Studies of the Properties of Paver Block using Fly Ash

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Abstract— In these days the use of concrete Paver Block in road pavement is widely used. Such a time concrete Paver Block is better option in road construction as compared to the conventional road which is made by bitumen and gravel in a cost view of point and better suitability. India is a developing country so here the construction of roadway and building plays an important role. Now days most of the work related with building or roadway is done by cement concrete design mix. In this thesis I have design paver block by using Cement Concrete mixture of Design Mix M35 which is made of 10mm Coarse Aggregate, OPC 43 Grade Cement and Fine Aggregate and paver block is of dimension 200 x 160 x 80 mm. In this process use the partial replacement of Cement with Fly Ash in percentage of 0%, 5%, 10%, 15%, 20%, 25%, and 30% respectively and also, added Gypsum constantly 2% by weight of cement in total mixture of Cement Concrete. Superplasticizer is used as an admixture which is added 2% by weight of cement constantly in the production of concrete mixture. The function of this admixture is to reduce the water cement ratio. The Paver Block curing process is done for 7 days, 14 days and 28 days respectively to find its compressive strength. The main objective of this thesis is to use waste products like fly ash for the production of Paver Block which will useful in construction.

Key words: Coarse Aggregate, Fine Aggregate, OPC 43 Grade Cement, Fly Ash, Compressive Strength, Flexural Strength, Paver Block

I. INTRODUCTION

The concept of using interlocking paver block is very old. The first time road using paver block was constructed in 5000 B.C. by the Minoans. About 2000 years ago, with the help of labour and military group the first time roman constructed pavement roads. Since, this process is continued and culture is followed for constructing pavement roads. Concrete Paving Blocks were first manufactured in the Netherlands in 1924. It was probably World War II that led to the growth of concrete blocks as a paving material. Concrete block pavement (CBP) was introduced in The Netherlands in the early 1950s as a replacement for baked clay brick roads. The general worldwide trend towards beautification of city pavements, the rising cost of bitumen's as a paving material and the rapid increase in construction and maintenance cost have encouraged designers to alternate paving material such as concrete blocks. The strength, durability and aesthetically pleasing surface of pavers have made CBP ideal for many commercial, municipal and industrial applications.

In 1960 German developed high efficiency machinery tools for the construction of interlocking paver block. Manufacturing technology quickly followed by countries like South Africa New Zealand, Australia, Europe and England in the 1970's.

At present Germany is the leading country in the production interlocking paver block i.e. near about 100 million square meters. In 1970's century interlocking paver block technology followed by Canada and spread to the United States. In 1994, North American gives output of 160 million square feet interlocking paver block.

Interlocking pavements are adjustable and flexible pavements. Here, Flexible pavement means that loads are equally distributed throughout the base area by point to point contact. When the load is applied thoroughly over the section of paver block the section gets deformed but suddenly when the load is removed its gets back to its original position. Such type of pavements gives advantage over rigid forms of pavement, which bear to crack more readily should the base move from loads or natural settlement due to weather. Interlocking paver blocks are highly resistant to abrasion, freeze - thaw cycles, chemicals and spills of oil and gasoline, deicing salts, which can quite literally melt asphalt. Interlocking concrete paver blocks are ready for immediate use after installation, there is no demand for curing or dry of the surface and they are quickly and easily repaired without any special equipment or materials.

For the past 50 years, significant research activities for the development and refinement of CBP technique have been going on many on in many countries like India Argentina, Australia, Canada, France, The Netherlands, UK and USA.

In interlocking concrete block pavement, the blocks make up the wearing surface and they are a major load spreading component of the pavements. Paving block is intended for us as the wearing surface on clay paving system. As such they are subjected to pedestrian and light or heavy vehicular traffic.

Paver block is produced from the concrete mixture of cement, aggregate, sand and water. Sometimes use the additives such as super plasticizer.

