An Experimental Investigation on Geopolymer Concrete with Partial Replacement of Fine Aggregate with Rubber Crumbs and Steel Fibre

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Abstract- **This project focuses on the study of sustainability to the cement – less geopolymer concrete by partially replacing fly ash by GGBS and fine aggregate with rubber crumbs obtained from waste tyre. Geopolymer concrete has become more popular in recent years due to the fact that it is significantly more environmentally friendly than standard concrete. Geopolymer concrete usually includes the fly ash, fine aggregate and coarse aggregate activated by means of alkaline liquids like sodium silicate and sodium hydroxide which is effective in oven curing. For the purpose of utilizing Geopolymer concrete for the insitu applications, fly ash is partially replaced by means of Ground Granulated Blast Furnace slag which requires ambient curing conditions. Further, the rubber crumb is obtained by shredding the waste rubber tyre. By using rubber crumb in construction purpose, it reduces the exploitation of natural resources and environmental pollution. Geoploymer concrete of grade M40 with rubber crumb as a replacement of fine aggregate was studied for its strength and durability properties.**

In this study, the optimum mix ratio with 10% rubber crumbs paver blocks were casted. The strength and durability results of optimum mix paver block is compared with conventional geopolymer paver block.

Key words: Rubberized geopolymerr concrete with steel fibre.

I. INTRODUCTION

Geopolymer concrete is an innovative and sustainable alternative to traditional Portland cement-based concrete. Traditional concrete production is a significant contributor to carbon dioxide emissions, as the manufacturing of Portland cement involves high energy consumption and releases substantial amounts of CO2. Geopolymer concrete, on the other hand, is produced by activating aluminosilicate materials with an alkaline solution, resulting in a lower carbon footprint.

For the alkaline liquid activator, potassium based or sodium based activators are used. In this study, sodium based activator was used. It is a combination of sodium hydroxide and sodium silicate solution. The sodium solution was prepared by dissolving the sodium hydroxide pellets in distilled water. After the solution reaches to the room temperature, the sodium silicate solution is added at a ratio of 1:2.5 and mixed all together. This solution was prepared a day before casting the specimens. At the end of this mixing, the alkaline solution was added to the aggregates and the mixing is continuedfor specified period of time. It is glossy in nature. Geopolymer are formed when various alumina and silica containing materials react under highly alkaline conditions and forms a three dimensional network of Si- O-Al-O bonds.

II.BINDER MATERIALS

In this study, 40% GGBS and 60% of Fly ash is used as a binder materials.

GGBS

Ground Granulated Blast Furnace Slag which is a by-product of iron manufacturing industry is an accepted mineral admixture for use in concrete. This granulated material when further ground to less than 45micron is called Ground Granulated Blast Furnace Slag (GGBS).

FLY ASH (CLASS F)

Low calcium fly ash (Class F) is one of the deposits produced in the burning of coal. In this work, Class F fly ash is to be used which was collected from Mettur Thermal Power Station, Salem. Generally, Class F fly ash providesgood pozzolanic activity and it contains less than 10% of lime (CaO).

III. RUBBER CRUMB

Rubber crumb are obtained from shredding the waste rubber tyres. Rubber tires after their lifespan, contain materials, which cannot be decomposed in an environment-friendly manner and lead to severe environmental problems. Rubber can be decomposed via burning, but it adversely affects the atmosphere. Alternatively, these scrap tires can be used in concrete as replacement of aggregates. The demand for tires continuously increases as the number of vehicles increases. As the scrap rubber tires are not easily biodegradable, therefore it is acute challenging for the industries to handle such waste. On the other hand, the natural aggregates used for making concrete are finite and are rapidly dwindling. The frequent use of conventional concrete also necessitates a careful selection of the constituent materials for avoiding undesirable consequences like alkali-silica or alkali carbonate reactions and many others. Usually, the rubber crumb is treated with the 1M NaOH solution to reduce its hydrophobic nature.

