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A N I N T E R N A T I O N A L J O U R N A L

Experimental Investigation on Self-Compacting Self-Curing Concrete Incorporated with the Light Weight Aggregates

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ABSTRACT

Self-Compacting Concrete (SCC) flows around obstructions by its self-weight to fill entirely and self-consolidate (without any need for vibration), without any part of disconnection and chunking. The eradication of the need for consolidation leads to better quality concrete and substantial improvement of running conditions. The fresh state of SCC mixes will usually have huge amount of fine fillers, including cement, and produce excessively high compressive strength concrete. In order to overcome the workability problem Super Plasticizer (SP) and Viscosity Modifying Agent (VMA) are used. Here, the workability admixtures are fixed at a constant rate of 2% based on the weight of cement. This technique examines special applications in cases of bottleneck reinforced sections, rafts, tunnel linings, highly reinforced columns, underwater repairs, bridge piers and placements. LECA and Vermiculite have high porosity, and are added to concrete mixtures to create a lightweight concrete mix. An attempt has been made to develop a combination of self-compacting and self-curing concrete with each 5% and 10% of LECA and Vermiculite as a partial replacement to fine aggregate. As there was no proper mix design for the development of this modern concrete, the design has been carried out based on EFNARC specifications for the design strength of M_{40} *grade concrete. The porosity of light weight aggregate provide source of water for internal curing of concrete which enhances concrete strength and durability. Based on more trials, it was noticed that the concrete with 10% of LECA and Vermiculite in individual provides good results.*

Key words: Self-compacting concrete, Vermiculite, Diatomaceous, Internal curing, LECA.

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INTRODUCTION

Self-Compacting Concrete

SCC was purposely designed to be able to fill every corner of the form and encapsulate all reinforcement with maintained constancy only under the impact of gravitational forces, without segregation or bleeding. This makes SCC so helpful wherever pouring of concrete is difficult, such as in cumbersome reinforced concrete members or in critical work forms. The basic workability and mechanical properties on SCC with light weight aggregates were investigated[1]in addition with steel fibers. The ultimate capability of Self-Compacting Concrete was to avoid isolation of particles and the basic nature of the fresh concrete can be realized by effective mix design. In this mix design, a small quantity of aggregate is restored by powder material such as diatomaceous earth minerals and vermiculate while the water contents is kept constant. Self-Compacting Concrete with a lower water cement ratio will usually have a high strength compared with conventional concrete, giving a perfect interface between the cement paste and the surrounding aggregate. The accelerated steam curing has been applied at a constant rate and the rate of strength development will be based on the complete maturity of concrete testing. The tensile strength may be safely assumed to be the same as the one for an ordinary concrete, since the paste volume has no much impact on tensile strength. An efficient self-compacting concrete was developed with various additives to suit for different environmental conditions[2].There are several more reasons for using SCC for instance, fast concrete placement and finishing, proper compaction in structures with congested reinforcement, and quieter construction in precast plants. Generally, there are the following approaches for developing more economical SCC:

(1) Incorporation of high volumes of economical pozzolonas, particularly fly ash, and/or mineral fillers, like (flour or) powder and/or quarry dust of limestone, marble, quartz or granite to reduce the cement content;
(2) Use of low cost water reducers; and
(3) Use of viscosity modifying agents to partially replace the cement with sand**.**

Self-Curing Concrete

In the 21st century, internal curing has emerged as an innovative technology that holds more efficient for making concrete with high resistance to early-age cracking and enhanced sustainability. Since the effective service life of concrete is a key component for producing a sustainable infrastructure, an internal curing can provide a positive approach in increasing the sustainability of our nation's infrastructure. The internal structure of self-cured high performance concrete with pre-wetted light weight aggregates subjected to autogenous shrinkage due to cracking under differential temperature was investigated [3]. Protected paste volume in concrete with internal curing agents with light weight aggregates was described[4]. Internal curing has an important effect on concrete to determine the effect of hydration and moisture distribution, as it influences significant concrete properties, such as strength, shrinkage, cracking, and durability[5].The American Concrete Institute (ACI- 308 / R-01) defined internal curing in its ACI Terminology Guide as "supplying water throughout a freshly placed cementitious mixture using reservoirs, via pre-soaked lightweight aggregates, that readily supply water as needed for hydration or to replace moisture lost through evaporation.

light weight aggregate in the concrete.

