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IMPROVING THE MECHANICAL PROPERTIES OF BOTTOM ASH BASED CONCRETE BY INCORPORATING ALCCOFINE

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ABSTRACT:

Concrete is the most commonly utilized construction material in today's development. Waste material like slag, fly ash, etc. can be utilized in concrete as replacement of its constituents that can be economical in nature. Huge amount of bottom ash is gathered from the thermal power plants as an industrial by product. Disposal of the bottom ash in environment is hazardous in nature and generate different types of human health diseases. Bottom ash as waste material can be disposed in concrete as replacement of river sand. Alccofine is used as Supplementary Cementitious Material (SCM) and it is also known as new generation ultrafine particle. Alccofine helps in improvement of the cementitious properties of concrete mix and helps in gaining strength of concrete. This study was carried for the improvement of the mechanical properties of Bottom ash based concrete incorporating Alccofine. The objectives of this study were as follows: (a) Effect of inclusion of Alccofine for improving the strength of bottom ash based concrete. (b) To determine mechanical properties of concrete: compressive, split tensile and flexural strengths. Experimental program consists of collection of materials from nearby sources i.e. Bottom ash collected from NTPC Badarpur Border, New Delhi and Alccofine was collected from the local dealer of Gurugram, Haryana. After collection of the material calculation of mix design of M40 grade was prepared with guidelines of IS 456:2000 and IS10262:2009. Replacement of bottom ash with sand was done in different proportions i.e. 10, 20 and 30% in M40 grade of concrete mix. Alccofine was partially replaced with cement up to 10% in every mix of concrete instead of control mix. These mixes specimens were prepared for testing compressive, flexural and Split tensile strengths at the ages of curing 7, 14 and 28 days. Results of experimental program showed that inclusion of alccofine in bottom ash based concrete improved the strengths of different types of concrete mixes. The workability of concrete reduced with the use of coal bottom ash as a replacement of fine aggregate. The above observation of this experimental investigation indicated that addition of bottom ash beyond 30% in concrete resulted in decreased mechanical strength. Whereas Alccofine can be used for the improvement of cementitious properties of concrete and bottom ash can be replaced by sand up to 20% with Alccofine.

Keywords: *Bottom ash, Alccofine, Cement, Sand, Strengths.*

1. Introduction:

Concrete is the most widely utilized construction material in building development. Concrete is a blended material that consists of different materials like hydraulic cement, water, fine aggregate and coarse aggregate. Whereas water helps in hydration of cement and cement works as a binding material, aggregate utilized as a filler material. It can be moulded in desired shape when in fresh state. Concrete is rigid in nature. Concrete has advanced compressive strength yet has low elasticity. The hardness and strength of concrete increase with the passage of time. Concrete is a material that can consumed waste material by replacing its constituents. Thermal waste constituents can be replaced in concrete through river sand to prevent the insufficiency of the stream (river) sand, which is utilized as a fine aggregate in concrete. By the utilization of waste materials in concrete nature can be preserved from the hazardous chemical and harmful elements, which are present in waste materials.

In Coal, based warmth (thermal) power plants vast volume of bottom ash is generated as a byproduct. Bottom ash is gathered at the base of thermal furnace and which is coarser in extent and nonflammable in nature. In

India, approximately 170 million of coal ash is generated in warmth power plants whereas this coal ash contains approximately 34 million tons of Bottom ash. Bottom ash is generally known as a miscellaneous particle, which comprises of magnetic and paramagnetic metals, glass, artificial and natural ceramic, unburned particles. Bottom ash contains pollutants that are acidic, toxic and radioactive matters. Bottom ash additionally has little harmful chemical composition like lead, arsenic, mercury, cadmium and uranium. Bottom ash increases chances of cancer and further respirational problems in human beings. Ingestion of the bottom ash has effects on the nervous system, causes mental problems, development delays, behavioral problems and it has possibility of creating lungs disorders, kidney disorders and gastrointestinal disease. Bottom ash has such severe impacts on environment when it is disposed in lagoons. These wet lagoons don't have proper lining which create problems in prevention of leaking and leaching by adulteration of groundwater is much more common. In leaching process toxic constituents of the bottom ash which disintegrate out and bleed with water. If such groundwater is the source of drinking water it will be very harmful to living beings health due to contamination of groundwater.

