A STUDY ON PERFORMANCE OF GGBS BLENDED CONCRETE AGAINST SULPHATE, CHLORIDE & SEA WATER ATTACK

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Abstract: Cement is one of the most extensively used versatile material in construction industry. Limestone which is used in cement manufacturing is a non renewable resource, but the development of the construction industry at global level need more amount of Portland cement for sustainable development. In manufacturing process it releases huge quantity of Carbon dioxide into the environment. Ground Granulated Blast Furnace Slag is a by-product of steel or iron manufacturing industry. We can't replace the cement with other materials completely but we can replace cement partially. It has been already proven to improve several performance characteristics of concrete. In this investigational purpose the GGBS replacement levels are 25%, 35%, 45% are selected. Durability of concrete specimens in terms of Chloride, Sulphate & sea water is tested separately over a period of 7, 14, 28, 56, 90 &120 days. The compressive strength test results shows that GGBS blended cement concrete has good resistance to chloride, sulphate & sea water attack in all replacement levels except in 45%replacement level & above.

Index Terms: **GGBS, OPC 53-S, concrete, Sodium Chloride, Sodium Sulphate, Super Plasticizer, Compressive strength.**

I. INTRODUCTION

Generally concrete contains cement, water, aggregates, additives or sometimes super plasticizers. Of all the materials cement plays an essential part in concrete. Because it is used to bind fine aggregate & coarse aggregate. In cement manufacturing process, it releases huge amount of green houses gases into environment. As per records nearly 2.4% of carbon dioxide is released into the atmosphere. The best way to decrease the CO_2 emission in cement industry is to replace cement with other materials. These replacement materials are also called as supplementary cementing materials. GGBS, silica fume, rice husk, fly ash...etc. are the supplementary cementing materials. GGBS is produced by grinding the granulated blast furnace slag IS; 12089-2009**[1]**. It is nonmetallic product & contains silicates and aluminosilicates of calcium. It poses an inherent ability to provide strength, stiffness & durability of concrete. It has ability to reduce the heat of hydration during concreting process. The addition of GGBS in concrete is advantageous for resisting environmental attack **[2].** Proper use of waste material will bring desired benefits in terms of energy resource conservation and environmental protection.

The approximate Molarity of Sodium Chloride in sea water is 0.5 M, so Chloride solution of strengths 0.75 M & 0.25 M were used to study of Chloride attack. Similarly the perctange of Sulphate content in the soil is approximately 5%, so Sulphate solution of strengths 4% & 6% were used for the study of Sulphate attack.

II .Literature review

D.Suresh& k.Naga Raju investigated on advantages and disadvantages of GGBS in cement replacement levels. GGBS blended cement concrete has good resistance when the concrete is subjected to aggressive environmental conditions. **A.A.Ramezanianpour** observed that, after 270 days curing in Sodium Sulphate solutions, the concrete containing 50% GGBS replacement level had good resistance. **P.Krishnam Raju** studied on the effect of sea water on compressive & flexural strength of OPC 53 grade. There is no significant reduction in compressive strength.

III. Materials:

Cement:

OPC 53-S (special cement) is used in this experimental purpose. The OPC 53-S cement is mostly used in pre-stressed concrete of higher grades, marine construction..etc. The cement is brought from the M.S Raju construction Pvt.Ltd concrete sleepers factory near Pendurthi, Visakhapatnam.

Table 1
Oxide composition of Portland cement

Oxide compound	Percentage
CaO	60-67
SiO_2	17-25
Al_2O_3	3-8
Fe_2O_3	0.5-0.6
MgO	0.5-4
SO_3	0.3-1.2
K_2O/Na_2O	2-3.5

GGBS:
It is by-product brought from Vizag steel plant. It is off -White in color. The specific surface area is 400 m^2/kg & its specific gravity is 2.75.

