IOSR Journal of Engineering (IOSR JEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 58-64

Study on Sustainable Light Weight Concrete Using Construction Demolition Waste and Ground Granulated Blast Furnace Slag Sintered Aggregates

Deepak R[1], Vandhana Devi V[2], Surjith Raj[3]
[1]*Assistant Professor, KCG College of Technology, Chennai, 600097, India.*
[2]*Associate Professor, KCG College of Technology, Chennai,600097, India.*
[3]*UG Student, KCG College of Technology, Chennai, 60009, India.*

Abstract: *Utilization of industrial waste as a construction material is a healthy sustainable practice to dispose the waste and conserve the available resources for future generations (Kiksuet al[1], 2017).There is an increasing pressure on the construction industry to reduce costs and improve the quality of our environment. The aim of this paper is to study the properties of sustainable light weight concrete which is made using Construction Demolition Waste (CDW) and Ground Granulated Blast furnace Slag (GGBS) sintered aggregates. The mechanical and durability properties of lightweight concrete is improved by partial replacement of coarse aggregate in concrete by sintered artificial aggregates. These aggregates were prepared by sintering the mixture of GGBS, Construction Demolition Waste, clay and coke breeze at definite proportion at a sintering temperature of 1200°C to 1300°C in a laboratory. The sintered CDW GGBS aggregates are light in weight, fire resistant and sulphate resistant. Tests were conducted for the prepared light weight aggregates and the results have been verified with the specifications given by Central Building Research Institute (CBRI), Roorkee. The quantities of sintered GGBS aggregate for 10%, 20%, 30%, 40% and 50% replacement by weight were estimated and the prepared mixes were examined for their suitability in structural use. The main findings of this investigation revealed that two types of waste materials could be reused successfully as partial substitutes for coarse aggregates in concrete mixtures. The test results for the nominal concrete and the concrete having sintered CDW GGBS aggregates have been analysed and compared. As a summary, 40% replacement of CDW GGBS aggregates has been effectively used for light weight structural concrete works without compromising the strength parameters compared to the concrete using the natural granite aggregates.*

Keywords: *Construction Demolition Waste, Ground Granulated Blast Furnace Slag (GGBS), Light weight aggregates Sintering, Sustainable light weight concrete*

I. Introduction

Concrete is the second most consumed material after water, with nearly three tons used annually for each person on the planet (Nithyaet al[2], 2017). Rapid development in the construction industry has increased the need for raw materials of concrete. Utilization of industrial waste as a construction material is a healthy sustainable practice to dispose the waste and conserve the available resources for future generations (Kiksuetal[1], 2017). Coarse aggregate is a vital element in concrete and its extensive use results in destruction of hills causing geological and environmental imbalance. The environmental impacts of crushed stone aggregate extraction are a source of increasing concern in many parts of the country. The impacts include loss of forests, noise, dust, blasting vibrations and pollution hazards. Unplanned exploitation of rocks may lead to landslides of weak and steep hill slopes. The concern about the depletion of natural sources and the effect on environment has particularly focused attention on possibility of use of synthetically produced (from waste materials) aggregates as an alternative to naturally occurring materials (Deepak and Devi[3], 2018). GGBS a byproduct of quenching molten iron slag form a blast furnace in water or steam has been used for the preparation of sintered aggregates to be used in concrete.

Worldwide, more than 50% of GGBS, a byproduct produced from iron smelting is disposed of in landfills. In addition to GGBS, Construction Demolition Waste (CDW) has also been used in the preparation of sintered aggregates. As far as cost concern, construction demolition waste is used as a partial replacement to GGBS. In the present situation, recycling of GGBS and CDW has become an increasing concern due to increasing landfill costs and current interest in sustainable development. The continuous depletion of natural coarse aggregates for construction purpose and dumping of GGBS as landfill are two severe problems that can be solved simultaneously by using CDW and GGBS aggregates in an actual production of concrete. The possibility of replacing coarse natural aggregate with CDW GGBS aggregates without losing strength and durability offers technical, profitable and eco-friendly benefits which are of great importance in the contemporary context of sustainability in the construction sector.

