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An Experimental Investigation on Precast Cement Concrete Paver Blocks Using Fly Ash

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***Abstract:** The rapid development of housing and infrastructure from last one decade continuously takes place in India. Along with that naturally, the product required to overcome this development produce in mass quantities like Pavement blocks, which are known as industrial products of precast made up by concrete, having various shapes and sizes utilizes in huge quantity in housing and infrastructure construction. The conventional materials to manufacturing these blocks utilize in large quantity, which may create an impact on natural recourses. To overcome this impact we can use different materials such as, Sisal fiber, waste glass, fly ash etc. which helps to save natural recourses and achieve economy so that buyers and sellers of this type of materials can also get benefited. The present experimental research investigation examines the effect of fly ash at the partial replacement of cement. Experiment is done on M33, M43 and M53 mix, with 5%, 10%, 15%, 20% & 25% partial replacement of cement. After getting an optimum percentage of all these, further experimental work is intended for the use of all these three in a single paving block. The replaced ingredients in this research are fly ash. Experimentation is carried out to find the workability test, water absorption test, compressive strength and flexural strength of the concrete paving blocks. Further, these studies compare an economical aspect of the conventional product and newly manufactured product.*

***Keywords:** Paver Block, Industrial Waste, Strength, Mix Proportion, Construction Industry*.

1. INTRODUCTION

Pavers are the modern day solution for less cost outdoor application. Paver block is used in various places like in street road and other construction places. Interlocking concrete Pavement has been largely used in a number of countries for quite something as a specialized problem solving technique for providing pavement in areas where conventional types of construction are less durable due to many operational and environment constraints. Concrete block pavements have become an attractive engineering and economical alternative to both flexible and rigid pavements. The strength, durability and pleasing surfaces have made paver blocks attractive for many commercial, municipal and industrial places such as parking areas, pedestrian walks, traffic intersections, container yards and roads. Interlocking paver blocks are installed over a compacted stone sub base and levelling bed of sand. Concrete paver blocks are made of concrete basically consisting of cement, fine aggregates, coarse aggregates (10 mm and below), water, chemical agents etc.

We all know for pavement of paver block required high compressive strength and to increase the compressive strength of paver blocks various efforts have been taken. Interlocking concrete paving blocks have various advantages over bitumen and concrete pavements in their structural, aesthetics, construction and maintenance, operational and economical characteristics. Like other pavement surfaces, the design of concrete paving blocks is based on environmental, traffic, sub grade support and pavement materials conditions and their interactive effect.

2. LITERATURE REVIEW AND PREVIOUS WORK

Atul Thakur et al (2017) studied partial replacement (by weight) of cement with RHA in paver blocks for determining the change in the compressive strength, water absorption and abrasive resistance of paver blocks. Partial replacement of cement in different percentage as like 0%, 15%, 20%, 25%, 30%, 35% and 45% has been done. The compressive strength has been determined at the end of 7, 28 and 56 days, water absorption test and abrasion resistance have been determined at 28 days.

B. Kaviya (2016) studied for manufacturing paving blocks with crusher dust is studied. Paving blocks replaced with crusher dust by various percentages and its properties have also been studied. The results show that replacing sand with crusher dust has a minimal reduction in weight and also it leads to the economy. Since the availability of sand is reducing now-a-days using of crusher dust will reduce polluting the environment since it is being dumped in many places.

Deshpande B. C and P. Darade M. M (2015) examines the effect of fly ash, as a partial replacement to cement and dust as a partial replacement to fine aggregate on the various properties of pavement block. The investigation is done on M30 mix using fly ash as a partial replacement by weight of cement. Experimentation is carried out to find the compressive strength, flexural strength and abrasion resistance of the concrete paving blocks.

Patel et al. (2014) noticed that foundry sand is technically sound, environmentally safe for sustainable development. Partial replacement of Cement with foundry sand in paver block so determined the change in the compressive strength and cost of paver block maximum replacement 50% so results are water absorption is 2% & compressive strength 23.48 N/mm2 cost of paver block is 20.13% lower than standard mix proportion.