Table 2
Chemical composition of GGBS

Compound	Fraction (%)
SiO_2	35
Al_2O_3	12
Fe_2O_3	1.3
CaO	42
MgO	8

Fine and coarse aggregate:
Zone II River sand is used for this experimental purpose. 20mm size coarse aggregates are used. The fine and coarse aggregate are brought from the local market. The specific gravity of fine & coarse aggregates is 2.74 and 2.76 respectively.

Table 3
Physical Properties Of Cement & GGBS mixture

Properties	OPC 53-S	OPC 53-S 75% + 25% GGBS	OPC 53-S 65% + 35% GGBS	OPC 53-S 55% + 45% GGBS
Fineness	2%	3%	3%	3%
Standard consistency	29%	30%	32%	34%
Initial setting time(mins)	65	68	74	85
Final setting time (mins)	340	350	380	430
Soundness(mm)	2	1	1	1

Water: Potable water is used for mixing and curing of concrete.

Sea water: In this experimental work sea water is only used for curing purpose. The sea water is replaced weekly twice. The pH & temperature of sea water is observed regularly.

Table 4
Major ion composition of sea water

S.No	Name	ions	mg/lit
1	Sodium	Na^{+}	10360
2	Magnesium	Mg^{++}	1294
3	Calcium	Ca^{++}	413
4	Potassium	K^{+}	388
5	Chloride	Cl^{-}	19355
6	Sulphate	SO_4^{2-}	2712

Table 5
pH and temperature results of different samples of sea water

S.No	Temperature (degrees)	pH
Sample 1	29	7.6
Sample 2	27	7.5
Sample 3	27	7.8
Sample 4	28	7.4

Table 6
Mix design for M40 grade concrete as per IS 10262-2009

Cement Kg/m^3	Fine aggregate Kg/m^3	Coarse aggregate Kg/m^3	Water liters
400	729.9	1242.8	197
1	1.82	3.1	0.4

Table 7
Super plasticizers properties

Properties	**Aura Cast 270m**
Appearance	Light yellow colored liquid
pH	Minimum 6
Volume mass@20^0	1.09 kg/liter
Chloride content	<0.2%
Normal dosage	0.5 to 3 liter /100 kg

IV. Experimental investigation

In this experimental investigation the GGBS replacement levels are 25%, 35% & 45% are selected to study the chloride, sulphate & sea water attack. As per IS 516-1959 the tests of concrete are conducted.

Casting of specimens:

The standard moulds of size 100 mm× 100 mm× 100 mm have been selected. The moulds have been fitted properly & then applied oil on all sides, before concrete is poured into the mould. The mixing was carried out for 3-5 minutes duration. Then concrete is poured into cubes & vibrated mechanically.

Curing the specimens:

After casting, the cubes are demoulded after 24 hours and then the specimens are kept in respective chemical solutions for curing purpose at room temperature for 7,14,28,59,90& 120 days respectively .

Testing the specimens

- Mix design of concrete is done for preparation of concrete as per IS 10262: 2009
- CTM is used to conduct the compressive strength of cubes.
- Formula for compressive strength is

  F= P/A

  Where P= failure load kN

  A=area of cube mm^2

V. Results and discussions:

An individual comparison strength of concrete with GGBS replacement by 0%,25%,35% and 45% is made for curing periods of 7,14,28,56,90&120 days. The target strength is reached in all replacement levels except in 45%.

R0-0% GGBS + 100% cement, R1-25% GGBS+75% cement, R3-35% GGBS+ 65% cement, R4-45% GGBS+ 55% cement.

