

An Experimental Study on Strength Improvement of Concrete Paver Blocks by Using Flyash, Glass Fiber and GGBS

G.Pragna¹, P.M.S.S.Kumar²

PG Scholar, Dept of Civil Engineering, Sanketika Institute of Technology and Management, P.M.Palem,
Visakhapatnam, Andhra Pradesh, India. ¹

Assistant Professor, Dept of Civil Engineering, Sanketika Institute of Technology and Management, P.M.Palem,
Visakhapatnam, Andhra Pradesh, India²

ABSTRACT: India is a developing country so here the construction of roadway and building plays an important role. Paver blocks are made from semi dry mixes of concrete with zero slump and stone chips lesser in size as compared to conventional concrete. The presently paver block is used in outdoor versatility application and also it is used in street road and other construction places. Paver block has low cost maintenance and easily replace with a newer one at the time of breakage. For improving strength and other parameter of paver block this study is necessary. In this project, compressive strength, flexural strength and water absorption of paver block were evaluated by replacing portion of cement with the flyash and GGBS in M30 grade concrete. Glass fibers were also included along with the fly ash and GGBS to determine the strength. Different proportions of glass fiber are added starting from 0.2% to 0.8% by weight of cement in the mix were added. The optimum fiber content from test results was found to be 0.4% by weight of cement. 15% to 60% by weight of cement was replaced with the fly ash. From the test results obtained the optimum fly ash and glass fiber content were found to be 30% and 0.4% respectively. Now 15% to 60% by weight of cement was replaced with the GGBS. From the test results obtained the optimum GGBS and glass fiber content were found to be 30% and 0.4% respectively. Cost analysis of paver block was done and was compared with conventional paver block. There was decrease in cost in replacement of cement with fly ash, GGBS respectively. The main objective of this project is to use waste products like fly ash, glass-fibre and GGBS for the production of Paver Block which will be useful in construction and makes eco-friendly.

KEYWORDS: Fly ash, Glass fibre, GGBS, strength parameter tests, cost optimization, Water Absorption test.

I. INTRODUCTION

Concrete block pavements (CBPs) are formed from individual solid blocks that fit closely next to one another to form a pavement surface. A typical CBP is placed on a thin bed of sand overlaying a sub base. CBP can be placed with a variety of shapes and patterns. There are joint spaces between blocks. These spaces are filled with sand having suitable grading. The blocks are restrained from two sides by edge restraints.

CPBs are manufactured from semi-dry mixes. During manufacturing process vibration and pressure is applied to the mix. By this process dense and strong CPB can be achieved to form strong and durable paving surfaces. Moreover interlocking behaviour of CBP gives the ability of spreading loads to larger areas.

CBP has several advantages they are available in different shapes, sizes, colour and patterns. So we can create beautiful pavements with more strength. Maintenance is very easy. Easily replaceable in very short time. Laying of paver blocks pavement has very less time. Before laying of road it gets its own strength by proper curing. Its life span is more. Easy to transport.

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The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labour. This limited use is largely due to the past experience formed when low strength cements and low quality admixtures were used as well as the restrictions imposed by standards. Therefore, in view of current concreting technologies and advances in materials production, there is a need to reform the negative impression, prevalent for a relatively longtime, to increase the use of admixtures in construction.

II. MATERIALS USED

Materials introduction

The materials that are adopted in this study are fly ash, glass fiber, GGBS, cement, fine aggregate, coarse aggregate and super plasticizer. The sources and properties of these materials described in below.

FLY ASH

Fly ash is a group of materials that can vary significantly in composition. It is residue left from burning coal, which is collected on an electrostatic precipitator or in a baghouse. It mixes with flue gases that result when powdered coal is used to produce electric power. Fly ash is purchased from National Thermal Power Corporation (NTPC) limited Visakhapatnam.



Fig 1. Fly Ash

Physical Requirement of Fly Ash

Physical requirement of fly ash		
Specific gravity	2.25	
	Requirement guide of fly ash	
	F	C
Fineness specific surface in kg-m ²	320	250
Lime reactivity	4.5	3.0
Compressive strength at 28 day in N/mm ² ,min	Not less than 80% of strength of corresponding plain cement mortar cubes	

GLASS FIBRE

Glass fiber (or glass fibre) is a material consisting of numerous extremely fine fibbers of glass. Glass fiber is formed when thin strands of silica-based or other formulation glass are extruded into many fibers with small diameters suitable. Alkali resistant E Glass fibres were used and the properties of glass fibres were shown in table

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Property	Diameter(μm)	Specific gravity	Failure strain	Elasticity(GPa)	Tensile strength(GPa)
Value	12	2.6	3%	80	2.5



Fig 2. Glass Fiber

GROUND GRANULATED BLAST FURNACE SLAG

Ground Granulated Blast furnace Slag (GGBS) is a by-product from the blast furnaces used to make iron.

