Feasibility Study of Fly Ash as a Replacement for Fine Aggregate in Concrete and its Behaviour under Sustained Elevated Temperature

Parvati V. K, Prakash K.B.

Abstract: Increasing shortage of natural fine aggregates in concrete at present leads to search for alternate sources for its replacement. In the present investigation of feasibility of using fly ash which is an industrial by product as a replacement of fine aggregate is studied. This paper presents the results of experimental investigation carried out to evaluate the strength performance of concrete by replacing natural sand by fly ash in various percentages when subjected to elevated temperature. The replacement of 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70% and 80% of fine aggregate with fly ash is considered and the concrete is exposed to elevated temperature of 200°C, 400°C, 600°C and 800°C. The various strength parameters studied are compressive strength, tensile strength, flexural strength and shear strength as per the relevant IS standards. The experimental results indicate significant improvement in strength properties of plane concrete with replacement of fine aggregate by fly ash when it is subjected to elevated temperature. Therefore it is feasible to adopt fly ash as a partial replacement of fine aggregate when it is exposed to elevated temperature and can be effectively used for structural concrete.

Index Terms: Experimental investigation, Fly ash, fine aggregate, replacement, strength, sustained elevated temperature, structural concrete

1. INTRODUCTION

HUMAN SAFETY in the event of fire is one of the considerations in the design of residential, public and industrial buildings. Concrete has a good service record in this respect. Unlike wood and plastics, concrete is incombustible and does not emit toxic fumes on exposure to high temperature. Composition of concrete is important because both the cement paste and the aggregate consist of components that decompose on heating. The permeability of concrete, the size of the element, and the rate of temperature rise are important because they govern the development of internal pressures from the gaseous decomposition products.

Currently in India, it is estimated that the annual consumption of cement concrete is to the tune of 400 metric tones. This will obviously cause an equal demand on the materials like sand, aggregates and other materials required to produce huge quantity of cement concrete. This will naturally cause depletion of all the natural resources connected in producing cement concrete every year. Also the production of huge quantities of cement requires large amount of energy, cause emission of CO_2 and carry forward the allied problems. Therefore the researchers are concentrating on finding out the supplementary cementitious materials which can replace cement partially or fully. In this direction, fly ash, blast furnace slag, silica fume, metakaoline and rice husk ash have shown promising results to replace cement partially. Thus came into existence the blended cements.

- *Parvati V. K , Associate Professor, Department of Civil Engineering, Gogte Institute of Technology, Udyambag, Belgaum, Karnataka, 590 008, India PH : 0-9945863468 E-mail : vinodparvati123@rediffmail.com.*
- *Prakash K.B., Principal, Government Engineering College, Haveri, Karnataka – 581110, India, PH: 0-9448267374. E-mail : kbprakash04@rediffmail.com*

Thus some of the industrial wastes are effectively utilized in the production of concrete. However, increasing shortage of natural fine aggregates in concrete at present has lead to search for alternate sources for its replacement. Fly ash is generally used as replacement of cement, as an admixture in concrete and in manufacture of cement. Enough studies have been carried out on partial replacement of cement by fly ash by earlier researchers. Fly ash could be very conveniently used as a partial replacement of sand in structural concrete. An increase in fly ash content results in higher strength for a given density, as fly ash is of pozzolonic nature.

M. Potha Raju [2] Investigated the changes in flexural strength of fly ash concrete under elevated temperature of 100°C, 200°C and 250°C for 1 hour , 2 hour, and 3 hours duration. The results showed that the fly ash content upto 20% showed improved performance compared with the specimens without fly ash by retaining, a greater amount of its strength.

Lankard et al., [3] investigated the changes in flexural strength of concrete containing gravel or limestone aggregate heated to temperatures upto 260°C. The results showed that the unsealed gravel and limestone concrete heat-treated at 79°C exhibited slight increase in flexural strength whereas concrete heat treated at 121°C and 260°C exhibited loss of flexural strength.

However less attention has been paid by researchers to use fly ash as a replacement for fine aggregate and its behavior under sustained elevated temperature.

The main objective of this experimental study is to investigate the strength performance of concrete produced by replacing natural sand by fly ash in various percentages like 0%, 10%, 20%, 30%,

International Journal Of Scientific & Engineering Research, Volume 4, Issue 5, May 2013
ISSN 2229-5518

40%, 50%, 60%, 70% and 80% when subjected to sustained elevated temperature of 200°C, 400°C, 600°C and 800°C. The various strength parameters studied are compressive strength, tensile strength, flexural strength and shear strength.

