International Journal on Emerging Technologies **6**(2): 60-71(2015)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

A Study on Properties of Concrete by Replacing of Fine Aggregates with Coal Fly Ash

Pawan Kumar* and Anoop Bishnoi**
**Research Scholar, Om Institute of Technology & Management, Hisar, (HR), INDIA*
***Assistant Professor, Om Institute of Technology & Management, Hisar, (HR), INDIA*

(Corresponding author: Pawan Kumar)
(Received 1 July, 2015 Accepted 04 August 2015)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Concrete- a material synonymous with strength and longevity has emerged as the dominant construction material for the infrastructure needs for the Twenty first century. In order to make use of coal ash popular in masonry mortar and structural concrete, research is going on worldwide. In India, research is also going on to utilize huge stocks coal ash in the different zones of the country. The prime objective of the study was to evaluate the structural properties and potential of concrete containing coal fly ash vis-à-vis that of concrete containing no coal fly ash of corresponding mix proportions and strength. The cubes were tested for the compressive strength and beams specimens were tested for flexural strength. Splitting tensile strength tests were conducted on cylinder specimens. The total numbers of 60 cubes, 40 beams specimens and 40 numbers of cylinders were tested for compressive strength, flexural strength and splitting tensile strength respectively at different ages to study the following aspect. The effect on unit weight of concrete after incorporating varying proportions of bottom ash. The effect of coal fly ash on workability (C.F) of fresh concrete. The effect on compressive, flexural and splitting tensile strength using bottom ash in varying percentages as a partial replacement of fine aggregates.

I. INTRODUCTION

Energy is the main backbone and blood stream of modern civilization of the world over, and the electrical power from thermal stations is a major source of energy on which hinges the functioning and growth of manhood. Energy in the form of electricity is a basic necessity for economic development and social progress. Power development is thus a major requirement of overall economic development. Thermal power electricity is generated from the coal fired thermal stations. Coal based thermal power stations generate electricity on one hand which is essential for our development and growth, on the other hand, these power stations also produce massive quantities of coal ash which could pose serious environment and other related problems. In thermal power stations, mainly two types of ashes are produced from burning of coal. The lighter one goes up the chimney and collected either by mechanical or by electrostatic precipitator is known as fly ash. Portion of fly ash escapes along with hot gases through chimneys. The other fraction containing coarser materials are collected at the bottom of the furnace, is called bottom ash. Fly ash is fine and carried away with flue gases. It is separated from hot gases in Electrostatic precipitator. Fly ash is in two type class f and c, in class f fly ash normally produces by burring anthracite or bituminous coal, usually has less than 5% CaO. Class f fly ash has pozzolanic only and in class c fly ash normally produced by burning lignite or sub bituminous coal. Some class c fly ash may have CaO content in excess of 10%. In addition to pozzolanic properties, class c fly ash also possesses cementations properties.

The prime objective of the study was to evaluate the structural properties and potential of concrete containing bottom ash vis-à-vis that of concrete containing no bottom ash of corresponding mix proportions and strength.

II. EXPERIMENTAL

Strength of concrete is considered its most valuable property although in different practical situations. Other characteristics such as durability, impermeability etc. may, in fact are more important. Nevertheless, the strength usually gives an overall picture of quality of concrete because strength is directly relates to the structure of hardened cement paste. To investigate the strength considerations the following tests were conducted:

(i) Compressive strength test
(ii) Flexural strength test
(iii) Split tensile strength test

Along with this test for workability was also conducted. The compression test was carried out on 150mm × 150mm × 150mm cubes, flexural strength tests was carried on 100mm × 100mm × 500mm prisms and split tensile strength test was carried out on 150mm × 300mm cylinders. The following materials were used in the experimental work.

1. Cement
2. Fine aggregates
3. Coarse aggregates
4. Fly ash
5. Super plastisizer

Table 1: Cement Test Results.

S. No.	Characters	Experimental Value	As per IS:8112 1989
1	Consistency of cement	31.0%	-
2	Specific Gravity	3.41	3.15
3	Initial Setting Time	55 Mins	>30 Mins
4	Final Setting Time	275 Mins	<600 Mins
5	Fineness of cement	10%	10%
6	Compressive Strength 3 days 7 days	23.5 N/mm^2 35.8N/mm^2	23 N/mm^2 33N/mm^2

Table 2: Sieve analysis of Fine Aggregates (Weight Taken = 1Kg).

