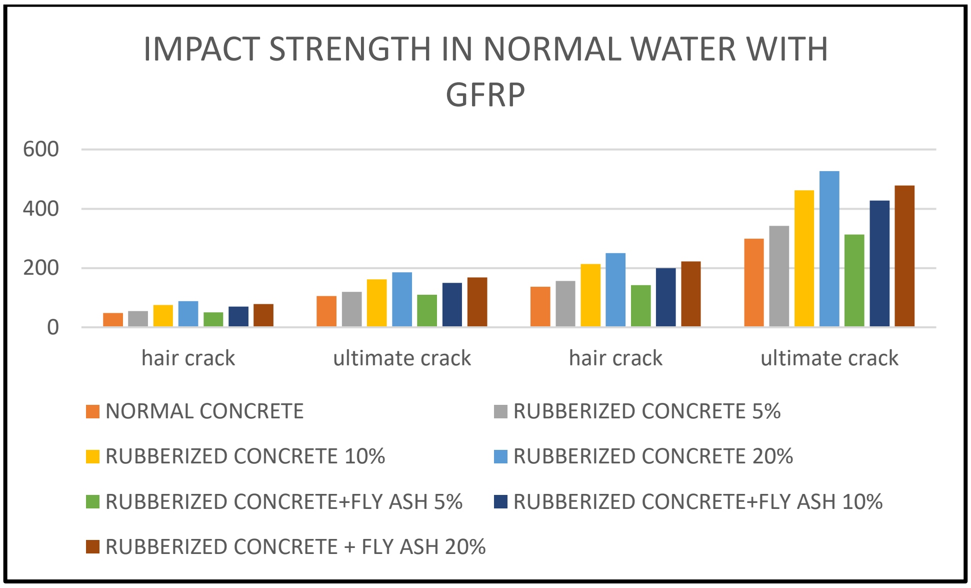

Figure 25: Graph showing impact strength in normal water with GFRP.

CONCLUSION:

Rubberized concrete can resist greater impact when immersed in sea water for 28days than in normal water thus it can be concluded that the rubberized concrete with greater percentage of rubber and fly ash can be used in marine environment as it can take greater impact. Adding GFRP confinement to the moulds can take greater impact in normal than without GFRP sheets.

Figure 26: specimens with GFRP sheets after impact test

CONCLUSION: - From the above tests on rubberized concrete in normal as well as sea water and its correlating with the normal concrete we can say that rubberized can be used in construction as the compressive strength of rubberized after 150 days in marine condition is same as that of normal concrete. the water absorption of rubberized concrete is also low which will be a beneficial factor for construction in marine environment. The test results of this study indicate that there is great potential for the utilization of waste tyres in concrete mixes in several percentages, ranging from 5% to 20%.

Based on present study, the following can be concluded: The strength of modified concrete is reduced with an increase in the rubber content; however lower unit weight meets the criteria of light weight concrete that fulfill the strength requirements as per given in table 5.9 by Neville in 1995. Concrete with higher percentage of crumb rubber possess high toughness The slump of the modified concrete increases about 1.08%, with the use of 1 to 10% of crumb rubber. Stress strain shows that concrete with a higher percentage of crumb rubber possess high toughness, since the generated energy is mainly plastic. Failure of plain and rubberized concrete in compression and split tension shows that rubberized concrete has higher toughness. The split tensile strength of the concrete decreases about 30% when 20% sand is replaced by crumb rubber. The flexural strength of the concrete decreases about 69% when 20% sand is replaced by crumb rubber. The compressive strength of the concrete decreases about 37% when 20% sand is replaced by crumb rubber. For large percentage of crumb rubber, the compressive strength gain rate is lower than that of plain concrete.

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