ISSN: 2278-0181
Vol. 2 Issue 12, December - 2013

Flexural Behaviour of Shell Lime Based Pre- stressed Self- Compacting Concrete

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Abstract

Self-Compacting Concrete (SCC) is a type of concrete which flows into place and around obstructions under its own weight to fill the formwork completely and self-compact, without any segregation and blocking. The present trend that is being adopted all over the world is to utilize effectively the treated and untreated industrial by- products as an ingredient in concrete. This trend not only helps in reusing the materials but also creates a greener future. This study focuses on the use of Shell lime in preparation of Self compacting concrete as partial replacement for cement. As concrete is weak in tension, it makes very much necessary to provide reinforcement for concrete for structural use. So this work also focuses on studying the flexural behaviour of pre- tensioned pre-stressed shell lime based Self compacting concrete beams.

Keywords- Compressive Strength, Deflection, Flexural behaviour, Self-Compacting Concrete, Shell lime, Pre-stress, Pre-tension.

1. Introduction

Self-compacting concrete (SCC) was first developed in Japan in the late 1980s as a concrete that can flow through congested reinforcing bars with elimination of additional compaction and without undergoing any significant segregation and bleeding under its own weight [1,2,3]. In recent times, this concrete has gained wide use in many countries for different applications and structural configurations. Adoption of SCC offers substantial benefits in enhancing construction productivity, reducing overall cost, improving work environment, it is used when there is a shortage of labour and helps in achieving higher surface quality [4]. Such innovative concrete requires high slump that can be easily achieved by Super plasticizer addition. To avoid segregation on super plasticizer addition the sand and aggregate content is increased by 4% to 5%. When the volume of coarse aggregate in the concrete is excessive, the opportunity of contact between coarse aggregate particles increases greatly, causing interlocking and the possibility of blockage on passing through spaces between steel bars is also increased. Therefore, the first point to be considered when designing SCC is to restrict the volume of the coarse aggregate. This reduction necessitates the use of higher volume of cement which increases the cost besides resulting in greater temperature rise. So cement should be replaced by other mineral admixture like blast furnace slag or fly ash or Shell lime powder [5]. The usage of mineral admixtures in the production of SCC not only provides economic benefits but also reduces heat of hydration [6]. It is also known that some mineral admixtures may improve rheological properties and reduce thermally-induced cracking of concrete due to the reduction in the overall heat of hydration and increase the workability and long-term properties of concrete [7,8]. Shell lime is obtained by burning a combination of shell lime and coal in a furnace. It has Calcium oxide (Cao) and has properties similar to the cement.

It is a well-established fact that the concrete has low tensile strength and it has insufficient ductility. These deficiencies can be minimized by providing conventional steel in the tensile regions of the member to sustain tensile stress or by the means of applying a pre-compression or pre-stress in the concrete cross section to alter load deformation characteristics.

This work outlines the preliminary results of research aimed at producing and evaluating SCC incorporating Shell lime powder to study the flexural behaviour of pre-tensioned shell lime based beams.

2. Significance of using Shell Lime

Before cement was developed, lime was used as binding material in the casting of lime concrete. This was obtained from naturally occurring lime stone deposits in the earth's crust. The naturally occurring resource is depleting fast and hence for sustainable development it needs to be conserved.

Naturally occurring molluscs like shell fish in the oceans have protective shells that contain $CaCo_3$ or lime. This resource can be tapped, as an alternative for the limestone deposits.

3. Experimental

3.1 Materials

3.1.1 Cement

In this experimental study, ordinary Portland Cement conforming to IS: 12269- 1987 was used. The physical and mechanical properties of the cement used are shown in Table 1.

