An Experimental Investigation on Concrete in Marine Environment

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Abstract— In this present investigation, the durability studies of concrete in marine environment were determined. The cements like OPC, PPC and PSC was used to make the concrete. The physical property such as fineness, setting time, specific gravity etc for cement and fineness modulus, water absorption etc for aggregates was calculated. Mix design for normal concrete M35 was calculated based on trial mixes and code IS: 10262-2009. The compressive strength of concrete was calculated for M35 concrete by using OPC, PPC and PSC at 3, 7, 28, 60, 90 and 120 days. The curing of specimens was done in normal water and sea water after casting. The split tensile and flexural strength of concrete was calculated for M35 concrete by using OPC, PPC and PSC at 3, 7, 28, 60, 90 and 120days. The curing of specimens was done in normal water and sea water after casting. Finally, we were compared all the results and concluded that PSC (Portland slag cement) was gave better durability results to compare with other cements.

Keywords: OPC, PPC, PSC, Concrete, Durability, Marine Environment

I. INTRODUCTION

The durability of cement concrete is defined as its ability to resist weathering action, Chemical attack, abrasion, or any other process of deterioration. Durable concrete will retain its original form, quality, and serviceability when exposed to its environment.

Concrete was considered to be very durable material requiring a little or no maintenance. When it is subjected to highly aggressive environment, the use of concrete in recent years, have spread to highly harsh and hostile conditions, the earlier impression that concrete is a very durable material is begin threatened, particularly on account of premature failures of number of structures in recent past. It is now recognized that strength of concrete alone is not sufficient the degree of harshness of environmental condition to which concrete is exposed over it is entire life is equally important. Therefore, both strength and durability have to consider explicitly at the design stage. It is interesting to consider yet another view point regarding strength and durability relationship.

The durability of concrete structures is closely related to the nature and severity of the environment in which they are located, as well as the nature of the concrete construction. This section considers the environments and associated mechanisms by which the environment can penetrate into concrete. The influence of the concrete itself in permitting or resisting environmental penetration is considered in later sections.

II. LITERATURE REVIEW

Robert E Melchers (2020) had presented a review paper on Long-Term Durability of Marine Reinforced Concrete Structures, the sustainability of reinforced concrete is critical, particularly for structures exposed to marine environments. Chlorides are implicated in causing or accelerating reinforcement corrosion and potentially earlier expensive repairs, yet there are many older reinforced concrete structures in good condition for many decades despite very high chloride levels at the reinforcement. The reasons for this are reviewed briefly, together with recent experimental work that better defines the role of chlorides. As reviewed herein, these include poor compaction, physical damage to concrete cover, concrete shrinkage, and alkali-aggregate reactions. The various observations presented are important for the proper understanding, analysis, and design of durable reinforced concrete structures exposed to chloride-rich environments.

Velu Saraswathy et al (2017) presented the comparative study of strength and corrosion resistant properties of plain and blended cement concrete types. The relative performances of mechanical, permeability, and corrosion resistance properties of different concrete types were compared. Concrete types were made from Ordinary Portland cement(OPC), Portland pozzolana cement (PPC), and Portland slag cement (PSC). Compressive strength test, effective porosity test, coefficient of water absorption, short-term accelerated impressed voltage test,and rapid chloride permeability test(RCPT) were conducted on M30 and M40 grades of concrete designed with OPC, PPC and PSC cements for 28 and 90day cured concrete types.Long-term studies such as microcell and electro chemical evaluation were carried out to understand the corrosion behaviour of rebar, embedded in different concrete types. Better corrosion resistant properties were observed for PSC concrete by showing a minimum current flow, lowest free chloride content, and lesser porosity. Besides PSC concrete has shown less coefficient of water absorption, chloride diffusion coefficient (CDC), sand lower corrosion rate and there by the time taken for initiation of crack extended.

Jian Zhuang Xiao et al (2017) had presented a review paper on use of sea sand and seawater in concrete construction: current status and future opportunities. This paper presents a critical review of existing studies on the effects of using sea-sand and/or seawater raw materials of concrete on the properties of the resulting concrete, including its workability, short and long-term strength as well as durability. It has been shown by existing research that concrete made with sea sand and seawater develops its early strength faster than that of ordinary concrete, but the former achieves a similar long-term strength to the latter. Use of sea-sand seawater concrete (SSC) also offers a good opportunity for the incorporation of recycled coarse aggregate (RCA) in concrete. The current understanding provides a solid basis for further research in the area to enable the wide use of SSC in concrete construction worldwide, particularly when combined with FRP as the reinforcing material.

