Study On Strength And Hydraulic Conductivity Of Gap Graded Concrete

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Abstract: Gap-graded concrete, sometimes referred to as no-fines, pervious, permeable, or enhanced porosity concrete, is an state-of-the-art approach to controlling, managing, and treating storm water runoff. When used in pavement applications, gap-graded concrete can effectively capture and store storm water runoff, thereby allowing the runoff to percolate into the ground and recharge groundwater supplies. Gap-graded concrete contains little or no fine aggregate (sand) and carefully controlled amounts of water and cementitious materials. The paste coats and binds the aggregate particles together to create a system of highly permeable, interconnected voids that promote the rapid drainage of water. Typically, between 15 and 25 percent voids are achieved in the hardened concrete, and flow rates for water through the gap-graded concrete are generally in the range of 192 to 1,724 inch/hr.[1].The compressive strength test was performed on gap-graded concrete at 7, 14 and 28 days on five different mixes. Furthermore infiltration rate was observed on all the five samples of gap-graded concrete.

Index Terms: Aggregates, Compressive Strength, Gap Graded Concrete, Infiltration, Permeability, OPC

1. INTRODUCTION

concrete is an amalgamated material, basically comprising of diverse components such as binding material, water, aggregates and admixtures. Amongst these constituents, aggregates (coarse and fine) play a pivotal role in concrete work and occupy 60-75% of over-all volume of concrete [2]. Gap-graded concrete (fig 1) is a distinct kind of concrete with comparatively high void content and high water penetrability to that of conventional concrete. The strength of this holey concrete is predominantly determined by total porosity, which in turn is dependent on a number of host factors, for example cement content, water to cement ratio, characteristics of aggregate and degree of compaction during placement of this concrete [3][4]. The compressive strength of gap-graded concrete at 28 days of curing ranges from 5 to 28 Mpa but can be increased to higher grades upto 46 Mpa with addition of some mineral admixtures, fine aggregates and super plasticizers [5]. Permeability is one of the pore structure dependent properties that also depend on aggregate size, compaction level, and gradation and cement content. Permeability of gap-graded concrete fluctuates widely from 0.003 to 3.3 cm/s. and serviceability problems. Physical clogging is caused due to sediments of sand, clay and debris built up on the surfaceAlgae, bacteria and plant root penetration are responsible for biological clogging. This leads to the reduction in permeability which in turn leads to susceptibility of inland flooding and freeze-thaw damage thus decrease the life span of gap-graded concrete pavements[8][9]. The aim of this study was to find best mix of gap-graded concrete and to perform the strength (compressive strength) and durability (permeability) test on gap-graded concrete. Different trial mixes were performed at water to cement ratio of 0.35, to find a balanced mix having less paste drain down effect and minimum tortuosity

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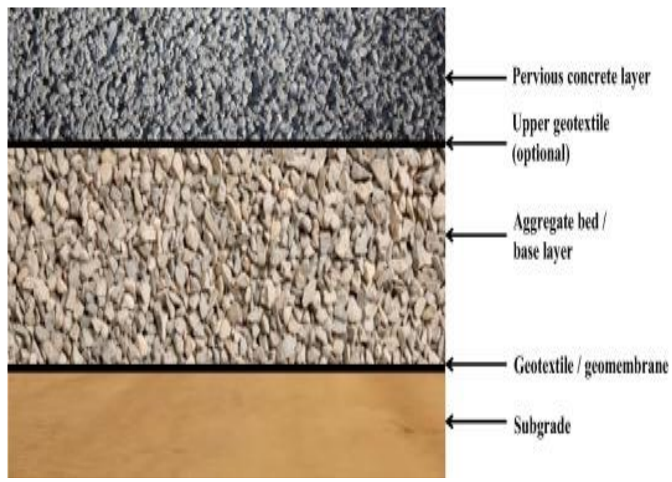

