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Implementation of Pervious Concrete Using Alternative Techniques and Methods to Increase its Strength

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Abstract: Pervious concrete is an unconventional and effective way to help us in solving the dire environmental problems by guiding us towards green and sustainable development. Replacing conventional concrete with pervious concrete has led to reduction in storm water runoff and increase the level of underground water table. The major problem of pervious concrete as compared to conventional concrete is its extremely low strength. This research is an extensive study to increase the strength of pervious concrete by using marble waste powder and waste glass frit as the partial replacement of cement (ordinary Portland cement). The tests were carried out by replacing 10 %, 20 % and 30 % of weight of the cement. The samples were tested for compressive, split tensile and flexural strength of concrete after allowing it to dry for 28 days.
Keywords: Pervious concrete, zero cement, strength, waste glass powder, waste marble powder

I. INTRODUCTION

Pervious concrete is a unique type of no fine concrete in which coarse aggregate, cement and water is used in controlled amounts. Pervious concrete pavement facilitates the percolation of storm water. It can be used as an alternative to conventional concrete which causes run off. Due to seepage of water through the concrete layer the ground water table level is recharged. No fine concrete is a mix of coarse aggregate (gravel, stone), cement, water, sand (less or zero amount). Due to absence of sand, there are voids in the concrete. Environmental protection agency states that about 92% of pollutants (oils and carbon constituents) present on ground are carried with the water during runoff. This pollution can be stopped if the water directly seeps into the ground without sliding off the surface. Construction of retention pond can be minimized by using no fine concrete for the purpose of storm water runoff.

A. Need of Pervious Concrete

According to recent findings, concretization was reported as the biggest reason behind water scarcity, forest depletion, de-banking of water bodies and elevated temperatures. Pervious concrete has provided a way to avoid these climate related problems. Use of pervious concrete to help recharge the already depleted ground water table could bring about a revolution in the construction sector. The strength of pervious concrete is comparatively lower than the strength of conventional concrete. There are different advantageous aspects of pervious concrete:

1) *Economic Aspect*: As mentioned earlier an investment of 220 billion USD is expected in the coming years. Due this huge amount of investment, there would be eminent changes in respect to construction sector such as: Struggle for increasing the profit margin, introduction of stricter environmental laws and rise in the value of water as a commodity. Pervious concrete has an eminent capability to adapt to all these changes whereas conventional concrete would fall short in fulfilling these demands. Cost effectiveness of pervious concrete is one of the most essential parameter. In a case study in Olympia around 48 % of cost effectiveness was brought into practice. Cost from 11.24 USD (conventional concrete) was reduced to a mere 6.02 USD (pervious concrete). When areas like parking lots, walkways and pavement are constructed with pervious concrete, requirement of detention pond is eliminated, since the concrete itself acts as a detention basin which in turn reduces the demand on sewer systems therefore reducing the overall cost. Since there is absence of sand and low amount of water requirement, the use of pervious concrete in places where commercial construction is carried out can be extremely beneficial.
2) *Environmental Aspect:* According to the Florida concrete and product association (one of the biggest pervious concrete implementers) conventional concrete is termed as hot and pervious concrete is designated as cool. Moreover, the roads and highways are contaminated by burnings of tyres. Oils and grease spills are common near petrol pumps and automation centres. The runoff water after precipitation collects these impurities and flows to the water bodies. This water is more harmful than the sewage water that is collected. Pervious concrete pavements help in collecting water in the ground, hence recharging the water table.

3) *Aesthetic Aspect:* Pervious concrete pavements when used in parks and walkways look different to the eye as compared to the regularly seen conventional concrete pavements. It can be used in different colours and sizes. Composite pavements of varying aggregate sizes look extremely pleasing to the eye. In regions where snowfall is seasonal, the snow collected on the pervious concrete melts quickly; due to the air circulation below the concrete surface, keeping the surface dry and fresh.
4) *Structural Aspect:* The void structure present in pervious concrete helps in preventing vehicular traction. At night, during monsoons the water does not retain on the surface avoiding the light reflection in water. Cases of water splashes are also reduced.

5). Leed Credits: U.S green building association has started providing credits for use of pervious concrete in Leed (leadership and environmental design). This has proven to be one of the foremost reasons for companies to opt for pervious concrete pavements. Since the colour of the pervious concrete pavement is light in colour, it absorbs less heat. Pervious concrete unlike impervious pavements complements the growth of trees and bushes in the nearby area. This helps in making the construction greener and better Leed credits.

