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EXPERIMENTAL STUDIES ON PERVIOUS CONCRETE

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ABSTRACT

In modern day infrastructure, use of impervious surfaces on pavements to rapidly collect and transport rain water runoff is very important. Due to this storm water reachesthe water bodies rapidly, in bigger volume and carries more contaminants thannatural conditions. Permeable pavement on parking lots, sidewalks, and driveways provides asolution to this problem. One such material that can be used to produce porous surfaces ispervious concrete. Even though no-fines concrete mix has been used for many years, thereare still many unresolved issues related to its structural performance and issues withreduced filtration capacity over time especially when exposed to real conditions. Thispaper presents a study describing a project pervious concrete system. The details of the construction technique including details of the material used are described in this paper.On-going tests to monitor the performance of this test slab are also described.

Keywords: Pervious concrete,Porous surface, Rain water runoff, No-fines concrete, Permeable pavement

1.0 INTRODUCTION

Pavement systems creating about 30-40 per cent of the total urban fabric have converted pervious natural ground into impervious systems, which have created a negative impression on the environment. These impressions can be broadly categorised as variations in hydrological aspect and temperature in the surrounding ambience. About the hydrological aspects, the existing dense pavement system being impervious in nature, increases the quantity of runoff and reduces the infiltration of rainwater into the ground, which may create a flood-like situation in low-lying areas. The runoff, which occurs immediately during rainfall, termed as the first flush, is highly-polluted and requires large treatment facilities before being discharged into natural water bodies. Further, the problems of water logging, hydroplaning and skidding, which affect road users, exist when the pavement is wet. Thus, pervious concrete enables to percolate the storm water into ground and helps to recharge the ground water table and excess water is stored in underground tank and used for domestic purpose.

Regarding temperature in the surrounding ambience, impervious pavement systems act as a heat storage media that stores heat and releases it back to the atmosphere, increasing results in an increase in the urban temperature by about

2-6°C compared to the surrounding rural areas. This results in thermal discomfort, which increases the consumption of electricity for cooling systems and other energy sources.

The United States is facing the problem of controlling air pollution from vehicle emissions, especially in growing urban areas. This study investigates the photocatalytic effect of titanium dioxide (TiO_2) applied onto pervious concrete pavement to remove some of these pollutants from the air, so that pervious concrete pavement can be installed for two sustainable applications: storm water management and air pollutant removal. The photo catalyst, TiO_2, activates with UV radiation to oxidize air pollutants, such as nitrogen oxides (NO_x) and volatile organic compounds (VOCs). When Titanium dioxide reacts with UV rays, NOx and Volatile Organic Compound breaks down into H_2O and CO. Thus, H_2O percolates into ground reaching ground water table, while the CO_2 gas which is liberated is been absorbed by plants which is planted along the pervious concrete

Pervious concrete (also called porous concrete, permeable concrete, no fines concrete and porous pavement) is a special type of concrete with a high porosity used for concrete flat work applications that allows water from precipitation and other sources to pass directly through, thereby reducing the runoff from a site and allowing groundwater recharge. Pervious concrete is made using large aggregates with little to no fine aggregates. The concrete paste then coats the aggregates and allows water to pass through the concrete slab.
Pervious concrete is traditionally used in parking areas, areas with light traffic, residential streets, pedestrian walkways, and greenhouses. It is an important application for sustainable construction and is one of many low impact development techniques used by builders to protect water quality.
Due to rapid urbanization most of the places are covered with impermeable surfaces like cement concrete. This has a major impact on the ground water table. Pervious Concrete pavement is an effective way to minimize this issue. Pervious concrete is an open graded structure with interconnected voids through which rain and storm water is permitted to percolate into the aquifer. It consists of cement, coarse aggregate, some percentage of fine aggregate and water. Pervious concrete is an environmental friendly building material and EPA (Environmental Protection agency) has identified it as a Best Management Practice (BMP) for storm water Management. It can be used for lower traffic roads, shoulders, sidewalks and parking lots. This will add points to a project with a sustainable material managing storm water, reducing ground water pollution.

In spite of having low Compressive and flexural strength, No-fines concrete has properties capable of being used as rigid pavement for low traffic volume roads. No fine concrete has greater permeability rate which will increase the infiltration rate and reduces the surface runoff. Compressive strength of no fine concrete is limited upto 15 Mpa. The no fine concrete concept is well described in following figure.

