

# Study of Porous Pavement Using GGBS as Partial Replacement of Cement

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**ABSTRACT:** India is facing acute shortage of groundwater. There is excess rainfall in some areas and scarcity of rainfall in other areas. There is no proper means of storage of rainwater in excess rainfall areas and the rainwater mixes with the sewage water and joins the sea. In the scarcity rainfall areas also, storage structures like dams, weirs, and barrage were in minimal number and it is inadequate to store the rain water during excess runoff. Also groundwater is being exploited artificially for the needs of industry, residential purposes, and agriculture. So it's great time to implement porous pavement in India which recharges the ground water to a great extent. Porous Pavement also known as Permeable, Gap Graded, No fines, Enhanced porosity concrete have a porosity of about 15 to 25 percent. It consists of cement, coarse aggregate, water with little to no fine aggregates. Water-cement Ratio can be in the range of 0.30-0.40. Porous pavement can be used in low traffic pavements, residential streets, tennis courts, parking lots.

In this paper, Porous Concrete of M20 grade is designed for road pavements by adding only 15% fine aggregate, PPC cement, 0%,10%,20% partial replacement of cement by Ground Granulated blast furnace slag which is a mineral admixture, water. Compressive strength of 150 cm cubes were tested at 7 days, 14 days and 28 days for 0%,10%,20% GGBS replacement of cement. The results came out to be 14.57,13.02,12.71 N/mm<sup>2</sup> for 7 days for 0%,10%,20% percent GGBS replacement and 17.6,16.8,17.06 N/mm<sup>2</sup> for 14 days for 0%,10%,20% GGBS replacement and 19.6,20.08,20.62 N/mm<sup>2</sup> for 28 days for 0%,10%,20% GGBS replacement. Falling head permeability test is carried out for 150 cm cube at 28 days and the permeability values comes out to be 2.501 x 10<sup>-3</sup> m/s, 2.413 x 10<sup>-3</sup> m/s, 2.346 x 10<sup>-3</sup> m/s for 0%,10%,20% GGBS replacement.

## I. INTRODUCTION

### 1.1 GENERAL

Permeable Concrete which is also known as no-fines, porous, gap graded and pervious concrete and enhanced porosity concrete has been found to be a reliable storm water management tool. By definition the permeable concrete is a mixture of gravel or granite stone, cement, water, little to no sand (fine aggregate) with or without admixtures. When permeable concrete is used for pavement, the open cell structures allow storm water to filter through the pavement and into the underlying soils thereby protecting the environment and the pavement surface.

Permeable concrete has the same basic constituents as conventional concrete that is 15%-30% of its volume consists of interconnected void network, which allows water to pass through the concrete. Permeable concrete can allow the passage of 3-5 gallons (0.014-0.023 m<sup>3</sup>) of water per minute through its open cells for each square foot (0.0929 m<sup>2</sup>) of surface area which is far greater than most rain occurrences. Permeable concrete is rough textured and has a honey combed surface. Pervious concrete is light in weight (about 1600 to 1900 kg/m<sup>3</sup>). Permeable concrete can be used in a wide range of applications such as pavements for residential roads, driveways, parking areas, tennis courts and low volume pavements, slope stabilisation, sub base for conventional concrete pavements.

### 1.2 ADVANTAGES AND DISADVANTAGES

Pervious concrete is advantageous for a number of reasons. One of the top concerns is its increase in permeability compared with conventional concrete. Pervious concrete shrinks less, has a lower unit weight, and higher thermal insulating value than conventional concrete.

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Although pervious concrete has advantages in many regards, it has limitations that must be considered when planning its use. Pervious concrete has a lower bond strength which leads to lower compressive strength. Formation of clog may takes place which reduces the permeability. Finally, since the use of pervious concrete in the United States is fairly recent, there is a lack of expert engineer and contractors required for its special installations

**1.3 TYPES OF PERMEABLE PAVEMENT** There are five types of permeable pavements:-

- Permeable asphalt (PA)
- Permeable concrete (PC)
- Permeable intermesh concrete pavers (PICP)
- Concrete grid pavers (CGP)
- Plastic grid pavers (PG)

**1.5 NEED FOR REPLACEMENT OF CEMENT**

Due to the use of cement in concrete, concrete has large carbon foot print. Cement is responsible for greenhouse gas emission causing a threat to environment through global warming and recent problems for raising of cost of cement.

