PERVIOUS CONCRETE WITH BOTTM ASH AND COPPER SLAG

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Abstract

Pervious concrete is a porous concrete with voids which has no fine aggregates in it thereby facilitating the drainage of rain and storm water. The interconnected porosity of the porous concrete facilitates runoff from paved areas thereby preventing water logging which causes discomfort to passengers on roads. Moreover the rough surface of the pervious concrete prevents skidding of vehicles and it has also been reported that it absorbs sound and minimizes the deposition of fine dust on the pavement surface. This type of concrete has been successfully used in pavement and parking lots. Several researchers have optimized the proportion of aggregate that can be used in pervious concrete in order to achieve maximum permeability. But as the void content increases the strength of the concrete is reduced. Pervious concrete can be designed by using little or no sand thereby proportioning the concrete to have considerable voids. The binder content is very minimum sufficient enough to just coat and bind the aggregate particles together. The coarse aggregate used can be of single gradation or gap graded to facilitate the formation of voids which are interconnected. Approximately 20 to 30% voids are present in the hardened concrete and research has shown that flow rate of 0.25 to 0.38 cm/sec can be achieved if the gradation of aggregate is designed with gap graded aggregate. The disadvantage of the pervious concrete is its low strength compared to conventional concrete. But it has been tested and reported that it has the sufficient strength that can take up the vehicle load and other loads for many other applications. This paper discusses about the suitable mix proportion for the pervious concrete that uses copper slag and bottom ash as fine aggregate and properties of the concrete in terms of strength and durability.

Keywords: *Pores, Strength, Permeability, Durability*

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1. INTRODUCTION

The use of pervious concrete as paving material is one of the recent research focuses and it has been found as one of the best material for storm water runoff. The advantage of using pervious concrete is to prevent the stagnation of water which causes discomfort to the vehicle drivers (Wanielista & Chopra, 2007).

Pervious concrete also improves the land use by facilitating the drainage of water to sub soil so that the land can be effectively used to collect the discharged water (ACI Committee 522, 2006). The other advantage of porous concrete is that it reduces the road noise due to the porous nature as the air voids dampen the sound between the tyre and the pavement Hendrickx (1998). However the strength and performance of the porous concrete is inferior to the conventional concrete and it depends primarily on the porosity (Crouch et al., 2003). Greater the porosity due to the void content lesser will be the strength but the infiltration rates will be more. A proper mix design should be done to minimize the void content so that the porosities range from 15 to 25% to maintain a balance between the infiltration rate and strength (Tennis et al., 2004). The factors influencing porosity are water/cement ratio and the compaction. A minimum of 10 psi vertical force compaction has been recommended by ACI Committee 522. Researchers have reported a water/cement ratio of 0.25 to 0.33 (Tennis et al. 2004). The advantage of using pervious concrete is that the water in filtered through this concrete is of good quality use of this concrete on pavement surface is one of the best management practice to reduce excessive runoff (Bury et al, 2006). The porous structure acts as a filter and removes the suspended particles and other contaminants in the water within the pervious concrete structure thereby discharging clean water to the sub soil beneath (Schaefer et al, 2006). The size and connectivity of the pores are the main factor to be considered in pervious concrete design. This is achieved by using a single sized aggregate or a gap graded aggregate. Aggregate- binder ratio is another factor that has to be considered in the porous concrete design. The amount of void content to be achieved in porous concrete depends on the specific area which has other factors like intensity of rainfall, drainage characteristics of sub soil and the specific application where it is to be used. Due to its low strength pervious concrete has been used in roads where the traffic intensity is less, in parking lots, walkways and slabs over the drains (Tennis et al, 2004). However Researchers have proved that use of fine aggregate up to 7% has considerably increased the strength by 57 to 84% and reduced the void ratio by 6 to 8% (Kevern et al, 2005). With various factors that have been discussed by many researchers (Ghafoori, 1995, Kandhal, 2002).) on the performance of the pervious concrete with respect to the constituents used this paper focuses on optimizing a mix ratio for achieving a pervious concrete with considerable strength that has sufficient flow rate to facilitate the storm runoff effectively. Many industrial by products have been used in conventional concrete to improve the characteristics of concrete in terms of strength and durability. In a similar way this paper discusses the use of copper slag which is a byproduct from copper smelting process and bottom ash which is another by product from thermal power plant. The quantities of these materials are disposed in enormous quantities causing land pollution and land acquisition. These materials have been used in conventional concrete and have proved to improve the strength of conventional concrete. Therefore, the main objective of this study is to investigate the effects of copper slag and bottom ash which are the industrial by products as fine aggregate on the performance of pervious concrete mixtures. The results of this study would lead to a better understanding of the manner in which industrial by products can be used to optimize a pervious concrete mixture depending on project or site-specific requirements.