II. MATERIALS

A. Waste Glass Powder (150 Microns)

Waste glass powder has high silica content and is non-crystalline in nature. When the particle size is equal to or below 75µm the powder is potentially pozzolanic. This powder is collected after cutting of glass is done in the workshops. The powder obtained has to be properly sieved, as there are chances that it may contain waste while collecting it. This glass can even be obtained by collecting waste glass pieces and then pulverizing it. The glass powder ranges from 150µm to 300µm.

Particulars	Proportion
Aluminum Oxide(SiO_2)	01.12%
Boron Trioxide(B_2O_3)	02.26%
Calcium Oxide(CaO)	11.39%
Magnesium Oxide(MgO)	03.16%
Potassium Oxide(K_2O)	01.02%
Sodium Oxide(NaO)	12.11%
Silicon Dioxide(SiO_2)	65.92%

Table 1. Chemical proportion of waste glass powder

B. Waste Marble Powder (150 Micron)

The global marble industry produces a total annual output of 68 million tonnes. Waste marble powder has proved to be a satisfactory replacement of cement in case of conventional concrete. About 25 % on marble is wasted in terms of powder.

Particular	Proportion
LOI	40.59%
Silicon Dioxide (SiO_2)	4.89%
Ferric Oxide (Fe_2O_3)	1.08%
Calcium Oxide (CaO)	31.3%
Sulphur trioxide (SO_3)	0.019%
Potassium oxide (K_2O)	0.891%
Potassium oxide (Na_2O)	0.593%

Table 2. Chemical proportions of waste marble powder

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C. Coarse Aggregate (12mm to 18mm)

Test performed	**Results**
Impact load test	13.15%
Los Angeles abrasion test	15.4%
water absorption	1.01%

Table 3. Tests performed on coarse aggregate

D. Cement (150 Microns)

Test performed	**Results**
Fineness of cement	2.61%
Standard consistency of cement	32%
Initial setting time of cement	32 mins
Final setting time of cement	600 mins

Table 4. Tests performed on cement.

E. Mix Design Proportion

The design of pervious concrete is not available in the IS code. Therefore, ACI 522R is to be referred for the mix design of pervious concrete.
Pervious concrete of strength 20Mpa
Design average cube strength at 28 days

$\frac{20}{0.75}$ = 26.66 N/mm2

$A/_C$ = 3

Optimum W/C ratio = 0.31

Density of Concrete = 2500 Kg/m3

Bulk Density of Cement = 1700 Kg/m3

Bulk Density of coarse aggregate:

12.5 mm = 1650 Kg/m3

A/C ratio by weight = $\frac{3 X 1650}{1700}$ = 2.91

III. EXPERIMENTAL METHODOLOGY

To provide a proper flow to the experimental investigation, few steps are to be followed chronologically.

A. *Collection of Materials*
Materials are to be properly procured since availability of material becomes a tedious process. The materials that are procured should be collected with their complete history. Finding or determining chemical proportions of the materials is a lengthy process in itself, therefore if the proportions are known it becomes extremely helpful.

B. *Physical Tests on Materials*
The tests that are carried out are helpful in determining the properties of the materials. Since the materials are exposed to environment it is necessary that the tests are carried out.

C. *Preparation of Samples*
The samples are prepared with the help of casts of beam, cube and cylinder. These iron casts must be thoroughly cleaned and greased from the inside. The concrete is dry mixed and water is added at 50% decrement. The concrete mix is laid in the casts and medium tamping is done. The sample is covered with transparent polythene sheet to avoid exchange of moisture.