III. EXPERIMENTAL PROGRAM

A. Materials Used

1) Ordinary Portland cement

Ordinary Portland cement of (53 Grade) with consistency confirming to IS 12269-1987 was used. The results of tests conducted on cement are presented in table along with the permissible limits for ascertaining quality of cement.

PROPERTIES	RESULTS
Fineness	94 %
Specific gravity	3.09
Normal consistency	32 %
Initial setting time	42 Minutes
Final setting time	468 Minutes

Table 1: Result for OPC

2) Portland Pozzolana cement

Portland Pozzolana cement of (53 Grade) with consistency confirming to IS 1489 (Part - 1) 1991 (fly ash based), IS 1489 (Part - ll) 1991(canalized clay) was used. The results of tests conducted on Cement are presented in table along with the permissible limits for ascertaining quality of cement.

PROPERTIES	RESULTS
Fineness	96 %
Specific gravity	2.56
Normal consistency	34 %
Initial setting time	56 Minutes
Final setting time	530 Minutes

Table 2: Results for PPC

3) Portland slag cement

Portland slag cement of with consistency confirming to IS 455:1987 was used. The results of tests conducted on cement are presented in table along with the permissible limits for ascertaining quality of cement

PROPERTIES	RESULTS
Fineness	93 %
Specific gravity	3.2
Normal consistency	33 %
Initial setting time	52 Minutes
Final setting time	540 Minutes

Table 3: Results for PSC

4) Fine Aggregate

Natural River sand of size below 4.75mm conforming to zone ll of IS 383-1970 is used as fine aggregate.

Physical Properties	Natural Fine Aggregate	As per IS code provision
Specific gravity	2.65	IS 383 – 1970
Sieve Analysis	Zone ll	IS 383 – 1970
Water absorption	0.8 %	IS 383 – 1970

Table 4: Results for FA

5) Coarse aggregate

Coarse aggregate consists of river gravel, crushed stone or manufactured aggregate with particle size equal to or greater than 4. 75mm.And having density of 2700kg/m^3 It shall comply with the requirements of IS383-1970. For the coarse aggregates, the following test has been carried out conforming to IS2386 (part 1) 1963. In this study coarse aggregate of maximum nominal size 20 mm was used and the physical properties are as follows.

Sl. No	Property	Results	AS PER IS CODE PROVISIONS
1	Specific gravity	2.74	IS 383 – 1970
2	Water absorption	1.2%	IS 383 – 1970

Table 5: Results for CA

6) Mix Design

M30 grade concrete mix design was carried out as per IS 10262-2009 and IS 456-2000.

Sl. No	Material	per m^3
1	Cement	359 kg
2	Fine Aggregate	699 kg
3	Coarse Aggregate	1208 kg
4	Water	162 liters
5	W/C ratio	0.45

Table 6: Mix proportions

7) Potable Water

Ordinary potable tap water available in laboratory was used for mixing and curing of reference concrete. It had a pH value of 7.1.

B. Preparation of Specimens

The ingredients for various mixes were weighed; required water was added and mixed by using a tilting drum type concrete mixture machine. Precautions were taken to ensure uniform mixing of ingredients. The specimens were cast in steel mould and compacted on a table vibrator. The specimens of 150mm× 150mm × 150mm size of cubes for compression strength were cast as per Indian standard IS:516 (1959). Specimens were de-moulded in 24 hours and cured.

C. Curing

1) Normal Water Curing

After demoulding, the specimens were kept in normal water curing having pH value of 7.1.

D. Sea Water Curing

After demoulding, the specimens were kept in sea water curing having pH value of 6.5 taken from bheemili beach, Visakhapatnam.