2. MATERIALS AND METHODS

Pervious concrete mix design does not follow any particular mix design procedure. Rather it has a range for the constituents that are used in it. From the literature review the range of aggregate/cement ratio used in this work is 3.5 to 4.5. copper slag and bottom ash of 0 to 20% were used as fine aggregate. The properties of copper slag obtained from Sterlite, Tuticorin is given Table 1 and Table 2. The properties of bottom ash which belongs to class C type obtained from NLC is given in Table 3.The water/cement ratio adopted was in the range of 0.2 to 0.35. The gradation of fine aggregate was chosen such that 50% of the aggregate passed the 20 mm sieve and were retained in 16 mm sieve and 50% of the aggregate passed 12.5 mm sieve and retained on 10 mm sieve. Copper slag that was used in this work as coarse and the particles ranged from 1.18 mm to 4.75 mm. Bottom ash obtained from North Madras Thermal power plant was also coarse and the particle size distribution ranged from 600 µm to 1.18 mm. There are several components involved in the making of porous concrete like A/C (Aggregate / Cement) ratio, bottom ash, copper slag and water/cement (W/C) ratio. Conventional method of experimentation considers only one factor at a time and a series of experiments are to be conducted sequentially varying the parameters. This method does not explain the influence of any factor and significance of interaction between the factors on the response. Statistically based experimental design techniques are much useful to plan the experimental trials and to reduce the number of trials when there are a number of controllable variables. Central composite design of response surface methodology has been used in this study to design the experiments and ANOVA analysis has been done to check the significance of the experimental data. The use of designed experiments helps to identify the variables and their interaction effects that have significant influence on the response. Conducting experiments based on the experimental design helps in deriving meaningful conclusions. It is also possible to find the optimal combination of the various components for the desired response. The limits of each component were decided based on preliminary trials. A total of 22 runs was designed and each combination was carried out for two trials and the mean value was adopted. Since the mix design of pervious concrete comprises of many factors with multiple constituents the trials were designed statistically using Design Expert Software. The number of trails that were obtained from the siftware were 21 runs. Each run was carried out as 2 trials and the average value was reported. The constituents were dry mixed for 2 minutes and then mixed with water for 2 minutes. The mixed concrete were filled in moulds to carry out various tests like compressive strength, void content and flow rate measurement.

Table-1 Chemical Properties of copper slag

Chemical component	% of chemical composition
Al_2O_3	3.01
Tio_2	0.60
Fe_2o_3	56
SiO_2	37
CaO	0.35
MgO	0.70
K_2O	1.12
Na_2O	0.45
CuO	0.77

Table-2 Physical Properties of copper slag

Specific Gravity	3.59
Hardness	7 Moh Scale
Conductivity mS/M	4.2
Chloride content	<0.00031

Table 3 Properties of bottom ash

Properties	Bottom ash
Specific gravity	1.84
Fineness, (m^2/kg)	212
Chemical components	
Silicon dioxide (SiO_2), %	30.25
Calcium Oxide (CaO), %	18.23
Alumina (Al_2O_3), %	31.16
Ferric Oxide (Fe_2O_3), %	7.81
Magnesia (MgO), %	2.31
Sodium Oxide (Na_2O), %	1.02
Potassium Oxide (K_2O), %	0.15
Sulphuric anhydride (SO_3), %	3.52
Manganese Oxide (MnO), %	0.03
Loss on Ignition, %	5.52