Chemical Composition of GGBS

- Calcium oxide = 40%
- Silica = 35%
- Alumina = 13%
- Magnesia = 8%

It is a granular product with very limited crystal formation, is highly cementitious in nature and, ground to cement fineness, and hydrates like Portland cement.

Typical physical properties:-

- Colour: off white
- Specific gravity: 2.9
- Bulk density: 1200 Kg/m³
- Fineness: 350 m²/kg



Fig 3. GGBS

CEMENT

Cement Ordinary Portland cement (OPC) of 53 grade conforming to IS: 12269-1999 was used for casting the paver blocks. Physical properties of OPC were given in table.

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Physical properties of OPC

Property	Value
Ordinary Portland cement (OPC) of 53 grade conforming to IS: 12269-1999 specific gravity	3.15
Consistency limit	33%
Initial setting time	140 minutes
Final setting time	310 minutes



Fig 4. Cement

COARSE AGGREGATES

Locally available crushed coarse aggregates of nominal size 10mm were used in this work. Physical properties of coarse aggregates used were given in the following table.

Property	Water absorption value	Specific gravity of aggregates	Aggregate impact value	Aggregate crushing value	Flakiness index	Elongation index
Value	0.45%	2.66	26%	27%	8%	9%



Fig 5. Coarse aggregate

FINE AGGREGATES

The sources of fine aggregates for paving blocks are river sand or, alternatively, artificial sand by crushing rocks. Fine aggregates were used conforming to IS 383 2002. Locally available sand conforming to IS Zone-II and specific gravity 2.66 was used as fine aggregate in the present experimental study for the production of paver blocks. Gradation details of fine aggregate were given in the table.

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Grading of fine aggregate

Sieve size in mm	Percent by weight of sand passing the sieve	Remarks
10	100	Conforms to grading ISO zone II, Fineness modulus= 3.034
4.75	90.1	
2.36	76.9	
1.18	62.2	
0.6	42.2	
0.3	16.2	
0.15	6	



Fig 6. Fine Aggregate

ADMIXTURE

A water reducing admixture, Sikament FF in liquid form was used in concrete. It has a relative density of 1.25 and pH range of 8-1

III. MIX PROPORTION

In this study, control mix S was designed as per IS 15658-2006 for M30 grade. Glass fibers are initially added in fractions of 0.2% to 0.8% by weight of cement. Optimum glass fiber content was obtained and then fly ash was replaced for cement in percentages of 15 to 60. . Optimum glass fiber content was obtained and then GGBS was replaced for cement in percentages of 15 to 60. The details of the mix proportions are given in the following table.

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Materials	Cement kg/m ³	Fine aggregate(k g/m ³)	Coarse aggregate(k g/m ³)	Water (litres)	Sikament FF(kg/m ³)	Glass fibre (% w of cement)	Fly ash (kg/m ³)	GGBS (kg/m ³)
Mix ID's								
S	364.23	748.15	1332.00	142.05	1.82	0%	0	0
S _f 0.2	364.23	748.15	1332.00	142.05	1.82	0.2%	0	0
S _f 0.4	364.23	748.15	1332.00	142.05	1.82	0.4%	0	0
S _f 0.6	364.23	748.15	1332.00	142.05	1.82	0.6%	0	0
S _f 0.8	364.23	748.15	1332.00	142.05	1.82	0.8%	0	0
S _{ffa} 15	309.60	748.15	1332.00	142.05	1.82	0.4%	54.63	0
S _{ffa} 30	254.96	748.15	1332.00	142.05	1.82	0.4%	109.27	0
S _{ffa} 45	200.33	748.15	1332.00	142.05	1.82	0.4%	163.90	0
S _{ffa} 60	145.69	748.15	1332.00	142.05	1.82	0.4%	218.54	0
S _{fg} 15	309.60	748.15	1332.00	142.05	1.82	0.4%	0	54.63
S _{fg} 30	254.96	748.15	1332.00	142.05	1.82	0.4%	0	109.27
S _{fg} 45	200.33	748.15	1332.00	142.05	1.82	0.4%	0	163.90
S _{fg} 60	145.69	748.15	1332.00	142.05	1.82	0.4%	0	218.54

IV. EXPERIMENTAL PROGRAM

Experimental program carried out includes the methodology and testing procedures of paver blocks by using glass fibers, fly ash and GGBS.