There are several ways to dispose off the bottom ash without any hazardous impact on environment. It can be consume in concrete as partly substituted by fine aggregate. Assets of bottom ash are similar in appearance and particle dimension distribution to fine aggregate (River sand) and have some chemical properties. The literature available showed that strength and workability decreased at higher content of bottom fly ash. However, alccofine is very fine in nature and rich in calcium hydroxide. Therefore, it was planned to include alccofine. This inclusion had possibility of improvement in properties and higher replacement of sand.

2. EXPERIMAENTAL PROGRAM:

This investigation was done for the improvement of the mechanical properties of bottom ash based concrete by incorporating alccofine in M40 grade of concrete.

Materials and Mix Proportions:

Bottom ash recycled as the partial replacement with bottom ash because its physical properties are similar to the river sand. Bottom ash is coarser in nature and some chemical properties, which attract to use this material in concrete. Bottom ash collected from the NTPC Badarpur Boarder, New Delhi, India. ***Alccofine*** material is ultrafine micro-particle that used as the supplementary cementitious material. Alccofine helps in the improvement strength of concrete. Alccofine was collected from local dealer. ***Cement*** is utilize as the binding material for the concrete, which binds the coarse aggregate with fine aggregate and helps in filling the small voids of concrete. Where specific gravity of cement is 3.15. Ordinary Portland Cement 43 grade is selected as per IS 8112:1989. ***Fine aggregate*** and ***Coarse aggregate*** were selected as per IS 383:1970. Where fine aggregate use for the casting was river sand and coarse aggregate used was broken granite-crushed stone. ***Super plasticizer*** is a water reducing chemical admixture and it helps in improvement of the workability of concrete.

There are different kinds of mix proportions were prepared of concrete for testing the mechanical properties of concrete. One mix was control mix and one was prepared with 10% Alccofine that replaced with cement, and other mix was prepared with utilization of bottom and alccofine both in different proportions i.e. 10%, 20% and 30% bottom ash and constant 10% alccofine with sand and cement respectively. These mix were design of M40 grade of concrete as per IS 10262:2009.

3. RESULTS AND DISCUSSIONS:

In the current exploration, Alccofine and Bottom ash were partly replaced by cement and fine aggregate respectively. This study was done for enhancement of the mechanical properties of bottom ash based concrete. In the preliminary stage of the investigation choice of percentages of the bottom ash and alccofine which is replaced from fine agg. and cement respectively. In another step mixes concrete were organized which was control and replacement mixes of the alccofine and bottom ash.

After choice of concrete mixes, casting and curing of these completed for the resolution of mechanical properties of the concrete i.e. compressive, Flexural and Split tensile strength. These strengths of concrete were determined and comparison of these strengths were done as follows:

3.1 Compressive Strength:

Compressive strength was determined at various ages of 7, 14 and 28 days as per IS 516-1959 with different forms of mixes of Alccofine and Bottom ash. Compressive strength was determined by taking the average strength of 3 cubes of 150mm.

3.1.1 Effect of Bottom ash

The results of compressive strength test shows that there was increase in the strength of concrete mixes with initial involvement of bottom ash as partial replacement of river sand and after further involvement of bottom ash strength decreases.