Table. 1: Properties of Cement

Physical property	Results
Fineness	2250 cm^2/gm.
Normal Consistency	29%
Vicat initial setting time (minutes)	62
Vicat final setting time (minutes)	190
Specific gravity	3.10
Compressive strength at 3-days	28.34 MPa
Compressive strength at 7-days	37.67 MPa
Compressive strength at 28-days	45.2 MPa

3.1.2 Shell lime powder

Shell lime is obtained by burning the combination of Shell lime and coal in a furnace. Advantages of using Shell lime are that it blends in the mix easily and forms a very good, cohesive mix. It also acts as a good viscosity modifier for fresh concrete paste, because of which usage of viscosity modifying agent can be minimized. The physical properties of Shell lime powder are shown in Table 2.

Table. 2: Properties of Shell lime powder

Physical Properties	Test Results
Specific gravity	3.09
Fineness	2663.15 cm^2/gm.

3.1.3 Aggregates

Locally available natural sand with 4.75mm maximum size was used as fine aggregate, having specific gravity 2.62 and water absorption capacity of 0.03%

Crushed granite stone with size ranging from 10mm to 20mm was adopted as coarse aggregate having a specific gravity of 2.64 for 20mm and 2.67 for 10mm.

3.1.4 Super plasticizer (SP)

The admixture used was based on poly carboxylic technology. It was used to provide necessary workability. Table 3 gives the properties of Super plasticizer.

Table. 3: Properties of Super plasticizer

Appearance	Light yellow coloured liquid
pH	6.5
Volumetric mass at 200° C	1.06 kg/litre
Chloride Content	<0.1%
Alkali Content	Less than1.5g Na_2O equivalent/ litre of admixture

3.2 Mix Proportioning

The total cementitious material in the mix is altered. In this, the cement is partially replaced by shell lime powder. The total water to be added is calculated keeping fixed water to cement ratio (0.33 to 0.42) and making necessary corrections for moisture content and water absorption of aggregates available. For calculating the amount of aggregate absolute volume method was adopted, details of which are given below.

Assume the ratio of Fine Aggregate (FA) to Coarse Aggregate (CA) as 60:40 (FA: CA). Therefore,

Total Volume of Aggregate = 1000- Volume of Air – Total Water – (Wt. of Cement/ Specific gravity of Cement) - (Wt. of Shell Lime/ Specific gravity of Shell Lime)

Weight of FA= 0.60 *Total Aggregate Volume* Specific Gravity of FA

Weight of CA= 0.40 *Total Aggregate Volume* Specific Gravity of CA

The dosage of Super plasticizer is kept as per the specification of the manufacturer. The VMA dosage is adjusted as per the needs. Based on the requirement for the element to be cast like strength, durability and free space between the reinforcement, the minimum amount of paste is calculated by laboratory trials by performing the mortar of SCC and performing the Slump flow test to determine the spread and segregation resistance and V- funnel to check the flow time of SCC. This calculation gives minimum paste content for sufficient passing ability. Once satisfactory mix is arrived, it is tested for properties like slump, flowing ability, passing ability and blockage using Slump cone, L-Box, U-Box and V-funnel respectively. A total of 3 trial mix was done. The details of trial mixes are as in Table 4.

Table. 4: Mix proportioning for 1m^3 of SCC

MIX	SCC1	SCC2	SCC3
Cement (kg/m^3)	412.5	500	550
Shell lime (kg/m^3)	137.5	200	150
Sand (kg/m^3)	800	700	735
20mm aggregate (kg/m^3)	-	233.4	230.5
10mm aggregate (kg/m^3)	677.31	433.4	427.5
Total water	230	230	240
Super plasticizer	1.65	2.1	1.95
Water/ powder	0.41	0.33	0.37

3.2.1 Self compacting tests on SCC mixes

Various tests were conducted on the trial mixes to check for their acceptance and self-compact ability properties. These tests include T_{50} slump flow, V-funnel, L- box, U- box. The acceptance criteria are given in table 5. The results of tests are given in Table 6.

