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Investigation on the Strength Development of Concrete Blended with GGBS

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Abstract: ***Blended cements are obtained by mixing Ordinary Portland Cement with mineral admixture or additives like fly ash, slag or silica fumes. Blended cements are now being considered superior as compared to conventional OPC category of cements. This led to the resurgence of blended cements. There was a concern that whether the blending of supplementary cementitious materials (SCM) while grinding at plant or mixing the SCM directly on site works better. In this research work, emphasis has been given on studying the performance of concrete made by Portland Slag Cement as well as concrete made with OPC and GGBS. For achieving these different cement contents of 300, 320, 340, 360, 380 kg/m^{3}were selected. The first sets of mixes were with Portland Slag cement and the second sets of mix were with Ordinary Portland Cement + GGBS maintaining the cementitious content in the mix for comparison. The w/c has been maintained for both the batches. Compressive strength results shows that PSC cement gave better performance than OPC+GGBS combination.***

Keywords: Blended cements; Portland Slag cement; GGBS; Compressive Strength

1. Introduction

Blended cements are obtained by mixing Ordinary Portland Cement with mineral admixture or additives like fly ash, slag or silica fumes. Blended cements are now being considered superior as compared to conventional OPC category of cements. This led to the resurgence of blended cements. Blast furnace slag is a by-product of the iron manufacturing in then water-quenched rapidly, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size, which is known as ground granulated blast furnace slag (GGBS). It can be used to replace as much as 80% of the Portland cement used in concrete. GGBS concrete has better water impermeability characteristics as well as improved resistance to corrosion and sulphate attack. Portland slag cement is a mixture of ordinary Portland cement and not more than 65% weight of granulated slag[1]. The use of GGBS leads to an improvement in the fresh properties of concrete[2]. But it is noticed by several researchers that the rate of hardening or slag cement is somewhat slower than that of ordinary Portland cement during early ages[3]. Extensive research carried out on the use of GGBS in combination with PC and other cementitious constituents in concretes indicated that lower early compressive strength due to slower hydration rate of GGBS. However Teng et al. 2013 stated that the difference in early age compressive strength becomes smaller at low w/c for GGBS Blended Concrete.

Qiang et al.[3] that 15% and 30% GGBS replacement levels gives better compressive strength at post 28 days. Khatri et al.[4]also stated that 35% GGBS provides better compressive strength at 28 days. In addition to these, Akçaozoglu and Atis[5] stated that use of 50% GGBS replacement in mortar can slightly improve compressive strength at 28 days. Moreover, slightly improved and comparable results were obtained by Guneyisi et al.[6]for 40% and 60% replacement level of GGBS. A GGBS-blended concrete paste can improve fluidity and reduce bleeding[7]. The GGBS blended concrete has also a reduced pore volume and pore connection which aids the concrete in resisting sulphate attacks and chloride induced corrosion[8].

2. Research Significance

There was plenty of work done on GGBS blended concrete and GGBS blended cement concrete. But there was not much work done on concrete made with exact quantity of GGBS used while cement preparation and cement replacement. This research deals with the studying the strength development of GGBS blended concrete by comparing the concrete made with equal percentage of GGBS in cement grinding in PSC and cement replacement with OPC.Portland slag cement was obtained by mixing 45% clinker with 55% GGBS. Hence OPC+GGBS combination concretes were mixed with 45% OPC + 55% GGBS. Water cement ratio has been fixed for comparison purpose.

3. Experimental Programme

3.1. Materials

The cements used were 53 grade Ordinary Portland Cement (OPC), conforming to IS: 12269 (2013) and Portland Slag Cement (PSC) conforming to IS: 455(1989). Ground Granulated Blast furnace slag obtained from Bangalore was used for the entire work. The chemical composition of the PSC cement and GGBS are shown in Table 1. Locally available river sand was used as the fine aggregate for concrete mixtures. The specific gravity of this sand determined as per IS: 2386-1968 Part III was 2.65, while the fineness modulus using the sieve analysis method described in IS: 2386-1968 Part III was

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determined to be 2.57. The maximum size of the coarse aggregate was 20 mm and the coarse aggregates were blended in the ratio 60:40 of 20 mm and 12 mm respectively. A naphthalene sulphonate based high range water-reducing admixture (HRWR) La Adcrete GFwas used in concrete mixtures to obtain the necessary workability.

