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JILID 2

PERFORMANCE OF GGBS CONCRETE IN STRENGTH DEVELOPMENT AND DURABILITY

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ABSTRACT

This paper deal with an investigation on the performance of concrete containing ground granulated blast-furnace slag (GGBS) as a partial cement replacement. The three engineering properties are compressive strength, oxygen permeability and water absorption. In addition chloride content in concrete immersed in sea-water was tested. Tests were conducted on concrete in which 40 and 60 percent (by-weight) of OPC was replaced by GGBS. Water cementitious (w:c) ratio of 0.4 was used for all mixes. Whilst w:c ratio of 0.5 was used for compressive strength, oxygen permeability and water absorption specimens. Concrete moist cured at 20 ℃, 27 ℃, cured at site and cured in sea-water were tested at ages between three days and one year for compressive strength. Water absorption, permeability and porosity tests were conducted for samples cured at 28 days, 180 days and 1 year. It was found that one year the compressive strength of moist cured concrete with w:c 0.4 containing 40% GGBS is significantly higher in comparison with the control, whilst specimens cured at other condition performed comparably with the control. It was found that specimens with w:c = 0.5 containing GGBS produce lower compressive strength than the control. However, it is comparable with the control beyond 120 days. It was found that w:c ratio of 0.4 produces lower permeability in comparison with w:c = 0.5. However all permeability values lie between the "high" and "low" permeability regions. The results also showed that with increasing age, the compressive strength of concrete increases. However the permeability and absorption values decreased with age.

INTRODUCTION

The use of supplementary cementitious materials like Ground Granulated BlastFurnace Slag (GGBS) in concrete construction is wide spread due to the economic, technical and environmental benefits of these materials (Diah, 1996). However concrete made with GGBS was reported to be sensitive to lack of curing (Diah et al, 1999). Water absorption can be used to compare different methods of curing, provided that the same conditioning is adopted for all specimens. The results will depend mainly on the volume of capillary pores and pore size distribution. Increasing the duration of water curing from one day to three days reduces water absorption considerably for mixes with slag exposed to hot environments.

The effect of duration of water curing is not significant in the case of OPC (Diah et al, 1999). Ramezanianpour (1995) reported that the reduction in the moist curing period produced lower strengths, higher porosity and more permeable concretes. The strength of concrete containing GGBS appears to be more sensitive to curing temperature than the control concrete (Sumadi et al, 1999). He also reported that concrete incorporating GGBS increased the resistance to chloride

MATERIALS

Cement

An Ordinary Portland Cement (OPC) complying with MS 522 (1989).

Aggregates

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

GGBS

Ground Granulated Blast Furnace Slag (GGBS) was used complying with MS 1387 (1995).

Superplasticizer

This research used a CONPLAST 2000 superplasticizer as chemical admixture complying with BS 5075 (1982).

MIX PROPORTION

The mix proportions comprising of cement, GGBS, coarse aggregate, fine aggregate and water for each batch of casting are shown in Table 1.0. The table shows the total weight of mix proportion for 1 m^3 of concrete.

SAMPLE PREPARATION

Specimens cured in water, at site and seawater was casted using 100-mm diameter of cylinder mould. Specimens cured at site and seawater were cored from 160 x 300 x 2400-mm beam and 200 x 200 x 2400 mm column, respectively. After 28, 180 and 365 days. 50mm diameter specimens were cored from beam and column to prepare for absorption and oxygen permeability test. For every tests conducted, average two results were calculated. Statical data analysis cannot be conducted due lack of data.

Table 1.0: Mix Proportions of concrete incorporating GGBS.*

Types	w/c	OPC	GGBS	Water	Sand	Coarse Aggregate
OPC	0.4	525	0	210	670	1005
S 40	0.4	315	210	210	670	1005
S 60	0.4	210	315	210	670	1005

* Weight in kg

TESTING PROCEDURE

Strength Development Test

Cube specimens (100mm side) were tested for compressive in accordance with BS 1881: Part 116 (1993). 100 mm cube specimens were casted in steel moulds. The specimens were demoulded after 24 hours and marked for later identification followed by immediate curing in water at 20°C and 27°C

Oxygen Test

The specimen was plattened and dried oven at 50°C or many hours before test. Dried specimens were stored for 24 hours in room at 20 ± 2°C degrees prior to testing. To obtain meaningful results, all specimens, whether cast or cored, were conditioned to the same temperature and moisture level before an oxygen permeablity test could be carried out. The specimens saturated with moisture will not give reading accurately on the gas flow meter.

