ADVANCED RIGID PAVEMENT TECHNOLOGY FOR ROADS

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Abstract—Due to its great water-permeability, pervious concrete is regarded an advanced pavement material in terms of its environmental advantages. An experimental study was conducted with two different water-to-cement ratios to determine the characteristics of pervious concrete. We evaluated the strength, unit weight under dry circumstances, void content, and permeability of the pervious concrete. As a result, all samples were anticipated to have the same amount of cement paste and 20 percent void content. Its uses and engineering features, including environmental advantages, structural properties, and durability are discussed in this presentation on concrete structures. As well as building procedures, both hydraulic and structural designs of concrete pavements are covered in detail.

Index Terms—RIGID, Structures, Durability, Hydraulic.

I. INTRODUCTION

Pervious concrete was first used in the 1800 year in Europe as pavement surfacing and load bearing walls. Cost efficiency was the main motive due to a decreased amount of cement. It became popular again in the 1920 year for two storied homes in Scotland and England. It became increasingly viable in Europe after the Second World War due to the scarcity of cement. It did not become as popular in the US until the 1970 year. Pervious Concrete has been around for hundreds of years. The Europeans recognized the insulating properties in structural buildings. Pervious concrete pavement is a unique and effective means to meet growing environmental demands. By capturing rainwater and allowing it to seep into the ground, pervious concrete is instrumental in recharging groundwater, reducing storm water runoff, and meeting U.S. Environmental Protection Agency (EPA) storm water regulations. In fact, the use of pervious concrete is among the Best Management Practices (BMP) recommended by the EPA— and by other agencies and geotechnical engineers across the country— for the management of storm water runoff on a regional and local basis. This pavement technology creates more efficient land use by eliminating the need for retention ponds, swales, and other storm water management devices. In doing so, pervious concrete has the ability to lower overall project costs on a first-cost basis. In previous concrete, carefully controlled amounts of water and cementitious materials are used to create a paste that forms a thick coating around aggregate particles. A pervious concrete mixture contains little or no sand, creating a substantial void content. Using sufficient paste to coat and bind the aggregate particles together creates a system of highly permeable, interconnected voids that drains quickly. Typically, between 15% and 25% voids are achieved in the hardened concrete, and flow rates for water through pervious concrete typically are around 480 in./hr (0.34 cm/s, which is 5 gal/ft2/ min or 200 L/m2/min), although they can be much higher. Both the low mortar content and high porosity also reduce strength compared to conventional concrete mixtures, but sufficient strength for many applications is readily achieved. While pervious concrete can be used for a surprising number of applications, its primary use is in pavement. This report will focus on the pavement applications of the material, which also has been referred to as porous concrete, permeable concrete, no-fines concrete, gap-graded concrete, and enhanced porosity concrete.

Pervious concrete pavement is a unique and effective means to address important environmental issues and support sustainable growth. By capturing storm water and allowing it to seep into the ground, porous concrete is instrumental in recharging groundwater, reducing storm water runoff. This pavement technology creates more efficient land use by eliminating the need for retention ponds, swales, and other storm water management devices. In doing so, pervious concrete has the ability to lower overall project costs on a first-cost basis. In previous concrete, carefully controlled amounts of water and cement materials are used to create a paste that forms a thick coating around aggregate particles. A pervious concrete mixture contains little or no sand, creating a substantial void content. Using sufficient paste to coat and bind the aggregate particles together relates a system of highly permeable, interconnected voids that drain quickly. Typically, between 15% and 25% voids are achieved in the hardened concrete. Permeable concrete pavements are mostly used in rural areas. This concept of pervious concrete is relatively new for rural road pavement. Pervious concrete has ability to flow water through it and this property help to recharge the ground water.