II. OBJECTIVE AND SCOPE

The objective of this dissertation is given below-

1) Here Paver Block is manufactured by using design mix M35 and makes the paver block more durable and effective.
2) Partial replacement of Cement is performed by Fly Ash in given percentage of (0 to 30) % with increment of 5% and make the Paver Block cheaper.
3) 10mm Coarse Aggregate is used by which it becomes cheaper and giving the same strength as given by using 20mm or more Coarse Aggregate.
4) Study the Compressive Strength of Paver Block in 7 days, 14 days and 28 days respectively.

III. NEEDS OF THE RESEARCH-

1) To enhances the properties like workability, Compressive Strength, Flexural Strength and also

increase its durability and concrete finishing by using Fly Ash in concrete.
2) The aim of this work is to study the use of Fly Ash waste material to produce concrete Paver Blocks.
3) Determine the engineering property of Fly Ash based Paver Block and compare them with conventional Paver Block.
4) To comment on the suitability and limitation of Paver Block in construction of pavements.

IV. LITERATURE REVIEW

A. K. Gupta.et.al., (2004). [32] They described uses of pervious use concrete in construction of pavement for improving their performance and they finally developed a strong and durable pervious concrete mixes for low-volume roads. The effects of two types of fine aggregates i.e. crushed stone and river sand, on various properties of pervious concrete was studied. The fine aggregate to coarse aggregate ratio was as 1:5.720, compared to conventional pervious cement concrete mixes. Cement content were varied from 300 kg/m3 to 340 kg/m3 with an increment of 10 kg/m3. In total 10 different pervious concrete mixes was prepared considering each level of cement content and each type of fine aggregate. In addition steel fibers were used to increase the strength parameter. The effect of such variation on the properties of pervious concrete mixes was studied.

Erdem Damci.et.al., (2008). [18] They characterized the fly ash and its effects on the compressive strength, properties of Portland cement. They finally indicated that fly ash samples in the ratio of 15% in clinker markedly increases the compressive strength value (61.1 N/mm^2) at 90 days and decreasing the particle size of fly ash in blended Portland cement causes an increase in compressive strength. This means that fineness is a more effective parameter than chemical composition in improving the strength development of fly ash mortars and it is suggested that fine fly ash can be used to obtain higher compressive strength values.

O. Kayali (2008) [16] studied about Fly ash lightweight aggregates in high performance concrete and obtained that concrete produced using fly ash aggregates is around 22% lighter and at the same time 20% stronger than normal weight aggregate concrete. Drying shrinkage is around 33% less than that of normal weight concrete. Moreover, the aggregates possess high durability characteristics that are required for high performance in structures. There are numerous research and journals which clearly explains behavior of fly ash and its properties in concrete that can help and guide many research areas like addition of fly ash to improve soil fertility and crop yield production which requires proper basic knowledge of fly ash.

Rafat Siddique, (2003) [22] studied the behavior of fly ash by replacing sand and obtained result which says that compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity of fine aggregate (sand) replaced fly ash concrete specimens were higher than the plain concrete (control mix) specimens at all the ages.

Charles Berrymana .et.al., (2005) [6] studied fly ash replacement for cement in reinforced concrete pipe with the water reducing admixtures and the results revealed that the maximum 7 days compressive strength was observed for the replacement of 35% Class C and 25% Class F fly ash. An increase of 15 % in durability and strength tests is observed in the concrete mixes containing 65% replacement of cement by Class C fly ash.

Niyazi Ugur Kockal .et.al.,(2011) [15] reveals the utilization of fly ash by replacing coarse aggregates with fly ash and concluded that durable high-strength air-entrained lightweight concretes could be produced using sintered or cold-bonded lightweight fly ash aggregates having comparable performance with the normal weight concretes. Fly ash aggregate lightweight concretes and the normal weight concrete, being air-entrained, were all highly resistant to freeze and thaw cycles, with a minimum durability factor.