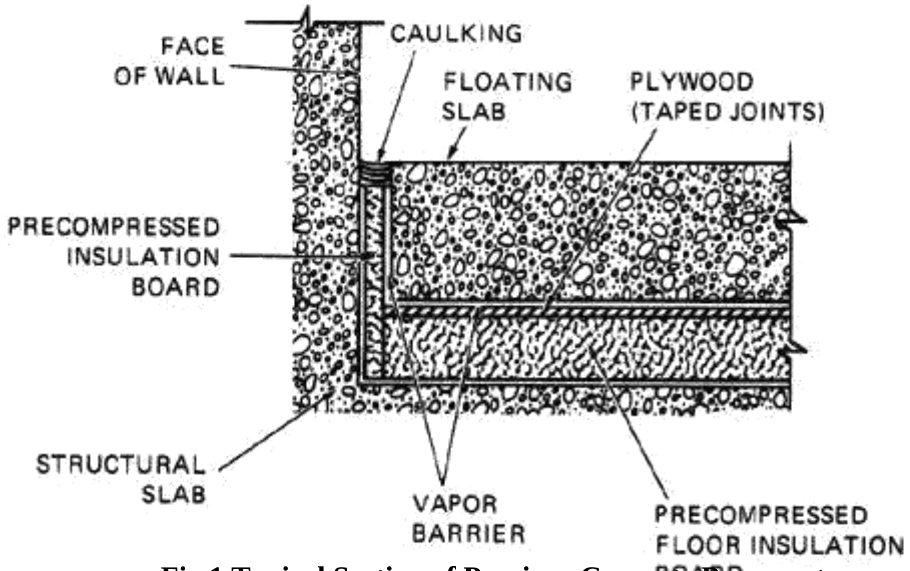

Fig 1 Typical Section of Pervious Concrete Pavement

Indian Institute of Technology Kharagpur (IIT Kharagpur) team has been developing the material customised for Indian conditions, which is still not used in India. It could be tested commercially on PPP basis in upcoming residential complexes and multiplexes, parking lots, parks, etc. This will not only reduce water logging owing to impervious land cover, but also reduce heat in the surrounding environment. Also, such places encounter less dust in comparison to busy roads. Hence, it is hypothesised that the wear and tear of pervious concrete pavements will be comparatively less, thus ensuring longer pavement life.

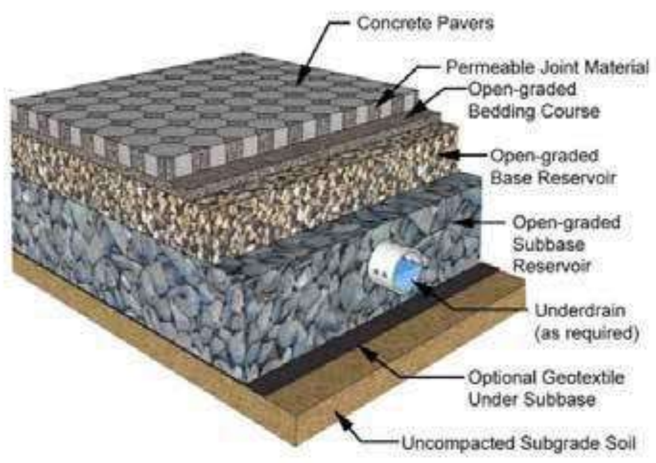

Fig 2. 3D view of Pervious Concrete Pavement

At present, one of the main limitations to broaden the potential applications of no-fines concretes is the low durability, since through their porosity, water and the relative dissolved aggressive substances can penetrate them and induce degradation processes. The durability problem could be reduced by manufacturing no-fines concretes with a hydrophilizing admixture. Which may reduce water uptake. Moreover, if reinforcements are introduced once that the corrosion has initiated, the corrosion rate is expected to be related to the moisture content of the thin layer of carbonated cement paste that covers the steel bar.

In addition, of interest to favour a sustainable development of no-fines concrete is the use of recycled aggregate in replacement of those natural.

In this work, no-fines concretes with three different mixtures corresponding to low (5-10 MPa), medium(15-20 MPa)and high(25-30 MPa)compressive strengths were manufactured.