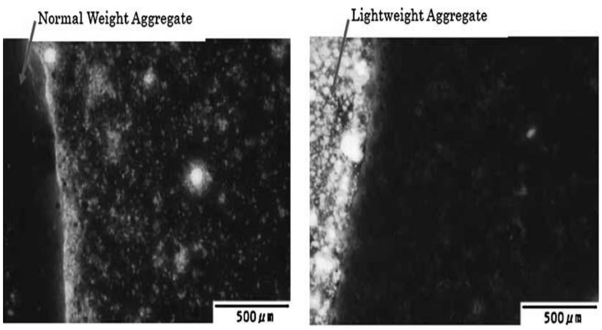
Basic Concept of The Self-Curing Concrete

The basic concept of the self curing concrete technology is to provide water for concrete, so that it can continue the curing process on its own. This is performed by encapsulating the water inside the ingredients used to make concrete. If the water just enumerated as mixing water; this would tends to many other performance related problems, such as bleeding, segregation, and etc[6]. Therefore, a special material shall be used; so that some of the water can be hidden into the material. The water movement in concrete with self-curing admixtures was examined[7].

The absorbed water will be released into the concrete over time after the concrete has been placed in the structure and hardened. By doing this the hardened concrete will be able to undergo continuous curing for a long time, which will promote towards a better hydration product. There are many types of material that can be used to impregnate the water. One example is by using feldspar; which is capable of hiding the water into its porous microstructure. The water impregnated diatomaceous earth minerals and vermiculate can be used to replace part of sand for the concrete mix[8].The differential humidity analysis of concrete with workability admixtures was studied[9,10]. They extended the study to compute the strengthening of microstructure with respect to various environmental conditions.

Interfacial Transition Zone Of LWA and NWA

Light weight aggregate gives more bond strength and durability to the structure compare to normal weight aggregate.



(a) Normal Weight Aggregate	(b) Light Weight Aggregate

Fig.1 Fluorescence Microscope Images showing ITZ

Fig.1 shows microscope images of Interfacial Transition Zone (ITZ) between cement paste and normal weight aggregate (left) and saturated LWA (right) under fluorescent spectroscopy and the darker ITZ in the fig. 1(b) indicates lower porosity and thus better bond characteristics could be achieved than fig. 1(a) in which the higher percentage of pores could be effectively observed from normal mix.

Diatomaceous Earth Mineral

Diatomaceous earth is a peculiar and a natural product obtained from very finer fossilized water plants. It is a naturally occurring siliceous sedimentary mineral compound obtained from microscopic skeletal of unicellular algae-like plants called diatoms. It is a mineral based pesticide consists of approximately 3% magnesium, 33% silicon, 19% calcium, 5% sodium, 2% iron and other trace minerals such as manganese, titanium, boron, copper and zirconium. The clear appearance of the earth mineral, LECA is clearly shown in fig. 2.

Fig.2 Diatomaceous earth (LECA)

LECA, also known as diatomite or kieselgur, as examined under bright field illumination on a light microscope. It is a soft, siliceous, sedimentary rock made up of shells of single cell diatoms and readily crumbles to a fine powder. Under the observation of the particle by FE-SEM, the internal characteristics of aggregate have a high porosity, hence used as light weight aggregate. The internal appearance of diatomaceous earth was observed through field illumination microscope and is shown in fig. 3.

