Experimental Study on Lightweight Aggregate Concrete

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Abstract

Lightweight concrete (LWC) has been successfully used since the ancient Roman times and it has gained its popularity due to its lower density and superior thermal insulation properties. Compared with normal weight concrete (NWC), LWC can significantly reduce the dead load of structural elements, which makes it especially attractive in multi-storey buildings. However, most studies on LWC concern "semi-lightweight "concretes, i.e. concrete made with lightweight coarse aggregate and natural sand to manufacture the "total-lightweight" concrete, more environmental and economical benefits can be achieved if waste materials can be used to replace the fine lightweight aggregate. With increasing concern over the excessive exploitation of natural aggregates, synthetic lightweight aggregate produced from environmental waste is a viable new source of structural aggregate material. The uses of structural grade lightweight concrete reduced considerably the self-load of a structure and permit larger pre-cast units to be handled. The mechanical properties of a structural grade lightweight aggregate made with fly ash and clay will bepresented.

It is well know that in general fly ash (FA) and silica fume (SF) increases the compressive strength, splitting tensile strength and flexural strength of concrete. In our study it was found that 10% replacement of fly ash and S.F. will increase the compressive strength, tensile and flexural strength. When FA & SF was increased to 20% the compressive strength, flexural splitting tensile will be decreased. However if the FA addition to the concrete is too high the pacts effect of FA weakens because of positive inference and the secondary hydration reaction is delayed.

The SF used in our test has high specific surface, high amorphous siO2 andsmallparticlesizeonlywithsuchchemicalandphysicalcharacteristics.

SF reacts with hydrates of cement and thus become a strong adhesive. It exerts a synergistic effort by promoting cement hydration and improving the uniformity in concrete. SF increases CSH gel hydrates which makes concrete stronger and more durable and adding of SF improves durability and strength ofconcrete.

Introduction

The effect of aggregate composition, the maximum particle size of light weight aggregate, mineral admixture and the volume percentage of sand on high strength semi light-weight concrete is investigated. The effects on compressive strength, splitting tensile strength, modulus of elasticity and dry apparent specific gravity are reported. Test results show that aggregate composition affects both physical and mechanical properties of semi-lightweight concrete. Reducing the maximum particle size of lightweight aggregate or introducing mineral admixture can improve its compressive strength and splitting tensile strength but these changes have negligible effect on its dry apparent specificgravity.

The Indian standard code (ISC) defines silica fume as "very fine non-crystalline silica produced in electric arc furnaces as a by-product of the production of elemental silicon or alloys containing silicon". The use of silica fume (SF) for production of high performance concretes is very common. Many extensive experiments were carried out by many researches around the world indicated that the usage of silica fume in concrete increases the concrete strengths, modulus of elasticity, chemical and abrasion resistance, in addition to enhancing durability, corrosion protection and mechanical properties. But there is not a clear, unique conclusion regarding the optimum silica fume replacement percentages, although some of the researchers have reported different replacement levels. No replacement materials were designed with a 28-days compressive strength of 50N/mm^2.

Most of normal weight aggregate of normal weight concrete is natural stone such as limestone and granite. With the increasing amount of concrete used, natural environment and resources are excessively exploited. Synthetic lightweight aggregate produced from environmental waste, like fly ash, is a viable new source of structural aggregate material. The use of light weight concrete permits greater design flexibility and substantial cost savings, reducing dead load, improved cyclic loading structural response, longer spans, better fire ratings, thinner sections, smaller size structural members, less reinforcing steel, and lower foundations costs. Weight of lightweight concrete is typically 25% to 35% lighter but its strengths is comparable to normal weight concrete. The conventional cement concrete is a heavy material having a density of 2400kg/m^{3,} and high thermal conductivity. The dead weight of the structure made up of this concrete is large compared to the imposed load to be carried, and a relatively small reduction in dead weight, particularly for members in flexure e.g., in high rise buildings, can save money and manpower in construction.

