Light weight characteristics of self compacting concrete using aluminium powder and fine pumice powder

Revathy.S[1], Josina Thomas[2],

[1] *MTech,Structural Engg and Construction Management Department of Civil Engineering,Indira Gandhi Institute of Engg and Technology,Kothamangalam,Kerala,India*
[2] *Assistant Professor, Department of Civil Engineering,Indira Gandhi Institute of Engg and Technology Kothamangalam,Kerala,India*

---***---

Abstract - *Combining the advantages of LWC and SCC is a new field of research.Considering its light weight of structure and ease of placement,Light-weight self-compacting concrete (LWSCC) may be the answer to the increasing construction requirements of slender and more heavily reinforced structural elements. This paper discusses the characteristics of three types of LWSCC,which are produced using fine pumice stone powder in one mix ,aluminium powder in second mix and for third mix complaining both pumice powder and aluminium powder. Lightweight aggregate SCC properties have been evaluated in terms of flowability, segregation resistance and filling capacity of fresh concrete as per the standards. The measurement of the mechanical properties of hardened lightweight aggregate SCC, including compressive strength, splitting tensile strength, and density, as well as its specific strength were also carried out. Results showed that Pumice stone powder met the requirements for structural applications.*

KeyWords **: Lightweight self compacting concrete,pumice stone powder, aluminium powder, flowability, passing ability, segregation resistance, compressive strength.**

1.INTRODUCTION

Concrete is the world's most widely used construction material owing to its excellent versatility, availability and economy. Despite all advantages associated with the use of concrete in civil engineering infrastructures, its use is sometimes limited in some structures because of its high self weight compared to other construction materials. Moreover, in recent years the construction sector has experienced a shortage in skilled workers as a result of an aging workforce and the difficulty to attract a new generation of skilled workers. Therefore, over the last few decades there has been a tremendous interest to develop new high performance materials that require less skilled workers to be placed/used. In this regard, the development of new types of high performance concretes, such as self-consolidating concrete (SCC) and lightweight concrete (LWC) responds to some of the urgent needs of the construction sector . The development of SCC has been perceived by many specialists as a giant step towards achieving high performance cement-based materials . It offers also limitless advantages in terms of durability, cost efficiency, and job site productivity. On the other hand, lightweight concrete can decrease the self weight of structures which can result in reduced members' sections and simplify construction. Therefore, lightweight concrete can save overall construction costs. Conventionally, lightweight aggregate concrete is mixed and produced in a similar manner as conventional concrete. This manufacturing method is usually associated with segregation problems in the mixture due to the low density of the aggregate used. In contrast, with a reduced aggregate content, self-consolidating concrete can be manufactured with a large volume of powders. This usually results in a concrete having an enhanced viscosity at the fresh stage and higher compressive strength at it hardens. Self-compacting concrete (SCC) is considered as a concrete which can be placed and compacted under its self-weight with little or no vibration effort and which is at the same time cohesive enough to be handled without segregation or bleeding . SCC was originally developed at the University of Tokyo, Japan in 1986 by Prof. Okamura and his team to improve the quality of construction and to overcome the problems of defective workmanship . It is used to facilitate and ensure the proper filling and good structural performance of the restricted areas and heavily reinforced structural members. SCC can also provide a better working environment by eliminating the vibration noise . Self-compacting lightweight aggregate concrete (SCLC) is a kind of high-performance concrete developed from self-compacting concrete (SCC). SCLC combines the favourable properties of lightweight aggregate concrete (LWAC) and SCC, needs no external vibration, and can spread into place, fill the formwork and encapsulate reinforcement without any bleeding or segregation . On the other hand, the use of chemical admixtures is always necessary when producing SCC in order to increase the workability and reduce the segregation. The content of coarse aggregate and water to binder ratio in SCC are lower than those of normal concrete. Therefore, SCC contains large amounts of fine particles such as, blast-furnace slag, fly ash and lime powder in order to avoid gravity segregation of larger particles in the fresh mix. The wide variety of the lightweight aggregate source result in distinguishing behaviour among the SCLCs. Thus, properties of SCLCs have to be examined individually .