IS Sieve designation	Wt. retained on sieve (gm)	Cumulative wt. retained (gm)	Cumulative %age wt. retained	%age passing
10mm	0	0	0	100
4.75mm	16	16	1.6	98.4
2.36	82	98	9.8	90.2
1.18	150	248	24.8	75.2
600 µm	133	381	38.1	61.9
300	298	679	67.9	32.1
150 µm	257	938	93.8	6.2
<150 µm	71	1000	100	-

Fineness modulus: 2.36

Table 3: Sieve analysis of Coarse Aggregates (Weight Taken = 5 Kg).

IS Sieve designation	Wt. retained on sieve (gm)	Cumulative wt. retained (gm)	Cumulative %age wt. retained	%age passing
80mm	-	-	-	100
40mm	-	-	-	100
20mm	-	-	-	100
10mm	4.6	4.6	92	8
4.75mm	0.34	4.94	98.8	1.2
<4.75µm	0.06	5.00	100	-

Fineness modulus: 6.9

Table 4: Sieve analysis for the Fly Ash (Wt. = 1Kg).

IS Sieve designation	Wt. retained on sieve (gm)	Cumulative wt. retained (gm)	Cumulative %age wt. retained	%age passing
10mm	-	-	-	100
4.75mm	14	14	1.4	98.6
2.36	24	38	3.8	96.2
1.18	54	92	9.2	90.8
600 µm	52	114	11.4	88.6
300µm	158	272	27.2	72.8
150 µm	400	672	67.2	32.8
<150 µm	328	1000	-	-

A. Trials for the Mix Design

With the calculate proportions including W/C, enough quantity as detailed below is prepared for casting 6 cubes of size 150mm × 150mm × 150mm, 3 for 7 days and 3 for 28 days strength tests. Trails for concrete mix are shown below:

Table 5: Trails for concrete mix.

Trails no	W/C	Adopted W/C	Water (lts.)	Cement (Kg.)	Fine aggregates (Kg.)	Coarse aggregates (Kg.)
1	0.45	0.50	213.4	426.7	510.0	1170
2	0.45	0.45	192.0	426.7	527.3	1210
3	0.45	0.43	183.5	426.7	532.7	1225

From the results of the trial mixes, the mix proportion finally selected is shown below:

Water (lts.)	Cement (Kg.)	Fine aggregates (Kg.)	Coarse aggregates (Kg.)
183.5	426.7	532.7	1225
0.43	1	1.25	2.87

Table 6: Designation of the concrete mixes.

Mix designation	Replacement level of bottom ash (%age)	Type of concrete
M1	0	Control mix
M2	20	Fly ash concrete
M3	30	Fly ash concrete
M4	40	Fly ash concrete
M5	50	Fly ash concrete

III. RESULTS AND DISCUSSION

In the present study the results of the tests conducted on plain and bottom ash concrete. The cubes were tested for the compressive strength and beams specimens were tested for flexural strength. Splitting tensile strength tests were conducted on cylinder specimens. The total numbers of 60 cubes, 40 beams specimens and 40 numbers of cylinders were tested for compressive strength, flexural strength and splitting tensile strength respectively at different ages to study the following aspects:

1. The effect on unit weight of concrete after incorporating varying proportions of bottom ash.
2. The effect of fly ash on workability (C.F) of fresh concrete.
3. The effect on compressive, flexural and splitting tensile strength using fly ash in varying percentages as a partial replacement of fine aggregates.

A. Behaviour of Fly Ash Concrete

The effect is investigated on concrete using fly ash as a partial replacement of fine aggregates for the following levels:

1. Replacement of fine aggregate by 20% fly ash.

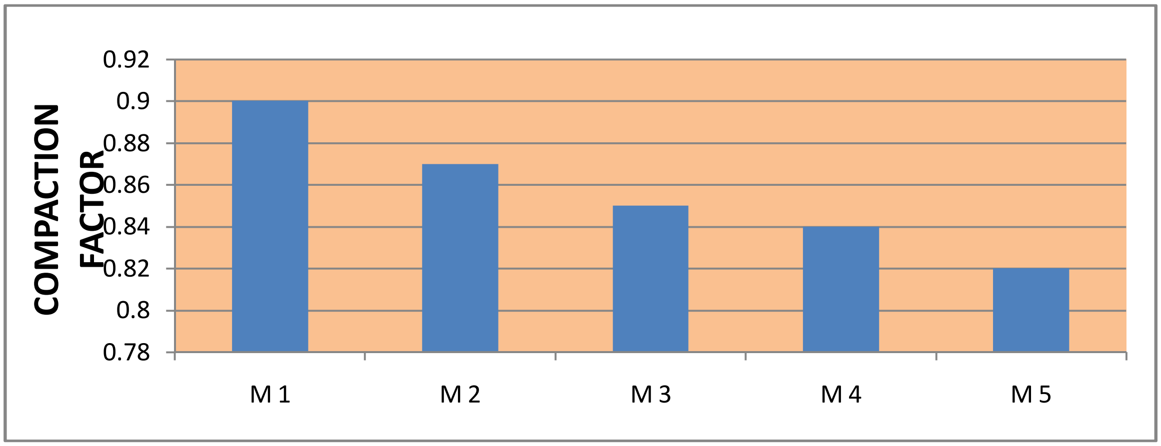

Fig. 1. Compaction Factor for the Fresh Concrete.

