BEHAVIOUR OF GLASS FIBER AND BOTTOM ASH ON CONCRETE

[1]Kamalnath.M, [2]Jose Ravindra Raj.B

[1]Post Graduate Student, [2]Assistant Professor
Structural Engineering, Department of civil engineering
Prist University, Trichy-Thanjavur Highway, Vallam, Thanjavur-613403

***ABSTRACT*: Bottom ash is a hazardous by-product from coal based thermal power plants. Glass fibre increases the flexural strength and strain capacity of the concrete. In this project, bottom ash can is replaced with fine aggregates. The study was conducted to evaluate the strength characteristics of glass fibre and bottom ash on concrete. The concrete mix design was done for M30 grade concrete. Mix was prepared for different combinations (0%, 25%, 35%, 50% and 100%) replacement of sand by bottom ash with (0.3% of glass fibre).The specimen such as cubes of 150 x 150 x 150 mm in size and cylinder of 150 x 300 mm in size, beam of 1000 x 100 x 200 mm in size are casted and evaluate the properties such as compressive strength, split tensile strength & flexural strength has been analyzed and it has been compared with control mix for the duration of 7 and 28 days.**

I.INTRODUCTION

1.1 General

Concrete is an artificial material which has wider applications in the construction industry. The basic ingredients of concrete are cement, sand, coarse aggregate and water. Plain cement concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Recent trends in concrete technology are to improve the workability, strength and resistance to smaller cracks in the concrete.

Addition of small closely spaced and uniformly dispersed fibers to concrete, acts as crack arresters and substantially improves the static and dynamic properties of plain concrete. The fibers of short length and small diameters can be used in high strength concrete to convert its brittle nature to a ductile one. The fibers used can be of steel, polypropylene, nylon, glass or carbon. Each of the above mentioned fiber has its own characteristic properties and limitations.

The coarser material, which falls into furnace bottom in modern large thermal power plants and constitute about 20% of total ash content of the coal fed in the boilers and is known as Bottom Ash. This paper presents the experimental investigations carried out to study the effect of use of bottom ash as a replacement of fine aggregate**.**

1.2 Glass Fiber

On a specific strength (i.e. strength to weight) basis, glass fiber is one of the strongest and most commonly used structural materials. Some Lab tested fibers have shown strength up to 6896 MPa and commercial grades range from 3448 – 4830 MPa. The continuous glass filaments are manufacture by two basic process i.e. by marble melt process and direct melt process respectively. To minimize abrasion related degradation of glass fibers, surface treatments (sizing's) are applied prior to gathering of fibers in to strands. Commonly glass fibers are round and straight and have diameters ranging from G (9-10.2 μm) to T (22.9 – 24.1 μm) are used. The glass fibers are available in different forms like continuous form, woven roving, surfacing mats, three dimensional and multidimensional (such as 5-D, 7-D, 11-D) etc. There are several glass fiber types with different chemical compositions providing the specific physical/chemical properties. E-glass (calcium aluminoborosilicate composition) is best for general purpose structural use. S-glass (magnesium aluminosilicate composition) is a special glass with higher tensile strength and modulus, good heat resistance, strong resistance to acids. C-glass has good chemical stability in chemical corrosive environments. T-glass fibre exhibits improved performance over E-glass such as 36% increase in tensile strength, 16% increase in tensile modulus, increased heat resistance, improved impact, electrical, thermal and chemical resistance properties. R-glass (magnesium-lime-aluminosilicate) has higher tensile strength and modulus compared to E-glass and gives higher resistance to fatigue, aging temperature and corrosion.

1.3 Bottom Ash

Energy is the main backbone of modern civilization of the world over, and the electric power from thermal power stations is a major source of energy, in the form of electricity. In India, over 70% of electricity generated in India, is by combustion of fossil fuels, out of which nearly 61% is produced by coal-fired plants. This results in the production of roughly 100 ton of ash. Most of the ash has to be disposed off either dry, or wet to an open area available near the plant or by grounding both the fly ash and bottom ash and mixing it with water and pumping into artificial lagoon or dumping yards. This causes the pollution in water bodies and loss of Productive land.