2. Research Significance

Concrete acts as nonflammable construction material; however most of its mechanical properties are changeable due to chemical and physical changes that may occur due to high temperature effect. In order to assess the structural safety of such structures after a fire, it is important that the effect of exposure to high temperature on mechanical properties of concrete should be well understood. The aim of this investigation is to study the influence of exposing to high temperature on some mechanical properties of concrete by replacing natural sand by fly ash in various percentages when subjected to elevated temperature. Relevant BIS codes are referred to conduct the various tests.

3. Materials and Methods

Ordinary Portland cement of 43 grade (IS 8112)[8] with specific gravity 3.15 was used in making the concrete. The fine aggregate used was sand of zone III and its specific gravity was 2.65 [9]. Course aggregates used in experimentation were 20m and down size and their specific gravity was found to be 2.75 [9]. Class F Fly ash used in this experimentation was obtained from Raichur Thermal Power Plant Karnataka. The specific gravity of fly ash is found to be 2.1. To improve the workability Glenium B233 superplasticizer was used. The dosage of superplasticizer was varied from 0.1% to 0.25% by weight of cement. Mix proportion used for M25 concrete (control concrete) was 1:1.34:3.27 with w/c = 0.45 (IS 10262:2009)[11]. Slump test was carried out to assess the workability in fresh state. The concrete was given sufficient compaction both through table vibration and hand compaction. After compaction the specimens were given smooth finish and were covered with gunny bags. After 24 hours, the specimens were demoulded and transferred to curing tank where in they were allowed to cure for 28 days. After 28 days of curing, the specimens were weighed accurately. They were transferred to on oven where they were subjected to an elevated temperature of 200°C, 400°C, 600°C and 800°C for 4 hours. After 12 hours of their cooling they were taken out of oven and weighed again accurately for loss in weight. They were visually observed for change in colour and cracks. After this they were tested for their respective strengths.
Concrete cube specimens of 150x150x150mm were cast and tested for compressive strength as per IS:516:1959 [12]. Cylindrical specimens of 150mm diameter x 300mm length were cast and tested for split tensile strength as per IS:5816-1999 [13]. To evaluate shear strength, L-shaped shear test specimens were prepared as proposed by Bairagi et al [7] from 150mm cubes by inserting a wooden block 90mm x 60mm in cross section and 150mm high into the cube moulds before casting of specimens. Beam specimens of 100mm x 100mm x 500mm were cast and tested for flexural strength as per IS 516-1959 [12].

4. Results And Discussions

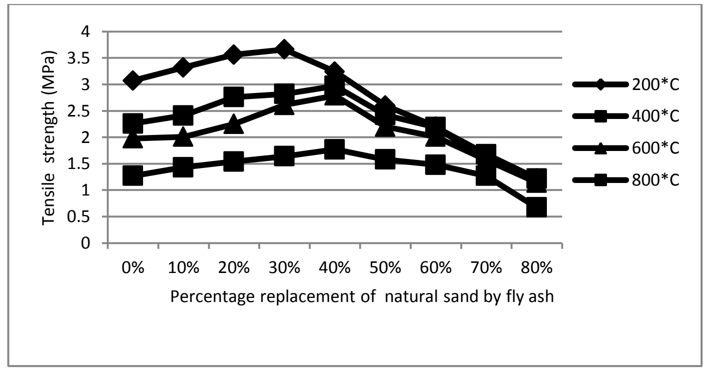
The variation of slump is shown in Fig. 1. From the slump test results obtained it is observed that as percentage replacement of sand by fly ash is increased, there is a decrease in slump value. An attempt is made to achieve workable mix, by varying the superplasticizer dosage in the range of 0.1% to 0.25% since w/c is maintained constant. The decrease in slump values is mainly attributed to the cohesive and stiffer mix resulted with higher fly ash content.
The variation in compressive strength, tensile strength, shear strength and flexural strength is represented in the form of graph as shown in Fig. 2, 3, 4 and 5.
The following observations were made when the concrete is subjected to sustained elevated temperature.

