International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622
International Conference On Quality Up-gradation in Engineering, Science & Technology
(IC-QUEST- 11th April 2015)

RESEARCH ARTICLE OPEN ACCESS

Performance Evaluation of Concrete using Industrial Waste Products as a Cement Replacing Materials

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Abstract
Cement concrete is the second most consumed substance on Earth after water. Concrete gained the popularity as a construction material due to the easy availability of its component materials, the easy formability, strength and rigidity upon setting and curing. Now a days', the substantial amount of waste materials, is being generated from the major industries; and this waste can be used in combination with cement and disposal of such industrial wastes would also be felicitated. Hence, these materials have attracted attention of many researchers for the exploring the possibility of utilization of such waste materials in making the sustainable construction material. This paper reports the experimental investigation to study the strength characterization of the concrete made from the pozzolanic waste materials. The pozzolanic materials such as fly ash and ground granulated blast furnace slag (GGBFS) were used as a cement replacing materials in combination with ordinary Portland cement. In this experimental programme ten trial mixes were prepared by varying the percentage of fly ash, GGBFS and also varying the percentage of cement. The water cement ratio was kept constant.The compressive, flexural and split tensile strengths for 7 and 28days'curing were evaluated for different mix proportions.
Keywords-Concrete; Fly ash; Ground granulated blast furnace slag (GGBFS).

I. INTRODUCTION

Over time, the cement forms a hard matrix which binds various ingredients together into a durable stone-like material with many uses. In modern times, experiments were conducted with the addition of other materials to create concrete with improved properties, such as higher strength, electrical conductivity or resistance to damages through spillage. The manufacture and use of concrete produce a wide range of environmental and social consequences. At present the cement industries produced approximate 5% of total CO_2 produced in the world. Present environmental conditions suggests reduction in the consumption of OPC. The development of these concrete has brought forth the need for admixtures to improve the performance of concrete. By-products from various industries cause a major environmental problem around the world. In order to encourage waste recycling and prevent waste dumping, a landfill tax has also been imposed in the developed countries. Mineral admixtures like Blast Furnace Slag and Fly Ash in concrete may be a suitable solution. Very fine materials such as fly ash, a product of coal-burning power plant, render the fresh concrete more plastic. Ground Granulated Blast Furnace Slag (GGBFS) is a by-product from the blast furnaces used to make iron.

II. BRIEF REVIEW OF THE LITERATURE

There have been several studies reporting the utilization of pozzolanic waste materials such as fly ash and ground granulated blast furnace slag. M. Kohubu [1]was one of the researches to point out the utilization of fly ash in making the concrete. Following researchers also worked on the same theme and even explored various other materials. Some of the significant works are reviewed briefly in this section.Dunstan[2]described preliminary a model for the strength of concretes containing industrial by-products such as fly ash, blast-furnace slag, and silica fume. Dubovoy *et al* [3] performed tests under separate contracts at different times for three manufacturers of ground granulated blast furnace slag to determine the performance of their products with Portland cement and concluded that use of slag can be beneficial without resulting in significant technical problems or adverse construction problems. Oluokun [4] worked for fly ash- cement and fly ash concrete mix design. Bijen [5] showed that Concrete made with fly ash and GGBFS as secondary raw materials as a part of rebars, the binder shows distinctive advantages over concrete with Portland cement only. Especially, the performances and sulphate attack were substantially improved. Malhotra [6] described the amount of CO_2 being contributed by the Portland cement industry and discussed how these emissions can be reduced considerably by the increased use of large volumes of fly ash and other supplementary cementing materials in the concrete industry. Hooton [7]reported the use of GGBFS as a supplementary cementing material for enhanced performance of concrete. Corrosion of reinforcement embedded in concrete causes most of the failures in concrete structures. Obla *et al*[8] discussed the fresh and hardened properties of concrete made with an ultra-fine fly ash (UFFA) produced by air classification. Shun-hu and BAO Xian-cheng [9]explained the investigated influence of the content of ground granulated blast furnace slag (GGBFS) with the area of 400 m^2/kg on the slump constant, the strength and the durability of the concrete. Dhadseand Bhangia[10] presented a review of different ways of using fly ash and subsequently, the policies of Govt. of India regarding utilization and disposal of fly ash. Environmental and occupational health hazards associated with fly ash were also discussed.Zhi Ge and Wang [11] studied the behavior of concrete made from both- fly ash and ground granulated blast furnace slag combined.Aggarwaland Gupta[12] reported the development of high volume fly ash concrete for construction with reference to its predecessors like HSC and HPC. Different ways of using Flyash in various sectors of civil engineering construction industry in India was presented by Alam and Akhtar[13]shows different ways of using Fly ash in various sectors of civil engineering construction industry in India. Yang and Li [14] discussed the effects of fly ash as a partial replacement of cement on the strength of concrete.