3. RESULTS AND DISCUSSION

Sieve analysis and specific gravity tests were conducted for coarse aggregate, copper slag and bottom ash. The basic tests on Portland cement of 53 grade were also performed. The concrete specimens were cured in water for 28 days and the tests were performed at the end of 28 days. Compressive strength was tested on 150 cm cube specimens by loading in a compression testing machine. Flow rate is measured using a falling head permeability apparatus (Kevern et al, 2005) which is a common practice reported by many researchers. The concrete samples in cylinder of size 12.5 cm height and 10 cm diameter were used to measure the flow rate using falling head permeability apparatus. The response surface graphs for the tests that were carried out are discussed as follows:

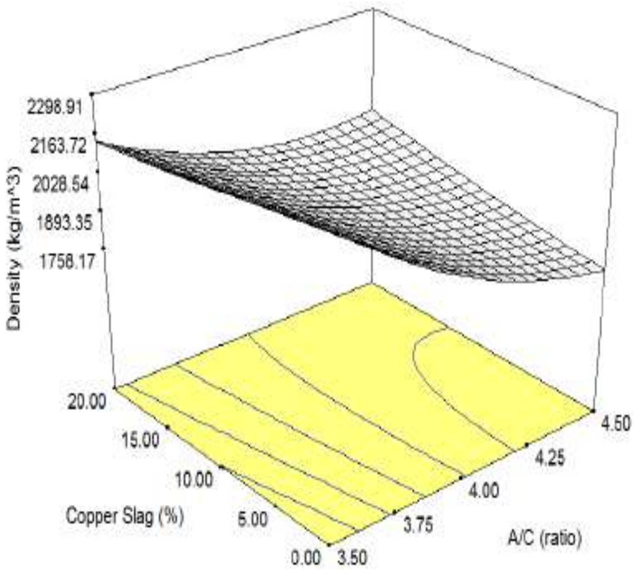

Fig-1 Response surface graph for Density

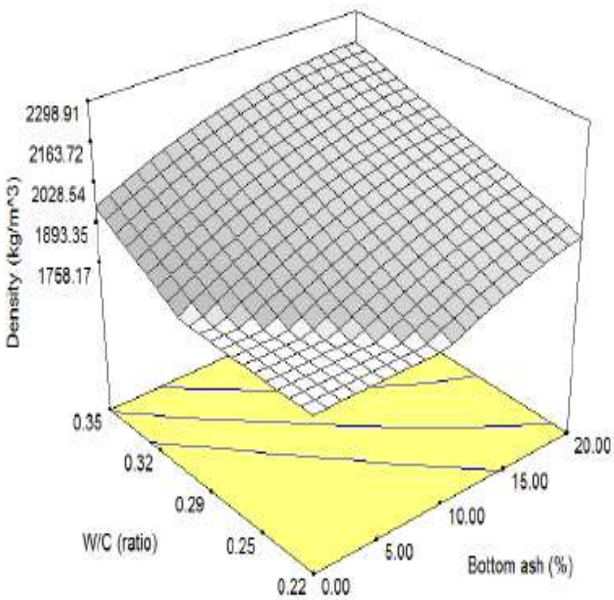

Fig-2 Response surface graph for Density

The density of the porous concrete as given in the response surface graphs (Fig-1 and 2) ranges from 1758 to 2298 kg/m3. However the mix design was done for a target density of 2000 kg/m3 and target strength of 15 MPa. The density was found to increase with increase in copper slag. Also it was observed that there was increase in density as the bottom ash content was increased.