Table 1: Chemical composition of GGBS and PSC cement used

Chemical Analysis	GGBS sample	PSC Sample
SiO_2%	31.86	25.66
Al_2O_3%	14.97	9.78
Fe_2O_3%	0.768	2.6
CaO%	33.75	49.0
MgO%	8.92	4.22
Actual SO_3%	2.45	3.42
K_2O%	0.55	0.61
Na_2O%	0.24	0.14
TiO_2%	0.34	0.41
P_2O_5%	0.03	0.11
MnO_3%	0.19	0.18
Cl%	0.05	0.01
Sulfate	1.08	0.28
Physical Analysis		
Blaine m^2/kg	458	340
R-45 Micron%	7.85	10.78

3.2 Mix proportions

To compare the strength development of concrete made with PSC and OPC+GGBS combination, different cement contents of 300, 320, 340, 360 and 380 kg/m^3were chosen. Mixture proportions has been performed using IS 10262 2009 as guidelines. The cementitious content was fixed for both with PSC cement and OPC + GGBS combination. In addition to that, the same quantity of GGBS blended while producing PSC was used for OPC+GGBS combination. Totally ten mixtures (5 with PSC cement and 5 with OPC+GGBS combination).

Ordinary Portland cement 45% was obtained by mixing of 55% GGBS. The mix proportion for both the concretes has been shown in Table 2 and 3 respectively. The concrete was mixed in a tilting drum mixer and the slump was around 100mm while casting the cube. In each mixture three specimens were cast to test the compressive strength of concrete. A total number of 120 specimens were cast for the present study. The test specimens were stored in moulds for 24 hours and after this period the specimens were marked and removed from the moulds and kept submerged in clean fresh water till the date of testing.

Table 2: Mix proportion for PSC concrete

Mix ID	PSC cement(kg/m^3)	Water (kg/m^3)	20mm Aggregate (kg/m^3)	12mm Aggregate (kg/m^3)	Sand (kg/m^3)	Admixture (kg/m^3)
PSC300	300	156	722	482	777	2.70
PSC320	320	160	712	475	766	2.88
PSC340	340	163	703	468	756	3.06
PSC360	360	162	698	465	750	3.24
PSC380	380	152	750	412	754	3.42

Table 3: Mix proportion for OPC+GGBS concrete

Mix ID	OPC (kg/m^3)	GGBS (kg/m^3)	Water (kg/m^3)	20mm Aggregate (kg/m^3)	12mm Aggregate (kg/m^3)	Sand (kg/m^3)	Admixture (kg/m^3)
OGC300	135	165	156	774	516	833	2.70
OGC320	144	176	160	705	470	758	3.84
OGC340	153	187	163	696	464	748	4.08
OGC360	162	198	162	690	460	742	4.32
OGC380	171	209	152	693	462	745	4.56

3.3 Properties of concrete investigated

3.3.1 Compressive strength

Compressive strength tests were carried out at the end of 1, 3, 7, 28, 90 and 180 days for the concrete cube specimens of size 150 mm, using a Compression Testing Machine (CTM) as per IS: 516-1959. The compressive strength results presented in the discussions are the average of three readings.

4. Results and Discussions

4.1 Compressive strength of PSC concrete

Figure 1 shows the compressive strength development of concrete PSC concretes at 3, 7, 28 and 90 days. At 3 days, the strength development of PSC concretes for 300kg/m^3 and 320kg/m^3 was around 60% of that of 28 days compressive strength and for higher cement contents 340, 360 and 380kg/m^3, it was found to be more than 75% of that of 28 days compressive strength. At 7 days, the strength development of PSC concretes for all the

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concretes were around 95% of that of 28 days compressive strength except 380kg/m^3, where it was around 85%. At 90 days, the strength development of PSC concrete with cement contents 300 and 320kg/m^3 was found to around 120% of that of 28 days compressive strength, where for other cement contents it was found to be around 145% of that of 28 days compressive strength. The compressive strength results revealed that there was not much increase in the strength between 7 and 28 days.