Wang and Miao[15] reported the influence of high temperature curing at early ages on the hydration characteristics of a complex binder containing ground granulated blast furnace slag (GGBFS). Tamilarasan and Perumal [16]studied the workability of concrete with GGBFS as a cement replacement material with and without the addition of super-plasticizer. Aggarwal and Gupta [17] concluded the use of High Volume Fly ash Concrete (HVFC) in construction.

Mathew and Paul [18] detailed the influence of fly ash and GGBFS in laterized concrete exposed to elevated temperatures. Joshi et al[20] performed the experimental work to replace cementitious material by using Fly-ash, silica fume and GGBFS and also suggested maximum utilization of cement replacing materials in concrete considering strength parameters so that it provides a strong base, economy in the construction field.

Based on the afore-mentioned review of literature, an effort is made in this investigation to study the combined effect of fly ash and ground granulated blast furnace slag (GGBFS) as a cement replacing materials in combination with ordinary Portland cement for with different percentages on the compressive, split tensile and flexural strengths of the concrete. The investigation involved the experimental study to assess the effect of pozzolanic waste materials such as fly ash and ground granulated blast furnace slag (GGBFS) when used as a cement replacing materials with ordinary Portland cement on the strength parameter of concrete.

III. EXPERIMENTAL PROGRAMME

The particulars of the materials used in the present investigation along with the methodology of investigation are described in this section.

A. Materials

The materials used in the study include cement, crushed sand, aggregates, water and cement replacing materials such as fly ash and ground granulated blast furnace slag (GGBFS).

The cement used in the said investigation comprised of Ordinary Portland Cement (53 Grade), fly ash and GGBFS were sponsored by Ambuja Cements Ltd. Crushed sand andcoarse aggregates (metal I and metal II) brought from a supplier by reference of Ambuja Cements Ltd.

B. Methodology

The experimental programme involved the combination of Ordinary Portland Cement (OPC) and mineral admixtures such as fly ash and GGBFS. Two combinations with the percentage variation in cement replacing materials and cement were considered. In the Combination I, out of total cementitious material the cement percentage was reduced from 65% to 20% at the interval of 5% and the remaining amount of cementitiousmaterial was divided by GGBFS and fly ash in 80% and 20% respectively. Similarly for Combination II, GGBFS and fly ash were divided in 85% and 15% respectively.

For each combination ten trials were performed. In each trial, 6 cubes, 2 beam and 2 cylinder were cast. Water-Cement ratio was kept constant at 0.37 for each trial. The mix design was carried out confirming to IS:10262-2009 for concrete grade of M40.

The moulds with standard dimensions i.e. 150×150×150 mm were filled with concrete in 3 layers by poking with tamping rod and vibrated by the table vibrator. The vibrator was used for 30 second and it was maintained constant for all specimens. Along similar lines, the beams of size 100x100x500 mm and cylinders of size 100 mm diameter and 300 mm length were also cast. The moulds were allowed for 7 and 28days' curing. Thereafter, the samples weretested for their respective strengths.

IV. RESULTS AND DISCUSSION

The ratio of materials obtained from the mix design was *1:0.37:1.09:2.19*. The compressive strength obtained for this ratio with 100% OPC was found to be39.32and 53.62MPa for 7 and28 days' curing. The slump was found to be 60mm and compaction factor was 0.868.

The 7 and 28 days'curing compressive strength, slump and compaction factor of concrete with 100% OPC was considered as a baseline in the present investigation and is referred as 'Controlled Mix'.

In the context of the results obtained, following different tests on fresh and hardened concrete are discussed in the subsequent sections.