IV. RESULTS

A. Compressive Strength

1) Normal water curing

CEMENT / DAYS	3 DAYS	7 DAYS	28 DAYS
OPC	18.14	27.86	40.28
PPC	17.18	26.02	38.88
PSC	16.98	27.08	40.32

Table 7: Comparison for OPC, PPC and PSC in normal water curing

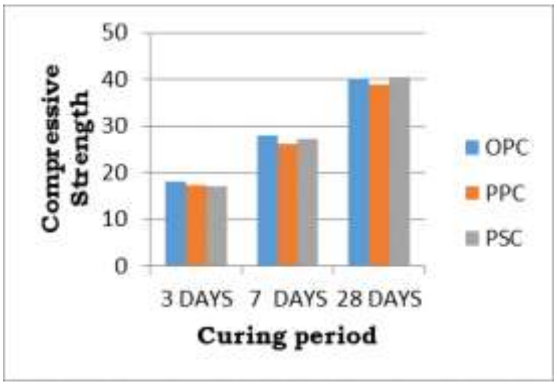

Fig. 1: Comparison for OPC, PPC and PSC in normal water curing

2) Sea water curing

CEMENT / DAYS	3 DAYS	7 DAYS	28 DAYS
OPC	16.28	25.88	38.28
PPC	16.84	25.64	37.86
PSC	16.06	26.64	39.34

Table 8: Comparison for OPC, PPC and PSC in sea water curing

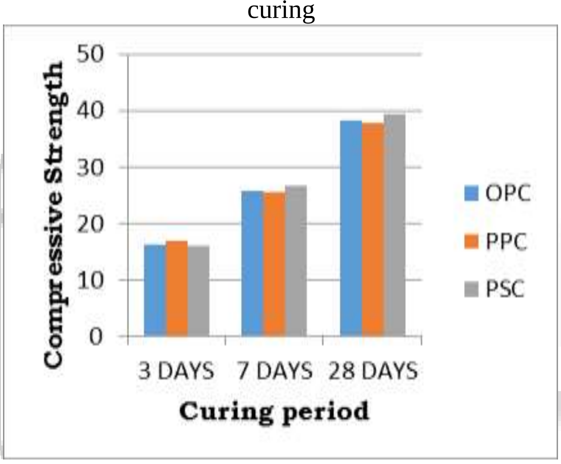

Fig. 2: Comparison for OPC, PPC and PSC in sea water curing

B. Flexural Strength

1) Normal water curing

CEMENT / DAYS	3 DAYS	7 DAYS	28 DAYS
OPC	1.88	2.98	4.46
PPC	1.73	2.92	4.52
PSC	1.96	3.02	4.68

Table 9: Comparison for OPC, PPC and PSC in normal water curing

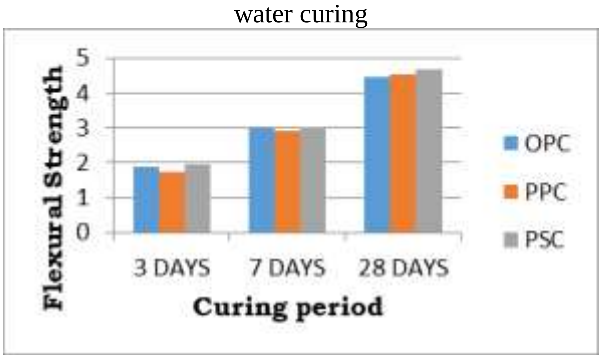

Fig. 3: Comparison for OPC, PPC and PSC in normal water curing

2) Sea water curing

CEMENT / DAYS	3 DAYS	7 DAYS	28 DAYS
OPC	1.68	2.80	4.22
PPC	1.70	2.82	4.38
PSC	1.86	2.92	4.64

Table 10: Comparison for OPC, PPC and PSC in sea water curing

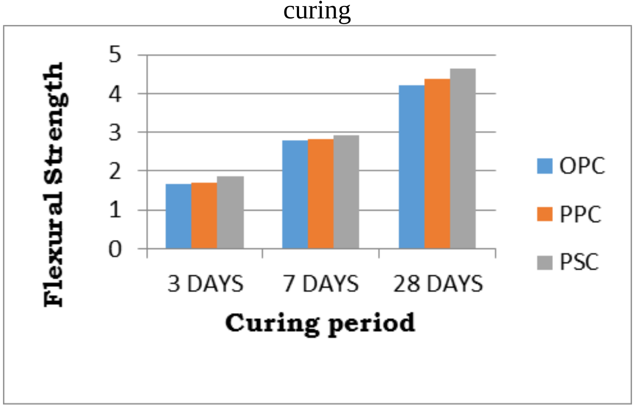

Fig. 4: Comparison for OPC, PPC and PSC in sea water curing

C. Split Tensile Test

1) Normal water curing

CEMENT / DAYS	3 DAYS	7 DAYS	28 DAYS
OPC	1.58	2.78	4.24
PPC	1.66	2.88	4.34
PSC	1.72	2.93	4.38

Table 11: Comparison for OPC, PPC and PSC in normal water curing

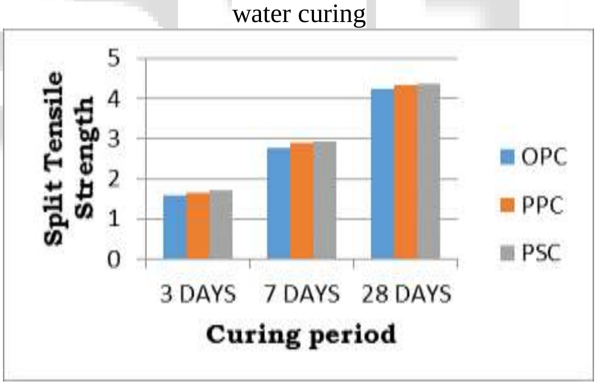