The results of compressive strength test are as follow:

- There was an increase of 4.06%, 8.92% and 1.64% when the strength of control mix CM(31.84MPa) was compared with the strengths of mixes M1(33.13MPa), M2(34.68MPa), M3(32.36MPa) at the age of 7 days.
- An increase of 4.19%, 8.58% and 3.4% for mixes M1(46.28MPa), M2(48.23MPa), M3(45.93MPa) and decrease of 7.65% for mix M4(41.02MPa) was observed at the age of 14 days as compared to control mix CM(44.42MPa).
- Similarly, at the age of 28 days, an increase of 3.03%, 5.56% and 0.15% for mixes M1(51.03MPa), M2(52.28MPa), M3(49.6MPa) and decrease of 6.99% for mix M4(46.04MPa) was observed as compared to reference mix CM(49.53MPa).

The maximum compressive strength was of mix M2(52.28MPa) with 10% bottom ash and alccofine at 28 days.

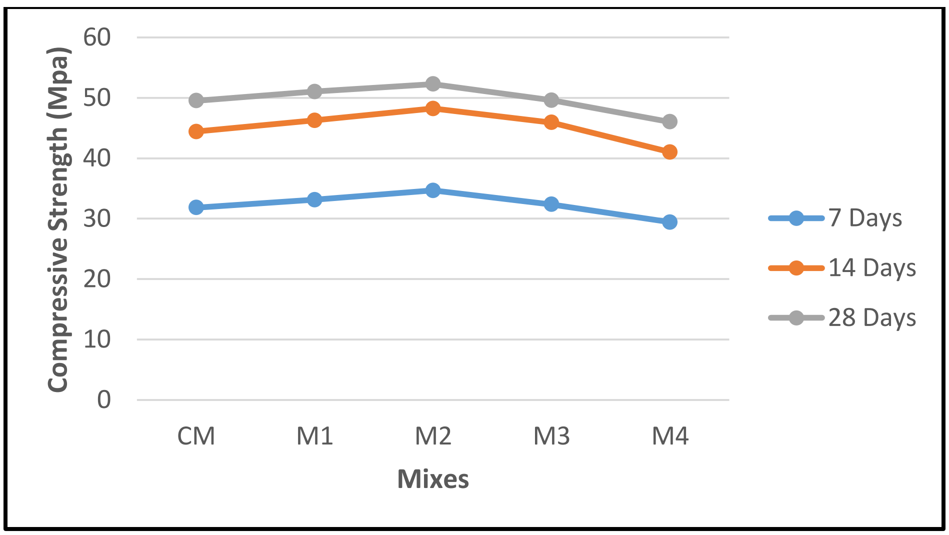

Fig: 3.1 Compressive strength of various concrete mixes.

3.1.2 Effect of curing time:

- Compressive strength of all the mixes increases with the age of concrete.The reference mix CM showed an increase of 39.52% strength from 7 to 14 days and 11.53% strength from 14 to 28 days.
- The M1, M2, M3 and M4 mixes attained a relatively constant strength of 38.9-39.7% from 7 to 14 days and 8-12.25% from 14 to 28 days of curing.

3.2 Flexural Strength:

Flexural strength of concrete were determined at the ages of 7, 14 and 28 days as per IS 516:1959.

3.2.1 Effect of Bottom ash:

The results of flexural strength test shows that there was increase in the strength of concrete mixes with initial involvement of bottom ash as partial replacement of river sand and after further involvement of bottom ash strength decreases.

The results of flexural strength test are as follow:

- An increase of 5.6%, 5% and 1.04% when the strength of control mix CM(3.89MPa) was compared with the strengths of mixes M1(4.1MPa), M2(4.08MPa), M3(3.93MPa) at the age of 7 days.
- An increase of 2.17%, 3.7% and 1.53% for the mixes M1(4.72MPa), M2(4.79MPa), M3(4.69MPa) and decrease of 3.66% for mix M4(4.45MPa) was observed at the age of 14 days as compared to control mix CM(4.62MPa).
- Similarly, at the age of 28 days, an increase of 1.87%, 3.3% and 0.45% for mixes M1(4.95MPa), M2(5.02MPa), M3(4.88MPa) and decrease of 3.2% for mix M4(4.7MPa) was observed as compared to reference mix CM(4.86MPa).