S.NO.	DESCRIPTION	VALUE
1	Specific gravity	0.54
2	Fineness modulus	2.36
3	Water absorption	-

TABLE 1 PROPERTIES OF RUBBER CRUMB

IV STEEL FIBRE

Steel Fibres are widely used in concrete based composite projects worldwide. Steel Fibres are made under strict quality control process and gives excellent strength and durability to the concrete eliminating cracking. Steel Fibre is available in stainless steel grades and also in carbon steel grades

SI.NO	DESCRIPTION	VALUE
1	Length	30mm
2	Diameter	0.55 mm
3	Tensile strength	1150 Mpa
4	Aspect ratio	60
5	Specific gravity	7.85

TABLE 2 PROPERTIES OF STEEL FIBRE

V. ALKALINE SOLUTION

Sodium hydroxide and sodium silicate is used in this study. Sodium hydroxide solution is prepared by dissolving sodium hydroxide pellets in distilled water. The molarity of the sodium hydroxide is taken as 12 Mol. The ratio between the sodium hydroxide and sodium silicate is taken as 1: 2.5.

VI. MIX RATIO

BINDER (Fly ash + GGBS)	FINE AGGREGATE	COARSE AGGREGATE	ALKALINITY SOLUTION (NaOH + Na2SiO3)	STEEL FIBER
Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3
408	554.4	1293.6	144	4.08
1	1.35	3.17	0.35	0.01

TABLE 3 MIX RATIO

Reference: Fly ash based geopolymer concrete (2010)
Author: B V Rangan , Curtin university

EXPERIMENTAL INVESTIGATION

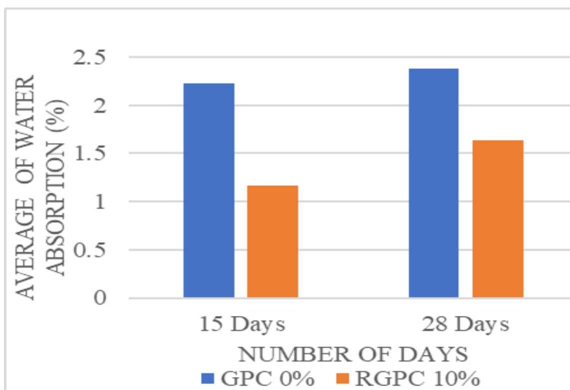
The strength and the durability test was carried out on the paver blocks with optimum mix ratio and conventional geopolymer concrete.

VII WATER ABSORPTION TEST

The cubes of size 100 mm were cast for the different mixes and allowed for ambient curing. The test were done with a duration of 15 and 30 days.

Specimen	Age of concrete	Average water absorption (%)
RGPC 0%	15 Days	2.22
	30 Days	2.38
RGPC 10%	15 Days	1.17
	30 Days	1.63

TABLE 4 WATER ABSORPTION RESULTS



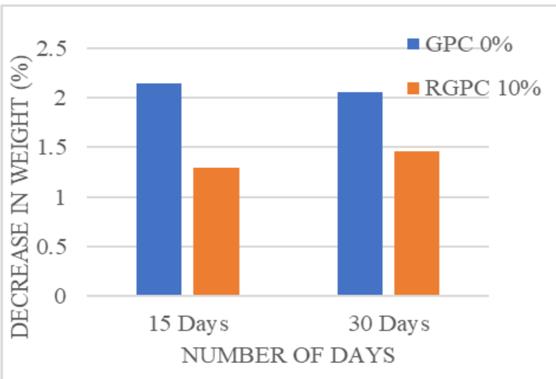
GRAPH 1 WATER ABSORPTION RESULTS

VIII ACID RESISTANCE TEST

The 100 mm cubes were casted for different mixes and also for curing. The cubes were tested by soaking them in (HCL) hydrochloric acid solution as ASTM C1898-20 code book.

