Effect of Direct Marine Exposure on Strength of Blended Concretes

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Abstract— Tons of water is annually used as mixing, curing and cleaning around the world, in concrete industry. As there is a scarcity of fresh drinkable water around the world; so there is a need to save fresh water and hence possibilities of using seawater as mixing as well as curing water should be investigated seriously. The experimental investigation was carried out to study the strength performance of ordinary Portland cement (OPC) concrete, Fly ash concrete and GGBS concrete using both potable water and marine water. Hardened concrete was tested for compressive strength to ascertain the feasibility of blended concretes when concrete is subjected to marine environment. Accordingly, Compressive strength of concrete test at the age of 56 days was tested for M50 grades of Normal, Fly ash and GGBS concrete. It was concluded from this study that Sea water can be used for concrete compression members.

Key words: OPC, Blended Concretes

I. INTRODUCTION

Several billion tons of water is annually used as mixing, curing and cleaning around the world, in concrete industry. As there is a scarcity of fresh drinkable water around the world; so there is a need to save fresh water and hence possibilities of using seawater as mixing as well as curing water should be investigated seriously. Additionally, if use of seawater as concrete material is permitted, it will be very convenient and economical in the construction; especially in the coastal works. However; most of the reinforced concrete codes do not permit the use of seawater due to risk of early corrosion of reinforcement. The effect of seawater on concrete deserves special attention as the coastal and offshore structures are exposed to simultaneous action of a number of physical and chemical deterioration processes. Moreover, 80 percent of the earth is covered by seawater either directly or indirectly (e.g. winds can carry sea water spray up to a few miles in land from the coast). Concrete piers, decks, break-water, and retaining walls are widely used in the construction of harbors and docks. The use of concrete offshore drilling platforms and oil storage tanks is already on the increase (Akshat et al., (2015)).

Civilization in olden days took place along the sea shores or river fronts and it is obvious that the structures were then subjected to marine environment. Hence all the olden days constructions were obviously made of marine exposure resistant materials. Today Concrete is the most sought after construction material and it is not resistant to marine exposure. When the concrete is exposed to sea water, the action of carbon dioxide would result in the formation of calcium carbonate thereby reducing the alkalinity of the concrete, sulphates. This forms Ettringite and Gypsum and causing physical expansion and leaching and chlorides would cause a reduction in alkalinity of the concrete and leaching.

Clauses 5.4.3 and 5.4.4 of IS 456: 2000 outlined the use of sea water in concrete. Accordingly mixing or curing of concrete with sea water is not recommended because of presence of harmful salts in sea water. Under unavoidable circumstances sea water may be used for mixing or curing in plain concrete with no embedded steel after having given due consideration to possible disadvantages and precautions including use of appropriate cement system. Water found satisfactory for mixing is also suitable for curing concrete. However, water used for curing should not produce any objectionable stain or unsightly deposit on the concrete surface. The presence of tannic acid or iron compounds is objectionable.

The Clause 8.2.8 of IS 456: 2000 specifies the minimum grades of concrete to be adopted when the concrete is exposed to marine environment. Accordingly concrete in sea-water or exposed directly along the sea coast shall be at least M20 Grade in the case of plain concrete and M30 in case of reinforced concrete. The use of slag or pozzolana cement is advantageous under such conditions however qualitative advantage is nowhere studied or documented. Special attention shall be given to the design of the mix to obtain the densest possible concrete.

No construction joints shall be allowed within 600 mm below low water-level or within 600 mm of the upper and lower planes of wave action. Where unusually severe conditions or abrasion are anticipated, such parts of the work shall be protected by bituminous or silicon-fluoride coating or stone facing bedded with bitumen.

ACI: 318-1983 gives no specific reference to sea water. It recommends that mixing water shall be potable and free from salts. Mortar test cubes made with non-potable mixing water shall have 7days and 28 days strength equal to at least 90% of strength of similar specimen made with potable water.