Pervious concrete pavement is unique and effective technique to meet the future demand. Strength of the pervious concrete is low as compared to conventional concrete as it is all due to high porosity. This dissertation analyses the effectiveness of Permeable concrete in pavement. This was achieved by analyzing the properties and characteristics of Permeable concrete. The performance of Permeable concrete was compared with a concrete sample that is comparable to the material used for the construction of conventional concrete road pavements. Permeable concrete is mostly used in no pavements applications, limited use in pavements applications. This is to assess the suitability for Permeable concrete to be used for the construction of road pavement. The tests conducted to determine the fresh concrete properties were the slump test and compacting factor tests. These were complimented by hardened concrete tests including the following: compressive strength, indirect tensile strength. After that there are comparisons made between the both types of concrete. It was found that Permeable concrete pavements possess some positive features like increased skid resistance and high permeability but lacks the high strength required for highly traffic areas. Permeable concrete has proven to have properties suitable for use in low volume traffic areas. The properties found may change depending on the aggregate particle chosen, however this aspect requires further investigation. Nevertheless, if Permeable concrete pavements can be implemented, it will have numerous positive effects on the environment.

Fig.1. Concrete Model of past technology

Advantages present technology reduces the storm water runoff , Eliminates the need for detention ponds and other costly storm water management practices, Replenishes the aquifers and water table, Allows more efficient land development, Prevents water from entering into the stream and also prevents it from being polluted, Less need for storm sewer, Green building alternative suitable for many application, Natural run-off allows rainwater to drain directly to sub-base, Reduced pollution prevents environmental damage, Keeps pavement surfaces dry even in wet situation, such as green houses, Allows water and air to get to the roots of trees within a parking area, Pervious concrete performs noise absorption, Water purifying performance, A parking lot properly constructed from pervious concrete has a life span ten times as, long as an asphalt lot, thereby providing excellent long term benefits. It is true that the initial costs for pervious pavement may be slightly higher due to the preparation of the sub-base, but those who look long term will realize the economic benefits, Useful for irrigation that is retain water to be used for irrigation, Lower installation costs due to the elimination of costly curbs, gutters, storm drain, outlets, and retention basins that cost two to three times more to construct than pervious. Less money will be needed for labor, construction and maintenance of ponds, pumps, drainage pipes and other storm water management systems, Allows for the use of existing storm sewer systems for new developments, Lower life-cycle costs equal to that of conventional concrete that if properly constructed will last for 20 to 40 years. Pervious requires fewer repairs than asphalt, and can be recycled once it has reached its lifecycle. And also some Disadvantages, Runoff from adjacent areas onto pervious concrete needs to be prevented, The parking areas are generally limited to auto parking and occasional trucks, If reinforcement is required, epoxy coated bars should be used, Concrete is variable in permeability; over vibration significantly reduces permeability, It is still a new material that requires acceptance from cities and states. Application of present work Environmental, Safety and Economics.

II. LITERATURE REVIEW

Gesoglu M. et al.[1], in their paper entitled “Investigating the properties of pervious concretes containing waste tire rubber”. Three types of rubber were used in the production of rubberized plain pervious concrete mixtures which was obtained by partially replacing the aggregate with rubber. Nguyen H.D et al. [2] have studied the “Use of seashell by-products (SBP) considered as coarse aggregate in pervious concrete pavers”. Here 20%, 40% and 60% of SBP were added to the mixture by replacing the natural aggregates. The test result showed that pervious concrete containing less than 40% SBP had better strengths with good permeability and void content which is nearly to the pervious concrete containing with only natural aggregate. Ajamu S.O et al.[3] have studied the “Evaluation of structural performance of pervious concrete in construction”. In the present research structural property and permeability of pervious concrete made with different coarse aggregate size is presented. In this experiment different aggregate to cement ratio is used. Coarse aggregate size 9.375 mm, 18.75 mm were used for preparation of pervious concrete. Ketanet.al.[4],has conducted an “Experimental investigation of pervious concrete using titanium Dioxide”. They have partial replaced cement by TiO_2 they have laid pervious concrete trial mixes with the different size of aggregates with and without fine aggregates and tests for compression strength, water permeability, porosity and density. Kuo W.T et al.[5] have studied the “Utilization of washed municipal solid waste incinerator bottom ash as a coarse aggregate in pervious concrete”. In the present study washed municipal solid waste incinerator bottom ash (MSWIBA) was used as aggregate in pervious concrete. Various mechanical properties such as permeability test, compressive strength, tensile strength of the material are carried out. Mishra N. et al.[6] have studied paper “Investigate the proportion of ground granulated blast furnace slag (GGBS) to be used to attain a good pervious geopolymer concrete” . It was prepared from fly ash class-C, sodium silicate, sodium hydroxide solution and coarse aggregate various ratio of fly ash and GGBS was used. The physical and mechanical properties of pervious geo-polymer concrete (PGC) will be beneficial for the forthcoming use of fly ash and GGBS geo-polymer in the construction field of pervious concrete which will lead to reduce the cement consumption and environmental issue.