3. MATERIAL USED

- **Cement:** Ordinary Portland cement (OPC) of 33, 43 & 53 grade was used for casting the paver blocks.
- **Fly Ash:** It 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 Rajrajeshwari Ltd., Mandideep, and Bhopal.
- **Coarse Aggregates**: Locally available crushed coarse aggregates of nominal size 10mm were used in this work
- **Fine Aggregates:** 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.
- **Water:** Tap water was used in this experiment. The properties are assumed to be same as that of normal water. Specific gravity is taken as 1.00.
- **Super Plasticizer:** To increase the compressive strength, reduced the consumption of water and maintains the slump value, poly-carboxylic ether based super plasticizer complying with IS: 9103-1999 were used.

4. MIX PROPORTION

Mix design for M33, M43 and M53 grade with 5 %, 10 %, 15 %, 20 % and 25 % fly ash are reported in the table (1-3) shown below.

Table 1 Mix Proportions for M33 Grade

S. No.	Mix	Fly-Ash (Kg/m^3)	Cement (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (Kg/m^3)	Fine Aggregate (Kg/m^3)
1	M33 F.A0	0	314.25	1116	180	619
2	M33 F.A5	15.71	298.53	1116	180	619
3	M33 F.A10	31.42	282.82	1116	180	619
4	M33 F.A15	47.13	267.11	1116	180	619
5	M33 F.A20	62.85	251.40	1116	180	619
6	M33 F.A25	78.56	235.68	1116	180	619

Table 2 Mix Proportions for M43 Grade

S. No.	Mix	Fly-Ash (Kg/m^3)	Cement (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (Kg/m^3)	Fine Aggregate (Kg/m^3)
1	M43 F.A0	0	365.25	1174	190	568
2	M43 F.A5	18.26	346.98	1174	190	568
3	M43 F.A10	36.52	328.72	1174	190	568
4	M43 F.A15	54.78	310.46	1174	190	568
5	M43 F.A20	73.05	292.20	1174	190	568
6	M43 F.A25	91.31	273.93	1174	190	568

Table 3 Mix Proportions for M53 Grade

S. No.	Mix	Fly-Ash (Kg/m^3)	Cement (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (Kg/m^3)	Fine Aggregate (Kg/m^3)
1	M53 F.A0	0	379.80	1238.4	144.3	696.3
2	M53 F.A5	18.99	360.81	1238.4	144.3	696.3
3	M53 F.A10	37.98	341.82	1238.4	144.3	696.3
4	M53 F.A15	56.97	322.83	1238.4	144.3	696.3
5	M53 F.A20	75.96	303.85	1238.4	144.3	696.3
6	M53 F.A25	94.95	284.85	1238.4	144.3	696.3

5. EXPERIMENTAL PROGRAM

A total of 54 concrete mixes were prepared; three of the mixes were made of 100% ordinary Portland cement (no Fly ash content). The remaining 51 mixes were prepared by adding fly ash content as a partial replacement to cement i.e. 5 %, 10 %, 15 %, 20 % and 25 %.

Following test procedures are conducted in this paver block experiment:

- Workability Test.
- Water Absorption Test.
- Compressive Strength Test.
- Flexural Strength Test.

5.1 WORKABILITY TEST

Workability is the property of freshly mixed concrete that determines the ease with which it can be properly mixed, placed, consolidated and finished without segregation. The workability of fresh concrete was measured by means of the conventional slump test as per IS; 1199(1989). Before the fresh concrete was cast into moulds, the slump value of the fresh concrete was measured using slump cone.

Fig. 1: Workability Test Conducted in Lab

5.2 WATER ABSORPTION TEST

For concrete pavers, the test procedure involves drying a specimen to a constant weight, weighing it, immersing it in water for the 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).

Formula used is Water absorption = [(A – B)/B] x 100%.
Where A= weight of saturated surface dried sample in gms
B=weight of oven dried sample in gms.

5.3 COMPRESSIVE STRENGTH TEST

The compressive strength is taken as maximum compressive load resisted by per unit area. The failure load was noted. In each category, cubes were tested and their value is reported. The compressive strength was calculated as follows,
Compressive strength (MPa) = Failure load / cross sectional area.

Fig. 2: Compressive Strength Test

5.4 FLEXURAL STRENGTH TEST

Flexural strength test was conducted on specimens under two point loading as per IS 15658:2006. The average ultimate flexural tensile stress was determined from the failure flexural loads.