Specimen	Age of concrete	Average decrease in weight (%)
RGPC 0%	15 Days	2.06
	30 Days	2.15
RGPC 10%	15 Days	1.30
	30 Days	1.46

TABLE 5 ACID RESISTANCE RESULTS

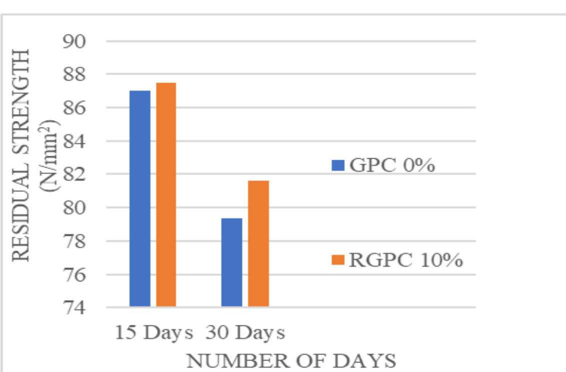


GRAPH 2 DECREASE IN WEIGHT IN ACID RESISTANCE TEST

COMPRESSIVE STRENGTH AFTER ACID RESISTANCE TEST

Specimen	Age of concrete	Average decrease in compressive strength (N/mm^2)	Average residual strength (N/mm^2)
RGPC 0%	15 Days	12.98	87.02
	30 Days	20.67	79.33
RGPC 10%	15 Days	12.52	87.48
	30 Days	18.41	81.59

TABLE 6 LOSS IN COMPRESSIVE STRENGTH AFTER ACID RESISTANCE TEST



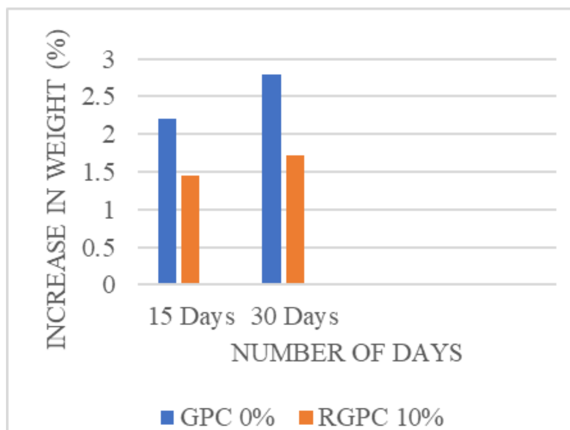
GRAPH 3 RESIDUAL STRENGTH

IX SULPHATE ATTACK TEST (Na_2SO_4)

The resistance of concrete to sulphate attacks was studied by determining the loss of compressive strength or variation in compressive strength of concrete cubes immersed in sulphate water having 5% of sodium sulphate (Na2SO4) by weight of water and those which are not immersed in sulphate water. The concrete cubes of 100mm size were cured and dried for one day were immersed in 5% Na2SO4.The concentration of sulphate water was maintained throughout the period.

Specimen	Age of concrete	Average increase in weight (%)
RGPC 0%	15 Days	2.21
	30 Days	1.45
RGPC 10%	15 Days	2.79
	30 Days	1.71

TABLE 7 SULPHATE ATTACK RESULTS

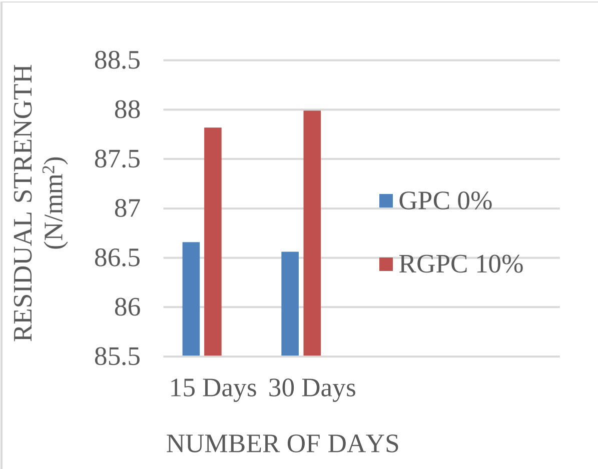


GRAPH 4 IINCREASE IN WEIGTH AFTER SULPHATE ATTACK

COMPRESSIVE STRENGTH AFTER SULPHATE ATTACK TEST

Specimen	Age of concrete	Average decrease in compressive strength (N/mm^2)	Average residual strength (N/mm^2)
RGPC 0%	15 Days	13.34	86.66
	30 Days	13.44	86.56
RGPC 10%	15 Days	12.18	87.82
	30 Days	12.01	87.99