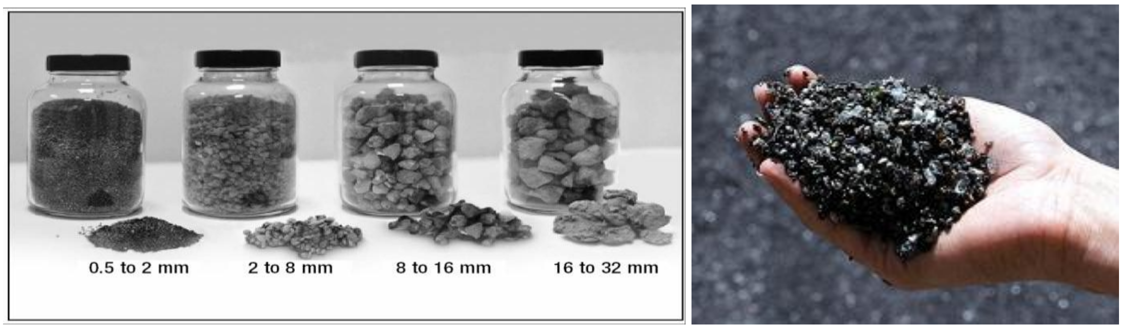


Fig. 1.1 Bottom Ash

1.4 Need for Study

The continuous reduction of natural resources and the environmental hazards posed by the disposal of coal ash has reached alarming proportion such that the use of coal ash in concrete manufacture is a necessity than a desire. The use of coal ash in normal strength concrete is a new dimension in concrete mix design and if applied on large scale would revolutionize the construction industry, by economizing the construction cost and decreasing the ash content.

II. LITRATURE REVIEW

Maslehuddin et. al.,(1989) have conducted experimental investigations were carried out by replacing sand by equal weight of fly-ash, with sand replacement levels of 0, 20 and 30 % and w/c ratio of 0.35, 0.40, 0.45and 0.50, keeping cement content constant at 350 kg/m3 in all mixes. Compressive Strength gain and corrosion resistance was higher for sand replaced with fly-ash mixtures. Also, the corrosion rate of reinforcing steel bars in concrete was lowest in 30% replacement level.

A study on the potential of using bottom ash as pozzolanic material was done by **Tarun R et. al.,(1989).** The quality was improved by grinding until the particle size retained on sieve 325 mm was less than 5% by weight. The results showed that pastes of cement with replacement by original or ground bottom ash, between 10-30% resulted in longer initial setting time, depending on the fineness of the ashes, compared to setting time of the cement paste. Original bottom ash mortar had higher water requirement than that of the cement mortar and ground bottom ash mortar had lesser water requirement than that of the cement mortar. Bottom ash could be used as a pozzolanic material if it was ground having retention on 325-micron sieve less than 5%.

The municipal solid waste bottom ash (MSWBA) was used as alternative aggregate for the production of building concrete presenting a characteristic strength at 28 days of 25 Mpa by **Maslehuddin et. al.,(1989).**

Wu Yao, et. al., (2003) compared concretes containing different types of hybrid fibers at the same volume fraction (0.5%) in terms of compressive, splitting tensile, and flexural properties. Three types of hybrid composites were constructed using fiber combinations of polypropylene (PP) and carbon, carbon and steel, and steel and PP fibers. Test results showed that the fibers, when used in a hybrid form, could result in superior composite performance compared to their individual fiber-reinforced concretes. Among the three types of hybrids, the carbon–steel combination gave concrete of the highest strength and flexural toughness because of the similar modulus and the synergistic interaction between the two reinforcing fibers.

