International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 5, Issue 1, pp: (125-133), Month: April - September 2017, Available at: www.researchpublish.com

Strength Evaluation of Pre-Cast Concrete Paver Block, Using Steel Slag & Pet Fibres

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Abstract: **The main aim of this study is to evaluate the performance of concrete paving block where steel slag was used as a partial replacement of fine aggregate with addition of waste PET fibres in different proportions. The performance was evaluated in term of effect on compressive strength, flexural strength of Steel slag and PET fibre reinforced concrete. The standard zigzag type 60mm thick paver blocks were casted and tested. Laboratory experimentation was carried out to analyze the performance of M35 grade of concrete.**

Keywords: **Concrete paver blocks, Steel slag, PET fibre, Compressive strength and Flexural strength.**

I. INTRODUCTION

Interlocking concrete pavements are special Dry mix precast piece of concrete, commonly used in exterior landscaping pavement applications. Concrete paving blocks are ideal materials on the footpaths for easy laying, better look and finish. Interlocking paver blocks are installed over a compacted stone sub base and leveling bed of sand. Concrete paver blocks are made with concrete basically consisting of cement, fine Aggregates, coarse aggregates (10 mm and below), water, chemical pigments, etc. Overall performance of concrete paver blocks is mainly depending upon properties of materials, water cement ratio, mixing process and curing process.

There is a growing interest to increase the basic properties of concrete by using waste materials as alternative aggregate materials. This type of use of a waste material can solve problems of lack of aggregate in various construction sites and reduce environmental problems related to aggregate mining and waste disposal. The use of many different materials as aggregate substitutes such as coal ash, blast furnace slag and steel slag aggregate. Slag is a by-product generated during manufacturing of pig iron and steel. Primarily, the slag consists of limestone (CaO) and silica (SiO2). Other components of blast furnace slag include alumina oxide (Al2O3) and magnesium oxide (MgO), as well as a small amount of sulfur (S), while steelmaking slag contains iron oxide (FeO) and magnesium oxide (MgO) .

In other hand the Plastics consumption now in days have become an integral part of our lives. The amounts of plastics consumed annually have been increasing steadily. There are several factors that contribute to the growth of plastics consumption such as low density, fabrication capabilities, long life, lightweight, and low cost of production. Due to this only in India approximately 40 million tons of solid waste is Produced annually. This is increasing at a rate of 1.5 to 2% every year. Plastics constitute 12.3% of total waste produced most of which is from discarded water PET bottles. The PET bottles cannot be disposed of by dumping or burning, as they produce uncontrolled fire or contaminate the soil and vegetation. For easy consume of PET waste, it can be used as a substitute of polypropylene fibres in concrete. PET is polyethylene terephthalate. It is a plastic resin and the most common type of polyester. Two monomers modified ethylene glycol and purified terephthalic acid, are combined to form the polymer called polyethylene terephthalate. The properties of concrete are mainly affected by its ingredients. Concrete is strong in compression but weak in tension and brittle one. The ductility of concrete can be increase by reinforcing with fibers. The fibers act as micro crack arrester in cement composites. Many commercial fibers like steel, carbon, glass etc. are available for reinforcing the concrete. The research in developing fiber reinforced concrete is ongoing process. The cheap fibers obtained from waste materials may be used for manufacture of cement composites. It reduces cost of concrete and solves somewhat waste disposal problems.

The aim of this study is to evaluate the performance of concrete paving block where steel slag will be used as a partial replacement of fine aggregate with addition of waste PET fibres in different proportions. The performance will be evaluated in term of effect on compressive strength, flexural strength, of SS (steel slag) and PET fibre reinforced concrete.

II. MATERIALS USED AND CASTING

Cement: -Portland pozzolana cement (Fly ash based) was used. JK cement from a single lot was used throughout the course of the investigation. The physical properties of the cement as determined from various test Conforming to Indian Standard IS: 1489-1991.

Coarse aggregate: - Locally available Crushed stones size between ≤ 12 mm was used in this work. The crushed aggregates tend to improve the strength because of interlocking of angular particles, while rounded aggregates improved the flow because of lower internal friction. The aggregates were tested as per IS: 383-1970.

