Study on Durability Parameters of High Strength Concrete Using Slag Sand and Quarry Sand

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Abstract - *India is 2nd largest consumer of cement after china. But nowadays Cement industries produce about 10% of the world's carbon dioxide which affects the environment and cause imbalance in the ecosystem. In India, the sudden boom in infrastructure has made Indians the largest consumers of materials required for the construction where the issue of durability over strength plays a vital role. In this present study slag sand and quarry sand are used as replacement for natural sand alongside with micro silica and fly ash as a partial replacement for cement, since the outcome of slag behavior is unknown with the materials used, hence slag sand ratio is replaced ranging from 10% until 60% with quarry sand along with 6% and 12% addition of micro silica to the weight of cement and fly ash percentage is freeze to 20% for the complete investigation. The main objective of any construction is durability along its serviceable period and purpose of this investigation is to find the optimum mix proportion with different percentage addition of admixtures that aid in achieving durability in mass construction.*

Key Words: **Water Permeability Test, RCPT, Ion Penetration, Penetration Depth, Slag Sand, Quarry Sand**

1. INTRODUCTION

Advent of industrial products like admixtures, plasticizers, retarders etc have eased the construction work, meanwhile aiding in depletion of natural resources and increase in pollution. Each ton of cement created generates roughly 800kg of carbon dioxide into the atmosphere. India produces cement in large quantities around 520million ton's every year. It leads to generation of 416 million tons of carbon dioxide every year. This issue has lead to research the use of byproducts as the replacement of basic materials in conventional concrete. This has helped Engineers to try and create sustainable concrete industry. In India, the availability of basic materials like Natural River sand and coarse aggregates are highly uneconomical based on its availability which intern leads in raising the cost of construction works. There was a myth at the beginning of the research that the industrial products and byproducts were not good enough to be used in the high strength concrete mixes or concrete grades above M_{35} - M_{40}. But nowadays due to the advancements in the research and improvements in manufacturing techniques, the byproducts are now being researched for their usage in the high strength concretes with various combinations and trials to come up with an optimal concrete mix that is good in terms of both strength and durability and steps to improve them. collapse of certain structure due inefficient workmanship and designs leads to economic loss, life loss, and many other factors, concrete is a great devoured material in the universe.70% of that volume is made of aggregates and subsequently over abuse of natural river sand is observed. Leading governments of numerous nations and states are banning sand mining due to lack of "Natural River Sand" (NRS) and the prices have sky rocketed (Rs.80, 000 to 1, 50,000 for every truck load) leading to augmentation in construction expenditure. But India being the world's most populated country the capitol income of the country plays an important role in construction as well hence it is mandatory to design a structure which not only gives higher compressive strength but also is durable meanwhile usage or natural sand is not completely banned but is substantially reduced, which paves way for new re era in infrastructure.