D. *Testing of Samples*
Samples are tested for their respective strengths. The values noted are in tabular form.

1) *Compressive Strength (IS: 516- 1959):* The performance of the test was carried out on a compression testing machine with casted cube samples. Three samples of each proportion of replacement were carried out. The compressive strength analysis was conducted on 10%, 20%, 30%. The glass analysis is denoted in table no.6 and marble analysis are denoted in table no. 5. The load (p) that is obtained on the machine is divided by (a) i.e. the area of the cube surface.

$$\text{Compressive strength} = \frac{failure\ load\ (p)}{Area\ (a)}$$

2) *Flexural Strength (IS 415: 1949):* The performance of the test was carried out on flexural testing machine with casted beam samples. The samples of each proportion of replacement were carried out. The flexural strength analysis was conducted for 10%, 20%, 30% of marble and glass. The glass analysis is denoted in table no.8 and marble analysis is denoted in table no. 7. The load obtained is equated through

$$\text{Flexural strength} = \frac{M}{Z}\ \text{(MPa)}$$

$$Z = \frac{B \times D^2}{6}$$

$$M = \frac{(P \times 10160) \times L}{4}$$

Where,
P is failure load
L is length of beam in mm
D is diameter of beam in mm
B is width of beam in mm

3) *Split Tensile Strength (IS 516- 1959):*

The performance of the test was carried out on compression testing machine with casted cylinder samples. The test is carried out by placing a rod at the center of the curved surface of the sample. Three samples of each proportion of replacement were carried out. The split tensile strength analysis was conducted on 10% , 20% , 30%. The marble analysis is denoted in table 9 and the glass analysis in table
10. The load (P) that is obtained on the machine is divided by the area of the cylindrical surface (a).

$$\text{Split tensile strength} = \frac{Failure\ Load\ (P)}{Area}$$

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IV. RESULTS AND DISCUSSION

Table 5. Compressive strength for replacement by waste marble powder.

Material	Replacement (%)	Compressive Strength Sample 1 (MPa)	Compressive Strength Sample 2 (MPa)	Compressive Strength Sample 3 (MPa)	Average (MPa)
Marble	10%	5.3	6.2	5.7	5.7
Marble	20%	2.2	0.4	1.3	1.3
Marble	30%	0	1.3	1.8	1.03

Table 6. Compressive strength for replacement by waste glass powder.

Material	Replacement (%)	Compressive Strength Sample 1 (MPa)	Compressive Strength Sample 2 (MPa)	Compressive Strength Sample 3 (MPa)	Average (MPa)
Glass	10%	4.9	6.2	5.7	5.69
Glass	20%	6.2	5.3	4.8	5.4
Glass	30%	4.8	3.5	4.9	4.4

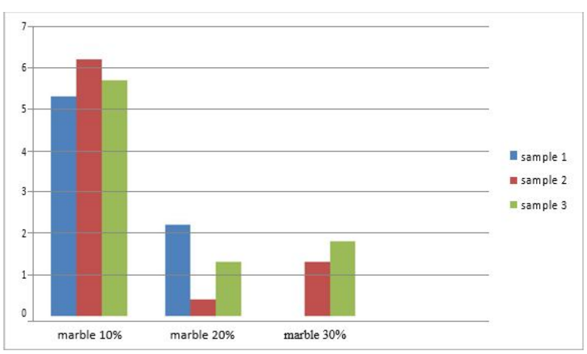

Fig. 1 Compressive strength of marble powder samples in MPa

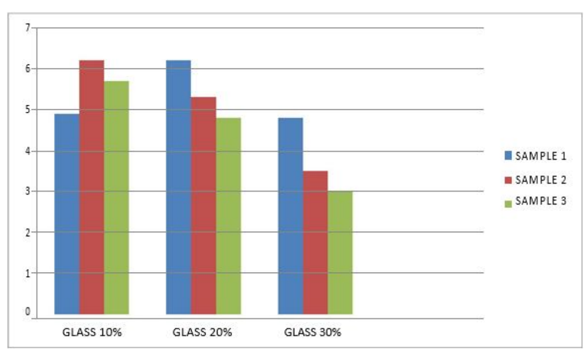

Fig 2. Compressive strength of glass powder in MPa

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Table 7. Flexural strength for replacement by waste marble powder

Material	Replacement (%)	Flexural Strength Sample 1 (MPa)	Flexural Strength Sample 1 (MPa)	Flexural Strength Sample 1 (MPa)	Average (MPa)
Marble	10%	1.5	1.4	1.4	1.41
Marble	20%	0.6	0.5	0.6	0.57
Marble	30%	0.6	0.6	0.63	0.62

Table 8. Flexural strength for replacement by waste glass powder

Material	Replacement (%)	Flexural Strength Sample 1 (MPa)	Flexural Strength Sample 1 (MPa)	Flexural Strength Sample 1 (MPa)	Average (MPa)
Glass	10%	1.4	1.4	1.5	1.45
Glass	20%	1.3	1.3	1.4	1.35
Glass	30%	1.2	1.2	1.3	1.25