1.1 MATERIALS AND MIXES

A. Ordinary Portland Cement

The cement used for the entire experiment is Ordinary Portland cement of 53 grade conforming to IS 12269. The cement was tested for fineness and specific gravity. Specific gravity of the cement obtained as per the test was 3.15. The cement used is fresh and without any lumps. It is the basic ingredient of concrete, mortar and plaster.

B. Fine Aggregates

They are aggregate most of which passes 4.75mm IS Sieve. M Sand is used as the fine aggregate. Sieve analysis is carried out and as per sieve analysis it comes under Zone-II. The limits for each zone as per IS: 383 – 1970.

C. Coarse Aggregates

Aggregate most of which is retained on 4.75mm IS Sieve and containing only so much finer material as is permitted for the various types described in this standard. As per IS: 10262 – 1982 clause 3.6 explaining the combination of different coarse aggregate fractions two different sizes, 20mm and 12.5mm size coarse aggregates were used which results in an overall grading conforming to Table 2 of IS: 383 - 1970.

D. Chemical Admixture (Super Plasticizer)

Super plasticizer (normal) 4% by the weight of cement is used in the concrete for improving the workability condition of the concrete.

E. Pumice stone powder

Pumice is a natural material of volcanic origin produced by the release of gases during the solidification of lava, and it has been used as the aggregate in the production of lightweight concrete in many countries around the world. So far, the use of pumice was dependent on the availability and limited to the countries where it is locally available or easily imported.The use of pumice as aggregate or mineral additive in the production of self-compacting concrete may be a good approach for the production of lightweight, easy workable, economic and environmentalist concrete.

F. Aluminium Powder

The aluminium powder reacts with the cement and forms hydrogen bubbles to form within the mix, thereby increasing the volume-to-weight ratio of the concrete mix. After the mix is cast into the desired form and the volume-increasing chemical reactions occur, the concrete mix,which is still soft, is autoclaved. The use of aluminium powder caused the expansion of concrete which led to irregular shapes and dimensions. The expanded layers were cut to form the required shape and size. The compressive and tensile strengths of lightweight concrete (LWC) of density 1700 kg/m3 to 1800 kg/m3 with different aluminium powder content were investigated using cube specimens.

fig. 1. Pumice powder

Fig.2. Aluminium Powder

2. MIX DESIGN OF SCC

Regarding concrete mix design, the standard mixture proportion of SCC was determined through preliminary experimentation. SCC should satisfy flowability, segregation resistance ability, filling ability, and so on in its fresh state. Accordingly, in this research The European Guidelines for Self Compacting Concrete , was applied to the capability of SCC in the fresh state.The standard of The European Guidelines for Self Compacting Concrete is as Table 4.5. Immediately after mixing of the concrete, the deformability and flowability of fresh SCC was evaluated using the following tests: slump-flow (mm), time required to reach 500 mm of slump-flow (s), time required to flow through the V-funnel (s) and filling height of the U-Box (mm) and L Box (mm). All SCC specimens were cast without hand compaction or mechanical vibration.After casting, all the specimens were covered with plastic sheets and water saturated burlap, and left at room temperature for 24 hours. They were then demolded and transferred to the moist curing room maintained at 23 ± 2 ˚C and 100% relative humidity until testing. The compressive strength, of concrete were determined. The compressive strength was measured for 7, and 28 days. The average compressive strength of three cylinders was considered for each age.

3.MIX SELECTION

The grade of concrete adopted for investigation is M30 with Water cement ratio 0.43 and chemical admixture used is MasterGlenium ACE 30IT.

4.RESULTS AND DISCUSSIONS

Fresh Stage Properties

a) Slump-Flow Value

Describes the flowability of a fresh mix in unconfined conditions. It is a sensitive test that will normally be specified for all SCC, as the primary check that the fresh concrete consistence meets the specification. Visual observations during additional information on the segregation resistance and uniformity of each delivery. The following are typical slump-flow classes for a range of applications the test and/or measurement of the T_{500} time can give: SF1 (550 - 650 mm) is appropriate for unreinforced or slightly reinforced concrete structures that are cast from the top with free displacement from the delivery point (e.g. housing slabs) formwork. SF3 will often give better surface finish than SF 2 for normal vertical applications but segregation resistance is more difficult to control.Target values higher than 850 mm may be specified in some special cases but great care should be taken regarding segregation and the maximum size of aggregate should normally be lower than 12 mm.