Based on a microstructure model predicted, a procedure for the diffusivity of high strength concrete by considering water-to-binder ratio, silica fume replacement ratio, and degree of hydration as major influencing factors. They concluded that diffusivity of concrete can be reduced by adding silica fume which makes the microstructure of concrete denser. The properties evaluated were development of compressive strength, secant modulus of elasticity, strain due to creep, shrinkage, swelling and moisture movement. Other researchers studied the effect of high temperature on the performance of lightweight concrete with silica fume in terms of compressive and splitting tensile strengths, weight loss and mechanical properties.

Fly ash, GGBS were used in the current study to replace ordinary Portland cement (OPC), natural sand (NS) and coarse aggregate (CA), respectively, and thereby to manufacture lightweight concrete (LWC). The improvement in thermal insulation is of great significance to the conservation of energy. The reduction in dead weight is normally achieved by cellular construction, by entraining large quantities of air, by using no-fines concrete and lightweight aggregates which are made lighter by introducing internal voids during the manufacturingprocess.

Lightweight aggregate is a relatively new material. For the same crushing strength, the density of concrete made with such an aggregate can be as much as 35 percent lower than the normal weight concrete. In addition to the reduced dead weight, the lower modulus of elasticity and adequate ductility of lightweight concrete may be advantageous in the seismic design of structures. Other inherent advantages of the material are its greater fire resistance, low thermal conductivity, low coefficient of thermal expansion, lower erection and transport costs for pre-fabricatedmembers.

Light-Weight Aggregates

Light-weight aggregates may be grouped in the following categories:

1. Naturally occurring materials which require further processing such as expanded-clay, shale and slate, vermiculiteetc.,
2. Industrialby-products,suchassinteredpulverizedfuelash(flyash)’foamedor expanded-blast-furnace slag, hemaliteand
3. Naturally occurring materials, such as pumice, foamed lava, volcanic tuff and porouslimestone.

Light-Weight Concrete

Structural lightweight concrete has an in-place density (unit weight) on the order of 90 to 115 lb/ ft3 (1440 to 1840 kg/m3) compared to normal weight concrete with a density in the range of 140 to 150 lb/ ft3 (2240 to 2400 kg/m3). For structural applications the concrete strength should be greater than 2500 psi (17.0 MPa). The concrete mixture is made with a lightweight coarse aggregate. In some cases a portion or the entire fine aggregate may be a lightweight product. Lightweight aggregates used in structural lightweight concrete are typically expanded shale, clay or slate, pumice materials that have been fired in a rotary kiln to develop a porous structure. Other products such as air-cooled blast furnace slag, hemalite are also used. There are other classes of non-structural lightweight concretes with lower density made with other aggregate materials and higher air voids in the cement paste matrix, such as in cellular concrete. These are typically used for their insulation properties. The above properties focuses on structural lightweightconcrete.

Experimental Investigation
Out Line of Experimental Program
The experimental Investigation consists of casting & Testing of series A,B,C,D,E.

- The first series consists of casting & Testing of Cubes, cylinders & prisms with Mix proportion 1 : 1.425 : 3.10 with M20 grade of concrete in the following:

A1 C + F.A + C.A;
A2 C + [H + S] + C.A;
A3 C + [H + S] +C.A
A4 C + [S + 0.3 H] + 0.7 C.A;
A5 C + [S + 0.4 H] + 0.6C.A

Where in A2, Sand is 70% &Hemalite is 30% , A3 ,Sand is 60% &Hemalite is 40% A4 & A5 are casted & tested by increasing Volume percentage of sand by 30% ,40% & decreasing the C.A to the same volume percentage of sand by weight.

The second series consists of casting & testing of cubes, prisms & cylinders of same mix proportion but replacing 100% cement with 10% fly ash & 5% silica flume.