Fig. 5: Comparison for OPC, PPC and PSC in normal water curing

2) Sea water curing

CEMENT / DAYS	3 DAYS	7 DAYS	28 DAYS
OPC	1.52	2.61	4.14
PPC	1.60	2.74	4.22
PSC	1.78	3.02	4.34

Table 12: Comparison for OPC, PPC and PSC in sea water curing

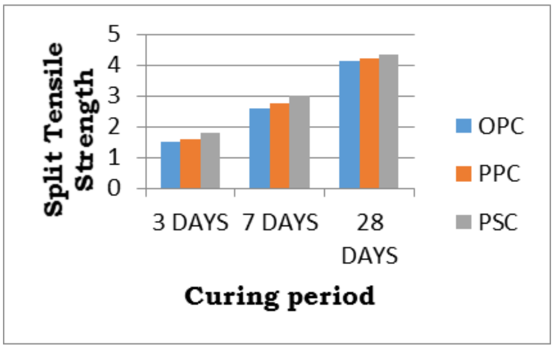

Fig. 6: Comparison for OPC, PPC and PSC in sea water curing

V. Durability Tests

A. Compressive Strength

1) Normal Water curing

CEMENT	28 DAYS	60 DAYS	90 DAYS	120 DAYS	180 DAYS
OPC	40.28	40.34	40.34	40.36	40.36
PPC	38.88	38.92	38.92	38.94	38.94
PSC	40.32	40.34	40.36	40.38	40.38

Table 13: compressive strength (N/mm²) NWC

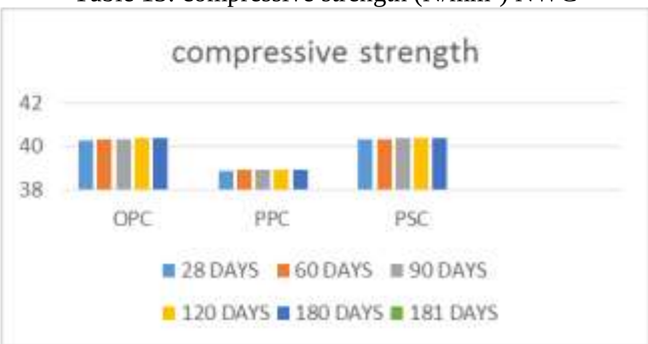

Fig 7: compressive strength (Normal water curing)

For normal water curing, the compressive strength of concrete was increased with time and Portland slag cement was given more strength to compare with other two cements.

2) Sea water curing

CEMENT	28 DAYS	60 DAYS	90 DAYS	120 DAYS	180 DAYS
OPC	38.28	36.28	36.24	36.24	36.22
PPC	37.86	37.64	37.58	37.56	37.52
PSC	39.34	38.94	38.9	38.88	38.88

Table 14: compressive strength (N/mm²) SWC

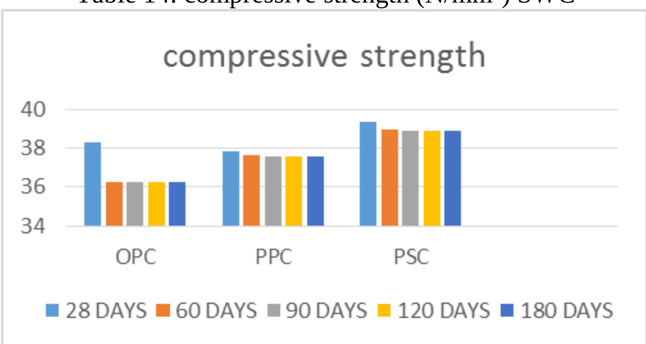

Fig 8: compressive strength (Sea water curing)

For Sea water curing, the compressive strength of concrete was increased with time upto 60 days later it was decreased. Portland slag cement was given more strength to compare with other two cements. The overall result compare with normal water curing, the sea water results was less.