The specimen were carefully assembled in the cell of the permeability apparatus to ensure that there are no leakages, particularly between the cylindrical surface of the specimen and snugly fitting collar and in all fittings up to the bubble flow meter. It was also ensure that there was no obstruction to the pipe delivering the oxygen. The pressure of 3 bar (3 x 10^{-2} Nm^{-2}) was chosen due to the practicability reason that to achieved a stabilized pressure, it required a time duration of only 5 to 30 minutes. Flow rate reading was taken at every 5 minutes interval; this procedure was repeated until the difference between successive reading is less than 3%. Reading was recorded when the flow rate has stabilized.

The specimens were weighted before and after test, although the masses of the specimens were not required for the determination of permeability values. It was considered useful to note and record the mass in cases where operators subjected the specimens to changes in moisture condition due to long period of exposure and handling.

Absorption Test

The concrete specimen with 150mm diameter was kept in oven for 48 hours with 50°C. The specimen was then weight and the reading recorded on specimen before immersing into water (room temperature at 27°C). The weight of specimen was monitored until complete saturation has achieved.

Results of the investigation show that the time taken to reach saturation was about 72 hours. Absorption capacity (AC) represents the maximum amount of water the concrete can absorb. It is calculated from the difference in weight between the saturated surface dried (SSD) and oven dried (OD) states, expressed as a percentage of the oven dried weight. The investigation involves the specimens moist cured at 27°C cured at site and immersion in sea-water. Each point represented the average of at least three specimens.

$$AC = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100$$

Where: W_{SSD} = Sample in saturated surface dry condition
W_{OD} = Sample is oven dry condition

RESULTS AND DISCUSSION

Compressive Strength

The results of compressive strength investigation had shown in Figure 1.0 to 3.0. Tests were performed on concrete at specimen ages ranging between three days and one year.

The initial rate of hydration of GGBS in concrete is slower than that of Portland cement, but the strength development at later ages is greater. Generally concrete at all replacement levels of GGBS behaves in a similar manner to the plain concrete control with regard to the effect of curing temperature. The rate of strength development, the magnitude of the maximum highest strength development attained. The time of its attainment is highly dependent on the percentage of GGBS replacements, water-cementitious ratio, the physical and chemical characteristics of the Portland cement, curing temperature and curing condition.

The strength values of concrete containing GGBS at early ages tend to be lower in comparison with the control, particularly at higher replacement levels of GGBS in concrete.

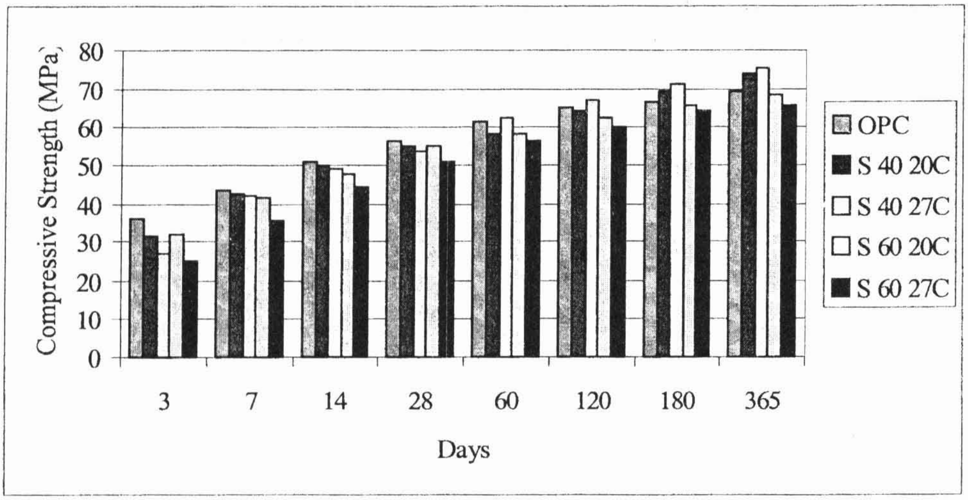

Figure 1: The compressive strength values of concrete moist cured at 20°C and 27°C