Fig. 3: Flexural Strength Test

6. RESULTS AND DISCUSSIONS

6.1 RESULT OF WORKABILITY TEST

Figure 5.1, 5.2 & 5.3 shows the results of workability of concrete with cement replacement by fly ash in various percentages ranging from 5%, 10%, 15 %, 20 % and 25 %. As the fly ash content increases (i.e. cement content decreased) workability decreases. As there is a reduction in fineness modulus of the cementitious material, quantity of cement paste available is less for providing lubricating effect per unit surface area of aggregate. Therefore, there is a restrain on the mobility.

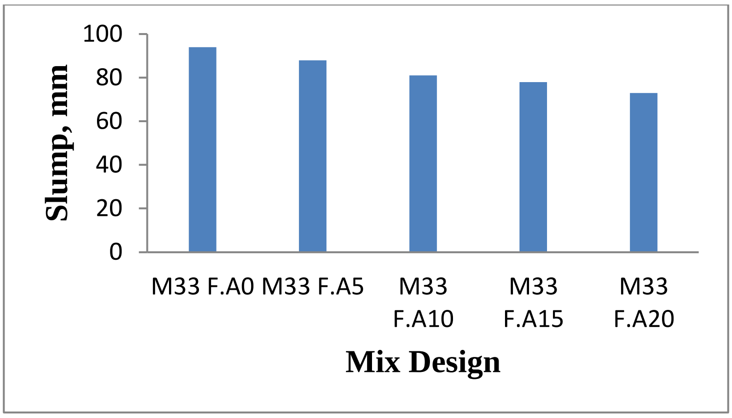

Fig. 4 Slump Versus Fly ash Percentage as Replacement of Cement for M33

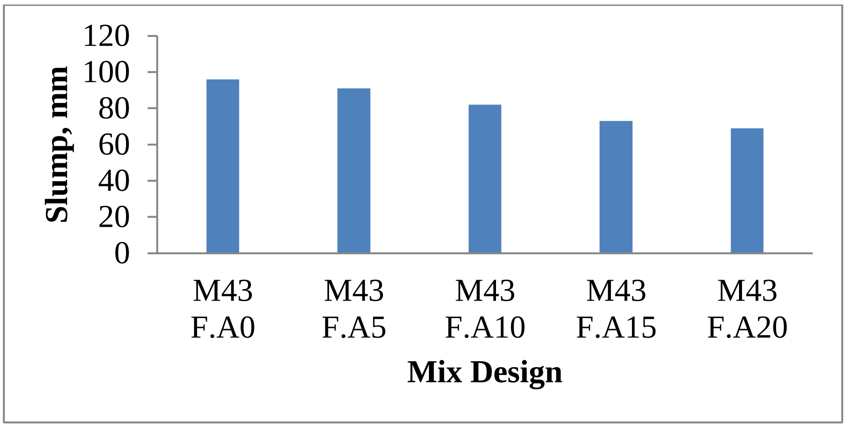

Fig. 5 Slump versus Fly Ash Percentage as Replacement of Cement for M43

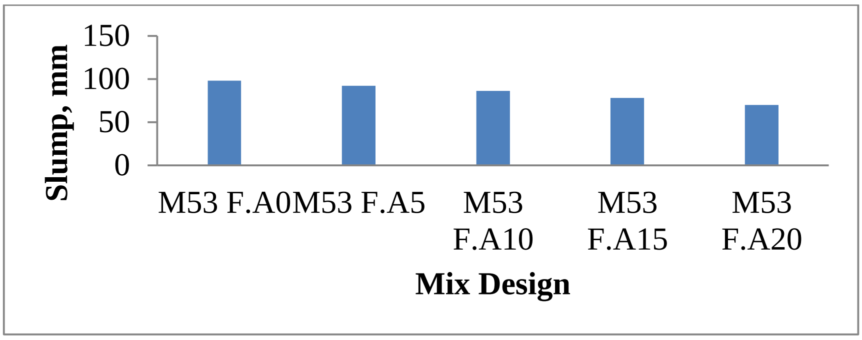

Fig. 6 Slump Versus Fly ash Percentage as Replacement of Cement for M43

6.2 WATER ABSORPTION TEST OF PAVER BLOCK FOR M33, M43, AND M53

The water absorption values of the concrete paver blocks at the age of 28 days for M33, M43 and M53 grade are determined and the results were presented in table 5.4-5.7.

