EXPERIMENTAL INVESTIGATION ON CEMENT WITH PULVERISED FLYASH AND GROUND GRANULATED BLAST FURNACE SLAG (TRIPLE BLEND) IN DESIGN MIX CONCRETE

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Abstract - *The advancement of concrete technology can minimize the demand on energy and natural resources as well as reduce the impact of pollutants on the environment. The usage of supplemental cementitious materials (SCMs) like fly ash (FA), blast furnace slag, silica fume, metakaolin (MK), and rice has been proven in recent years by a number of researchers. Husk ash (RHA), hypo sludge, and other additives can save building costs by helping to improve the various qualities of concrete in both its fresh and hardened Stages. This research presents laboratory studies on the optimal content of fly ash and Granulated blast furnace slag (GGBS) as partial cement substitutes for studying the strength properties of concrete. Portland cement was partially replaced by 30% of GGBS and Fly ash by 20% respectively. The water to cementations ratio was maintained at 0.45 for all mixtures. The strength characteristics of the concrete were evaluated by conducting Workability, Compressive strength test, Splitting Tensile strength test, Flexural strength test, Water penetration test and Rapid chloride penetration test. Compressive strength tests were performed at 7 and 28 days of curing, and split tensile and flexural strength tests were performed at 28 days of curing. The test results proved that the compressive strength, split tensile strength and flexural strength of concrete mixtures containing GGBS and Fly ash remains same. Once an optimal point for GGBS and fly ash was reached, at about 30% of GGBS and 20% of fly ash of the total binder content, further additions did not improve the flexural strength, compressive strength, or split tensile strength.*

***Key Words*: Cement, fly ash, GGBS, CO2 and Global Warming**

1. INTRODUCTION

Behind China but ahead of the US and Japan, the Indian cement industry is the world's second-largest cement producer. It is acknowledged as a core sector, contributing over 1.3% of GDP and supporting over 0.14 million jobs. 350 micro cement plants make up the remaining 210 large cement plants, which together have a combined installed capacity of 410 tons in the country. The states of Andhra Pradesh, Rajasthan, and Tamil Nadu are home to 77 of the 210 big cement plants in India.

Directly releasing waste into the environment can have negative effects on the environment. The importance of recycling waste has thus been highlighted. To use natural resources more effectively and preserve the environment from waste deposits, waste can be used to create new goods or used as admixtures. The natural fertility of the soil is ruined when these industrial wastes are dumped on surrounding property.

2.NEED AND SCOPE OF THE STUDY

The cement industry is expected to reach 550-600 million tonnes per year (MTPA) due to increasing demand in various sectors of residential, commercial and industrial construction. Because of high usage of cement, the natural resource is getting degraded and co2 is emission is getting increased. Waste slag from industries are dumped and used in the landfills which is an important cause of land pollution. Slag is highly available material with low cost and cement is in demand which cost higher.

3. AIM AND OBJECTIVE

To lower the cost, enhance the stability and durability of concrete, a trial cube test of cement which includes pulverised fly ash and ground granulated blast furnace slag is being conducted. Testing and concluding the application of raw materials and developing the design mix are the first activities. The next step is to mix a test batch of concrete and record its qualities. The cubes are examined for the durability test's hardened concrete properties after the days have been counted. Finally, the test results are provided for the comparison of concrete grades M30 and M25. An evaluation of raw materials, including testing, application, and mix design. Conducting trial mixes and measuring fresh concrete, with a focus on durability. Providing comparative studies.

4. METHODOLOGY

Using my literature review as a starting point, I drew inferences about the exam scores and the number of mixed-up items. The data in my literature analysis is based on a careful examination of the necessary test methods and standard setup for aggregates, fly ash, cement and GGBS. My journal research of the experiments I conducted using cement with flyash and cement with ground granulated blast furnace slag helped me to identify the optimal mix proportion for my trial mix experiment. The journal article demonstrates the strength, workability, and durability of flyash and GGBS with cement. GGBS, fly ash, and cement have all been used in experimental studies with concrete. The study of the fly ash and GGBS mix percent in my experiment test process.

