Effect of Water Cement Ratio on Permeable Concrete

Mohd Younis Mir, Jagdeesh Chand

Abstract: ***Permeable concrete is a special type of concrete that permits water to percolate through it. It is also known by the name porous concrete or pervious concrete. The presence of voids in this concrete provides a free path for water to pass through it. This property of permeable concrete helps to reduce the runoff water from the site instantly by percolating it to ground hence acts as a source for ground water recharge. The permeable concrete is prepared by using coarse aggregate with little or no fine aggregete. In case of permeable concrete one can use a water/cement ratio between 0.28 to 0.40. The density of permeable concrete is lesser when compared to conventional concrete. The minimum and the maximum values of densities of permeable concrete are 1600 kg/m^3 and 2000 kg/m^3 respectievely. Hence the self weight of permeable concrete is lesser when compared to normal concrete. The previous studies on permeable concrete indicate that the compressive strength of permeable concrete is less than that of conventional concrete. This fact limits the use of permeable concrete pavements to light traffic loading only. However the strength properties of permeable concrete can be modified by using different admixtures. Tons of waste glass are produced in a year all over the world which cannot be decomposed hence makes the enviroment unsustainable. So the glass powder when milled down into micro size particles is a better choice to use as replacement to cement because of composition of silica in it. The use of glass powder in concrete increases the compressive strength of concrete and is an important step towards sustainable enviroment. In this paper the effect of varaition in water-cement ratio on compressive strength and permeability has been worked out by variying the water to cement ratio in case of permeable concrete with 10 % glass powder replacement by mass of cement.***

Index Terms: Compressive strength, glass powder, tensile strength, water-cement ratio.

MANUSCRIPT
MOHD YOUNIS MIR, M.tech. Student, Civil engineering department/Chandigarh university, Gharuan Mohali Chandigarh Punjab.
ER. JAGDEESH CHAND Assistant professor, Department of Civil Engineering, Chandigarh University, Gharuan, Mohali Punjab.

I. INTRODUCTION

The speciality of permeable concrete that differ it from conventional concrete is its high porosity that allows accumulated water from precipitation or any other source to pass through it.

Hence the permeable concrete helps to reduce the runoff water from the site instantly and helps in ground water recharge. The presence of inter-connected voids in permeable concrete makes it possible to pass water through it easily. But due to the pressence of these voids in permeable concrete, the compressive strength of permeable concrete is less than that of normal concrete.The compresive strength of permeable concrete ranges from 3.5 MPa to 28 MPa. However by using different admixtures the compressive strength of permeable concrete can be increased.The void ratio of permeable concrete ranges from 15% to 40 %. Due to the presence of these voids in permeable concrete, it acts as a light weight concrete. The permeable concrete is prepared by using a binding material, coarse aggregate, admixture, water and little or no fine aggregate. However by using the little amount of fine aggregate the durabilty of permeable concrete can be increased. But the use of fine aggregate in larger quantities may result in the reduction of permeability. In this paper 10% of cement is replaced by glass powder as the waste glass when milled down to micro size particles, it undergoes pozzolanic reaction with cement hydrates hence forms (calcium slicate hydrate). Some studies finded that the glass powder used upto 10% replacement by mass of cement improves the compressive strength of concrete. But beyond 10% it has some adverse effects on concrete. The pores of permeable concrete gets blocked with time by the accumulation of dust and other particles on the surface of permeable concrete that results in the reduction of permeability of concrete. This problem can be overcome by regular cleaning of concrete surface that can be accomplished through wetting the surface of concrete and vacuum sweeping. The first attempt to use the permeable concrete was performed by European in the 1800_s in road pavement surfaces and load bearing walls. In Scotland and England permeable concrete was used in two storey homes. Due to the scarity of cement in Europe, permeable concrete became increasingly vaible. Indians make use of permeable concrete in 2000.

Applications of permeable concrete:

Several unique properties of permeable concrete make it more economical and benificial in some works where conventional concrete remains uneconomical. Parking areas can be constructed by using permeable concrete. Light traffic road can be made by permeable concrete. Some other applications of permeable concrete are residential streets, padestrian walkways, zoological parks, bridge embankments, solar energy storage system and greenhouses.