FIG 1 *GAP GRADED CONCRETE*

2 EXPERIMENTAL PROGRAMME

2.1 MATERIALS

The experimental study of gap-graded concrete was performed in the laboratory. Before going towards the trial mix of concrete, the different properties of materials used in gap-graded concrete were determined to meet the permissible limits and to get the desired properties.[10][11] .As there is no standard mix code for gap graded concrete provided by the BIS, the mix proportions were chosen by trail and error method followed by IS:10262(2009) and ACI 522R[12][1] ,total of five concrete mixes were prepared. Water-cement ratio is an important parameter for pervious mix, as it directly controls the workability. The w/c ratio should be such that it produces medium workability, because an increase and decrease in the w/c ratio leads to over/under workable mix. From the laboratory study, the limiting range for the water-cement ratio is selected and is kept in between 0.32-0.35[14][15]. The optimum w/c ratio obtained for the complete hydration was achieved to be 0.35.The properties like specific gravity, consistency, initial and final setting time of cement were performed and are in the permissible limits[13]. Moreover properties like abrasion, water absorption, specific gravity, crushing value and bulk density of coarse aggregates were performed and all the obtained values are in permissible limits[10][11]. The grading of aggregates were performed as sieve analysis and 10 to 20 mm aggregates were used in making all the five mixes of gap-graded concrete. Furthermore 10% of fine aggregates were used in two mixes (M_3 and M_5) to observe the effect on strength and infiltration rate respectively. The fine aggregates were used from a range of (90micron-2.36mm) with fineness modulus of 2.355.

Table 1- *Properties of cement*

S No.	Property	Observed limit	Permissible Limit (IS 8112-2013)
1	Specific gravity	3.15	3.10-3.15
2	Initial setting time	49 minutes	>30 minutes
3	Final setting time	284 minutes	< 600 minutes
4	Consistency	27.7%	26-33%

Table 2- *Aggregate properties*

Concrete Mix	Proportion of Cement to Coarse Aggregate	Max Size Coarse Aggregates	Coarse Aggregates (mm)	Percentage of Fine Aggregates (%)
M_1	1.5:3	20mm (from 4.75-20mm)	10 – 18	0
M_2	1:4	20mm (from 10-20mm)	20	0
M_3	1:4	20mm (from 10-20mm)	20	10 (2.36mm passing)
M_4	1:4	16mm (from 6.3-16mm)	10	0
M_5	1:4	15mm (from 4.75-16mm)	10	10 (2.36mm passing and 90 micron retaining)

Table 3- *Trial mix proportion*

S No.	Property	Specified requirements	Aggregate 1(10mm)	Aggregate 2(20mm)
1	Abrasion Value	30% 0r 50%	14.8	13.5
2	Water Absorption	5%	0.68	0.54
3	Specific Gravity	2.1-3.2	2.56	2.56
4	Crushing Value	30%	12.9	13.0
5	Bulk Density (kg/l) Loose compacted	- -	1.53 1.66	1.52 1.67

×150mm). Testing is done for 7days, 14 days and 28 days of curing age. This is the main test for checking the strength of Gap graded concrete and general guidelines of the ASTM C39/C39M were followed during the testing.

Compressive strength = Crushing load (on specimen)/Area of specimen

Fig 2- *Compressive testing machine*

Permeability Test

The procedure of test on the apparatus is in accordance with [16].The apparatus consists of a cylindrical water reservoir with hemispherical base of same diameter mounted on a moving stand. The cylindrical portion is not provided with covering on the top and to vary the flow from the hemispherical bottom portion, a value is connected to its base. A graduated pipe is attached on the external face of the cylindrical portion from top to bottom. The water reservoir of the apparatus is made of stainless steel and the stand is composed of casted iron. A special type of stainless steel cylinder specimen having diameter 12 inch and height 15 inch is used. It has having two marked lines at 10 mm and 15 mm at a height of 12 inch above the bottom in order to maintain the head between the two marked lines. The gap-graded concrete is filled up to the bottom mark of the cylinder keeping the 10mm and 15mm lines visible for head maintaining. The portion above the base marked line acts as the fitted ring for checking permeability instead of having an external ring.