TABLE 8 LOSS IN COMPRESSIVE STRENGTH AFTER SULPHATE ATTACK TEST



GRAPH 5 RESIDUAL STRENGTH AFTER SULPHATE ATTACK TEST

X SORPTIVITY

Sorptivity of concrete refers to the measure of the capacity of the material to absorb and transmit water or other fluids through capillary action. ASTM C 1585-13 code book is referred.

As per ASTM C1585-13

$S = I/\sqrt{t}$

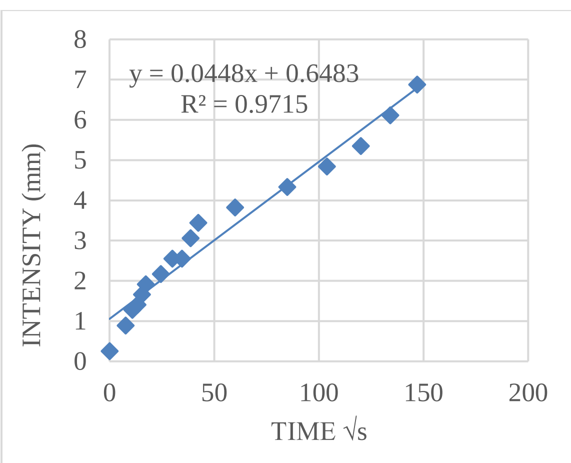
S= Sorptivity in mm

t = enlapsed time in minutes

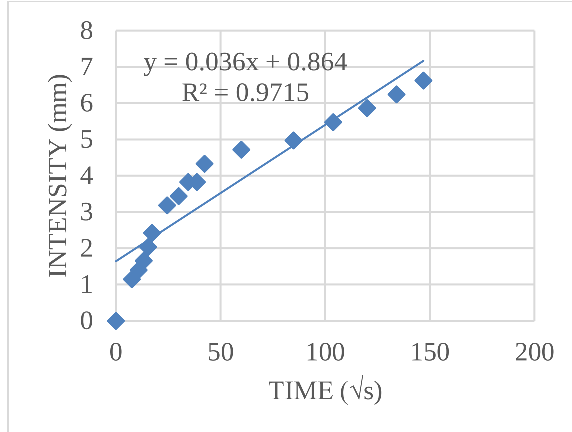
$I = \Delta w/Ad$

where, Δw= change in weight (W2-W1)

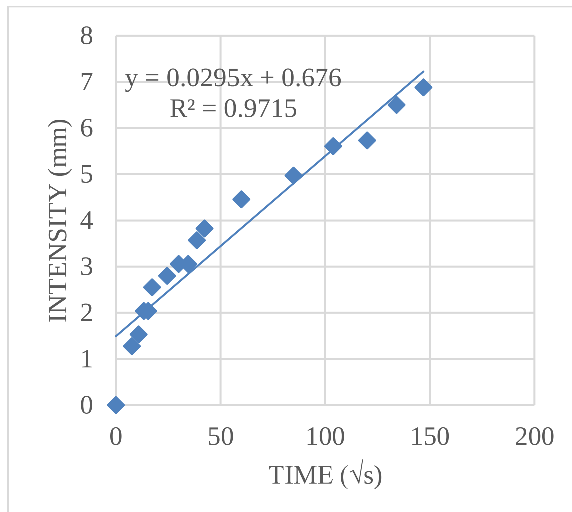
A= Surface area of the specimen through which the water penetrated, d= density of water