Table 8
Slump cone values

S.No	Replacement level	Slump value Mm
1	100% cement +0% GGBS	80
2	75% cement +25% GGBS	85
3	65% cement +35% GGBS	90
4	55% cement +45% GGBS	95

Table 9
7 Days Compressive Strength Results

Replacement/ curing	Normal water (N/mm^2)	Sea water (N/mm^2)	0.25 M NaCl (N/mm^2)	0.75 M NaCl (N/mm^2)	4% Na_2SO_4 (N/mm^2)	6% Na_2SO_4 (N/mm^2)
RO	38	39	36	34	36.5	35
R1	37	38.5	34.5	32.1	35	33
R2	35.8	37	33.3	31	34.2	32
R3	35	36.25	32	30	33.5	31.5

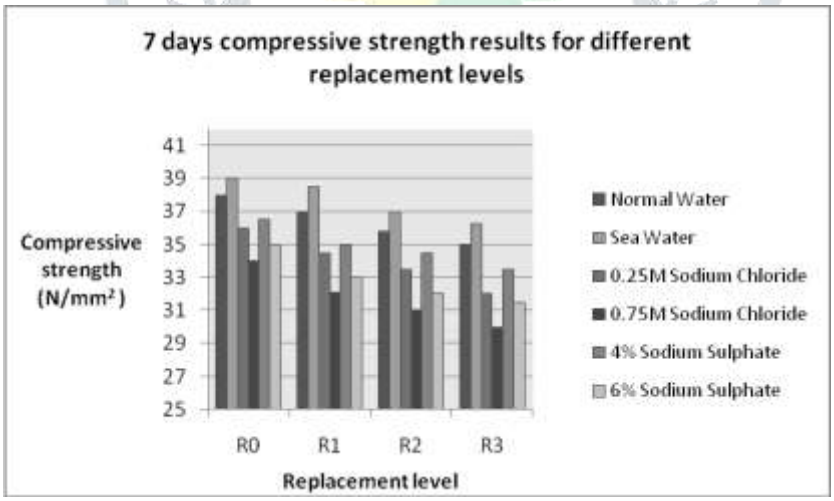

Chart 1 :7 Days Compressive Strength Results For Different Replacement Levels

Table 10
14 Days Compressive Strength Results

Replacement/ curing	Normal water (N/mm^2)	Sea water (N/mm^2)	0.25 M NaCl (N/mm^2)	0.75 M NaCl (N/mm^2)	4% Na_2SO_4 (N/mm^2)	6% Na_2SO_4 (N/mm^2)
RO	44	45.5	43.1	40	42	41
R1	45.5	46.6	44.2	42	43	42.5
R2	42.9	44	42	41	41.5	40
R3	41	43	39.5	37	38	36.5

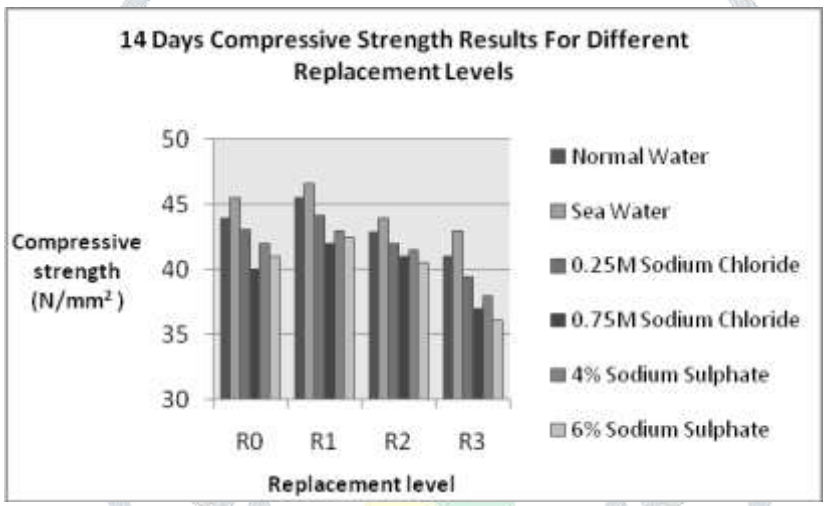

Chart -2 14 Days Compressive Strength Results for Different Replacement Levels

7 days & 14 days compressive strength results for sea water curing are 4.7% to 2.2% higher when compared with normal water for all replacement levels. 7 days compressive strength results for RO replacement are higher when compared with other replacement levels. 14 days the compressive strength results for R1 replacement level are high when compared other replacement levels.