Paver blocks were casted for conventional mix, then Glass fibers were also included along with the fly ash and GGBS to determine the strength. Different proportions of glass fiber are added starting from 0.2% to 0.8% by weight of cement in the mix were added. 15% to 60% by weight of cement was replaced with the fly ash by keeping glass fiber content constant. Now 15% to 60% by weight of cement was replaced with the GGBS.

Mix Design

All the concrete mixes in the project are prepared As per IS: 10262-2009 the concrete mixes are prepared in this project.

Testing Data

Specific gravity of cement=3.15

Specific gravity of sand =2.69

Specific gravity of aggregate=2.66

Specific gravity of chemical admixture =0.32

Zone of sand =II

Mix proportion Grade – M30

Type of cement used – OPC 53 grade conforming to IS 12269-1987

Mix-proportions

Cement = 364.23kg/m³

Water = 142.05 litres

Fine aggregate = 748.15 kg/m³

Coarse aggregate = 1332 kg/m³

Chemical admixture = 1.82 kg/m³

Water-cement ratio = 0.39

Ratio of cement: fine aggregate: coarse aggregate is 1:2.05:3.66

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Experiments

Following test procedures are conducted in this paver block experiment.

- Compressive strength test
- Flexural strength test
- Water absorption test

1. Compressive strength test:

Compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate. After preparing and curing of the specimen, it placed in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast. Align the specimen centrally on the base plate of the machine. Rotate the movable portion gently by hand so that it touches the top surface of the specimen. Apply the load gradually without shock and continuously at the rate of 140kg/cm²/minute till the specimen fails. Record the maximum load and note any unusual features in the type of failure. Minimum three specimens should be tested at each selected age. If strength of any specimen varies by more than 15 per cent of average strength, results of such specimen should be rejected. Average of these specimens gives the crushing strength of concrete.



Fig.7. Loading test specimen for compressive strength test on UTM

2. Flexural strength test:

The bed of the testing machine shall be provided with two steel rollers. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints. The distance between the outer rollers (i.e. span) shall be 3d and the distance between the inner rollers shall be d. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.

The load shall be applied at a rate of loading of 180 kg/min for the 10.0 cm specimens.

Calculation

The Flexural Strength or modulus of rupture (**fb**) is given by

$$fb = pl/bd^2 \quad (\text{when } a > 20.0\text{cm for } 15.0\text{cm specimen or } > 13.0\text{cm for } 10\text{cm specimen})$$

or

$$fb = 3pa/bd^2 \quad (\text{when } a < 20.0\text{cm but } > 17.0 \text{ for } 15.0\text{cm specimen or } < 13.3 \text{ cm but } > 11.0\text{cm for } 10.0\text{cm specimen.})$$

Where,

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a = the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen

b = width of specimen (cm)

d = failure point depth (cm)

l = supported length (cm)

p = max. Load (kg)



Fig.8. Loading specimen for flexural strength test on UTM

3. Water absorption test:

One of the most important properties of a good quality concrete is low permeability, especially one resistant to freezing and thawing. A concrete with low permeability resists ingress of water and is not as susceptible to freezing and thawing. Water enters pores in the cement paste and even in the aggregate. For concrete pavers, the test procedure involves drying a specimen to a constant weight, weighing it, immersing it in water for specified amount of time, and weighing it again. The increase in weight as a percentage of the original weight is expressed as its absorption (in percent).

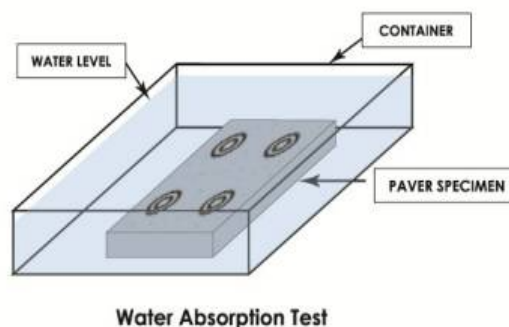


Fig.9. Water Absorption test

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Formula used is Water absorption = $[(A - B)/B] \times 100\%$.

Where A= weight of saturated surface dried sample in gms

B=weight of oven dried sample in gms.