b) The Density Test

It were conducted on concrete blocks made with pumice powder at varying percentages of 0, 5, 10, 15, 20,and 25 volume.

c) Passing Ability

It describes the capacity of the fresh mix to flow through confined spaces and narrow openings such as areas of congested reinforcement without segregation, loss of uniformity or causing blocking. In defining the passing ability, it is necessary to consider the geometry and density of the reinforcement, the flowability/filling ability and the maximum aggregate size. The defining dimension is the smallest gap (confinement gap) through which SCC has to continuously flow to fill the formwork.

d) Segregation Resistance

It is fundamental for SCC in-situ homogeneity and quality. SCC can suffer from segregation during placing and also after placing but before stiffening. Segregation which occurs after placing will be most detrimental in tall elements but even in thin slabs, it can lead to surface defects such as cracking or a weak surface.

To determine the fluidity and workability properties of SCC, V-funnel tests were performed to gather information about flowing ability and viscosity with flow diameter and time of fresh concrete. Besides, the L-box and U-box tests were performed to determine the passing ability from narrow sections of fresh concrete. These fresh concrete tests were conducted according to The standard of The European

Table -2: The results of fresh concret experiment for Group I mixture.

Mixture		CM1	CM2	CM3	PM1	PM2	PM3	PM4	PM5
Flow diameter	mm	703	723	720	640	690	708	720	700
V-funnel flow time	Sec	12	10	8.8	16	20	17	14	17
V-funnel time delayed 5 min	Sec	15	16	14	21	24	20	19	23
L-box ratio	h_2/h_1	0.76	0.81	0.83	0.72	0.77	0.82	0.79	0.76
U-box value	h_2-h_1	10	8	6	13	16	15	20	15

Guidelines for Self Compacting Concrete , prepared by the European Working Group on Self-Compacting Concrete. Furthermore, to produce proper selfcompacting mixes, several preliminary trials on self-compacting pumice concrete were carried out. For each mixture, the flow diameter, time to flow a diameter of 50 cm (T50 time), flow diameter after one hour, V-funnel flow time, V-funnel times delayed 5 min, L-box ratio, air temperature and the unit weight of fresh concrete were measured. The details of the fresh concrete tests for SCC were given elsewhere.The V-funnel flow test is performed to evaluate the fluidity of SCLC and the ability for SCLC to change its path and to pass through a constricted area.

Table -3: The results of fresh concrete experiments for Group II mixture

Mixture		AM1	AM2	AM3	AM4
Flow diameter	mm	650	670	700	719
V-funnel flow time	Sec	21	14	12	11
V-funnel time delayed 5min	Sec	14	16	20	20
L-box ratio	h_2/h_1	0.7	0.81	0.88	0.9
U-box value	h_2-h_1	12	15	20	26

For this test, the V-funnel apparatus is shown in Fig. 3, the total time for SCLC to flow through the V-funnel was measured.

According to The standard of The European Guidelines for Self Compacting Concrete ,class 1 SCC Tv is smaller than 8 s and class 2 SCC Tv is 9–25 s . According to the result from table 1 the flow diameters of concrete containing pumice powder and not containing pumice powder were measured as 660–720 mm and 700–770 mm respectively. For all mixtures, as w/(c + m) rate increases, flow diameter also increases because of shear stress and viscosity of concrete decreased. The results show that as density of SCLC increases, its workability increases, too. This is a prospective result since the spread and placement properties of SCC are provided by its weight. Due to increasing weight of the mix, the spreading capability will be enhanced at the fresh stage.The V-funnel flow times were measured as 12–20 s in the first group of experiments. Besides, in this group, increasing pumice powder rate decreased the passing ability of SCC, and flow time was extended because of the segregation rate exceeded the optimum value. the V-funnel flow times on the amount of recommended values can be considered suitable for V-funnel flow time. The difference of V-funnel time delayed 5 min was 6–8 s Group I. The standard of The European Guidelines for Self Compacting Concrete Committee indicated that if there is a difference of more than 3 s according to first flow time, static segregation occurs. Therefore, the static segregation risk increases, since the viscosity of fresh concrete decreases, as the amount of water increases on the optimum value in fresh concrete. As a result of this, V-funnel time, delayed 5 min, extends. Besides, the static stability of fresh concrete has increased and V-funnel time, delayed 5 min, has been shortened since the viscosity of fresh concrete has increased without further increasing the shear stress of the fresh concrete as the amount of fly ash has increased. The V-funnel time, delayed 5 min, increased when the lightweight aggregate ratio increased as w/(c + m) was constant. It was seen that the L-box (h2/h1) ratio increased as the amount of mineral additives and w/(c + m) ratio increased for all mixtures. Besides, it increased when the amount of normal aggregates increased in all mixtures, i.e. the passing ability increased as unit weight of fresh concrete increased.