Ibrahim H.A and Razak H.A [7] have studied the addition of palm oil clinker on properties of pervious concrete. In this study, Palm oil clinker is taken as the coarse aggregate in the fabrication of pervious concrete. Raw materials like

Portland cement Type I, 10 mm size coarse aggregate and fixed water-cement ratio of 0.3 are used. Here, natural aggregate are replaced by Palm oil clinker ranging from 0-100%. Yeih W et al. [8] have studied the engineering properties of pervious concrete made with air-cooling electric arc furnace slag as aggregates. It is observed from the experiment that porous concrete prepared from EAFS aggregates have better mechanical strength and water permeability than that made with natural river gravels. Zaetang Y et al. [9] have studied the utilization of coal ash to be geo-polymer binder to form coarse aggregate in pervious concrete. This study explains the use of Fly Ash (FA) as a geo-polymeric binder along with coarser aggregate to manufacture pervious concrete. During the study properties such as effect of concentration of NaOH, replacement of fly ash with ordinary Portland cement (OPC) and the impact of curing temperature pervious geopolymeric concrete (PGC) were analyzed . Zaetang Y et al. [10] have studied the utilization of lightweight aggregates in no fine/porous concrete. Diatomite (DA) and pumice (PA) were used as natural LWAs in thermal conductivity about 3-4 times compared with pervious concrete containing natural aggregate. The densities were 558–775 kg/m3 which were lower than 800 kg/m3 and suited for use as insulating concrete. Kuo W.T et al. [11] have studied the utilization of washed municipal solid waste incinerator bottom ash as a coarse aggregate in pervious concrete. In the present study washed municipal solid waste incinerator bottom ash (MSWIBA) was used as aggregate in pervious concrete. Hossain T et al. [12] have studied the pervious concrete using brick chips as coarse aggregate-An experimental study. The properties of pervious concrete such as strength, permeability and void ratio were investigated. Different sizes of aggregate were used here. Stone aggregates were also used here for comparison purposes. Relationships among various parameters i.e. strength, void ratio, aggregate size, permeability for two different pervious concrete are also presented here. Tho-in T et al. [13]have studied pervious high calcium fly ash geo-polymer pervious concrete (PGC) .It is prepared by the mixture of lignite fly ash (FA), sodium silicate (NS), sodium hydroxide (NH) solution and coarse aggregate. Putman B.J and Neptune A.I [14] have studied the comparison on of the test specimen preparation techniques for pervious concrete pavement. This study mainly focused fabrication of pervious concrete having similar properties of pervious concrete pavements. Jang J.G et al. [15] have studied a novel eco-friendly porous concrete fabricated with coal ash and geo polymeric binder: Heavy metal leaching characteristics and compressive strength here, coal bottom ash is taken as coarse aggregate and geo-polymer as binder.

According to introduction and Literature the present Work objectives are, (i) to determine the compressive and flexural strength of pervious concrete. (ii)To determine the durability, properties of permeable concrete. (iii) To compare the properties of permeable concrete with the existing concrete pavement (iv) Evaluate the structural performance characteristics of all the materials potentially used in permeable pavement designs, namely concrete, base and sub grade materials.