V. MATERIAL USED

A. Cement

Ordinary Portland cement is that hydraulic compound when its mixes with water and gets hardened and after its settlement it shows as water resistant property. When this ordinary Portland cement mix with aggregates and water its act as binding material to form a concrete mixture.

1) Physical Properties: OPC

Ordinary Portland Cement43 Grade (IS 8112-1989)

Specific gravity	3.15
Fineness	7%
Consistency limit	33%
Initial setting time	130 min.
Final setting time	425 min.
Unit weight (kg/lit.)	1.30

2) Chemical Properties: OPC

Chemical Properties: OPC (IS 8112-1989)

Oxide	Percent Content
CaO	60-70
SiO_2	17-25
Al_2O_3	3.0-8.0
Fe_2O_3	0.5-6.0
MgO	0.1-4.0
K_2O	0.4-1.3
Na_2O	0.4-1.3
So_3	1.3-3.0

3) Cement Consistency Test of Cement

Cement Consistency Test of Cement

Sr. No.	Percentage of Water	Depth of Needle in Cement Paste in mm
1.	25	38
2.	26	36
3.	27	33
4.	28	25
5.	29	14
6.	30	8
7.	31	4

4) Compressive Strength of Cement

Compressive Strength of Cement

Sl. No.	Days	Compressive Strength in N/mm^2
1	7	30
2	14	37
3	28	42

B. Fly Ash

1) Physical Properties: Fly Ash

Physical Requirement of Fly Ash (IS 3812-2003 Part 1)

Physical Requirement of Fly Ash		
Specific gravity	2.25	
	Requirement grade 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 percent of the strength of corresponding plain cement mortar cubes	

2) Chemical Properties: Fly ash

Chemical Requirement of Fly Ash (IS 3812-2003 Part 1)

Chemical Requirement of Fly Ash	
SiO_2 + Al_2O_3 + Fe_2O_3 in percent by mass, Min.	70.0
SiO_2 in percent by mass, Min.	35.0
Reactive silica in percent by mass, Min.	20.0
MgO in percent by mass, Max.	5.0
SO_3 in percent by mass, Max.	3.0
Na_2O in percent by mass, Max	1.5
Total chlorides in percent by mass, Max	0.05
Loss on ignition in percent by mass, Max	5.0

3) OMC of Fly Ash

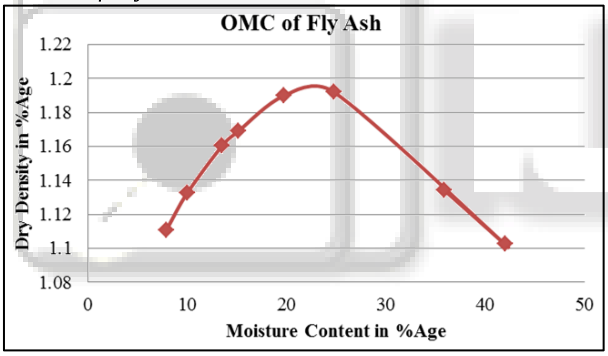

Fig. 1: OMC of Fly Ash

C. Aggregate

1) Fineness modulus of Aggregate

Fineness modulus of Aggregate

Type of Aggregate	Fineness modulus
Coarse	6.270
Fine (sand)	2.308

2) Specific Gravity of Aggregate

Specific Gravity of Aggregate

Type of Aggregate	Size of Aggregate (mm)	Specific Gravity
Coarse	10	2.85
Fine (sand)	-	2.68

3) Water Absorption

Type of Aggregate	Size of Aggregate (mm)	% Age Water Absorption
Coarse	10	0.70
Fine (sand)	-	0.86

Table 3.10 Water Absorption of Aggregate

D. Water

pH value of water used in mixing with ingredients in practical work is 6.

E. Super Plasticizer

To increase the Compressive Strength, reduced the consumption of water and maintain the slump value a poly carboxylic ether based super plasticizer complying with IS: 9103-1999 were used.