Table 7: Workability in term of Compaction Factor.

Mix Type	**M1**	**M2**	**M3**	**M4**	**M5**
C.F.	0.90	0.87	0.85	0.84	0.82

The specific surface is increased due to the increased fineness and a greater amount of water is needed for the mix ingredients to get a closer packing, it results in decrease in workability of mix.

C. Density of Concrete

The density of hardened concrete at saturated surface dried condition was measured at the age of 28 days. From the result in the Table 8, it can be seen that the density of hardened concrete decreased with the increase of the fly ash content. This is due to lower specific gravity of the fly ash, which is 1.68 compared to 2.65 of the natural sand. However, compared with the large difference in the specific gravity of bottom ash and the natural sand, the decrease of the density of the hardened concrete was not as high as anticipated. This is probably due to the factor that fly ash is finer than natural sand and also its particles are spherical, therefore, the fly ash has a better physical filling effect than the natural sand; this should lead to a higher packing degree of the hardened concrete, as a result, the decrease in the density was not very great.

Table 8: Density of concrete.

Mix Type	M1	M2	M3	M4	M5
Density (Kg/m^3)	2480	2467	2437	2408	2400

E. Compressive Strength

The results of compressive strength with age of concrete with and without fly ash in varying proportions are presented in Table 9 -12. The result of compressive strength with age of concrete with and without fly ash in varying proportions are presented in figures. The test results indicate that, fly ash concrete gives comparable strength to that of control concrete the gain of compressive strength of concrete mixes with respect to their compressive strength at 90 days is shown in table: 13

Table 9: Test results for compressive strength at 7 days.

Mix Type	Loads (KN)	Compressive strength (MPa)	Av. Compressive strength (MPa)
M1	550	24.4	24.74
	555	24.7	
	565	25.11	
M2	520	23.11	23.26
	525	23.33	
	525	23.33	
M3	500	22.22	22.48
	505	22.44	
	490	21.78	
M4	485	21.55	21.7
	500	22.22	
	480	21.33	
M5	460	20.44	20.15
	450	20	
	450	20	

Table 10: Test results for compressive strength at 28 days.

Mix Type	Loads (KN)	Compressive strength (MPa)	Av. Compressive strength (MPa)
M1	740	32.89	33.33
	750	33.33	
	760	33.77	
M2	685	30.44	30.43
	680	30.22	
	690	30.67	
M3	665	29.55	29.55
	660	29.33	
	670	29.78	
M4	625	27.78	28
	630	28	
	635	28.22	
M5	585	26	26.37
	595	26.44	
	600	26.67	

Table 11: Test results for compressive strength at 56 days.

Mix Type	Loads (KN)	Compressive strength (MPa)	Av. Compressive strength (MPa)
M1	800	35.55	35.4
	795	35.33	
	795	35.33	
M2	720	32	32.15
	725	32.22	
	720	32	
M3	710	31.55	31.78
	715	32.78	
	720	32	
M4	690	30.67	30.6
	690	30.67	
	685	30.44	
M5	685	30.44	30.44
	680	30.22	
	690	30.67	

Table 12: Test results for compressive strength at 90 days.

Mix Type	Loads (KN)	Compressive strength (MPa)	Av. Compressive strength (MPa)
M1	840	37.33	37.18
	820	36.44	
	840	37.78	
M2	820	36.44	36.07
	800	35.55	
	815	36.22	
M3	830	36.89	36.74
	820	36.44	
	830	36.89	
M4	800	35.55	35.26
	790	35.11	
	790	35.11	
M5	800	35.55	35.18
	795	35.33	
	780	34.67	

Table 13: Compression behavior of Fly Ash with age.