Table 11: 28 Days Results Compressive Strength

Replacement/ curing	Normal water (N/mm^2)	Sea water (N/mm^2)	0.25 M NaCl (N/mm^2)	0.75 M NaCl (N/mm^2)	4% Na_2SO_4 (N/mm^2)	6% Na_2SO_4 (N/mm^2)
RO	49.65	48.5	49.6	48.6	49.5	48.6
R1	51	50	50	49	50.2	49
R2	53.5	51.5	52.85	51.1	51.95	50
R3	46	45	43.5	42	45	43

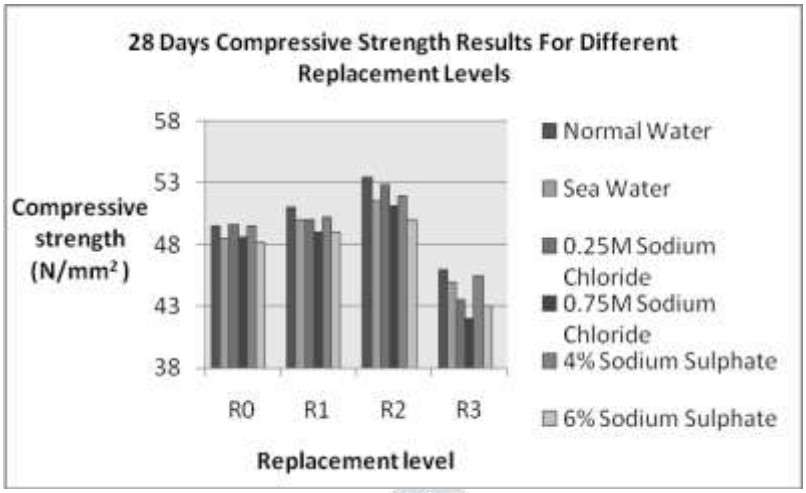

Chart-3: 28 days compressive strength results

- For 28 days the compressive strength results for R3 GGBS replacement level are higher when compared with other replacement levels. There is no considerable difference in compressive strength when the concrete is subjected to high concentration of Sodium Chloride & Sodium Sulphate i.e. 0.75 M NaCl & 6% Na_2SO_4 solutions .

Table12
56 Days Compressive Strength Results

Replacement/ curing	Normal water (N/mm^2)	Sea water (N/mm^2)	0.25 M NaCl (N/mm^2)	0.75 M NaCl (N/mm^2)	4% Na_2SO_4 (N/mm^2)	6% Na_2SO_4 (N/mm^2)
RO	52.5	51	52	50.8	51.5	50
R1	55	52.2	53.5	52	53	52.5
R2	58	55.5	56	53	55.5	54.2
R3	47.5	46	44.6	42.5	46	44.5

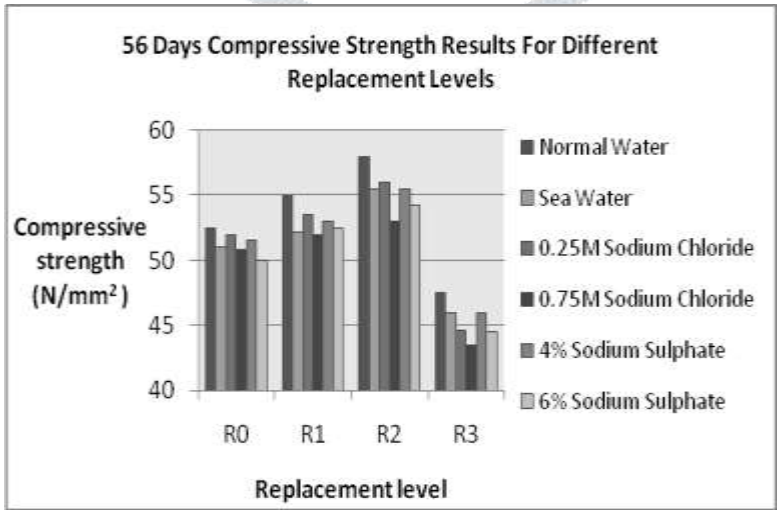

Chart 4- 56 days Compressive strength results

The % loss in compressive strength for Chloride attack ranges from 2.72% to 16.52% lesser when compared with normal water curing for all replacement levels. Similarly for Sulphate & sea water attack is 1.9% to 6.55 % lesser when compared with normal water curing. The specimens are turning to white from grey colour due to salt formation on the surfaces for 56 days respectively.

