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Performance Evaluation of Environmentally Sustainable Precast Cement Concrete Paver Blocks Using Fly Ash and Addition of Polypropylene Fibre

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Abstract
The paver blocks are manufactured from zero slump plain concrete is a small element used for outdoor applications and flexible road surfaces. Depending upon the traffic intensity these are fabricated with various thicknesses, dimensions and shapes to meet with the requirement of variousapplications.In the present study M30 grade paver blocks with thickness 60mm and 80mm with replacement of OPC by 30% fly ash and addition of polypropylene fibre @ 0.0% to 0.5% with increment of 0.1% by weight of cement have been manufactured to access the suitability for Indian road surfaces for different applications. The blocks have been tested at the age 7 and 28 days for strength and durability criteria. For strength properties compressive strength and flexural strength test were conducted, both being important for applications for road surfacing.
The result of compressive strength and flexural strength indicates that it is feasible to use OPC replaced by 30% fly ash and addition of 0.3% PPF in manufacturing of paver blocks. Paver blocks have attained target compressive strength and flexural strength at 28 days in all the grades. The present study is important for paver block manufacturers as it meets the objectives such as mix design, strength and durability requirements for Indian roads associated with utilization of waste material fly ash. Also, the study will help the nation economy for 20% level in future, along with sustainability of virgin materials.

Key Word-Polypropylene fibre, Fly ash, Compressive Strength, Flexural Strength, Paver block, water absorption.

Introduction

Precast cement concrete paver blocks are solid, unreinforced products made out of cement concrete of low water-cement ratio. These are made in varied dimensions with different grades of concrete to fulfil the need of diversified traffic environmental conditions. The paver blocks are manufactured from concrete composite comprising of cement, water, aggregates and super plasticizer, which are available locally everywhere in country. Pavers blocks are pre-fabricated in the factory using press/vibrating table system before their actual use. These are used in surface layer of pavements, urban and semi urban roads, village roads, streets, foot paths, gardens, passengers waiting sheds, petrol pumps bus stops, platforms, industry, etc. Precast paver blocks are ideal materials for pavements and footpaths along roadside where a lot of face lift is being given owing to easy laying, better look, easy to repair and ready to move after laying. Paver blocks are economical as they do not break and these have 100% salvage value in case of replacement. The term precast means that the blocks are manufactured and hardened before laying and are brought to job site. The paver blocks are manufactured in such a fashion that these interlock with each other during laying to maintain structural strength.

Pavements surface using blocks are made by using individual interlocking paver blocks by installing one to another. These are laid on prepared sub grade with sand bed below bounded by edge restraints from both sides. The blocks are laid in proper bond with joints in between to have structural stability. These joints are filled with sand of suitable grading. The interlocking mechanism of concrete block pavement provides sufficient area for load spreading. Concrete block pavements have certain advantages over asphalt and concrete pavements. The general advantages are maintenance, operational, structural, aesthetics and economical. A well-constructed interlocking pavement provides better performance. The use of fly ash in concrete paver blocks as part replacement of Portland cement is with the objective to reduce cement particulate content and hence heat of hydration which results in economy and durability enhancement. It will also help in energy saving in cement production. It is a good option for safe disposal of fly ash which is a waste from electric power generation plants. The advancement in industrialization worldwide, the production of electricity has increased manifold which has resulted into availability of large amount of fly ash at thermal power plants whose safe disposal is a burden. The utilization of fly ash in manufacturing of paver blocks will provide relief for safe and economic disposal of fly ash.
Cement concrete is strong under compressive loads at the same time it is inherently poor under tensile stresses. It is of brittle nature so it is not advisable to make paver blocks from concrete of such nature. The material for paver blocks has to be ductile. Thus to make concrete ductile, polypropylene fibres are added in small proportions during manufacturing of paver blocks to encounter the impact and flexural stresses which are inevitable on road surface during running of traffic. The micro crack formation in concrete at early stage due to plastic shrinkage may also be addressed with the addition of polypropylene fibres.

2. Objectives

1. To prepare design mix for zero slump concrete composite for manufacture of paver block M30 grade designation of thickness 60 mm and 80 mm by replacing OPC with 30% fly ash and adding PPF @0.1%, 0.2%, 0.3%, 0.4% and 0.5% in each grade.
2. To test the strength properties of hardened paver blocks for various design mixes i.e. compressive strength and flexural strength at 07 and 28days of age.
3. To establish optimum dosage of PPF addition in manufacturing of paver blocks with 30% fly ash.
4. To study cost effectiveness of paver block with optimum dosage of polypropylene fiber.