A. Compressive Strength

It can be observed from Figure 1 and 2 that with decrease in cement contents and increase in the contents of fly ash and GGBFS, the compressive strength of the concrete is found to decrease for any curing period. Further, the compressive strength is found to increase with increase in curing period in respect of all the trial mixes.

The performance of the various mixes with respect to cement contents, curing periods and that of cement replacing materials is discussed below.

It is observed that the compressive strength for all the mixes is found to decrease with the decrease in cement content. This is attributed to the decrease in the availability of alkali for pozzolanic reaction. It can be clearly seen from Figure 1 and 2, there is a significant decrease of strength for both combinations as compared to Controlled Mix for 7 and 28 days' curing. For 7 and 28 days' curing, the value of compressive strength for Combination I, for the first trial with 65% cement content is found to decrease by 6.33% and 9.75% respectively, which is successively decreasing up to 16.73% and 22.68% respectively for 20% cement content. Similarly for Combination II, for the first trial decrease in the strength is found to be 3.15% and 4.85% respectively, which is observed to decrease up to 13.45% and 20.25% respectively for 20% cement content.

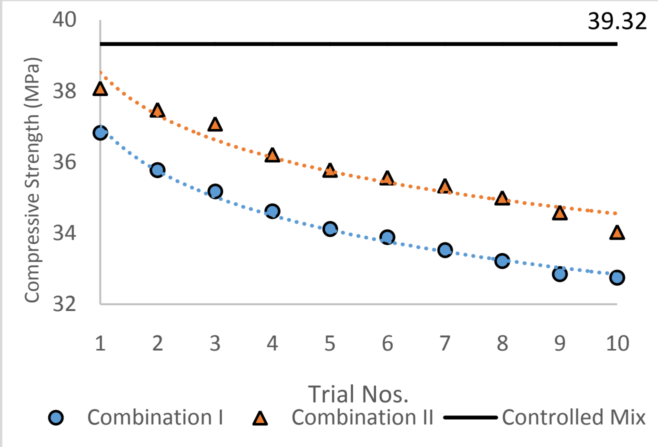

Figure 1: Comparison of 7 days' curing Compressive strength of Combination I and II w.r.t. Controlled Mix

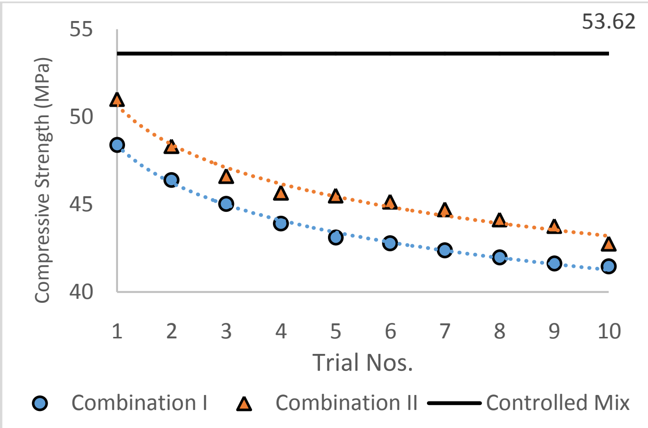

Figure 2: Comparison of 28 days' curing Compressive strength of Combination I and II w.r.t. Controlled Mix

The Figure 1 and 2 shows the variation of 7 and 28 days' strength respectively of Combination I and II togetheras compared toControlled Mix.The compressive strength for Combination II is found to be on higher side than Combination Iwhich is attributed to increase in GGBFS content and decrease of Fly ash content.

B. Compaction Factor and Slump

The values of the compressive strengths in respect of different trial mixes and various curing periods considered in the present investigation vis-à-vis compaction factor and slump for both combinationsis shown in Figure3 and 4 respectively.It is observed that the slump value decreases from 60 mm for Controlled Mix to 45 mm in both combinations for the first trial and goes on increasing up to 55 mm for last trial.

The compaction factor value is found to be increasing for both combinations and the values in case of

Combination II are on higher side. For higher values of the compaction factor, the compressive strength is found to be less and with increase in the compaction factor, the strength is found to be decreasing. The graphical representation of compressive strength and compaction factor is as shown in Fig. 3 and 4.