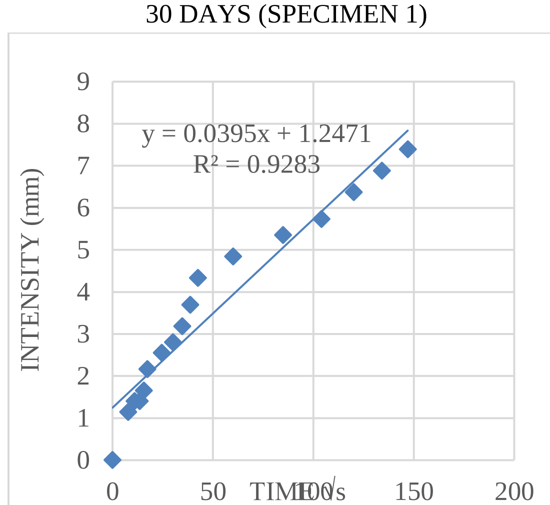
GRAPH 6 SORPTIVITY TEST FOR RGPC 0% AT 30 DAYS (SPECIMEN 1)



GRAPH 7 SORPTIVITY TEST FOR RGPC 0% AT 30 DAYS (SPECIMEN 2)



GRAPH 8 SORPTIVITY TEST FOR RGPC 10% AT 30 DAYS (SPECIMEN 1)

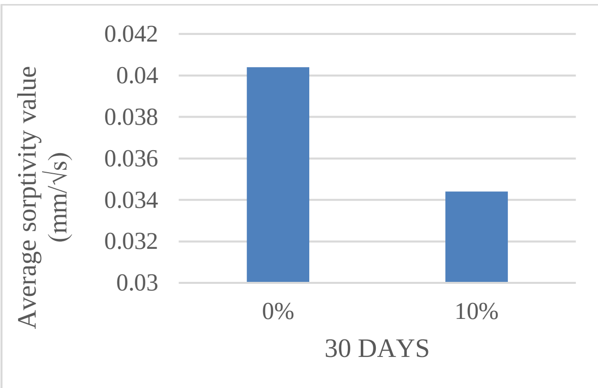


GRAPH 9 SORPTIVITY TEST FOR RGPC 10% AT 30 DAYS (SPECIMEN 2)

SORPTIVITY RESULTS AT 30 DAYS

PERCENTAGE (%)	Sorptivity value of specimen (1) (mm/√s)	Sorptivity value of specimen (2) (mm/√s)	Average sorptivity value (mm/√s)
0%	0.036	0.0448	0.0404
10%	0.0295	0.0394	0.0344