Fine Aggregates: - Crushed stone coarse sand confirming to IS 383-1970 was used as fine aggregate. The sand was sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm. It was conformed to grading zone II and grey in color. Sieve analysis and physical properties of fine aggregate were tested as per IS: 383-1970.

Steel Slag: - Steel slag was taken from the nearby Iron and steel making industry located at Batala Punjab. It was black and grey in colour.

Plastic fibres: - Fibre is used in the construction industry as a secondary reinforcement which arrest micro cracks, increase strength and resistance to abrasion. The post consumed PET mineral water bottles were collected and the fibers were cut after removing the neck and bottom of the bottle. The length of fibers was kept 18-20 mm and the breadth was 1 mm to 2mm.

Water: - Generally, water that is suitable for drinking is satisfactory for use in concrete. As per IS: 456-2000 potable water is considered satisfactory for mixing and curing of concrete.

The material testing is done in laboratory as per recommendation of IS Code -383-1970, IS Code-8112-1989, IS Code 2386 (part 1-8) etc.

Mix design: - The M35 mix design was calculated according to IS 10262:2009 and IS 15658:2006. As per table 1 of IS15658:2006, for light-traffic the grade Designation of paver blocks is M35 and recommended minimum thickness for M35 is 60mm. The percentage share of steel slag and pet fibre reinforcement in each mix are shown in Table 1 and 2.

Table 1: Mix Proportion detail

Mix Proportion		
	Ratio	**kg/m3**
Cement Content	1	493
Fine Aggregates Content	1.69	835
Coarse Aggregates Content	1.88	927
Water	0.40	185

Table 2- Details of Mix ID

Mix ID	**Cement**	**Steel slag**	**Fine Agg.**	**Coarse Agg.**	**Pet fibres (by wt of cement)**
MIX1	100	0	100	100	0
MIX2	100	0	100	100	0.5
MIX3	100	0	100	100	1
MIX4	100	25	75	100	0
MIX5	100	50	50	100	0
MIX6	100	25	75	100	0.5
MIX7	100	25	75	100	1
MIX8	100	50	50	100	0.5
MIX9	100	50	50	100	1

Preparations of concrete paver blocks: - Standard zigzag type moulds having size 245×120×60mm were used for paver blocks. All mould were cleaned and oiled from inner surfaces. Then the moulds were filled and compacted as per standard procedures. The moulds were open manually with the help of spanner after 24 hours of casting.

Table 3- The numbers of samples used for each concrete mix are shown in table below

Type of test	Thickness of paver block	Total No. of block	No. of blocks for 7 days testing	No. of blocks for 28 days testing	Remarks
Compressive strength	60mm	6	3	3	6*9=54
Flexural strength	60mm	3	-	3	3*9=27
	TOTAL	9			81

III. EXPERIMENTAL PROGRAMME

Compressive Strength Test: - The Zigzag shape test specimens of size 245× 120× 60 mm were prepared for testing the compressive strength concrete. In compression testing machine there was a separate arrangement for testing the concrete paver block, which was equipped with two steel bearing blocks for holding the specimen. Alternatively, 4 mm thick plywood sheets of size larger than the specimens by a margin of at least 5 mm from all edges of the specimen were used for capping the specimens. The concrete mixes with varying percentage of steel slag and pet fibres were cast into paver blocks mould for subsequent testing. These tests were carried out in accordance with IS 15658:2006 and IS: 516-1959. The compressive strength test was conducted at curing ages of 7-days and 28 days. The compressive strength test results of all the mixes and different curing ages are shown in Table 4.

