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Behaviour of Self Compacting Blast Furnace Slag Aggregate Concrete

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Abstract—*Concrete is the most extensively used material in the construction industry. Self compacting concrete (SCC) is a modern and innovative concrete which plays a vital role in concrete family. It is a non-segregating and a non-bleeding concrete with high flow ability that is placed and compacted by means of its own weight and suitable for placing in congested reinforcement. It fills all the nooks of the formwork without manual or mechanical vibrators with less screeding. SCC utilizes the dusts as admixtures like fly ash, silica fume, blast furnace slag which are Pozzolanic or hydraulic in nature. These are currently waste products from industries and are costly to dispose off. This practice not only helps in reuse of the waste material but also creates a cleaner and greener environment. The Iron industries produce a huge quantity of blast furnace slag (BFS) as by–product, which is a non–biodegradable waste material. In the present study BFS has been utilized as a coarse aggregate in concrete making. The researchers concluded that 30% of cement can be replaced by fly ash for better flow, hardened and durability properties of SCC. The results of present study showed that BFS Aggregates has properties similar to natural aggregates and could be alternative to stone aggregates. The various researchers study the behavior and use of self compacting concrete made up of stone aggregates. This paper is giving an overlook to contribution made by various researchers.*

Keywords*: Self Compacting Concrete (SCC), Screeding, Admixture, Blast Furnace Slag (BFS).*

1. INTRODUCTION

Concrete is the by far most extensively used man made construction material in the world. Concrete commonly consists of cement, coarse aggregate, fine aggregate and water. Cement is the ingredient used to bind the all other ingredients in concrete by hydration process. Sometimes admixtures are used in concrete to change the properties such as flow, strength and durability properties of concrete. Mineral admixtures dosage is higher than chemical admixtures dosage. If chemical admixtures are added more than defined, then it has a very wide range of negative effects on the properties of fresh as well as hardened concrete. Self Compacting Concrete is the most important invention considered in concrete technology. It has been used in concrete industries as it satisfies the deformability and stability. Self compacting concrete is a high performance concrete which deforms by its own weight without mechanical vibration. The fresh and durability properties of self compacting concrete increased by using industrial by products such as fly ash, silica fume, ground granulated blast furnace slag, rice hush ash etc. The addition of various industrial by products in SCC also diminishes environmental pollution. The researchers concluded that cement can be replaced by fly ash up to 30% for better flow, hardened and durability properties of SCC. The results of present study showed that BFS Aggregates has properties similar to natural aggregates and could be alternative to stone aggregates.

2. LITERATURE REVIEW

Rodriguez de Sensale G et al. (2015) developed a Simple and rational Methodology to design Self-Compacting Concrete Mixes through an optimization process to improve the flow properties and strength properties, so that SCC gives an economical solution of concrete mix over normal concrete mix. Since it has been considered that concrete exists of two phases i.e. paste and aggregate. Hence the developed procedure of SCC has been divided into three stages i.e. optimization of concrete phases, calculation of proportions for first trail mix and experimentally casting of first trail batch on the basis of second stage. The optimization of the two phases uses experimental trail mixes performed in laboratory. The calculation of the first trial batch proportions is based on the optimization results. The paste content kept 38%, 40% and 42% in total volume of concrete which is quite more compared to conventional concrete. The compressive strength of concrete in first trail batch is varying from 32.6 to 63.3 Mpa.

Rahmat Madandoust et al. (2012) studied experimentally the flow and strength properties of SCC with Metakaolin. Total fifteen mixes were casted with three different water-binder ratios of 0.32, 0.38 and 0.45 and cement replaced by Metakaolin in five proportions from 0% to 20%. The flow properties investigated by slump test, visual stability index, T50, V-funnel and L-box and strength properties were tested for compressive strength, splitting tensile strength, ultrasonic pulse velocity (UPV). The slump flow values are between 660 and 715 mm can be produced with lower dose of high range water reducer (HRWR) in SCC containing Metakaolin and can achieve proper stability without using viscosity modifying agent at different W/B ratios. The SCC with Metakaolin improved both short term and long term compressive, spilt tensile strength and decreased the absorption.