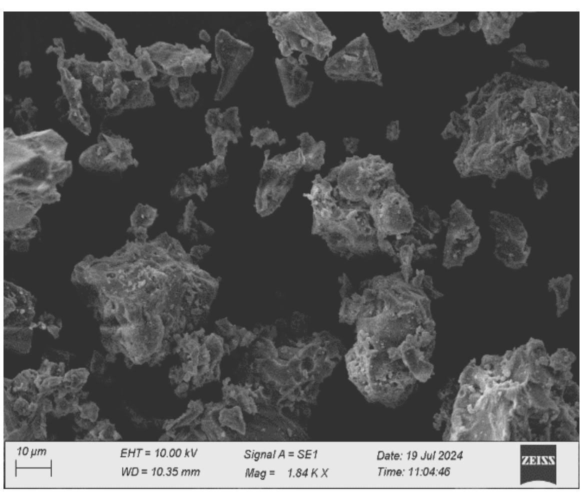
TABLE 9 SORPTIVITY RESULTS

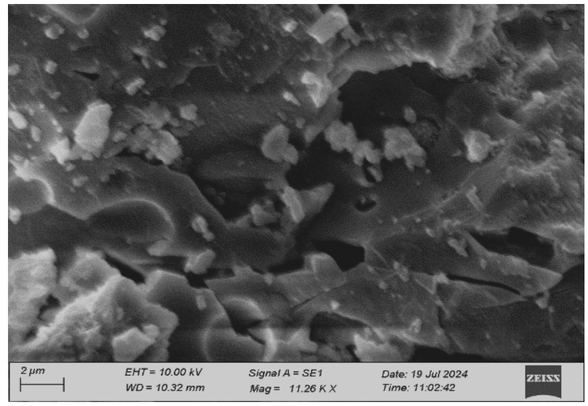


GRAPH 10 AVERAGE SORPTIVITY VAULES AT 30 DAYS

XI SEM ANALYSIS OF RGPC 0%

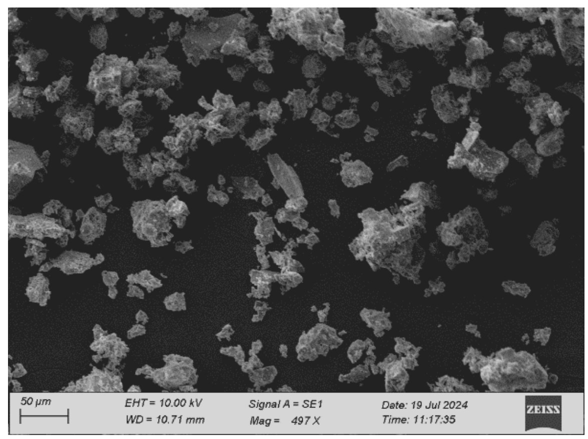
SEM, which stands for Scanning Electron Microscopy, is a powerful technique used in various scientific and industrial fields to examine the surface and the structure of materials at a micro and nanoscale level. High-resolution images show how the geopolymer gel envelops the aggregates and the extent of the physical interlocking.

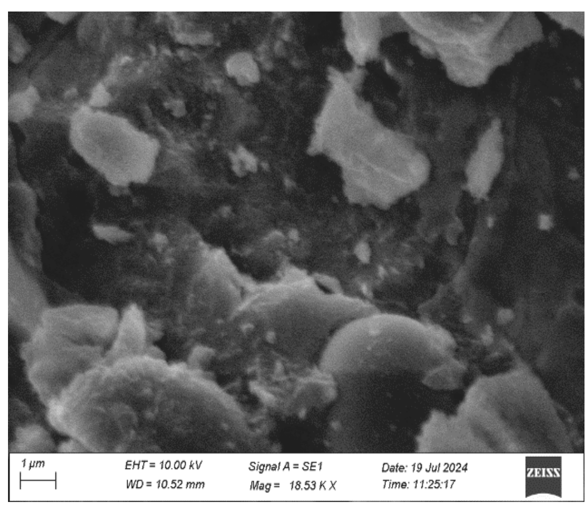




SEM ANALYSIS OF RGPC 10%

SEM image helps to study the Si- O-Al-O bond formation between the silica and the alumina material under a highly alkaline conditions. It also ensure the proper distribution of rubber crumb in concrete. Pre-treating the rubber crumbs enhanced the bonding in the interfacial transition zone.





XII CASTING OF PAVER BLOCKS

The paver blocks were casted as per IS 15658: 2006 code book. The specification of the paver block

- Shape : Hexagonal
- Side length : 120 mm
- Thickness of paver block : 60 mm

FIG.1 PAVER BLOCKS

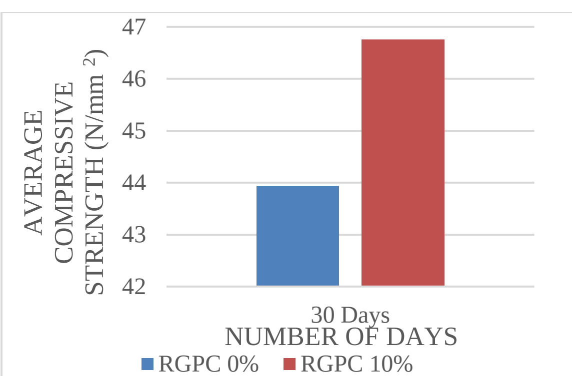
This paver block can be used in medium traffic roads, pedestrian ways and playground pathways.

XIII COMPRESSIVE STRENGTH TEST ON PAVER BLOCK

The compressive strength test for paver blocks are done as per the IS15658:2006 code book. The pavement was placed between two plates. The bottom was fixed and the top was allowed to compressive the pavement while applying the loads.