3. Literature Review

Chamundeswari et al. carried out study on concrete replacing OPC by C class fly ash @ 50%, 55% and 60% and adding PPF @ 0.9% in all the mixes of M35 grade and found that better compressive strength was obtained at 50% level of replacement. Gummadi et al. evaluated flexural strength of fly ash polypropylene composite by varying concentration of fly ash @ 0%, 10%, 15%, 20% and 25% by weight and reported that strength of the composite increases up to 10% level for smaller size particles of 53-75µm.Kashiyani et al. studied the water absorption of interlocking concrete paver blocks by adding polypropylene fiber@ 0.1%, 0.2%, 0.3%, 0.4% and 0.5% and found that water absorption reduces up to 0.4%. and studied the strength of interlocking concrete paver blocks by adding polypropylene fiber in the ratio of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% by weight and found 0.4% PPF addition for maximum flexural strength. Naraganti et al. evaluated flexural strength of M30 grade concrete adding sisal and PP fiber @ 0.5%, 1.0%, 1.25% and 1.50% by volume of concrete of 12 mm length. The strength increases with age in both the cases and the maximum flexural strength was obtained at 1.50% in both cases separately. Shrivastava and Bajaj, studied high volume fly ash concrete of M20, M50 and M70 grade, replacing OPC by fly ash @ 35%, 50% and 70% and reported that maximum flexural strength was attained at 35% replacement level with 12% saving in cost. Karasava et al. studied concrete for manufacture of paver blocks by replacing fine aggregate with fly ash @0%, 25% and 40% by weight and concluded that flexural strength of 6 MPa at 7 days satisfied the target value.

4. Experimental Program

a) Methodology for the Present Study

The flow chart shown in Figure 1. depicts the detailed methodology for the present study.

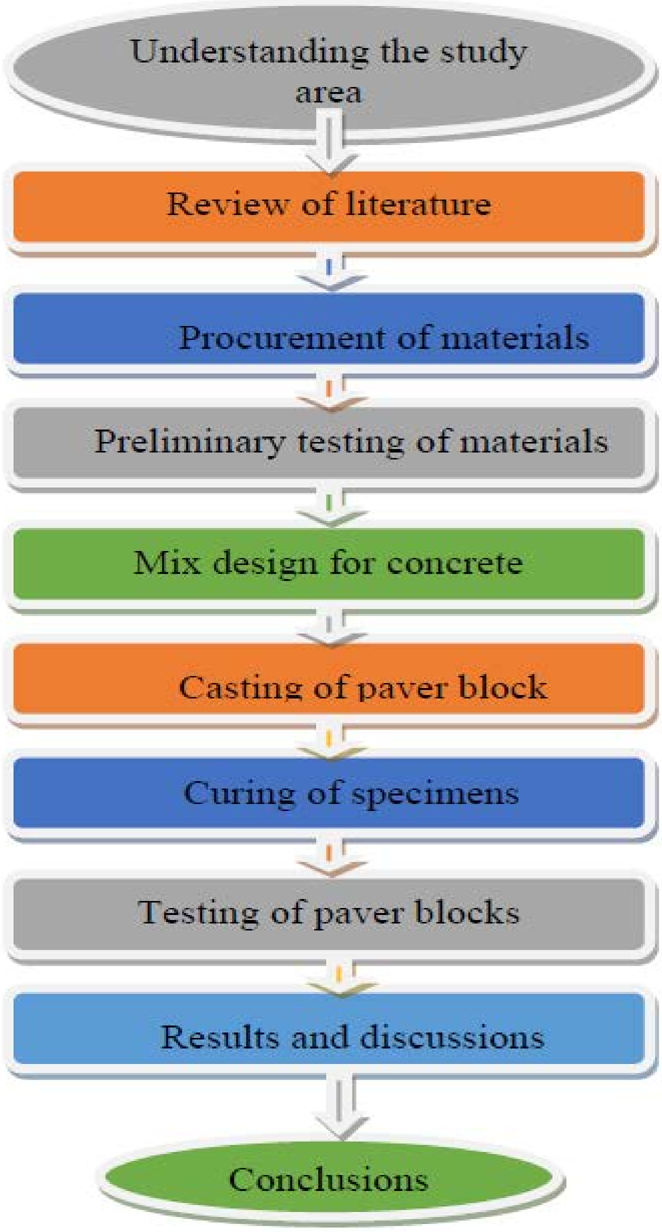

Figure 1: Methodology for present study.