A. *Objective and Scope of this Study*

The objective this study is to test hardened concrete for compressive strength to ascertain the feasibility of blended concretes when concrete is subjected to marine environment. Accordingly Compressive strength of concrete test at the age of 7 days, 14 days, 28 days and 56 days was tested for M50 grades of Normal, Fly ash and GGBS concrete.

B. *Concrete Mix Proportioning*

The mix design or concrete mix proportioning was carried out as per IS: 10262-2009 “concrete mix proportioning - guidelines”. Three types of concretes viz; Normal concrete, Fly ash concrete and GGBS concrete were considered for the study and the corresponding mixes were proportioned. Three concrete grades i.e. M30, M40 and M50 in each type of said concretes were done. In addition to these concretes, a Reference concrete was also made with both potable water mixing and curing using 53 grade ordinary Portland cement.

Normal concrete means mix proportioning was carried out using 53 grade ordinary Portland cement and all other remaining ingredients were unchanged. The mix proportioning was also carried out with marine water for all the four concrete grades.

II. Literature review

A. Normal Concrete Exposed to Marine Water

Akinkurolere and school (2007) studied the influence of salt water on the compressive strength of concrete. They have investigated compressive strength of concrete considering salt water from Lagos Lagoon in Nigeria. Wegian (2010) investigated the effect of sea water for mixing and curing on the compressive, tensile, flexural and bond strengths of concrete. Mbadike and Elinwa (2011) conducted research work on effect of salt water in the production of concrete.

B. Studies on Concrete Strengths using Fly Ash Concrete and Marine Water

The geopolymer was claimed to be durable in some aggressive environments such sulfate and fire (Bakharev, 2005; Kong et al., 2007). The geopolymer concrete could resist synthetic seawater without strength degradation and significant weight loss (Fernandez-Jimenez et al., 2007). Chalee et al., (2009) in their study, developed a model for predicting chloride penetration in fly ash concrete under long-term exposure in a marine environment is developed. Chalee et al., (2010), in their paper on "Utilization of fly ash concrete in marine environment for long term design life analysis", presented the performance of 7-year fly ash concrete exposed to hot and high humidity climate in marine conditions. Marthong and Agrawal (2012) studied the effect of fly ash additive on concrete properties. Three grades of ordinary Portland cement i.e. 33, 43 and 53 were used with a fly ash replacement by 10%, 20%, 30% and 40% dosages. The period of exposure considered in the study was 7, 28, 56 and 90 days.

C. Ground Granulated Blast Furnace Slag (GGBS) Concrete and Marine Water

From the magazine Civil + Marine (UK) (2007), it was noted from an article in on GGBS and concrete properties, that GGBS helps to avoid early age thermal cracking as the setting time will be extended slightly. The authors studied the influence of salt weathering on the properties of concrete. Four different concrete mixes, one with OPC, two with 65% replacement of ground granulated blast furnace slag (GGBS) and one with 35% rapid hardening Portland cement and 65% of GGBS. The total cementitious content is 450 kg/m^3. Pavia and Condren (2008) studied the durability of ordinary Portland cement verses ground granulated blast furnace slag concrete exposed to silage effluent (grass conserved as silage for winter feed). Daisuke et al., (2009) studied the effect of sea water as mixing water on the hydration characteristics of blast-furnace slag cement. In their investigations, cement paste with OPC was used with the replacement of BFS at 20%, 55% and 90%.

D. Ternary Concretes (Combination of 2 or More Pozzalona as a Partial Replacement of Cement) in Marine Environment

Markandeya Raju Ponnada, S Siva, Harish Dharmala, worked on Compressive Strength of Concrete with Partial Replacement of Aggregates with Granite Powder and Cockle Shell (2016).

Markandeya Raju Ponnada, Siva Prasad Bandaru, studied the Effect of sea water curing on properties of concrete.

Markandeya Raju Ponnada and Kameswari Ponnada, reviewed on Construction and Demolition Waste Management (Nov. 2015).

