International Journal of Engineering Research And Management (IJERM)
ISSN: 2349- 2058, Volume-03, Issue-07, July 2016

A Review on Ground Granulated Blast-Furnace Slag as a Cement replacing material

Er. Kimmi Garg, Er. Kshipra Kapoor

***Abstract*— Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. Concrete plays a vital role in the development of infrastructure Viz., buildings, industrial structures, bridges and highways etc. leading to utilization of large quantity of concrete. On the other side, cost of concrete is attributed to the cost of its ingredients which is scarce and expensive, this leading to usage of economically alternative materials in its production. This requirement is drawn the attention of investigators to explore new replacements of ingredients of concrete. The present technical report focuses on investigating characteristics of concrete with partial replacement of cement with Ground Granulated Blast furnace Slag (GGBS). The topic deals with the usage of GGBS and advantages as well as disadvantages in using it in concrete. This usage of GGBS serves as replacement to already depleting conventional building materials and the recent years and also as being a by product it serves as an Eco Friendly way of utilizing the product without dumping it on ground.**

***Index Terms*— GGBS, GGBS in concrete, other materials with GGBS**

I. INTRODUCTION

Concrete is probably the most extensively used construction material in the world with about six billion tones being produced every year. It is only next to water in terms of percapita consumption. However, environmental sustainability is at stake both in terms of damage caused by the extraction of raw material and CO_2 emission during cement manufacture. This brought pressures on researchers for the reduction of cement consumption by partial replacement of cement by supplementary materials. These materials may be naturally occurring, industrial wastes or by-products that are less energy intensive. These materials (called pozzalonas) when combined with calcium hydroxide, exhibits cementetious properties. Most commonly used pozzalonas are fly ash, silica fume, metakaolin, ground granulated blast furnace slag (GGBS). This needs to examine the admixtures performance when blended with concrete so as to ensure a reduced life cycle cost. There are competing reasons, in the long term, to extend the practice of partially replacing cement with waste by products and processed materials possessing pozzolanic properties. Lately some attention has been given to the use of natural pozzolans like GGBS as a possible partial replacement for cement. Amongst the various methods used to improve the durability of concrete, and to achieve high performance concrete, the use of GGBS is a relatively new approach; the chief problem is with its extreme finesse and high water requirement when mixed with Ordinary Portland cement. The present paper focuses on investigating characteristics of concrete with partial replacement of cement with GGBS. The Blast-Furnace slag is a by-product of the 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 0C to 1600 0C. The molten slag has a composition of about 30% to 40% SiO_2 and about 40% CaO, which is nearly similar to the chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag, which consists of mainly siliceous and aluminous residue is then water-quenched and cooled rapidly, resulting in the formation of a glassy crystalline granulates. This glassy granulates are dried and Pulverized which is known as ground granulated blast-furnace slag (GGBS).The production of GGBS requires less additional energy as compared with the energy needed for the production of Portland cement. The replacement of Portland cement with GGBS will lead to significant reduction of carbon dioxide gas emission. GGBS is therefore an environmental friendly construction material. It can be used to replace as much as 80% of the Portland cement used in concrete

Fig 1: Ground Granulated Blast slag

II. LITERATURE REVIEW

Shariq et al.(2008) studied the effect of curing procedure on the compressive strength development of cement mortar and

Manuscript received Aug 08, 2016

Er. Kimmi Garg, M.Tech Scholar, Department of Civil Engineering, Universal Institutions of Engineering and Technology, Lalru

Er. Kshipra Kapoor, Assistant Prof. & Head, Department of Civil Engineering, Universal Institutions of Engineering and Technology, Lalru

concrete incorporating ground granulated blast furnace slag. The compressive strength development of cement mortar incorporating 20, 40 and 60 percent replacement of GGBFS for different types of sand and strength development of concrete with 20, 40 and 60 percent replacement of GGBFS on two grades of concrete are investigated. Tests results show that the incorporating 20% and 40% GGBFS is highly significant to increase the compressive strength of mortar after 28 days and 150 days, respectively.

Peter et al. (2010) studied the BS 15167-1 which requires that the minimum specific surface area of GGBS shall be 2750 cm2/g (BS 15167-1:2006). In China, GGBS is classified into three grades; namely S75, S95 and S105. The GB/T18046 requires a minimum surface area of 3000 cm2/g for grade S75 GGBS, 4000 cm2/g for grade S95 and 5000 cm2/g for grade S105, which are higher than the BS EN's requirements (GB/T18046-2008). It was reported that slag with a specific surface area between 4000 cm2/g and 6000 cm2/g would significantly improve the performance of GGBS concretes.