Production of artificial aggregates from GGBS and CDW is an innovative step towards the industrial waste disposal in large quantity. Since aggregate constitute about 70% of the total volume of the concrete, the inclusion of GGBS and CDW in the form of coarse aggregates not only conserves natural resources but also facilitates high volume utilization of GGBS and CDW in concrete, saving in cost of construction, thermal and acoustic insulation, etc., apart from reducing the environmental problems due to large scale dumping of this waste material.By making light weight aggregates, the self-weight of the structure will be reduced. At the same time, the structure should be durable and economical so that it can be affordable to all. Hence, sintered CDW GGBS aggregates have been produced using the mixture of industrial wastes (GGBS), construction demolition waste (CDW), locally available natural binder materials (clay), coke and water. The commercial production of artificial lightweight aggregates from flyash through sintering has started in 1960s (Dolby[4], 1995). The utilization of these waste materials in concrete reduces environmental impact from the manufacture of concrete using conventional materials (Shi et al[5], 2015).

Experimental Procedure

The effect of using CDWGGBS as a partial replacement of coarse aggregate on mechanical and durability properties of concrete in various percentages was investigated.

II. Materials

Portland cement of Grade 53 conforming to Indian Standard Specification BIS 12269-1987[12] was used. Locally available natural river sand was used as fine aggregate and crushed stone with 20mm size was used as coarse aggregate. The properties of fine aggregate and coarse aggregate were found in accordance with BIS 383-1970[13]. The specific gravity of the fine aggregate and coarse aggregate was 2.5 and 2.6 respectively. The unit weight of sand and coarse aggregate was 1757 kg/m^3 and 1569 kg/m^{3}respectively. Locally available ground granulated blast furnace slag (GGBS) and Construction demolition waste in the surrounding locality was used. GGBS with specific gravity 2.75 and bulk density 0.84 g/cc was used. Locally available clay with specific gravity of 2.24, moisture content of 15.65% and liquid limit of 62.3% was used. Coke with specific gravity of 2.26 was used in the mix. Some researchers have investigated the use of fly ash instead of GGBS and CDW for partial replacement. The review of literature shows that the specific gravity of these fly ash aggregates was 16-46%, less than that of normal weight aggregates and possesses higher water absorption. Sintered fly ash aggregate concrete have 28day compressive strengths in the range of 27-74 MPa with densities in the range of 1651-2017 kg/m^3(Manu et al[6], 2017). The durability properties of fly ash aggregate concrete indicate that the performance is satisfactory for structural applications. This study aims to determine the mechanical and durability property of concrete using sintered construction demolition waste ground granulated blast furnace slag aggregates by partial replacement for natural coarse aggregates without sacrificing the strength and durability of concrete. Inclusion of sintered aggregates will facilitate numerous benefits such as reduction in dead loads, steel reinforcements and transportation cost, faster construction etc. (eurolightcon[7], 1998).

Mix Proportions of Concrete Mixtures

Various trials were made by mixing the raw materials at different proportions. A suitable mix ratio was determined by testing the sintered CDWGGBS aggregates with respect to their strength characteristics for the production of artificial aggregates. In this experimental investigation, a mix has been produced by palletizing the mixture of 60% GGBS, 20% CDW, 10% clay and 10% coke. The palletized natural aggregates were sintered at 1200- 1300 degree Celsius.

The concrete mix design procedures recommended for the development of light weight aggregate concrete varies from conventional aggregate concrete mix design. The porous feature of light weight aggregate causes reduction in its compressive strength capacity and reduces the free water from the paste matrix (Manu et al[6], 2017). From literature it was found that combined aggregate grading facilitates proper aggregate packing within the concrete mix (Wegen and Bigen[8], 1985). A control mixture (V0) was designed to obtain 28 days compressive strength of 26.5 MPa. Five more concrete mixtures denoted by V10, V20, V30, V40 and V50 were prepared by replacement of coarse aggregate with CDWGGBS aggregates in 10%, 20%, 30%, 40% and 50% respectively.