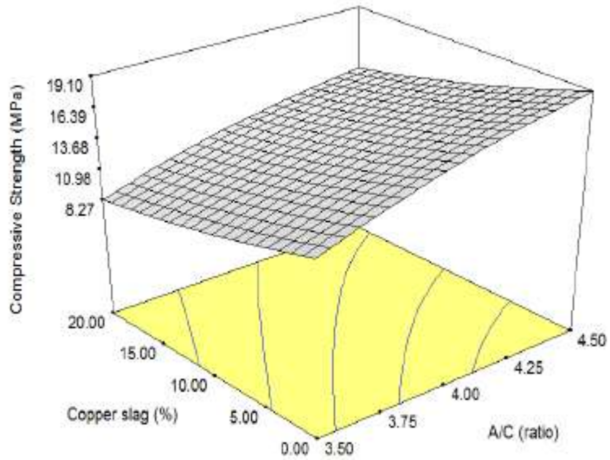

Fig-3 Response surface graph for Compressive strength

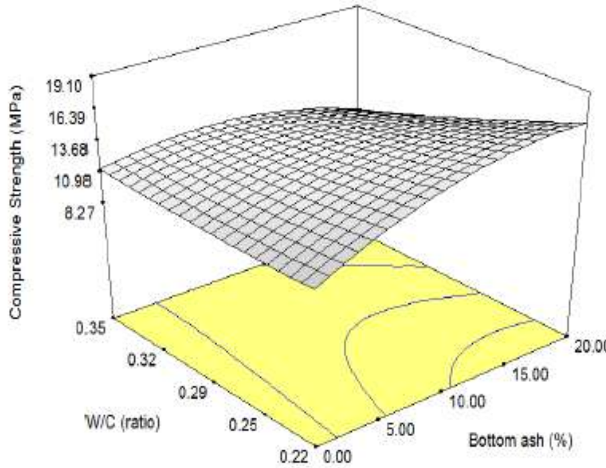

Fig-4 Response surface graph for Compressive strength

The compressive strength ranged from 8.27 to 19 MPa. The response surface graphs (Fig 3 and 4) shows that as there were increase in copper slag and A/C ratio the compressive strength of the concrete also increased. The same trend was observed as there was increase in bottom ash content. But as the W/C ratio increased there was decrease in the compressive strength.

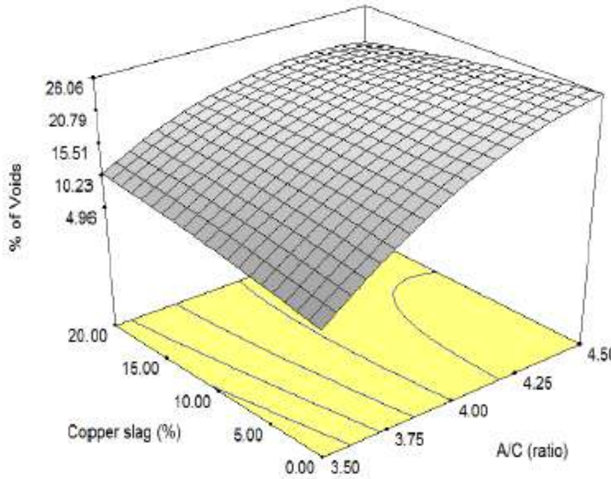

Fig-5 Response surface graph for % of voids

Volume of voids ranged from 4.96 to 26.06 %. The response surface graph in Fig 5 shows that the volume of voids increased as the A/C ratio and copper slag was increased. Bottom ash and W/C ratio did not have much influence in the voids content of the pervious concrete as shown in Fig 6.