Table. 5: SCC- Acceptance Criteria

Method	Properties	Range of values
Slump flow	Filling ability	650-800mm
V- funnel	Viscosity	6-12 sec
L- box	Passing ability	0.8-1.0
U- box	Passing ability	0-30

Table. 6: SCC- Test results on SCC Mixes

Mix	SCC1	SCC2	SCC3
Slump flow (mm)	700	750	700
V- funnel (sec)	9	7.59	7.4
L- box (H_2/H_1)	0.9	0.89	0.92
U- box (H_2-H_1)	25	15	21

The results of self compactability test shows that three mixes satisfy the acceptance criteria for self-compacting concrete. Hence these mixes were chosen as successful mixes. The cube specimens of size 150x150x150mm were tested for the compressive strengths.

The pre-tensioned pre- stress beams of dimension 60x100x1800mm were cast consisting of high tensile steel wire of diameter 7mm, with a constant eccentricity of 25mm and pre- stressing force of 3.3 tonnes. Beams were cured in moulds itself for 7 days by covering them with wet clothes. After high tensile wires were released from pre-stressing bed, beams were taken out of the mould and placed in water for remaining 21 days curing. Buttons were fixed on one face of the beam in middle portion to take dial gauge readings.

3.3 Experimental setup for flexural test

Loading arrangements and boundary conditions of the simply supported beam while testing the pre-stressed concrete beams is as shown in figure 1. Two dial gauges are placed below the mid point of the beam to measure the central deflections. And another dial gauge is placed below the platform where beam is placed. Uniformly applied static load is applied at 1/3rd and 2/3rd points of the beam till its failure. Dial gauge reading are noted at 50kg intervals and demec gauge reading are noted down at 100kg intervals till the hair cracks appeared on the beam and crack load is noted. After crack load, the dial gauges are removed and central deflections are noted down using vertical scale fixed to the machine. Load is applied continuously further till the failure of the beam and the failure load is noted.

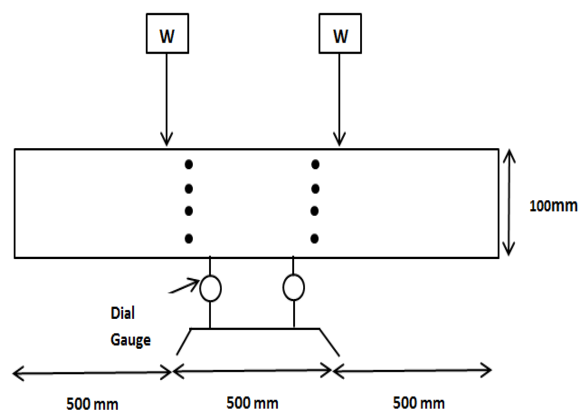

Figure 1: Loading arrangements for flexural test of pre-stress SCC beams

4. Result and discussion

4.1 Compressive strength

All the three mixes were tested for compressive strength of concrete. Fig 2 shows the variation in compressive strength values obtained for SCC with partial replacement of Cement by Shell lime powder.

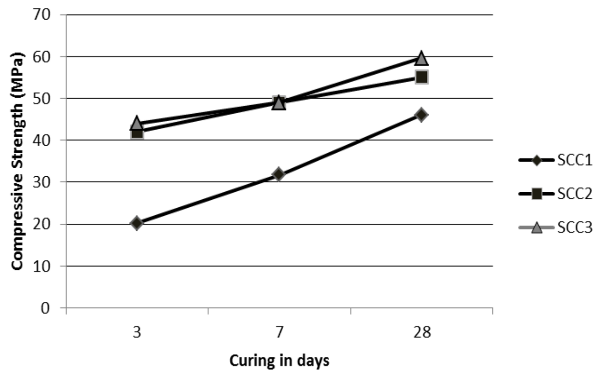

Figure 2: Average Compressive strength of Concrete

According to the results, among all the three mixes, the mix which contained 20mm aggregate showed the better compressive strength.

4.2 Flexural test on pre-stressed beams

The pre-stressed concrete beams are tested as for flexure and the Fig 3 through Figure 5 shows the variation of deflection with respect to the loads.