Table 4: Compressive Strength Values for various Concrete Mix

Mix ID	Cement	Steel slag	Fine Agg	Coarse Agg.	Pet fibres (by wt of cement)	Compressive Strength (N/mm^2)	
						7 days	28 days
MIX1	100	0	100	100	0	36.66	45.80
MIX2	100	0	100	100	0.5	44.59	51.54
MIX3	100	0	100	100	1	40.85	47.32
MIX4	100	25	75	100	0	42.27	49.20
MIX5	100	50	50	100	0	37.68	46.24
MIX6	100	25	75	100	0.5	47.04	54.52
MIX7	100	25	75	100	1	43.57	49.41
MIX8	100	50	50	100	0.5	44.48	50.04
MIX9	100	50	50	100	1	39.59	47.02

***Flexural strength*: -** This test was conducted on 245 x 120 x 60mm zigzag type paver block specimens. Tests were carried out in accordance with IS 15658:2006 and IS: 516-1959 on Compression Testing machine. The apparatus used for the test was the same as in compressive strength test with some modifications. The results of the flexural strength of controlled mix (M1X1) and mix containing steel slag and pet fibres (M1X2 to MIX9) cured at 28 days are presented in Table 5.

Table 5: Flexural strength Values for various Concrete Mix

Mix ID	Cement	Steel slag	Fine Agg.	Coarse Agg.	Pet fibres (by wt of cement)	Flexural strength (N/mm^2) 28 days
MIX1	100	0	100	100	0	3.23
MIX2	100	0	100	100	0.5	4.29
MIX3	100	0	100	100	1	4.10
MIX4	100	25	75	100	0	4.16
MIX5	100	50	50	100	0	3.94
MIX6	100	25	75	100	0.5	4.75
MIX7	100	25	75	100	1	4.24
MIX8	100	50	50	100	0.5	4.26
MIX9	100	50	50	100	1	4.01

IV. RESULTS AND DISCUSSION

In compressive strength test, there was maximum increase of 28.31% and 19.03% strength of concrete paver blocks by using 25% steel slag and 0.5% pet fibre reinforcement after 7 and 28 days of curing. The compressive strength was also increased up to 12.53%, 3.31%, and 7.42% 0.96% by using 0.5%, 1% pet fibre and 25%, 50% steel slag after 28 days respectively, shown in figure 1 to 5.

While combine use of steel slag and pet fibre reinforcement, there was increase of compressive strength up to 7.88%, 9.25%, and 2.66% with using 1% pet fibre-25% steel slag, 0.5%-50% and 1%-50% after 28 days respectively. The 25% replacement of steel slag with sand and 0.5% pet fibre reinforcement addition in concrete shown better result in both combine and separate cases. The use of steel slag and pet fibre reinforcement was also beneficial in flexural strength of concrete paver blocks up to certain limit. The maximum increase of 47.05% flexural strength by using 25% steel slag and 0.5% pet fibre reinforcement after 28 days of curing.

The large amount of flexural strength was increased up to 32.81%26.93%, and 28.79%, 21.98% by using 0.5%, 1% pet fibre and 25%, 50% steel slag respectively, shown in fig 5 to10. During combined use of steel slag and pet fibre reinforcement, there was increased in flexural strength of 31.26%, 31.88%, and 24.14% by using 1% pet fibre-25% steel slag, 0.5%-50% and 1%-50% respectively. The combination of 0.5% pet fibre and 25% steel slag gave optimum results for both, Compressive strength and flexural strength. This may be attributed to better interlocking effect of PET fibers reinforcement, to arresting micro cracks at initial stage.

In Both cases it was found that after certain limit, the compressive strength and flexural strength were decreases due to use of more percentage of steel slag and pet fibre reinforcement, whether it was use as combine or separate form. The reason behind that, the steel slag aggregates were replaced with the sand. The reduction of strength after 25% replacement of steel slag with sand due to sub angular shape of the aggregate and the bonding region or interfacial transition zone (ITZ) in concrete is going to weak. At the macroscopic level, there is two reaction of hydration, one is cement-slag-water and second is between slag and water. In lower replacement level here is not any serious effect in reaction of hydration, after increase the dose of steel slag, the requirement of water for hydration is also increased.

