STUDY ON MECHANICAL PROPERTIES OF FIBER REINFORCED HIGH STRENGTH LIGHTWEIGHT CONCRETE

A.Vasudev
M.Tech Student, Department of Civil Engineering, GPREC
Sri.V.K.VISWESWARA RAO
Assistant Professor, Department of Civil Engineering, GPREC,

ABSTRACT:-Lightweight aggregate concretes can be used in structural applications, with strengths equivalent to normal weight concrete. The main benefit in using this lightweight concrete is, it helps in reduction of self-weight or dead loads of a structure. The present study is to achieve high strength lightweight concrete by using lightweight expanded cay aggregate (LECA). In this study LECA is used in concrete as both coarse and fine aggregate and also in combinations with normal weight aggregates. Density of concrete is the main criteria in designating the type of concrete. The density of lightweight concrete is to be in range of 1120 $^{kg}/_{m^3}$ and 1910 $^{kg}/_{m^3}$. Three mixes i.e, all lightweight aggregates and combination of lightweight aggregate with normal weight aggregates are prepared. Additional mixes are prepared by replacing 10% silica fume with cement and 2% steel fibers to weight of cement to the above three mixes. Mechanical properties are evaluated to the mixes. The maximum compressive strength of 68 Mpa is achieved to the mix containing the combination of lightweight fine aggregate(LWFA) and normal weight coarse aggregate (NWCA) in the addition of 10% silica fume and 2% steel fibers at 28 days.

***KEYWORDS:-*Lightweight aggregate , High strength, LECA, Silica fume, Steel fibers**

1. INTRODUCTION:

The aggregates in concrete play a phenomenal role as far as concrete properties are considered. Aggregate is a very important ingredient in concrete; the aggregates used are the most mined materials in the world. Its excess use in concrete will trigger ecological and environmental disturbance. The attention about exhaustion of natural resources and the effect on atmosphere has predominantly focused and considered on the use of synthetically produced aggregates as a substitute to naturally occurring resources. This practice can provide solution towards waste management and preservation of natural resources up to large extent. In early 1950 's the use of concrete blocks was accepted in UK for load bearing of inner side of cavity walls. Soon thereafter the development and production of artificial LWA made it possible to produce LWC with high strengths,which is suitable for structural work. Commonly available synthetically produced lightweight aggregates (LWA) which are suitable for structural applications are: expanded clay/shale/slate aggregates,blast furnace slag aggregate, sintered fly ash aggregate Lightweight expanded clay aggregates (LECA) or expanded clay is made by heating clay to around $1,200^0$c in rotary kiln. The yielding gases expand the clay by thousands of small bubbles forming during heating producing a honeycomb structure. LECA is approximately in round shape or oval shape due to circular movement of rotary kiln. It is available in different sizes and densities. In Many researches Leca is used as self curing agent because of its nature.From structural point of view, lightweight aggregate concrete (LWAC)mixtures have an advantage of being light with improved thermal and sound insulation properties. As per ACI committee report, the structural lightweight aggregate concrete having a minimum 28 days and compressive strength of 17 Mpa and equivalent density of 1120-1920 $^{kg}/_{m^3}$.Lightweight concrete has been successfully used for marine applications and in shipbuilding. In 1984, Thomas A. Holm estimated that there were over 400 LWC bridges throughout the world. The expanded clay and slate institute proves that the most of the bridges are in good condition. According to ACI material journal by Marcia, Andrian Loani, Mihai fillip, Ian Pepenar(1994), it was found that in Japan LWC has been used since 1964 as in construction of railway platforms.