Fig3- *Infiltrometer and sample in specimen*

The time of infiltration is recorded and used in following formula;

$$I = \frac{KM}{D^2} \times t \text{ In/hr.} \quad (1)$$

K= rate of permeability, M= mass of water, T= time of infiltration, D= diameter of specimen

3 RESULTS AND DISCUSSIONS

3.1 Compressive strength

The compressive strength test was performed at the curing age of 7, 14 and 28 days. Concrete mix M_1 shows highest 28 day strength as it shows 66 % of gain of strength because the ratio of cement with respect to aggregate was very high and the size of aggregate was also between (4.75 to 20mm), the smaller sized aggregates where also responsible for making the mix impermeable. Moreover concrete mix M_2 prepared with coarse aggregate size of 20 mm and coarse aggregate ratio of 1:4 shows least strength. The 28 day strength of mix M_5 in which 10% of sand was used shows 69% of gain of strength when compared to 7 day aged sample of concrete. . However, the compressive strengths of each mix is so different. It can be seen that with the increase of aggregate size, the compressive strength increases rapidly but by changing the size of aggregate and cement content it can be deterred.

Table 4- *Compressive strength (Mpa)*

S No.	Mix	Compressive Strength (7 days) (Mpa)	Compressive Strength (14 days) (Mpa)	Compressive Strength (28 days) (Mpa)
1	M_1	22.43	28.84	34.00
2	M_2	8.55	11.55	13.63
3	M_3	11.42	15.17	17.64
4	M_4	11.45	15.02	17.23
5	M_5	14.00	19.12	20.37

3.2 Infiltration

Infiltration test was performed on all the 5 samples of gap graded concrete at the age of 28 days as shown in table 5. Concrete mix M_1 shows almost 0% rate of infiltration as void content was not maintained due to mixture of aggregates of the size between 10 to 20 mm and more cement content. infiltration rate of 19.12-15.70 mm/sec, was regarded as high permeable rate while infiltration rate of 3.71 mm/sec was considered as standard permeable rate. The highest rate of infiltration was observed in case of mix $M_{2,}$ which attains 19.12 in 13 sec{time noted on the stopwatch when the water touches the surface of concrete till when 40lb's of water is infiltrated maintaining the head constant between the marked lines. However it gradually decreases due to insertion of 10% of fine aggregate along with 10 mm size of coarse aggregate.

Table 5*- Infiltration*

S.No.	Mix no.	Infiltration time (seconds)	Permeability mm/sec	Remarks
1	M_1	Infinite	0	Zero Permeable
2	M_2	13	19.12	Highly Permeable
3	M_3	16	15.70	High Permeable
4	M_4	18	13.50	High permeable
5	M_5	67	3.71	Standard permeable

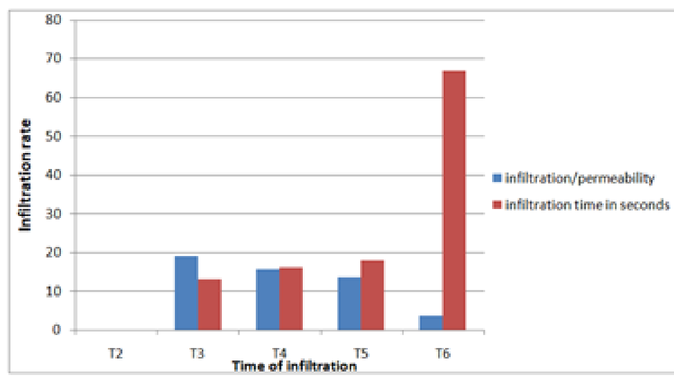

Fig 4 *Infiltration rate in mm/sec and time in seconds*

4 CONCLUSIONS

The key conclusion of this research is that by changing the gradation or size of aggregates the strength and infiltration properties are deterred. By maintaining the constituent properties of gap graded concrete, it can be used as best remedy to overcome the flooding problems in urban areas as it allows the water to flow through it. Furthermore maintaining compressive strength more than 20 Mpa, it can be used in high speed pavements instead of parking lots and footpaths. The use of small percent (10%) of sand can enhance the strength of gap graded concrete to good extent. Infiltration rate was too high when concrete was prepared without inclusion of fine aggregates. Thus maintaining balance between void ratio, cement content and coarse aggregates and fine aggregates, a perfect mix of this gap graded concrete can be obtained to meet all the desired properties.

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