V. RESULTS AND DISCUSSIONS

Designation of paver blocks:

Name	Description
S	Standard paver block
S _f 0.2	S+ 0.2% glass fibers
S _f 0.4	S+ 0.4% glass fibers
S _f 0.6	S+ 0.6% glass fibers
S _f 0.8	S+ 0.8% glass fibers
S _{ffa} 15	S+15% cement replacement with fly ash +0.4% glass fibers
S _{ffa} 30	S+30 % cement replacement with fly ash + 0.4% glass fibers
S _{ffa} 45	S+45 % cement replacement with fly ash + 0.4% glass fibers
S _{ffa} 60	S+60% cement replacement with fly ash + 0.4% glass fibers
S _{fg} 15	S+15 % cement replacement with GGBS + 0.4% glass fibers
S _{fg} 30	S+30 % cement replacement with GGBS + 0.4% glass fibers
S _{fg} 45	S+45 % cement replacement with GGBS + 0.4% glass fibers
S _{fg} 60	S+60 % cement replacement with GGBS + 0.4% glass fibers

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1. Test results of Glass fiber Paver blocks: Compressive strength test:

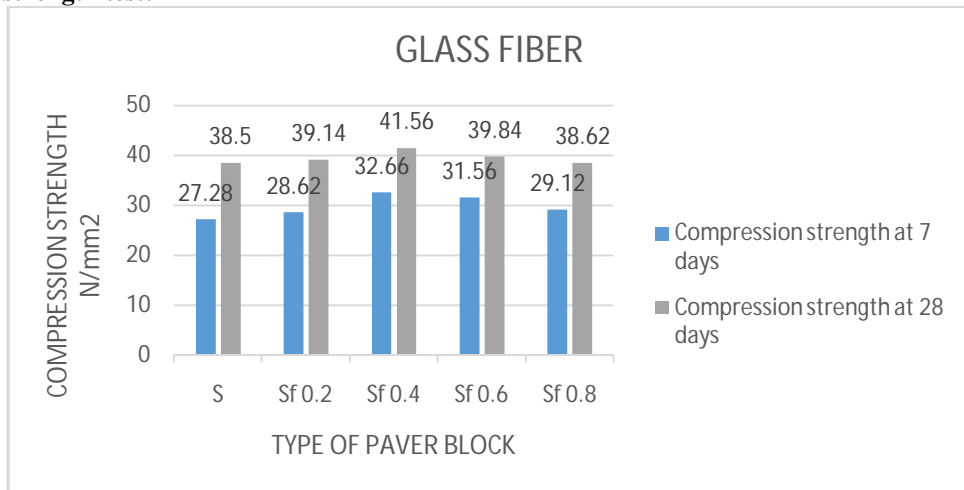


Fig.10 Compressive strength at 7 & 28 days

Fig.10 shows the variation of compressive strength at the age of 7 & 28 days for normal, 0.2%, 0.4%, 0.6% and 0.8% glass fiber addition. There is an increase of 19.72% in compressive strength at 0.4% glass fiber addition compared to normal paver block at 7 days. There is an increase of 7.5% in compressive strength at 0.4% glass fiber addition compared to normal paver block at 28 days. Optimum content of glass fibers occurs at 0.4% by weight of cement.

Flexural strength test:

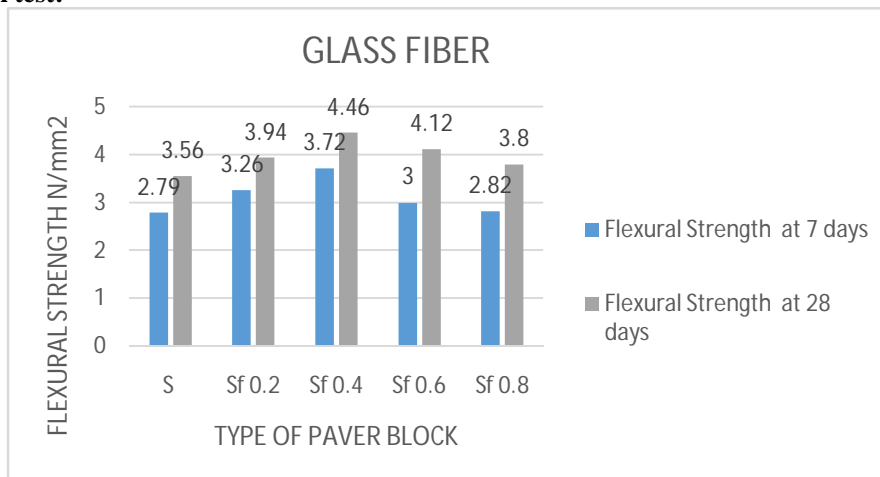


Fig.11 Flexural strength variation at 7 & 28 days

Fig.11 shows the variation of Flexural strength at the age of 7 & 28 days for normal, 0.2%, 0.4%, 0.6% and 0.8% glass fiber addition. There is an increase of 35.77% in Flexural strength at 0.4% glass fiber addition compared to normal paver block at 7 days. There is an increase of 25.28% in Flexural strength at 0.4% glass fiber addition compared to normal paver block at 28 days. Optimum content of glass fibers occurs at 0.4% by weight of cement.