Mojtaba Valinejad Shoubi et al. (2013) reviewed in their research the specifications, production method and degree of effectiveness of some industrial byproducts such as GGBS, Silica Fume and PFA as cement replacement to achieve high performance and sustainable concrete which can lead not only to improving the performance of the concrete but also to the reduction of ECO2 by reducing the amount of PC showing how they affect economical, environmental and social aspects positively.

Aveline Darquennes et al. (2011) determined the slag effect on cracking. Their study focuses on the autogenous deformation evolution of concretes characterized by different percentages of slag (0 and 42% of the binder mass) under free and restraint conditions by means of the TSTM device (Temperature Stress Testing Machine).

Elsayed (2011) investigated experimentally in his study the effects of mineral admixtures on water permeability and compressive strength of concretes containing silica fume (SF) and fly ash (FA). The results were compared to the control concrete, ordinary Portland cement concrete without admixtures. The optimum cement replacement by FA and SF in this experiment was 10%. The strength and permeability of concrete containing silica fume, fly ash and high slag cement could be beneficial in the utilization of these waste materials in concrete work, especially in terms of durability.

Reginald Kogbara et al. (2011) investigated the potential of GGBS activated by cement and lime for stabilization/solidification (S/S) treatment of a mixed contaminated soil. The results showed that GGBS activated by cement and lime would be effective in reducing the leachability of contaminants in contaminated soils. Martin et al. (2012) studied the influence of pH and acid type in the concrete. The conclusions were that concrete tested cannot adequately address the durability threat to all parts of wastewater infrastructure over a significant life span due to the extraordinarily harsh nature of this form of attack.

Wang Ling et al. (2004) analyzed the performance of GGBS and the effect of GGBS on fresh concrete and hardened concrete. GGBS concrete is characterized by high strength, lower heat of hydration and resistance to chemical corrosion.

Venu Malagavelli et al. [1] studied on high performance concrete with GGBS and robo sand and concluded that the percentage increase of compressive strength of concrete is 11.06 and 17.6% at the age of 7 and 28 days by replacing 50% of cement with GGBS and 25% of sand with ROBO sand.

Luo et al. [2] experimentally studied the chloride diffusion coefficient and the chloride binding capacity of Portland cement or blended cement made of Portland cement and 70 % GGBS replacement with or without 5 % sulphate. They found that (i) chloride diffusion coefficient decreased; (ii) chloride ion binding capacity improved in samples of blended cement.

Clear [3] concluded that higher the proportion of GGBS, the slower the early age strength development.

Oner and Akyuz studied on optimum level of GGBS on compressive strength of concrete and concluded that the optimum level of GGBS content for maximizing strength is at about 55–59% of the total binder content.

Qian Jueshi and Shi Caijun [5] studied on high performance cementing materials from industrial slag and reviewed the recent progresses in the activation of latent cementitious properties of different slag. They opined that Alkali-activated slag, such as blast furnace slag, steel slag, copper slag and phosphorus slag should be a prime topic for construction materials researchers.

III. HISTORY OF USING GGBS IN CONCRETE

There are many examples of using the GGBS concrete in the construction; following are some examples where the GGBS concrete were used.

1. World Trade Centre, New York (about 40% replacements).
2. Airfield Pavement of Minneapolis Airport (35 % replacement).
3. Atlanta„s Georgia Aquarium (worlds one of the largest aquarium), (20% to 70% replacements).
4. Detroit Metro Terminal Expansion (30% Replacement).
5. The Air Train linking New York's John Kennedy International Airport with Long Island Rail Road Trains (20%-30% replacements).
6. Tsing Ma Bridge, Hong Kong (59%-65% replacement).

From the above examples it is cleared that the world is aware of the advantages of GGBS uses in concrete. The main aim of the use of GGBS is to improve the durability, reduce the maintenance cost, to increase the service life, increase the economy of the construction with using the cheaper material as a replacement of the cement, and to reduce the cement consumption. Today it is necessary to reduce the carbon footprints as it affects the environment and ultimately affects the life on the planet and around 5% CO2 equivalent is produced from the single industry i.e. from cement industry.

In production of one ton of cement it consumes about 5000MJ of energy, 1.5 tonnes of mineral extraction, and produces 0.95 tonnes of CO2 equivalent, this consumption of natural resources and formation of large amount of CO2 equivalent it is necessary to find some alternative material instead of the cement which has cementitious.

IV. CHEMICAL COMPOSITION OF GGBS

The chemical composition of a slag varies considerably depending on the composition of the raw materials in the iron production process. Silicate and aluminates impurities from the ore and coke are combined in the blast furnace with a flux which lowers the viscosity of the slag. In the case of pig iron production the flux consists mostly of a mixture of limestone and forsterite or in some cases dolomite. In the blast furnace the slag floats on top of the iron and is decanted for separation.