Mix Type	Compressive strength (f_c) N/mm^2				f_{c7}/f_{c90}	f_{c28}/f_{c90}	f_{c56}/f_{c90}
	7 days	28 days	56 days	90 days			
M1	24.74	33.33	35.40	37.18	0.665	0.896	0.952
M2	23.26	30.43	32.15	36.07	0.645	0.844	0.891
M3	22.48	29.55	31.78	36.74	0.612	0.804	0.865
M4	21.70	28.00	30.60	35.26	0.615	0.794	0.868
M5	20.15	26.37	30.44	35.18	0.573	0.750	0.865

Table 14: Compression behavior of Fly Ash concrete v/s Plain Concrete.

Mix Type	Strength gain = Strength of Fly Ash concrete x100 / Strength of Plain concrete			
	7 days	28 days	56 days	90 days
M2	69.79	91.30	96.46	108.22
M3	67.45	88.66	95.35	110.23
M4	65.11	84.01	91.81	105.80
M5	60.46	79.12	91.33	105.55

It is observed from the tables that fly ash concrete attains the compressive strength at a slower rate than that of plain cement concrete. 'M3' fly ash concrete at the age of 90 days attains compressive strength equivalent to 110% of the compressive of plain concrete at 28 days where as 'M2', 'M4' and 'M5' attains 105-108% of strength at the same age. The gain of compressive strength by different types of fly ash concrete w.r.t. their compressive strength at the age of 90 days varies from 57%-65% at 7 days, 75%-85% at 28 days and varies between 86%-90% at 56 days. It is clear that fly ash concrete gains strength at a slow rate in the initial period and it acquires strength at faster rate beyond 28 days due to some pozzolanic reaction of fly ash. After the age of 28 days the increase in the pozzolanic activity of fly ash is sufficient to contribute to the compressive strength. The compressive strength of concrete decreases with the replacement level of the fine aggregate because fly ash particle are softer than fine aggregates.

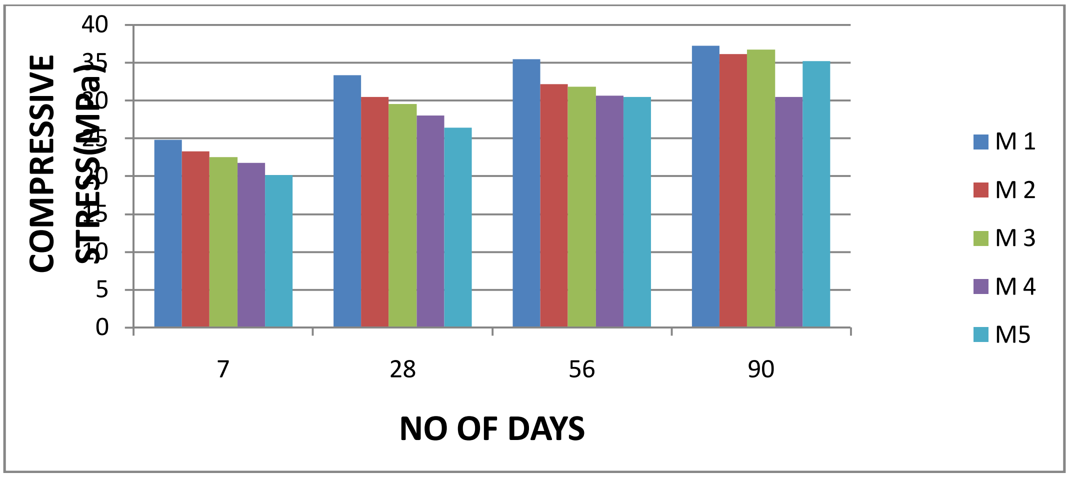

Fig. 2. Compressive Strength of Concrete.

IV. FLEXURAL STRENGTH

A primary concern in designing concrete for use in highway application is the flexural strength on concrete. The flexural strength or the modulus of rupture of concrete is an indirect measure of the tensile strength and it is the most often used test by highway department in evaluating concrete for payment. The results of flexural strength of concrete are shown in the tables 15-18 for the concrete under study at the ages of 7, 28, 56, and 90 days. The results are plotted in figs. 4-5, showing the variations in strength of different types of fly ash concrete.

Table 15: Test results for flexural strength at 7 days.

Mix Type	Loads (KN)	Flexural strength (MPa)	Av.Flaxural strength (MPa)
M1	6 6.4	2.4 2.56	2.48
M2	6 6	2.4 2.4	2.4
M3	5.6 5.8	2.24 2.32	2.28
M4	5.4 5.6	2.16 2.24	2.2
M5	5 5.2	2 2.08	2.04

Table 16: Test results for flexural strength at 28 days.