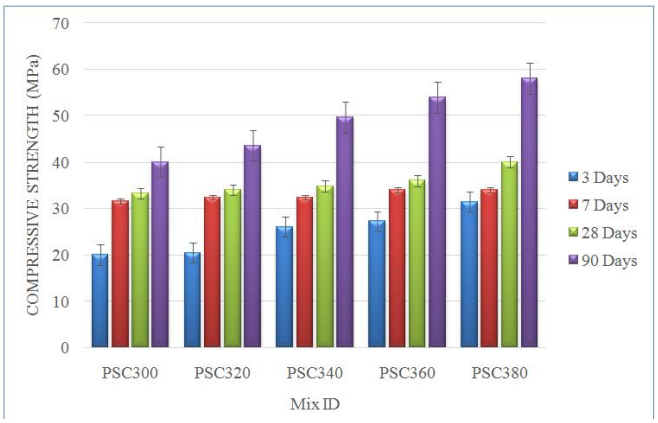

Figure 1: Compressive strength of PSC concrete

4.2 Compressive strength of OPC+GGBS concrete

Figure 2 shows the compressive strength development of concrete OPC+GGBS concretes at 3, 7, 28 and 90 days. At 3 days, the strength development of OPC+GGBS concretes for all cementitious content around 80% of that of 28 days compressive strength. At 7 days, there was not much increase in the strength development of OPC+GGBS concretes for all the mixes. At 90 days, the strength development of OPC+GGBS concrete was found to have around 140% of that of 28 days compressive strength for all the mixes.

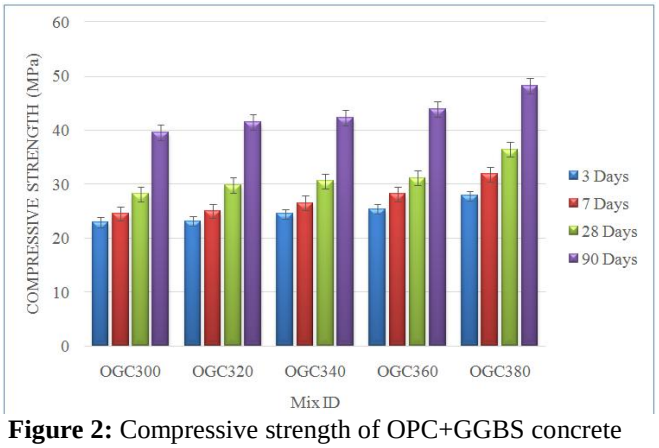

Figure 2: Compressive strength of OPC+GGBS concrete

4.3 Comparison of compressive strength of blended concretes at 3 days

Figure 3 shows the compressive strength development of concrete PSC and OPC+GGBS concretes at 3 days. It was observed that there was slight increase in strength of around 14% in OPC+GGBS concrete than PSC concretes at 300 and 320 kg/m3 cementitious content. Whereas for other cementitious content, there was a decrease in compressive strength of around 6 to 11% in OPC+GGBs concrete than PSC concretes.

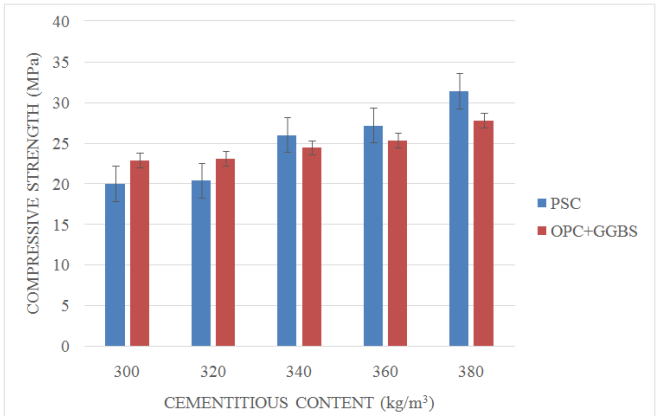

Figure 3: Compressive strength of blended concretes at 3 days

4.4 Comparison of compressive strength of blended concretes at 7 days

Figure 4 shows the compressive strength development of concrete PSC and OPC+GGBS concretes at 7 days. It was observed that there was decrease in strength of around 18% to 22% in OPC+GGBS concrete than PSC concretes except 380 kg/m^3 cementitious content. For 380kg/m^3 cementitious content, there was a decrease in compressive strength of around 6% in OPC+GGBS concrete than PSC concrete.