Typical chemical composition:
Calcium oxide = 40%
Silica = 35%
Alumina = 13%
Magnesia = 8%
The glass content of slag's suitable for blending with Portland cement typically varies between 90-100% and depends on the cooling method and the temperature at which cooling is initiated. The glass structure of the quenched glass largely depends on the proportions of network-forming elements such as si and Al over network-modifiers such as Ca, Mg and to a lesser extent Al. Increased amounts of network-modifiers lead to higher degrees of network DE polymerization and reactivity. It is a granular product with very limited crystal formation, is highly cementitious in nature and, ground to cement fineness, and hydrates like Portland cement.

Typical physical properties:-
Colour: off white
Specific gravity: 2.9
Bulk density: 1200 Kg/m3
Fineness: 350 m2/kg

V. BENEFITS OF USING GGBS IN CONCRETE

Sustainability

It has been reported that the manufacture of one tonne of Portland cement would require approximately 1.5 tonnes of mineral extractions together with 5000 MJ of energy, and would generate 0.95 ton 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 ton 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 colored concrete, the pigment requirements are often reduced with GGBS and the colors 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.

CONCLUSIONS

The following conclusions can be drawn from the experimental investigations conducted on the behavior of concretes with GGBS as partial replacements for cement-

1. The partial replacement of cement with GGBS in concrete mixes has shown enhanced performance in terms of strength and durability. This is due to the presence of reactive silica in GGBS which offers good compatibility.
2. It is observed that there is an increase in the compressive strength for different concrete mixes made with partial replacement of cement by GGBS. The increase in strength is due to high reactivity of GGBS with Cement.
3. The use of GGBS as a replacement of cement helps to reduce the Energy consumption in the manufacturing of cement.
4. It has been reported that the manufacture of one ton of Portland cement would require about 1.5 tons of mineral extractions together with 5000 MJ of energy, and would generate about 0.95 ton of CO2 equivalent, with replacement of GGBS we can reduce the quantity of carbon equivalent produced with a material which is a by-product of Steel industry and readily available.
5. Concrete with reduced permeability increases the durability of the structure.
6. Use of GGBS in the concrete generates less heat while mixing with the water as against cement. It also helps to reduce the heat of hydration resulting less shrinkage and temperature cracks in the concrete.
7. As we know that concrete is vulnerable to sulphate attack on account of the Presence of Tri calcium Aluminates (C3A) in clinker. Reaction is formed with sulphate particles present in the atmospheric moisture and natural soil water, leading to internal stress & cracks in the Concrete. GGBS mixed cement concrete produces more resistance to sulphate attacks.

REFERENCES

[1] Aveline Darquennes, Stephanie Staquet, and Bernard Espion. (2011). "Behaviour of Slag Cement Concrete under Restraint Conditions". European Journal of Environmental and Civil Engineering, 15 (5), 787-798.
[2] Elsayed, A.A. (2011). "Influence of Silica Fume, Fly Ash, Super Pozz and High Slag Cement on Water Permeability and Strength of Concrete". Jordan Journal of Civil Engineering, 5 (2), 245-257.
[3] Martin O'Connell, Ciaran McNally, and Mark G. Richardson. (2012). "Performance of Concrete Incorporating GGBS in Aggressive Wastewater

Environments". Construction and Building Materials, 27 (1), 368-374.
[4] Mojtaba Valinejad Shoubi, Azin Shakiba Barough, and Omidreza Amirsoleimani. (2013). "Assessment of the Roles of Various Cement Replacements in Achieving Sustainable and High Performance Concrete". International Journal of Advances in Engineering and Technology, 6 (1): 68-77.
[5] Peter W.C. Leung, and Wong, H.D. (2010). "Final Report on Durability and Strength Development of Ground Granulated Blast Furnace Slag Concrete". Geotechnical Engineering Office, Civil Engineering and Development Department, the Government of Hong Kong.
[6] Reginald B. Kogbara, and Abir Al-Tabbaa. (2011). "Mechanical and Leaching Behaviour of Slag-Cement and Lime-activated Slag Stabilized/Solidified Contaminated Soil". Science of the Total Environment, 409 (11), 2325-2335.
[7] ASTM C 989-940, Standard specification for ground granulated blast furnace slag for use in concrete and mortars
[8] Ground granulated blast-furnace slag - Wikipedia, the free encyclopaedia
[9] http://www.ukcsma.co.uk/what_is_ggbs.html
[10] http://www.ecocem.ie/technical,working.htm
[11] http://ggbsreviewgroup.blogspot.in/
[12] http://www.vcem-global.com/technical.html
[13] Venu Malagavelliet.al./International Journal of Engineering Science and Technology Vol. 2(10), 2010, 5107-511.
[14] European Journal of Scientific Research ISSN 1450-216X Vol.88 No-1 October, 2012, pp.155163@Euro journals Publishing, Inc. 2012 http://www.europeanjournalof scientific research.com.