2.0 BACKGROUND

*M.UmaMaguesvari and V.L. Narasimha*studied the influence of fine aggregate and coarse aggregate quantities on the properties of pervious concrete. Materials used are OPC Type I, fine aggregate corresponding to grading

II and four sizes of coarse aggregate namely, 4.75mm to 9mm, 9mm to 12.5mm, 12.5mm to 16mm, 16mm to 19.5mm. Mixes were prepared with the water cement ratio of 0.34, cement content of 400kg/m3 and maintaining the aggregate cement ratio as 4.75:1. Fine aggregate was replaced with coarse aggregate in the range of 50 - 100 % by weight. Various mechanical properties of the mixes were evaluated. Coefficient of permeability was determined by using falling head permeability method. The relationship between the strength, abrasion resistance, permeability and total void present in aggregate based on angularity number has been developed. Suitability of pervious concrete as a pavement material is discussed. Their study illustrates angularity number, which influence properties and behaviour of pervious concrete with fine aggregate and coarse aggregates. It is observed that the increase in fine aggregate results in reduction of volume of voids which in turn increase of compressive strength, flexural strength and split tensile strength. Angularity number is more for higher size aggregate and which is reduced when size of aggregate reduces. The range of compressive strength varies between 10 N/mm2 to 26 N/mm2 when the angularity number varied from 8 to 4. Increasing the aggregate size increases angularity number. Coefficient of permeability increases from 0.4 cm/sec to 1.26 cm/sec when the angularity number is in the range of 4 to 8. The optimum mixes in each coarse aggregate size are identified based on the compressive strength, Void present in aggregate (based on angularity number) and permeability are M1F30, M2F30, M3F20 and M4F20. However, the influence of angularity number on the abrasion value of the pervious concrete could not be established.

Mr. V. R. Patil,Prof. A. K. Gupta, Prof. D. B. Desai studied that our cities are being covered with building and the air-proof concrete road more and more. In addition, the environment of city is far from natural. Because of the lack of water permeability and air permeability of the common concrete pavement, the rainwater is not filtered underground. Without constant supply of water to the soil, plants are difficult to grow normally. In addition, it is difficult for soil to exchange heat and moisture with air; therefore, the temperature and humidity of the Earth's surface in large cities cannot be adjusted. This brings the phenomenon of hot island in city. At the same time, the plash on the road during a rainy day reduces the safety of traffic of vehicle and foot passenger. The research on pervious pavement materials has begun in developed countries such as the US and Japan since 1980s. Pervious concrete pavement has been used for over 30 years in England and the United States. Pervious concrete is also widely used in Europe and Japan for roadway applications as a surface course to improve skid resistance and reduce traffic noise. However, the strength of the material is relatively low because of its porosity. The compressive strength of the material can only reach about 20 - 30MPa. Such materials cannot be used as pavement due to low strength. The pervious concrete can only be applied to squares, footpaths, parking lots, and paths in parks. Using selected aggregates, fine mineral, admixtures, organic intensifiers and by adjusting the concrete mix proportion, strength and abrasion resistance can improve the pervious concrete greatly.

We were able to develop strong and durable pervious concrete mixes for low-volume roads. The effects of two types of fine aggregates, i.e. Crushed Stone and River Sand, on various properties of pervious concrete were studied. The fine aggregate to coarse aggregate ratio were as 1:5.720, compared to conventional pervious cement concrete mixes. Cement content was varied from 300 kg/m3 to 340 kg/m3 with an increment of 10 kg/m3. In total 10 different pervious concrete mixes were prepared considering each level of cement content and each type of fine aggregate. In addition, steel fibre was used to increase the strength parameter. The effects of such variation on the properties of pervious concrete mixes were studied.

*Shihui Shen, Maria Burton, Bertram Jobson, Liv Haselbach*evaluated thatthe United States is facing the problem of controlling air pollution from vehicle emissions, especially in growing urban areas. This study investigates the photocatalytic effect of titanium dioxide (TiO2) applied onto pervious concrete pavement to remove some of these pollutants from the air, so that pervious concrete pavement can be installed for two sustainable applications: storm water management and air pollutant removal. The photo catalyst, TiO2, activates with UV radiation to oxidize air pollutants, such as nitrogen oxides (NOx) and volatile organic compounds (VOCs). This study compared different methods to apply TiO2 onto the surface of pervious concrete and measured the photocatalytic activity of the concrete, the infiltrating characteristics of the pervious concrete, and its ability to withstand environmental impact. High pollutant reductions were seen with a driveway protector mix, a commercial water-based TiO2 preparation, TiO2 in water, a cement–water slurry with low cement concentration, and the commercial PURETI coating. It was found that nitrogen oxide (NO) was efficiently removed with each of these treatments, while VOCs displayed more variability in removal efficiency. Different coating methods can cause different degree of infiltration rate reduction depending on the specific design of coating materials while none of the application methods decreased the infiltration rates below levels applicable for standard hydrological design. When pervious concrete was compared to traditional concrete, pervious concrete showed higher NO reductions.