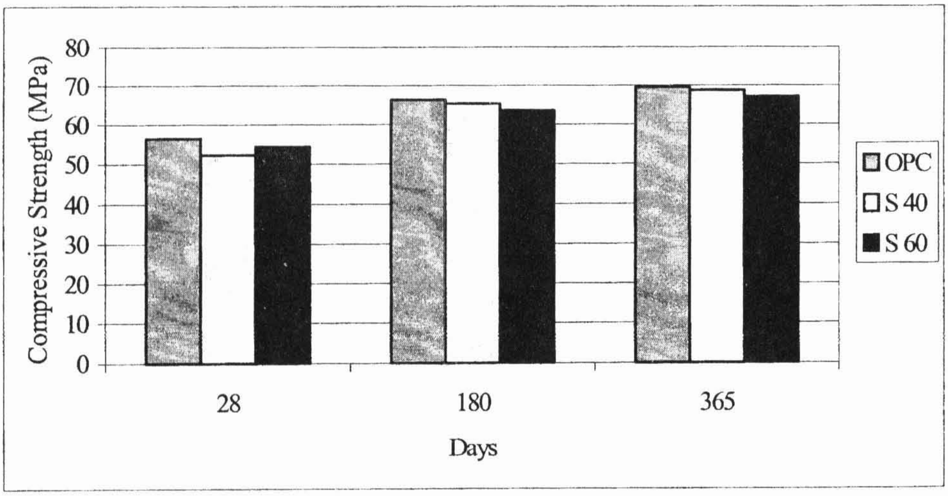

Figure 2: The compressive strength values of concrete cured at site

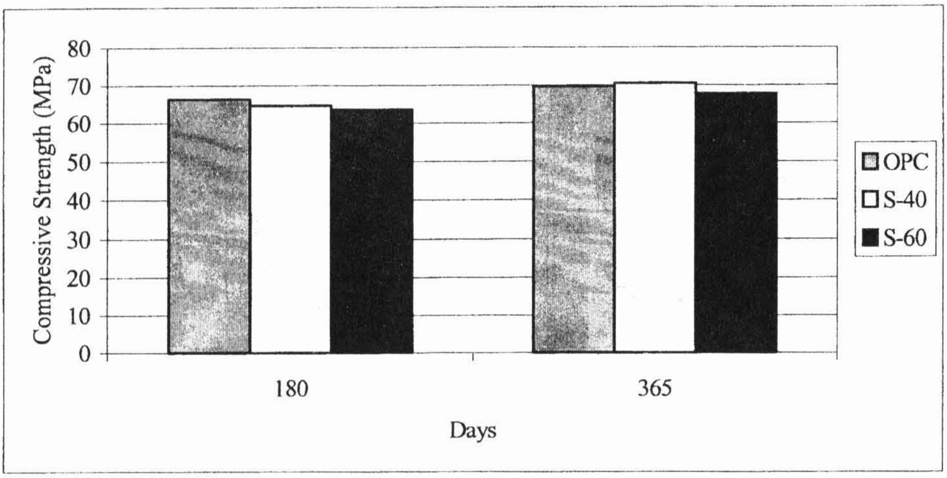

Figure 3.0: The compressive strength values of concrete cured at sea water

Permeability of Oxygen

The specimens with w/c = 0.4 incorporating replacement levels of GGBS produce lower permeability in comparison with OPC concrete (Figure 4.0 to 5.0). The results show that irrespective of the replacement levels of GGBS in concrete, the specimens moist cured at 27°C with w/c = 0.4 achieve the lowest permeability values. The results also show that there is significant effect of adequate curing on permeability achievement.