5.LITERATURE STUDY

Since cement is a crucial component of construction all over the world, it is a significant source of carbon dioxide (CO_2) emissions, accounting for about 2.4 percent of all CO_2 emissions from energy and industrial sources. Both directly and indirectly, the heating of limestone releases carbon dioxide (CO_2) into the atmosphere, while utilising fossil fuels to heat the kiln results in indirect emissions of CO_2. Cement emits direct emissions as a result of a chemical reaction known as calcination. Due to its high concentration of calcium carbonate, a substance required to produce cement, limestone crushing and heating is a significant source of greenhouse gases at cement manufacturing facilities. About 0.8 tonnes of carbon dioxide are released during the manufacture of one tonne of cement. The first article in my investigation focused on the impact of flyash on the strength properties of a roller-compacted concrete pavement, and it was crucial to moving forward with my experiment. In accordance with the research methods utilised in this article, cement was substituted at various percentages, including 20%, 30%, 40%, and 60%.and it was evaluated by the use of experiments using concrete cubes that contained 318 kg of cement per cubic metre. The mixture when 60% of the cement is substituted with fly ash yields the lowest strength values across all ages. Flyash's contribution to concrete's strength is smaller than that of cement, even up to a certain point, which causes the mixture's strength to decrease. The following article was a test research using GGBS to partially substitute cement in concrete. The process includes testing of raw materials, identifying mix with the replacement of GGBS, and compressive strength testing. Analysis was done on the 7 and 28-day strength tests using 20, 30, 40, and 60% of GGBS in place of cement. Concrete reaches its maximum compressive, flexural, and tensile strength at a 30% replacement of cement with GGBS. My case study involved the commercial project of building Tidel Park in Pattabiram, where GGBS was used to replace mineral additives. 35% of the mineral combination was replaced; the project had a value of 279 crores and covered 11.4 acres. Concrete is M35 grade. Concrete has a 180-minute retention time, and 51.97 Mpa of strength can be attained in 28 days. The 0.5 lakh cubic metres of concrete employed in this project has potential strength. Cement savings as a percentage of project value are 0.80%.

6. MATERIALS AND ITS PROPERTIES

6.1 CEMENT

In general, cement can be defined as a material with very good adhesive and cohesive properties that allows it to bond with other materials into a compact mass. Locally available Ordinary Portland cement of 53 grade of the ACC cement Branch complies with ISI standards was procured and the following tests were performed in accordance with IS: 8112-1989. In the chemical composition AI_2O_3 is 1.23, CI is 0.02, MgO is 1.03, LSF is 0.92, C_3A is 7.09, SO_3 IS 1.42 and loss of Ignition is 2.5 and physical properties of OPC is fineness is $309m^2/Kg$, specific gravity is 3.1, soundness is 1mm, comp. strength for 7 days is 45.6Mpa, comp. strength for 28 days is 62.4 Mpa, the initial setting time is 121min and the final setting time is 203min.

6.2 FINE AGGREGATES

Local river sand that is free of organic matter. The sand size passing through the sieve is 4.75 mm, and a 150 µm IS sieve was used in the study. It is important to make sure the screen is clean before use. (IS: 2386 (Part I) - 1963). The physical properties of the fine aggregate fineness modulus are 3.1, specific gravity is 2.80.the bulk density of loose aggregate is 1320 kg/m^3 and compacted aggregate is 1760 kg/m^3 in the Zone –II grading.

6.3 COARSE AGGREGATES

The maximum size coarse aggregate used here is 20mm. We used the IS 383:1970 to find out the proportion of mix of coarse aggregate, with 60% 10mm size and 40% 20mm. Physical Properties of Coarse Aggregate is specific gravity is 2.73. fineness modulus is 3.93 and the bulk density of loose aggregate is 1440 kg/M3 and compacted aggregate is 1590kg/M3, the water absorption is 0.5%.

6.4 FLY ASH

Fly ash is a finely divided mineral residue produced by burning ground or pulverized coal in thermal power plants to generate electricity. Fly ash is a beneficial mineral additive for concrete. It affects many properties of concrete in both fresh and hardened states. Moreover, utilization of waste materials in cement and concrete industry reduces the environmental problems of power plants and decreases electricity generation costs.