III.PROPOSED WORK

3.1 Materials

Pervious concrete uses the same materials as conventional concrete, with the exceptions that the fine aggregate typically is eliminated entirely, and the size distribution (grading) of the coarse aggregate is kept narrow, allowing for relatively little particle packing. This provides the useful hardened properties, but also results in a mix that requires different considerations in mixing, placing, compaction, and curing. The mixture proportions are somewhat less forgiving than conventional concrete mixtures—tight controls on batching of all of the ingredients are necessary to provide the desired results.

Materials used in present work Top course (Pervious concrete) Cement, Coarse aggregate, Water Base course, Coarse aggregate & Cobbles is Cement to achieve the desired strength of pervious concrete, the type of cement to be used should satisfy the requirements of the laid down Indian Standards and the cements to be used should have a certain properties such as It should be an excellent binding material. It should possess good plasticity. It should have enough initial setting time i.e. it should not be less than 30 minutes. It should offer good resistance to moisture. It is easily workable. Color of cement should be uniform. The cement should be free from any lumps. The various types of cement, explained below, can be used for development of Pervious Concrete, such as Ordinary Portland cement (33 Grade, 43 Grade, 53 Grade).Coarse Aggregate Coarse aggregate are an important material used in the production of concrete products, it occupies approximately 60-70% of the volume. It reduces volume changes due to drying shrinkage of cement-water paste. The size and shape of coarse aggregates have significant influence on strength, and infiltration capability of pervious concrete. Clean coarse aggregate and potable water promote bonding, ensuring strength and durability. The single sized aggregates used in the pervious concrete mixtures typically range from those retained on 4.75mm sieve up to 19mm aggregates. Larger gradations provide a rougher surface, frequently smaller sized aggregates are used for aesthetic purposes. Higher strengths are generally achieved with rounded gravels (Tennis et al. 2004).

Water plays an important role in production of concrete in that it starts reaction between the cement and water. The amount of water in concrete controls many fresh and hardened properties in concrete including workability, compressive strengths, permeability and water tightness, durability and weathering, drying shrinkage and potential for cracking. For these reasons, limiting and controlling the amount of water in concrete is important for both constructability and service life. Water used for mixing and curing of concrete shall be clean and free from injurious amount of oil, salt, acid, vegetable matter or other substances harmful to the finished concrete. It shall meet the requirements stipulated in IS: 456 – 2000.

Base Course Uniformity of sub grade support is a key criterion for placing pervious pavement. Since sub grade and sub base preparation are critical components of pervious concrete pavement performance, refer to “Hydrological Design Considerations” and “Structural Design Considerations”. Base course is the layer directly below the pervious concrete layer and generally consists of aggregate or stabilized sub-grade. It provides additional load distribution, contributes to drainage, uniform support to the pavement and a stable platform for construction equipment.

3.2 Mix Calculations

Data:-

Dimension of mould = 0.15m X 0.15m X 0.15m
Density of pervious concrete = 2000 kg/m3
Ratio of concrete = 1:4 (Cement: Aggregate)
Water Cement ratio = 0.30 Volume of 1 mould
V = 3.375x10-3 m3
WKT, Density = Weight / volume Therefore,
Weight = Density X Volume
Weight = 2000 X 3.375x10-3
Weight = 6.75 kg
Quantity of cement = 1/ 1+4 X6.75 = 1.35 kg
Quantity of Aggregate = 4/1+4 X6.75 = 5.4 kg
Amount of water = Water/Cement = 0.3
Therefore, Water = 0.30 X Quantity of cement = 0.30 X 1.35 =0.405 Liter
Therefore quantity of material required to cast 1 concrete cube is, Cement = 1.35 kg Coarse
Aggregate = 5.4 kg
Water = 0.405 Liter