The recent trend in the concrete technology towards high performance concrete or low water/solid binder mass ratio concrete encountered some problems. One of the major problem with such mixture is its increased tendency to undergo early-age cracking. while this cracking may or may not effect the compressive strengths of these concrete, it likely to effect the long term durability. To avoid these problems researches are incorporating self curing agents in concrete. Concrete incorporating self-curing will represent a new trend in concrete construction in this new decade. Due to the increased use of high performance concrete , several techniques are used for incorporation of internal curing water in concrete. Several researches have proposed the use of saturated lightweight aggregates to provide internal curing of concrete. Murat Emre Dilli et al.(2015) concluded that due Leca having a very high water absorption its provides better internal curing compared to the conventional mix at low water cement ratios. J.Alexandre Bogas et al.(2014) studied on the influence of mineral additions on the shrinkage of structural expanded clay lightweight concrete and concluded that the shrinkage of LWC depends on how the volume of LWA varies, keeping the same volume of paste and increasing the volume aggregate, and also the shrinkage of LWAC can either be decreased or be about the same, which depends on the type of LWA and its water content. Deividas Rumsys et al.(2017) studied the properties of lightweight concrete with recycled polyethylene and expanded clay aggregate. They conclude that concrete mix having a density of 1950 to 2050 $^{kg}/_{m^3}$ with plastic waste aggregates has 28 days compressive strength higher than 40 Mpa and using pre-wetted expanded clay aggregate with same cement mortar resulted in the density of 1900$^{kg}/_{m^3}$ with compressive strength upto 70.2 Mpa. it was also that using silica fume as micro fillers in concrete gives higher compressive strength and lower water absorption when compared to ground quartz microfiller. Thiago melo Grabois et al.(2016) stated that concretes containing coarse and fine lightweight aggregates shows higher drying shrinkage than those concretes having only coarse lightweight aggregates.

In recent times to improve the mechanical properties and to achieve high strengths steel fibers are used in concrete which is attractive material in application of construction. These steel fibres are available different types and sizes of steel fibres which are required. Certain limits for selecting the proportion of steel fibres are proposed by researches for adding steel fibres which depend on the type and size of those fibres. Jisun Choi et al.(2014) studied the influence of fibres on strength and toughness of all lightweight aggregates. They concluded that the shear strengths of both lightweight and normal weight concretes were improved by adding steel fibres steel fibres were the most effective in increasing the toughness of both all-lightweight concrete and normal concrete. H.T.Wang et al.(2013) studied the mechanical properties of fiber reinforced lightweight concrete. The results show that the compressive strength high strength lightweight concrete slightly improves with addition of steel fibres but split tensile and flexural strengths were improved significantly. These were attributed by the effect of steel fibre arresting the cracks. Till now many researchers have mainly studied on all-lightweight aggregate concrete and effect of steel fibre proportions in addition to it. In this paper, it is aimed to achieve high strength lightweight concrete by considering all lightweight aggregates and also combinations of lightweight with normal aggregates with addition of silica fume and steel fibres which are to be in lightweight density range. The mechanical properties of all lightweight aggregates and combination of lightweight aggregates with normal aggregates with silica fume and steel fibres are studied and discussed.

2. MATERIALS AND EXPERIMENTAL PROCEDURE:

2.1 MATERIALS

2.1.1. CEMENT:

In this work we use Ordinary Portland Cement of 53 grade of Ultra Tech brand whose properties are explained in the below table.

Table 1: Physical properties of Cement

Properties	Results
Specific gravity	3.13
Initial setting time	51 min
Final setting time	260 min
Standard consistency	33.96%

2.1.2. AGGREGATES:

In this paper four types of aggregates are used. They are

- Expanded clay(LECA) 4-8mm
- Crushed expanded clay (LECA) 0-4 mm
- Locally available coarse aggregate of size 10 mm
- Locally available river sand of size 4.75mm

Table 2: Physical properties of Coarse aggregate

Test	Result	
	Locally available coarse aggregate	For expanded clay aggregate(LECA)
Bulk density	1536 Kg/m^3	612.33 Kg/m^3
Specific gravity	2.808	1.36
Crushing value	13.83%	2.26
Impact test	11.29%	-
Elongation index	20.34%	-
Flakiness index	16.95%	-
Water absorption	-	18 %

2.1.3. ADMIXTURE (GLENIUM B-233)

Super plasticizer is one of the important components used in this high strength concretes for reduction of water. In this present paper poly carboxylic ether based super plasticizer i.e. Glenium B-233 is been used whose physical properties are explained as followed.