The maximum compressive strength was of mix M2(5.02MPa) with 10% bottom ash and alccofine at 28 days.

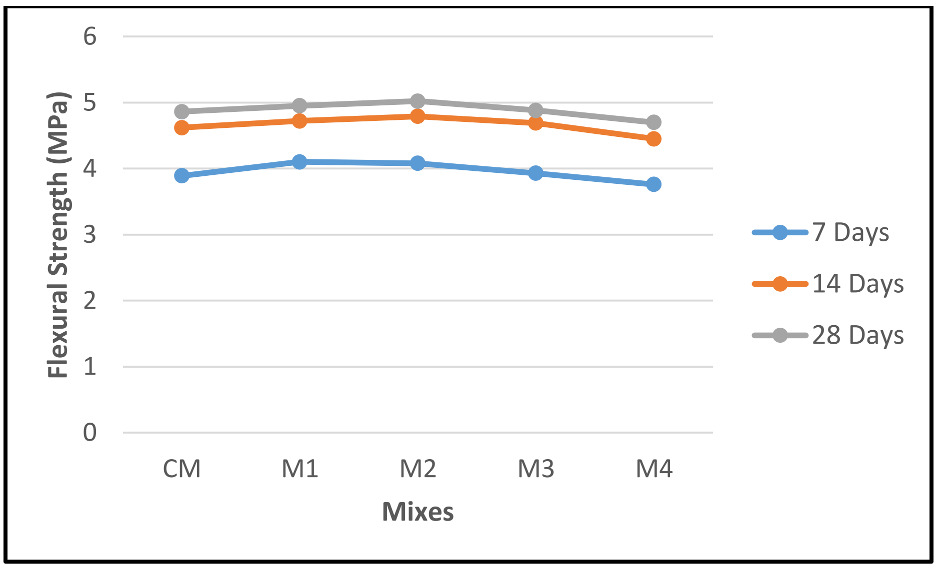

Fig: 3.2 Flexural strength of various concrete mixes.

3.2.2 Effect of curing time:

- Flexural strength of all the mixes increases with the age of concrete. The reference mix CM showed an increase of 18.8% strength from 7 to 14 days and 5.2% strength from 14 to 28 days.
- The M1, M2, M3 and M4 mixes attained a relatively constant strength of 15.2-19.3% from 7 to 14 days and 4% to 5.7% from 14 to 28 days of curing.

3.3 Split tensile strength:

Spilt tensile strength of concrete was determined at various ages of 7, 14 and 28 days as per IS 516:1959. Strength of the samples were taken as average of two cubes of 150mm dimensions. Split tensile strength was determined as per IS 5816:1999.

3.3.1 Effect of Bottom ash:

The results of split tensile strength test shows that there was increase in the strength of concrete mixes with initial involvement of bottom ash as partial replacement of river sand and after further involvement of bottom ash strength decreases.

The results of split tensile strength test are as follow:

- An increase of 2.24%, 3.5% when the strength of control mix CM(3.16MPa) was compared with the strengths of mixes M1(3.23MPa) and M2(3.27MPa) at the age of 7 days.
- An increase of 1.33%, 5.03% and 0.8% for mixes M1(3.84MPa), M2(3.98MPa), M3(3.82MPa) and decrease of 4.9%, for mix M4(3.60MPa) was observed at the age of 14 days as compared to control mix CM(3.79MPa).
- Similarly, at the age of 28 days, an increase of 2.48%, 3.5% for mixes M1(4.1MPa), M2(4.15MPa) and decrease of 0.73%, 3.97% for mixes M3(3.98MPa), M4(3.85MPa) was observed as compared to reference mix CM(3.85MPa).

The maximum compressive strength was of mix M2(4.15MPa) with 10% bottom ash and alccofine at 28 days.