Santosh Kumar Karri, G. V. Rama Rao, P. Markandeya Raju studied on Strength and Durability Studies on GGBS Concrete.

Sirile Eathakoti, Navya Gundu, Markandeya Raju Ponnada suggested an An Innovative No-Fines Concrete Pavement Model", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Vol. 12, Issue 5, Ver. III, (Sep. - Oct. 2015), pp34-44.e-ISSN: 2278-1684, p-ISSN: 2320-334X.

Markandeya Raju Ponnada, and Pranathi Singuru, presented the Advances in manufacture of mooncrete

Markandeya Raju Ponnada experimented on combined effect Of flaky and elongated aggregates On strength and workability of concrete.

Suvarnalatha et al., (2012) in their study conducted on estimation of GGBS and HVFA strength efficiencies in concrete with age, replacement of HVFA from 0% to 70% at the increment of 10% for M20, M40 and M60 grade concretes were considered with an exposure period of 28, 90 and 180 days. The investigation revealed that the partial replacement of cement with HVFA in concrete mix showed enhanced performance in terms of strength and durability in all grades and this is due to the presence of reactive silica in HVFA. It was also observed that there is an increase in the compressive strength for different concrete mixes adopted in the study made with HVFA replacement. The investigation reveals that compressive strength of GGBS at 40% replacement attains more strength for M20 and M40 grades whereas at 50% replacement more strength is attained by M60. Compressive strength of HVFA attains more strength at 40% replacement in case of M20 grade whereas at 500% replacement the strength is more for M40 and M60 grades.

E. Concluding Remarks on Literature

From the literature, it is clear that there are certain factors to be considered when sea water is used for mixing and/or curing in concrete. Some international codes (Indian, ACI etc.,) of practice accept use of sea water for concrete making under some special conditions and recommend pozzolana blended cements for superior performance of concrete exposed to sea water mixing / curing conditions. However, a qualitative comparison is required. This study is an attempt in this direction

III. Experimental work

The experimental investigation was carried out in order to study the strength performance of various concretes such as Normal concrete i.e. ordinary Portland cement (OPC) concrete, Fly ash concrete i.e. ordinary Portland cement concrete with fly ash replacement and GGBS concrete i.e. ground granulated blast furnace slag cement concrete using both potable water and marine water. The cement selected is ordinary Portland cement with 53 Grade. Hardened concrete was tested for compressive strength to ascertain the feasibility of blended concretes when concrete is subjected to marine environment. Accordingly Compressive strength of concrete test at the age of 56 days was tested for all M50 grades of Normal, Fly ash and GGBS concrete.

A. *Materials*

The various materials used in the experimental investigation are ordinary Portland cement, fly ash, GGBS cement, fine aggregate, coarse aggregate, water, marine water.

1) *Cement*

Ordinary Portland cement of 53 grade (MAHA Cement) confirming to IS 12269:1987 (Specification for 53 grade ordinary Portland) was used in the present experimental investigation. Its specific gravity is 3.15. The cement was tested as per the procedure given in Indian standards IS 4031 (1988).

2) *Fly ash*

Fly ash is an industrial waste obtained from thermal power stations. In this investigation, the fly ash was obtained from NTPC, Visakhapatnam. The physical properties and chemical properties of fly ash that was used

B. *Mix Proportioning*

The mix design or concrete mix proportioning was carried out as per IS: 10262-2009 "concrete mix proportioning - guidelines". Three types of concretes viz; Normal concrete, Fly ash concrete, GGBS concrete were considered for the study and accordingly mix proportions are calculated. Four concrete grades i.e. M30, M40 and M50 were designed. The calculations of mix proportioning for M30 are presented here.

