An Experimental Investigation to Study the Effect of Use of Chemical and Mineral Admixtures on Properties of Concrete

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***Abstract* - A utilization of supplementary cementitious materials is well accepted because of the several improvements possible in the concrete composites and due to the overall economy. The present paper is an effort to quantify the 28-day cementitious efficiency of Ground Granulated Blast Furnace Slag (GGBS) in concrete at the various replacement levels with the help of literature review found and studied. This paper consist of a review extensively conducted on publications related to utilization of waste materials as cement replacement with an intention to develop a process so as to produce an eco-friendly concrete having similar or higher strength and thus simultaneously providing a remedy to environmental hazards resulting from waste material disposal.**

Keywords - Ground-granulated blast-furnace slag (GGBS or GGBFS), Supplementary cementitious material, Efficiency of Concrete

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I. INTRODUCTION

Concrete is one of the important construction material used in the world in all engineering works including the infrastructure development at all stages. It has been used in construction sector for a long time and proved that, it is a cheap material and its constituents are widely available in nature. Due to wide spread usage and fast infrastructure development in all over the world, there is shortage of natural materials. The quality of concrete is determined by its mechanical properties as well as its ability to resist the deterioration. It's a great opportunity for the concrete industry that they can save natural materials by replacing natural materials with Ground granulated blast furnace slag (GGBS). Ground Granulated Blast Furnace Slag has been constantly in use as cementitious replacement for sustainable infrastructure.

A. Admixtures -

There are two types of admixture -

- Chemical admixtures
- Mineral admixtures

B. Need of GGBS as a Mineral Admixture -

Ground-granulated blast-furnace slag (GGBS or GGBFS) is a by-product of iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace, and the resulting molten slag floats above the molten iron at a temperature of about 1500^{o}C to 1600^{o}C. The molten slag has a composition of 30% to 40% silicon dioxide (SiO_2) and approximately 40% CaO, which is close to the chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag, which mainly consists of siliceous and aluminous residues, is then rapidly water- quenched, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size which is known as ground granulated blast furnace slag (GGBS). The production of GGBS requires little additional energy compared with the energy required for the production of Portland cement. The replacement of Portland cement with GGBS will lead to a significant reduction of carbon dioxide gas emission. GGBS is therefore an environmentally friendly construction material. It can be used to replace as much as 80% of the Portland cement when used in concrete. GGBS concrete has better water impermeability.

C. Here are some benefits for GGBS -

Sustainability - It has been reported that the manufacture of one tonne of Portland cement would require approximately 1.5 tons of mineral extractions together with 5000 MJ of energy, and would generate 0.95 tonne of CO2 equivalent. As GGBS is a by-product of iron manufacturing industry, it is reported that the production of one tonne of GGBS would generate only about 0.07 tonne of CO2 equivalent and consume only about 1300 MJ of energy.

Colour - Ground granulated blast furnace slag is off-white in colour. This whiter colour is also seen in concrete made with GGBS, especially at replacements greater than 50%. The more aesthetically pleasing appearance of GGBS concrete can help soften the visual impact of large structures such as bridges and retaining walls. For coloured concrete, the pigment requirements are often reduced with GGBS and the colours are brighter.

Setting Times - The setting time of concrete is influenced by many factors, in particular temperature and water/cement ratio. With GGBS, the setting time will be slightly extended, perhaps by about 30 minutes. The effect will be more pronounced at high levels of GGBS and/or low temperatures. An extended setting time is advantageous in that the concrete will remain workable for longer periods, therefore resulting in less joints. This is particularly useful in warm weather.

D. Chemical Admixture -

Chemical Admixtures are the ingredients in concrete other than Portland Cement, water, and aggregate that are added to the mix immediately before or during mixing. Producers use admixtures primarily to reduce the cost of concrete construction; to modify the properties of hardened concrete; to ensure the quality of concrete during mixing, transporting, placing, and curing; and to overcome certain emergencies during concrete operations.

II. SCOPE AND OBJECTIVES -

i. To enhance the property of concrete.
ii. To minimize the use of conventional material by using mineral admixtures and chemical admixtures.