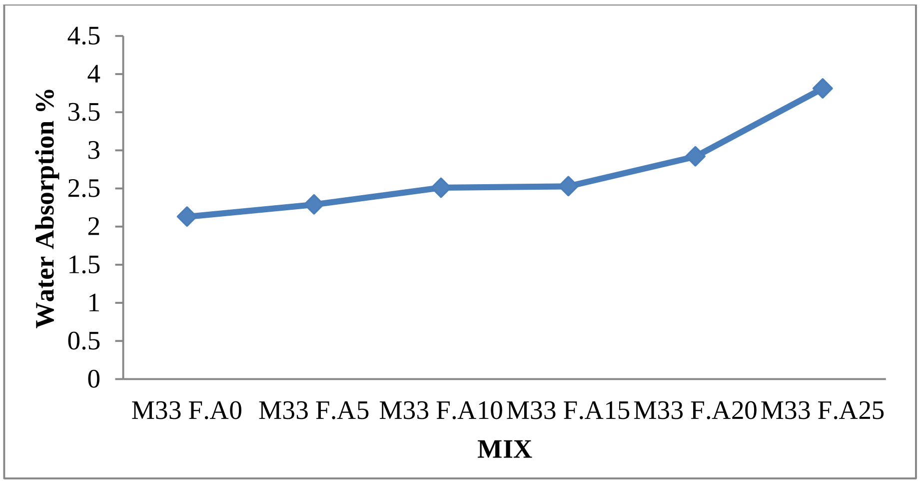

Fig. 7: Water Absorption for M33

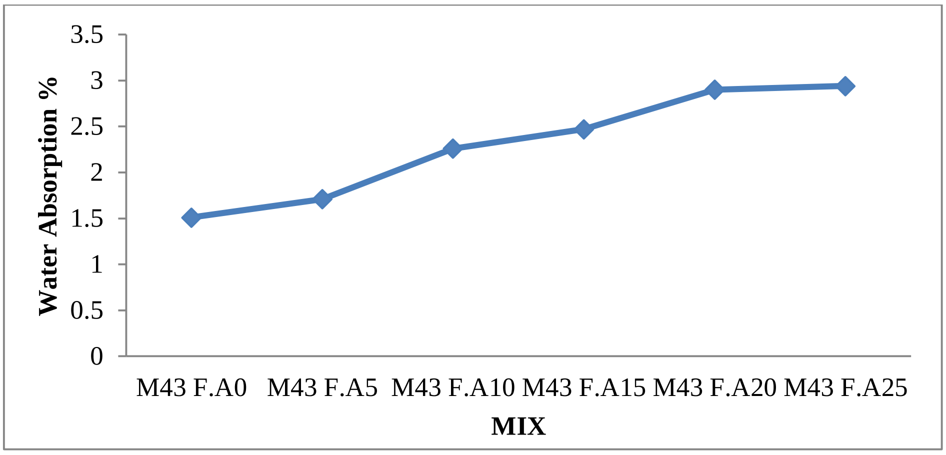

Fig. 8: Water Absorption for M43

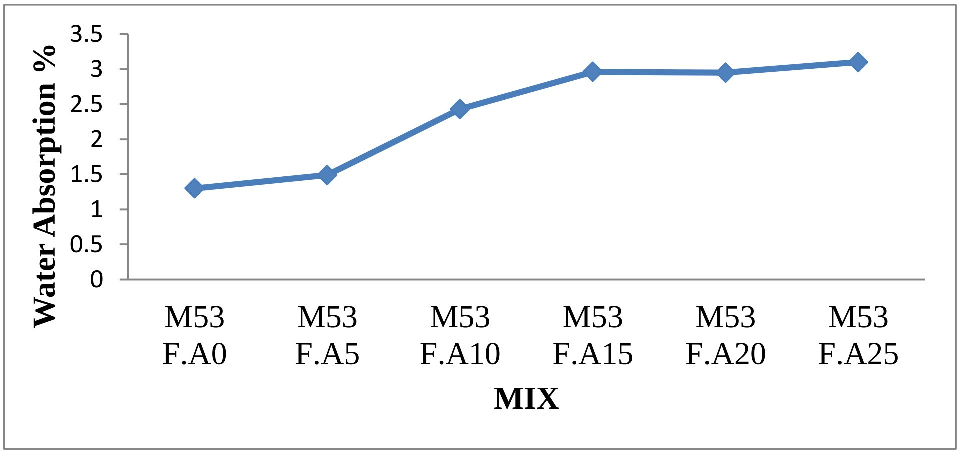

Fig. 9: Water Absorption for M53

6.3 COMPRESSIVE STRENGTH TEST RESULTS OF CEMENT REPLACEMENT FOR M33, M43, AND M53

Fig. 10 is drawn between compressive Strength and percent of Fly Ash at 7, 21 and 28 days. At 20 % Fly Ash in sample shows the high Compressive strength of Paver Block at 7, 21 and 28 days. Then increase of Fly Ash as % of the cementitious material, compressive Strength of paver block decrease but at 20% replacement of cement with Fly Ash strength increase then further decrease. At 20% of fly ash maximum compressive strength of paver block at 7, 21 and 28 days are 28.80, 36.21 and 42.01 N/mm^2.

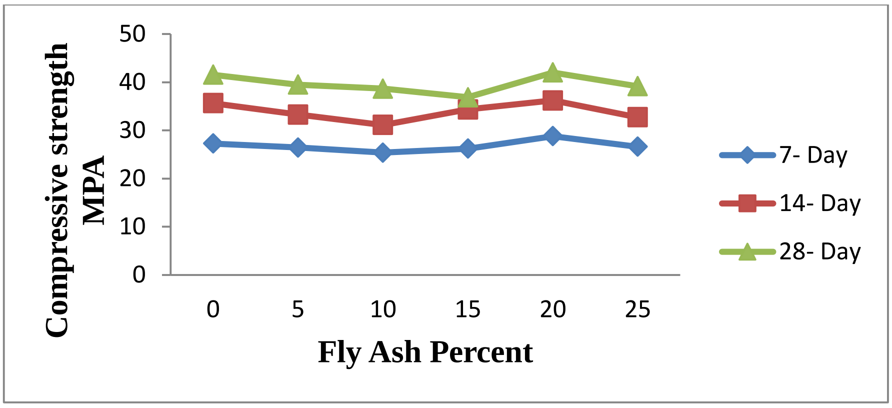

Fig. 10: Compressive Strength versus Fly Ash Percentage for M33 Grade I Type Paver Block

The compressive strength of concrete paver block for the M43 grade was increasing with the inclusion of fly ash compared to standard concrete paver block at 7, 21 and 28 