An attempt was made to develop 'Light Weight Concrete' in which fly ash and bottom ash were used as partial replacement of cement and fine aggregate **Siddique et. al., (2003).** The effects of furnace bottom ash on workability, compressive strength, and permeability, depth of carbonation and chloride penetration of concrete were investigated by Siddique et. al.,(2003) The natural sand was replaced with furnace bottom ash by 30, 50, 70 and 100 % by mass at fixed free w/c ratio of 0.45 and 0.55 and cement content of 382 kg/m3. The results showed increase in the workability of concrete, and decreased compressive strength, at fixed cement content and w/c ratio. No adverse influence on the long-term strength was observed. Air permeability, sorptivity and carbonation rate for bottom ash concrete was higher as compared to control concrete. However the chloride transport coefficient decreased with the increase of the replacement level up to 50%, beyond which it increased. A lightweight concrete using flyash (FA), furnace bottom ash (FBA) and Lytage (LG) as a replacement of OPC, natural sand and coarse aggregate respectively was manufactured.

Yeol Choi et. al., (2005) have studied splitting tensile strength and compressive strength of GFRC and PFRC at 7, 28 and 90 days. Test results indicate that the addition of glass and polypropylene fibers to concrete increased the splitting tensile strength of concrete by approximately 20–50%, and the splitting tensile strength of GFRC and PFRC ranged from 9% to 13% of its compressive strength. Based on this investigation, a simple 0.5 power relationship between the splitting tensile strength and the compressive strength was derived for estimating the tensile strength of GFRC and PFRC.

Ilker Bekir Topcu et. al., (2007) have done experimental investigation to study the effects of replacement of cement (by weight) with three percentages of fly ash and effects of addition of steel and polypropylene fiber. Current day knowledge of concrete technology focuses attention primarily on the use of different materials in the production of concrete, industrial wastes in particular. The use of fly ash in concrete today is an important subject and is growing in importance day by day. Using fly ash in concrete may both provide economic advantages and better properties in the production of concrete. Besides, concretes produced with three different replacement ratios of fly ash and three different types of steel and polypropylene fibers were compared to those without fibers used in concrete with FA. According to the results of the study, addition of fibers provide better performance for the concrete, while fly ash in the mixture may adjust the workability and strength losses caused by fibers, and improve strength gain.

Sivakumar. A, et. al., (2009) have conducted experimental investigation carried out on high strength concrete reinforced with hybrid fibers (combination of hooked steel and a non-metallic fiber) up to a volume fraction of 0.5%. The mechanical properties, namely, compressive strength, split tensile strength, flexural strength and flexural toughness were studied for concrete prepared using different hybrid fiber combinations – steel–polypropylene, steel–polyester and steel–glass. The flexural properties were studied using four point bending tests on beam specimens as per Japanese Concrete Institute (JCI) recommendations. Fiber addition was seen to enhance the pre-peak as well as post-peak region of the load–deflection curve, causing an increase in flexural strength and toughness, respectively. Addition of steel fibers generally contributed towards the energy absorbing mechanism (bridging action) whereas, the non-metallic fibers resulted in delaying the formation of micro-cracks. Compared to other hybrid fiber reinforced concretes, the flexural toughness of steel–polypropylene hybrid fiber concretes was comparable to steel fiber concrete. Increased fiber availability in the hybrid fiber systems (due to the lower densities of non-metallic fibers), in addition to the ability of non-metallic fibers to bridge smaller micro cracks, are suggested as the reasons for the enhancement in mechanical properties.

Aggarwal et al (2010) discussed that the replacement of fine aggregates with bottom ash can easily be equated to the strength development of normal concrete at various ages.

Rama Mohan Rao.P et. al., (2015) have done experimental investigation of different volume Fractions of glass fibers with 25% and 40% replacement of cement by flash and studied the compressive, split tensile strength and flexural strength at age of 7 days, 28 days of the concrete. Test results indicate that strength of concrete decreases with increase in the percentage of fly ash and there is an increase of about 8.5% to 16% in split Tensile Strength. The volume Fraction of glass Fiber, 0.3% gives better strength values compared to control mix.

III. METHODOLOGY

3.1 Mix Design

3.1.1 Indian Standard Method of Mix Design

The design of concrete mix will be based on the following factors, using physical properties of materials.

(a) Grade of concrete: This gives the characteristic strength requirements of concrete. Depending upon the level of quality control available at the site, the concrete mix has to be designed for a target mean strength which is higher than the characteristic strength.