A. *Material used*:

a. **Binding material:** Ordinary portland cement of 43 grade with 3.14 speciific gravity used as per cement to coarse aggregate ratio as 1:4.
b. **Coarse aggregate:** 8 mm and 12 mm coarse agregate of specific gravity 2.72 are used by 1:1 ratio in this context.
c. **Water:** Normal water free from chemical substances and other suspended particles is used.
d. **Glass powder:** Glass powder of 150 µm to 300 µm size with specific gravity of 2.45 has been used in this paper (10 % replacement by mass of cement).

Comparison of chemical composition between cement and glass powder is given below in table 1:

Chemical Composition of cementing materials	Glass powder (%)	Cement (%)
Silica (Sio_2)	72.5	20.5
Alumina (Al_2O_3)	0.4	4.8
Iron oxide (Fe_2O_3)	0.2	2.9
Calcium oxide (CaO)	9.8	62
Magnesium oxide (MgO)	3.2	2.8
Unit weight (kg/m^3)	2575	3150
Specific gravity	2.45	3.15

(Table 1): Comparison of chemical composition between glass powder and cement.

II. METHODOLOGY

In this paper several trials for permeability have been made in order to select the size of coarse aggregate. Seven trials are made out of which six samples are rejected as permeability in these samples determined was away from the optimum range which is 288 inch/hour to 770 inch/hour as per codal reccomendation. Whereas in the seventh sample, in which 8 mm and 12 mm aggregete are used by 1:1 ratio, the permeability of 664.7 inch/hour is determined. These two sizes of coarse aggregate are further used in this paper for compressive strength and permeability tests on different w/c ratios. This paper studied the effect of variation of water-cement ratio on compressive strength of permeable concrete along with 10% glass powder replacement by mass of cement. In this paper experiments have been performed on water cement ratios of 0.29, 0.31, 0.33, 0.35 and 0.37. Some previous studies showed that the compressive strength of permeable concrete increases by increasing the water-cement ratio however some researcher found that increase in water-cement ratio results in reduction of compressive strength of permeable concrete. In this paper the corresponding changes in compressive strength in permeable concrete with (10% glass powder replacement by mass of cement) by changing water-cement ratio is worked out on all above mentioned water-cement ratios. The glass powder is used in order to increase the compressive strength as the compressive strength of permeable concrete is less than conventional concrete. But the excessive use of glass powder may result in the reduction of permeability. Three samples are casted on each water-cement ratio hence tested for compressive and split tensile strengths after 7 and 28 days. The average of three results in each case has been taken as a final result. The whole research studied that the maximum 7 and 28 days compressive strength is determined on water-cement ratio of 0.35 ie, 9.25 MPa (after 7 days) and 16.44 MPa (after 28 days).The compressive strength and permeability in each case has been plotted further in this paper. Also the previous studies showed that permeability of concrete increased when the w/c ratio was increased. This is because of two facts: 1. due the presence of large and inter-connected pores in concrete, formation of high capillary porosity takes place. 2. Microcracks at the interfacial transition zone between binding material paste and agreggate are increased. However permeability on each water-cement ratio is plotted in this paper that showed the maximum permeability is achieved on water-cement ratio of 0.37 i.e, 664.7 in/hour. The density of permeable concrete is less than that of normal concrete because of the presence of voids in it. So the self weight of structure of permeable concrete is less as compared to equivalent normal concrete structure.

III. RESULTS AND DISCUSSION:

The variation in compressive strength and split tensile strength in permeable concrete on each value of water-cement ratio is recorded.On each w/c ratio, three samples have been casted. The average of the three results has been taken as the final result. Similar process is followed in case of split tensile strength test. Also the permeabily corresponding to each value of water-cement ratio is calculated in this study. The results obtained in this context are all shown as following in the table 2.