The Order Of Casting
B1 = [C + 10% fly ash + 5% Silica flume] + F.A + C.A
B2 = [C + 10% fly ash + 5% Silica flume] + (Sand + Hemalite) +C.A
B3 = [C + 10% fly ash + 5% Silica flume] + (Sand + Hemalite) + C.A
B4 = [C + 10% fly ash + 5% Silica flume] + (Sand + Hemalite) +C.A
B5 = [C + 10% fly ash + 5% Silica flume] +(Sand + Hemalite)+ 0.6 +C.A

Where in B2, B3 the sand &Hemalite percentage is 70% & 30% , 60% & 40%. B4 & B5 are casted based on increasing volume percentage of sand method by 30% & 40% & decreasing the C.A to the same volume percentage of sand byweight.

- The third series of casting & testing of cubes, prisms & cylinders with the same mix proportion but replacing cement by 20% Fly Ash & 5% Silica fume.
- The fourth series of casting & testing of cubes, cylinders, prisms of same mix proportion but replacing cement by 10% GGBS & 5%SF.
- The fifth series consists of testing & casting of cubes, prisms & Cylinders of same proportion replacing the cement by 20% GGBS & 5%SF.

The dimensions and details were shown in fig 1.0
The sizes of cubes are 150mm X 150mm X 150mm

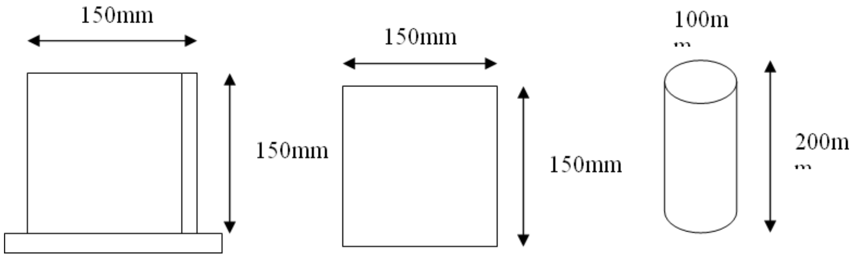

Figure 1.0: Cross sectional details of cubes and cylinder.

Mix Design

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible.

Objects

The main objects of concrete mix design are:

1. To achieve the stipulated minimum strength anddurability
2. To make the concrete in the most economicalmanner

Design of concrete mix requires complete knowledge of the various properties of the constituent materials, the implication in case of change on these conditions at the site, the impact of properties of plastic concrete on the hardened concrete and complicated inter-relationship between the variables.

For low and medium strength concrete, the strength is mainly influenced by the water cement ratio, and is almost independent of the other parameters. The properties of high strength concretes with a compressive strength above 26.66 Mpa, are influenced by the properties of aggregate and aggregate cement ratio in addition to that of the water cement ratio.In this paper Entroy and Shack lock's method are adopted which is an easy and accurate method for high strength concrete mixes. For purpose of design, Entroy and Shack lock have suggested empirical graphs relating compressive strength to an arbitrary "Reference number" for concretes made with crushed granite coarse aggregate and irregulargravel.

Test Results and Discusions

It is well know that in general fly ash silica fume increases the compressive strength, splitting tensile strength and flexural strength of concrete. In our study it was found that 10% replacement of fly ash and S.F. will increase the compressive strength, tensile and flexural strength. When FA & SF was increased to 20% the compressive strength, flexural splitting tensile will be decreased.

The FA in concrete reacts with CH to increase the CSH gel hydrates and density of hardened cement paste. Thus, the strength and modulus of elasticity of theconcrete are higher than those of the reference sample without the fly ash. However if the FA addition to the concrete is too high the pacts effect of FA weakens because of positive inference and the secondary hydration reaction is delayed. They result in weaving of mechanical properties of concrete. The SF used in our test has high specific surface, high amorphous siO2 and small particle size only with such chemical and physical characteristics. SF reacts with hydrates of cement and thus become a strong adhesive. It exerts a synergistic effort by promoting cement hydration and improving the uniformity in concrete. SF increases CSH gel hydrates which makes concrete stronger and more durable and adding of SF improves durability and strength of concrete. The compressive strength result of concrete with Hematite aggregate is slightly less than that of normal concrete with normal aggregate sand.