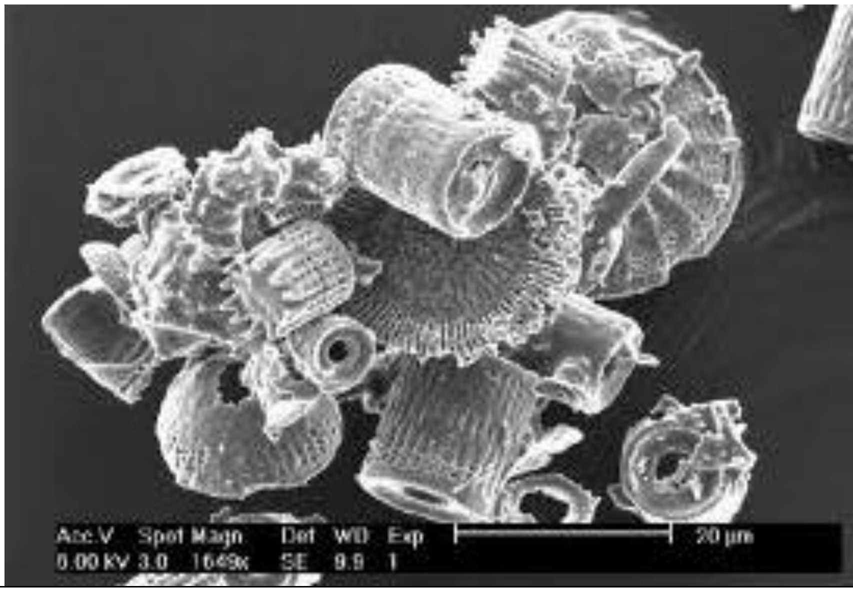


Fig.3 Diatomaceous earth as viewed under bright field illumination on a light microscope.

The diatomaceous earth was examined for various properties as per IS specifications. The physical indexes for LECA are given in Table 1. The result from the table specifies the basic needs for internal curing concrete with self-compacting admixtures. From table 2, the internal composition of minerals for LECA observed from X-Ray Diffraction instrument exactly delivers positive approach to produce an effective self-compacting self-curing concrete.

Table.1 Physical Indexes of LECA

Properties	**Test Values**
Colour	White
Appearance	Powder
Permeability	1.60
Ph	8.00
Moisture (%)	0.22
Specific Gravity	2.30
Fineness Modulus	4.60
Water absorption test (24 hrs soaking)	29.4%
Water absorption test(5 hrs boiling & 24 hrs soaking)	86.2%
Porosity test	85.38%

Table.2 Chemical Indexes of LECA

Particle	**Composition %**
SiO_2 (%)	90.5
Al_2O_3 (%)	0.82
Fe_2O_3 (%)	0.76
TiO_2 (%)	0.26
CaO (%)	0.18
MgO (%)	0.32
Ignition on Loss	0.2

Vermiculite

Vermiculite is well implemented to concrete ingredients to create a reducable concrete mix. It is formed by the alteration and/or weathering of the minerals like biotite and phlogopite. All mica minerals break into very thin sheets and the mineralogists call this as micaceous cleavage. Like the mineral talc, vermiculite has many layers of water sandwich between the layers of silicate. Consequently, when vermiculite is incinerated, the water is driven off from the core layer of the light weight particles and hence the mineral expands. Thus, the effective mode of expanded and lighter form of vermiculite is used extensively in industries, construction and agriculture. The various properties of vermiculite aggregates are given in table 3. The general appearance of vermiculite aggregate is shown in fig. 4.