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Water absorption test:

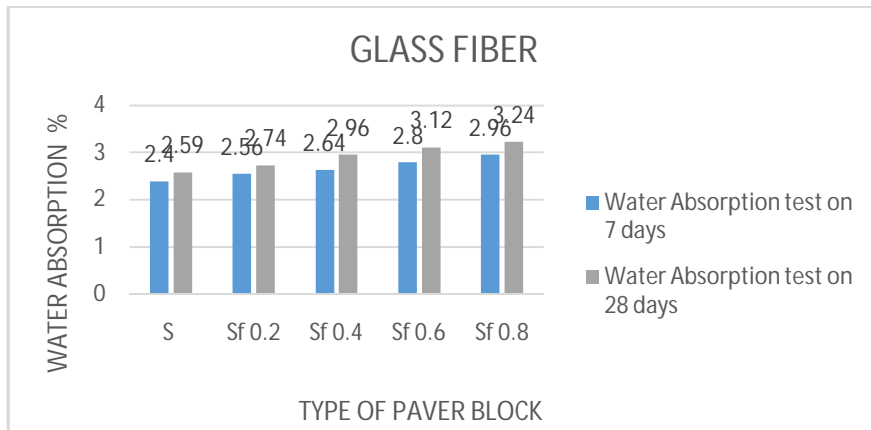


Fig. 12 Water absorption variation at 7 & 28 days

Fig. 12 shows the variation of Water absorption at the age of 7 & 28 days for normal, 0.2%, 0.4%, 0.6% and 0.8% glass fiber addition. There is an increase of 16.67% in Water absorption at 0.4% glass fiber addition compared to normal paver block at 7 days. There is an increase of 20.46% in Water absorption at 0.4% glass fiber addition compared to normal paver block at 28 days. Optimum content of glass fibers occurs at 0.4% by weight of cement.

2. Test Results of Fly ash and glass fiber Paver blocks

Compressive strength test:

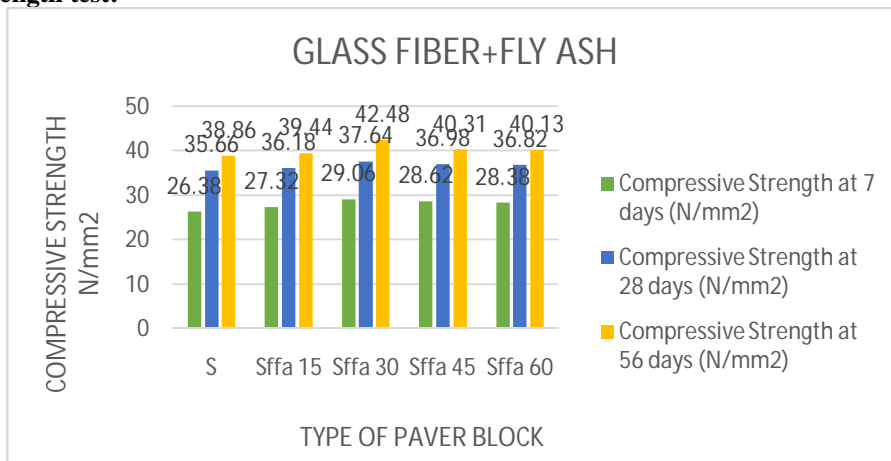


Fig. 13 Compressive strength variation at 7, 28 & 56 days

Fig. 13 shows the variation of compressive strength at the age of 7, 28 & 56 days for normal, 15%, 30%, 45%, and 60% cement replacement with fly ash along with optimum fiber addition i.e. 0.4%. There is an increase of 10.16% in compressive strength at 30% of fly ash replaced by cement compared to normal paver block at 7 days. There is an increase of 5.55% in compressive strength 30% of fly ash replaced by cement compared to normal paver block at 28 days. There is an increase of 11.09% in compressive strength 30% of fly ash replaced by cement compared to normal paver block at 56 days. The optimum combination of glass fiber and fly ash at 0.4% and 30% by weight of cement.