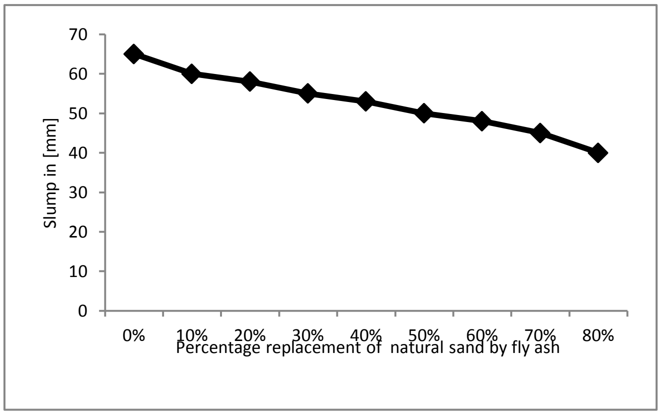
1. It is observed that the residual compressive strength of concrete when subjected to elevated temperature of 200°C for 4 hours, is higher at 40% replacement of natural sand by fly ash. After 40% replacement the compressive strength decreases. The percentage increase in the compressive strength at 40% replacement of natural sand by fly ash is about 16% as compared to reference mix (0% replacement)
2. It is observed that the residual shear strength of concrete when subjected to elevated temperature of 200°C for 4 hours, is higher at 40% replacement of natural sand by fly ash. After 40% replacement the shear strength decreases. The percentage increase in the shear strength at 40% replacement of natural sand by fly ash is about 30% as compared to reference mix (0% replacement).
3. It is observed that the residual tensile strength of concrete when subjected to elevated temperature of 200°C for 4 hours, is higher at 40% replacement of natural sand by fly ash. After 40% replacement the tensile strength decreases. The percentage increase in the tensile strength at 40% replacement of natural sand by fly ash is about 20% as compared to reference mix (0% replacement).
4. It is observed that the residual flexural strength of concrete when subjected to elevated temperature of 200°C for 4 hours is higher at 40% replacement of natural sand by fly ash. After 40% replacement the flexural strength decreases. The percentage increase in the flexural strength at 40% replacement of natural sand by fly ash is about 64% as compared to reference mix (0% replacement).
5. Similar trend is observed the concrete is subjected to elevated temperature of 400°C, 600°C and 800°C. Again the strength parameters are maximum at 40% replacement of natural sand by fly ash.

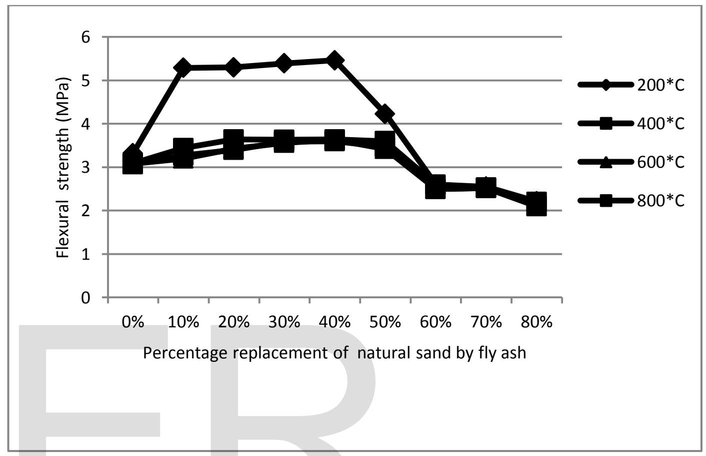
6. At 200°C cement paste is compact and there is no spalling of concrete. At 400°C cement paste starts to become loose but is continuous and combined with aggregates. At 600°C the surface colour is frecnch grey

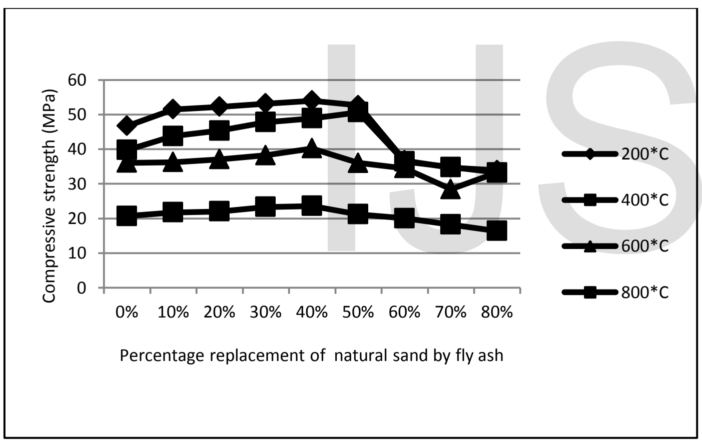
International Journal Of Scientific & Engineering Research, Volume 4, Issue 5, May 2013
ISSN 2229-5518