Darshan S. Shah, Prof. Jayesh Kumar Pitroda, Prof.J.J. Bhavsar studiedPervious concrete and concluded that it is a relatively new concept for rural road pavement, with increase into the problems in rural areas related to the low ground water level, agricultural problem. Pervious concrete has introduced in rural road as a road pavement material. Pervious concrete as a paving material has seen renewed interest due to its ability to allow water to flow through itself to recharge groundwater level and minimize storm water runoff. This introduction to pervious concrete pavements reviews its applications and engineering properties, including Environmental benefits, structural properties, and durability. In rural area cost consideration is the primary factor which must be kept in mind. So that in rural areas costly storm water management practices is not applicable. Pervious concrete pavement is unique and effective means to meet growing environmental demands. By capturing rainwater and allowing it to seep into the ground. This pavement technology creates more efficient land use by eliminating the need for retention ponds, swell, and other costly storm water management devices.

The following conclusion comes through the study of the pervious concrete pavement in rural areas becomes more suitable to meet the rural area requirement such as to reduce the storm water runoff, to increase the ground water level, to eliminate the costly storm water management practices. From the above case study we conclude that there is a considerable saving in amount about 29 □ / m3 or 193 □ / m2 or 18 □ / feet2 for construction of 1m X 1m X 0.15m size pavement. Pervious concrete is the relatively new concrete for the pavement construction in rural areas having cost benefits and pervious concrete extensively used worldwide because of their environmental benefits, hydraulic and durability properties.

*By Paul D. Tennis, Michael L. Leming, and David J. Akers.*evaluatedPervious concrete as a paving material has seen renewed interest due to its ability to allow water to flow through itself to recharge groundwater and minimize storm water runoff. This introduction to pervious concrete pavements reviews its applications and engineering properties, including environmental benefits, structural properties, and durability. Both hydraulic and structural design of pervious concrete pavements are discussed, as well as construction techniques.

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 pervious 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.

3.0 THE LABORATORY WORK

This study consists of re pervious concrete. Six concrete cubes of size 150 mm x 150 mm x 150mm samples are taken from each mix design. M 40 mix design is chosen for the test. Four design mix is done as plain, 0.5%rubber crumb, 1 % rubber crumb, 1.5% rubber &2.0% crumb by the weight.

3.1 Cement

3.1.1 Aggregates Ordinary Portland cement of 53 Grade (Ultratech) is used throughout this work. The properties of cement used are given in Table 1.

Name of the Test	Experimental Results	Standard values
Specific Gravity of Cement	3.15	Not Specified
Consistency	32.40	Not Specified
Initial Setting Time	150 minutes	Shall not be less than 30 minutes
Final Setting Time	550 minutes	Shall not be more than 600 minutes
Fineness of Cement	280kg/m^2	Shall not be less than 225 m^2/kg
Soundness of Cement	0.8 mm	Shall not be more than 10mm

Table 1 Properties of Cement

3.2 Course Aggregate

Normal Coarse Aggregates of Angular shape is used. Coarse Aggregates is kept to a narrow Gradation. Two types of aggregates used. of size passing through 20 mm are sieve and retained on 12.5 mm IS sieve.2nd set of aggregates passing through 12.5 mm IS sieve and retained on 4.75mm IS sieve.

Test conducted	Result	
	Aggregate size	
	20 mm	12.5 mm
Specific Gravity	2.8	2.65
Water Absorption	0.87%	3.05%
Crushing value	17	21
Flakiness Index	20	25

Table 2 Properties of Course Aggregate

3.4 Water

Water sample collected DYPCET College Campus (Kolhapur, Maharashtra) is used throughout this work. The properties of water used in given in Table 4.