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Flexural strength test:

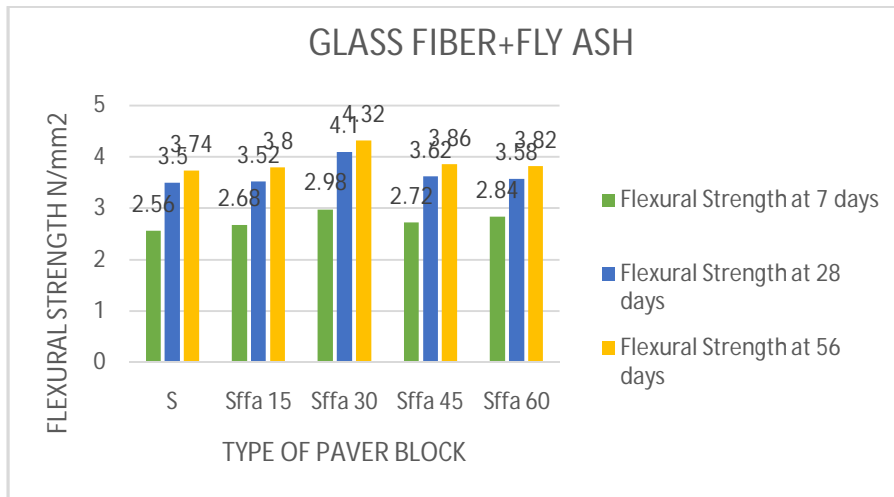


Fig.14. Flexural strength variation at 7, 28 & 56 days

Fig.14 shows the variation of compressive strength at the age of 7, 28 & 56 days for normal, 15%, 30%, 45%, and 60% cement replacement with fly ash along with optimum fiber addition i.e. 0.4%. There is an increase of 16.40% in flexural strength at 30% of fly ash replaced by cement compared to normal paver block at 7 days. There is an increase of 17.14% in flexural strength 30% of fly ash replaced by cement compared to normal paver block at 28 days. There is an increase of 15.50% in flexural strength 30% of fly ash replaced by cement compared to normal paver block at 56 days. The optimum combination of glass fiber and fly ash at 0.4% and 30% by weight of cement.

Water absorption test:

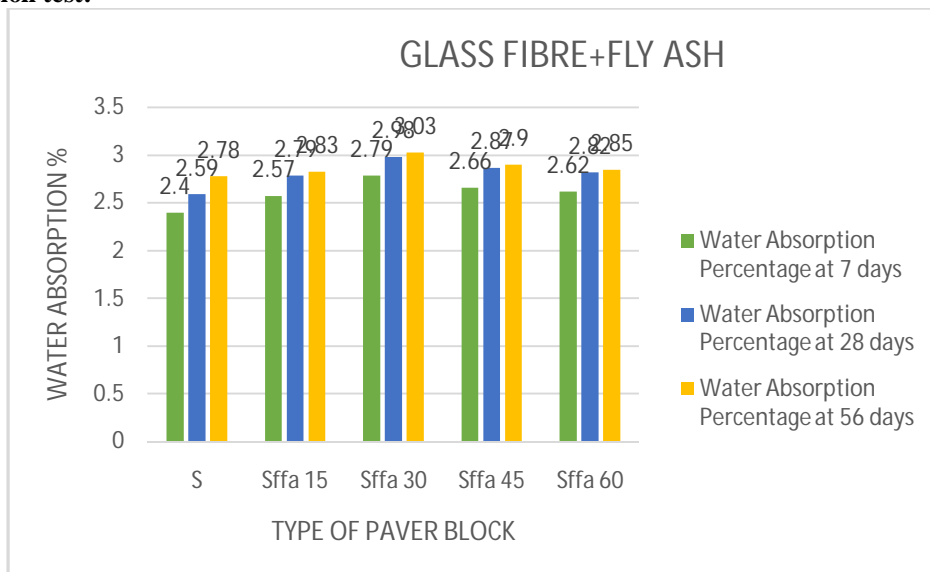


Fig.15 Water absorption variation at 7, 28 & 56 days

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Fig.15 shows the variation of water absorption at the age of 7, 28 & 56 days for normal, 15%, 30%, 45%, and 60% cement replacement with fly ash along with optimum fiberaddition i.e. 0.4%. There is an increase of 16.25% in water absorption at 30% of fly ash replaced by cement compared to normal paver block at 7 days. There is an increase of 15.06% in water absorption 30% of fly ash replaced by cement compared to normal paver block at 28 days. There is an increase of 8.99% in water absorption 30% of fly ash replaced by cement compared to normal paver block at 56 days. The optimum combination of glass fiber and flyash at 0.4% and 30% by weight of cement.