Table 3: Physical properties of super plasticizer

Properties	Results
Appearance	Light brown colored liquid
Specific gravity	1.09
Ph	6.9
Type	Poly-carboxylic ether based

2.2. EXPERIMENTAL PROCEDURE

2.2.1. MIX PROPORTION AND PREPARATION OF THE SPECIMEN:

The mix design is prepared as per code ACI 221.2-98 “Standard practice for selecting proportions for Structural Lightweight Concrete”. In this different designs are proposed for different mixtures like all-lightweight aggregate concrete and also combinations of lightweight aggregate with normal weight aggregates. The material constituents which are considered for mix are cement, Expanded clay(4-8mm), crushed expanded clay (0-4mm),locally available fine and coarse aggregate, water, super plasticizer, silica fume and steel fibres. First the proportion of expanded clay which is required for the mix is pre-soaked in water for 24hrs before the mix is to be prepared. The LWA should be in saturated state which prevents the aggregate in absorbing the mixing water. If the LWA is not in saturated state while mix is prepared the aggregate absorbs the mixing water because of its high water absorption capacity this causes insufficient or improper mix and which delays in the formation of C-S-H gel. Due to this the strength of the specimen gets reduced and target strength cannot be achieved. As we are proposing high strength concrete, super plasticizers are used in this which helps in decreasing the water content up to 20% without decrease in workability. Specimens are prepared for different mixes and they are air cured for 24 hrs then water cured for 28 days. After curing period the specimens are removed from water and they are to be tested in dry state.

Table 4:mix proportions of concrete mixes

Mix	Cement	LWCA	LWFA	N.WF.A	N.W.C.A	Super plasticizer	water	w/c	Silica fume	Steel fibres
Mix-1	765.33	248.51	406.71	-	-	7.653	112.58	0.14	-	-
Mix-2	688.79	248.51	406.71	-	-	7.653	112.58	0.14	76.53	15.30
Mix-3	717.86	329.23	-	736.52	-	7.17	136.74	0.19	-	-
Mix-4	646.07	329.23	-	736.52	-	7.17	136.74	0.19	71.78	14.35
Mix-5	717.86	-	443.82	-	549.49	7.17	114.61	0.16	-	-
Mix-6	646.07	-	443.82	-	549.49	7.17	114.61	0.16	71.78	14.35

2.2.2. METHODOLOGY:

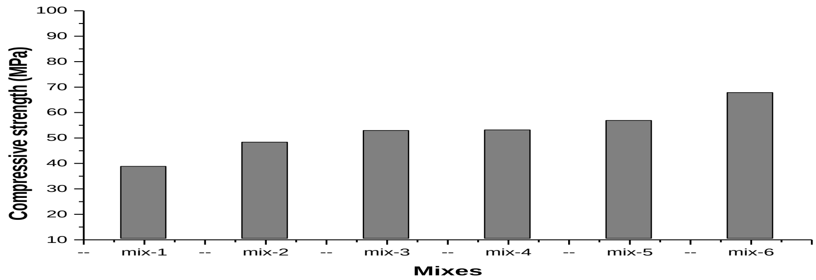
2.2.2.1. COMPRESSIVE STRENGTH: Assessment of compressive strength is one of the method to recognize the mechanical characteristic of concrete. To carry out this test a 100X100X100 mm specimen is casted and cured for a period not less than 28 days.

2.2.2.2. SPLIT TENSILE STRENGTH: It is a test which is used to determine the tensile strength of the concrete by using a cylindrical specimen of 100X150 mm size which is casted and cured for 28 days.

2.2.2.3. FLEXURAL STRENGTH: It is a test which iu used to determine the flexural strength of concrete by using a beam specimen of 100X100X500 mm size which is casted and cured for 28 days.

3. RESULTS AND DISCUSSIONS:

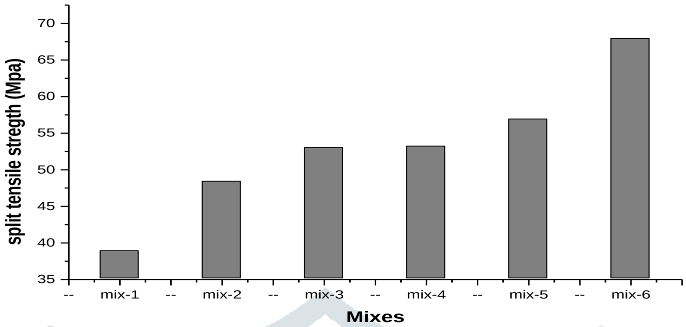
3.1. COMPRESSIVE STRENGTH: After proper 28 days of curing, one of the mechanical property i.e., compressive strength of specimens which are prepared by all-lightweight and combination of lightweight aggregate with normal aggregates and to these 10 % silica fume and 2% steel fibres are added. Then the compressive strength is calculated for all this mixes. The detail test results of the various mixes are explained in the table-5 plotted below.