Casting and Testing of Specimens

150 mm concrete cubes were cast for compressive strength and acid resistance, 150 x 300 mm cylinders for split strength and samples of size 500 x 100x 100 mm for flexural strength. All the test specimens were stored at room temperature in the casting room. The specimens were immersed in curing tank after 24 hours. After a required period of curing (28 days), the specimens were taken out of curing tank and their surfaces were wiped off. Tests were performed after 28 days following BIS 516:1959[14].

After 28 days of curing the specimens cast for acid resistance test were immersed in a solution containing 1% H_2SO_4 for 60 days. For alkalinity test, the broken pieces of tested specimens for compressive strength after 28 days of curing were again broken into small pieces using the hammer and then powdered. Each of the powder samples (25 grams) were mixed into 100 ml of distilled water. The aqueous solution was allowed to stand for 72hrs and it was often agitated, to enable more of free lime of hybrid cement paste to get dissolved in water. The pH of the aqueous solution was measured using pH meter (Nithyaet al[2], 2017).

III. Results and Discussion

Compressive Strength

Compressive strength is the primary design parameter for the structural engineers. According to CEB/RILEM concrete having densities between 1600 and 2000 kg/m^3 and a compressive strength more than 15MPa can be considered as structural concretes (CEB RILEM recommendations[9], 1978).Concrete compressive strength is primarily governed by strength of both aggregate and paste matrix. Though the strength of the aggregate is low, the strength of the matrix and the extent of its arching action over the aggregate govern the strength of concrete (Baradhan-Roy et al[10], 1995) mixtures made with sintered CDWGGBS aggregates was determined at 28 days of curing. At 28 day, control mixture V0 achieved a compressive strength of 26.6 MPa, whereas mixture V10 achieved a compressive strength of 27 MPa. An increase in compressive strength of 1.2%, 2.5%, 4.2% and 5.4% was achieved for V10, V20, V30, V40 mixtures respectively in comparison with V0 mix. A decrease in compressive strength of 5.1% was observed for the mix V50. The inclusion of 40% of SCDWGGBS aggregates as partial replacement for coarse aggregate has increased the compressive strength of concrete slightly but the use of SCDWGGBS aggregates reduces the self-weight of structures up to a maximum of 20% when compared to normal concrete. The variation of compressive strength of concrete with and without SCDWGGBS aggregates is shown in figure 1.

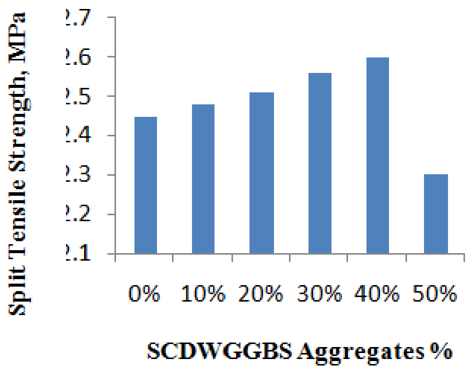

Fig 1 – Effect of SCDWGGBS aggregates on compressive strength of concrete

Split Tensile Strength

The 28th day split tensile strength of concrete mixtures made with and without SCDWGGBS aggregates was determined. The variation in split tensile strength with SCDWGGBS aggregates was similar to that observed in the case of the compressive strength. The 28 day split tensile strength of control mix V0 was found as 2.45 MPa. The increase of 1.1%, 2.4%, 4.3% and 5.2% was observed for the mixtures V10, V20, V30, V40 respectively and a decrease of 4.8% for V50 mixture was observed at 28 days. Figure 2 depicts the deviation of split tensile strength of concrete containing different percentages of SCDWGGBS aggregates with that of conventional concrete.