VI. Mix Design

A. M35 Mix-design for Paver Blocks

Mix design for M 35 grade for the construction of Paver Block are calculated as per IS 10262:2009 Concrete Mix Proportioning guideline (First Revision). Cement, aggregate, Fly Ash, water and Superplasticizer is taken as tested in the lab.

Sr. No.	Materials	Contents	Ratios
1	Cement	372.5 kg/m^3	1.00
2	Water	149 kg/m^3	0.40
3	Fine aggregate	1062.02 kg/m^3	2.85
4	Coarse aggregate	921.06 kg/m^3	2.47
5	Chemical admixture	8.3 kg/m^3	0.02
6	Water-cement ratio	-	0.40

Table VII: (A) Mix Proportions for Trial in kg/m^3

The above value gives the ratios for conventional mix design of Paver blocks. In this experiment i.e. construction of Paver Blocks cement was replaced by the Fly Ash with 5%, 10%, 15%, 20%, 25% and 30%. The effects of replacement of cement by Fly Ash at various percentages have been considered by Compressive Strength analysis and Flexural Strength analysis. A trail mix proportion for cement which was replaced by various percentage of Fly Ash has been shown below.

Sr. No.	Cement %	Fly ash %	Water %	Superplasticizer by weight of cement, %	F. A. %	C. A. %
1	100	0	0.40	2	100	100
2	95	5	0.40	2	100	100
3	90	10	0.40	2	100	100
4	85	15	0.40	2	100	100
5	80	20	0.40	2	100	100
5	75	25	0.40	2	100	100

Table VII: (B) Mix Proportions for Trial in % age

VII. Experimental Process

A. Casting

1) The moulds are used for making of concrete Paver Block as per IS: 15658-2006 methods of tests for Strength of concrete.
2) Paver back mould of 200×160×80 mm size.
3) Firstly decide the number of sample to be taken during concreting.
4) Before casting of materials shuttering oils should be used inside the mould properly.
5) Collect the all material in the pan before the mixing properly.

6) Mix the all material in the pan.
7) Use of vibrating machine/table in compacting concrete to a voids formation of air voids in concrete.
8) Submerge the specimen in water at a temperature of 27° C for 7 days, 14 days and 28 days respectively.
9) Finally check its compressive strength as per as IS: 15658-2006.

Fig. VIII: (A) Mixing of Material

Fig. VIII: (B) Slump Test (Taken Sample Value = 0 mm)

Fig. VIII: (C) Casting concrete Paver Blocks

B. Curing Process

Curing is a process where a concrete specimen or concrete structure is cured under water for different no. of days for different specimen. For example paver block is cured for 15 to 21 days and then its compressive strength will be checked.

C. Testing Procedure

The test was carried out with specimens at different curing ages. The test was initiated at 7, 14 and 28 days of age of the concrete mixes.

Fig. VIII: (D) Cross Section of Concrete Paver Block Specimens after Curing

VIII. RESULTS AND DISCUSSION

The Paver Block is designed on the basis of IS: 15658 -2006 as per M-35 Grade Designation of-Paver Blocks. The results which are comes out from testing is given below-

A. Compressive strength of paver block

These results show Compressive Strength of Paver Block with partial replacement of cement with Fly Ash at 7, 14 and 28 days and there is also comparison of Compressive Strength is also shown in figure.