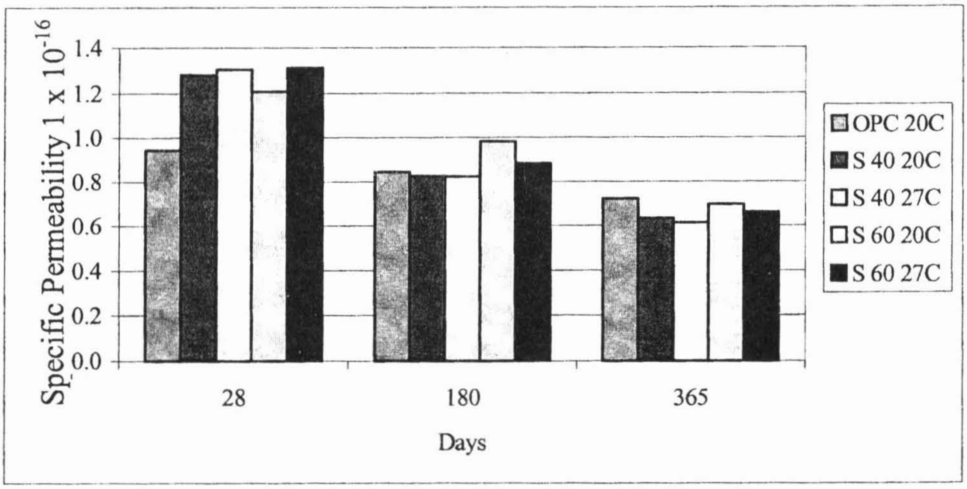

Figure 4.0 : The oxygen permeability of concrete moist cured at 20°C and 27°C

The results indicate that specimens incorporating GGBS cured at various curing regimes produce lower permeability values than control concrete. For examples immersed seawater, there is no significant effect on permeability performance. The specimens cured at site produce the lowest permeability values. However, these are comparable with various curing regimes.