HARDENED STAGE PROPERTIES

Compressive Strength

The compressive were conducted on the concrete specimens with pumice stone powder at varying percentages of 0, 5, 10, 15and 20 by volume in a compression testing machine for 7 days and 28 days in accordance with the Bureau of Indian specifications. The compressive strength test was conducted on cube specimens of 150 mm size.

Table-4 : Compressive strength of concrete with fine aggregate partially replaced by pumice powder powder.

Mix Designation	% of replacement of fine aggregates by pumice stone powder	7 Days (MPa)	28 Days (MPa)
CM1	0	32.5	46.7
CM2	0	34	48.8
CM3	0	32	44.9
PM1	5	33	49.3
PM2	10	31.9	48
PM3	15	33.4	48.4
PM4	20	32.5	47.5
PM5	25	31.4	46.4

From Table 4 and Figure , it is observed that the 7 days, and 28 days compressive strengths of concrete initially increase as the replacement percentage of pumice powder increases, become maximum at about 15% and later decreases. It can be seen clearly that there a reduction in the strength at the 15% replacement. Pumice powder when ground to a very fine powder, SiO2 react chemically with alkalis in cement and form cementitious product that help contribute to the strength development. Also it may be due to the pumice powder effectively filling the voids and giving rise to a dense concrete. When comparing the strength gain with the normal concrete,

Table-5: Compressive strength of concrete versus percentage of replacement of cement by Aluminium powder.

Mix Designation	Aluminium powder (%)	7 Days (MPa)	28 Days (MPa)
AM1	0.2	20.54	27.04
AM2	0.4	18.71	25.28
AM3	0.6	17.64	24.94
AM4	0.8	16.87	24

it can be seen that there is increment of strength even at 15% powder replacement. This must be due to the dilution effect takes over and the strength starts to drop. The presents of excess pumice powder, forms weak pockets in the concrete that reduces the concrete strength. In the first group, the dry unit weights of concrete samples were specified between 1400-2300 kg/m3 and 2400 kg/m3 for those produced with lightweight aggregate and control samples not containing mineral additive. Although there is not a very big difference between them, replacing of pumice powder instead of cement in mixture has reduced unit weight. Besides, the unit weights of concretes reduced as w/(c + m) ratio and amount of mineral additive increased in mixture. The reason of this is that the increase of the spaces in concrete structure with the increase in the w/(c + m) ratio and mineral additives replaced instead of cement have lower specific gravity than cement.

In the second group it is observed that the unit weight of concrete decreases monotonically as the replacement percentage of aluminium powder increases. Unit weight of concrete without aluminium powder is higher than with aluminium powder.

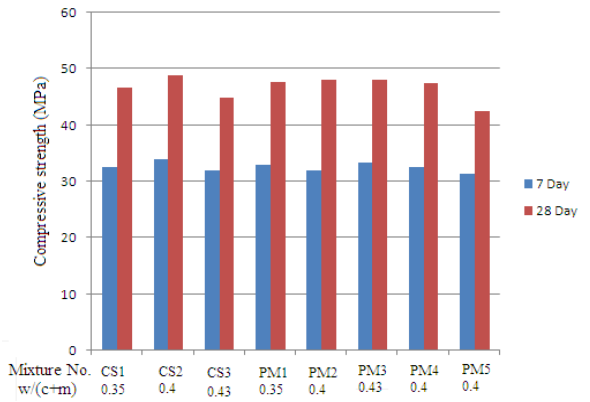

Fig.-4. Compressive strength of concrete versus percentage of replacement of fine aggregate by pumice stone powder.