Water-cement ratio	Compressive strength (MPa)		Split tensile strength (MPa)	
	7 days	28 days	7 days	28 days
0.29	4.44	9.27	1.41	2.61
0.31	5.01	11.26	1.56	2.75

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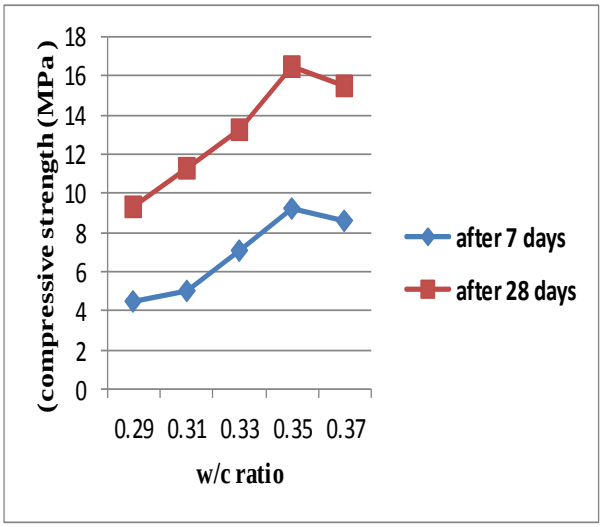
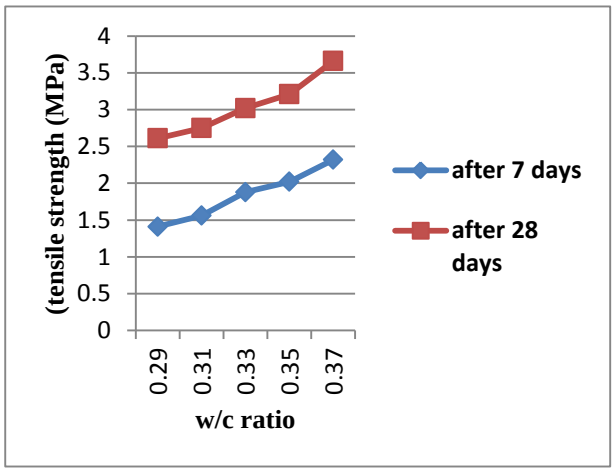
0.33	7.03	13.25	1.88	3.02
0.35	9.25	16.44	2.02	3.21
0.37	8.58	15.49	2.32	3.66

(Table no.2): Compressive and tensile strength of permeable concrete on verious w/c ratios.

(Graph) Compressive strength vs water cement ratio.



As it is clearly shown in the table above that the maximum compressive strength of permeable concrete after 28 days i.e, 16.44 MPa is achieved on water-cement ratio of 0.35. This value of water-cement ratio can be used for the permeable concrete in road pavements and other applications to meet the challenge of both compressive strength and desired permeability. The tensile strength of pervious concrete also showed the increment by increasing the w/c ratio from 0.29 to 0.37. The minimum and maximum tensile strengths are achieved on 0.29 and 0.37 respectievely. The minimum tensile strength after 7 days was achieved on w/c ratio of 0.29 i.e, 1.41 MPa and after 28 days it was 2.62 MPa again on w/c ratio of 0.29. whereas the maximum tensile strength after 7 days and 28 days was achieved on w/c ratio of 0.37 i.e, 2.32 MPa (after 7 days) and 3.66 MPa (after 28 days) . The results of split tensile strength tests are shown in the graph below.



(Graph) tensile strength vs water-cement ratio.

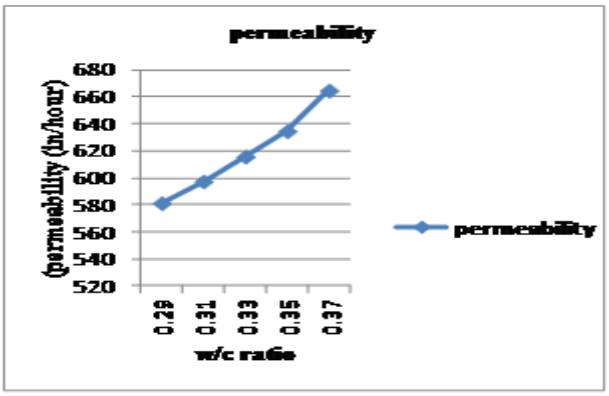
The method followed for permeability test in this study is as per American code (ASTM C1701). The cylinderical samples of size 12 inch diameter and 6 inch height have been casted. The internal surface of moulds used for permeability were wrapped with polythene before filling of concrete such that all the water could pass only through the cross section of sample and no water would be allowed to flow out through the curved surface of the sample. After prewetted by one gallon (3.78 kg) of water, Five gallons (19 kg) of water were passed through each sample. The time of percolation through each sample taken by 5 gallon (19 kg) of water was recorded in each case. The permeability was calculated by using the following formula:

$$I = \frac{KM_W}{D^2T}$$

I= Infiltration rate (in/hour).
K=constant = 126870.
D = diameter of sample (inches).
M_w = mass of water (pounds).
T = time of percolation (seconds).
The value of infiltration rate should lie between optimum range of 288 in/hour and 770 in/hour as per codal recommendation. The permeability and density on each value of water-cement ratio has been worked out in this context and is shown in both tabular as well as graphical representation as below.

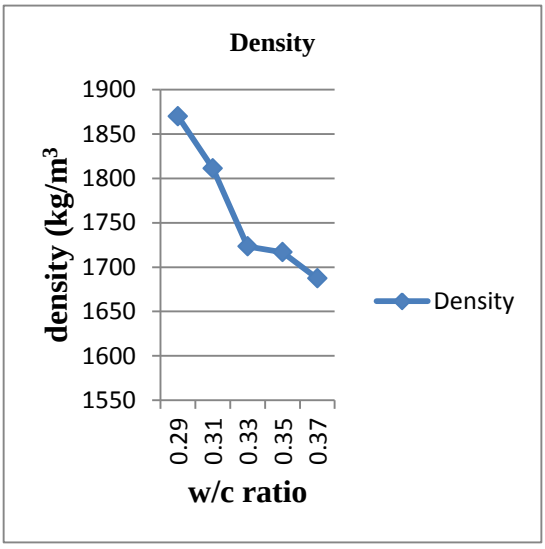
Water-cement ratio	Permeability (inch/hour)	Density (kg/m^3) (after 28 days)
0.29	581.30	1870.04
0.31	597.39	1811.2
0.33	615.77	1723.3
0.35	634.52	1716.94
0.37	664.7	1687.40

(Table no 3): Showing different w/c ratios and corresponding permeability and density.



(Graph) Permeability vs water cement ratio.

The above graph clearly shows the permeability of 581.30 in/hour is achieved on w/c ratio of 0.29 whereas the permeability of 664.7 in/hour is achieved on w/c ratio of 0.37. So the minimum and maximum permeability occurs on water-cement ratio of 0.29 and 0.37 respectively. It resulted that the permeability of pervious concrete increases from 581.30 in/hour to 664.7 in/hour with increase in w/c from 0.29 to 0.37. So it is clear from this study that if the water-cement ratio is increased, the permeability of concrete is also increased.



(Graph): Density vs w/c ratio.

However the density of pervious concrete is not so much affected by w/c ratio. But a little decrement in density is observed in this study while changing the w/c ratio from 0.29 to 0.37.

IV. CONCLUSION

This study concluded that the maximum compressive strength of permeable concrete after 28 days with 10% replacement of cement by glass powder Is achieved on a water-cement ratio of 0.35 which is 16.44 MPa. Also this paper showed that the permeability of concrete increases with increase in water-cement ratio and the maximum permeability of pervious concrete is determined on water-cement ratio of 0.37 which is 664.7 in/hour. So, to meet the challenge of both compressive strength and permeability in pervious concrete this paper suggests us to select of the water-cement ratio of 0.35 that can be used on sites for different applications of permeable concrete to overcome the problem of compressive strength and to maintain the desired permeability. The maximum tensile strength after 28 days in this study is achieved on w/c ratio of 0.37 i.e, 3.66 MPa. However the tensile strength after 28 days achieved on w/c ratio of 0.35 i.e, 3.21 MPa is also enough for the construction of different pervious concrete structures. The benefit of using glass powder here is to improve the strength of permeable concrete and use of glass powder in permeable concrete is a dominant step towards the development of sustainable enviroment. But the centre of attention in this study is to meet the challenge of both the compressive strength and permeability simultaneously which is determined on water-cement ratio of 0.35.

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