Assem A et al. (2012) discussed the effect of Metakaolin and silica fume on the durability of self-consolidating concrete (SCC). The silica fume was replaced the cement by 3%,5%,8% ,11% and Metakaolin was replaced the cement by 3%,5%,8%,11%,15%,20%,25%. The durability performance of SCC was evaluated by the results of drying shrinkage, freezing and thawing, salt scaling, and rapid chloride, permeability tests. The addition of MK increases the viscosity and passing ability of SCC mixtures. It has been reported that the presence of silica fume increases the compressive strength but also increases the dosage of HRWR which was lesser in case of Metakaolin. The drying shrinkage decreased with increasing MK and SF contents and scaling resistance is highly enhanced by adding MK compared to Silica Fume and chloride permeability decreases with Metakaolin. It has been concluded that the optimum percentage of silica fume and Metakaolin are 8% and 25% respectively.

Alexandre Bogas J et al. (2012) carried out a study on Self-compacting lightweight concrete produced with expanded clay aggregate. The coarse aggregate contents kept constant and flow properties such as slump flow, V- funnel, L-box and U-box performed. The maximum and minimum compressive strength obtained are 37.4 and 60.8 respectively. Flow ability and segregation resistance increases with paste content. Light weight clay concrete showed better deformation capacity. Flow time was 25% higher and elastic modulus higher in Clay aggregate concrete

Corinaldesi V et al. (2011) carried out an experimental study to find the role of industrial by-products such as limestone powder, fly ash, rubble powder (which is obtained from the rubble recycling process) and recycled aggregates in Self Compacting Concrete. The water to cement ratio was kept 0.45 with super plasticizer dosage ranging from 1% to 2% by weight of cement. The flow properties were evaluated by slump test, L-box and segregation resistance and compressive strength of concrete tested at 1, 3, 7 and 28 days of curing. The mix with rubble powder as mineral additive gives effective rheological properties and the mix with fly ash gives maximum 28days compressive strength due to its Pozzolanic behavior. It has been concluded that the mix with rubble powder and coarse recycled aggregates gives good flow properties with unchanged mechanical properties.

Rame Gowda M et al. (2011) studied self compacting mortar mixes using local waste materials such as Rice husk ash (RHA) and quarry dust. In this investigation the cement was partially replaced by RHA and sand was partially replaced by quarry dust to develop self compacting mortar (SCM) mixes. The RHA percentage replaced by cement varies in the range of 5–20% and quarry dust percentage replaced by sand fixed to 40% based on earlier results. The mechanical and flow properties of a desired SCM mix without RHA and quarry dust was compared with self compacting concrete containing rice husk ash and quarry dust at different ages of curing. The compressive test results showed that the compressive strength of SCM mixes with RHA and quarry dust is less than normal mixes at early ages and the differences become lesser at later ages. It has been reported that concluded that replacing cement by RHA with 5 to 10% gives good flow and strength properties.

Tarun Naik R et al. (2011) used high volume of fly ash to achieve high strength and economical self compacting concrete. In this experimental study Portland cement is replaced by Class C fly ash in the range of 35 to 55percentage. The results showed that using of high volume fly ash decreases the dosage of chemical admixtures such as superplasticizer and viscosity modifying agent. The compressive strength of this high strength economical self compacting concrete is about 62Mpa at 28 days curing for 35% replacement of Class C fly ash and 48Mpa at 28 days for 55% replacement. It has been concluded that high strength self compacting economical concrete has many applications in pre casting industry produced when replacing cement with Class C fly ash.

Eva Vejmelkova et al. (2010) studied experimentally the properties such as flow, strength and durability of self compacting concrete with Metakaolin and blast furnace slag in two different mixes separately. The mix with Metakaolin required more water and super plasticizer content compared to the mix with slag to satisfy the flow properties. The mixes with Metakaolin exhibited low viscosity, high initial strength and with slag exhibited high viscosity, low initial strength respectively. The freeze resistance of Metakaolin mix was excellent compared to slag mix. It has been concluded that the mix with Metakaolin gives better results compared to slag mix.