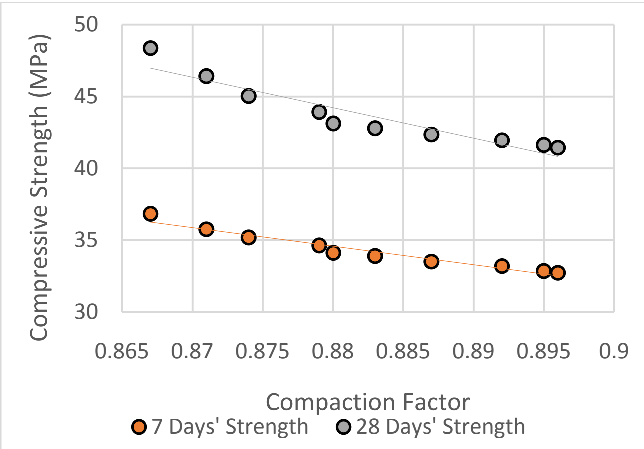

Figure 3: Relation of compressive strength with compaction factor for Combination I

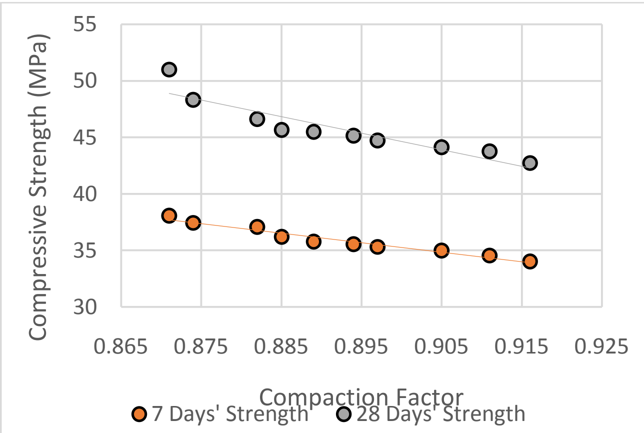

Figure 4: Relation of compressive strength with compaction factor for Combination II

C. FlexuralStrength

The values of flexural strengths, as obtained from the modulus of rupture test, for the various trial mixes in respect of all the curing periods, are shown in Figure 5 and 6 for 7 and 28 days' curing respectively.

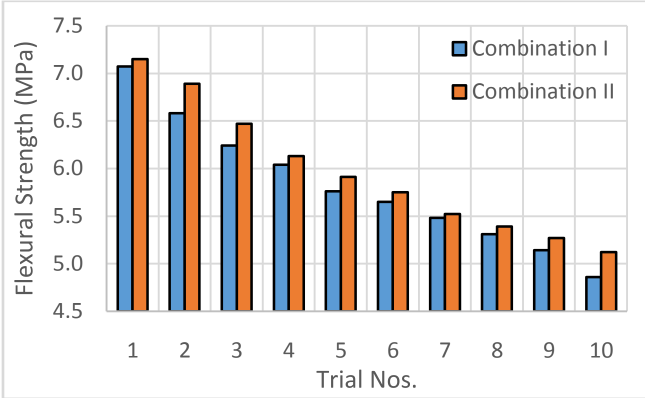

Figure5: Comparison of 7 days' Flexural strength of Combination I and II

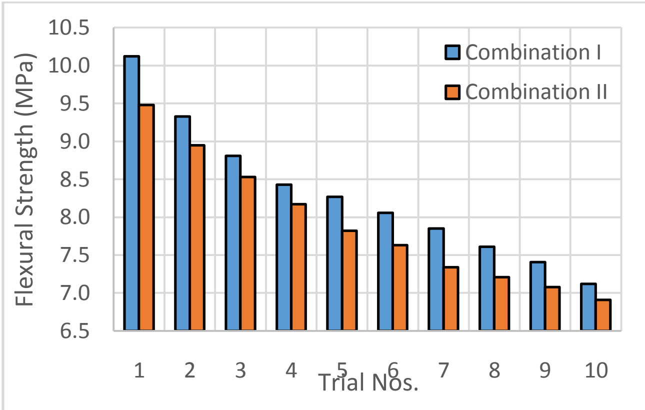

Figure6: Comparison of 28days' Flexural strength of Combination I and II

The values of the flexural strength for 7 days' curing for Combination II is observed to be on higher side as compared to CombinationI. While values of the flexural strength for28 days' curing for Combination I is observed to be on higher side as compared to Combination II.

