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Study on Beam and column joint with Self-Compacting,Self Curing Concrete And replacement of cement by using Fly Ash and M Sand

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Abstract: This paper presents the performance of Self Compacting Self Curing Concrete (SCSCC) which consists of 30% of class C fly ash for the replacement of cement, 100 % of Manufactured Sand (M sand) for river sand, water reducing admixture of Glenium B233 and self-curing compound of Polyethylene glycol (PEG 400). M 25 concrete mix is designed with different proportions of PEG 400 from 0% to 2% by weight of cement. Fresh and hardened properties of Self Compacting Concrete (SCC) and Self Curing (SC) are studied in terms of flowability and workability, compressive strength and split tensile strength. The fresh properties of SCC are determined as per EFNARC and found satisfactory. It is observed that the addition of 1% of PEG 400 by weight of cement gives better compressive strength and it is taken as optimum dosage for making SCSCC. Glenium B233 of 0.6 % is added in SCSCC to improve the workability. The compressive strength and split tensile strength of SCSCC are found satisfactory as that of conventional concrete. In order to check the adoptability of the developed SCSCC for structural purpose, a beam-column joint is made. Non-destructive tests are performed on beam-column joints, and the quality and compaction effect of concrete are compared. Destructive tests on beam-column joints showed better results for SCSCC specimen in terms of load carrying capacity, deflection and initial stiffness than the conventional concrete joint.

Keywords: *Self-compacting concrete (SCC), Self-Curing Concrete (SC), Superplasticizer, Workability, Non-Destructive testing.*

1. Introduction

Self-Compacting Concrete (SCC) is a concrete which requires no vibration for compaction. When handling with SCC segregation or bleeding should be taken care. SCC ensures the proper filling capability in heavily reinforced structural members, thereby enhancement in performance. Some of the advantages of SCC include (i) shortening of the construction time and labour cost (ii) better quality surface finishing (iii) reduction of noise due to vibration and (iv) better working conditions. Generally such concrete requires a high slump and this may be obtained by adding proper superplasticizer. Segregation may be avoided by increasing the percentage of fine aggregate. When increasing the content of fine aggregate cement content also should be increased. To minimize the adverse effects of cement, mineral admixtures such as silica fume, fly ash and blast furnace slag may be used. Fly ash is widely used in concrete because of benefits such as heat reduction and pozzolanic activity.

The performance and durability of concrete depends on method of curing also. In conventional curing spraying of water/ keeping under wet condition is followed. A new technique called Self Curing (SC) which provides additional moisture in concrete for more effective hydration of cement. There are two major methods available for self-curing, namely, internal curing and external curing. These methods use materials which may either be added in concrete during manufacturing process or after casting the structural elements depending on the application. In the recent past, the researchers showed interest to investigate the performance of SCC and SC for various applications in civil engineering. Kim et al (1996) have investigated on self-compacting concrete with various percentage of fly ash for the cement content. The fresh and hardened properties were studied and it is observed that the 30% replacement of fly ash to the cement gives high workability compare with that of other percentage replacement. Nan Su et al (2001) have proposed the simple mix design, first the amount of aggregates required is determined, and the paste of binders is then filled into the voids of aggregates to ensure that the concrete thus obtained has flow ability, self-compacting ability and other desired SCC properties. The amount of aggregates, binders and mixing water, as well as type and dosage of super plasticizer (SP) to be used are the major factors influencing the properties of SCC.

Slump flow, V-funnel, L-flow, U-box and compressive strength tests were carried out to examine the performance of SCC, and the results indicate that the proposed method could produce successfully SCC of high quality. The method involved determines aggregate Packing Factor (PF) and influence on the strength, flow ability and Selfcompatibility ability. Brouwers and Radix (2005) have addressed experiments and theories on SelfCompacting Concrete. Mixes, consisting of slag blended cement, gravel (4–16 mm), three types of sand (0– 1, 0–2 and 0–4 mm) and a polycarboxylic ether type superplasticizer, were developed. These mixes are extensively tested, both in fresh and hardened states, and meet all practical and technical requirements such as medium strength and low cost. It follows that the particle size distribution of all solids in the mix should follow the grading line as presented by Andreasen and Andersen. Burak et al (2006) have investigated five mixtures with different combinations of water/cement ratio and superplasticizer dosage levels and several tests such as slump flow, L-box and V-funnel, were carried out to determine optimum parameters for the selfcompatibility of mixtures. And they studied the compressive strength development, modulus of elasticity and splitting tensile strength of mixtures.