6.4.1 FLY ASH IN OPC

Fly ash can be used in Portland cement concrete to improve concrete performance. Portland cement is made of calcium oxide (CaO), some of which is released in the Free State during hydration. As much as 20 pounds of free lime is released during hydration of 100 pounds of cement. The Physical Properties of FLYASH as shown in Table 1

Physical Form	Off White Powder
Specific Gravity	2.3
Specific Surface area	400-600 m2/Kg
Bulk Density(Loose)	1000-1100 Kg/m3
Bulk Density (vibrate)	1200-1300 Kg/m4

Table - 1: Physical Properties of FLYASH

6.5 GROUND GRANULATED BLAST FURNACE SLAG (GGBS)

Crushed blast furnace is a by-product of blast furnace slag, a solid waste mass disposed of by the Indian steel industry. These operate at temperatures around 1500 degrees Celsius and are fed a carefully controlled mixture of iron ore, coke and limestone. Iron ore is reduced to a residue of iron and slag floating on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has been rapidly quenched in large volumes of water. Quenching optimizes cement properties and produces granules resembling coarse sand. This granulated slag is dried and pulverized into fine powder. The Chemical Composition (%) of Ground Granulated Blast Furnace Slag (GGBS) and Physical Properties of Ground Granulated Blast Furnace Slag (GGBS) as shown in Table 2&3

S	0.48
IR	0.31
Glass Content	91
Cl	0.006
MgO	7.5
SO3	0.22
MnO	0.1
Loss on Ignition	0.15

Table - 2: Chemical Composition (%) of Ground Granulated Blast Furnace Slag (GGBS)

Physical Form	Off White Powder
Specific Gravity	2.8
Specific Surface area	365 m2/Kg
Slag Activity 7 days	71.29
Slag Activity 28 days	81.93

Table - 3: Physical Properties of Ground Granulated Blast Furnace Slag

6.6 Water (IS: 456-2000)

The water used for mixing and curing is clean, free of harmful levels of oils, acids, alkalis, salts, sugars, organics, or other substances that can harm concrete. Drinking water is used for mixing concrete

6.7Casting and Curing of Control Specimen

For each blend, 3 cubes of size 150mm x 150mm x 150mm, 3 cylinders of 150mm diameter and 300mm height, and 3 prisms of 100mm x 100mm x 500mm were cast using steel molds. Cast samples were kept at ambient temperature for 24 hours. After 24 hours they were demolded and placed in water for curing. Cubes are used to determine the compressive strength of concrete for 7 days and 28 days. Three cylinders were used to determine the split tensile strength of concrete for 28 days. Three prisms were used to determine the Flexural strength of concrete for 28 days by two-point bending test with a supporting span, using universal testing machine of capacity 1000kN

Sl.No	Material	Quantity In Kg	Sp. Gravity
1	Cement	185	3.1
2	Flyash	74	2.3
3	GGBS	111	2.8
4	20 MM	763	2.73
5	12.5 MM	381	2.73
6	M.Sand	763	2.76
7	Water	167	1
8	Admixture	3.7	1.1

Table - 4: Mix proportion per cubic meter of concrete for M30

Sl.No	Material	Quantity In Kg	Sp. Gravity
1	Cement	153	3.1
2	Flyash	68	2.3
3	GGBS	156	2.8

4	20 MM	779	2.73
5	12.5 MM	415	2.73
6	M.Sand	790	2.76
7	Water	156	1
8	Admixture	3.4	1.1

Table - 5: Mix proportion per cubic meter of concrete for M25

7. DESIGN MIX

As per IS 10262:2009 M30 and M25 grades were blended and used to create the test samples. For compressive and split strength, standard metallic cube moulds (150*150*150 mm) were cast. The hand-filled concrete cubes were compacted using a table vibrator. After 24 hours, the specimens were demoulded and submerged in water for various testing ages. Three samples were tested at each age to determine the average compressive and split strengths. A 200 MT capacity compression testing equipment was used for the test.

M30 TRIAL MIX SHEET							
Materials	SSD wt.	Moisture		Water Absorption		Dry	Batch
	Per m^3	in %	Per m^3	in %	Per m^3	Weight	Weight
Cement	185					185	5.55
Fly ash	74					74	2.22
GGBS	111	0.00 %	0.00	0.00 %	0.00	111.0	3.33
20 MM	763	0.00 %	0.00	0.50 %	3.82	759.2	22.78
12.5 MM	381	3.00 %	11.43	0.50 %	1.91	390.5	11.72
Crushed Sand	763	0.00 %	0.00	3.89 %	29.68	733.3	22.00
Free Water	167					191	5.73
Admixture	3.7					3.70	0.111
Total	2448		11.43		35.40	2448	73.43