Karoline A et al. (2010) studied the effect of the finesses and content of Metakaolin on Self Compacting Concrete properties such as flow and strength properties. Three different types of finesses of Metakaolin have been used and Metakaolin replaces the cement by 5% and 35% by mass of cement at 40%, 45%, 50%, 55% paste volumes. It was found that usage of superplasticizer and Metakaolin increases with increasing finesses of Metakaolin due to decreasing of friction between aggregate and superplasticizer usage and strength decreases with increasing of paste volume due to less aggregate respectively. It has been concluded that the mixes with 45% and 50% of paste volume in total volume of concrete gives better strength and good cohesion and reduced superplasticizer usage.

Selçuk Türkel et al. (2010) studied the fresh and hardened properties of SCC made with different aggregate such as limestone and basalt aggregate and mineral admixtures such as fly ash (FA) and limestone powder (LP). The mixture combination of LP and Limestone aggregates showed better fresh and mechanical properties compared to the basalt and fly ash mix. The mixture contains LP and limestone aggregate influenced the slump flow positively by 21% compared to FA and basalt aggregate. Compressive strength of SCC made with limestone aggregates and FA combinations is about 15 to 27% higher when compared to LP and basalt aggregate. The mixtures with basalt exhibited negative effect on the fresh properties due to angular shape and rougher surface. Mineral admixtures were more dominant than aggregates on flow properties and Super plasticizer dosage decreased with increased quantity of total powder. FA and LP mix was increased frost resistance due to increasing of air content in concrete.

Zhimin Wu et al. (2009) studied experimentally on workability of self compacting concrete with light weight aggregates (LWA). The workability studied in two mixes with fixed coarse aggregate (LWA) and fine aggregate content and water, cement, fly ash increased by 7%. The workability of the two mixes of fresh self compacting light weight concrete (SCLC) was tested by slump flow, V-funnel, L-box, U-box, wet sieve segregation, and surface settlement tests. The distribution of LWAs along the specimen has been verified by the column segregation test and the cross-section images. The workability was increased but the resistance to segregation was decreased with the increasing of the paste content. The 28days compressive strength was increased by 15% with increasing the materials content by 7%.

Mehmet Gesog˘lu et al. (2009) studied properties of self-compacting concretes made with binary, ternary, and quaternary cementitious additives of fly ash, blast furnace slag, and silica fume. The binder content (450Kg/m^3) and water to cement ratio (0.44) was kept constant for all mixes. Fresh properties of the mixes were tested by slump flow diameter, slump flow time, L-box height ratio, and V-funnel and the hardened properties of the concretes were tested for chloride permeability, electrical resistivity, compressive strength, and ultrasonic pulse velocity. For increasing any mineral admixture decreased the chloride ion content and increases the durability. Using mineral admixtures enhanced the electrical resistivity of the concretes with increasing cementitious materials. The optimum mix with 10% of fly ash and 10% silica fume was given about 78 Mpa at 28days.

Dinakar P et al. (2008) studied the durability properties of self compacting concrete with high volume replacements of fly ash. The Strength of six self compacting concrete mixes of various grades with fly ash proportions of 0%, 10%, 30%, 50%, 70% and 85% weight of cement were compared with five different mixtures of normal conventional vibrated concrete. The durability properties were studied by water absorption, acid attack and chloride attack. The tests were showed that the lower strength self compacting concrete grades (20-30Mpa) can be produced with 70-85% fly ash replacement and higher strength grades (60-90Mpa) can be produced with 30-50% fly ash replacement. The maximum water absorption was in the range of 4.06–4.91% at 85% replacement and in normal vibrated concrete in the range of 1.68–4.93%. The absorption decreased with reduction of voids and SCC showed more voids compared to normal vibrated concrete. The loss of weight was decreased with increasing the fly ash replacement percentage when subjected to 3% H2SO4 solution. Chloride ion permeability is less in high volume fly ash SCC than normal vibrated concrete.