- **Compressive strength for various Concrete Mixes (7 and 28 days) in graphically form**

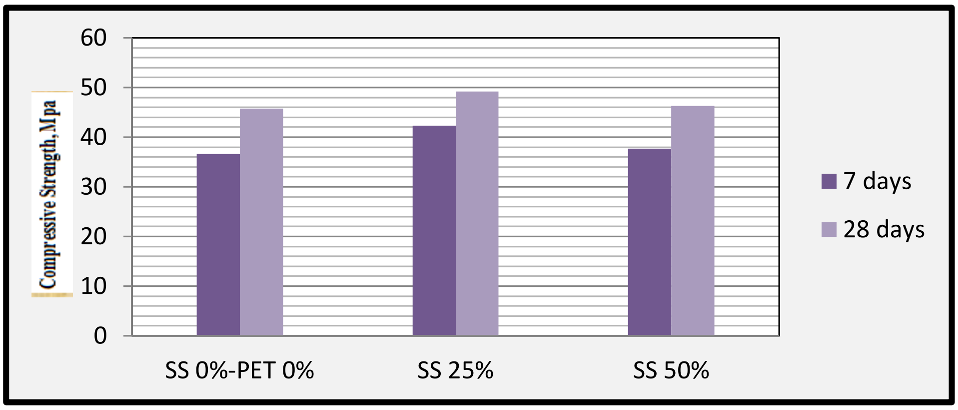

Fig1: Ordinary concrete vs steel slag concrete

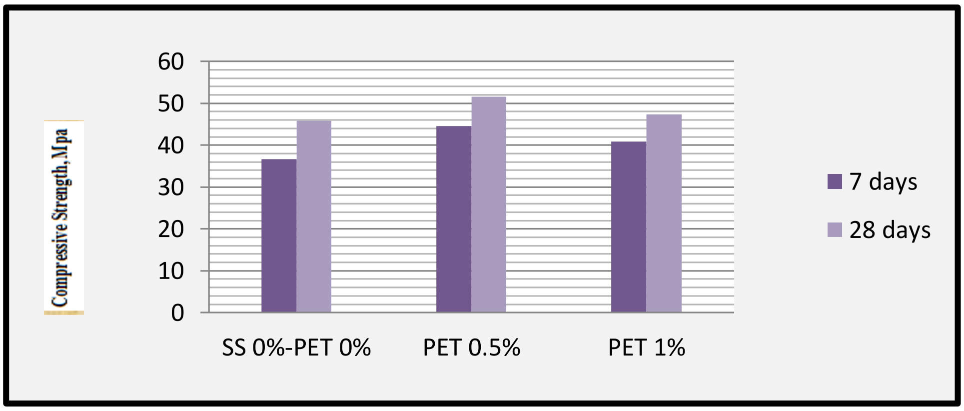

Fig2: Ordinary concrete vs Pet fibre reinforced concrete

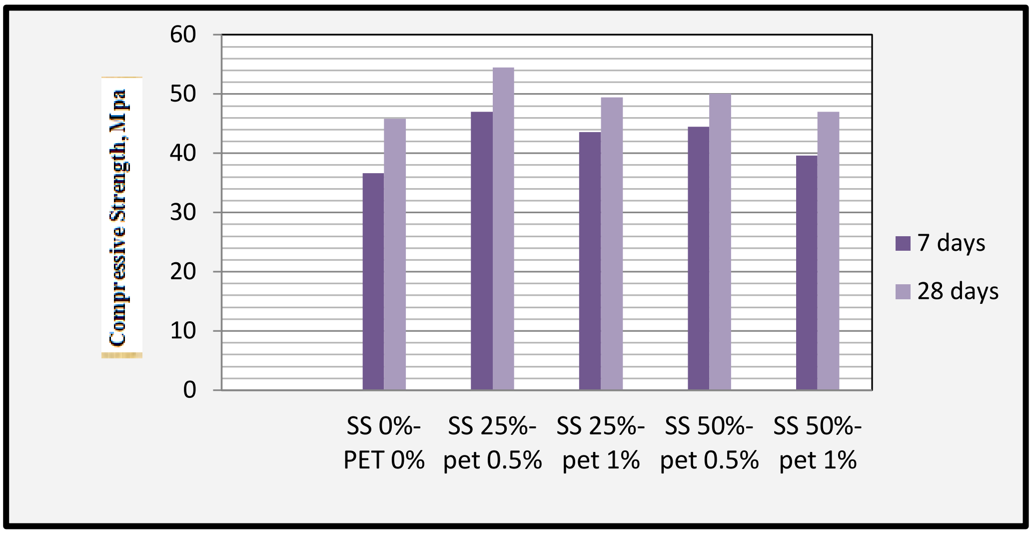