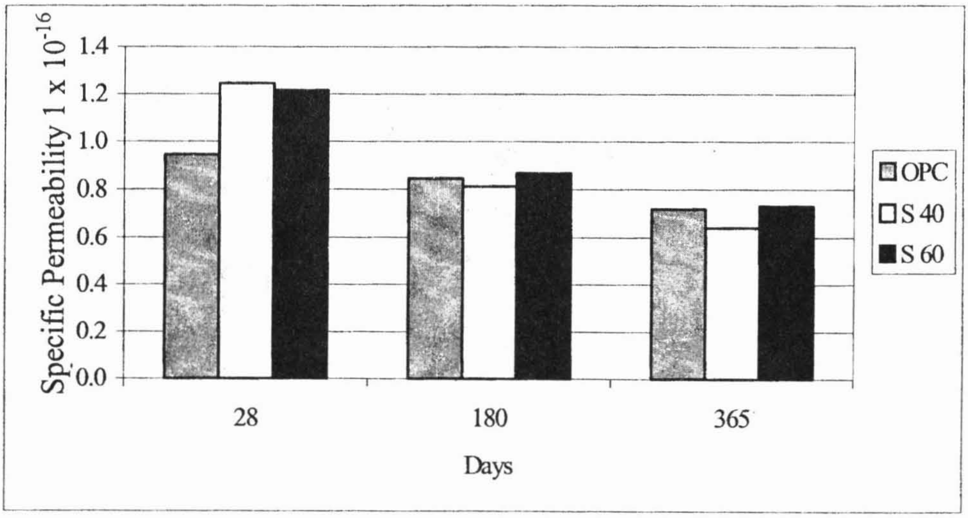

Figure 5.0: The oxygen permeability of concrete cured at site

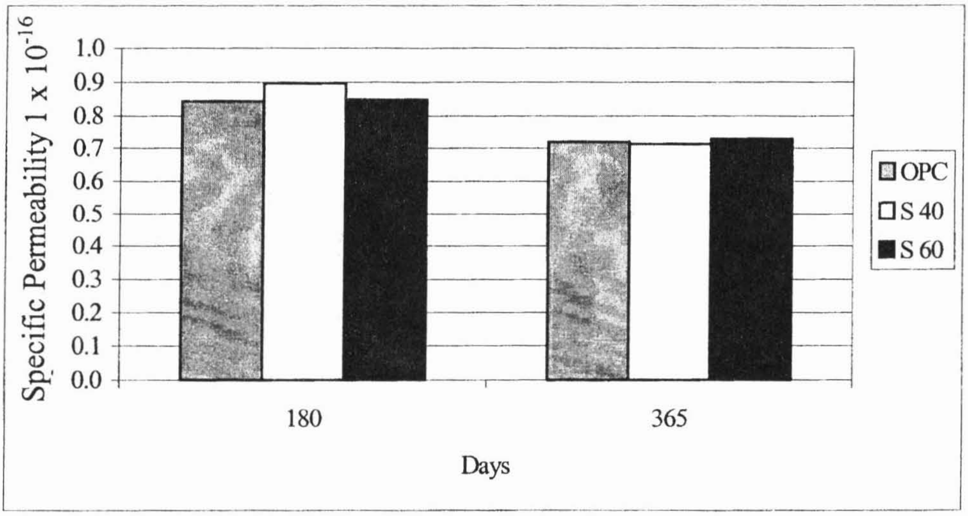

Figure 6.0: The oxygen permeability cured in seawater

Water Absorption

The results show that higher replacement level of GGBS produces lower absorption value. The results also indicate that specimens immersed in seawater produce lower absorption value in comparison with the control. However there is comparable results for both curing regimes. All values lie within the low absorption region (Figure 7.0 to 9.0).

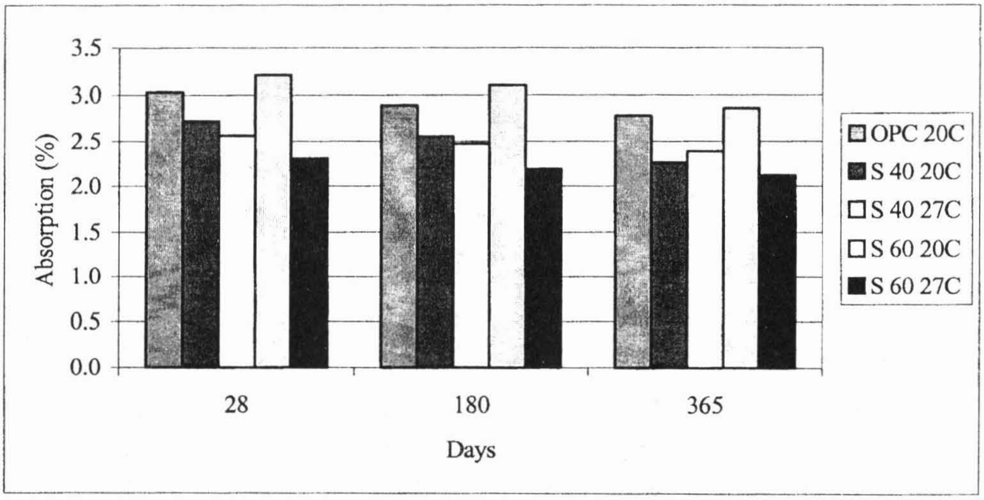

Figure 7.0: Water Absorption values of specimen moist cured at 20°C and 27°C, w/c = 0.4