Hence it is necessary to find an alternate material which should have very similar properties of cement and it should be ecofriendly and cost effective also. Thus this project involves the replacement of cement by Ground Granulated Blast Furnace Slag.

**1.6 SCOPE**

- To drain the storm waters into the underground during rainfall and thus recharges the ground water.
- To eliminate flood control measures such as constructing expensive retention ponds.

## II. EXPERIMENTAL WORKS

**2.1. GENERAL** In this chapter, an experimental work is done for the specimen of 15 cubes of sizes 150x150 x150mm. The cubes were casted and tested for their compressive strength after curing for 7days, 14 days and 28 days and also for constant head permeability test.

**2.2. MATERIALS USED**

- Portland Pozzolana Cement
- Ground Granulated Blast Furnace Slag
- Coarse Aggregate
- Fine Aggregate (10 – 15%)
- Water

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### 2.3. CHEMICAL COMPOSITION OF GGBS

Chemical	Present In GGBS
CaO	30-50%
SiO <sub>2</sub>	28-38%
Al <sub>2</sub> O <sub>3</sub>	8-24%
MgO	1-18%
MnO	0.68%
TiO <sub>2</sub>	0.58%
K <sub>2</sub> O	0.37%
N <sub>2</sub> O	0.27%

### 2.4. SLUMP TEST RESULTS

Trail	GGBS for 0%	GGBS for 10%	GGBS for 20%
Slump cone value	15 mm	30 mm	20 mm
Type of slump	True slump	True slump	True slump
Slump Range 'mm'	0-25	25-75	0-25
Workability	Very low	Low	Very low

Fig 1 - Processing of eggshell waste

### 2.5. COMPACTION FACTOR RESULTS

Trial	GGBS for 0%	GGBS for 10%	GGBS for 20%
Weight of partially compacted concrete in kg	16.22	16.62	16.48
Weight of fully compacted concrete in kg	18.57	19.01	19.20
Compaction factor	0.90	0.87	0.86
Workability	Low around (0.87)		

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### 2.6. FLOW TABLE RESULTS

Trial	GGBS for 0%	GGBS for 10%	GGBS for 20%
Spread diameter 'cm'	38	42	44
Flow value	52.50%	68%	76%



Figure 2.1 Casting of specimen



Figure 2.2 Compression Test

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## III. RESULTS

**Table 3.1 Compression test results of Porous Concrete at 7 days**

Trail	Load in kN	Area of cube in mm <sup>2</sup>	Compressive stress in N/mm <sup>2</sup>
GGBS for 0%	327	150x150	14.53
GGBS for 10%	293	150x150	13.02
GGBS for 20%	286	150x150	12.71

**Table 3.2 Compression test results of Porous Concrete at 14 days**

	Load in kN	Area of cube in mm <sup>2</sup>	Compressive stress in N/mm <sup>2</sup>
GGBS for 0%	396	150x150	17.60
GGBS for 10%	378	150x150	16.80
GGBS for 20%	384	150x150	17.06

**Table 3.3 Compression test results of Porous Concrete at 28 days**

Trail	Load in kN	Area of cube in mm <sup>2</sup>	Compressive stress in N/mm <sup>2</sup>
GGBS for 0%	391	150x150	17.37
GGBS for 10%	402	150x150	17.86
GGBS for 20%	414	150x150	18.40

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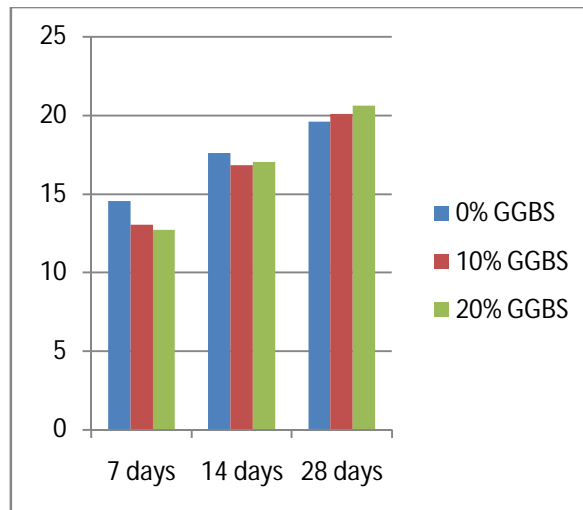