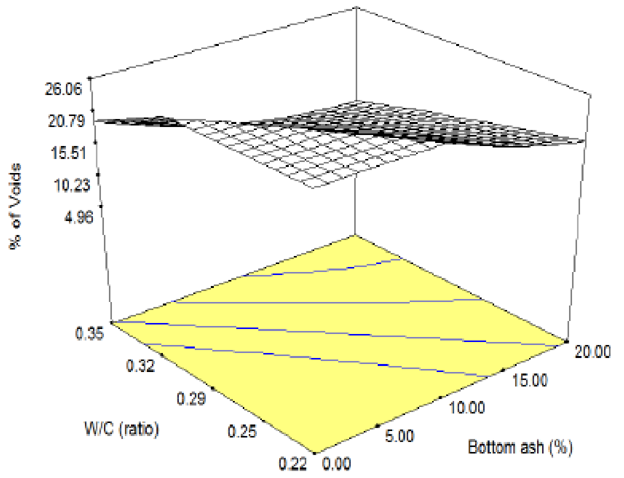

Fig-6 Response surface graph for % of voids

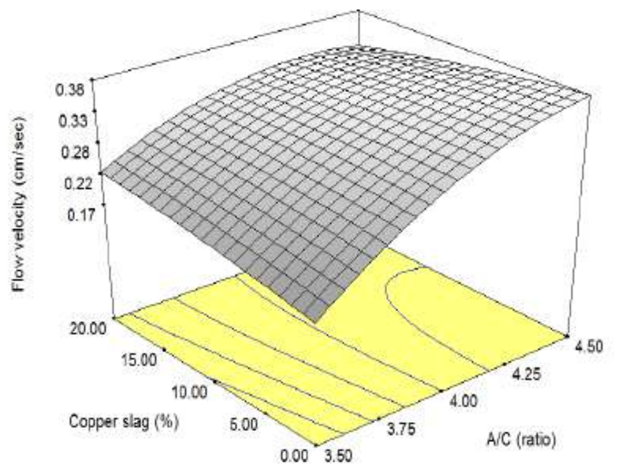

Fig-7 Response surface graph for flow velocity

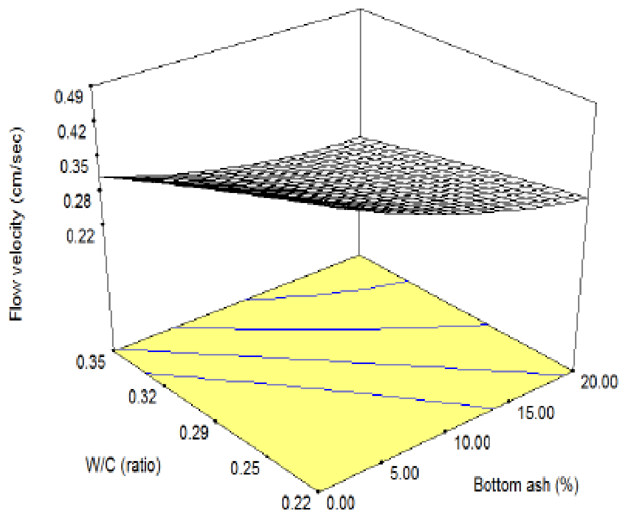

Fig-8 Response surface graph for flow velocity

The flow velocity was measured using a falling head permeability test set up. The flow velocity ranged from 0.17 to 0.38 cm/sec. It was found that the flow velocity increased as the A/C ratio and the copper slag as increased as given in the response surface graph of Fig 7. There was not much influence of bottom ash and W/C ratio on the flow velocity.

As the production of pervious concrete is a multivariable process, optimization was done for the range of factors used in the experimental investigation. The criteria for optimization were maximum strength and maximum flow velocity. The optimized values are given in Table 4. Trials were carried out for these optimized values and it was observed that the experimental values were close to the predicted values.

Table-4 Optimized Values

A/C (ratio)	Copper slag (%)	W/C (ratio)	Bottom ash (%)
0.4	5	0.32	5

Table-5 Predicted and Observed Results

	Density (kg/m^3)	Compressive Strength(MPa)	% of voids	Flow velocity (cm/sec)
Predicted	1997.7	13.85	17.4	0.29
Observed	2011.2	15.3	18.5	0.31

4. CONCLUSION

The test results on pervious concrete as given in this paper shows that bottom ash and copper slag can be used as a filler material in the place of fine aggregate that is used in this type of concrete. The compressive strength was found to increase with increase in bottom ash and copper slag content. Also it was found that copper slag improved the volume of voids and flow velocity.

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