Table -6: Concrete design mix proportion of M30 Grade

M25 TRIAL MIX SHEET							
Materials	SSD wt.	Moisture		Water Absorption		Dry	Batch
	Per m^3	in %	Per m^3	in %	Per m^3	Weight	Weight
Cement	153					153	4.59
Fly ash	68					68	2.04
GGBS	156	0.00 %	0.00	0.00 %	0.00	156.0	4.68
20 MM	779	0.00 %	0.00	0.50 %	3.90	775.1	23.25
12.5 MM	415	3.00 %	12.45	0.50 %	2.08	425.4	12.76
Crushed Sand	790	0.00 %	0.00	3.89 %	30.73	759.3	22.78
Free Water	156					180	5.41
Admixture	3.4					3.40	0.102
Total	2520		12.45		36.70	2520	75.61

Table -7: Concrete design mix proportion of M25 Grade

8. RESULTS AND DISCUSSION

8.1Tests on Fresh Concrete

8.1.1Workability Characteristics

Slump Cone Test: The slump cone is properly cleaned and oiled on the interior surface. The consistometer is then set down on a flat surface with the droop cone put inside the consistometer's cylindrical sheet metal pot. The cone is then four levels deep with concrete. Using a 16 mm tamping rod, each layer is tamped 25 times. The cone is fully filled, its initial height is determined, and it is then carefully lifted off the ground. The final reading is recorded together with a drop in height at the centre of the slumped concrete.

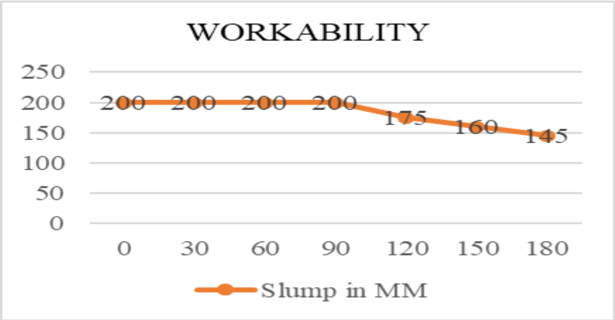

Chart - 1: Workability of M30 in N/mm²

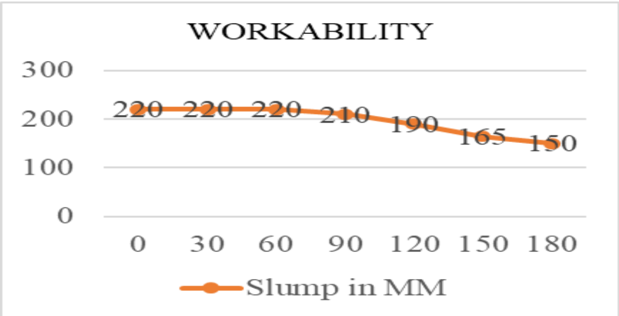

Chart - 2: Workability of M25 in N/mm²

8.1.2 Compressive Strength Tests result

Fig – 1 and 2 shows the compressive strength of concrete for cubes of all mixtures at 7 and 28 days of curing. For different % substitutions of cement by FA and GGBS, only 6 cubes were cast. The outcome demonstrates that the compressive strength rose with the addition of fly ash up to 20% and GGBS up to 30% replace by weight of cement, and that any additional addition of FA and GGBS causes the compressive strength to decrease. Initial compressive strength increases by 84.93% for the first 7 days and by 150.43% for the first 28 days for M30 Grade. Initial compressive strength increases by 93.68% for the first 7 days and by 125.4% for the first 28 days for M25 Grade.