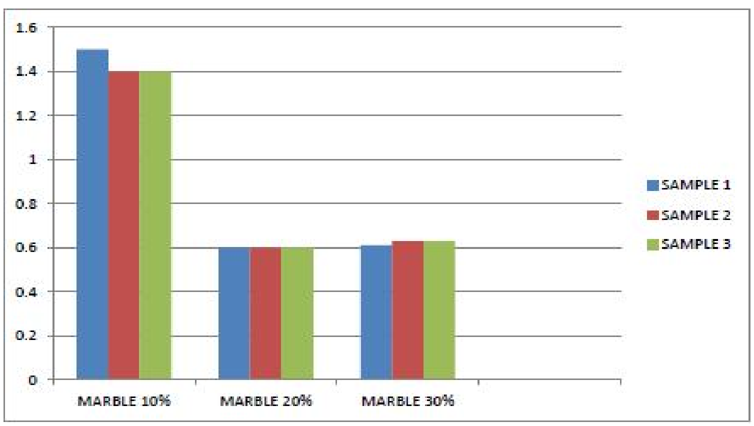

Fig 3. Flexural strength of marble powder samples in MPa.

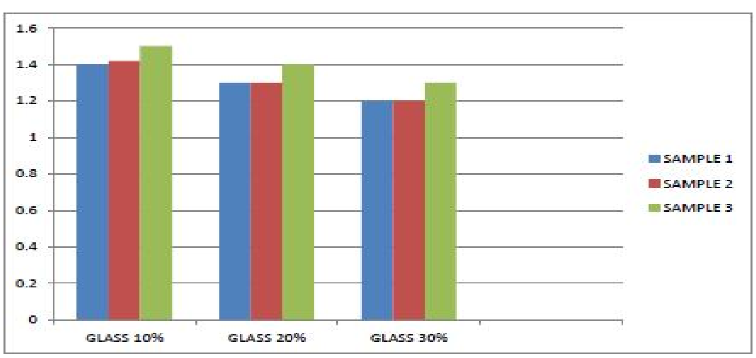

Fig 4. Flexural strength of glass powder samples in MPa.

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Table 9. Split tensile strength for replacement by waste marble powder

Material	Replacement (%)	Split Tensile Sample 1 (MPa)	Split Tensile Sample 1 (MPa)	Split Tensile Sample 1 (MPa)	Average (MPa)
Marble	10%	0.95	0.97	0.96	0.96
Marble	20%	0.52	0.54	0.51	0.52
Marble	30%	0.45	0.48	0.49	0.47

Table 10. Split tensile strength for replacement by waste glass powder.

Material	Replacement (%)	Split Tensile Sample 1 (MPa)	Split Tensile Sample 1 (MPa)	Split Tensile Sample 1 (MPa)	Average (MPa)
Glass	10%	0.92	0.94	0.99	0.95
Glass	20%	0.92	0.89	0.9	0.91
Glass	30%	0.879	0.82	0.8	0.83

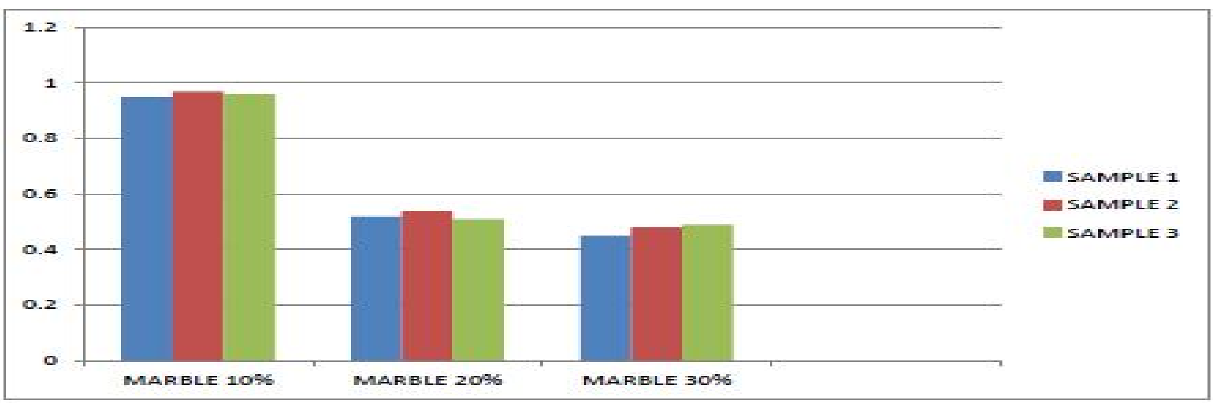

Fig 5. Split tensile strength of marble powder samples in MPa.