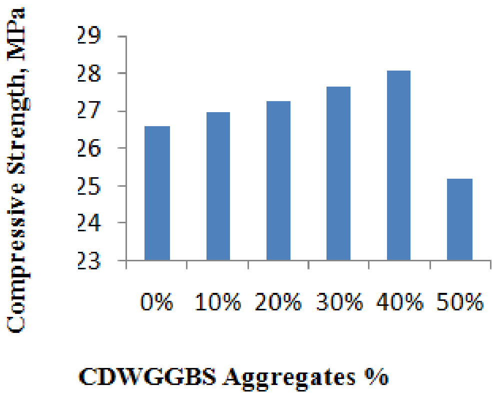

Fig 1 – Effect of SCDWGGBS aggregates on split tensile strength of concrete

Flexural Strength

The 28th day flexural strength of concrete mixtures made with and without SCDWGGBS aggregates was determined. The variation in flexural strength with SCDWGGBS aggregates was similar to that observed in the case of the compressive strength. Like compressive strength and split tensile strength, the flexural strength of concrete mixes varied marginally with an increase in SCDWGGBS content. The 28th day flexural strength of conventional mix V0 was found to be 3.4 MPa. The increase of 1.1%, 2.9%, 4.5% and 5.25% was observed for the mixtures of V10, V20, V30 and V40 respectively and a decrease of 6.05% was observed at 28 days. Figure 3 depicts the deviation of flexural strength of concrete containing different percentages of SCDWGGBS aggregates with that of conventional concrete.

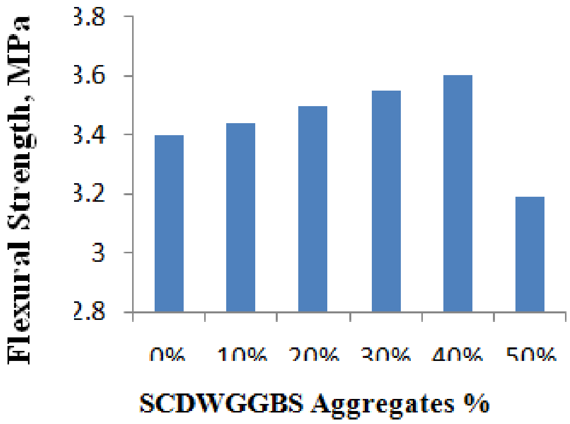

Fig 3 – Effect of SCDWGGBS aggregates on flexural strength of concrete

Correlation Analysis

References from various literature shows that the concrete mixes will have relationship between different strength which is highly influenced by factors like characteristics of aggregates, quality of concrete, etc. Therefore it is essential to model the relationship between various strengths such as compressive strength, split tensile strength and flexural strength. Table 1 shows the obtained regression equation and correlation co-efficient whereas figure 4 and 5 depicts the linear regression relation between split tensile strength and flexural strength with that of compressive strength.

Based on the linear regression relation between split tensile strength and compressive strength at correlation level of 99.8%, the rate of change between the strengths were found to be 10.28%. At a correlation level of 99.76% of the data scatter, the rate of change of flexural strength as a function of compressive strength was estimated as 14.22%. From the correlation analysis it is found out that, high value of correlation coefficient emphasizes that there is a strong relationship between split tensile strength and flexural strength with that of compressive strength.

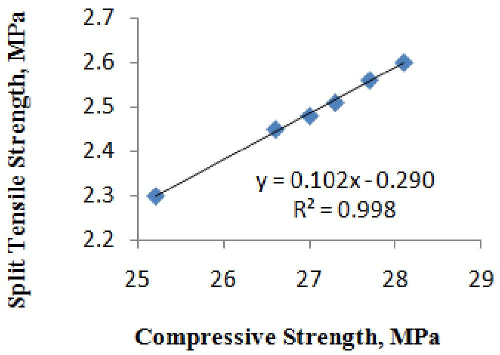

Fig 4 – Correlation analysis between compressive strength and split tensile strength

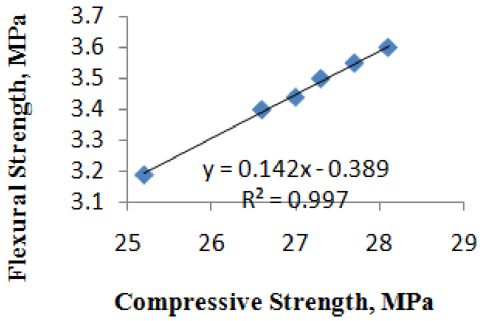

Fig 5 – Correlation analysis between compressive strength and flexural strength

Table 1 – Correlation Analysis

S.No	A	B
Relationship	CS vs SS	CS vs FS
Linear Equation	y = 0.1028x – 0.2904	y = 0.1422x – 0.3898
Regression Co-efficient	R^2= 0.998	R^2= 0.9976