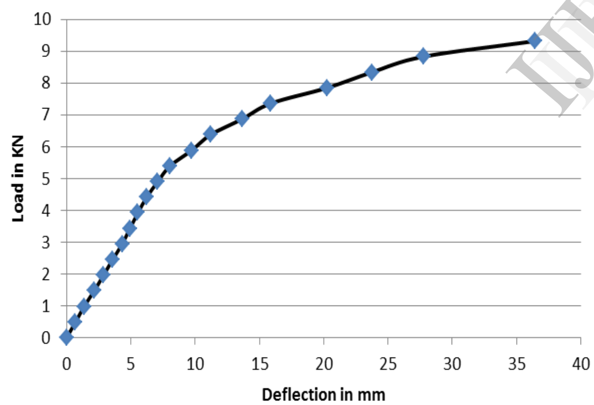

Figure 3: Load versus deflection curve for pre-stressed SCC 1 beam

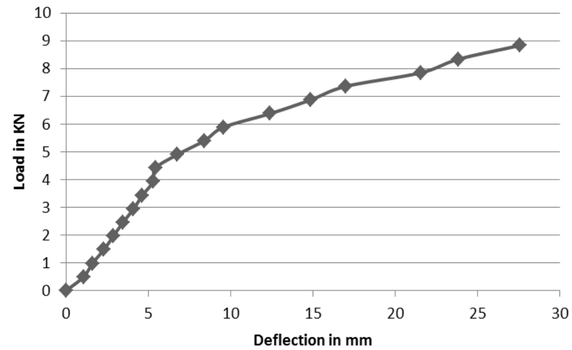

Figure 4: Load versus deflection curve for pre-stressed SCC 2 beam

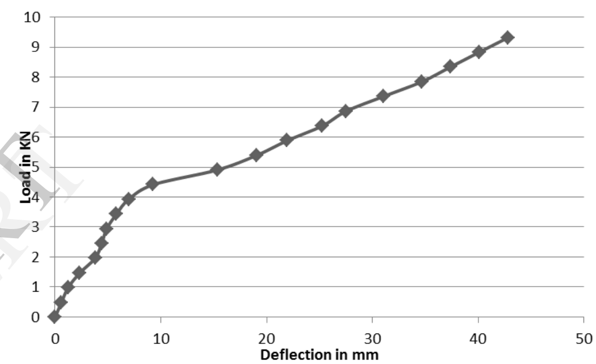

Figure 5: Load versus deflection curve for pre-stressed SCC 3 beam

According to the results, in SCC 1 beam small uniformly distributed cracks appeared while the beam failed and the crack load is at 7.85 kN. In SCC 2 beam well distributed large number of cracks appeared in the middle third position of the beam while the beam failed and the crack load was 6.87 kN. In SCC 3 beam a number of well distributed cracks appeared in the middle third position of the beam before failure and the crack load is 5.39 kN.

5. Conclusion

The latest researchers are concentrating on the ways to create new concrete by using various industrial wastes. The addition of the shell lime into concrete was a step that was taken to utilize shell lime obtained from burning a combination of shell lime and coal in a furnace. Various properties of shell lime integrated SCC mixes such as self compactability, compressive strength is evaluated. Along with these properties the flexural test on pre- tensioned pre-stressed concrete beams were conducted. From the experimental investigations, the following conclusions were arrived at:

i. The addition of Shell lime powder makes the concrete mix stiff, so there was no bleed water in concrete, due to which VMA was not used in any mix.
ii. The compressive strength of SCC 3 was higher than other 2 mixes for 28 days of curing.
iii. Among three mixes SCC 1 pre-stress beam recorded higher crack load of 7.85 kN.
iv. Among three mixes SCC 3 pre-stressed beam recorded higher facture load of 9.81 kN.
v. The manufacture and use of shell lime can solve the disposal problem of the shell generated by consumption of marine creatures.

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