Name of the Test	Experimental Result	Standard values as per IS 456-2000
Chloride	250 mg/l	RCC max. 500 mg/l
Sulphate	160 mg/l	PCC max. 2000 mg
pH Value	7.8 mg/l	Shall not be less than 6
Inorganic Solids	794 mg/l	Max. 3000 mg/l
Suspended Matte	24 mg/l	Max. 2000 mg/l
organic solids	66 mg/l	Max. 400 mg/l

Table 3 Properties of Water

4.0 Mix design

The following mixture proportioning approach can be used to quickly arrive at pervious concrete mixture proportions that would help attain void content of freshly mixed pervious concrete when measured in accordance with ASTM C1688 similar to the target value.

Determine the dry-rodded unit weight of the aggregate and calculate the void content.

Estimate the approximate percentage and volume of paste needed. The volume of paste (Vp) is then estimated as follows:

Vp (%) = Aggregate Void Content (%) + CI (%) - Vvoid (%)

Where CI = compaction index and

Vvoid = design void content of the pervious concrete mix.

The value of CI can be varied based on the anticipated consolidation to be used in the field. For greater consolidation effort a compaction index value of 1 to 2% may be more reasonable. For lighter level of consolidation, a value of 7 to 8% can be used. NRMCA used a value of 5% to get similar values between measured fresh pervious concrete void content (ASTM

(%) will reduce the paste volume.

C1688) and design void content. Using a smaller value for CI

Mix proportion A:-

Aggregate void content (%)	47%
Compaction Index (%)	5%
Volume of void	20%

Table 4 Assumptions for mix design

Hence,Vp (%) = Aggregate Void Content (%) + CI (%) - Vvoid (%)

1.Vp (%) = 47% + 5% - 20%

Hence, Vp = 32%

4.1Calculate the volume of paste

Vp in m^3 per cubic meter of pervious concrete:

Vp =Vp(%) Hence Vp = $0.32m^3$

Select the w/c ratio for the paste. Recommended values are in the range of 0.25 to 0.36. Hence w/c ratio assumed = 0.25

4.2Calculation of Absolute Volume of Cement (Vc)

Vc = Vp/ (1+ (w/C x RDc))

Where: RDc is the specific gravity of cement

Hence Vc =0.32/ (1+(0.25 x 3.15)) = 0.179 m^3 = 563.85 kg/m^3

4.3. Determination of volume of water (Vw)

Vw = Vp – Vc

Vw = 0.32 -0.179 = 0.141 m^3 = 141 kg/ m^3

4.4Calculate the volume of SSD aggregate.

Vagg = 0.48 m^3= 1392 kg/ m^3

Material	Quantity	For one cube
Cement	563.85 Kg	1.98 kg
Aggregate	1392 kg	4.87kg
Water	141 litres	0.5litres
Admixture	1.5 %	1.5 %

Table 5 Proportion of materials

4.5 Void Ratio

Void ratio is the ratio between total volumes minus solid volume divided by total volume of concrete. The formula for calculating the percentage of voids is given below, Percentage of Vvoids = (V total - V solid) X 100 / V total

4.6 Compressive Strength

Total number of 21 cubes specimens were casted and tested. The concrete mixes of different proportion M1, M2, M3, M4, M5, M6, and M7. Were tested to compression strength as per Indian standards figure 6 shows the compressive strength while conducting test in compression testing machine. Compressive strength = P/A

P = Applied load in N

A = Area of the cube in mm^2

5.0 CASTING AND TESTING OF SPECIMENNS

Fig.3 Test Specimens for compression & Permeability Test

Fig.4 Test Specimen

Fig.5 Compression Test

Fig.6 Permeability Test

Fig.7 Permeability Test Apparatus

6.0 RESULT

Mix	Void %	Cement in kg	Course Aggregate(Kg)		Water
			12.5 mm	20 mm	
M 1	20	441.09	1183.2	295.8	150
M2	25	365.04	1183.2	295.8	125
M3	30	286.65	1183.2	295.8	99
M4	35	211.05	1183.2	295.8	73

Table 6 Mix Proportions for Different Mixes

Mix	Void %	Compressive Strength N/mm² (7 Days)
M 1	20	6
M2	25	5.5
M3	30	2.9
M4	35	1.8