5. Materials Used

a) Ordinary Portland cement (OPC)

Cement is a finely ground material which possess adhesive and cohesive properties. It is obtained by burning a mixture of argillaceous and calcareous materials at high temperature of about 145ºC as per Neville et.al. The Portland cement has mainly three grades, namely OPC33 grade,OPC43 grade andOPC53grade.The classification of cement is attained on the basis of the strength of cement at 28 days as per Aggarwal ei.al. Cement acts as a binder in production of paver block. In this research, 43 grade OPC procured from local market of Patna conforming to IS: 8112 has been used. The results obtained for the physical properties are given in Table1.

Table 1: Physical properties of OPC 43 grade.

Physical property	Observed results
Normal consistency (%)	30
Initial setting time (minute)	94
Final setting time (minute)	245
Fineness (using 90 µm IS sieve) (%)	6
Soundness (mm)	2.0
Specific gravity	3.15
Compressive strength (N/mm^2) 03days 07days 28days	25 35.5 44.5

b)Coarse Aggregates(CA)

The aggregates most of which are retained on4.75 mm IS sieve are known as coarse aggregates. These can be crushed or uncrushed gravel. In the present research stone cursed aggregates has been used of maximum nominal size 10 mm procured from local market, maihar, M.P. The coarse aggregates tested according to IS: 2386. Test results of sieve analysis and physical properties of coarse aggregates.

Table 2: Physical properties of coarse aggregates.

Properties	Results
Bulk density (loose) kg/m^3	1440
Specific gravity	2.63
Water absorption (%)	0.48
Impact value (%)	14
Abrasion value (%)	19

c) Fine Aggregate(FA)

Natural river sand or Artificial sand (stone crushed sand) with fraction passing 4.75 mm IS sieve are called fine aggregates. The river sand procured from son river, Satna (M.P.)conforming to IS: 383 has been used for the present research. The sand has been tested as per IS: 2386. The test results of the sieve analysis and physical properties observed of fine aggregates.

Table 3: Physical properties of fine aggregates.

Properties	Observed values
Bulk density (loose)kg/m^3	1567
Specific gravity	2.57
Water absorption (%)	0.60

Fly ash is used in various sectors. One such sector is concrete manufacture. The fly ash concrete results in poor early strength and long term good strength. It has low heat of hydration. It fills the voids of concrete resulting in more durable concrete products and thus increases the life of product. In the present study, the fly ash has been procured fromVijay tiles, khramseda satna, M.P.

Table 4: Physical properties of fly ash.

Sr. No.	Property	Observed value
01.	Specific gravity	2.08
02.	Class	F-type

d) Chemical Admixture (Super Plasticizer)

Paving blocks are manufactured from semi-dry concrete which have poor flow under vibration. Use of chemical admixture improves workability as per Concrete Institute. Midrand. BASF Master Glenium SKY 8233 super-plasticizer based on Polycarboxylic Ether (PCE) chemical admixture has been used for manufacture of cement concrete interlocking paver blocks. It complies with IS: 9103 BASF Master Glenium SKY 8233 procured from local market Govindpura J.K Road, Bhopal

e) Water

Potable tap water was used for casting and curing of paver blocks. The water confirms to the requirements of IS: 456.

f) Polypropylene(PP)

The polypropylene has been used in the form of polypropylene fibre (PPF) of Suppliers Real door & Frame, Supplier Company is located in Industrial area Govinpura J.K Road, Bhopal. The brand name of PPF is Recron 3s. Standard dosage of 125gm/50 kg bag of cement is recommended by the manufacturer. The required quantity of PPF is soaked in water for a minute and then this water added to concrete batch and mix, to get excellent dispersion. The specifications of Recron 3s supplied by the suppliers.

Table 5: Specifications of Recron 3s.

Property	Value
Cut length	12 mm
Shape of fiber	Triangular
Specific gravity	0.91
Effective diameter	25-40 micron
Tensile strength	4000-6000 kg/cm^2
Melting point	165^o C
Dosage rate	125gm/50 kg cement

Source: Real door & Frame

Figure 2: Polypropylene fibre.

Table 6: Mix design of M30 grade concrete with 30% fly ash and varying % of PPF.

Mix ID	Cementitious material		Water	Fine aggregate	Coarse aggregate	SP	PPF
	Cement	**Fly ash**					
kg/m^3							
M30F30P0.0%	**269**	**116**	**152**	**953**	**879**	**2.08**	**0**
M30F30P0.1%	**269**	**116**	**152**	**953**	**879**	**2.08**	**0.385**
M30F30P0.2%	**269**	**116**	**152**	**953**	**879**	**2.08**	**0.770**
M30F30P0.3%	**269**	**116**	**152**	**953**	**879**	**2.08**	**1.155**
M30F30P0.4%	**269**	**116**	**152**	**953**	**879**	**2.08**	**1.540**

M30F30P0.5%	**269**	**116**	**152**	**953**	**879**	**2.08**	**1.925**

6. Compressive Strength Test

The paver block specimens 4 in number shall be selected randomly and physically checked for observation of dimensions, aspect ratio and plan area before testing as per code. The compressive testing machine of capacity 200 tons used for test. The specimen shall be capped with 4mm thick plywood sheets of size larger than the specimen and placed between the bearing plates of the CTM and tightened by hand. The load shall be applied without any jerk and increase continuously @15±3 N/mm^2 per minute until the specimen fails. The failure load is recorded in N. The apparent compressive strength of the paver block is calculated by using formula, compressive strength = failure load/ plan area in N/mm^2, for the individual specimen.