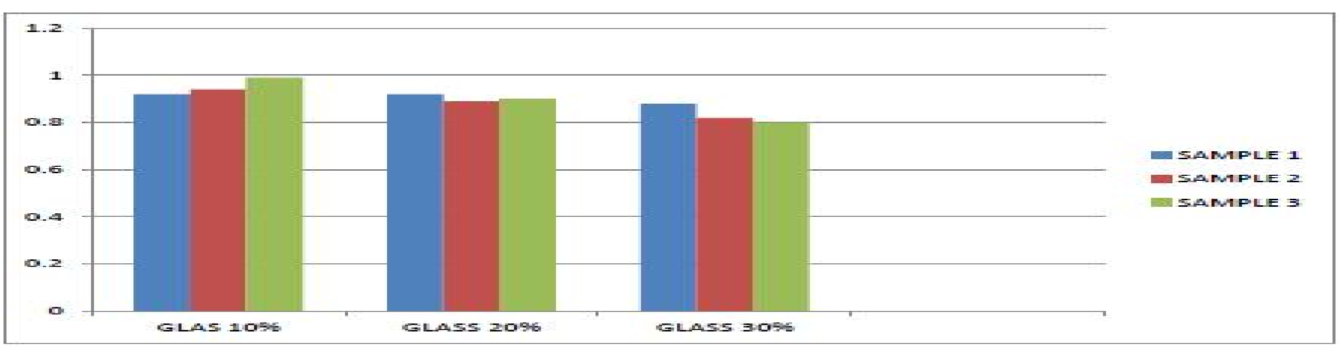

Fig 6. Split tensile strength of glass powder samples in MPa.

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The observations are drawn in comparison of non-replacement samples. None of the above replacements could match the strength attained by non-replacement concrete. The compressive strength attained by 0% replacement samples was noted as highest at 5.77 MPa. This strength was equalled by 10% replacement with waste marble powder. After increasing the replacement percentage to 20 and 30, the compressive strength of samples plummeted five times.

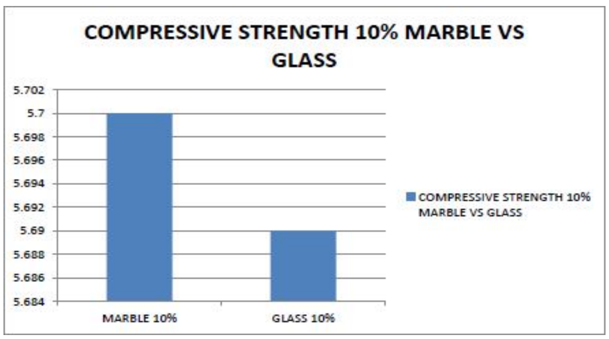
The compressive strength of glass powder replacement showed a steady decline from 5.69 MPa to 5.4 MPa to 4.4 MPa. The flexural strength of 0% replacement samples was noted at 1.76 MPa, 10 % glass replacement showed the highest value after 0% replacement 1.45 MPa. The highest value of split tensile strength is for 0% replacement that is 1.21 MPa.

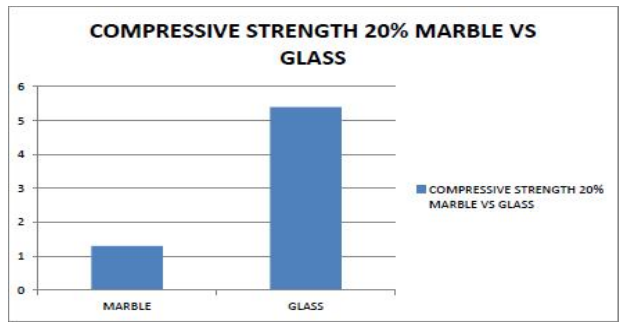
The conventional pervious concrete samples that were designed for M20 grade concrete; failed to achieve the designed strength. The experimental observations are as follows:

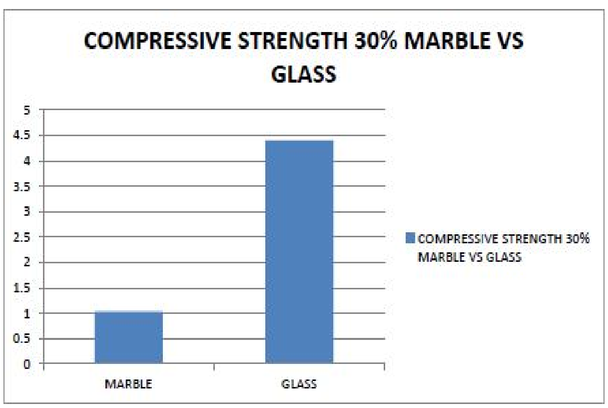
A slurry paste was observed at the lower surface of the samples. This cement-water slurry paste reduced the porosity of the samples.

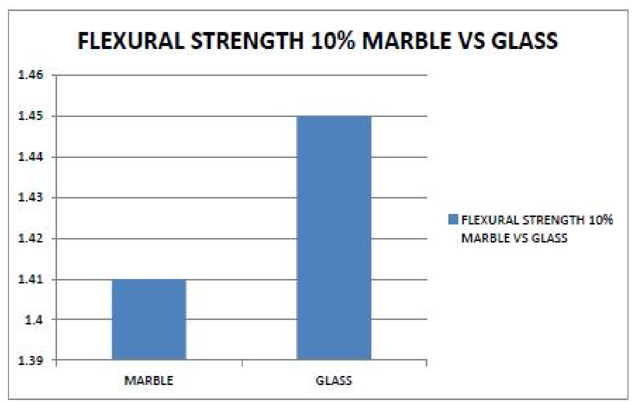
During batch mixing of 20% and 30% replacement with waste marble powder, the mix became extremely dry.

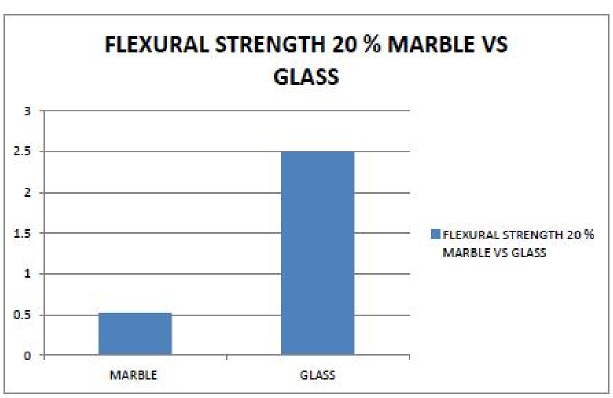
When the samples were covered with transparent polythene sheets, moisture was retained at the inner surface of the sheet, but in case of 20% and 30% marble no moisture content was noted.