Sr. No.	Curing period day	Compressive Strength in N/mm²						
		0% Fly Ash	5% Fly Ash	10 % Fly Ash	15 % Fly Ash	20 % Fly Ash	25 % Fly Ash	30 % Fly Ash
1	7	33.14	30.71	30	27.85	30.71	28.21	26.42
2	14	33.92	32.85	35.71	33.21	33.92	35.71	32.14
3	25	35.71	41.07	35.71	39.28	39.28	42.14	36.42

Table IX: (A) Compressive strength of Paver Block at 7, 14 and 28 days

1) *Compressive Strength of Paver Block at 7 days*

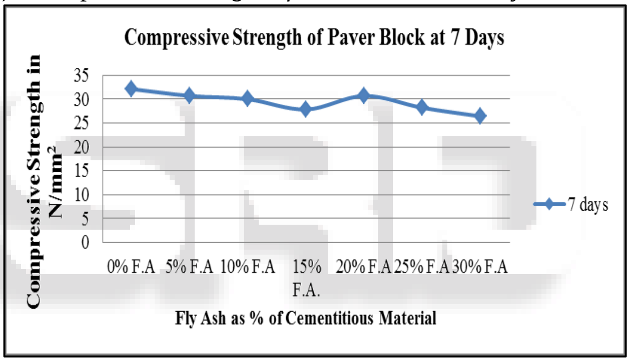

Fig. IX: (A) Compressive Strength of Paver Block at 7 Days

The above figure is drawn between Compressive Strength and percent of Fly Ash at 7 days. At 0% Fly Ash in sample shows high Compressive strength of Paver Block at7 days. Then increase of Fly Ash as % of cementitious material, Compressive Strength of Paver Block decrease but at 20% replacement of cement with Fly Ash strength increase then further decrease.

2) *Compressive Strength of Paver Block at 14 days*

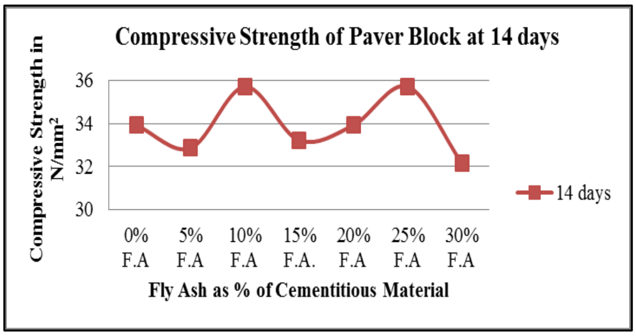

Fig. IX: (B) Compressive Strength of Paver Block at 14 Days

The above figure is drawn between Compressive Strength and percent of Fly Ash at 14 days. The Compressive Strength for Paver Block at 10% and 25%

replacement shows higher and equal strength. At 25% Fly Ash in sample shows high Compressive Strength of Paver Block at 14 days as economic point of view.

3) Compressive Strength of Paver Block at 28 days

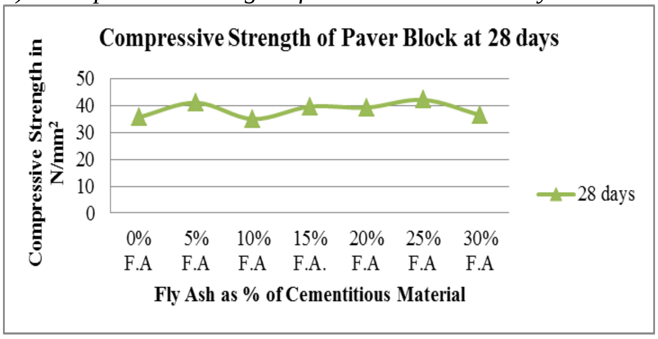

Fig. IX: (C) Compressive Strength of Paver Block at 28 Days

The above figure is drawn between Compressive Strength and percent of Fly Ash at 28 days. At 25% Fly Ash in sample shows high Compressive Strength of Paver Block at 28 days.