3. Test Results of paver blocks with GGBS and glass fibers Compressive strength test:

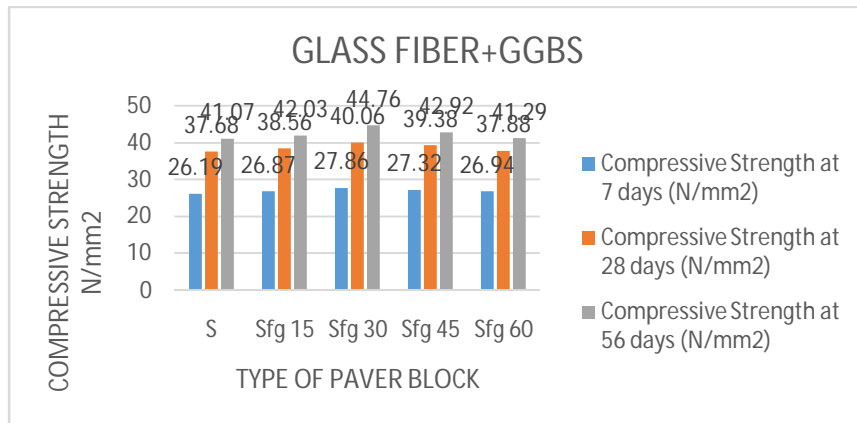


Fig.16 Compressive strength variation at 7, 28&56 days

Fig.16 shows the variation of compressive strength at the age of 7, 28 & 56 days for normal, 15%, 30%, 45%, and 60% cement replacement with GGBS along with optimum fiberaddition i.e. 0.4%. There is an increase of 6.37% in compressive strength at 30% of GGBS replaced by cement compared to normal paver block at 7 days. There is an increase of 6.31% in compressive strength 30% of GGBS replaced by cement compared to normal paver block at 28 days. There is an increase of 11.50% in compressive strength 30% of GGBS replaced by cement compared to normal paver block at 56 days. The optimum combination of glass fiber and GGBS at 0.4% and 30% by weight of cement.

Flexural strength test:

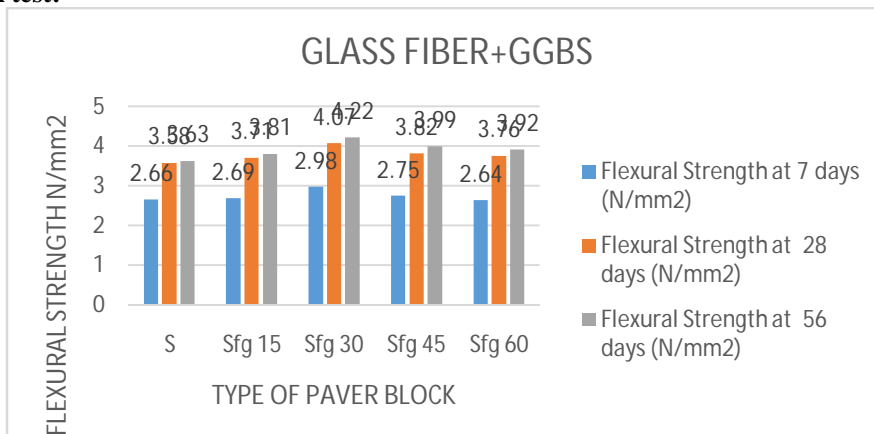


Fig.17 Flexural strength variation at 7, 28&56 days with GGBS

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Fig.17 shows the variation of compressive strength at the age of 7, 28 & 56 days for normal, 15%, 30%, 45%, and 60% cement replacement with GGBS along with optimum fiber addition i.e. 0.4%. There is an increase of 12.03% in flexural strength at 30% of GGBS replaced by cement compared to normal paver block at 7 days. There is an increase of 13.69% in flexural strength 30% GGBS of replaced by cement compared to normal paver block at 28 days. There is an increase of 16.25% in flexural strength 30% of GGBS replaced by cement compared to normal paver block at 56 days. The optimum combination of glass fiber and GGBS at 0.4% and 30% by weight of cement.