2. LITREATURE REVIEW

M C Nataraja, et al. (2014) in their research they used copper slag as fine aggregate with respect to strength parameter. Tests were conducted with OPC 43 grade cement with 20% increment up to 60% and 100% replacement for M 60 .In the end 60% was found to give high strength. Whereas100% replacement also gave considerable strength but not as great as 60%. Which clearly indicated that strength dropped after 60% .which proves the optimum replacement. Research conducted by **T. Shanmugapriya and R.N Uma. (2012)** Used Quarry sand as partial replacement to natural sand with silica fume as a part of cementitious material with 10%,20% ,50%,70% replacement of natural sand and 1.5%,2.5% and 5.0% addition of micro silica with OPC .In their research they found that 50% was found to obtain optimum design strength with 5% micro silica but only strength test were conducted. addition to this **Aditya dhagat and Manav Mittal. (2013)** conducted research and they replaced partially micro silica with cement and fly ash. The basic idea of replacing this was to economize the overall cost of concrete used in construction by achieving suitable strength. Addition to this, the harmful effect caused due to utilization of concrete on environment was considerably reduced with 48%cement, 43% fly ash and 5% micro silica. This mixture gave considerably higher strength when tested for 7, 14 and 28 days compared to control mix. According to **Prem Kumar ,Dr. Pradeep Kumar. (2015)** they encased the use of blast furnace slag as a replacement for natural sand with 25% increment up to 100% for both M20 and M30 grades .With 1:4 cementitious proportion for mortar cubes and concluded that the percentage between 60-75% provided greater strength and beyond 75% the strength gradually dropped .therefore 60% was set as optimum replacement that can be adopted in construction. Similarly **Mudasir Hussain Pandit et al.(2014):** Used flyash, microsilica and recycled concrete aggregates, their idea was to completely replace cement with fly ash and microsilica with increments in microsilica .Addition of 5% uptil 15% and replacing coarse aggregate with concrete aggregate of 5% increment uptil 15% for an M25 grade concrete mix .It was observed that due to addition of fly ash there were permeability issues but increase in replacement of concrete aggregates minimized that issue but the percentage was freeze to 10% considering various safety factors. **Chetan Khajuria and Rafat Siddique. (2014):** In their research they used iron slag as partial replacement for natural river sand in concrete .This research concentrates mainly on strength parameters by replacing 10%,20% and 30% slag with natural river sand (NR SAND) .After testing they concluded that addition of 10% slag there was increase in 26% strength after 7 day curing , 50% increase in strength after 28 day curing period and 43% increase in strength after 56 day curing period compared to control mix . But addition of 20% and 30% slag there was an aggumentation in strength up to 68%,91%, 71% and 125%,113%,87% after 7,28,56 days. **P.S Kothari and Dr.R. Malathy (2014):** Used steel slag as partial replacement for fine aggregates NRsand for M_{20} they concentrated mainly on strength criteria , tests were conducted and fine aggregates were replaced by 10%,20%,30%,40% and 50% under 28 day curing OPC 43 grade cement was used with 20mm max size coarse aggregates were used in accordance. In their tests 30% slag replacement showed promising results in strength both moment of elasticity and moment of rupture tests were also conducted and similar trend followed. This research was carried out to approve slag sand usage in construction which benefited in areas like cost reduction, environmental pollution reduction, mass utilization, reduced wastage etc. **Krishna Prasanna .et al.(2014)** :In their study they utilized slag sand for high strength concrete mix as a suitable replacement for river sand . The replacement ranged from 5% to 35% with 5% increments between mixes for M_{80} concrete .During their progress 30% replacement provided promising results with respect to compressive test, split tensile test and flexure test parameters compared to other mixes.

3. MATERIALS USED

3.1 CEMENT

Ordinary Portland Cement of 53 grade satisfying the conditions in IS:8112-1989[14] with specific gravity of 3.15

3.2 FLYASH

fly ash is used as partial replacement at 20% to the weight of cementitious material in both cases with specific gravity of 2.82 satisfying the requirements as per IS:3812-1999[15]

3.3 MICRO SILICA

Micro silica is used as a partial replacement at 6% for case I and 12% for case II to the weight of cementations material and specific gravity was found to be 2.75

3.4 FINE AGGREGATES

In this experimental study, usage of river sand is completely eliminated except for control mix blend performed initially for strength comparison only. slag sand is used as partial replacement to Quarry sand. passing through 4.75 micron IS sieve and retaining in 150 micron IS sieve. In this study sieve analysis was performed on slag sand and categorized as ZONE II. with specific gravity for slag sand and quarry sand being 2.56 and2.57.Satisfying the conditions in IS:383-1978[13]

3.5 COARSE AGGREGATES

No replacement was made for coarse aggregates, except the selection of size, Material that range from 20mm and 12.5mm downsize aggregates were. based on properties mentioned in IS:383-2016 and specific gravity was found to be 2.67

3.6 WATER

For this experiment study 0.28 W/C ratio was kept constant thought based on IS 10262 for mix design.

3.7 CHEMICAL ADMIXTURE

In this experiment superplasticizer AURAMIX 400 was used. AURAMIX 400 is a PCE-based admixture (polycarboxylic ether polymer) for low water cement ratio and suitable for self-compacting concrete. For this experiment at least 100mm slump was maintained based on trial and error for each combination.

4. METHODOLOGY AND TESTING

Casting and curing process of beams, cubes and cylinders areas usual. The surface preparation has to be made. The inside of the moulds are to be oiled thoroughly. Finally the concrete was mixed using a pan mixer (SKILLET MIXER). Due to its advantages over traditional transit mixer in uniform mixing, moulds were casted and de-molded after 24 hrs and immersed in a curing tank. and testing was conducted for specimens for 7,14,28 and 56 days. following table shows the percentage taxonomy of concrete mix proportions used in this study

4.1 WATER PERMEABILITY TEST

Permeability test was performed to determine the water impermeability of concrete at certain pressure of 5Kg/cm^2. This experimentation was carried out with reference to DIN 1048-1991 part-5 known as flow under pressure differential. Specimen dimensioned 150X150X150mm is cast in the tally of 3mix per test. Following 28 days of curing the examples are desiccated completely prior to escalating them on contraption. Water is constrained on to the testing face at Pressures of 5Kg/cm^2 perpetually for 3 days. Which is thereafter split into 2 halves and deepness of penetration is deliberate utilizing digital vernier calipers. Subsequent outcomes observed from examination progression are tabulated underneth.