Fig3: Ordinary concrete vs steel slag and Pet fibre reinforced concrete

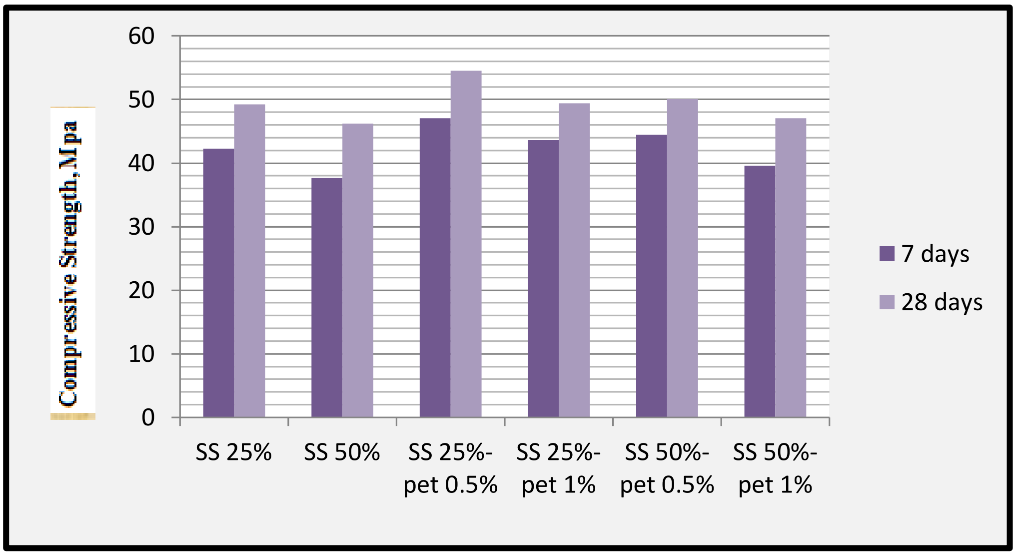

Fig4: Steel slag concrete vs Steel slag and Pet fibre reinforced concrete

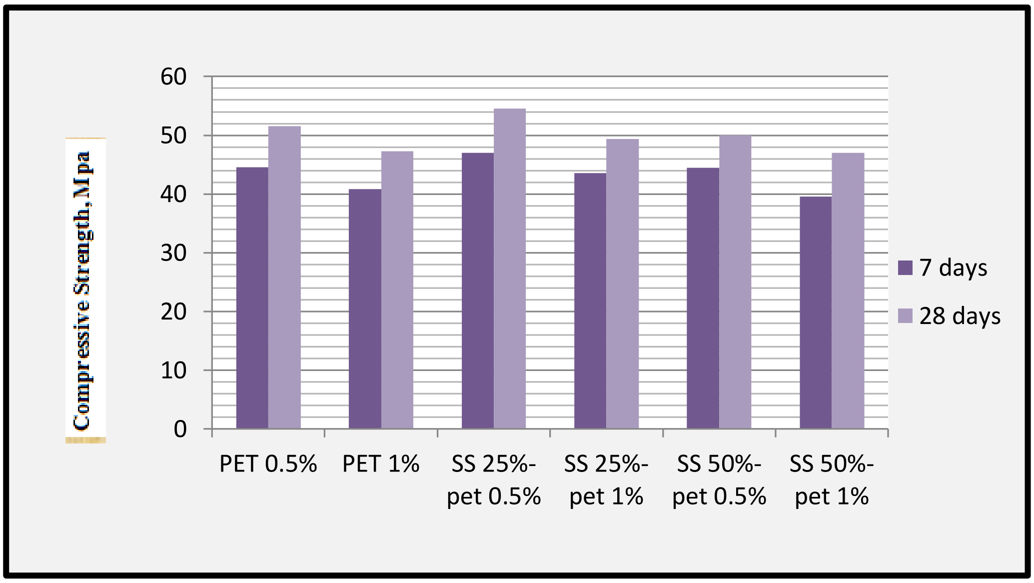

Fig5: Pet fibre reinforced concrete vs Steel slag and Pet fibre reinforced concrete