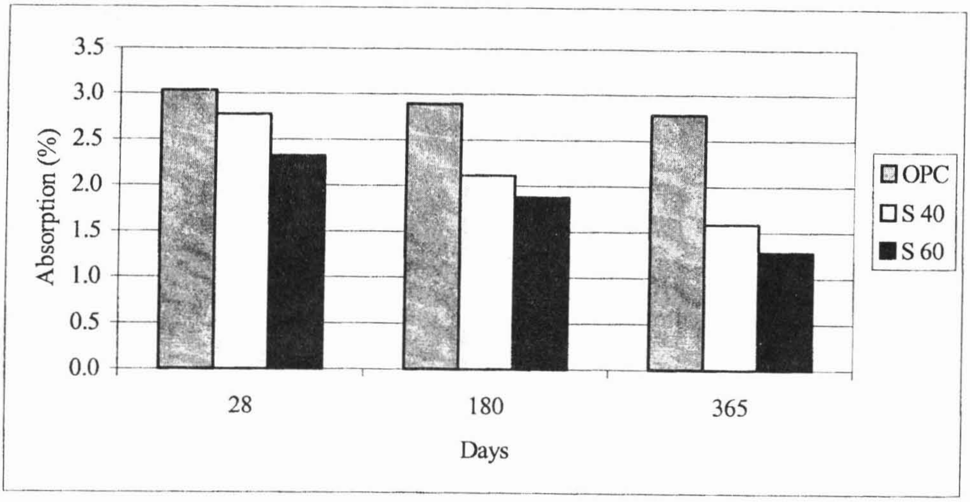

Figure 8.0: Water absorption values of specimen cured at site

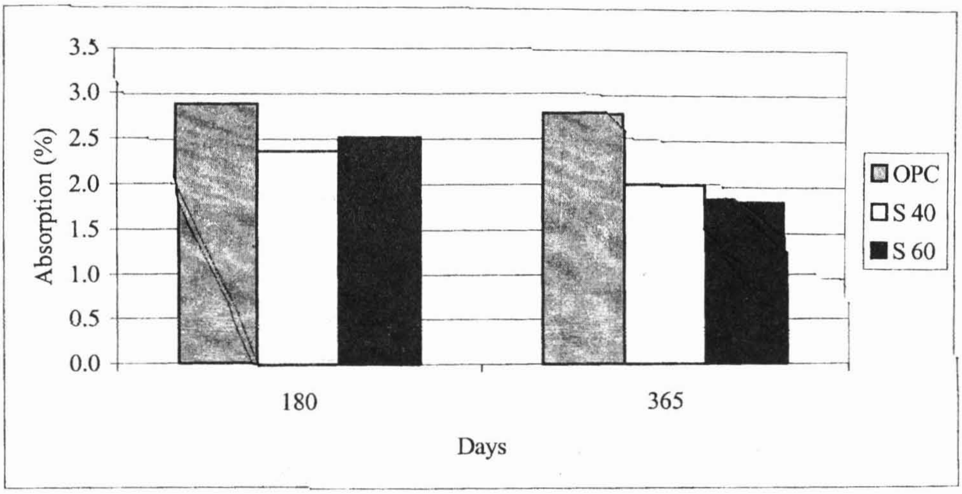

Figure 9.0: Water absorption values of specimen immersed in seawater

CONCLUSIONS

Compressive Strength

Generally concrete at all replacement levels of GGBS behaves in a similar manner to plain concrete control with regard to the effect of curing temperature. The strength values of concrete containing GGBS at early ages tend to be lower in comparison with the control, particularly at higher replacement levels. At same time, the specimens containing GGBS cured at higher temperature produce higher strength value.

Specimens immersed in seawater and cured at site achieved relatively lower compressive strength than the control concrete. However these are comparable strength achievement for various curing regimes.

Oxygen Permeability

Generally concrete at all replacement levels of GGBS behaves in a similar manner to the plain concrete control with regard to the effect of curing temperatures. The specimens cured at site produce the lowest permeability value. Specimen immersed in seawater; there is no significant effect of curing condition on permeability achievement. All specimen permeability values lie within the average permeability region. The concrete incorporating 40% GGBS moist cured in water at 20°C and 27°C are adequate to produce the lowest permeability. However, the concrete incorporating 40% to 60% slags is important in concrete development in future.

Water Absorption

The concrete incorporating GGBS produce lower absorption value in comparison with the control. However, the results seem to have no clear effect of curing temperatures and replacement level of GGBS in concrete on the absorption achievement. The specimen cured at site produces lower absorption value in comparison with the other curing regimes. All specimen decreases in absorption values with increasing age. The results also show that there is no clear of water-cementitious ratio values on absorption development in concrete. All values lie within the low absorption region.

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