4.2 RAPID CHLORIDE PENETRATION TEST

This experimentation was carried out with respect to ASTMC C 1202-97. In order to initiate corrosion activity the chloride ions must well infiltrate the clear cover accommodated for the concrete structures to reach reinforcements. Chloride ions travel along these paths to break inside. convection- mechanism is Cl ions get into concrete by capillary action. Here ions travel from higher concentration regions to inferior concentrations This technique utilizes electrical indication of the capability of concrete

5. EXPERIMENTAL OBSERVATIONS

5.1 WATER PERMEABILITY TEST

This experimentation was carried out with reference to DIN 1048-1991 part-5 known as flow under pressure differential. The test specimen is taken out of the assembly and split using compression testing machine with semicircular plates placed as supports at top and bottom. The depth of penetration is calculated using vernier calipers as soon as the sample splits, delay in which leads to evaporation and unrealistic result.

5.2 RAPID CHLORIDE PENETRATION TEST

This experimentation was carried out according to ASTMC C 1202-97 attributes. In order to achieve corrosion activity the chloride ions must impregnate the clear cover accommodated for the concrete structures to reach reinforcements Chloride ions chase these paths to break in and damage the reinforcement. This test duplicates that phenomenon to check the degree of resistance offered by concrete blend.

5.2.1 RCPT CALCULATIONS

To determine the degree of CI ion permeability of the sample we use,

$$[900\times (I_0+I_{30}+I_{60}+\ldots\ldots+2I_{330})+I_{360}]\div 1000$$

Where

I_0=initial value at 0 min

I_{30}= successive value at 30 min

I_{60}= successive value at 60 min

I_{360}=final value at 360 min

6. RESULTS AND DISCUSSIONS

1). Water permeability test was carried out on cube specimen subjected to Pressures of 5Kg/cm^2 which were induced for curing period of 28 days. It was clear that none of the trail mix samples permitted water beyond 25 mm penetration, which is safe beyond margin and addition to this **TRAIL MIX 7** (6% microsilica with50% slag sand replacement) and **TRAIL MIX 15** (12% microsilica with 50% slag sand replacement) . offered lesser permeability result of 84.3% resistance compared to other samples of the blends and almost similar trend followed for **TRAIL MIX 15** offered lesser permeability result of 78.2% resistance when compared to control mix It was found that most of the combinations gave satisfactory results. according to figure 1 among which both 6% and 12% microsilica combinations for 50% slag sand replacement were less permeable compared to other combinations

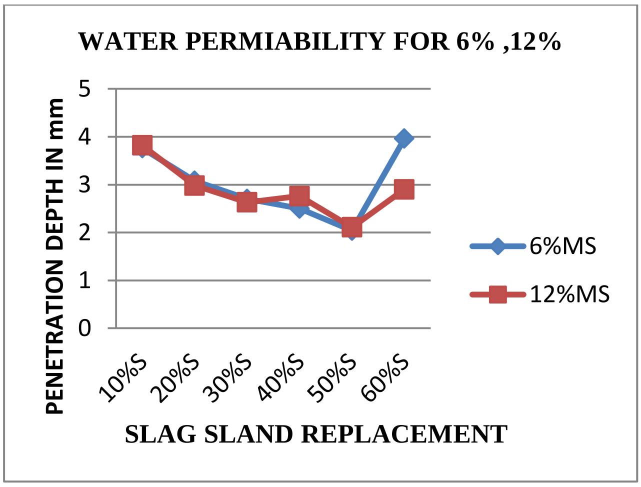

Figure 1: Water penetration depth comparison for 6% blends and 12% blends

2). RCPT was conducted on disc specimens cured for a period of 28 days. Due to the addition of micro silica which were superfine in nature and usage of slag sand made the penetration of CI ions nearly impossible and from the graph 2 it was confirmed that none of the samples permitted CI ion penetration beyond safety criteria and all the concrete mix proportions satisfy the safety criteria according to Table 3 All the test results for ion penetration fall below 2000 which can be termed as "VERY LOW" .and both 6% and 12% microsilica blends proved promising among which **TRAIL MIX 5 (**30% slag replacement attribute for 6% micro silica) and **TRAIL MIX 15 (** 60% slag replacement for 12% microsilica) offered lesser penetration value compared to 6% microsilica blends eventually proving the use of this combinations in underwater construction is permissible.