Mix Type	Loads (KN)	Flaxural strength (MPa)	Av. Flexural strength (MPa)
M1	8.0 8.6	3.20 3.44	3.32
M2	8.0 8.0	3.20 3.20	3.20
M3	7.0 7.6	2.80 3.04	2.92
M4	6.0 6.5	2.40 2.64	2.52
M5	6.0 6.0	2.40 2.40	2.40

Table 17: Test results for flexural strength at 56 days

Mix Type	Loads (KN)	Flexural strength (MPa)	Av. Flaxural strength (MPa)
M1	9.0 9.2	3.60 3.68	3.64
M2	8.8 8.8	3.52 3.52	3.52
M3	9.0 8.8	3.60 3.52	3.56
M4	8.6 8.6	3.44 3.44	3.44
M5	8.6 8.6	3.44 3.44	3.44

Table 18: Test results for flexural strength at 90 days.

Mix Type	Loads (KN)	Flaxural strength (MPa)	Av. Flaxural strength (MPa)
M1	10.0 12.0	4.00 4.80	4.40
M2	10.0 9.6	4.00 3.84	3.92
M3	9.6 9.2	3.84 3.68	3.76
M4	9.6 9.4	3.84 3.76	3.80
M5	9.4 9.4	3.76 3.67	3.76

The gain of flexural strength of concrete mixes with respect to their flexural strength at 90 days is shown in Table:19

Table 19: Flexural behaviour of Fly Ash concrete with age.

Mix Type	Flexural strength (f_t) N/mm^2				F_{t7}/f_{t90}	F_{t28}/f_{t90}	F_{t56}/f_{t90sss}
	7 days	28 days	56 days	90 days			
M1	2.48	3.32	3.64	4.40	0.564	0.754	0.830
M2	2.40	3.20	3.52	3.92	0.612	0.820	8.898
M3	2.28	2.92	3.56	3.76	0.160	0.767	0.947
M4	2.20	2.52	3.44	3.80	0.579	0.663	0.905
M5	2.04	2.40	3.44	3.76	0.542	0.638	0.915

Table 20: Flexural Behavior of Fly Ash Concrete v/s Plain Concrete.

Mix Type	Strength gain = Strength of Fly Ash concrete x100 / Strength of Plain concrete			
	7 days	28 days	56 days	90 days
M2	72.3	96.4	106.0	118.0
M3	68.7	88.0	107.2	113.0
M4	66.3	75.9	103.6	114.4
M5	61.4	72.3	103.6	113.3

It is observed from the table that the fly ash concrete gain flexural strength at slow rate than plain concrete. The flexural strength gain depends upon the percentage replacement of fine aggregates. The flexural strength gain is more at 20% replacement of fine aggregates with fly ash. At higher percentages the strength gain decreases and it is minimum at 40% and 50% replacement level. Plain concrete attains 56, 45 and 83% strength at 7, 28, and 56 days of its flexural strength at 90 days respectively. Whereas the fly ash concreter mixes attains flexural strength between 54-62%, 63-82% and 91-95% for mixes 'M2', 'M3', 'M4' and 'M5' respectively.

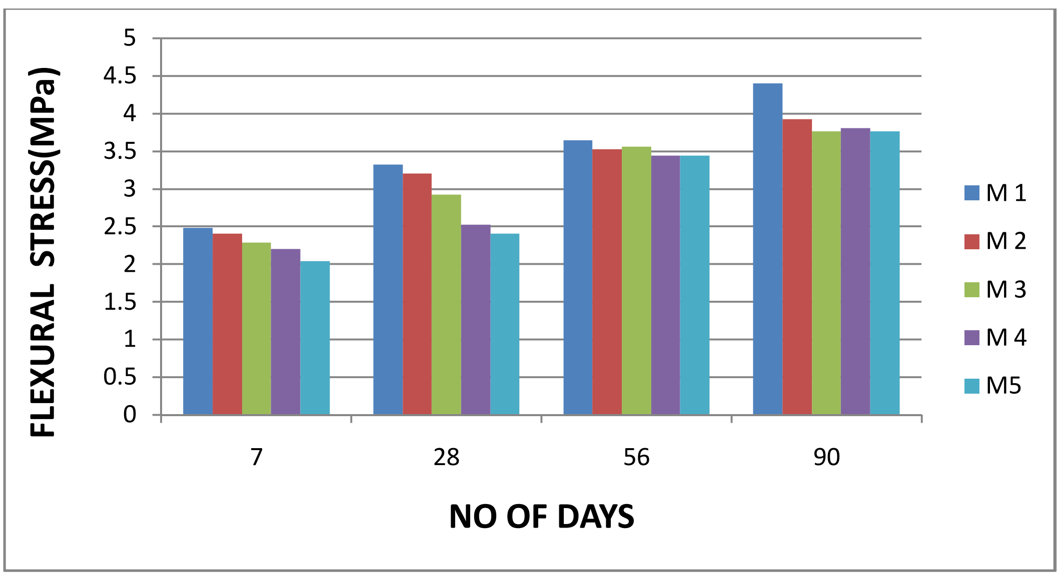

Fig. 3. Flexural Strength of Concrete.