Figure 3: Compressive strength test setup.

7. Flexural Strength Test

The paver blocks manufactured will be used for road surfacing. The flexural property of the paver block is very important to be observed when used on roads where traffic is running. The test specimen shall be checked for length, width, thickness and aspect ratio. The apparatus used for the test shall be same as per IS: 15658 and IS: 516. The supporting rollers of the machine should have diameter in the range of 25mm to 40mm. The distance from centre to centre of rollers shall be adjusted to fix the specimen -50mm. Four paver block randomly selected for the test and kept with capping material as per IS: 15658. The load shall be applied without any shock and increased continually @ 6kN/minute and shall be increased until failure of the specimen.

Figure 4: Flexural strength test setup.

8. Results and Discussion

a) Compressive Strength

1. Corrected Compressive Strength of 60 mm Thick Paver Blocks with OPC Replaced by 30% Fly Ash and varying proportions of PPFfor M30 grade of paver blocks

The corrected compressive strength results of 60 mm thick paver blocks with OPC replaced by 30% FA and addition of 0.0% to 0.5% PPF at different ages are tabulated in Table 7. The paver blocks have been named according to their grade designation, FA replacement proportion and PPF addition. The variation of corrected compressive strength with age for M30 grade of paver blocks has been shown graphically.

Table 7: Corrected compressive strength results of 60 mm thick M30 grade of paver blocks with varying proportions of PPF.

Grade	WCR	SP	PPF	Thick	Corrected compressive strength (N/mm^2)	
					07 Days	28 Days
M30F30P0.0	0.43	2.08	0.000	60	23.63	35.80
M30F30P0.1	0.43	2.08	0.385	60	23.80	37.50
M30F30P0.2	0.43	2.08	0.770	60	24.96	38.40
M30F30P0.3	0.43	2.08	1.155	60	25.53	39.10
M30F30P0.4	0.43	2.08	1.540	60	24.83	38.80
M30F30P0.5	0.43	2.08	1.925	60	24.60	38.40

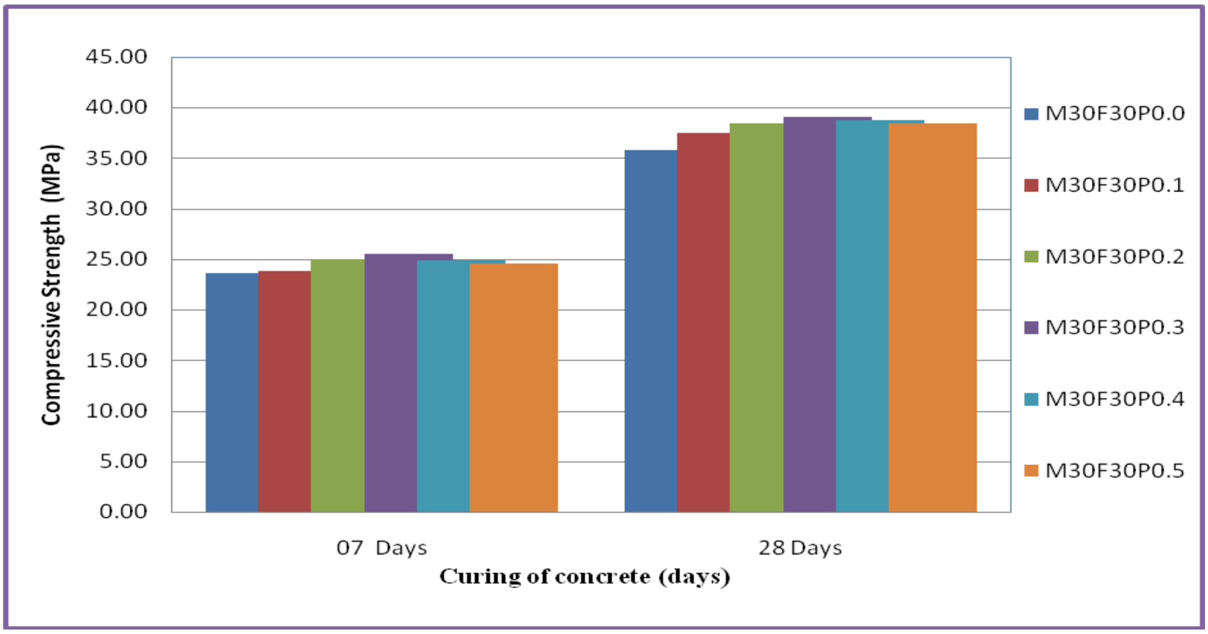

Figure 5: Variation of corrected compressive strength with age for M30 grades with varying proportions PPF for 60mm thick paver block.