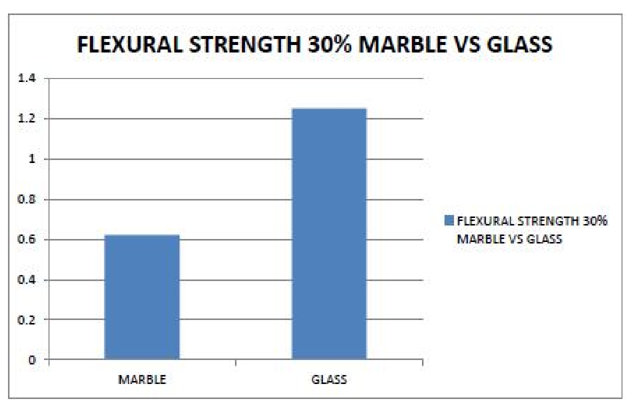


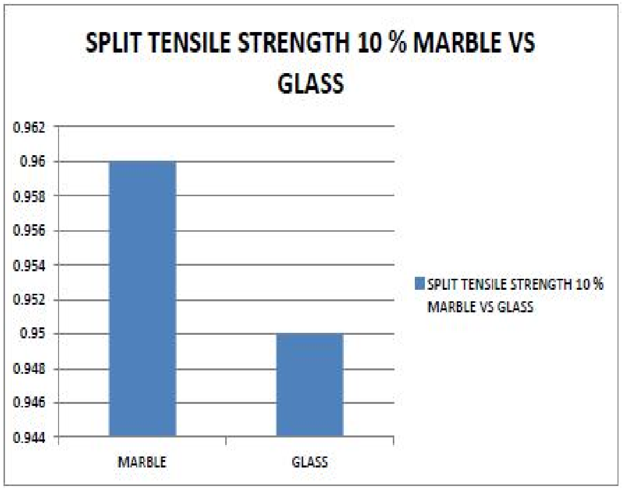


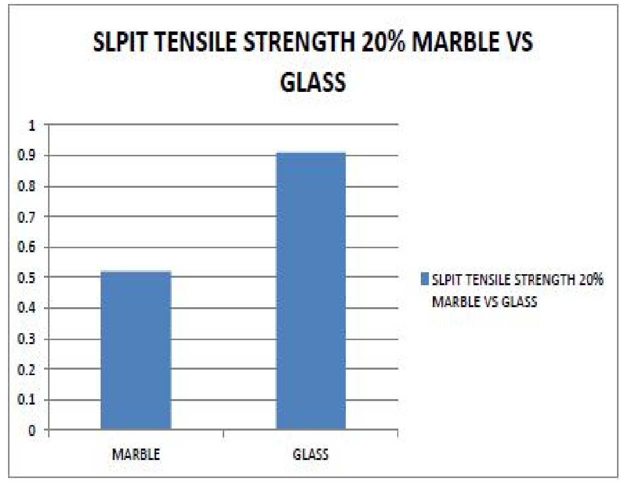


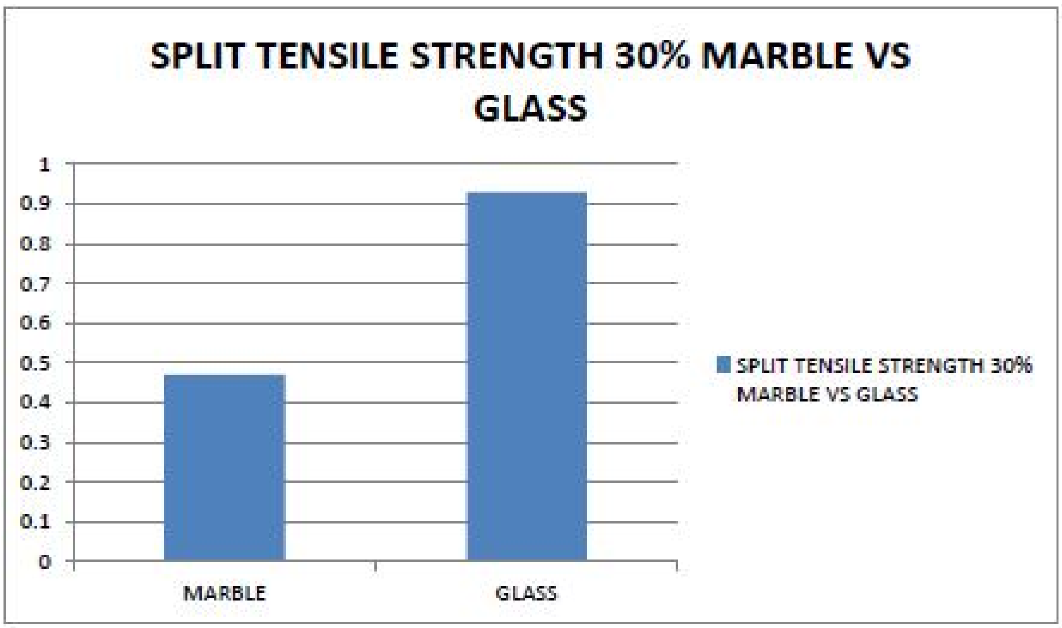












V. CONCLUSION

Though the concrete cannot be used at places where frequent load is exerted like parking lots or walkways. The o% replacement mix could be used in parks. The climatic conditions in India do not resemble the conditions in United States, therefore ACI reports must be followed with keeping the climatic conditions in consideration. 10% replacement by waste marble powder could prove as a waste management technique. Waste glass powder mix acts as a stable component and shows gradual decrease unlike waste marble powder that shows staggering variations.