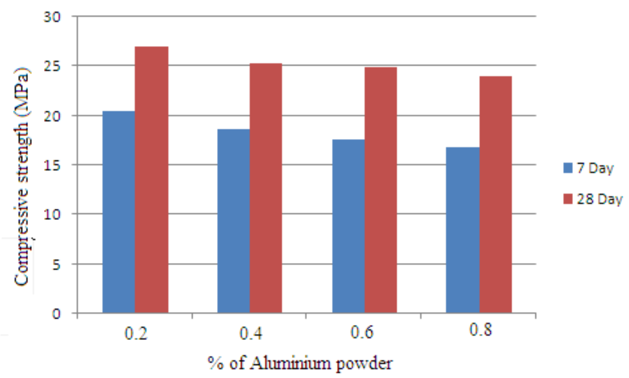

Fig -5. Compressive strength of concrete versus percentage of Aluminium powder.

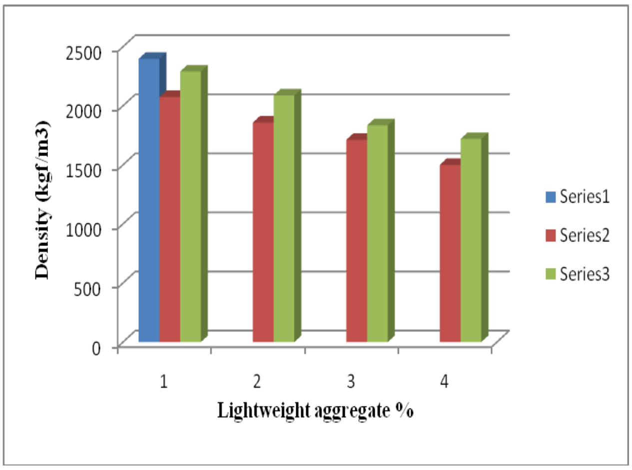

Fig 6. Density of concrete versus percent replacement of cement by Pumice and Aluminium powder.

5.CONCLUSION

a. In conventional selfcompacting concrete 7 days and 28days compressive strength is 34 and 48.8MPa respectively. But in group 1 Self compacting lightweight concrete, is found to be 33 and 48.4MPa respectively.

b. Optimum strength is obtained at 15% replacement of fine aggregate by pumice stone powder.

c. In gropup 2 mixture the compressive strength values are 20.54 and 27.04MPa respectively and strength value decresing as the aluminium content increases.

d. In all mixtures, the increase in the amount of pumice powderdid not improve the self-compatibility properties. As a result of visual inspection of pumice, the shear stress of concrete may have decreased because of more porous and roughness surface structure of pumice.

e. Because of the pumice and natural aggregate usage together in SCLC, the unit weight, thermal conductivity and ultrasonic pulse velocity values of the concrete samples decreased while the compressive strengths and water absorption ratios increased with replacing fly ash instead of cement in the second group. However, this reason is not related to the fly ash but the pumice ratio.

f. The increase of lightweight aggregate rate (i.e. decrease of density) increased the V-funnel flow time of SCC. There are two reasons for this. First, the flow time extends as unit weight decreases since the flow reason of concrete is its own weight exceeding the threshold stress. Therefore, the V-funnel flow time which was a little above the recommended value may be acceptable. The second reason is that the increase in the amount of lightweight aggregate in mixture also increased the tendency to segregation of fresh concrete. The lightweight aggregate and normal aggregate combinations may lead to maximum compacting, and less segregation may be investigated to leave the minimum air void in the design of SCLC.

g. Compressive strength decreases as aluminium powder is increased.

h. The density of self compacting concrete reduces with increase of percntage of cement by aluminium powder.

i. It is recommended that the utilization of pumice powder powder is feasible as it providing better compressive strength upto a limit of 15% and also reducing the density.

j. Aluminium powder reducing the density of self compacting light weight concrete and make possible to state as it as SCLC however its compressive strength declining.