2) Corrected Compressive Strength of 80 mm Thick Paver Blocks with OPC Replaced by 30% Fly Ash and varying proportions of PPFfor M30 grade of paver blocks

The corrected compressive strength results of 80 mm thick paver blocks with OPC replaced by 30% FA and addition of 0.0% to 0.5% PPF at different ages are tabulated in Table 4.9. The paver blocks have been named according to their grade designation, FA replacement proportion and PPF addition. The variation of corrected compressive strength with age for M30 grades of paver blocks has been shown graphically in Figure 6.

Table 8: Corrected compressive strength results of 80 mm thick M30 grade of paver blocks with varying proportions of PPF.

Grade	WCR	SP	PPF	Thick	Corrected compressive strength (N/mm^2)	
					07 Days	28 Days
M30F30P0.0	0.43	2.08	0.000	80	23.24	35.30
M30F30P0.1	0.43	2.08	0.385	80	23.54	37.10
M30F30P0.2	0.43	2.08	0.770	80	24.70	38.10
M30F30P0.3	0.43	2.08	1.155	80	25.50	38.70
M30F30P0.4	0.43	2.08	1.540	80	24.60	38.40

M30F30P0.5	0.43	2.08	1.925	80	24.36	38.06

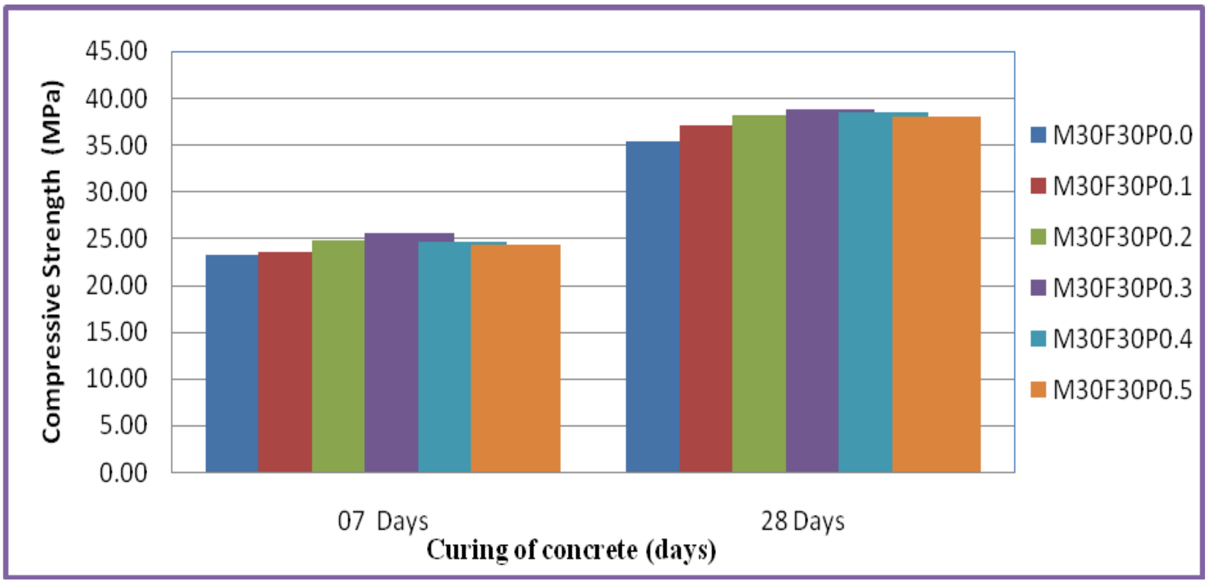

Figure 6: Variation of corrected compressive strength with age for M30 grades with varying proportions PPF for 80mm thick paver block.

B) Flexural Strength

Flexural strength of M30 grade paver blocks of 60 mm thickness with replacement of OPC by 30% fly ash and addition of polypropylene fiber at the rateof0.0% to 0.5%for7 and28dayswasobservedandtabulatedinTable9, shown graphically in Figure 7.. The paver blocks have been named as per their proportions in the mixes.