III. LITERATURE REVIEW -

A. Oner and S. Akyuz (2007) [1], has given investigation on optimum level of GGBS on the compression strength of concrete. They also have shown that, percentage of GGBS for making concrete, improves the compressive strength significantly.

K. Ganesh Babu and V. Sree Rama Kumar (2008) [2], has shown an effort to quantify the 28-day cementitious efficiency of ground granulated blast furnace slag (GGBS) in concrete at the various replacement levels. The replacement levels in the concrete studied varied from 10% to 80% and the strength efficiencies at the 28 days were calculated. Overall, the prediction of the strength of concretes varying from 20 to 100 MPa with GGBS levels varying from 10% to 80% by this method was found to result in a regression coefficient of 0.94, which was also the same for normal concretes . Finally, it was observed that for obtaining equal strength in concretes at 28 days, by adopting the efficiencies evaluated in the present investigation, it will be required to have an additional 8.5% and 19.5% increase in the total cementitious materials at 50% and 65% cement replacement levels, agreeing well with the values 10% and 20% additional material reported earlier.

Dubey (2012) [3],studied the effect of blast furnace slag on concrete by replacing cement from 5% to 30%; from the experimental studies it was observed that the optimum replacement of ground granulated blast furnace slag was 15 % without much reduction in the compressive strength. Only a reduction of 5 % in strength was observed .Concrete cubes were cast of size 150 × 150 × 150 mm and cured for 7, 14 and 28 days. It was concluded that increasing the percentage of blast furnace slag resulted in decrease in compressive strength.

Tamilarasan & Perumal (2012) [4], conducted an experimental study for the effects of replacing cement with ground granulated blast furnace slag on the compressive, split tensile and flexural strengths of concrete. In this study GGBS was used to replace cement from 0 to 100% in 5% increments, for this study M20 and M25 grades of concrete were used and it was concluded that tensile, compressive and flexure strength increased in all levels of replacements adopted. Compression tests were carried out at 3, 7 and 28 days curing, split tensile and flexure were carried out at the end of 28 days. The results obtained for M20 grade concrete were all above 20 MPa. The compressive strength increased up to 30% (optimum mixes) thereafter there was a decrement observed till 60% replacement level. Tensile and flexural strength increased with an in replacement of GGBS up-to 60% level.

Maiti & Raj (2010) [5], did an experimental study on concrete mix design on Portland cement replacements by GGBS from 50 to 65% for M20 grade concrete. Tests were conducted to determine the compressive strength of concrete after moist curing of 28 and 90 days. The test results led to the conclusion that with the increase of percentage of GGBS in concrete, the chloride ion permeability decreases. It was recommended to increase more than 50% GGBS in concrete to reduce harmful alkali-silica reaction. The heat of hydration of concrete using flyash and GGBS was less than that of concrete with only ordinary Portland cement. Ground granulated blast furnace slag is the safest option to mitigate alkali – silica reaction in concrete.

Mohamed (2012) [6], conducted an investigation on the locally available ground granulated blast furnace slag to protect the environment against waste dumping and to promote local products. The slag content such (20, 30, 40, 50, 60 and 80%) was used. Blast furnace slag had shown a positive effect on both the flexural and compressive strength of concrete after 28 days. The real gain in strength was noticed after the 28 day mark especially when 120 grade GGBFS was used. The long term strength of slag cement depended on many factors such as the amount of slag and Portland cement, and water to cement ratio. Clinkers have well reacted with slag, but a slight difference in the resulting resistance was observed mainly at medium and long term. The best resistance at 28 days was obtained with higher C3S and the C3A content. It was also noted that the minor elements played an important role in the slag reaction. The results of the long-term mechanical tests have shown that regardless the type of clinker used, the performance in compressive strength was very significant. An average of 30% increase in resistance with regards to the findings recorded at 28 days was also noted. The major reasons of such increase were higher C3S content and its quick reaction with water which provided an important degree of resistance.