It is seen from the results that 'M4' mix type gives comparable flexural strength of 3.92 MPa at the age of 90 days which can be used for pavement application. Results show that with the increase in the fly ash percentage, the flexural goes on decreasing. The flexural strength of fly ash concrete decreases with the increase in replacement of the fine aggregates and at the same time it is seen that flexural strength of fly ash concrete increases with the age.

The reason behind the strength behaviour is same as that of compressive strength behaviour. Moreover, the flexural strength is affected to more extent with the increase in fly ash content. Hence it is concluded that the fly ash concrete gains flexural strength with the age and it is comparable but is still less than that of plain concrete, it is because of the fact that there is poor interlocking between the aggregates as fly ash particles are spherical in nature.

V. SPLITTING TENSILE STRENGTH

The results of splitting tensile strength with age of concrete with and with Fly ash in varying proportions are presented in table 21-24.

Table 21: Test results for Splitting Tensile Strength at 7 days

Mix Type	Loads (KN)	Splitting Tensile Strength (MPa)	Av. Splitting Tensile Strength (MPa)
M1	160 150	2.26 2.12	2.19
M2	140 150	1.98 2.12	2.05
M3	150 130	2.12 1.84	1.98
M4	135 120	1.91 1.7	1.8
M5	110 130	1.56 1.84	1.7

Table 22: Test results for Splitting Tensile Strength at 28 days.

Mix Type	Loads (KN)	Splitting Tensile Strength (MPa)	Av. Splitting Tensile Strength (MPa)
M1	180 190	2.55 2.70	2.62
M2	175 180	2.50 2.55	2.52
M3	165 170	2.33 2.41	2.37
M4	155 165	2.19 2.33	2.26
M5	155 160	2.19 2.26	2.23

Table 23: Test results for Splitting Tensile Strength at 56 days.

Mix Type	Loads (KN)	Splitting Tensile Strength (MPa)	Av. Splitting Tensile Strength (MPa)
M1	210 215	2.97 3.04	3.01
M2	200 200	2.83 2.83	2.83
M3	195 190	2.76 2.69	2.72
M4	190 190	2.69 2.69	2.69
M5	190 190	2.69 2.69	2.69

Table 24: Test results for Splitting Tensile Strength at 90 days.

Mix Type	Loads (KN)	Splitting Tensile Strength (MPa)	Av. Splitting Tensile Strength (MPa)
M1	240 240	3.40 3.40	3.40
M2	230 235	3.26 3.33	3.30
M3	230 230	3.26 3.26	3.26
M4	225 230	3.18 3.26	3.22
M5	225 225	3.18 3.18	3.18

Table 25: Splitting tensile behaviour of Fly Ash concrete with age.

Mix Type	Splitting Tensile Strength (MPa) (f_{st}) N/mm^2				f_{st7}/f_{st90}	f_{st28}/f_{st90}	f_{st56}/f_{st90}
	7 days	28 days	56 days	90 days			
M1	2.19	2.62	3.01	3.40	0.644	0.770	0.885
M2	2.05	2.52	2.83	3.30	0.621	0.764	0.860
M3	1.98	2.37	2.72	3.26	0.607	0.727	0.834
M4	1.80	2.26	2.69	3.22	0.560	0.702	0.835
M5	1.70	2.23	2.69	3.18	0.535	0.701	0.846

Table 26: Splitting tensile behaviour of Fly Ash concrete v/s Plain concrete.

Mix Type	Strength gain = Strength of Fly Ash concrete x100 / Strength of Plain concrete			
	7 days	28 days	56 days	90 days
M2	78.2	96.2	108.0	126.0
M3	75.6	90.5	103.8	124.4
M4	68.7	86.2	102.7	123.0
M5	64.9	85.1	102.7	121.4