(b) Type of cement: The type of cement is important mainly through its influence on the rate of development of compressive strength of concrete as well as durability under aggressive environments ordinary Portland cement (OPC) and Portland Pozzolona cement (PPC) are permitted to use in reinforced concrete construction.

(c) Maximum nominal size of aggregate: It is found that larger the size of aggregate, smaller is the cement requirement for a particular water cement ratio. Aggregates having a maximum nominal size of 20mm or smaller are generally considered satisfactory.

(d) Minimum water cement ratio: The minimum w/c ratio for a specified strength depends on the type of cement.

(e) Workability: The workability of concrete for satisfactory placing and compaction is related to the size and shape of the section to be concreted.

3.1.2 Mix Design for M30 Concrete by IS Method

Characteristic compressive strength for M30 grade is 30N/mm^2

Target Strength for Mix Proportion:

$f'_{ck} = f_{ck} + 1.65s$

$= 30 + 1.65 \times 6$

$= 39.9$ N/mm2

Selection of Water Content:

Max water content for 20mm aggregate = 186 litres
From table 2
= 186+ 0.6/100*186
= 187.116 lit

Calculation of Cement Content:

w/c ratio = 0.43
Cement ratio = 187.116/0.43
= 432.55 kg/m^3
Table 5; minimum cement content for several exposure condition =320kg/m3
432.55 > 320 kg/m^3
Hence ok.

Determination of Fine Aggregate:

M-30 mix for fine aggregate
0.98 = [187.116+ (432.55/3.14) + (fa/0.31*2.64)*(1/1000)]
Fa = 536.55kg/m^3

Determination of Coarse Aggregate:

0.98 = [187.116+ (432.55/3.14)+ (Ca/(1-0.31)*2.64)*(1/1000)]
Ca = 1195.49kg/m^3

Mix:

Cement: Fine aggregate: Coarse aggregate: Water
1: 1.24: 2.76:0.43

Quantity per m^3

Cement	=	432.55 kg/m^3
FA	=	536.55 kg/m^3
CA	=	1195.49 kg/m^3
W/c ratio	=	187.12 litter

IV. TEST FOR CONCRETE

4.1Compressive Strength

4.1.1 Compressive Strength Results in N/mm^2 for 7 days

Glass Fibre (%)	Compression Strength in N/mm^2				
	0% BA	25% BA	55% BA	85% BA	100% BA
0%	32.72	28.25	24.85	21.98	8.2
0.5%	35.91	36.46	28.48	26.68	17.9

4.1.2 Compressive Strength Results in N/mm^2 for 28 days

Glass Fibre (%)	Compression Strength in N/mm^2				
	0% BA	25% BA	55% BA	85% BA	100% BA
0%	36.93	35.83	34.92	37.7	12.52
0.5%	38.24	39.32	36.22	35.9	26.4

4.2Tensile strength for cylinder

4.2.1 Tensile Strength Results in N/mm^2 for 7 days

Glass Fibre (%)	Compression Strength in N/mm^2				
	0% BA	25% BA	55% BA	85% BA	100% BA
0%	0.75	0.73	0.71	0.65	0.58
0.5%	0.78	0.80	0.75	0.71	0.65

4.2.2 Tensile Strength Results in N/mm^2 for 28 days

Glass Fibre (%)	Compression Strength in N/mm^2				
	0% BA	25% BA	55% BA	85% BA	100% BA
0%	1.91	1.80	1.78	1.75	1.62
0.5%	1.92	2.3	1.85	1.81	1.73