B. Flexural Strength Normal Water curing

CEMENT	28 DAYS	60 DAYS	90 DAYS	120 DAYS	180 DAYS
OPC	4.46	4.48	4.50	4.50	4.52
PPC	4.52	4.52	4.54	4.56	4.56
PSC	4.68	4.70	4.70	4.72	4.74

Table 15: Flexural strength (N/mm²) NWC

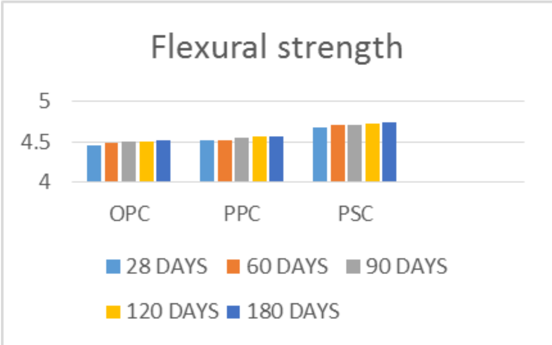

Fig 9: Flexural strength (Normal water curing)

For normal water curing, the flexural time and Portland slag cement was given more strength to compare with other two cements.

1) Sea Water curing

CEMENT	28 DAYS	60 DAYS	90 DAYS	120 DAYS	180 DAYS
OPC	4.22	4.22	4.20	4.16	4.16
PPC	4.38	4.40	4.38	4.36	4.36
PSC	4.64	4.68	4.66	4.64	4.64

Table 16: Flexural strength (N/mm²) SWC

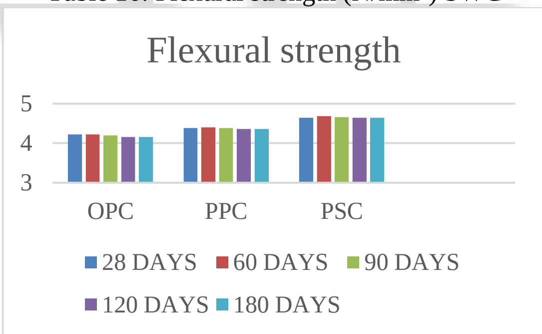

Fig 10: Flexural strength (Sea water curing)

For sea water curing, the flexural strength of concrete was increased with time and Portland slag cement was given more strength to compare with other two cements.

C. Split tensile Strength

1) Normal Water curing

CEMENT	28 DAYS	60 DAYS	90 DAYS	120 DAYS	180 DAYS
OPC	4.24	4.24	4.26	4.28	4.28
PPC	4.34	4.36	4.36	4.38	4.38
PSC	4.38	4.40	4.42	4.42	4.44

Table 17: Tensile strength (N/mm2)NWC

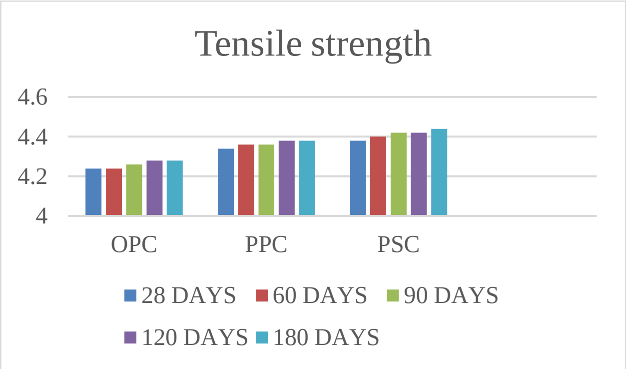

Fig 11: Tensile strength (Normal water curing)

For normal water curing, the tensile strength of concrete was increased with time and Portland slag cement was given more strength to compare with other two cements.

2) Sea Water curing

CEMENT	28 DAYS	60 DAYS	90 DAYS	120 DAYS	180 DAYS
OPC	4.14	4.14	4.12	4.10	4.08
PPC	4.22	4.20	4.20	4.18	4.16
PSC	4.34	4.34	4.32	4.32	4.30

Table 18: Tensile strength (N/mm^2) SWC

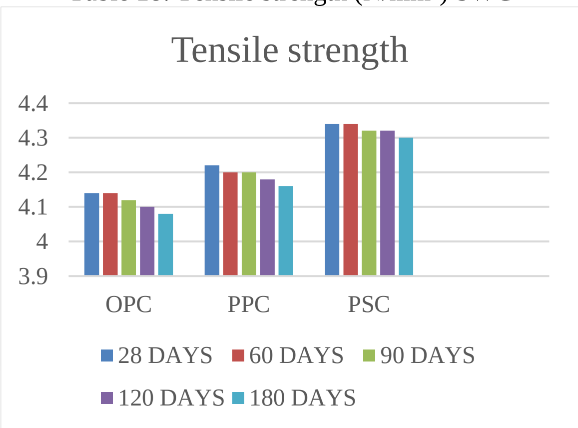

Fig 12 Tensile strength (Sea water curing)

For sea water curing, the tensile strength of concrete was increased with time and Portland slag cement was given more strength to compare with other two cements.