Table 7 Compressive test results

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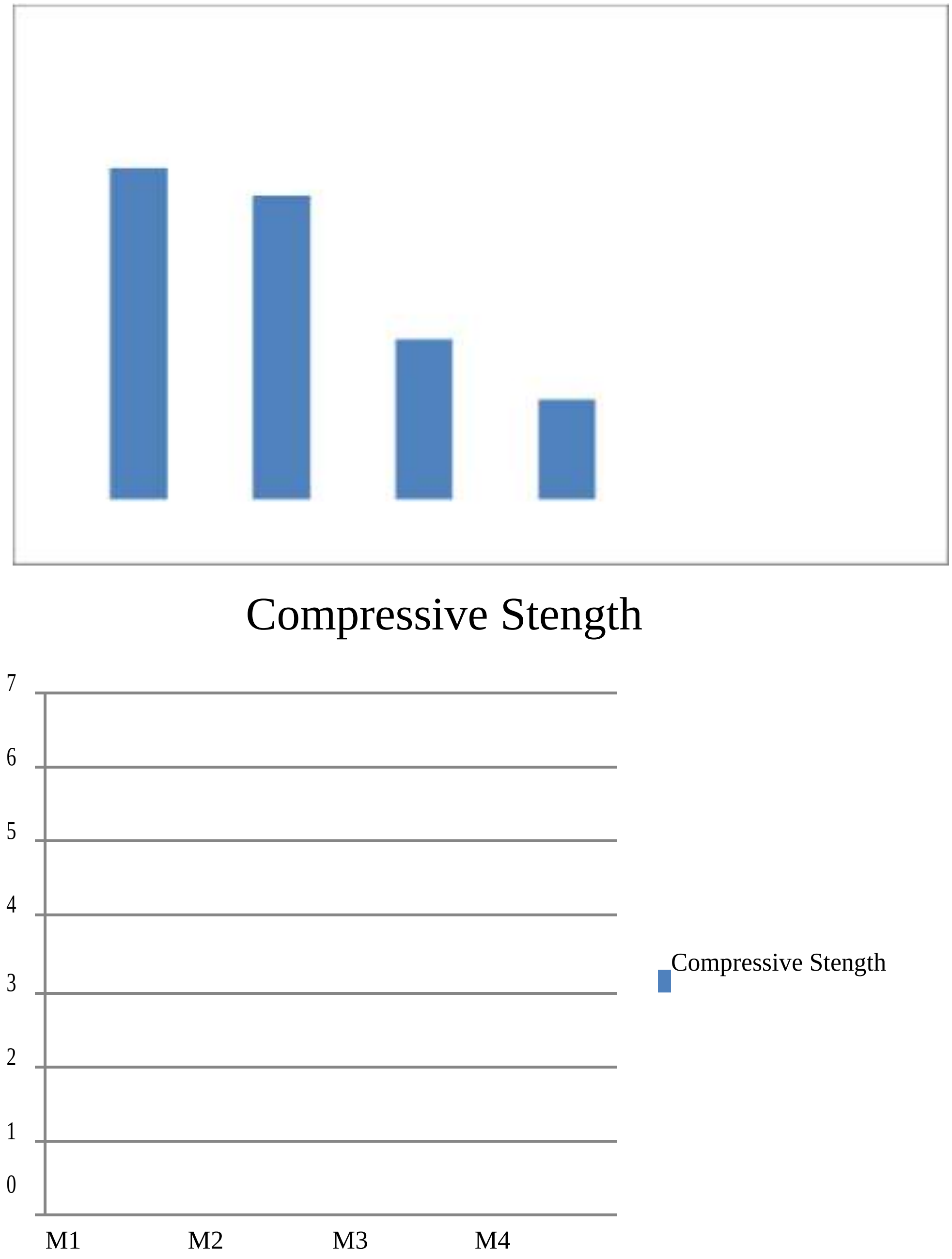

Fig.8 Comparison of compressive strength for different mixes

7. CONCLUSIONS

The following are the conclusions and recommendations made by this study. According to the Experimental results, it has been observed that,

1) If the voids ratio increases, compressive strength & flexural strength values are reduced.
2) The compressive strength of pervious concrete with 12mm size aggregates are more compared to 20mm size aggregates.
3) Compared to conventional mix, large quantity of admixtures (AlgiTech) are required for Pervious concrete.
4) The mix M4 gives 83.24% more Compressive Strength, 72.53 % more Flexural strength & 34.11% less Void ratio compared to the Mix M1.
5) The mix M1 gives 51.78% more voids ratio (Maximum), 45.42% less Compressive Strength and 42.42% less Flexural strength compared to the mix M4.
6) Therefore, the Mix M4 can be used as M10 grade of pervious concrete from both strength and void ratio properties in pavements.

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