days.The graph illustrates that compressive strength at 7, 21 and 28 days increases with the inclusion of fly ash till 10 % inclusion and later it decreases. There was an increase of 4.7 % in compressive strength at 10 % fly ash inclusion compared to normal paver block at 28 days. At 10% of fly ash maximum compressive strength of paver block at 7, 21 and 28 days for M43 are 36.28, 44.67 and 48.54 N/mm^2.

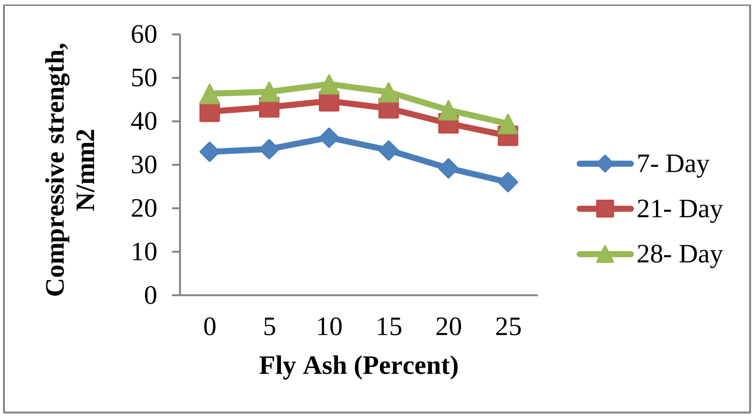

Fig. 11: Compressive Strength versus Fly Ash Percentage for M43 Grade I Type Paver Block

The compressive strength of concrete paver block for M53 is increasing with the increase in fly ash content compared to standard concrete paver block at 7, 21 and 28 days. It is observed that at 20 % of fly ash maximum strength was attained and later with an increase in fly ash content strengths are falling down. The increment in the compressive strength at 20 % fly ash content is 2.76 %, 4.44% and 5.99 %at the age of 7, 21 and 28 days respectively. At 20% of fly ash maximum compressive strength of paver block at 7, 21 and 28 days for M53 are 44.30, 47.20 and 56.60 N/mm^2.