4) Compressive Strength of Paver Block at 7, 14 and 28 days

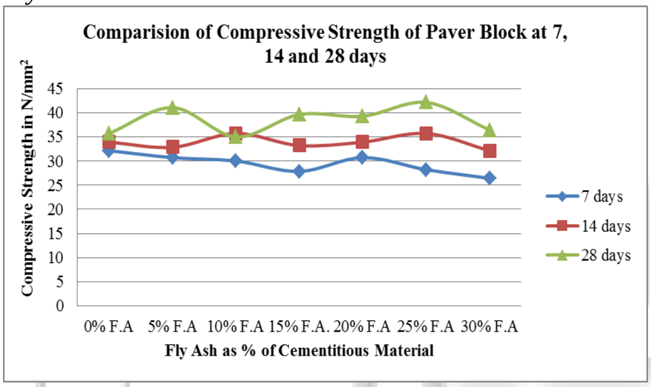

Fig. IX: (D) Compressive Strength of Paver Block at 7, 14 and 28 Days

Above figure shows the comparison of Compressive Strength of Paver Block at 7 days, 14 days and 28 days. It is seem that the Compressive Strength goes on increasing with the increase in Fly Ash but after the replacement of 25% 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 25 % Fly Ash.

B. Flexural Strength Test of Concrete Mixes

As per IS: 15658 -2006 Flexural Strength of M-35Mixes shown in following table below.

These results show Flexural Strength of concrete mix with partial replacement of cement with Fly Ash at 7, 14 and 28 day.

Sr. No.	Curing period day	Flexural Strength in N/mm^2						
		0% Fly Ash	5% Fly Ash	10 % Fly Ash	15 % Fly Ash	20 % Fly Ash	25 % Fly Ash	30 % Fly Ash
1	7	4.5	4.2	3.9	4.2	3.9	4.2	4.2
2	14	5.4	5.7	5.1	5.1	5.4	5.4	4.8
3	25	6.3	6.6	6.3	6	5.4	5.7	5.1

Table IX: (B) Flexural Strength of Paver Block at 7, 14 and 28 days

1) Flexural Strength at 7 days

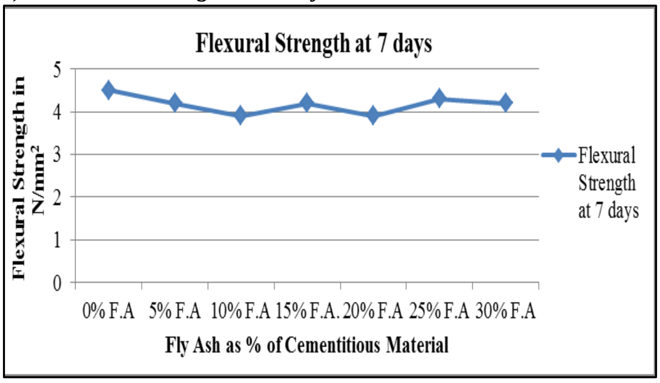

Fig. IX: (E) Flexural Strength of M-35 Mixes at 7 Days

The Flexural Strength of Paver block decreases as percentage of Fly Ash increase as partial replacement of cement but all the samples at 0%, 15% and 25% Fly Ash concrete satisfying Flexural Strength requirement specified by IS 15658:2006.

2) Flexural Strength at 14 days

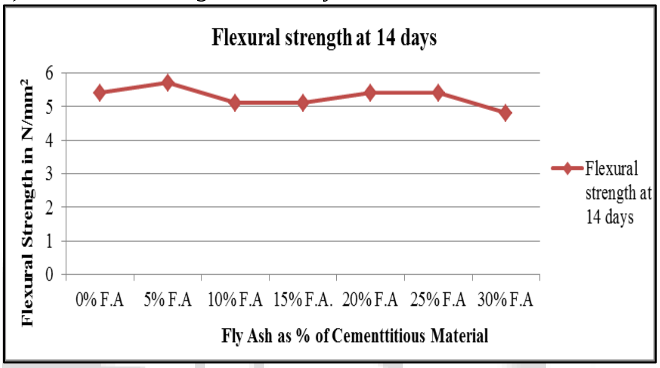

Fig. IX: (F) Flexural Strength of M-35 Mixes at 14 Days

The above figure is drawn between Flexural Strength and percent of Fly Ash at 14days. At 5% Fly Ash in sample shows high Flexural Strength of concrete mix at 14 days. Figure show that increase of Fly Ash as % of cementitious material, Flexural Strength of Paver Block decrease then at 20% and 25% replacement of cement with fly ash strength increase then further decrease. But all the samples of Fly Ash concrete satisfying Flexural Strength requirement specified by IS 15658:2006.