Table 13
90 days compressive strength results

Replacement/ curing	Normal water (N/mm^2)	Sea water (N/mm^2)	0.25 M NaCl (N/mm^2)	0.75 M NaCl (N/mm^2)	4% Na_2SO_4 (N/mm^2)	6% Na_2SO_4 (N/mm^2)
RO	56	55.25	54	51	53.9	52.1
R1	57.5	57	55.6	53	55	54
R2	58	57.55	57.5	55	56.8	55.5
R3	49.65	49.1	46	44	47	45.1

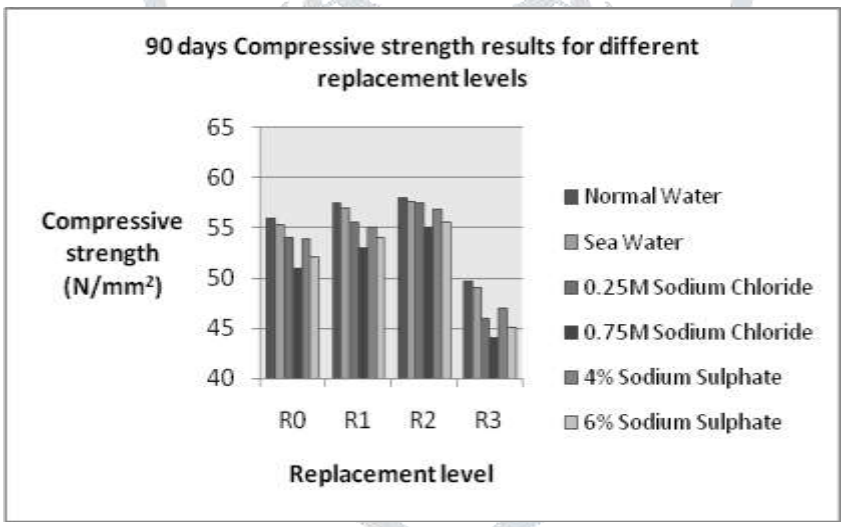

Chart -5 90 days compressive strength results

The % loss in compressive strength for chloride attack ranges from 0.86 to 11.37 % lesser when compared with normal water. Similarly for sulphate attack & sea water attack the % loss in compressive strength ranges from 2.06 to 6.96 % lesser when compared with normal water curing for 90 days respectively.

Table 14
120 days compressive strength results for different replacement

Replacement/ curing	Normal water (N/mm^2)	Sea water (N/mm^2)	0.25 M NaCl (N/mm^2)	0.75 M NaCl (N/mm^2)	4% Na_2SO_4 (N/mm^2)	6% Na_2SO_4 (N/mm^2)
RO-0%	59	57	56.25	55	55.2	54
R1-25%	61.1	59	58	57	57.5	56
R2-35%	63	61	60.2	59	59.5	58
R3-45%	52.5	50.65	49.5	47	49	47.5