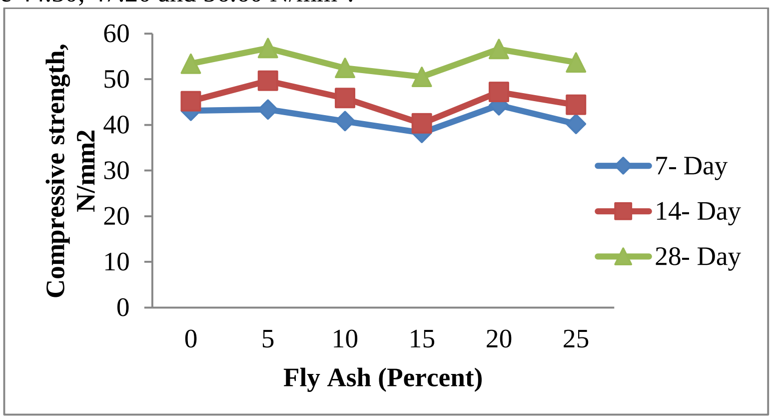

Fig. 12: Compressive Strength versus Fly Ash Percentage for M53 Grade Paver Block

6.4 FLEXURAL STRENGTH TEST RESULTS OF CEMENT REPLACEMENT FOR M33 GRADE

The Flexural Strength of concrete is tested at the interval of 28 days and it seems that Flexural Strength goes on decreasing with the increase in Fly Ash as a cementitious material. At 5% Fly Ash in sample shows high Flexural Strength of concrete mix at 28 days i.e. 5 N/mm2.

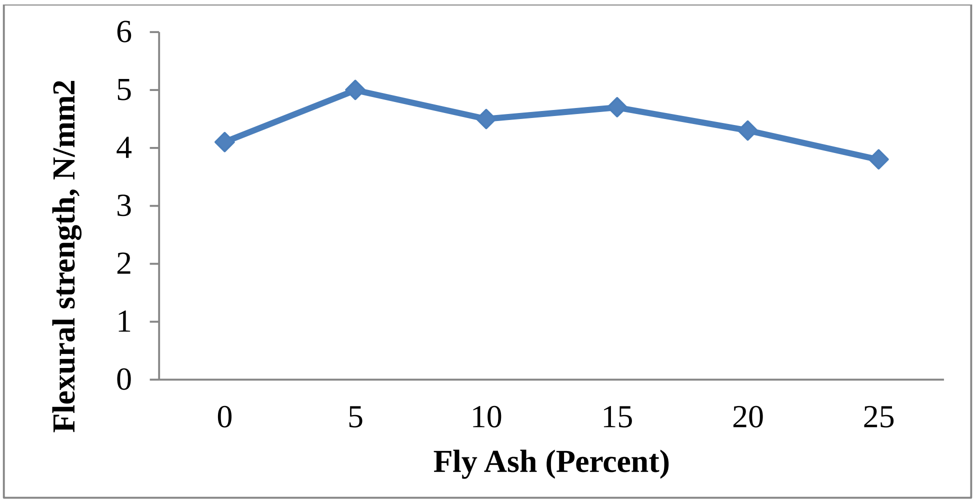

Fig. 13: Flexural Strength versus Fly Ash Percentage for M33 Grade Paver Block

The graph illustrates that flexural strength at 28 days increases with the inclusion of fly ash till 15% inclusion and later it decreases. At 15% Fly Ash in sample shows high Flexural Strength of concrete mix at 28 days i.e. 5.3 N/mm2.