1) Flexural Strength of 60 mm Thick Paver Blocks with OPC Replaced by 30% Fly Ash and varying %age of PPFfor M30 grade of paver blocks

Table 9: Flexural Strength results of 60 mm thick M30 grade of paver blocks with varying proportions of PPF.

Grade	WCR	SP	PPF	Thick	Flexural strength (N/mm^2)	
					07 Days	28 Days
M30F30P0.0	0.43	2.08	0.000	60	3.65	4.56
M30F30P0.1	0.43	2.08	0.385	60	3.80	4.76
M30F30P0.2	0.43	2.08	0.770	60	3.97	5.30
M30F30P0.3	0.43	2.08	1.155	60	4.24	5.94
M30F30P0.4	0.43	2.08	1.540	60	4.28	5.72
M30F30P0.5	0.43	2.08	1.925	60	4.08	5.48

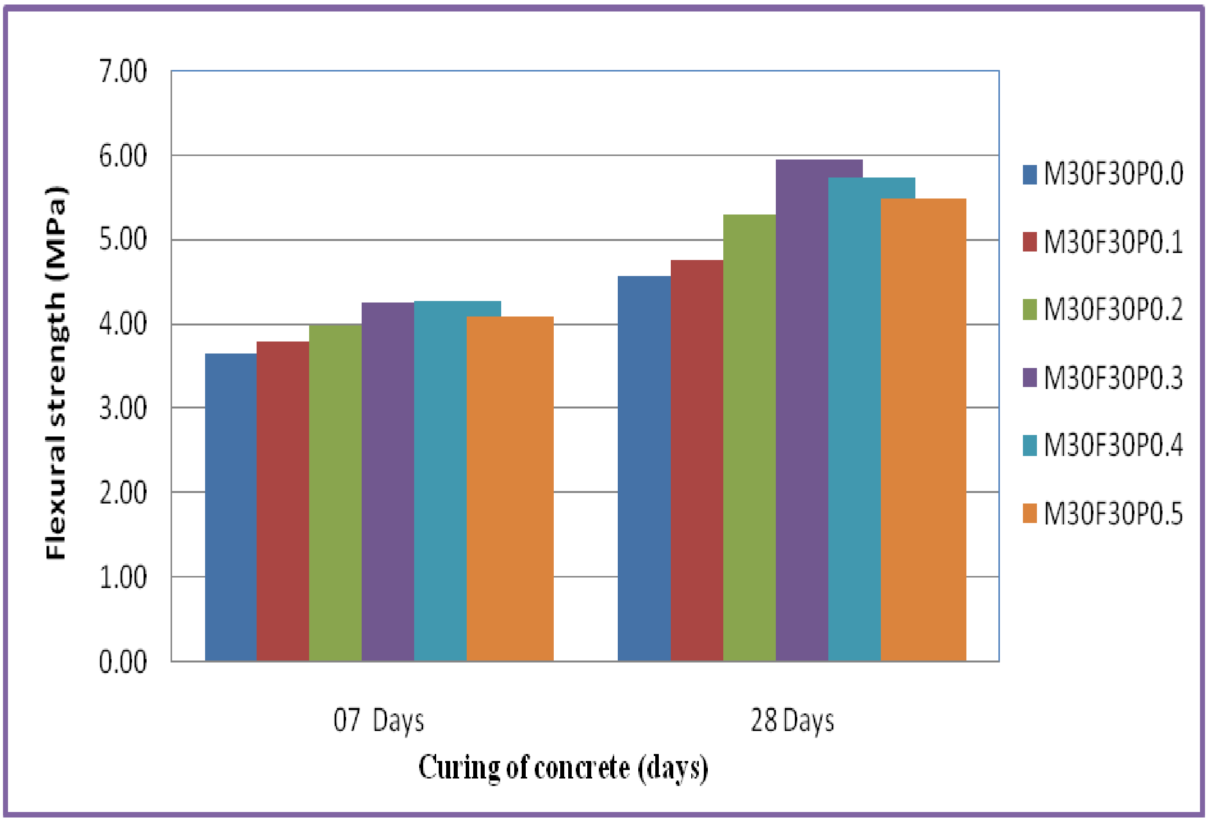

Figure 7: Variation of Flexural Strength with age for M30 grades with varying proportions PPF for 60mm thick paver block.

2) Flexural Strength of 80 mm Thick Paver Blocks with OPC Replaced by 30% Fly Ash and varying %age of PPFfor M30 grade of paver blocks

Flexural strength of M30 grade paver blocks of 80 mm thickness with replacement of OPC by 30% fly ash and addition of polypropylene fiber at the rateof0.0% to 0.5%for7 and28dayswasobservedandtabulatedinTable10, shown graphically in Figure 8. The paver blocks have been named as per their proportions in the mixes.