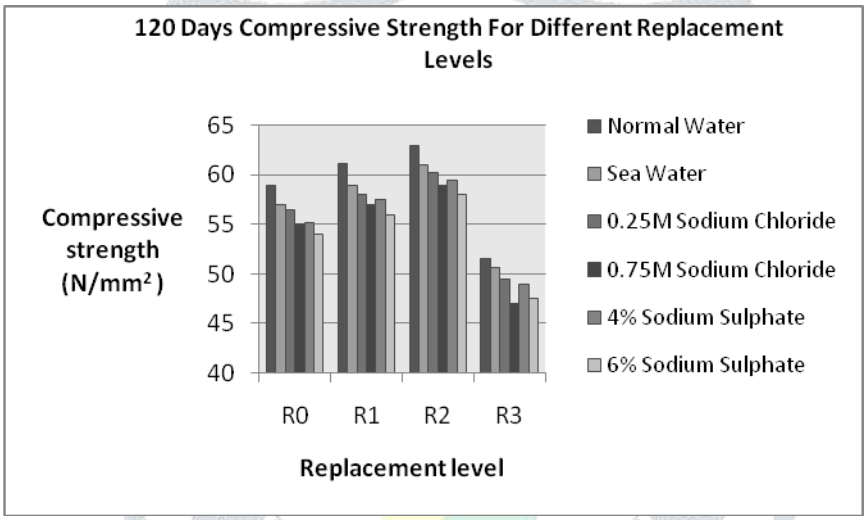

Chart-6: 120 Days Compressive Strength Results For Different Replacement Levels

There is no decrease in compressive strength when the concrete is subjected to 120 days curing in Chloride & Sulphate solutions. So that the concrete containing 35% GBBS replacement level is more durable against Chloride, Sulphate & sea water attack.

Table 15
% Loss in compressive strength for Chloride, Sulphate & Sea water attack when compared with normal water for 120 days

S.No	Replacement	% Loss in compressive strength in 0.25 M NaCl attack	% Loss in compressive strength in 0.75 M NaCl attack	% Loss in compressive strength in 4% Na_2SO_4 attack	% Loss in compressive strength in 6% Na_2SO_4 attack	% Loss in compressive strength in sea water attack
1	**R0**	4.66	3.38	6.44	8.47	3.38
2	**R1**	5.07	6.71	5.89	8.34	3.43
3	**R2**	4.44	6.34	5.55	7.93	3.17
4	**R3**	5.71	10.47	6.66	9.52	3.56

VI. Conclusions & recommendations:

Chloride attack:-

- No significant changes were observed in weight & compressive strength when the specimens were exposed to 0.25 M & 0.75 M NaCl solutions respectively.
- For 120 days the percentage loss in compressive strength for 0.25 M Sodium Chloride attack for 0%, 25%, 35% & 45% GGBS replacement level are 4.66, 5.07, 4.44&3.88. Similarly the % loss in compressive strength for 0.75 M Sodium Chloride solution are 3.38, 6.71, 6.34 &10.47 respectively.

Sulphate attack:-

- No significant changes were observed in weight when the specimens were exposed to 4% and 6% Sodium Sulphate solutions respectively.
- The percentage loss in compressive strength for 4% Sodium Sulphate attack for 0%,25%,35% & 45% GGBS replacement levels are 6.44,5.89,5.55 & 4.85 similarly the % loss in compressive strength for 6% Sodium Sulphate attack are 8.47,8.34,7.93 & 7.76 for 120 days respectively.
- There is no considerable change in compressive strength when the concrete is subjected to high concentrations.

Sea water attack:-

- The percentage loss in compressive strength for sea water attack for 0%, 25%, 35% & 45% GGBS replacement level are 3.38, 3.43, 3.17 & 1.65 for 120 days respectively.
- There was no damage to the surface of the test specimens after exposure to Sea water up to 120 days.
- There was a colour change to the specimens after exposure to sea water up to 120 days i.e from grey to white colour due to salt formation on specimens.

Over view:-

- With the increase in the replacement level, the compressive strength increases gradually up to 35% replacement level for all different curing conditions.
- After 35% replacement level the compressive strength decreased drastically for all different curing conditions.
- The target strength is reached in all replacement levels expect in 45% for all different curing conditions.
- After 35% GGBS replacement it cannot be used effectively as a binder material but it acts like filler material in concrete, because it loses its participation in hydration process.
- Concrete containing 35% GGBS replacement has good resistance against Chloride, Sulphate & Sea water attack.

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