Comparison of Self Weight

Light weight concretes can be used for structural applications, with strengths equivalent to normal weight conventional concrete. There are various benefits of using light weight aggregate and one major factor is the reduction in dead loads which leads to financial savings in foundations and reinforcement. Though light weight aggregates are less stiff than the equivalent normal strength concrete, it is mitigated by the reduction in self-weight to be carried, which leads to slight reduction in the depth of a beam or slab. The use of sintered CDWGGBS aggregates in concrete reduces the self-weight of the structure up to 18% at 40% replacement of light weight aggregates. Figure 6 depicts the comparison of self-weight of concrete containing different percentages of SCDWGGBS aggregates with that of conventional concrete.

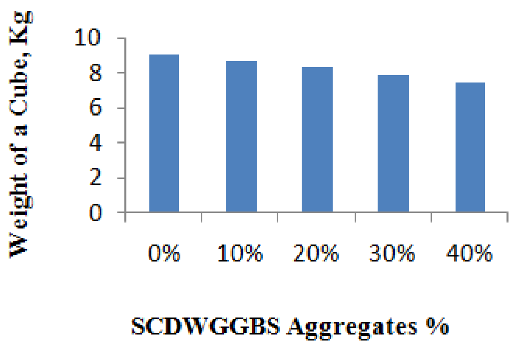

Fig 6 – Effect of SCDWGGBS aggregates on flexural strength of concrete

Durability Properties

The durability of concrete plays a significant role in serviceability requirements (Nithyaet al[2], 2017). The strength of concrete is mainly dependent on the capacity of a fluid penetrate the concrete's microstructure which is called as permeability (Zhang & Zong[11], 2014). So the durability property of concrete is determined by the acid resistance test and alkalinity test.

Acid Resistance Test

The acid resistance property of the taken concrete mixtures was calculated by measuring the percentage of weight loss and compressive strength at the age of 60 days. From the test results it was observed that a decrease in compressive strength of 19.1%, 20.7%, 21.1%, 22.6%, 20.2% and 22.9% was achieved for V0, V10, V20, V30, V40 and V50 respectively when compared with the compressive strength of the specimens tested at 28 days. Figure 7 shows the comparison of compressive strength at 28 days and 60 days of testing.

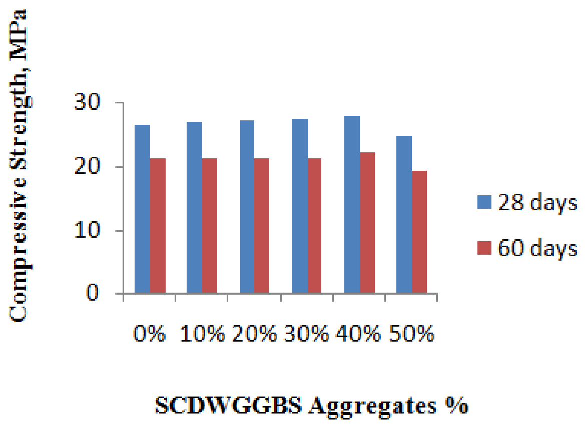

Fig 7 – Compressive strength of concrete after acid resistance test

Alkalinity Measurement

Determination of pH of concrete is necessary as it relates to alkali-silica reaction, carbonation and corrosion of embedded steel (Nithyaet al[2], 2017). Alkali-silica reactivity has been recognized as a potential source of distress in concrete. From the literature review it was found out that if pH increases, then the chances for alkali-silica reaction increases. It was inferred from the test results, the pH value of concrete with and without SCDWGGBS aggregates remains the same.