3.3 Casting& Testing

Specimen the proportions used are 1:4and material for making these test specimens are ordinary Portland cement and locally available coarse aggregates. Specimen 15 cm size Mix. Ratio 1:4 Mixing of Concrete for Cube Test Mixing of the concrete is done by hand. (Hand Mixing) Hand Mixing First the required quantity of materials are weighed as per the calculations i.e. cement, coarse aggregate and water. Then the mixing of cement and coarse aggregates are done on a watertight none-absorbent platform until the mixture is thoroughly blended and until is of uniform color then water is added to the mix until the concrete appears to be homogeneous and of the desired consistency. Casting the specimens were cast in iron moulds of cube 150mmX150mmX150mm and timber beams of 100mmX100mmX500mm. This conforms to the specification of BS 1881:1983. The moulds were cleaned on oiled on their inside surfaces first in order to prevent sticking of concrete on the surfaces. The moulds were then assembled and bolts and nuts tightened to prevent leakage of the plastic concrete mix.

Procedure for Compressive strength Concrete Cube Test

1. Remove the specimen from the water after specified curing time and wipe out excess water from the surface.
2. Take the dimension of the specimen.
3. Clean the bearing surface of the testing machine.
4. Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
5. Align the specimen centrally on the base plate of the machine.
6. Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
7. Apply the load gradually without shock and continuously at the rate of 140 kg/cm2 /minute till the specimen fails
8. Record the maximum load and note any unusual features in the type of failure.

Fig .2. Casting of cube specimen

Fig.3. Curing of cubes

3.4. Material Testing

Test on Pervious Concrete Test on fresh concrete: The test on fresh pervious concrete are carried out on workability properties of concrete, they are given below, Compaction factor test, Slump test, Compaction factor test: - Compaction factor test is the workability test for concrete conducted in laboratory. The compaction factor is the ratio of weights of partially compacted to fully compacted concrete. It was developed by Road Research Laboratory in United Kingdom and is used to determine the workability of concrete The compaction factor test value for the pervious concrete is 0.82, which is further depends on the material composition and admixture dosage in the concrete mix.

Slump testis the steel slump cone is placed on a solid, impermeable, level base and filled with the fresh concrete in three equal layers. Each layer is rodded 25 times to ensure compaction. The third layer is finished off level with the top of the cone. The cone is carefully lifted up, leaving a heap of concrete that settles or 'slumps' slightly. The upturned slump cone is placed on the base to act as a reference, and the difference in level between its top and the top of the concrete is measured and recorded to the nearest 10mm to give the slump of the concrete. When the cone is removed, the slump may take one of three forms. In a true slump the concrete simply subsides, keeping more or less to shape. In a shear slump the top portion of the concrete shears off and slips sideways. In a collapse slump the concrete collapses completely. Only a true slump is of any use in the test. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which the flow test (see separate entry) is more appropriate. The slum value for the pervious concrete is 80mm, which is further depends on the material composition and admixture dosage in the concrete mix.

Hardened test on concrete is the hardened tests to be carried out on pervious concrete are Compressive strength test, Flexural test. Compressive Strength is the pervious concrete system and its corresponding strength are as important as its permeability characteristics. The strength of the system not only relies on the compressive strength of the pervious concrete but also on the strength of the soil beneath the support. The studies indicate that pervious concrete has lower compressive strength capabilities than conventional concrete and will only support light traffic loadings. This project conducted experimental studies on the compressive strength of pervious concrete as it related to water-cement ratio, aggregate-cement ratio, aggregate size, and compaction Pervious concrete mixtures can develop compressive strengths in the range of 500 psi to 4000 psi (3.5 MPa to 28 MPa), which is suitable for a wide range of applications. Typical values are about 2500 psi (17 MPa). The cubes which are tested contain different composition of material, different water cement ratio and different sizes of aggregate.