Deepa (2012) [7], conducted a comparative study on mechanical properties of different ternary blended concrete by incorporating ground granulated blast furnace slag, silica fume and flyash. The properties investigated included workability, compressive strength and flexural strength. Mix design for M30 grade concrete was carried out, the dosage of superplasticizer used was 0.78% of cement weight. The specimens were prepared by using both hand compaction and using vibrating table; curing of the specimens was done for 28 days and 90 days. The ternary blends replacements were done from 0 to 30% in 5% increments. Silica fume replacement gave the highest strength in flexure after 28 and 90 days. Silica fume also gave the highest compressive strength after 90 days. The author also concluded that by using industrial waste materials environment can be made more sustainable.

Rafat Siddique and Rachid Bennacer (2012) [8], has shown the comprehensive details of the physical, and chemical reactions and hydration reaction. Use of GGBS accelerates the hydration of ordinary Portland cement at early hours of hydration. Inclusion of GGBS enhanced the workability of mortar/concrete, and also increased the setting times of cements. Strength of mortar incorporating GGBS is related to the surface area and particle size distribution (PSD) of GGBS. Blended cements containing slag (60% replacement) demonstrated superior sulfate resistance than ordinary Portland cement. Use of GGBS enhances the chloride binding capacity increased of cement mortar.

P. Dinakar, Kali Prasanna Sethy and Umesh C. Sahoo (2013) **[9],** has given a mix proportioning method which was proposed for the design of SCC using GGBS based on the strength requirements and considering the efficiency of GGBS. Using the proposed methodology and earlier established efficiency values for GGBS, self-compacting GGBS concretes of strengths ranging from 30 to 100 MPa, at various replacement levels ranging from 20% to 80% can be developed. The proposed methodology consists of five steps, all of which are based on simple calculations. The total powder content is fixed in the first step, the percentage of slag is fixed based on the strength required and the efficiency (k) is determined for the same percentage with the equation proposed earlier in the second step. In the third step the water content required for developing the SCC is determined and in the fourth step the coarse and fine aggregates are determined using the appropriate combined aggregate grading curves of DIN standards. Finally the self-compactability of the fresh concrete is evaluated through the slump flow and V-Funnel tests for flowability, the L-Box test for the passing ability. The experimental investigations on self-compacting GGBS concretes designed with the proposed mix design method, shows that the compressive strengths of the concretes obtained here surpass very high strengths of 90 MPa at 28 days and 100 MPa at 90 days. The design method also presents a way for obtaining high volume replacements up to 80% for 30 MPa.

Nileena M S and Praveen Mathew (2014) [10], has given their efforts on the SCC with GGBS and GBS. They show that, there was only very small difference in compressive strength of specimens replaced with GGBS for cement and GBS for fine aggregate and was found to be 20% as that of control mix. The splitting tensile strength of specimens with GGBS and GBS was found to be lower than that of specimens without any replacements. Flexural strength replaced specimens was found to have no significant difference when compared with control specimens. The Ultrasonic Pulse Velocity for all the specimens was found as excellent and it shows that there is no crack or undulations inside the specimens. There was significant difference in elastic modulus values for control specimens and specimens replaced with GGBS and GBS. Use of GGBS and GBS is found to have any negative impact on the various hardened properties of Self Compacting Concrete (SCC).

IV. CONCLUDING REMARKS -

The extensive literature survey has given an insight to the authors and supported to gain in depth knowledge and understanding on cement replacements that may be adopted in practice with different industrial waste materials. This work has given information about previous studies and that information helped the authors to undertake systematic experimental investigation for revisiting the issues in hand, such as the pollution in land and air that had been caused by the industrial wastes as there were no method of disposing these wastes but dumping them as land fill which led to serious health hazards. It was only after research, it was found that these industrial wastes had some good properties such as binding of aggregates and enhanced strength and durability of concrete, so these industrial waste materials could be used as a cement replacement in construction industry thereby reducing the cost of cement which in turn reduced the construction cost and at the same time an effective way was found to dispose of industrial waste materials there by reducing environmental health hazards and reducing pollution. Keeping these facts in mind a study needs to be conducted which would help to select the characterization and development of eco-friendly concrete using optimum quantity of industrial waste. This paper reviewed on existing research works on cement replacements done by adding different industrial waste materials. This paper mainly focused on different percentages of replacement by waste material. The importance of this review paper is that it has opened up the field of recycled waste material concrete field to study the strength and durability of concrete in compression and tension and also to study the durability aspects of such concrete.

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