Table 10: Flexural Strength results of 80 mm thick M30 grade of paver blocks with varying proportions of PPF.

Grade	WCR	SP	PPF	Thick	Flexural strength (N/mm^2)	
					07 Days	28 Days
M30F30P0.0	0.43	2.08	0.000	80	3.58	4.48
M30F30P0.1	0.43	2.08	0.385	80	3.73	4.66
M30F30P0.2	0.43	2.08	0.770	80	3.88	5.18
M30F30P0.3	0.43	2.08	1.155	80	4.35	5.80
M30F30P0.4	0.43	2.08	1.540	80	4.14	5.56
M30F30P0.5	0.43	2.08	1.925	80	3.98	5.34

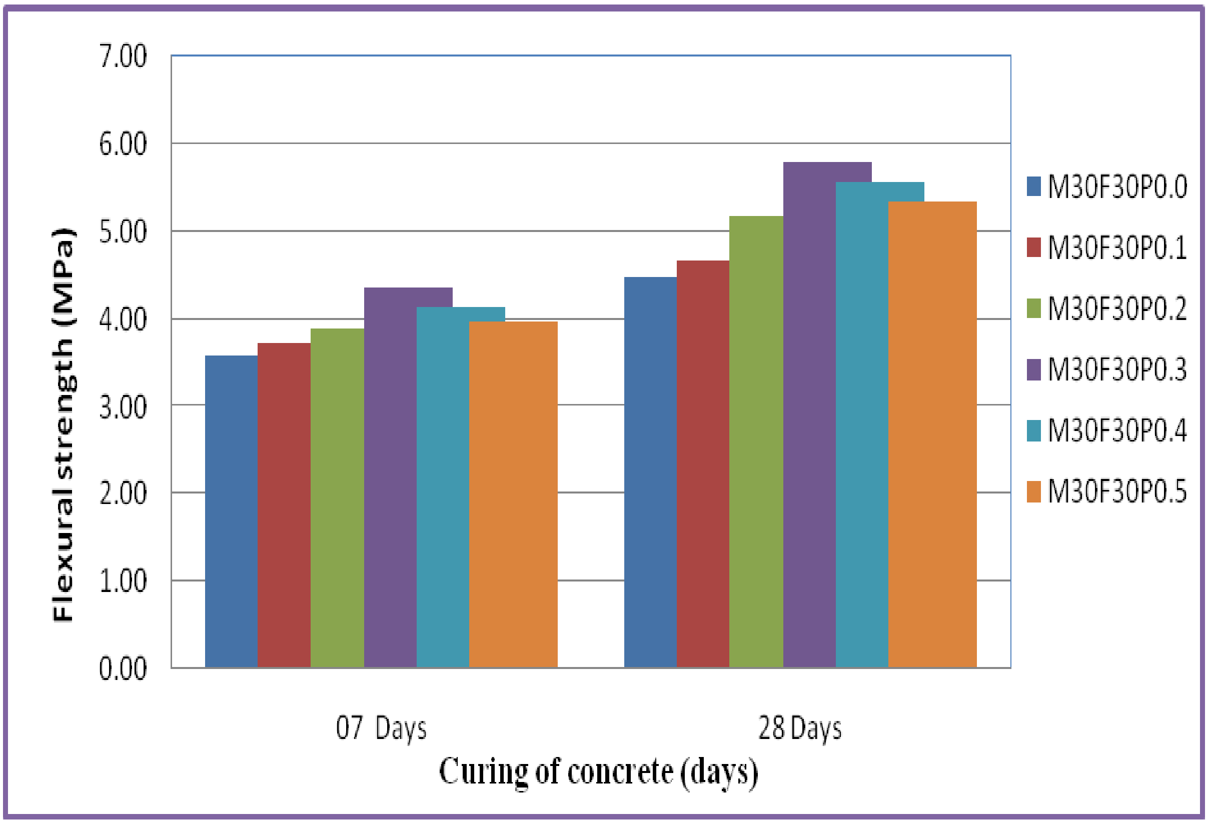

Figure 8: Variation of Flexural Strength with age for M30 grades with varying proportions PPF for 80mm thick paver block.

Cost Effectiveness

The cost of manufacture of paver block with optimum addition of 0.3% PPF and 30% replacing OPC by fly ash has been calculated in Table 11.

Table 11: Cost Effectiveness.