IV. Conclusion

This study has demonstrated the feasibility of using sintered CDWGGBS aggregates in concrete as partial replacement for coarse aggregate by evaluating the strength and durability properties of the concrete. The following conclusions were drawn based on the various test results arrived from the mixtures of concrete:

(i) The sintered CDWGGBS lightweight aggregates were light brown in color.

(ii) The manufactured light weight artificial aggregates had the following properties: water absorption of 11%, crushing strength of 6.2%, impact value of 16.3% and specific gravity of 2.2. Also the sintered CDWGGBS aggregates confines to the standards given by CBRI, Roorkee.

(iii) The self-weight of the sintered CDWGGBS aggregate concrete was less when compared with normal conventional concrete. There was a 20% reduction in the self-weight of sintered CDWGGBS concrete when compared with normal conventional concrete.

The main findings of this investigation revealed that two types of waste materials could be reused successfully as partial substitutes for coarse aggregates in concrete mixtures. The environmental impacts caused by landfilling of construction and demolition waste are estimated to increase 20.2 % by 2025. If 50 % of recycling rate can be achieved in 2025, the environmental impacts will reduce 33.2 % and it further reduce 46.0 % if 100 % of recycling (Mahaet al[12], 2018). As a summary, 40% replacement of CDW GGBS aggregates has been effectively used for light weight structural concrete works without compromising the strength parameters compared to the concrete using the natural granite aggregates.

References

[1]. N.Kisku, H.Joshi, M.Ansari, S.K.Panda, S.Nayak, S.C.Dutta, A critical review and assessment for usage of recycled aggregate as sustainable construction material, Construction Building Material 131 (2017), 721-740.
[2]. M.Nithya, A.K.Priya, R.Muthukumaran, G.K.Arunvivek, Properties of concrete containing waste foundry sand for partial replacement of fine aggregate in concrete, Indian Journal of Engineering & Material Sciences, Vol 24, April 2017, 162-166.
[3]. R.Deepak, V.Vandhana Devi, Experimental Investigation on concrete with construction demolition waste flyash aggregates, International Journal of Recent Innovation in Engineering & Research, 2018, 56-61.
[4]. P.G.Dolby, Production and properties of Lytag aggregate fully utilized for the North Sea, in: International symposium on Structural lightweight aggregate concrete. The Norwegian Concrete Association, Sandefjord-Norway, 1995, pp. 326-335.
[5]. C.Shi, Z.Wu, K.Lv, L.Wu, A review on mixture design methods for self-compacting concrete, Construction Building Materials, 84 (2015), 387-398.
[6]. S.Manu, P.Nadesan, P.Dinakar, Strcuctural concrete using sintered flyash lightweight aggregate: A review, Construction and Building Materials, 154 (2017), 928 - 944.
[7]. EurolightCon (1998) LWAC Material Properties State of the art. The European Union - BriteEuRam III. Document BE96-3942/R2.
[8]. G.J.L.Wegen, J.M.J.M.Bijen, Properties of concrete made with three types of artificial PFA coarse aggregates, International Journal of Cement Composites & Lightweight concrete, 7 (3) 1985, 159-167.
[9]. CEB, Functional classification of lightweight concrete, Recommendations LC2, second edition, RILEM, 1978.
[10]. B.K.Baradhan-Roy, Lightweight aggregate concrete in the UK, in I.Holand et al. (Ed) CEB/FIP International Symposium on Structural Lightweight aggregate concrete, Sandefijord, Norway, 1995, pp 52-69.
[11]. S.P.Zhang, L.Zong, Advance Material Science Engineering, 2014, 16-24.
[12]. Chooi Mei Mah, Takeshi Fujiwara, Chin SiongHo, Environmental impacts of construction and demolition waste management alternatives, Vol 63, 2018, 343-348.
[13]. IS 12269:1987 Indian Standard Specifications for Ordinary Portland Cement (53 grade), Bureau of Indian Standards, New Delhi.
[14]. IS 383:1970 Indian Standard Specifications for coarse and fine aggregates from natural sources for concrete, Bureau of Indian Standards, New Delhi.
[15]. IS 516:1959 Indian Standard Methods of tests for strength of concrete, Bureau of Indian Standards, New Delhi.