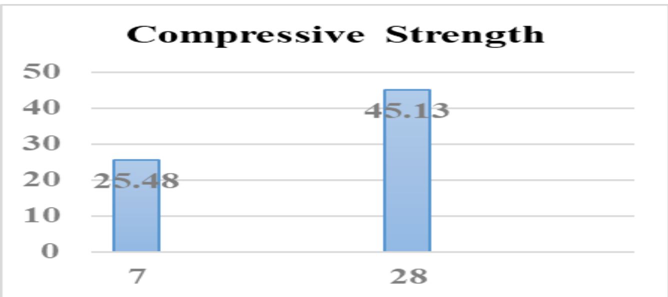

Fig - 1: Compressive strength test results of M30 in N/mm²

Compressive strength in 7 days 84.93 %, Compressive strength in 28 days 150.43 %

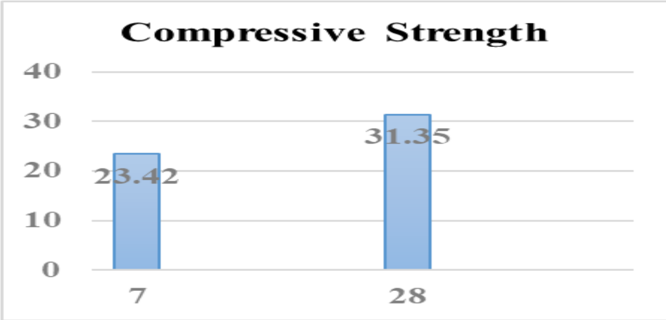

Fig - 2: Compressive strength test results of M25 in N/mm²

Compressive strength in 7 days 93.68 %, Compressive strength in 28 days 125.4 %

8.1.3 Tensile Strength Tests result

Fig- 3 and 4 shows the split tensile strength of concrete for cylinders made of all mixtures after 28 days of curing. For different % substitutions of cement by FA and GGBS, only 3 cylinders were cast. The addition of fly ash up to 20% and GGBS up to 30% replace by weight of cement increases the split tensile strength of cylinders; however, any further FA and GGBS reduces split tensile strength. Figure 3 & 4 depicts it, demonstrating how curing affects the split tensile strength of M30 and M25 Grade.

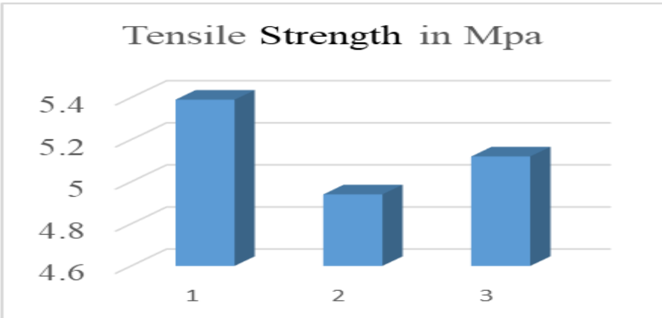

Fig - 3: Tensile strength test results of M30 in N/mm²

The average Tensile strength of concrete is 5.15 Mpa at 28 days of curing

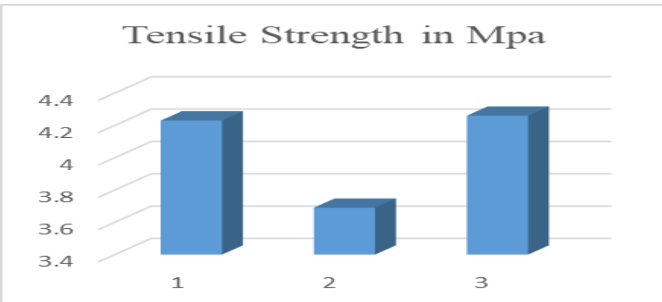

Fig - 4: Tensile strength test results of M25 in N/mm²

The average Tensile strength of concrete is 4.06 Mpa at 28 days of curing

8.1.4 Flexural Strength Tests result

Fig -5 and 6 shows the flexural strength of concrete for prisms, for all mixtures, after 28 days of curing. Only 3 prisms were cast in order for FA and GGBS to replace various percentages of cement. The addition of fly ash up to 20% and GGBS up to 30% replace by weight of cement increases the flexural strength of prisms, however any additional FA and GGBS reduces flexural strength. The average flexural strength of M30 was 3.36 Mpa at 28 days of curing. The average flexural strength of M25 was 2.61 Mpa at 28 days of curing. Figure 5 and 6 illustrates the impact of curing on the flexural strength of M30 and M25 Grade.