1) *Mix Calculations*

The mix calculations per unit volume of concrete shall be as follows:

- Volume of concrete = $1m^3$
- Volume of cement = $\frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$ = $0.1448\ m^3$
- Volume of water = $\frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000}$ = 0.202 m^3
- Volume of all in aggregates=[a-(b+c)] = [1(0.1448+0.202)]=0.7095 m^3
- Mass of coarse aggregate = (e x volume of CA x Specific gravity of CA x1000) = 0.7095 x 0.576 x 2.69x 1000 =1099 kg
- Mass of fine aggregate = (e x volume of fine aggregate x Specific gravity of fine aggregate x 1000) 0.7095×0.424 x 2.57 x 1000 = 773 kg

a) Summary of Mix Proportioning - (Normal Concrete)

Sl. No	Concrete Ingredient	Grades of Concrete (Per Cum. Quantities)
		M50
1	Cement (kg)	433
2	Water (kg)	202
3	Fine aggregate (kg)	773
4	Coarse aggregate (kg)	1099
5	Water cement ratio	0.467

Table 1: Summary of Mix Proportioning

2) *Mix Proportioning of Fly ash concrete*

Fly ash concrete designated as F, means mix proportioning was carried out with an optimum replacement of 25% of fly ash in ordinary Portland cement with 53grade. All other ingredients remain unchanged. The mix proportioning was made for all the three grades of concrete i.e. M50

Sl. No	Concrete ingredient	Grades of concrete (per cum. quantities)
		M45
1	Cement (kg)	324.75
2	Fly ash (kg)	108.25
3	Water (kg)	202
4	Fine aggregate (kg)	773
5	Coarse aggregate (kg)	1099
6	Water cement ratio	0.467

Table 2: Grades of concrete

3) *Mix Proportioning of GGBS concrete*

GGBS concrete designated as G, means that the concrete is prepared using cement replaced with 55% slag content in the mix proportioning and other ingredients were unchanged. The mix proportioning was carried out for M50 grade concrete and the proportions are presented in following Table

Sl. No	Concrete ingredient	Grades of concrete (per cum. quantities)
		M45
1	GGBS (kg)	216.5
2	Cement (kg)	216.5
3	Water (kg)	202
4	Fine aggregate (kg)	773
5	Coarse aggregate (kg)	1099
6	Water cement ratio	0.467

Table 3: Grades of concrete

C. *Slump Cone Test*

The test is used extensively in site all over the world. The slump test does not measure the workability of concrete, but the test is very useful in detecting variations in the uniformity of a mix of given nominal proportions.

The slump test is done as prescribed by IS: 516.

The apparatus for conducting the Slump test essentially consists of a metallic mould in the form of a cone having the internal dimensions as under

- Bottom diameter: 200 mm
- Top diameter: 100 mm

The mould for slump is a frustum of a cone, 300 mm high. It is placed on a smooth surface with the smaller opening at the top, and filled with concrete in three layers. Each layer is tamped twenty five times with a standard 16 mm diameter steel rod, rounded at the end, and the top surface is strucked off by means of sawing and rolling motion of the tamping rod. The mould must be firmly fixed against its base during the entire operation. This is facilitated by handles or foot-rests brazed to the mould. Immediately after filling, the cone is slowly lifted vertically up, and the unsupported concrete will now slump and hence the name of the test. The difference in level between the height of the mould and that of highest point of subsided concrete is measured. This difference in height in mm is taken as slump of concrete. The slump observations are presented in following Table.

Sl. No	Mix Designation	Slump (mm)
Normal water mixing and sea water curing		

1.	M50 (25% Fly ash)	145
2.	M50	135
3.	M50 (50% GGBS)	135
Normal water curing and sea water mixing		
4.	M50 (25% Fly ash)	130
5.	M50	140
6.	M50 (50% GGBS)	145
Sea Water mixing, Sea Water curing		
7.	M50 (25% Fly ash)	140
8.	M50	140
9.	M50 (50% GGBS)	140
Normal water curing and normal water mixing		
10.	M50 (25% Fly ash)	140
11.	M50	140
12.	M50 (50% GGBS)	150

Table 4: Slump observations

1) Tests on Hardened Concrete

The objective of testing the hardened concrete is to determine the compressive strength. Accordingly tests were conducted for all the concretes at the age of 7 days, 14 days, 28 days and 56 days.

