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CAPABILITY OF GGBS CONCRETE EXPOSED TO SEA WATER

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ABSTRACT

This paper reported studies the penetration of chloride into Ground Granulated Blast-Furnace Slag (GGBS) concrete with exposure on marine environment. Test were conducted on Ordinary Portland Cement (OPC) concrete and 60 percent (by weight) of Ordinary Portland Cement (OPC) replaced by GGBS (S-60). The specimens immersed in sea water were tested for chloride penetration. The results show that higher replacement level of GGBS in concrete significantly reduce the chloride content in concrete. The results also show that chloride concentration decreases with increasing depth into concrete.

Keyword : Concrete, Ground Granulated Blast-Furnace Slag, Sea Water, Chloride, Replacements.

1. INTRODUCTION

Mix four basic ingredients –water, cement, sand and aggregate and you have concrete. However, if you want concrete that is stronger, more durable and wards of the attacks of chemical and weather, then you need to go beyond the basics and consider using cement replacements material such as Ground Granulated Blastfurnace Slag (GGBS)[Robin, et al, 1992]. Using GGBS to partially replace OPC in concrete mixtures can provide many benefit. When added in the right proportions, GGBS concrete improves the workability of fresh concrete and increase the strength and durability of hardened concrete [Diah, 1996].

Ground Granulated Blastfurnace Slag (GGBS) is a by-product from Blastfurnace Slag, a by-product of iron making. It was first used as a constituent of Portland Blastfurnace Cement in 1880 in Germany and since then blended cements containing GGBS have been widely available, particularly in Continental Europe. More recently the use of separately – supplied GGBS which is blended with Portland Cement in the concrete mixer, has become common place throughout the world including Malaysia.

The principal cause of the corrosion of embedded reinforcing steel is the presence of chloride in concrete. Concrete structures located in marine environments that are subject to chloride attacks. The main aim of study was to provide a comparison of the resistance OPC and GGBS concrete to the penetration of chloride. Chloride content have been used as indicator to monitor penetration of chloride into concrete. From the result presented, there is no reason why GGBS concrete cannot be used for marine structure in Malaysia for future concrete.

2. MATERIALS

2.1. Aggregates

The fine and coarse aggregates were local natural sand and crushed gravel, respectively. A coarse aggregate with a nominal size of 20 mm and a medium fine aggregate grading were used throughout [BS 882, 1992].

2.2. Cement

The Ordinary Portland Cement (OPC) was used "CAP SELADANG" produced by Tenggara Cement Manufacturing Sdn., Bhd., Johor, Malaysia. The physical properties and chemical analysis of which are given in Table 1.0 complying with MS 522 [1989]. These were obtained in a large single bulk sample. The samples were transferred to plastic sacks and sealed in airtight steel drums until used.

2.3. Ground Granulated Blastfurnace Slag

Ground Granulated Blastfurnace Slag from APMC was used. The chemical composition of the GGBS slag is also shown in Table 1.0 complying with MS 1387 [1995].

TABLE 1: AVERAGE OF PHYSICAL AND CHEMICAL ANALYSIA OF OPC AND GGBS

Description of Test	OPC	GGBS
Physical Tests		
Specific gravity	3.28	2.90
Surface area (m/kg^3)	314	420
Chemical analysis (%)		
Silica dioxide (SiO_2)	20.20	28.2
Aluminium oxide (Al_2O_3)	5.7	10.0
Ferric oxide (Fe_2O_3)	3	1.8
Calcium oxide (CaO)	62.58	50.4
Magnesium oxide (MgO)	2.60	4.6
Sulphur trioxide (SO_3)	1.80	2.2
Sodium oxide (Na_2O)	0.16	0.14
Potassium oxide (K_2O)	0.87	0.6
Loss on Ignition (LOI)*	2.7	0.2

2.4. Water

Tap water was used throughout to makes the concrete. It has been established that the mains water had chloride content typically around 10 ppm. This level of chloride concentration was therefore considered to cause on significant contribution to the measured chloride contents of hardened concrete.

3. MIX PROPORTIONS

The mix proportions comprising of cement, GGBS, coarse aggregate, fine aggregates and water for each batch of casting are shown in Table 2.0. OPC concrete mixed was designed using DOE method. The design strength chosen for the concrete mixes at 28 day was 50 N/mm^2. The water/cement of the mix was kept constant at 0.5 and total of cementitious was also kept constant at 420 kg/m^3.

TABLE 2: MIX PROPORTIONS OF CONCRETE INCORPORATING OF GGBS

Types	W/C	Cement (kg)	GGBS (kg)	Water (kg)	Fine aggregates (kg)	Coarse aggregate (kg)
OPC	0.5	420	0	210	712	1068
S – 60	0.5	168	252	210	712	1068

4. CURING

100 x 100 x 2400 mm column were casted in timber formwork. Casting was conducted inside laboratory and compacted with a poker vibrator for three minutes. After 24 hours the specimens were demoulded and cured using wet gunnysack for 28 days. Every three days, the specimens were sprayed with water in order to maintain the moisture condition. The specimens were then immersed in seawater in upright position for 180 and 365 days.