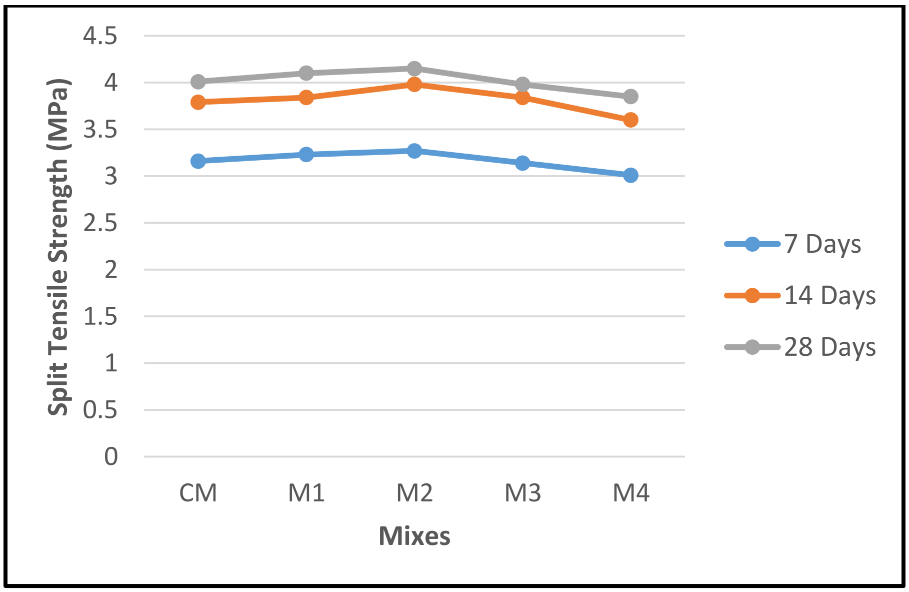

Fig: 3.3 Split tensile strength of various concrete mixes.

3.3.2 Effect of curing time:

- Split tensile strength of all the mixes increases with the age of concrete. The reference mix CM gained increase in strength of 20% from 7 to 14 days and 5.83% from 14 to 28 days.
- The M1, M2, M3 and M4 mixes attained a relatively constant strength of 18.9-19.3% from 7 to 14 days and 4.2% to 7% from 14 to 28 days of curing.

3.4 Correlation between Compressive strength, Flexural strength and Split Tensile Strengths:

3.4.1 Correlation between Compressive and Flexural strengths:

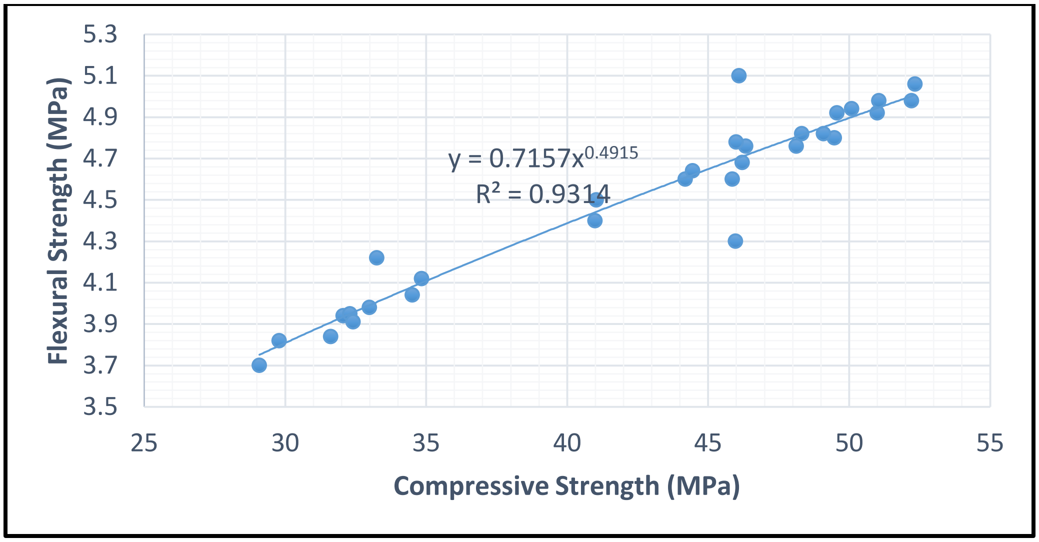

Fig: 3.4.1 Average relationship between Compressive and Flexural strength

Whereas the Fig.3.4.1 show this average relationship of the 7, 14 and 28 days strength simultaneously than the equation shows:

$y = 0.7157x^{0.4915}$ . . . . eq. 1

$R^2 = 0.9314$

Where:

y = Flexural strength in MPa.
x = Compressive strength of cubes in MPa.
R^2 = Coefficient of determination.

3.4.2 Relationship by experimental and theoretical values:

Table: 3.4.1 Comparison of experimental and theoretical values

Mixes	Experimental Values		Theoretical values as per IS 456:2000	Ratio fr/√fck
	28 days compressive strength (fck)	28 days Flexural strength (fr) from eq. 1		
CM	49.53	4.86	4.93	0.67
M1	51.03	4.95	5	0.691
M2	52.25	5.02	5.06	0.689
M3	49.6	4.88	4.93	0.686
M4	46.04	4.7	4.75	0.683
				Average = 0.6838

Table 3.4.1 shows the observations of the ratio of flexural strength (fr) to the square root of the cube compressive strength (√fck) of the experimental values and theoretical values. The obtained average value for different concrete mixs is calculated as 0.6838. The general relationship comes out to be “fr = 0.6838√fck” whereas it was slightly lesser than IS 456:2000 (0.7√fck) which gives the average value as 0.7. It might be due to the properties of materials that are used in the concrete mixes.

3.4.3 Ratio of compressive strength and flexural strength:

Table: 3.4.2 Ratio of compressive strength to flexural strength at different ages.

Mixes	Ages		
	7 Days	14 Days	28 Days
CM	8.18	9.61	10.19
M1	8.08	9.8	10.31
M2	8.5	10.06	10.41
M3	8.23	9.79	10.16
M4	7.82	9.21	9.79

From the Table: 3.4.2 the ratio of compressive to flexural strength are 8.18, 9.61 and 10.19 times at the ages of 7, 14 and 28 days respectively for the mix CM. The mixes M1, M2, M3 and M4 showed the constant variation of 7.82-8.18 times at the age of 7 days, 9.21-10.06 at the age of 14 days and 9.79-10.41 times at the age of 28 days of the flexural strength.

3.4.4 Correlation between Compressive and Split Tensile Strengths:

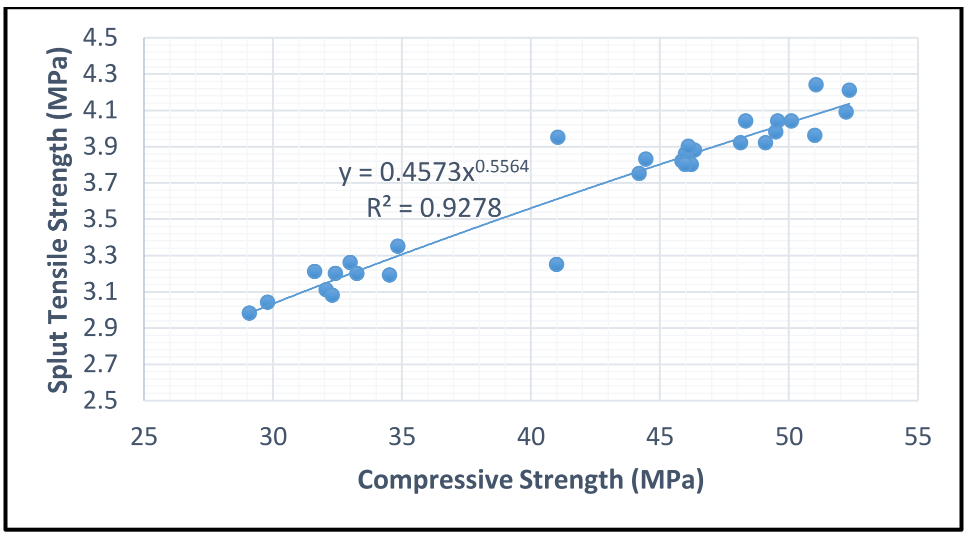

Fig: 3.4.2 Average relationship between Compressive and Split Tensile strength

Whereas the Fig.3.4.2 show this average relationship of the 7, 14 and 28 days strength simultaneously than the equation shows:

$y = 0.4573x^{0.5564}$ . . . . Eq. 2

$R^2 = 0.9278$

Where:

y = Split Tensile strength in MPa.

x = Compressive strength of cubes in MPa.

R^2 = Coefficient of determination.

3.4.5 Relationship by experimental and theoretical values:

Table: 3.4.3 Comparison of experimental and theoretical values

Mixes	Experimental Values		Theoretical values as per IS 456:2000	Ratio $ft/(fck)^{0.56}$
	28 days compressive strength (fck)	28 days Split tensile strength (ft) from eq. 2		
CM	49.53	4.01	4.05	0.499
M1	51.03	4.1	4.12	0.453
M2	52.25	4.15	4.18	0.451
M3	49.6	3.98	4.06	0.447
M4	46.04	3.85	3.89	0.45
			Average = 0.45	

Table 3.4.3 shows the observations for the ratio of Split tensile strength (ft) to the 0.56 power of the compressive strength $(fck)^{0.56}$ of the experimental values and theoretical values. The obtained average value for different concrete mix was 0.45. Then the general relationship was “$ft = 0.45(fck)^{0.56}$” whereas it was slightly lesser than IS 456:2000 which gives the average value as $0.456(fck)^{0.56}$. It might be due to the properties of materials which used in the concrete mixes.

3.4.6 Ratio of compressive strength and split tensile strength:

Table: 3.4.4 Ratio of compressive strength to split tensile strength at diff. ages

Mixes	Ages		
	7 Days	14 Days	28 Days
CM	10.07	11.72	12.35
M1	10.25	12.05	12.44
M2	10.6	12.12	13.13
M3	10.31	12.02	12.46
M4	9.78	11.39	11.96

Compressive strength was observed to be 10.07, 11.72 and 12.35 times of the split tensile strength at the ages of 7, 14 and 28 days, respectively for the control mix CM. The mixes M1, M2, M3 and M4 showed the variation of 9.78-10.31 times at the age of 7 days, 11.39-12.12 times at the age of 14 days and 11.96-13.13 times at the age of 28 days of the split tensile strength as shown in Table 3.4.4.

Therefore, it can be concluded from the above results that strength in terms of compressive strength, flexural strength and split tensile strength can be increase with the addition of alccofine into the matrix.

Concrete of strength M40 grade can be develop with bottom ash and alccofine which can be used as a strength material. A relationship of compressive strength vs flexural strength and compressive strength vs Split tensile strength of the bottom ash based concrete showed the same behavior as obtained in the conventional concrete.

4. Conclusions:

Based on results and discussions of present study, following conclusions could be attained:

1. Inclusion of Alccofine improves the strengths of different types of mixes.
2. The workability of concrete decreased with the increase in bottom ash content due to extra fineness of bottom ash.
3. Strength of bottom ash based concrete showed the same behavior at different curing ages as observed conventional concrete.
4. Investigation indicated that addition of bottom ash beyond 30% in concrete resulted in decreased mechanical strength.
5. Maximum compressive strength of 52.28Mpa observed with 20% bottom ash in this matrix.
6. An increase in compressive, flexural and split tensile strength with the increase of curing ages. The range of strengths increase from 15.2-39.7% and 4-12.25% for the ages of 7-14 days and 14-28 days.
7. This study demonstrates that substituting fine aggregate with bottom ash offers technical, economic and environmental advantages.

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