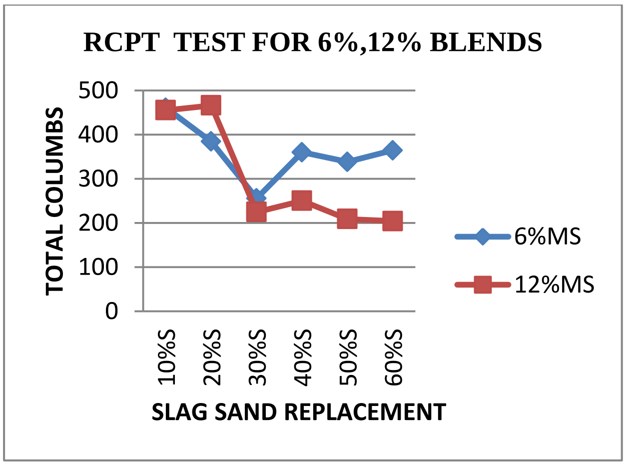

Figure 2: RCPT test comparison for 6% and 12% microsilica

Table 1: Hierarchy of concrete blend percentage for 6% and 12% microsilica

SL NO	MIX PROPORTIONS						
	HIERARCHY	OPC	MICRO SILICA	FLY ASH	QUARRY SAND	S-SAND	NR-SAND
Trail 1	0@0	74	0%	0%	0	0	100
Trail 2	6@0	74	6%	20%	100	0	0
Trail 3	6@10	74	6%	20%	90	10	0
Trail 4	6@20	74	6%	20%	80	20	0
Trail 5	6@30	74	6%	20%	70	30	0
Trail 6	6@40	74	6%	20%	60	40	0
Trail 7	6@50	74	6%	20%	50	50	0
Trail 8	6@60	74	6%	20%	40	60	0
Trail 9	12@0	68	12%	20%	100	0	0
Trail 10	12@10	68	12%	20%	90	10	0
Trail 11	12@20	68	12%	20%	80	20	0
Trail 12	12@30	68	12%	20%	70	30	0
Trail 13	12@40	68	12%	20%	60	40	0
Trail 14	12@50	68	12%	20%	50	50	0
Trail 15	12@60	68	12%	20%	40	60	0

Table 2: Water permeability results for concrete mix proportions

SL NO	MIX PROPOTIONS	PERMIABILITY DEPTH mm
1	6%,10%	3.76
2	6%,20%	3.08
3	6%,30%	2.70
4	6%,40%	2.50
5	6%,50%	2.04
6	6%,60%	3.96
7	12%,10%	3.82
8	12%,20%	2.98
9	12%,30%	2.63
10	12%,40%	2.76
11	12%,50%	2.11

Table 3: RCPT safety criteria to determine ion penetration

CHLORIDE PERMIABILITY	CHARGES PASSING IN COULOMBS	CONCRETE TYPE
HIGH	>4000	High w-c ratio(>0.6)
MODERATE	2000 to 4000	Moderate w-c ratio (0.40 to 0.50)
LOW	1000 to 2000	Low w-c ratio (<0.40)
VERY LOW	100 to 2000	Concrete with Latex
NEGLIGIBLE	<100	Polymer concrete

Table 4: Rcpt Test Criteria values For Safety Comparison

SL NO	MIX PROPORTIONS	RESULTS in coulombs
1	6%,10%	460.823
2	6%,20%	384.322
3	6%,30%	255.614
4	6%,40%	360.019
5	6%,50%	338.417
6	6%,60%	364.519
7	12%,10%	455.423
8	12%,20%	466.221
9	12%,30%	225.015
10	12%,40%	250.130
11	12%,50%	208.811
12	12%,60%	204.312

7. CONCLUSION

A. Under Durability parameter, water permeability test gave overall promising results under which depth of water penetration was not beyond 25mm and 50% slag replacement was found to be less permeable .Whereas from RCPT test 60% slag replacement displayed low penetration resistance.

B. From the above investigations, it was noticed that adding micro fines with slag sand for high strength concrete is advisable and slag sand being economical in availability (Rs. 200-600/ton). Replacement of 40%-60% was found to be appropriate and even when different admixtures are added to improve its durability. Comparing the results from both blend combinations, 12% blend combinations marginally displayed superiority over 6% blend combinations but considering economic wise 6% blend combinations proved promising.

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