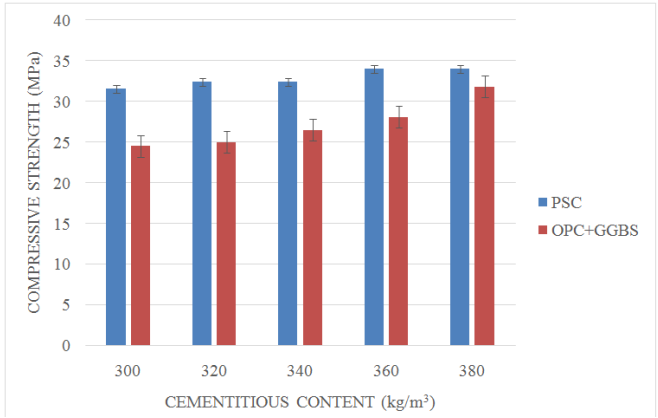

Figure 4: Compressive strength of blended concretes at 7 days

4.5 Comparison of compressive strength of blended concretes at 28 days

Figure 5 shows the compressive strength development of concrete PSC and OPC+GGBS concretes at 28 days. It was observed that there was decrease in strength of around 9% to 15% in OPC+GGBS concrete than PSC concretes. From the results, it is clear that the strength of PSC cements at 28 days was higher than the OPC+GGBS combination, keeping the OPC+GGBS combination common in both the cases.

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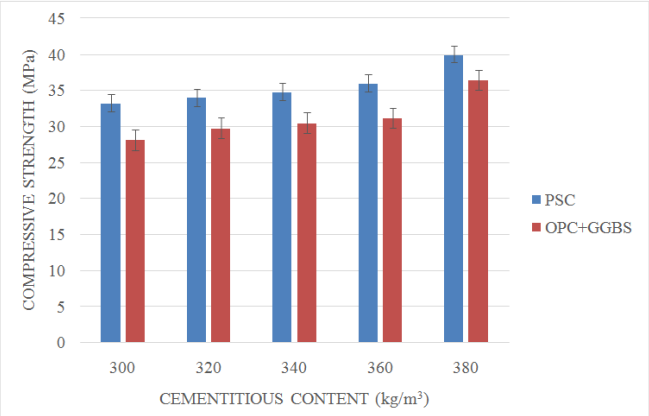

Figure 5: Compressive strength of blended concretes at 28 days

4.6. Comparison of compressive strength of blended concretes at 90 days

Figure 6 shows the compressive strength development of concrete PSC and OPC+GGBS concretes at 90 days. It was observed that the compressive strength was almost equal in low cementitious content such as 300 and 320kg/m^3. Whereas for other concretes there was decrease in strength of around 14% to 18% in OPC+GGBS concrete than PSC concretes. From the results, it is clear that the strength performance of PSC cements at 90 days was higher than the OPC+GGBS combination, keeping the OPC+GGBS combination common in both the cases.

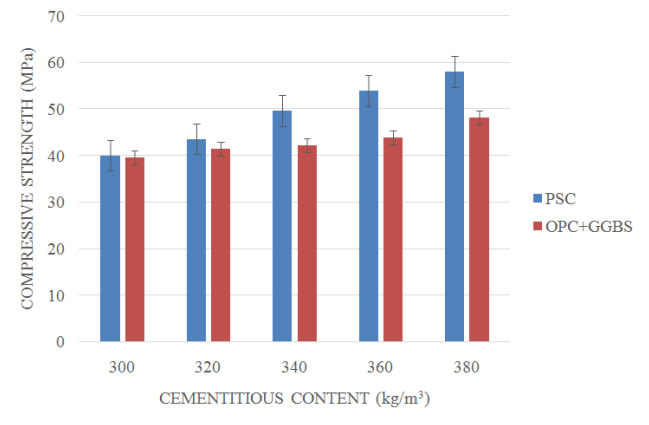

Figure 6: Compressive strength of blended concretes at 90 days

5. Conclusions

From the experimental work carried out and the analysis of the results following conclusions seem to be valid with respect to the utilization of PSC and OPC+GGBS.

- PSC cement was found be better than OPC+GGBS combination, when the GGBS content was same in both PSC and OPC+GGBS combination
- At 28 days, all mixtures containing PSC cements was found to have higher strength than OPC+GGBS combination.
- At lower cement contents of 300 and 320 kg/m^3, the compressive strength of both PSC and OPC concretes were found be closer at 90 days.
- When the cementitious content is increased beyond 320 kg/m^3, the 90 days strength was found to be higher in PSC cement than OPC+GGBS combination
- There was not much increase in strength in PSC cement between 7 and 28 days.

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