From the above graph, mix prepared with the combination of LWF.A and NWC.A with addition of 2% steel fibers and 10 % silica fume showed the highest compressive strength of 68Mpa. And mix with All lightweight aggregates without addition of any admixture or fibre shows the lowest value of 39Mpa.

SPLIT TENSILE STRENGTH TEST:

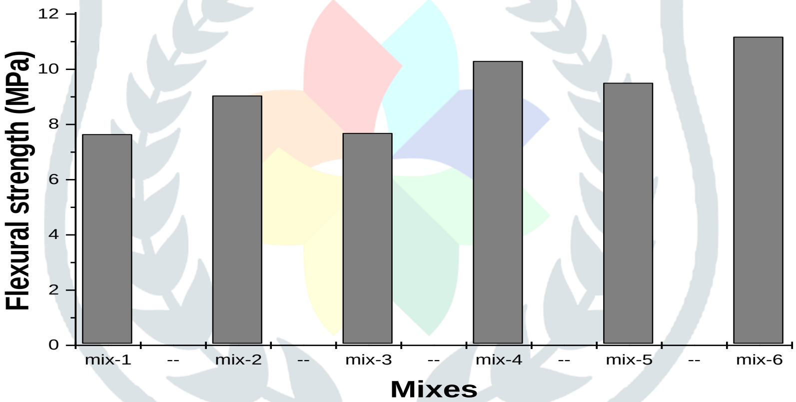
The mixes M-1,M-3,M-5, showed the lower split tensile strength values when compared to M-2,M-4,M-6 respectively. This is because in the mixes M-2,M-4,M-6 2% steel fibres are added to the weight of cement. The values are plotted in table-5:



For the above graph mix M-3 which contains combination LWCA and NWFA shows the lowest split tensile strength value of 2.22Mpa when compared to other mix values. And mix M-6 shows the highest split tensile value of 5.41Mpa which contains combination of LWFA and NWCA with the addition of 10% silica fume and 2% steel fibres to the weight of cement.

FLEXURAL STRENGTH:

The mixes M-1,M-3 showed the lowest flexural strength values when compared to other mix values. The mixes M-2,M-4,M-6 showed the maximum values. This is because it contains steel fibres. The values are plotted in the below table-5



the above graph, it shows that mixes M-1, M-3 has the lowest flexural strength value of 7.65 and 7.69 Mpa respectively. And M-6 which shows the highest Flexural value of 11.18 Mpa as it contains 2% steel fibres.

Table 5: Variation of mechanical properties for different mixtures

Mix	Proportions	Compressive strength (Mpa) at 28 days	Split tensile strength(Mpa) at 28 days	Flexural strength(Mpa) at 28 days
mix-1	All LWA	39	3.18	7.65
mix-2	All LWA +10%silica fume+2% steel fibres	48.5	4.45	9.05
mix-3	LWC.A+NWF.A	53.1	2.29	7.69
mix-4	LWC.A+NWF.A+10%silica fume+2% steel fibres	53.3	3.50	10.30
mix-5	LWC.A+NWF.A	57	4.61	9.51
mix-6	LWC.A+NWF.A+10%silica fume+2% steel fibres	68	5.41	11.18

CONCLUSIONS:

In the present study, high strength light weight concrete is achieved. from this study following conclusions are observed :

1. The maximum strength values for all mechanical properties are achieved for the mix M-6 which contains combination of LWFA and NWCA in addition with 10% silica fume and 2% steel fibres to the weight of cement.
2. The maximum percentage change in compressive strength values are observed between mixes M-1 and M-2 with 19.5 % by addition of steel fibres and silica fume admixture.
3. The maximum percentage change in strength values of split tensile and flexural strengths are observed between the mixes M-3 and M-4 with 34% and 25% respectively. This is because of addition of steel fibres and silica fume admixture.

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