- **Flexural strength for various Concrete Mixes (28 days) in graphically form**

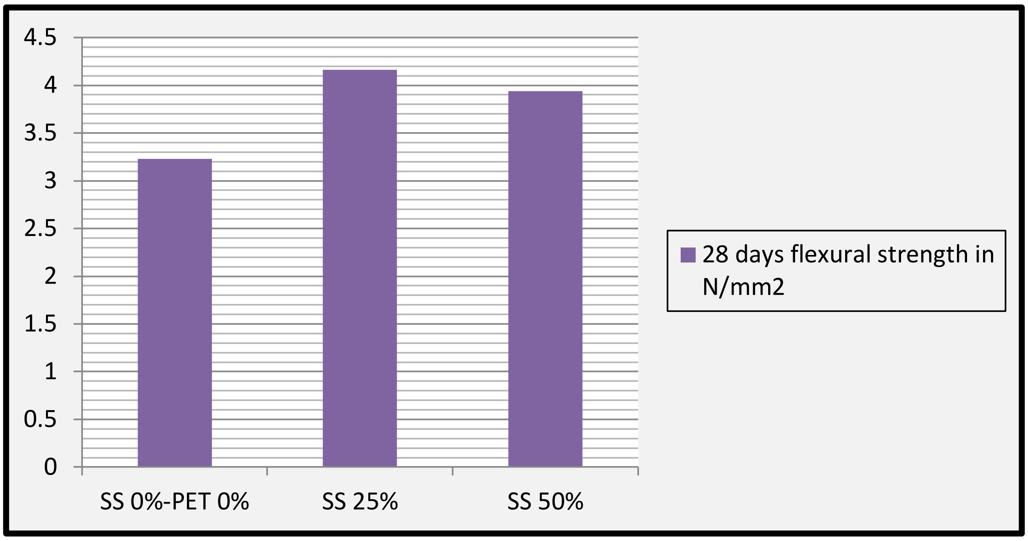

Fig6: Ordinary concrete vs steel slag concrete

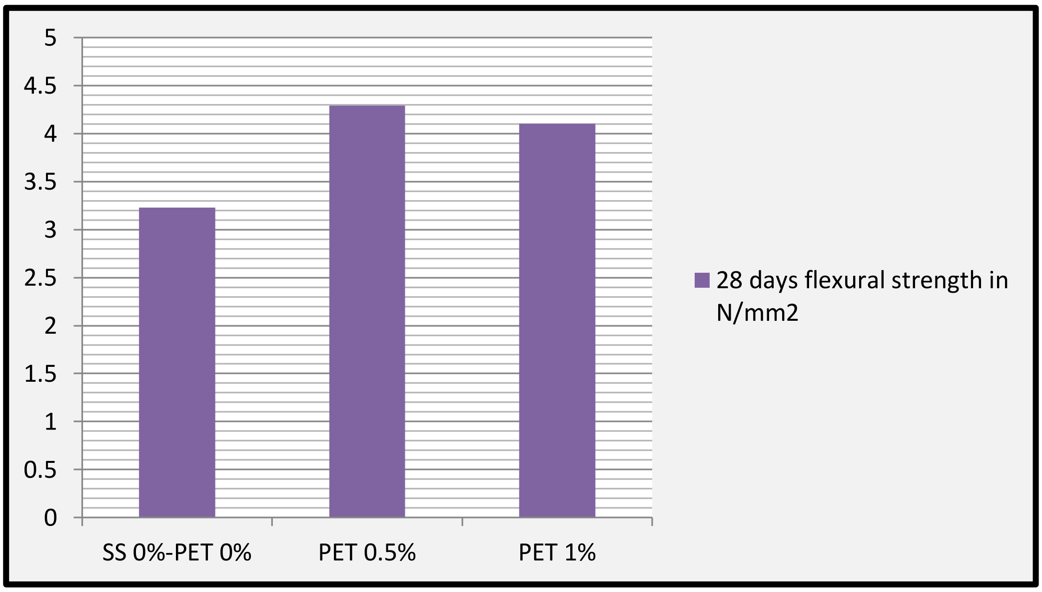

Fig7: Ordinary concrete vs Pet fibre reinforced concrete

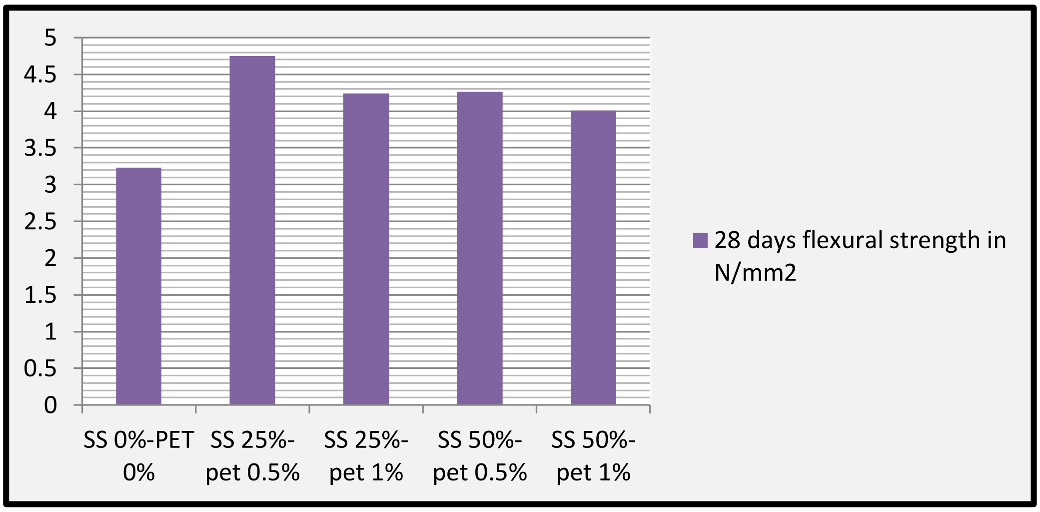

Fig8: Ordinary concrete vs steel slag and Pet fibre reinforced concrete

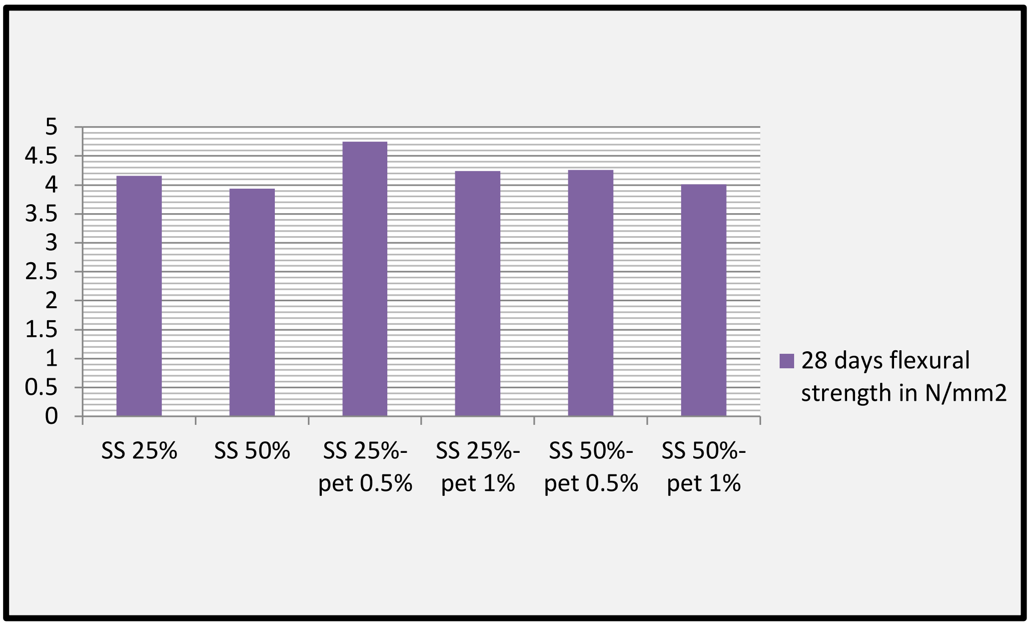

Fig9: Steel slag concrete vs Steel slag and Pet fibre reinforced concrete

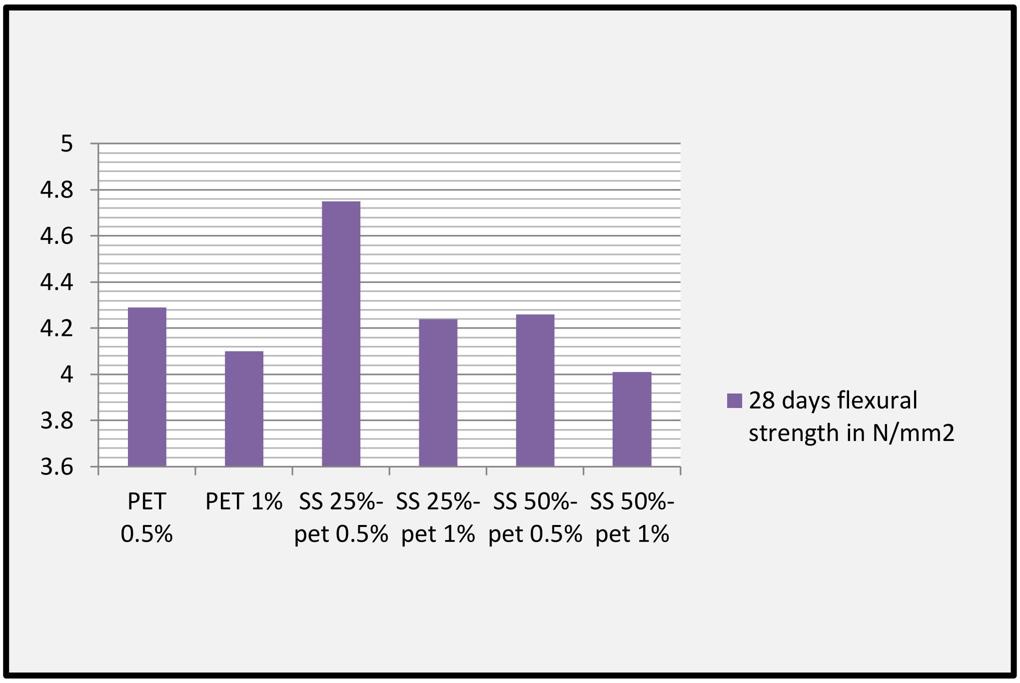

Fig10: Pet fibre reinforced concrete vs Steel slag and Pet fibre reinforced concrete

V. CONCLUSION

1. There was maximum increase of 19.03% in compressive strength of concrete paver blocks by using 25% steel slag and 0.5% pet fibre reinforcement.

2. The maximum increase of 47.05% flexural strength by using 25% steel slag and 0.5% pet fibre reinforcement was observed.

3. The combination of 0.5% pet fibre and 25% steel slag gave optimum results for both, Compressive strength and flexural strength.

4. On increasing the percentage of pet fibre from 0.5 to 1% and steel slag from 25 to 50%, the strength was decreased for both, Compressive strength and flexural strength.

VI. FUTURE SCOPE OF STUDY

The present study leaves scope for the technologists to further study the following aspects:-

1) Other more different shapes of concrete paver blocks can be analyzed by same study procedure.

2) Higher grades or lower grades of concrete can be analyzed by same study procedure.

3) Higher thickness or lower thickness of concrete paver blocks can be analyzed by same study procedure.

4) Effect of admixtures with use of same study can be analyzed.

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