Specimen	Average compressive strength (N/mm^2)
RGPC 0%	43.9
RGPC 10%	46.75

TABLE 10 COMPRESSIVE STRENGTH OF PAVER BLOCKS



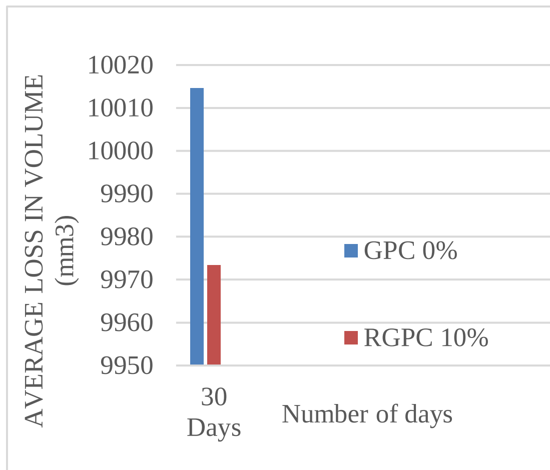
GRAPH 11 COMPRESSIVE STRENGTH

XIV ABRASION TEST FOR PAVER BLOCK

An abrasion test for paver blocks is a standardized procedure used to evaluate the resistance of paver blocks to surface wear caused by friction and mechanical action. The test simulates the wear and tear that the paver blocks will experience in real-life conditions, such as pedestrian traffic or vehicular movement.

The specimen for abrasion test were casted as a cube with the dimension of 70 mm x 70 mm x 60 mm

SPECIMEN	AVERAGE LOSS IN VOLUME (mm^3)
RGPC 0%	10014.6
RGPC 10%	9973.33

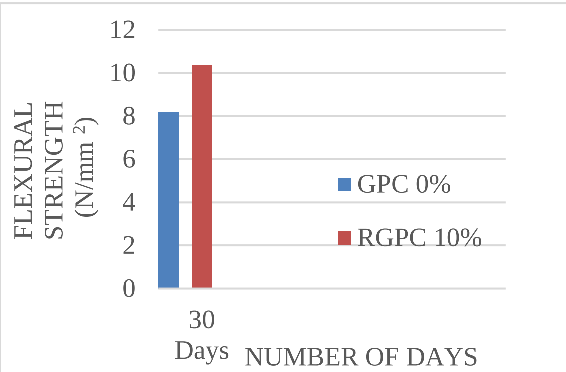


FLEXURAL STRENGTH TEST ON PAVER BLOCKS

The flexural strength on paver block were tested in universal testing machine under center point loading as per IS 15658:2006 code book.

FIG.2 CENTRE POINT LOADING

SPECIMEN	AVERAGE FLEXURAL STRENGTH (N/mm²)
RGPC 0%	8.19
RGPC 10%	10.36



CONCLUSION

The geopolymer concrete properties can be enhanced by considering the replacement of fine aggregate by 10% rubber crumbs and 1% of steel fibre. From the durability test results, the water absorption decreases in RGPC 10% when compared with RGPC 0% of about 31.51%. The specimen with 10% rubber crumb shows high compressive strength of about 2.76% than RGPC 0% after acid resistance test. The strength can be enhanced by treating the steel fiber with anti-corrosion coating like epoxy. Compared to RGPC 0% specimen, the RGPC 10% specimen shows high compressive strength of about 1.62%, than RGPC 0% after sulphate resistance test. From the sorptivity test results, the rate of absorption of RGPC 10% specimen is less than RGPC 0% of about 14.85%. From the abrasion test results, the loss of the volume in RGPC 10% paver block is less than the RGPC 0% of about 0.41%. Compared to RGPC 0% paver blocks, the compressive strength and flexural strength of RGPC 10% paver blocks have increased about 6.09% and 10.70%. The results conclude that geopolymer with 10% rubber crumb as replacement of fine aggregate and 1% steel fiber is more efficient than conventional geopolymer concrete. The bonding and the strength can be increased by using nano-silica materials. Since the geopolymer is made up of all earthy materials, the sisal fiber can be insisted of steel fiber and can be examined.

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