Flexural Strength is after the 28-day curing period, the prepared pervious concrete beams (plain and fiber-reinforced) were tested for flexural strength properties. The tests were conducted in accordance with the third point loading of ASTM C293. The modulus of rupture was computed for use in thickness design of pervious concrete structures. The sample breaks were in the middle third of the span. The modulus of rupture (MR), was computed using the following formula:

MR = (P*L) / (B*D2)

Where, P= the load (force) at the fracture point

L = Span length (distance between supports)

B = width

D = thickness Flexural strength in pervious concretes generally ranges between 150 psi (1 MPa) and 550 psi (3.8 MPa).

Permeability Test is Permeability refers to the ease with which water can flow through pervious concrete. The permeability of each sample, K, was computed using the following formula:

K= (Q*L)/(A*t*h) ,

Where, Q = Volume

L = Length

A = Area

t = time

h = head Each sample was subjected to a 1 inch head over the saturated sample for a period of 60 seconds after which the water level was measured and recorded. The average diameter was measured and calculated for each sample.

IV.RESULTS

An experimental program was devised to study the strength and durability characteristics of pavement quality concrete. Tests were performed on hard concrete cured under standard laboratory conditions, and compressive and flexural strengths were observed at curing ages of 7and 28 days. A discussion of results was carried out and the major conclusions drawn from the study are elaborated here in.

Table.1. Physical Properties of Materials

Sl.no	Material	Property	Value
1	Cement	• Type • Grade • Specific gravity	OPC 43 3.15
2	Coarse aggregate	• Specific gravity • Bulk density	2.6 150 Kg/m³

Table.2. Compressive Strength of the Pervious Concrete Specimen

CUBE NO	SIZES OF CUBE (m)	WEIGHT OF CUBE IN (kg)	DENSITY OF CUBE (kg/m3)	STRENTH IN DAYS (N/mm^2)	
				7 DAYS	28DAYS
Cube 1	0.15x0.15x0.15	6.020	1783.70	1.76	2.71
Cube 2	0.15x0.15x0.15	6.235	1847.40	1.92	2.96
Cube3	0.15x0.15x0.15	6.590	1952.59	3.37	5.18

Table.3. Compressive Strength of the conventional concrete specimen

CUBE NO	SIZES OF CUBE (m)	STRENTH IN DAYS (N/mm^2)	
		7 DAYS	28DAYS
Cube 1	0.15x0.15x0.15	5.20	8.02
Cube 2	0.15x0.15x0.15	5.68	8.76
Cube3	0.15x0.15x0.15	9.98	15.33