Ilker Bekir Topcu et al. (2008) studied effect of Marble Dust (MD) on properties of Self Compacting Concrete such as flow and strength properties. The cement was replaced by marble dust at certain contents of 0, 50, 100, 150, 200, 250 and 300 kg/m3. The slump test, L-Box test and V-Funnel test performed on fresh concrete and compressive strength and spilt tensile strength properties tested on hardened concrete. The test results showed that the fresh properties and hardened properties were quite better when MD is below 200kg/m3 and further increase in MD effects negatively on these properties.

Yun Wang Choi et al. (2006) studied experimentally on flow and mechanical properties of high-strength lightweight self-compacting concrete (HLSCC). The SCC prepared with light weight coarse (LC), fine (LF) and natural coarse aggregate (NC). The ratios of lightweight coarse aggregate (LC) and total coarse aggregate (LC and NC) varies as 0, 25, 50, 75,100% of total coarse aggregate and the ratios of lightweight fine aggregate (LF) and total fine aggregate (LF and NF) varies as 0, 25, 50, 75,100% of total fine aggregate. The study was analyzed at its fresh condition and its mechanical properties such as compressive strength, splitting tensile strength, elastic modulus and density at 28 days at the hardened condition. The compressive strength results showed that light weight coarse aggregates (LC) mixes up to 75% decreased the compressive strength by 6% compared to control mix with natural coarse aggregates (NC) and light weight fine aggregates (LF) mixes up to 50% increased the strength by 8% to 20%.

D'Aloia Schwartzentruber L et al. (2006) discussed the Rheological behavior of fresh cement pastes developed from a Self Compacting Concrete (SCC) mixes. The SCC was designed by varying super plasticizer and viscosity enhancing admixtures (VEA). The VEA affects both viscosity and shear yield stress. An increase of the VEA content increases the rheological parameters of SCC mixes. When the SP dosage close to the optimum, the VEA does not modify the rheological behavior of the paste and it is used to bring stability of concrete. The shear yield stress values obtained are good with those obtained from flow curves. It has been obtained the correlations between spread and yield stress, and between flow time and viscosity.

Hans-Wolf Reinhardt et al. (2006) studied the influence of heat curing on the pore structure and compressive strength of self-compacting concrete (SCC). The heat curing has done at 40^0C, 60^0 C and 80^0C by thermocouple. The heat curing of the self compacting concrete increases the pore size but not the volume of concrete. The change of the pore size distribution is correlated with (w/c) ratio of the concretes. The mean pore radius of the concrete was influenced with increasing water to cement ratio. When the temperature is in between 40^0 C and 60^0 C the compressive strength was deceased and after that slightly increased.

Zeghichi L (2006) studied the properties of concrete with crystallized slag replaced with natural gravel and granulated slag with natural sand. The total replacement of natural coarse aggregate with crystallized slag effects positively on flexural and compressive strength of concrete at 3, 7, 28, 60 days. The partial replacement of natural fine and coarse aggregate with slag aggregates gains long term strength at 5 months but entire replacement of natural aggregates effects negatively the strength.

3. CONCLUSION

1. The amount of fine aggregates, coarse aggregates, binders, mixing water, mineral additives as well as type and dosage of chemical admixtures are the factors influencing the mechanical and flow properties of Self Compacting Concrete.
2. Adding the mineral additives and chemical admixtures such as fly ash and super plasticizer increases the workability of Self Compacting Concrete.
3. The test results showed that Slag aggregates has similar properties in terms of specific gravity, unit weight and texture as natural aggregates and it would not cause any harm to concrete if incorporated into it.
4. The test results showed that the steel slag 40% replacement increases the compressive, tensile and flexural strengths of the concrete for all grades of concrete and after that any further replacement of steel slag decreases the compressive strength.
5. The researchers showed that using blast furnace slag as coarse aggregates in concrete has no negative effects on the short and long term properties of hardened concrete.

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