Fig.4 Vermiculite

Table.3 Physical Indexes of **Vermiculite**

Properties	**Test Values**
Cleavage	Perfect
Color	Yellow brown
Specific Gravity	2.4
Density	2.5
Fineness Modulus	4.736
Water absorption test (24 hrs soaking)	18.4%
Water absorption test (5 hrs boiling & 24 hrs soaking)	71.7%
Porosity test	26%

EXPERIMENTAL INVESTIGATION

All the concrete mixtures were mixed for five minutes in a laboratory counter current mixer. From each concrete mixture, 150 x 150 x 150 mm Cubes and 300 mm x 150 mm Cylinders were cast. The cubes were used for the determination of compressive strength, and the cylinders were cast for determining the Split tensile strength. The beam of 500 x 100 x 100 mm is cast and the flexural strength was calculated. The flow time for each concrete mixture was determined using the V-funnel, L- Box and Slump flow test. The mix proportion is shown in Table 4and for each mixture, the compressive, split tensile and Flexural strength were determined at 28 days of curing.

Table 4. Mix proportion

S.No	Material	Quantity Kg / m^3		
		Control Mix 0%	5% Leca / Vermiculite	10% Leca / Vermiculite
1.	Cement	450	450	450
2.	Fine Aggregate	540	513	486
3.	Leca / Vermiculite	-	27	54

4.	Coarse Aggregate	920	920	920
5.	Water	180	180	180

RESULTS AND DISCUSSION

Workability Test

The test on fresh concrete was made as per EFNARC specifications. It was tested for significant properties like slump flow, L box and V funnel and the results have been given in Table 5.

Table 5. Workability results

S.no	Mix	Slump Flow (mm)	L Box (mm)	V funnel (mm)
1.	0%	628	0.86	7
2.	5% LECA	529	0.90	11
3.	10% LECA	610	0.88	12
4.	5% Vermiculite	580	0.96	8
5.	10% Vermiculite	605	0.90	9

From the results shown in table 5, it was found that the slight variation in flow properties has been observed based on the variation in percentage of aggregates. It was noticed that the concrete mix with light weight aggregates shows little resistance to the flow nature than the control mix because of the presence of minute pores, as the pores will absorb the water and creates the weight to the particle leads to the particle resistance to movement. It was observed that the addition of light weight aggregates at a 10% gives reasonable sign than 5% addition as per EFNARC conditions. The use of 10% LECA and Vermiculite aggregates in individual to the mix shows better performance at a rate of 13.27% and 4.13% than 5% replacement. In comparison with control mix, the reduction in percentage of flow for LECA and vermiculite aggregates was found to be 18.71% and 2.8% for 5% and 10% replacement of LECA, and 7.6% and 3.8% for 5% and 10% replacement of vermiculite aggregate. Therefore, incorporation of LECA and Vermiculite as light weight aggregate (LWA) upto 10% have some effect on workability values.

Mechanical Properties

The tests on hardened concrete were made as per IS specifications. It was tested for significant properties like compression test on cube, split tensile test on cylinder and flexural test on prism as shown in fig. 5 to fig. 7.and the results have been given in Table 6.

Fig.5 Compression Test on Cube

Fig.6 Split Tensile Test on Cylinder

Fig.7 Flexural Test on Prism

Table 6. Mechanical strength of concrete

S.No	Mix	Compressive Strength Mpa	Split tensile Strength Mpa	Flexural Strength Mpa
1.	0%	42.60	4.00	5.20
2.	5% LECA	41.90	3.86	5.86
3.	10% LECA	44.76	4.20	6.42
4.	5% Vermiculite	42.60	3.92	5.46
5.	10% Vermiculite	45.82	4.62	6.20