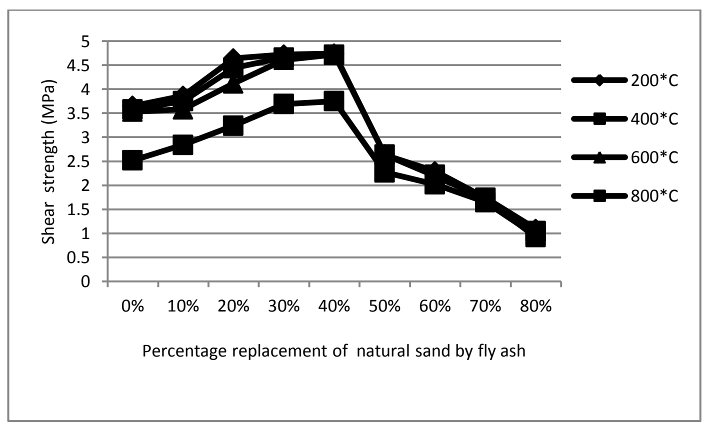
with slight red and cracks appear and cement aggregate interface is destroyed. At 800°C the structure of cement paste is honeycomb structure and large cracks exist in cement paste which is separated from aggregate.











CONCLUSIONS

International Journal Of Scientific & Engineering Research, Volume 4, Issue 5, May 2013
ISSN 2229-5518

The following conclusions are derived from the results reported in the paper.

a. Results of investigation reveal that it is feasible to replace natural sand by fly ash to achieve strength, economy and to achieve problem of waste disposal.
b. The compressive strength, tensile strength, shear strength and flexural strength were found to increase with increase in the percentage replacement of natural sand by fly ash upto 40% at elevated temperature of 200°C and thereafter decrease.
c. Similarly when concrete is subjected to sustained elevated temperature of 400°C, 600°C, 800°C the strength parameters are maximum corresponding to 40% replacement of natural sand by fly ash.
d. The results of this investigation suggest that the fly ash could be very conveniently used as a partial replacement of natural sand in structural concrete even at sustained elevated temperature.
e. Slump values were found to reduce with increase in percentage replacement and to achieve workable mix suitable dosage of superplasticizer is necessary.

Acknowledgements

The authors would like to thank Dr. A.S Deshpande, Principal, G.I.T, Belgaum and Dr. S. C. Pilli, Principal K.L.E.S.C.E.T Belgaum for giving all the encouragement needed which kept the enthusiasm alive. Thanks are also due to the management authorities of both the colleges and others who constantly boosted the morale by giving all the help required. Thanks are also due to authorities of Grasim Industries Bangalore(Cement Division) and BASF construction Chemicals (India) Pvt Ltd. Bangalore for sponsoring the materials

References

[1] Malhotra H. L. "*Effect of Temperature on the Compressive Strength of Concrete*" Magazine of Concrete Research, 1956, 8 No. 23, 85-94.

[2] Potha Raju M., Shobha M., Rambabu K., "*Flexural Strength of Fly Ash Concrete Under Elevated Temperatures*" Magazine of Concrete Research, 2004, 56 No. 2, March 83-88.

[3] Lankard D.R., Birkimer D.L. Foundriest F.F. and Snyder M.J., "*Effects of Moisture Content on the Structural Properties of Portland Cement Concrete Exposed to Temperatures of 500°F in Temperature and Concrete,* " ACI Special Publication SP 25-3, American Concrete Institute, 1971, pp 59-102.

[4] Mohamedhbai G.T., G., "*The Residual Compressive Strength of Concrete Subjected to Elevated Temperatures*" Concrete, 1983, December 22 to 27.

[5] Siddique R. " *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.

[6] Rajamane N.P, Annie Peter, Ambily P.S, " *Prediction of Compressive Strength of Concrete with Fly ash as Sand Replacement Material"* Cement and Concrete Composite, Vol.29, 2007, pp 218-223.

[7] Bairagi N.K Modhera C.D, "*Shear Strength of Fiber Reinforced Concrete.*" ICI Journal, January -March 2001, pp 47-53.

[8] IS: 8112-1989: *Specification for 43 Grade Ordinary Portland Cement.*

[9] IS: 383-1970: *Specification for coarse and fine aggregates from natural sources for concrete*.

[10] IS: 2386 (Part-I,II, III and IV) -1963: *Method of Tests for Aggregates for Concrete.*
[11] IS 10262 -2009 -: *Recommended Guide Lines for Concrete Mix Design.*

[12] IS: 516-1959: *Method of Test for Strength of Concrete.*

[13] IS: 5816-1999: *Splitting Tensile Strength of Concrete Method of Test.*