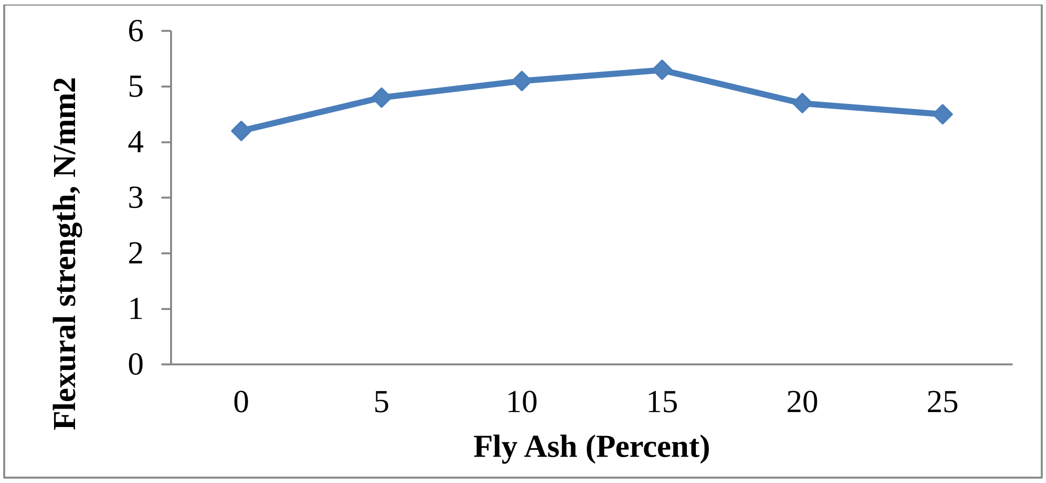

Fig. 14: Flexural Strength versus Fly Ash Percentage for M43 Grade Paver Block

6.5 FLEXURAL STRENGTH TEST RESULTS OF CEMENT REPLACEMENT FOR M53 GRADE

The Flexural Strength of concrete is tested at the interval of 28 days and it seems that Flexural Strength goes on decreasing with the increase in Fly Ash as a cementitious material. At 5% Fly Ash in sample shows high Flexural Strength of concrete mix at 28 days i.e. 6.7 N/mm2.

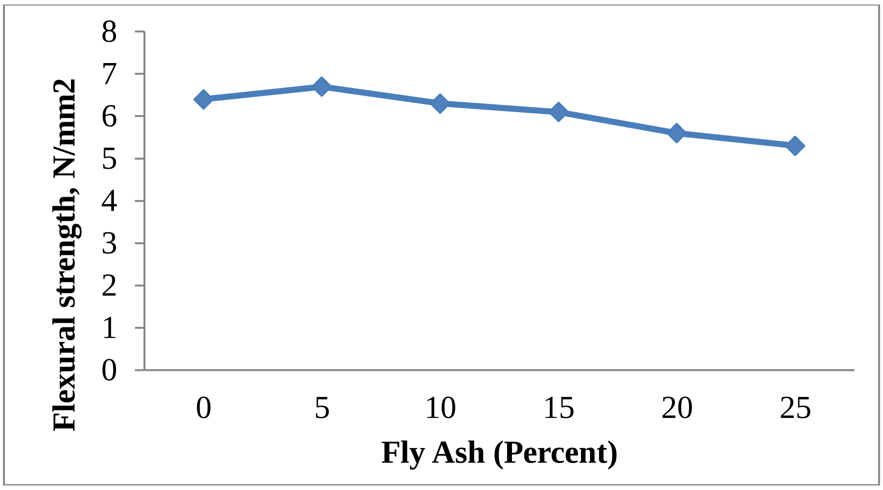

Fig. 15: Flexural Strength versus Fly Ash Percentage for M53 Grade Paver Block

7. COST ANALYSIS FOR M33, M43, and M53

Material cost estimation includes the cost of water, cement, fine aggregate and coarse aggregate for a particular design mix. As per the mix design calculation, we obtained that the weight of water, cement, fine aggregate and coarse aggregate respectively for concrete. As the water is largely available material in India hence its cost can be neglected. The present study shows that the replacement of cement by fly ash in M33 can be done as much as 20% (by weight). Analysis of the cost of concrete with and without fly ash is given below in table 4.