5. CHLORIDE PENETRATION TEST

5.1. Sample Preparation

The specimens immersed in seawater were tested for chloride penetration. All specimens comprised of 50 mm diameter cylinder cored at the centre portion from the 200 mm x 200 mm x 2400 mm sample cured for 180 and 365 days and dried in the oven at 105°C to remove any residual pore fluid. The cylinders were cut into slices of 10-mm thickness using a wet diamond-tipped cutter and crushed using the compressive strength test apparatus. The powder samples were then sieved using no. 200 sieve and collected for analysis. The increment slices corresponded to dept of 10-70 mm from the concrete surface. Specimens cored for chloride penetration test. Test was performed in accordance with BS 1881 [1991].

5.2. Procedure

The samples were weighted into a stoppered conical flask the quantity of the sample expected to be equivalent to about 2 grams cement and dispersed with 25 ml water and added 10 ml nitric acid (d = 1.42). The samples were then added with 50-ml hot water and heated to near boiling and kept warm for 10 minutes to 15 minutes. (If the supernatant liquid is turbid, filter through a rapid paper and wash with hot water). The specimens were cooled to room temperature and added a measured excess of standard (0.1 N $AgNO_3$ in 1 litre). The specimens were added 2 ml to 3 ml nitrobenzene then stoppered the flask and shaked vigorously to coagulate the precipitate. Finally, the specimens were added 1 ml ferric indicator solution (100 ml cold saturated solution of ammonium ferric sulphate plus 10 ml nitric acid (d = 1.42)) and titrated with standard 0.1 N ammonium thiocyanate to the first permanent red colour.

5.3. Calculation

The results were report as anhydrous calcium chloride per cent of cement content

$$CaCl_2\%\ of\ cement\ content = \left(V - \frac{tX}{0.1}\right)\frac{0.555}{M} \times \frac{100}{C}$$

Where M = weight of sample (gram)
V = volume of 0.1 N $AgNO_3$ added
t = titre of NH_4CNS solution
X = normality of NH_4CNS solution
C = cement content % of samples

6. RESULT AND DISCUSSIONS

Chloride concentration at different depths into the concrete specimens were measured by drilling the concrete at selected depths to obtained powder samples which were subsequently analyzed chemically. The chloride content with depth for the specimen exposed to 180 days and 365 days of immersion in sea water are shown in Table 3.0. The lowest chloride content is given by the specimen containing 60% GGBS for 180 days in sea water. The highest chloride content is given by the specimen without GGBS. The results shows that higher replacement levels of GGBS in concrete produce lower chloride content in concrete. The results show that with GGBS concentration of chloride near the surface corresponds to a similar relationship of higher chloride concentrations with decreasing depth. The results also show that chloride concentration decreases with increasing depth into concrete.

Table 3.0 also shows the concentration of chloride content in the concrete immersed in sea water at 365 days. The concentration of chloride content indicates that the increase corresponds to a long immersion in sea water. The sample incorporating 60% GGBS achieves the lowest chloride content. The highest chloride content is given by the specimen without GGBS. The results show that with GGBS replacements in concrete significantly reduce the chloride content in concrete. The results also show that chloride content decreases with increasing depth into concrete. Mangat et al [1994] have reported that replacing 40% of cement with GGBS slag increase the intruded pore volume of cement paste. The rate of corrosion of rebar embedded in concrete containing a similar replacement level of GGBS is lower. Mangat and Molloy [1991] reported that the replacement of cement by up to 40% GGBS has no significant influence on rebar corrosion. At 60% GGBS content the corrosion rate of reinforcement is significantly reduced.

TABLE 3: CHLORIDE CONTENT IN CONCRETE IMMERSED IN SEA-WATER

Layer	Depth From surface (mm)	Chloride content (%)			
		180 days		365 days	
		OPC	S-60	OPC	S-60
1	10	0.0340	0.0337	0.2200	0.2060
2	20	0.0302	0.0291	0.2100	0.1700
3	30	0.0265	0.0206	0.2000	0.1600
4	40	0.0234	0.0180	0.1700	0.1500
5	50	0.0190	0.01147	0.1460	0.0840
6	60	0.0158	0.0120	0.1270	0.0530
7	70	0.0130	0.0080	0.0830	0.0200

7. CONCLUSION

The concentration of chloride content indicates an increase corresponds to a long immersion in sea water. The sample incorporating 60% GGBS achieves the lowest chloride content. The highest chloride content is given by the specimen without GGBS.

The results show that higher replacement level of GGBS in concrete significantly reduce the chloride content in concrete. The results also show that chloride concentration decreases with increasing depth into concrete. Overall can be said GGBS can be highly resistant to the ingress of chloride. Provided the user is made aware of the properties of GGBS, there is no reason why GGBS concrete should not be increasingly employ in the production of durable and long lasting especially marine structure.

8. REFERENCES

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