D. Compression Test

Compression test was conducted on 150mm × 150mm × 150mm cubes. Concrete specimens were removed from curing tank and cleaned. In the testing machine, the cube is placed with the cast faces at right angles to that of compressive faces, then load is applied at a constant rate of 1.4 kg/cm^2/minute up to failure and the ultimate load is noted. The load is increased until the specimen fails and the maximum load is recorded. The compression tests were carried out at 7, 28, 90 and 180 days. For strength computation, the average load of three specimens is considered for each mix. The average of three specimens was reported as the cube compressive of strength.

$$\text{Cube compressive strength} = \frac{\text{Load}}{\text{Area of cross section}}$$

The compressive strength results are presented in Tables 3.10 below & the testing of specimens limits the following table shows the cross sections of selected steel sections which are assigned for bracing members.

Based on the results presented above the following bar charts are presented for understanding the performance.

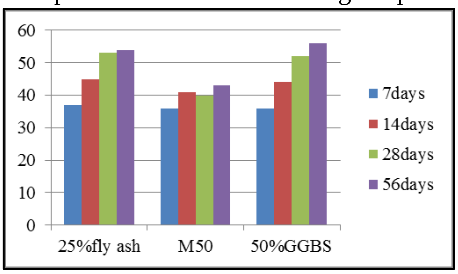

Fig. 1: Normal water mixing and sea water curing ()

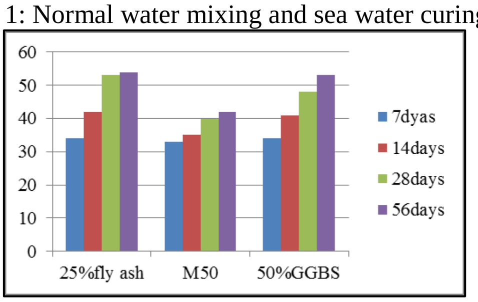

Fig. 2: Normal water curing and sea water mixing

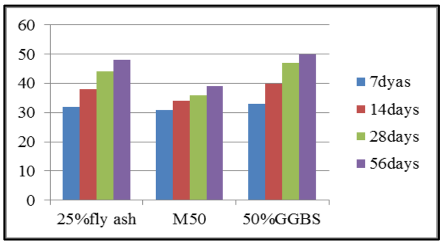

Fig. 3: Sea Water mixing, Sea Water curing

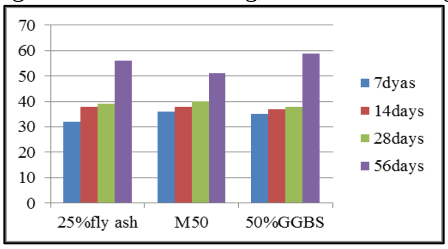

Fig. 4: Normal water curing and normal water mixing

IV. RESULTS AND DISCUSSION

A. Comparative performance of different concretes at different ages

Various graphs are drafted among different EXPOSURE conditions in terms of mixing water and curing water so that the comparison of different grades of concrete at different ages for normal, Fly ash and GGBS concretes can be studied.

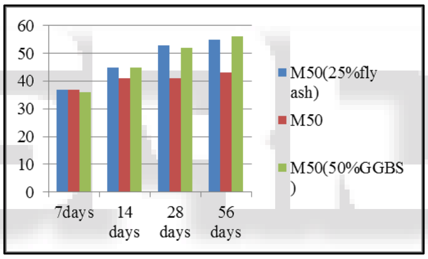

Fig. 5: Normal water mixing and sea water curing

For normal water mixing and sea water curing, Fly ash and GGBS concrete performed almost similaly and better than normal concrete at 28 days and 56 days.