VI. Conclusion

A. Ordinary Portland cement

- The Percentage Loss of Compressive Strength for M35 grade of concrete in sea water curing compared to normal water curing at 7 days is 7.10.
- The Percentage Loss of Compressive Strength for M35 grade of concrete in sea water curing compared to normal water curing at 28 days is 4.96.
- The Percentage Loss of Flexural Strength for M35 grade of concrete in sea water curing compared to normal water curing at 7 days is 6.04.
- The Percentage Loss of Flexural Strength for M35 grade of concrete in sea water curing compared to normal water curing at 28 days is 5.38.
- The Percentage Loss of Tensile Strength for M35 grade of concrete in sea water curing compared to normal water curing at 7 days is 6.11.
- The Percentage Loss of Tensile Strength for M35 grade of concrete in sea water curing compared to normal water curing at 28 days is 2.35.

B. Portland pozzolana cement

- The Percentage Loss of Compressive Strength for M35 grade of concrete in sea water curing compared to normal water curing at7 days is 1.46.
- The Percentage Loss of Compressive Strength for M35 grade of concrete in sea water curing compared to normal water curing at 28 days is 2.62.
- The Percentage Loss of Flexural Strength for M35 grade of concrete in sea water curing compared to normal water curing at 7 days is 3.42.
- The Percentage Loss of Flexural Strength for M35 grade of concrete in sea water curing compared to normal water curing at 28 days is 3.09.
- The Percentage Loss of Tensile Strength for M35 grade of concrete in sea water curing compared to normal water curing at 7 days is 4.86.
- The Percentage Loss of Tensile Strength for M35 grade of concrete in sea water curing compared to normal water curing at 28 days is 2.76.

C. Portland slag cement

- The Percentage loss of Compressive Strength for M35 grade of concrete in sea water curing compared to normal water curing at 7 days is 1.62.
- The Percentage loss of Compressive Strength for M35 grade of concrete in sea water curing compared to normal water curing at 28 days is 2.43.
- The Percentage loss of Flexural Strength for M35 grade of concrete in sea water curing compared to normal water curing at 7 days is 3.311.
- The Percentage loss of Flexural Strength for M35 grade of concrete in sea water curing compared to normal water curing at 28 days is 0.85.
- The Percentage Loss of Tensile Strength for M35 grade of concrete in sea water curing compared to normal water curing at 7 days is 2.31.
- The Percentage Loss of Tensile Strength for M35 grade of concrete in sea water curing compared to normal water curing at 28 days is 0.91.

D. Durability

- For normal water curing the compressive strength was increased with time for all three types of cement. Portland slag cement was given more strength 40.38 for 180 days to compare with OPC and PPC.
- For Sea water curing the compressive strength was increased with time up to 28 days later it was decreased and it was low value to compare with the normal water curing results. Portland slag cement was given more strength 38.94 for 60 days to compare with OPC and PPC.
- For normal water curing the flexural strength was increased with time for all three types of cement. Portland slag cement was given more strength 4.74 for 180 days to compare with OPC and PPC.

- For Sea water curing the flexural strength was increased with time up to 28 days later it was decreased and it was low value to compare with the normal water curing results. Portland slag cement was given more strength 4.68 for 60 days to compare with OPC and PPC.
- For normal water curing the tensile strength was increased with time for all three types of cement. Portland slag cement was given more strength 4.44 for 180 days to compare with OPC and PPC.
- For Sea water curing the tensile strength was increased with time up to 28 days later it was decreased and it was low value to compare with the normal water curing results. Portland slag cement was given more strength 4.34 for 60 days to compare with OPC and PPC.

In the view of compressive strength, split tensile strength and flexural strength of M35 grade concrete, Portland slag cement gave better result to compare with Ordinary Portland cement and Pozzlona Portland cement in sea water curing, normal water curing and durability studies also.

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