3) Flexural Strength at 28 days

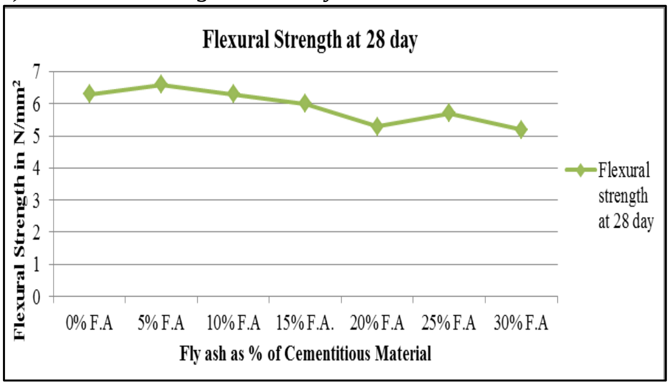

Fig. IX: (G) Flexural Strength of M-35 Mixes at 28 Days

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

C. Water Absorption Test of Paver Block

The ability of a material to absorb and retain water is known as its water absorption. It mainly depends on the volume, size and shape of pores, present in the material. The completely dried pavement blocks are weighed and immersed in clean water for 24 hours (W_w).The block is then removed from water and then weighed (W_d).

Sr. No.	Fly Ash %age	Wet Weight (W_w) in kg	Dry Weight (W_d) in kg	% Water Absorption (W %)
1	0% Fly Ash	5.2	5.06	2.76
2	5% Fly Ash	5.34	5.22	2.29
3	10% Fly Ash	5.3	5.17	2.51
4	15% Fly Ash	5.25	5.12	2.53
5	20% Fly Ash	5.28	5.13	2.92
6	25% Fly Ash	5.29	5.14	2.91
7	30% Fly Ash	5.17	4.98	3.81

Table –IX: (C) Water Absorption Test at 2days as per IS: 15658:2006

As per IS: 15658:2006 water absorption of concrete Paving Block should be less than 7%. But maximum water absorption among all groups was found to be 3.81%. Which is much less than the requirement also it comply maximum water absorption requirement less than 10% as per IS: 2185 (Part I) 2005.

D. Conclusions

1) In this Compressive Strength analysis of Paver Block with 0%, 5%, 10%, 15%, 20%, 25%, 30%, fly ash are tested and graph shown that at 25% fly ash is partially replaced with OPC 43 grade give higher strength as compared to conventional mix i.e., is 0%. Then at 25% fly ash give economic value as compared to conventional mix i.e., is 0%.
2) The Compressive Strength and Flexural Strength increase with the increase in Fly Ash content up to 25% replacement, the values are acceptable according to IS 15658:2006.
3) Replacement of cement by Fly Ash up to 25% by weight has a negligible effect on the reduction of any physical and mechanical properties like compressive strength, flexural strength etc.
4) There is limitation in addition of Fly Ash in concrete to maintain the workability of concrete.
5) There are 10-20% reductions in cost with the addition of 25% fly ash in 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.

E. Recommendations for Future Studies

Use of Fly Ash as fine aggregates in Paver Blocks

1) If the Fly Ash fineness properties are improved, study about possibility of higher compressive strength values can be obtained by preparing different mixtures.
2) Effect of adding Fly Ash on Split Tensile Strength of Paver Block.
3) Weight loss property of Paver block in Acid solution (H_2SO_4) and alkali solution (NaOH).
4) Study on effect of carbonation on property of concrete Paver block and test of efflorescence.
5) Study on abrasion resistance, wearing resistance property of Paver Blocks in construction of pavements.

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