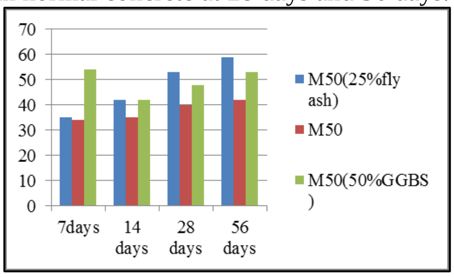

Fig. 6: Sea water mixing and normal water curing

For sea water mixing and sea water curing, GGBS concrete, followed by Fly ash and then normal concrete performed in the decending order at 28 days and 56 days.

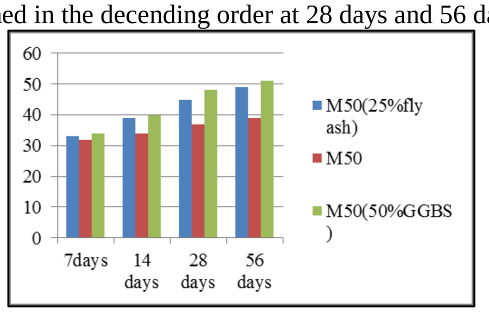

Fig. 7: sea water mixing sea water curing

For Sea water mixing and Sea water curing, GGBS concrete, followed by Fly ash and then normal concrete performed in the decending order at 28 days and 56 days.

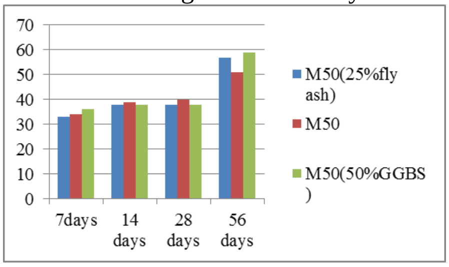

Fig. 8: Normal water mixing Normal water curing

For Normal water mixing and Normal water curing, GGBS concrete, followed by Fly ash and then normal concrete performed in the decending order at 28 days and 56 days.

1) Comparative performance of each grade of concretes at different ages for different types of concrete

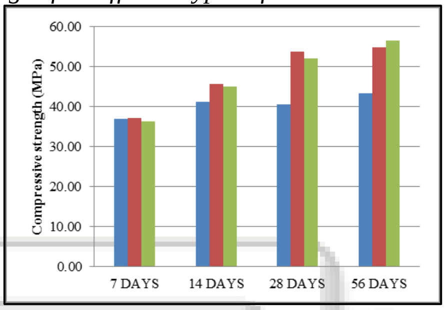

Fig. 9: Normal water mixing in M50 and sea water curing

a) For Normal water mixing and Sea water curing of M30, M40 and M50

- Sea water curing has an effect on the compressive strength of normal concrete (M30, M40 and M50) when compared to other concretes (25% flyash or 50% GGBS).
- Sea water curing does not affect the compressive strength of concrete when flyash is used as 25% in concrete.
- Sea water curing does not affect the compressive strength of concrete when GGBS is used as 50% in concrete.

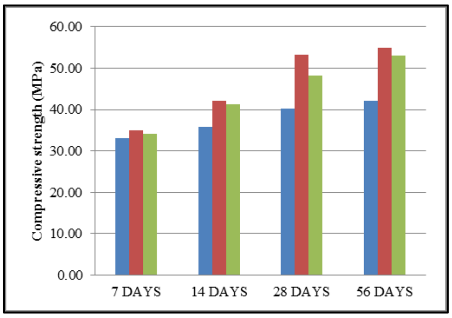

Fig. 10: Sea water mixing in M50 and normal water curing

b) For Sea water mixing and normal water curing of M30, M40 and M50

- Sea water mixing has an effect on the compressive strength of normal concrete (M30, M40 and M50).
- Sea water mixing has no effect on the compressive strength of concrete when flyash is used as 25% in concrete.
- Sea water mixing has also an effect on the compressive strength of concrete when GGBS is used as 50% in concrete.