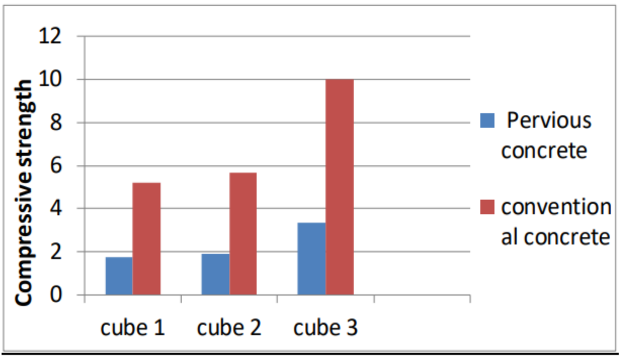

Fig.4.7 days of compressive strength

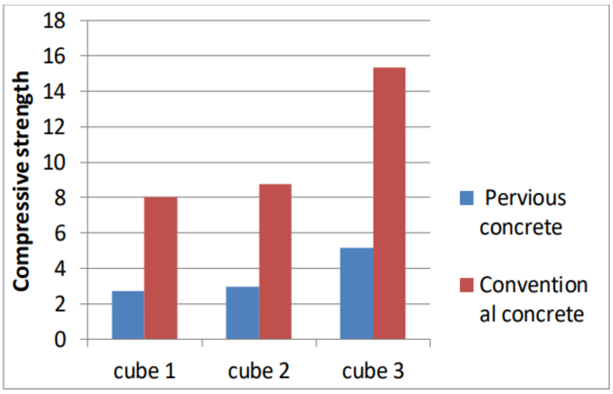

Fig.5.28 days of compressive strength

Table.4.Flexural Strength of the Specimen

CUBE NO	SIZES OF CUBE (m)	WEIGHT OF CUBE IN (kg)	DENSITY OF CUBE (kg/m3)	7 DAYS FLEXURAL STRENGTH TEST (N/mm2)
Cube 1	0.10x0.10x0.50	8.910	1782	0.66
Cube 2	0.10x0.10x0.50	9.230	1847.	0.69
Cube3	0.10x0.10x0.50	9.760	1952	0.92

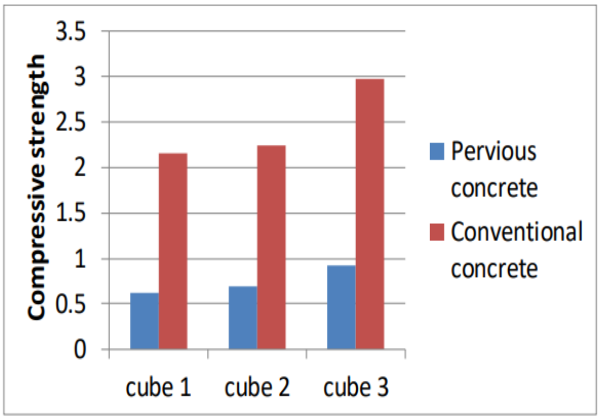

Fig.6.7 days of flexural strength

Table. 5. Compressive Strength of Pervious Concrete

SAMPLES	COMPRESSIVE STRENGTH IN N/Mm2	
	7 DAYS	28 DAYS
1	1.76	2.71
2	1.92	2.96
3	3.37	5.18

Table.6. Flexural Strength of Pervious Concrete

SAMPLES	FLEXURAL STRENGTH IN N/Mm2
	7 DAYS
1	0.66
2	0.69
3	0.92

V. CONCLUSION

The following conclusions are drawn based on the experimental investigations on compressive strength, flexural, durability, permeability considering the “environmental aspects” also: Pervious concrete has less strength than conventional concrete, it has 30%-40% strength of conventional grade concrete. Similarly the flexural strength values are also comparatively lower than the conventional concrete. Though the pervious concrete has low compressive, flexural strength it has high coefficient of permeability hence the following conclusions are drawn based on the permeability, environmental effects and economical aspects. It is evident from the project that no fines concrete has more coefficient of permeability. Hence, it is capable of capturing storm water and recharging the ground water. As a result, it can be ideally used at parking areas and at residential areas where the movement of vehicles is very moderate. Further, no fines concrete is an environmental friendly solution to support sustainable construction. In this project, fine aggregates as an ingredient has not been used. Presently, there is an acute shortage of natural sand all around. By making use of FA in concrete, indirectly we may have been creating environmental problems. Elimination of fines correspondingly decreases environment related problems. In many cities diversion of runoff by proper means is complex task. Use of this concrete can effectively control the run off as well as saving the finances invested on the construction of drainage system. Hence, it can be established that no fines concrete is very cost effective apart from being efficient. There was a considerable difference in the compressive strength between the conventional concrete and pervious samples. Pervious concrete is a special type of concrete with a high porosity used for concrete pavement applications that allows water from precipitation and other sources to pass directly through it, thereby reducing the runoff from a site and allowing groundwater recharge. Also by adopting the pervious concrete pavement we can control the flood. The future scope of present work is use 25 mm aggregate size for future study or analysis. Pervious concrete is a special type of concrete with a high porosity used for concrete pavement applications that allows water from precipitation and other sources to pass directly through it, thereby reducing the runoff from a site and allowing groundwater recharge. The work can be extended further to study the performance of the pavement quality concrete slabs etc.

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