Figure 3.1 Graphs for Compressive Strength

### 3.2 PERMEABILITY TEST FOR CONCRETE

Permeability (hydraulic conductivity) is the velocity of flow per unit hydraulic gradient. Two types of permeability tests were there. They are:-(1) the constant head test method, and (2) the falling head test method. The constant head test method is used for cohesionless soils ( $k > 10^{-4}$  cm/s) and the falling head test is mainly used for cohesive soils ( $k < 10^{-4}$  cm/s). We used falling head Permeability test for our project. A graduated glass pipe of cross sectional area 'a' (m<sup>2</sup>) is attached to the top cap of the vessel. The concrete cubes with cross sectional area 'A' (m<sup>2</sup>) are supported in between the vessels. The samples utilized in this test were circumferentially sealed with epoxy mortar to ensure axial flow of water without lateral leakage. The water level drops from a height  $h_1$  (m) to a height  $h_2$  (m) while passing a distance 'L' (m) in the concrete cube in time ' $\Delta t$ ' sec.

$$k = \frac{aL}{A} \frac{\log_e \left( \frac{h_1}{h_2} \right)}{(\Delta t)}$$

where,

k = coefficient of permeability in m/s

a = area of the stand pipe (diameter = 50mm) in mm<sup>2</sup>

A = Area of the specimen cube (150x150mm) in mm<sup>2</sup>

L = Length of the specimen (150mm) in mm

$h_1$  = Initial head in m

$h_2$  = Final head in m

$\Delta t$  = Time Required to fall in seconds

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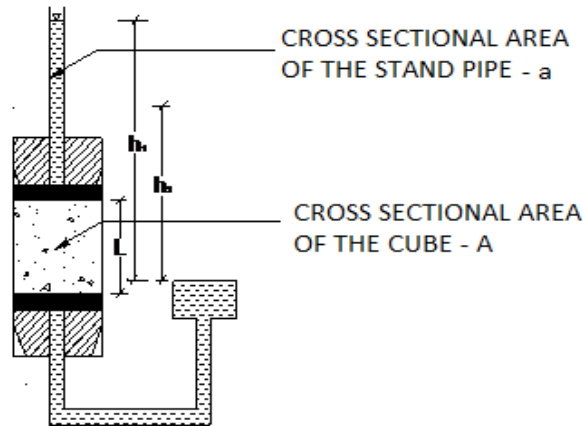


Figure 3.2 Falling Head test

Table 3.4 Permeability Test results

S.No	1	2	3
<b>GGBS Replacement</b>	0%	10%	20%
<b>Initial Head 'h<sub>1</sub>' in m</b>	1.2	1.2	1.2
<b>Final Head 'h<sub>2</sub>' in m</b>	0.3	0.3	0.3
<b>Time Required to fall 'Δt' in seconds</b>	7.258	7.52	7.735
<b>Permeability (m/s)</b>	2.501 x 10 <sup>-3</sup>	2.413 x 10 <sup>-3</sup>	2.346 x 10 <sup>-3</sup>

## IV. SUMMARY AND CONCLUSION

The influence of replacement of cement by ground granulated blast furnace slag has been studied and the conclusions were given depending upon the experimental results. The replacement of cement by ground granulated blast furnace slag in concrete increases the compressive strength of concrete. Increase of 10.13% strength can be achieved when 20% cement was replaced by ground granulated blast furnace slag in concrete when water/ cement ratio was maintained constant. Considering the strength criteria, the replacement of cement by GGBS is feasible up to 20%. Usage of GGBS in concrete can prove to be economical as it is very much cheaper than cement. Use of blast slag in concrete will reduce the disposal problem of blast slag, reduction of CO<sub>2</sub> emissions and hence prove to be environmental friendly thus paving for green concrete. There is no change in workability of concrete with addition of GGBS. Curing has to be done for 28 days for GGBS concrete for required strength to be achieved. The permeability of porous M20 concrete comes around to be 2.5x10<sup>-3</sup> m/s in falling head permeability test. This technology lets the dust down; degrade the pollutants in the seeping water. Buildings and pavements absorb and store solar heat, whereas porous pavements diffuse heat.

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