Paver blocks with 100 % OPC	**Paver blocks with OPC, fly ash, PPF composite**
Manufacture of 100 pieces of paver blocks by using cement 50 kg (1bag). Cost of 50 kg (1 bag) of OPC = Rs 300/-	Manufacture of 100 pieces of paver blocks by using (cement 35 kg + 15 kg fly ash + 0.125 kg PPF). Cost of 35 kg cement @ 300/50 kg = Rs 210/- Cost of fly ash(waste material) = Rs 0/- Cost of PPF0.125kg = Rs 30/- Totalcost = Rs 240/-
Saving in cost = 300-240 = Rs 60/-	

Percentage saving = $(\frac{60}{300}) \times 100$ = 20%

*Rest of the other materials and labor cost will remain constant in both the cases
Since, India is a large country with large number of rural/urban road network and other application areas where paver block can be consumed in large quantity. Manufacture of paver blocks by using waste material will help the nation by consuming waste materials, having zero production value, saving large amount of CO_2 emission and at the same time maintaining economy. From the above discussion, it can be concluded that for the sustainable world, it is necessary to conserve the raw materials by using waste materials in manufacturing of paver blocks which will help the nation economy environment friendly construction and is beneficial for paver block manufacturers.

9. CONCLUSIONS

❖ Corrected compressive strength for reference mixes increases with age in M30 grade in 60 mm and 80 mm thick paver blocks. At 28 days of curing the strength has increased slightly from target strength.

❖ Maximum gain in strength for all the grades at 28 days was observed with 0.3% PPF addition which may be taken as optimum dose.

❖ All the mixes with addition of PPF in varying proportions in all the grades at 28 days have attained the target strength.

❖ Effect of fly ash on hardened paver blocks tends to decrease the strength and with addition of PPF strength marginally increased.

❖ Flexural strength for the reference mixes increases with age in M30grade in 60 mm and 80 mm thick paver blocks. At 28 days reference mix attained target strength.

❖ Maximum gain in flexural strength for all the grades at 28 days was observed with 0.3% PPF addition which may be taken as optimum dose.

❖ Cost of paver blocks will increase in small amount due to addition of PPF.

❖ Fly ash is a waste materials to be used for manufacture of paver blocks of different grades and thicknesses the resulting product will be economical, energy saving and eco-friendly.

❖ OPC replaced by fly ash will earn more economy resulting into overall reduction in cost by 20% at optimum level of 0.3% PPF in all the grades and thicknesses.

10. REFERENCES

[1] Sachdeva SN, Aggarwal V, Gupta SM. High volume fly ash concrete for paver blocks. World Academy of Sci, Engg and Tech, Inter J of Civ, Arch, Stru and Cons Engg. 2014; 8(3):238-244.

[2] Siddique R. Performance characterstics of high-volume class F fly ash concrete. Cem and conc res.2004; 34:487-493.

[3] Raju JJ, John J. Strength study of high volume fly ash concrete with fibers. Inter J of AdvStruct and GeotechEngg. 2014; 3(1): 60-64.

[4] Singh G, Goel S. Performance evaluation of pet-polypropylene hybrid fiber reinforced concrete in terms of workability, strength and cost effectiveness. Inter J of Civ and StructEngg Res. 2016;3(2):85-94.

[5] Mohod MV. Performance of polypropylene fibre reinforced concrete. J of Mech and CivEngg. 2015; 12(1):28-36.

[6] Thirumurugan S, Sivakumar A. Compressive strength index of crimped polypropylene fibers in high strength cementitious matrix. World App Sci J. 2013;24(6):698-702.

[7] Kolli R. Strength properties of polypropylene fiber reinforced concrete. Inter J of Inno Res in SciEngg and Tech. 2013; 2(8): 3409-3412.

[8] Gencel O, Ozel C, Koksa F, Erdogmus E. Barrera GM, Brostow W. Properties of concrete paving blocks made with waste marble. J of Clean Prod. 2012; 21:62-70.

[9] Patel I, Modhera CD. Study effect of polyester fibers on engineering properties of high volume fly ash concrete. J of Engg Res and Studies. 2011; 2(1):159-166.

[10] Muhammed R, Varkey D. Experimental investigation on properties of geopolimer concrete paver block with the inclusion of polypropylene fibers. Inter J of Sci&Engg Res. 2016;4(10):10-15.

[11] Rao MVK, Murthy NRD, Kumar VS. Behavior of polypropylene fiber reinforced fly ash concrete deep beams in flexure and shear. Asian J of CivEngg (Building and Housing) .2011;12(2):143-154.

[12] Uygunglo T, Topcu IB, Gencel O, Brostow W. The effect of fly ash content and types of aggregates on the properties of pre-fabricated concrete interlocking (pcibs). Const and Build Mater. 2012; 30:180-187.