From the results shown in table 6, it was found that there is a good improvement in compression, split tensile and flexural strength for concrete mix with light weight aggregates than the concrete without any replacement. It was noticed that the concrete mix with light weight aggregates shows superior behavior because of the characteristic nature of water holding capacity. It was observed that the addition of light weight aggregates at a 10% gives reasonable sign than 5% addition. The use of 10% LECA and Vermiculite aggregates in individual to the mix shows better performance in compressive strength at a rate of 6.83% and 7.03% than 5% replacement. In comparison with control mix, the increase in percentage of strength for LECA and vermiculite aggregates was found to be 4.83% and 7.03% for 10% replacement of LECA and Vermiculite. Similarly, the average increase in percentage of 10% replacement of LECA and Vermiculite under split tensile and flexural test was found to be 9.29% and 17.59% respectively. The reason for decrease in strength for the conventional based concrete was due to the effect of self-desiccation from the surface of concrete. The presence of bond water and bulk water in the light weight aggregates helps to act as a reservoir for the occurrence of secondary hydration in the cement paste. The formation of secondary hydration leads to the better bond of ITZ thus reduces the bleeding effect of mix water in the concrete.

Durability Property

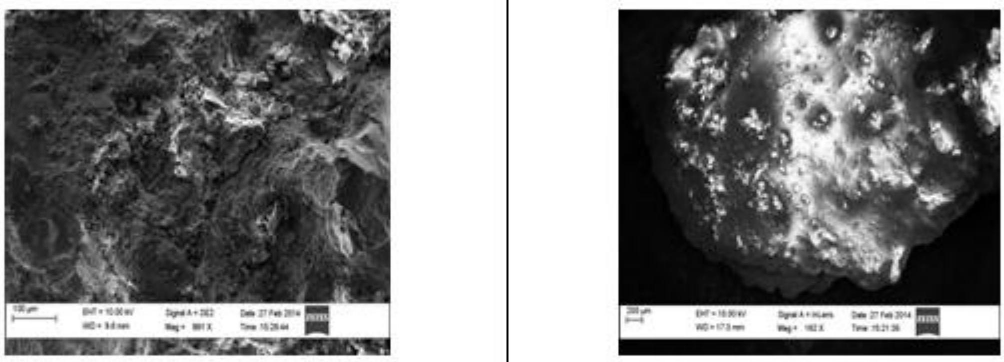
The concrete with and without replacement of light weight aggregates was analyzed for acid attack. Here, the test was carried out for the optimized value obtained from the mechanical strength tests on concrete. The concrete is completely immersed in 5% of diluted sulphuric acid in one liter of water. It was kept in direct observation for 56 days after 28 days curing period. The visual scale, weight / mass loss and strength deterioration effect was found and it was compared effectively. From fig. 8, it was cleared that the concrete with light weight aggregate suffered less deterioration than control mix. The complete scale of values is shown in table 7.

Table 7. Acid attack

Concrete Type	Visual Scale	Mass Loss %	Strength deterioration %
Control Mix	4 – Severe attack	14.6	23
10% LECA	2 – Mild attack	12.2	14
10% Vermiculite	2 – Mild attack	11.8	14

Microstructure Property

The presence of gel formation over the surface of the matrix for the optimized condition of the concrete with and without light weight aggregates were observed for SEM analysis through field emission atomic spectroscopy.



(a) Ordinary Concrete (b) Light Weight Sccsc

Figure 9. SEM Image

From the fig. 9(a), the appearance of hair line cracks could be observed at the core portion of the concrete which indicates the improper presence of gel products and de-bonding condition of concrete particles inside the matrix. From fig. 9(b), it is cleared that the uniform presence of hydration outputs from the influence of water with bogue's compounds of cement. The presence of minute pores in the light weight aggregate plays a significant role in the development of further activation of hydration because of the basic nature of water holding capacity.

CONCLUSIONS

From the various studies, the following are the results to be concluded.

- The workability and mechanical properties is significantly improved for 10% LECA and 10% Vermiculite as a partial replacement of fine aggregate.
- Saturated light weight aggregate (LECA and Vermiculite) had no negative effect on the overall properties of concrete.
- The incorporation of light weight aggregate can reduce the effect of self-evaporation which could yield a more durable concrete as observed from acid attack test.
- The development of well structured matrix under light weight aggregate than control matrix proves that the light weight aggregate concrete with self-compacting admixtures was more adaptive for various environmental conditions.

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