REFERENCES

[1]. Murat Kurt , Muhammed Said Gul , Rustem Gul Abdulkadir Cuneyt Aydin ,Turkay Kotan, "The effect of pumice powder on the self-compactability of pumice aggregate lightweight concrete"*Journal of Construction and Building Materials*, November2015,Vol.103,PP36-46.

[2].Erhan Guneyisi , Mehmet Gesog lu , Inan Altan , Hatice Oznur Oz "Utilization of cold bonded fly ash lightweight fine aggregates as a partial substitution of natural fine aggregate in self compacting mortars" *Journal of Construction and Building Materials*, October 2015,Vol.74,PP 9-16.

[3]. Fuat Koksal , Osman Gencel , Mehmet Kaya "Combined effect of silica fume and expanded vermiculite on properties of lightweight mortars at ambient and elevated temperatures",*Journal of Construction and Building Materials*,April 2015,Vol.88 PP 175-763.

[4]. Abdurrahmaan Lotfy, Khandaker M. A. Hossain, and Mohamed Lachemi "Lightweight Self-consolidating Concrete with Expanded Shale Aggregates: Modelling and Optimization"*International Journal of Concrete Structures and Materials* June 2015,Vol.9, No.2, pp.185–206.

[5].Li-Jeng Hunag, Her-Yung Wang, Shi-Yang Wang, "A study of the durability of recycled green building materials in lightweight aggregate concrete", *Journal of Construction and Building Materials,*August 2015,vol.96,pp353-359.

[6].Behnam Vakhshouri, ShamiNejadi, "Mix design of light weght self compacting concrete" *Case Studies in Construction Materials*,November 2015,Vol.4,PP 1-14.

[7]. Sherif Yehia, Mohammad Al Hamaydeh, and Sharef Farrag, "High-Strength Lightweight SCC Matrix with Partial Normal-Weight Coarse-Aggregate Replacement: Strength and Durability Evaluations" *J. Mater. Civ. Eng. American Society of Civil Engineers.* November 2014,Vol 26, PP 1-11.

[8]. J. Alexandre Bogas, J. de Brito, J. Cabaço, "Long-term behaviour of concrete produced with recycled lightweight expanded clay aggregate concrete", *Journal of Construction and Building Materials,*May 2014 ,vol.65,pp470-479.

[9]. J. Alexandre Bogas , Rita Nogueira, Nuno G. Almeida, "Influence of mineral additions and different compositional parameters on the shrinkage of structural expanded clay lightweight concrete"*Journal of Materials and Design,* December 2014,Vol.56,PP 1.39-1048.

[10].Mehmet Gesoglu , Erhan Guneyisi , Turan Ozturan , Hatice Oznur Oz , Diler Sabah Asaad "Self-consolidating characteristics of concrete composites including rounded fine and coarse fly ash lightweight aggregates"*Journal of Composites: Part B*,January 2014,Vol.60,PP 757-763.

[11]. Lijuan Kong, Lirong Hou, Yuanbo Du, "Chemical reactivity of lightweight aggregate in cement paste",*Journal of Construction and Building Materials,*April 2014,Vol.64,PP22-27.

[12]. Norlia Mohamad Ibrahim , Shamshinar Salehuddin, Roshazita Che Amat, Nur Liza Rahim and Tengku Nuraiti Tengku Izhar, "Performance of Lightweight Foamed Concrete with Waste Clay Brick as Coarse Aggregate",*Journal of Asia-Pacific Chemical, Biological & Environmental Engineering Society,* January 2013,vol.5, PP 497-501.

[13].Yong Jic Kim a, Yun Wang Choi , Mohamed Lachemi, "Characteristics of self-consolidating concrete using two types of lightweight coarse aggregates " *Journal of Construction and Building Materials*,September 2010 ,Vol.24,PP 11–16.

[14].M. Lachemi , S Bae K.,M. A. Hossain ,M. Sahmaran, "Steel–concrete bond strength of lightweight self-consolidating concrete" *Materials and Structures* ,October2009, vol.42,pp1015–1023.

[15].Rita Nemes and Zsuzsanna Józsa, "Strength of Lightweight Glass Aggregate Concrete", *Journal of Materials in Civil Engineering*, November 2006,vol. 18,pp 710-714.