Pervious concrete can achieve global success if it is used with proper quality control measures in developing countries. Being a new subject of research that is around a decade old, it can be scrutinized to get the desired outcome. Use of waste glass powder, waste marble powder, rice husk ash, sugarcane bagasse ash, hypo sludge and fly ash should be carried it in case of pervious concrete. Strength being one of the most important criteria, strength of pervious concrete must be studied and developed.

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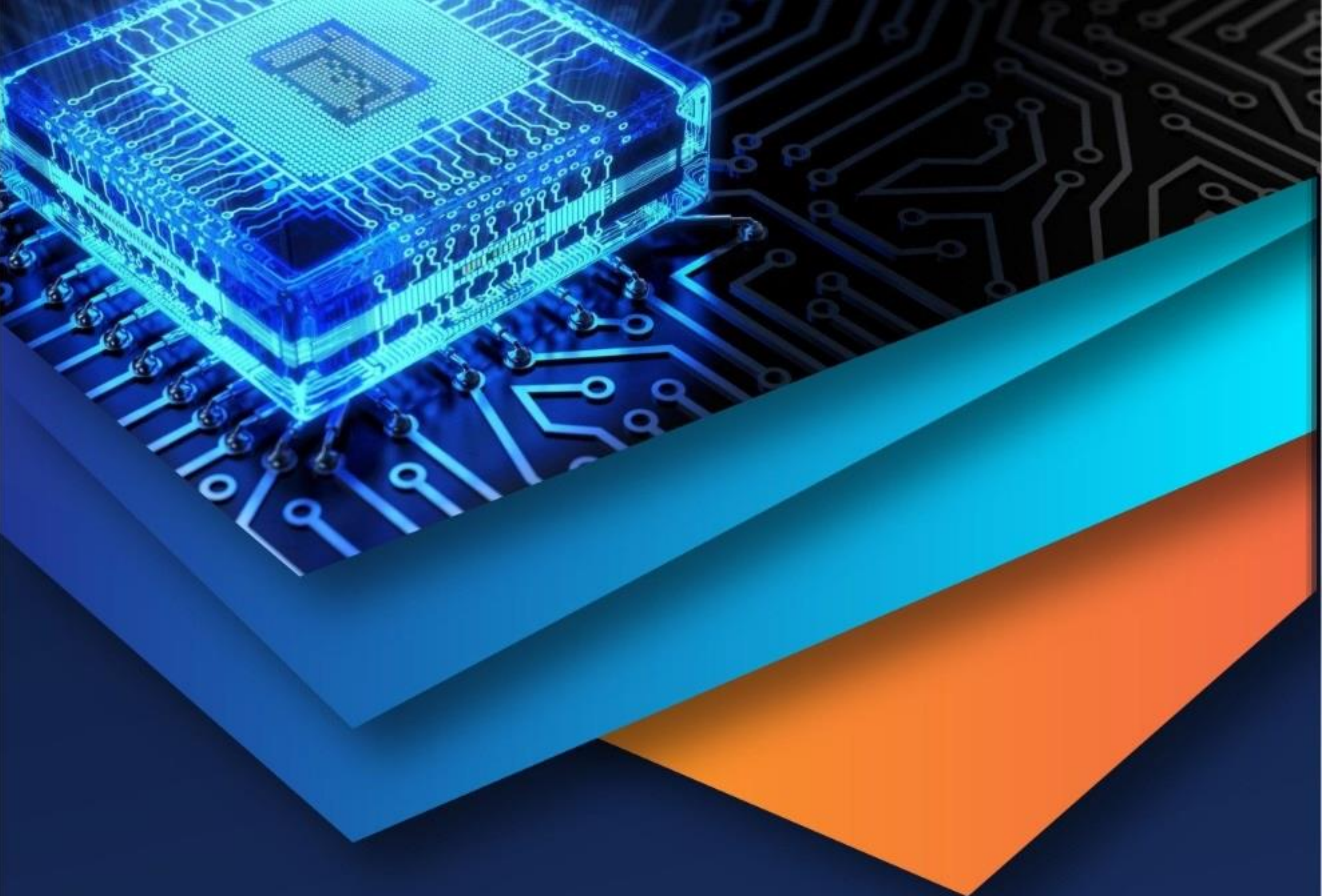

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