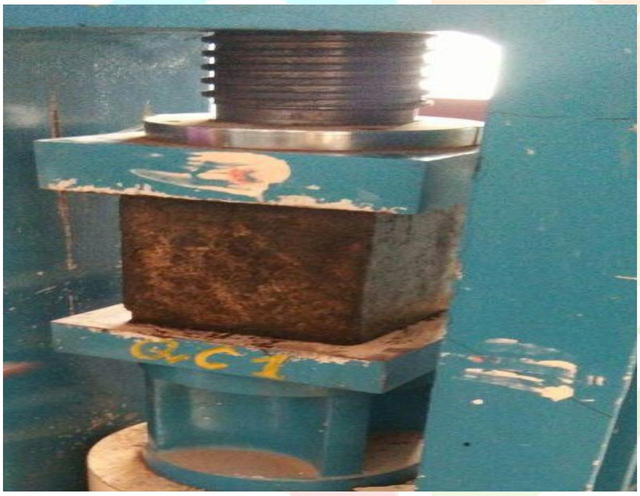
4.3 Durability test

4.3.1 Compressive Strength for 1% H_2SO_4 acid immersion on 7 days

Glass Fibre (%)	Compression Strength in N/mm^2				
	0% BA	25% BA	55% BA	85% BA	100% BA
0%	29.72	25.25	20.83	17.67	6.01
0.5%	31.46	33.91	25.11	23.83	11.2

4.3.2 Compressive Strength for 1% H_2SO_4 acid immersion on 28 days

Glass Fibre (%)	Compression Strength in N/mm^2				
	0% BA	25% BA	55% BA	85% BA	100% BA
0%	31.33	31	29.72	28.76	10.01
0.5%	35.21	36.32	33.22	31.02	22.4



V. RESULT AND DISCUSSION

Partial replacement of bottom-ash 0, 25, 55, 85, 100 percentages in fine aggregate. 0% and 25% replacement of bottom-ash reached the target compressive, tensile and durability. Partial replacement of bottom-ash 0, 25, 55, 85, 100 % in fine aggregate with 0.5% of glass fibre act as an admixture added in a concrete. In this composition 0, 25, 55, 85% reached the target compressive, tensile and durability. Compare these two compositions adding 0.5% admixture concrete given maximum strength and durability. Fully replacement of bottom-ash and fully replacement of bottom-ash with 0.5% glass fibre fail to give strength and durability.

VI. CONCLUSION

Bottom ash is the good replacement material for fine aggregate. Instead for fine aggregate can use bottom-ash in construction work. Due to scarcity of river sand cannot supply the fine aggregate in construction work. So need to go alternate material. Fully replacement of bottom-ash fails to give strength and durability of concrete. But 0 to 25 % gives better strength and durability of the concrete. So use 0.5% glass fibre as an admixture in replacement of bottom ash in fine aggregate 0 to 85% reached target strength and durability of the concrete. Using this up to 85% in fine aggregate reduced the demand in river sand.

REFERENCES

[1] Aggarwal. P et al., Civil Engineering Department, National Institute of Technology, Kurukshetra 136119, India Asian journal of civil engineering (building and housing) vol. 8, no. 1 (2007)

[2] Ilker Bekir Topcu, Mehmet Canbaz, "Effect of different fibers on the mechanical properties of concrete containing fly ash", *Construction and Building Materials*, 21 (2007) 1486–1491.

[3] Maslehuddin, M., Al-Mana, A.I., Shamim, M. and Saricimen, H., Effect of sand replacement on the early age strength gain and long term corrosion resisting characteristics of fly ash concrete, *ACI Materials Journal*, Jan-Feb (1989) 58-62

[4] 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, *ACI Materials Journal*, Jan-Feb1989

[5] Siddique, R., Effect of fine aggregate replacement with class F fly ash on mechanical properties of concrete, *Cement and Concrete Research*, **33**(2003) 539-547.

[6] Sivakumar. A, Manu Santhanam, "Mechanical properties of high strength concrete reinforced with metallic and non-metallic fibres", *Cement & Concrete Composites*, 29 (2007) 603–608.

[7] Tarun R. Naik and Bruce W. Ramme, High strength concrete containing large quantities of fly ash, *ACI Materials Journal*, March-April (1989) 111-116.

[8] Wu Yao, Jie Li, Keru Wu, "Mechanical properties of hybrid fiber-reinforced concrete at low fiber volume fraction", *Cement and Concrete Research*, 33 (2003) 27–30.

[9] Yeol Choi, Robert L. Yuan, "Experimental relationship between splitting tensile strength and compressive strength of GFRC and PFRC", *Cement and Concrete Research*, 35 (2005) 1587– 1591.