Water absorption test:

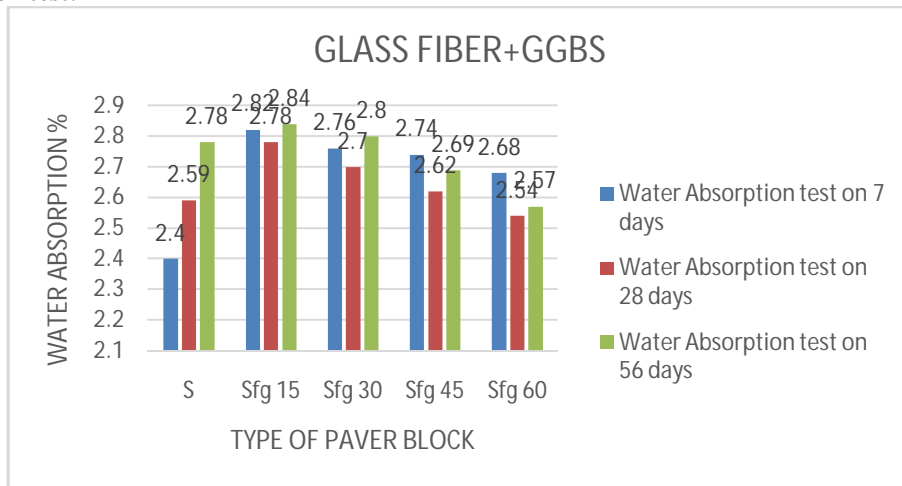


Fig.18 Water absorption variation at 7,28& 56 days

Fig.18 shows the variation of water absorption at the age of 7, 28 & 56 days for normal, 15%, 30%, 45%, and 60% cement replacement with GGBS along with optimum fiber addition i.e. 0.4%. There is an increase of 17.50% in water absorption at 30% of GGBS replaced by cement compared to normal paver block at 7 days. There is an increase of 7.30% in water absorption 30% of GGBS replaced by cement compared to normal paver block at 28 days. There is an increase of 2.16% in water absorption 30% of GGBS replaced by cement compared to normal paver block at 56 days. The optimum combination of glass fiber and GGBS at 0.4% and 30% by weight of cement.

Cost Evaluation

Cost details of materials used

S.No	Materials	Cost (Rs/Kg)
1	Cement	7.60
2	Sand	0.80
3	Quarry dust	0.40
4	Coarse aggregate	1.20
5	Dolomite powder	1.40
6	Sikament FF	82
7	Glass fibre	150
8	GGBS	1.5

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Cost details of Paver blocks

S.No	Type of paver block	Cost per unit (Rs)	Cost per unit meter(Rs)
1	S	9.82	5115
2	S _f 0.2	10.03	5224
3	S _f 0.4	10.24	5334
4	S _f 0.6	10.44	5442
5	S _f 0.8	10.65	5551
6	S _{ffa} 15	9.59	4995
7	S _{ffa} 30	8.94	4656
8	S _{ffa} 45	8.29	4318
9	S _{ffa} 60	7.64	3979
10	S _{fg} 15	9.60	5000
11	S _{fg} 30	8.96	4667
12	S _{fg} 45	8.32	4334
13	S _{fg} 60	7.68	4001

Table indicates that the cost of paver block increases with increase in glass fiber content. On replacement of cement with GGBS and fly ash mix the decrease in cost can be observed. There was an increase of 4.27% in cost at 0.4% addition of fibres. On replacement of cement with 30% fly ash along with addition of 0.4% fiber it is observed that there is decrease in cost by 9.80% compared to conventional paver block. On replacement of cement with 30% GGBS along with addition of 0.4% fiber it is observed that there is decrease in cost by 9.64% compared to conventional paver block.

VI. CONCLUSIONS

1. By the addition of glass fiber and optimum content of fiber of 0.4% by weight of cement the compressive strength and flexural strength of paver blocks increases.
2. There was an increase of 7.95% in compressive strength and 25.28% increase in flexural strength compared to conventional paver block at 28 dayson addition of 0.4% glass fibers.
3. There was an increase of 11.09% in compressive strength, 15.50% increase in flexural strength and 8.99% increase in water absorption compared to conventional paver block at 56 dayson addition of 0.4% glass fiberson 30% replacement of cement with fly ash.
4. There was an increase of 11.50% in compressive strength, 16.25% increase in flexural strength and 2.16% increase in water absorption compared to conventional paver block at 56 dayson addition of 0.4% glass fiberson 30% replacement of cement with GGBS.
5. On replacement of cement with 30% fly ash and 30% GGBS mix along with addition of 0.4% fibre it was observed that there was decrease in cost by 9.80% and 9.64% for each unit compared to conventional paver block.
6. Combined effect of GGBS and fly ash and glass fibres resulted in enhancement of strength properties with simultaneous decrease in cost, making the paver block economical.
7. In this study by using of combination of fibers and mineral admixtures in paver blocks makes increase in properties and decrease in cost and makes eco-friendly.

FUTURE SCOPE:

1. Tests can be continuing by mixing different proportions for strength optimization.
2. Only limited objectives analysed in a practical way to get comparison.
3. This project may extended to some more biopolymer mix for strengthening the paver blocks.

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