It can be concluded that due to higher GGBFS content, flexural strength is on higher side for 7 days' curing for Combination II. Also, due to higher fly ash content, flexural strength is on higher side for 28days' curing for Combination I.

D. Split Tensile Strength

The values of Split tensile strengths as obtained from the split tensile test for the various trial mixes for 7 and 28 days' curing, are shown in Figure 7 and 8 for 7 and 28 days' curing respectively.

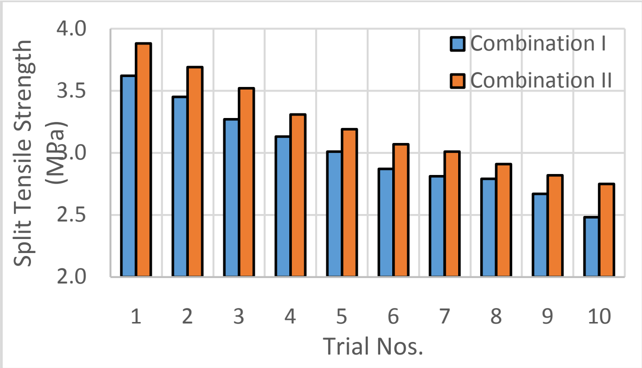

Figure 7: Comparison of 7 days' Split Tensile strength of Combination I and II

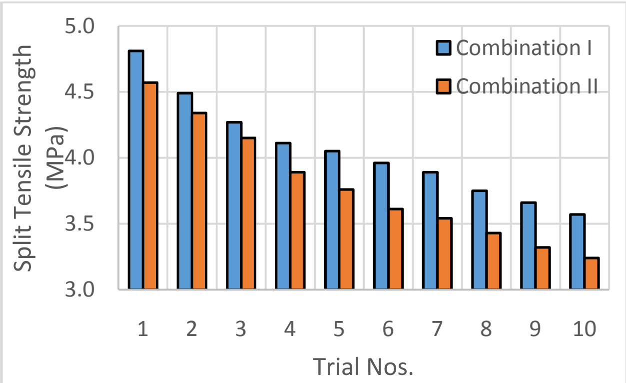

Figure 8: Comparison of 28 days' Split Tensile strength of Combination I and II

The values of Split tensile strength tests for 7 days' curing for Combination II are on higher side as compared to Combination I. While values of the Split tensile strength for28 days' curing for Combination I is observed to be on higher side as compared to Combination II.

It can be concluded that due to higher GGBFS content, Split tensile strength is on higher side for 7 days' curing for Combination II. Also, due to higher fly ash content, Split tensile strength is on higher side for 28days' curing for CombinationI.

V. CONCLUSIONS

Some of the broad conclusions deduced from the present study are as follows.

- With decrease in cement contents and increase in the contents of fly ash and GGBFS, the compressive strength of the concrete is found to decrease for any curing periodas compared to 'Controlled Mix'.
- The compressive strength for all the mixes is found to increase with the increase in cement content.
- With increase in compaction factor, the compressive strength of the concrete decreases.
- For Combination II,the flexural strength and split tensile strength was found to be on higher side for 7 days' curingforCombination I due to increase in GGBFS content.
- For Combination I, the flexural strength and split tensile strength was found to be on higher side for 28 days' curingforCombination II due to increase in fly ash content.
- The flexural strength is approximately 1.9 and 1.85 times more than the split tensile strength for Combination I and Combination II respectively for 7 days' curing, and 2 and 2.1 times for 28 days' curing.
- However, the compressive strength is considerably higher than the tensile and flexural strength in both the Combinations.

In view of some of the afore-mentioned findings emerged from the present investigation, it can be concluded that the pozzolanic waste materials such as fly ash and GGBFS, when used as a cement replacing materials in conjunction with OPC, can render the sustainable concrete.

VI. ACKNOWLEDGEMENT

The cooperation extended by Mr. Shrikant Varpe (Dy. Manager, PQM & CS Department) of Ambuja Cements Ltd., Mumbai in facilitating the experimental work in the laboratories of the Ambuja cement Ltd. is gratefully acknowledged.

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