In 1st phase

In the first set of casting of the control mix when only FA is released at 30% and 40% of Hematite the values of about 80% and 78% compared to the control mix. While increase volume sand method the compressive strength values are about 75% and 73% compared to the control mix. Here we have not used any admixtures and the weight of control mix cubes and weight of cubes with light weight aggregate are compared with the L.W.A. cubes, cylinder, prisms are reduced by 11% compared to the controlmix.

Here the strength is decreasing with the increase in percentage of Hemalite and in the Volume increasing of sand. When they are compared with nominal mix. As show in Table1.0 and fig 1.0

Table 1.0: Compressive strength result of concrete with Hematite aggregate FA is released at 30% and 40% of Hematite the values of about 80% and 78% compared to the control mix.

Control Mix	Compressive Strength N/mm^2
C + S + CA	27.11
C + (H+S) + CA	21.33
C + (H+S) + CA	20.88
C + (S + 0.3) + 0.7 CA	20.44
C + (S+0.4) + 0.60 CA	19.56

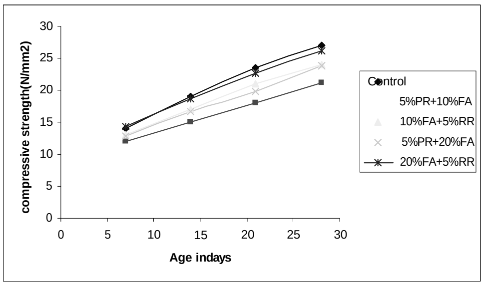

Figure 1.0: Compressive strength concrete.

In 2ND phase

In this case we have replaced cement by 10% FA & 5% SF and the value of control mix cube is increased by 10% more than control mix used and then the values for the replacement of the sand is 83% for 30% Hemalite and 79% for 40% Hemalite and incase of increase of sand by volume the values are 75% for 30% increase in sand and 70% for 40% increase in sand. By adding 10% FA and 5% SF the strength reaching the specified characteristics strength for the mix. As show in table 2 and fig 2

Table 2.0: Strength result of concrete with Hematite aggregate By adding 10% FA and 5% SF the strength reaching the specified characteristics strength for the mix.

Mix	Compressive Strength N/mm^2
C + 10% FA + 5% SF + FA + CA	30.2
C + 10% FA + 5% SF + (H+S) + CA	25.02
C + 10% FA + 5% SF + (H+S) + CA	23.84
C + 10% FA + 5% SF + (S + 0.3) + 0.7 CA	22.92
C + 10% FA + 5% SF + (S + 0.4) + 0.6 CA	21.24

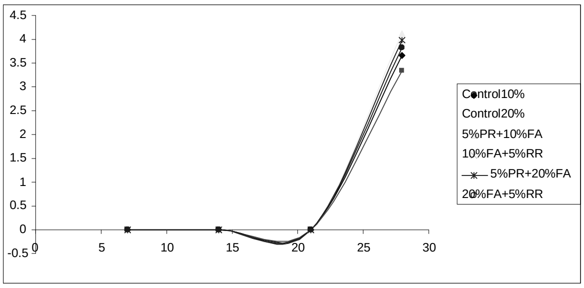

Figure 2.0: Tensile Strength of Concrete.

In 3rd phase

In this case we have replaced cement by 20% FA & 5% SF and then the values for the replacement of the sand is 93% for 30% Hemalite and 85% for 40% Hemalite and incase of increase of sand by volume the values are 79.1% for 30% increase in sand and 77% for 40% increase in sand. table 3 and fig 3

Table 3.0: replaced cement by 20% FA & 5% SF and then the values for the replacement of the sand is 93% for 30% Hemalite.