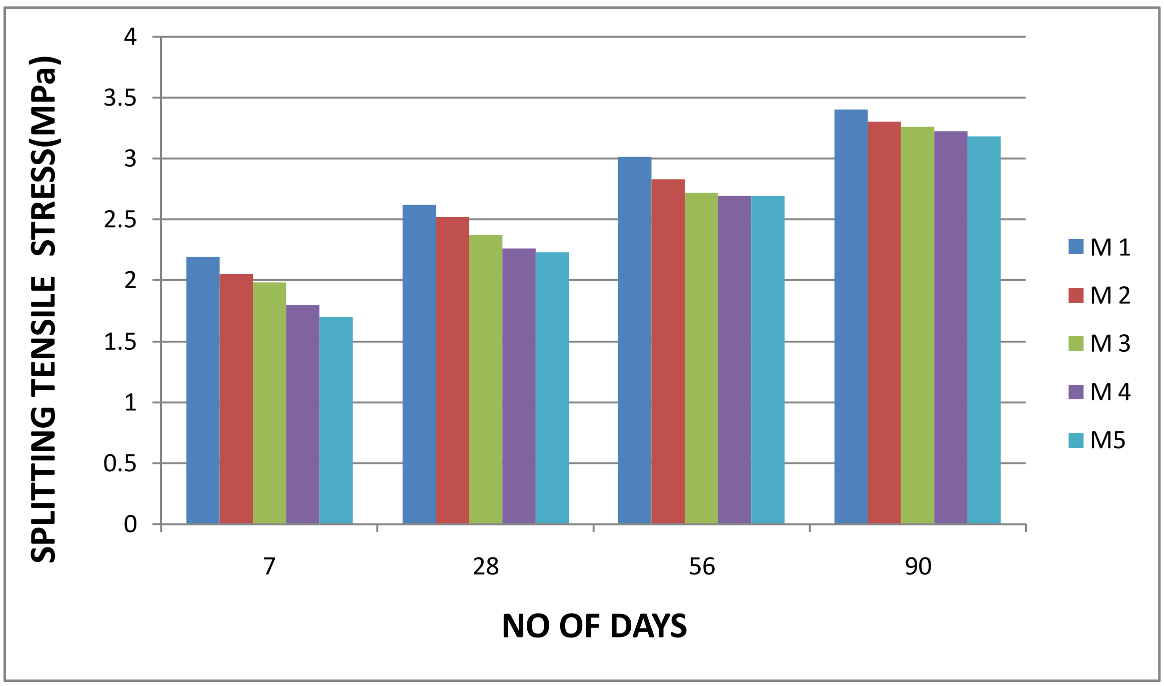

Fig. 4. Splitting Tensile Strength of Concrete.

It is observed from the tables that the splitting tensile strength of concrete decreases with the increase in the percentage of fine aggregates replacement with the bottom ash, but the splitting tensile strength increases with the age of curing. The rate of increase of splitting tensile strength decreases with the age. The splitting tensile strength gain is more at 20% replacement of fine aggregates with fly ash.

At higher percentages the strength gain decreases and it is minimum at 50% replacement level. Plain concrete attains 64%, 77% and 88% strength at 7, 28 and 56 days of its splitting tensile strength at 90 days respectively. Whereas the fly ash concrete attains splitting tensile strength between 62-86%, 60-83%, 56-83% and 53-84% fro mixes 'M2', 'M3', 'M4' and 'M5' respectively.

The strength gain of fly ash concrete w.r.t. plain concrete at 28 days is comparable, so we can use bottom ash concrete for the pavement application.

CONCLUSIONS

(i) The workability of concrete decreased with the increase in fly ash content. This is considered to be due to the increase in water demand which is incorporated by increasing the content of super plastisizer.

(ii) The density of concrete decreased with the increase in fly ash content. This is considered to be due to the low specific gravity of fly ash as compared to fine aggregates.

(iii) Compressive strength, Splitting tensile strength and Flexural strength of fine aggregates replaced fly ash concrete specimens were lower than control concrete specimens at all the ages. The strength difference between fly ash concrete specimens and control concrete specimens became less distinct after 28 days.

(iv) Compressive strength, Splitting tensile strength and Flexural strength of fine aggregate replaced bottom ash concrete continue to increase with age for all the fly ash contents.

(v) Mix containing 30% and 40% bottom ash, at 90 days, attains the compressive strength equivalent to 108% and 105% of compressive strength of normal concrete at 28 days and attains flexural strength in the range of 113-118% at 90 days of flexural strength of normal concrete at 28 days. The time required to attain the required strength is more for fly ash concrete.

(vi) Fly ash concrete attains splitting tensile strength in the range of 121-126% at 90 days of splitting tensile strength of normal concrete at 28 days.

(vii) Compressive strength of fly ash concrete containing 50% bottom ash is acceptable for most structural supplications since the observed compressive strength is more than 20 MPa at 28 days.