Table 4 Cost of Materials

Sr no.	Materials	(Rate Rs/ Kg)
1	Cement	7.6
2	Fly ash	2.75
3	Fine Aggregate	0.8
4	Coarse Aggregate	1.2
5	SP	82

Table 5: Cost of Each Paver Block with and Without Fly Ash for M33

S. No.	Type of Paver Blocks	Cost of each Paver Blocks Rs	Cost per cubic meter (Rs)
1	M33 F.A0	9.54	4971
2	M33 F.A5	9.65	5028
3	M33 F.A10	9.76	5085
4	M33 F.A15	9.87	5142
5	M33 F.A20	8.65	4508
6	M33 F.A25	8.10	4220

Table 6.2- 6.4 indicates that the cost of paver block increases with increase in fly ash content. On replacement of cement with fly ash, the decrease in cost can be observed.

Table 6: Cost of Each Paver Block with and without Fly ash for M43

S. No.	Type of Paver Blocks	Cost of each Paver Blocks Rs	Cost per cubic meter (Rs)
1	M43 F.A0	7.64	3979
2	M43 F.A5	8.29	4318
3	M43 F.A10	8.94	4656
4	M43 F.A15	9.49	4995
5	M43 F.A20	10.01	5224
6	M43 F.A25	9.12	5115

Table 7: Cost of Each Paver Block with and without Fly ash for M53

S. No.	Type of Paver Blocks	Cost of each Paver Blocks Rs	Cost per cubic meter (Rs)
1	M53 F.A0	9.98	5119
2	M53 F.A5	10.20	5334
3	M53 F.A10	10.31	5442
4	M53 F.A15	10.42	5551
5	M53 F.A20	9.69	4995
6	M53 F.A25	8.12	4318

8. CONCLUSION

Experimental results show the following outcomes:

1. In this Compressive Strength analysis of Paver Block with 0%, 5%, 10%, 15%, 20%, 25% fly ash are tested and the graph showed that at 20% fly ash is partially replaced with OPC 33 grade give higher strength as compared to conventional mix.
2. It seems that the Compressive Strength goes on increasing with the increase in Fly Ash but after the replacement of 20% the strength goes on decreasing. We can conclude that compressive strength of paver block with partial replacement of cement with Fly Ash is high at 28 days with the 20 % Fly Ash. At 20% of fly ash for OPC 33 grade maximum compressive strength of paver block at 7, 21 and 28 days are 28.80, 36.21 and 42.01 N/mm^2.

3. For OPC 43 grade, it was observed that the compressive strength of concrete paver block for the M43 grade was increasing with the inclusion of fly ash compared to standard concrete paver block at 7, 21 and 28 days.The graph illustrates that compressive strength at 7, 21 and 28 days increases with the inclusion of fly ash till 10 % inclusion and later it decreases. There was an increase of 4.7 % in compressive strength at 10 % fly ash inclusion compared to normal paver block at 28 days. At 10% of fly ash maximum compressive strength of paver block at 7, 21 and 28 days for M43 are 36.28, 44.67 and 48.54 N/mm^2.
4. For OPC 53 grade, it is observed that the compressive strength of concrete paver block is increasing with the increase in fly ash content compared to standard concrete paver block at 7, 21 and 28 days. It is observed that at 20 % of fly ash maximum strength was attained and later with an increase in fly ash content strengths are falling down. The increment in the compressive strength at 20 % fly ash content is 2.76 %, 4.44% and 5.99 %at the age of 7, 21 and 28 days respectively. At 20% of fly ash maximum compressive strength of paver block at 7, 21 and 28 days for M53 are 44.30, 47.20 and 56.60 N/mm^2.
5. There is a limitation in addition of Fly Ash in concrete to maintain the workability of concrete.
6. Use of Fly Ash in Paver block can solve the disposal problem, reduce cost and produce a „greener" Eco-friendly Paver Blocks for pavement.
7. Environmental effects of Fly Ash and disposal problems of Fly Ash can be reduced through this research.
8. Water absorption of the concrete paving block is determined as per IS: 15658: 2006. As per IS: 15658: 2006 water absorption of the individual concrete paving block should be less than 7% or maximum 6% by mass. But maximum water absorption among all groups was found to be 2.94 %, 3.10 % and 3.81 % which is much less than the permissible.
9. Fly ash is suitable for making paver blocks as the water absorption is less than 7%.

This research has successfully achieved its aims by proving that the fly ash can be partially used as an alternative material for cement. In addition to that, using fly ash in concrete is cost effective as fly ash is cheaper than cement and fine aggregate. Finally, the results of this investigation suggest that fly ash could be very conveniently used in structural concrete.

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