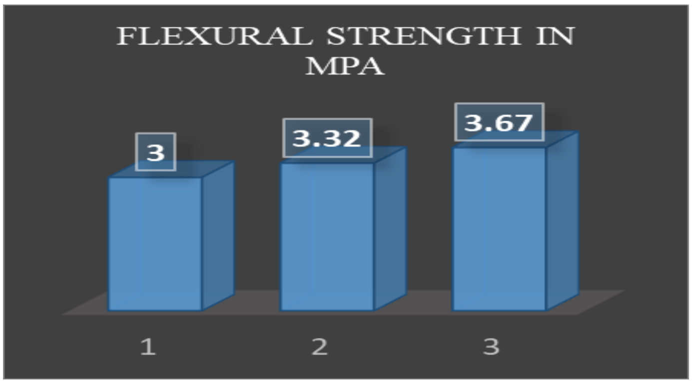

Fig - 5: Flexural strength test results of M30 in N/mm^2

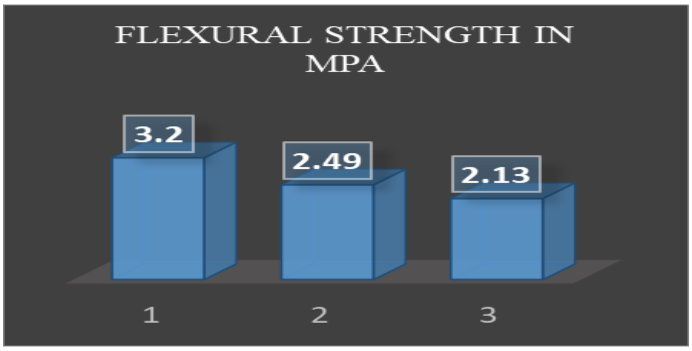

Fig - 6: Flexural strength test results of M25 in N/mm^2

9. CONCLUSION

The most effective amounts of fly ash and GGBS were discovered to be 20% and 30%, respectively. The maximum compressive strength for M30 grade using 30% GGBS and 20% fly ash as a cement substitute was determined to be 84.93N/mm^2 after 7 days of curing. At 28 days of curing, it was discovered that the compressive strength for M30 grade at 30% GGBS and 20% fly ash as a partial replacement of cement was optimal at 150.43 N/mm2.The maximum compressive strength for M25 grade using 35% GGBS and 20% fly ash as a cement substitute was determined to be 93.68N/mm^2 after 7 days of curing. At 28 days of curing, it was discovered that the compressive strength for M25 grade at 35% GGBS and 20% fly ash as a partial replacement of cement was optimal at 125.4 N/mm2. At 28 days of curing, 5.15 Mpa was determined to be the optimal value of split tensile strength for M30 grade at 30% of GGBS and 20% of fly ash as a partial replacement of cement. At 28 days of curing, 4.06 Mpa was determined to be the optimal value of split tensile strength for M25 grade at 35% of GGBS and 20% of fly ash as a partial replacement of cement. At 28 days of curing, it was discovered that the M30 grade's optimal flexural strength at 30% GGBS and 20% fly ash as a partial replacement for cement was 3.36 Mpa. At 28 days of curing, it was discovered that the M25 grade's optimal flexural strength at 35% GGBS and 20% fly ash as a partial replacement for cement was 2.61 Mpa.The consumption of cement is reduced by 50% by replacing Pulverized Fly ash and Ground Granulated Blast Furnace Slag.The consumption of cement is reduced by 50% which leads to savings in Consumption of natural resources like Limestone, Laterite, Hematite, Gypsum etc. The Emission of carbon dioxide is reduced by 50%.

REFERENCES

[1] Nikols Tosic, Snezana Marinkovic, Nenad Pecic, Ivan ignjatovic, Jelena Dragas, "long- term behaviour of reinforced beams made with natural recycled aggregate concrete and high volume fly ash concrete" construction and building materials, volume -176, 10 July 2018 pages 344 -358

[2] K.S. Tan, M.F.M. Zain, K.M. Ysof, M. Saffiudin, T.Y. Chang and K.S. Lee, "influence of quarry dust and silica fume on properties of high performance concrete" proceedings of second international conference on advances in strategic technologies

[3] M.L. Gambhir, Concrete Technology – Second Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi, 1995

[4] RafatSiddique "Effect of fine aggregate replacement with Class F fly ash on the mechanical properties of concrete". Cement and Concrete Research 33, 2003

[5] Subramani and K.S. Ramesh "Experimental Study on Partial Replacement of Cement with Fly Ash and Complete Replacement of Sand with M sand". International Journal of Application orInnovation in Engineering & Management, Volume 4, Issue 5, May 2015

[6] A.M. Neville, Properties of Concrete – Fourth and Final Edition, Pearson Education Limited, Essex, 2002.

[7] AmanJatale, KartikeyTiwari, SahilKhandelwal (Effects on Compressive Strength When Cement Is Partially Replaced by Fly-Ash). e-ISSN: 2278-1684 Volume 5, Issue 4 (Jan. -Feb. 2013), PP 34-43.

[8] BS 1881: Part 116: 1983, "Method for determination of compressive strength of oncrete cubes", Testing Concrete, British Standards Institution, London, 1983.

[9] IS – 10262 -2009 Guidelines for concrete