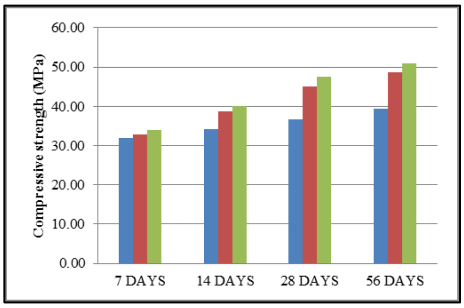

Fig. 11: Sea Water mixing in M50 and Sea Water curing

c) For Sea water mixing and Sea water curing of M30, M40 and M50

- Sea water mixing and curing has an effect on the compressive strength of normal concrete (M30, M40 and M50).
- Sea water mixing and curing affects the compressive strength of concrete when flyash is used as 25% replacement of cement in concrete.
- 50% of GGBS based concrete reached their ultimate strength slowly.

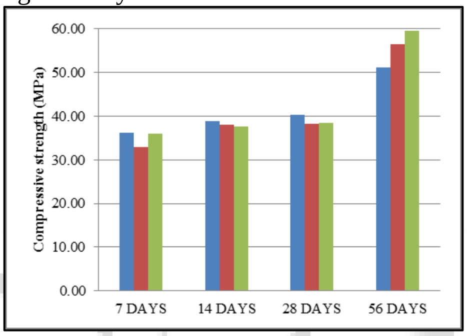

Fig. 12: Normal water mixing and curing in M50

d) For Normal water curing and Normal water mixing of M30, M40 and M50

- Normal water mixing in concrete and curing with normal water has no affect on the normal concrete

But other two blended concretes increase gradually their compressive strength from 28 days to 56 days

V. Conclusions

Based on the compressive strength of concretes of different grades, blends and EXPOSURE conditions in terms of mixing water and curing water, the following general and specific conclusions can be drawn.

1) For normal water mixing and sea water curing, Fly ash and GGBS concrete performed almost similay and better than normal concrete at 28 days and 56 days.
2) For sea water mixing and sea water curing, GGBS concrete, followed by Fly ash and then normal concrete performed in the decending order at 28 days and 56 days.
3) For Normal water mixing and sea water curing, Fly ash concrete, followed by GGBS concrete and then normal concrete performed in the decending order at 28 days and 56 days.
4) For Normal water mixing and Normal water curing, GGBS concrete, followed by Fly ash and then normal concrete performed in the decending order at 28 days and 56 days.
5) For Normal water curing and Sea water mixing of M30, M40 and M50

6) Sea water curing has an effect on the compressive strength of normal concrete (M30, M40 and M50) when compared to other concretes (25% flyash or 50% GGBS).
7) Sea water curing does not affect the compressive strength of concrete when flyash is used as 25% in concrete.
8) Sea water curing does not affect the compressive strength of concrete when GGBS is used as 50% in concrete.
9) For Sea water mixing and normal water curing of M30, M40 and M50
10) Sea water mixing has an effect on the compressive strength of normal concrete (M_{30}, M_{40} and M_{50}).
11) Sea water mixing has no effect on the compressive strength of concrete when flyash is used as 25% in concrete.
12) Sea water mixing has also an effect on the compressive strength of concrete when GGBS is used as 50% in concrete.
13) For Sea water mixing and Sea water curing of M30, M40 and M50
14) Sea water mixing and curing has an effect on the compressive strength of normal concrete (M30, M40 and M50).
15) Sea water mixing and curing affects the compressive strength of concrete when flyash is used as 25% replacement of cement in concrete.
16) 50% of GGBS based concrete reached their ultimate strength slowly.
17) For Normal water curing and Normal water mixing of M30, M40 and M50
18) Normal water mixing in concrete and curing with normal water has no affect on the normal concrete
19) But other two blended concretes increase gradually their compressive strength from 28 days to 56 days.

A. Recommendations

Sea water can be used for concrete compression members.

B. Further research is desirable in the area of

- Corrosive inhibitors to expand the adoption of sea water.
- Other cements and higher grades of concretes.
- Other RCC elements.
- Bond strength.
- Long term durability studies.
- Application of Sea water for structural Reinforced concrete tensile members.

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