Mix	Compressive StrengthN/mm^2
C + 20% FA + 5% SF + FA + CA	28.9
C + 20% FA + 5% SF + (H+S) + CA	26.89
C + 20% FA + 5% SF + (H+S) + CA	24.7
C + 20% FA + 5% SF + (S + 0.3) + 0.7 CA	23.2
C + 20% FA + 5% SF + (S + 0.4) + 0.6 CA	22.2

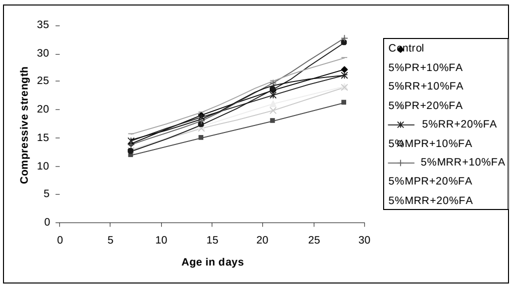

Figure 3.0: Comparison of Untreated and Treated Rubber Compressive Strength.

In 4th phase

In this case we have replaced cement by 10% GGBS(slag) & 5% SF and then the values for the replacement of the sand is 90.7% for 30% Hemalite and 84% for 40% Hemalite and incase of increase of sand by volume the values are 78% for 30% increase in sand and 76% for 40% increase in sand. From in table 4 and fig 4

Table 4.0: Replaced cement by 10% GGBS (slag) & 5% SF and then the values for the replacement of the sand is 90.7% for 30% Hemalite and 84% for 40%.

Mix	Compressive Strength N/mm^2
C + 10%GGBS + 5% SF + FA + CA	32.24
C + 10%GGBS+ 5% SF + (H+S) + CA	29.24
C + 10%GGBS + 5% SF + (H+S) + CA	27.04
C + 10%GGBS + 5% SF + (S + 0.3) + 0.7 CA	25.2
C + 10%GGBS + 5% SF + (S + 0.4) + 0.6 CA	24.6

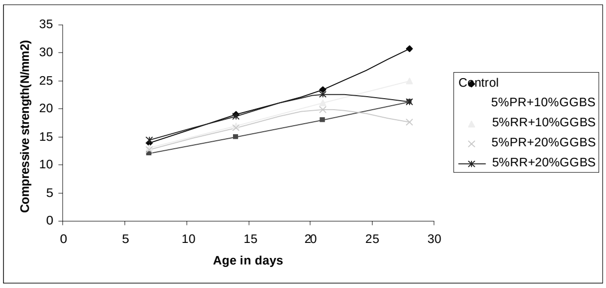

Figure 4.0: Compressive strength of GGBS (Slag).

In 5th phase

In this case we have replaced cement by 20% GGBS & 5% SF and then the values for the replacement of the sand is 91.7% for 30% Hemalite and 87.6% for 40% Hemalite and incase of increase of sand by volume the values are 81.9% for 30% increase in sand and 74% for 40% increase in sand. Table 5 and fig 5

Table 5.0: Replaced cement by 20% GGBS & 5% SF and then the values for the replacement of the sand is 91.7% for 30% Hemalite and 87.6% for 40%.

Mix	Compressive Strength N/mm^2
C + 20%GGBS + 5% SF + FA + CA	29.89
C + 20%GGBS+ 5% SF + (H+S) + CA	27.24
C + 20%GGBS + 5% SF + (H+S) + CA	26.04
C + 20%GGBS + 5% SF + (S + 0.3) + 0.7 CA	24.2
C + 20%GGBS + 5% SF + (S + 0.4) + 0.6 CA	22.06

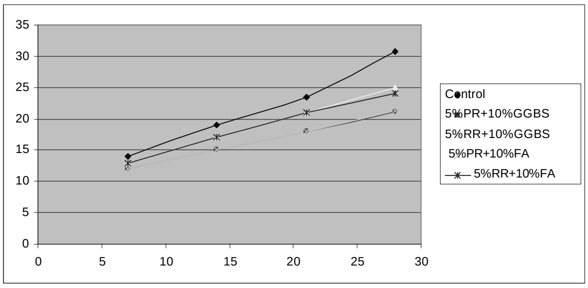

Figure 5.0: Comparison with 10% Fly ash and GGBS.

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