(viii) Even though the strength development is less for bottom ash concrete, it can be equated to lower grade of normal concrete and making utilization of waste material justifies the concrete mix-development.

(ix) Fly ash used as fine aggregates replacement enables the large utilization of waste product.

REFERENCES

[1]. Akthem A. Av-Manaseeer, Moir D.Hang and Karum W.Nasser 'Compressive strength of concrete containing fly ash, *Brine and Admixture' ACI Material J.* March-April 1988, pp109-116.

[2]. Chai Jaturapitakkul & Raungrut Cheerarot 'Development of Bottom Ash as pozzolainic *material'. J. of materials in Civil Engineering* Jan-Feb 2003, pp48-53.

[3]. Gambhir M.L. 'Concrete Technology', Publisher Tata McGraw Hill.

[4]. IS:383-1970. 'Specifications for Coarse and Fine Aggregates from Natural sources for Concrete' Bureau of Indian Standards, New Delhi, India.

[5]. IS:516-1959. 'Indian Standard Code of Practice Methods of Test for Strength of Concrete' Bureau of Indian Standards, New Delhi, India.

[6]. IS:1199-1959. 'Indian Standard Methods of Sampling and analysis of Concrete, Bureau of Indian Standards, New Delhi, India.

[7]. IS:8112-1989. Specifications for 43 Grade Portland Cement, Bureau of Indian Standards, New Delhi, India.

[8]. IS:10262-1982. 'Recommended guidelines for Concrete Mix Design' Bureau of Indian Standards, New Delhi, India.

[9]. J. Pera, L. Coutaxz, J. Ambroise, M Chababbet ' Use of incinerator Bottom Ash in concrete' Cement and Concrete Research volume **27**, 1997, pp 1-5.

[10]. Mohammed Maslehuddin, Abdulaziz, Al-Mana, Mahammed Shamim and Huseyin Saricimen. 'Effect of Sand Replacement on the Early Age Strength Gain and Long Term Corrosion Resisting Characteristics of Fly Ash Concrete' MCI Materials J.Jan-Feb1989, pp 58-62.

[11]. M.N. Haque, R.L. Day, B.W. Langan. 'Realistic Strength of Air-Entrained Concretes with and without Fly Ash' MCI Materials J. July-August 1989, pp 214-247.

[12]. M. Nisnevich, G. Sirotin and Y. Eshel. 'Light Weight Concrete Containing Thermal Power Station and Stone Quarry Waste' Magazine of concrete Research August 2003, pp 313-320.

[13]. P Won, Y.S Lec, C.G Park, H.G Park 'Durability Characteristics of Controlled Low Strength Material Containing Recycled Bottom Ash' Magazine of Concrete Research. Sep 2004, pp 429-436.

[14]. R.N. Swami, Sami A.R. Alli and D.D Theodorakepoulos 'Early Strength Fly Ash Concrete for Structural Application'. *ACI Material J.* Sep-Oct 1983, pp 414-422.

[15]. R. Siddique 'Effect of Fine Aggregate Replacement with Class F Fly Ash on Mechanical Properties of Concrete' Cement and Concrete Research, Vol. **33** (2003), pp 539-547.

[16]. R. Siddque 'Performance Characteristics of high Volume Class F Fly Ash Concrete' Cement and Concrete Research, Vol. **34** (2004), pp 487-493.

[17]. R. Siddque 'Effect of Fine Aggregate Replacement with Class F Fly Ash on the Abrasion Resistance of Concrete' *Cement and Concrete Research*, Vol. **33** (2003), pp 1877-1881.

[18]. Sivasundram and V.M. Malhotra 'High Performance High Volume Fly Ash Concrete' ICJ, Nov-2004, pp 13-21.

[19]. Tarun R. Naik and Bruce W. Ramme 'High Strength Concrete Containing Large Quantities of Fly Ash'. *ACI Materials J.* Mar-Apr1989, pp 111-116.

[20]. V.M. Malhotra, P. Kumar Mehta 'HVFA Concrete for Sustainable Development' ICJ, Nov-2004, pp 3-4

[21]. www.indiatogether.org/2005/may/env-flyash.htm.

[22]. www.flyash.org

[23]. Yun Bhai and P.A. Muhammed Bsheer 'Influence of Furnace Bottom Ash on Properties of Concrete' Structures and Buildings, Feb-2003, pp 85-92.

[24]. Yun Bhai, Ratiyah Ibrahim and P.A. Muhammed Basheer 'Properties of Light weight Concrete Manufactured with Fly Ash, Furnace Bottom Ash and Lytag' *International Workshop on Sustainable Development and Concrete Technology.*