The authors concluded that the optimum water/cement ratio for producing SCC is in the range of 0.84–1.07 by volume and higher splitting tensile strength and lower modulus of elasticity are obtained from SCC mixtures when compared with normal vibrated concrete. Paraiba et al (2008) have presented an experimental procedure for the design of selfcompacting concrete mixes. The test results for acceptance characteristics of self-compacting concrete such as slump flow; J-ring, V-funnel and LBox are presented. Further, compressive strength at the ages of 7, 28, and 90 days was also determined. Prakash and Manu (2011) have made an attempt to understand the influence of W/P ratio (water to powder ratio) and paste volume on the SCC using M sand. Using particle packing approach the combination of powder and aggregate were optimized. Using simple empirical test the optimum dosage of chemical admixtures was found. Fresh concrete tests such as slump flow and J-ring were carried out for SCC, and hardened concrete test like compressive strength of SCC were carried out. They observed that the high paste content is essential to achieve proper slump flow. They concluded that the manufactured sand can be possible to successfully utilize in producing SCC. Rafat (2011) has carried out an experimental program to study the fresh and hardened properties of SCC with five different percentage of class F fly ash ranging from 15% to 35%. They conducted tests such as slump flow, vfunnel, L-box, U-box test, compressive strength, splitting tensile strength, carbonation depth test and pH value test. It was concluded that it is possible to design an SCC mixes with fly ash content up to 35%. The fresh concrete properties of all SCC mixes give good results as well as the hardened properties of SCC. The carbonation depth increased with increase in age from 90 to 365 days in all SCC mixes. SCC made with fly ash reduced the rapid chloride ion penetrability to the very low range at the age of 90 and 365 days. Bushra and Shahinoor (2011) have discussed internal curing as an added advantage in concrete research. It has wider prospect to get benefit from the internal curing instead of traditional external curing. Lightweight aggregate are normally used in concrete for the internal curing which are available, cheap and easy to transport. It has a significant contribution in shrinkage reduction, enhancing durability, sustainability and hence improving overall concrete performance. It can aid the construction process economically resulting into effective resource utilization. Also considering environmental impact analysis this technique is found as a desirable one. Additionally introduction of internal curing can open doors for recycling and use of other potential materials. In this regards, internal curing is expected to be beneficial in many fold. Mucteba and Mansur (2011) have presented the experimental study on the properties of self-compacting concrete (SCC).The Portland cement was replaced with the fly ash, limestone powder, granulated blast furnace slag, basalt powder and marble powder of various proportion. And they investigated the influence of mineral admixtures on the workability, compressive strength, ultrasonic pulse velocity, density and sulphate resistance of SCC. From the results, they concluded that FA and GBFS significantly increased the workability and compressive strength of SCC mixtures. Nanak et al (2013) have investigated on self-compacting concrete of M30 grade concrete with normal, internal and external curing. In the case of normal curing they kept in water pond, for internal curing they used PEG 600 and kept in shadow, for external curing they coated with FAIRCURE WX WHITE (wax based) material and kept it in shadow. The fresh concrete property of SCC like slump flow test, V funnel and L box were carried out and gives required values as per EFNARC. This result shows that both internal and external curing concrete gives lesser compressive strength of 5 and 9 % respectively to that of normal curing. Patel and Jayeshkumar (2013) have suggested that the optimum dosage of PEG400 for maximum strengths (compressive, tensile and modulus of rupture) was found to be 1% for the M20.As percentage of PEG400 increased slump increased for M20 grade of concrete. Strength of self-curing concrete is on par with conventional concrete. Self-curing concrete is the answer to many problems faced due to lack of proper curing. SelfCuring concrete is an alternative to conventional concrete in desert regions where scarcity of water is a major problem. Guru et al (2013) have investigated on the cost effective SCC design for M25 grade for normal building construction. The normal strength concrete with desired strength, quality, cost and durability of SCC was developed by replacing 35% of fly ash (class F) replaced for cement content. They tried with three different SCC of different paste percentage (36.0, 37.7 and 38.8%) with that of normal M25 grade concrete. In this study they used 60 and 40% coarse aggregate size of 20 and 10 mm respectively. The paste percentage of 38.8% only attains the requirements of fresh concrete properties, and the compressive strength also increases to that of normal concrete. The cost of SCC is little higher than that of normal concrete but while considering labour cost, time and quality the SCC gives economical. Nikbin et al (2014) have studied an extensive evaluation and compared the mechanical properties of SCC between current international codes and some predictive equations proposed by other researchers. In this experimental study the mechanical properties of sixteen SCC mixes with different w/c ratio and different powder content are studied. When w/c ratio from 0.35 to 0.7 the compressive strength decreased by 66%, the modulus of elasticity decreased by 44% and the tensile strength also decreased by 51%. The relation proposed by Abrams can predict the compressive strength, based on w/c ratio. Tomasz and Jacek (2014) have investigated on the influence of high-calcium fly ash (HCFA) on the fresh and hardened properties of self-compacting concrete and high strength concrete. Up to 30% of HCFA was used as an additive for concrete or as a main constituent in cement. They studied and confirmed that the possibility of HCFA use in SCC, while assuming the fresh concrete properties and compressive strength of SCC. In this present study the benefits of both selfcompacting and self-curing are combined. The main objectives of the investigation are as follows.

A. To study the compressive strength of Self-curing Concrete (SC) by varying the percentage of PEG from 0.5% to 2.0% by weight of cement for M25 grade of concrete.

B. To study the flowability properties of SCC with 30% of fly ash (class C) and superplasticizer

C. To compare the mechanical properties such as compressive strength and split tensile strength of SCSCC with that of conventional concrete at 7 and 28 days

D. To investigate the structural behavior of SCSCC by conducting tests on beam-column joint

2. Experimental Investigation

2.1. Materials Used

The materials used in this study are ordinary Portland cement of 53 grades conforming to IS: 8112, manufactured sand, locally available coarse aggregate of maximum size 12.5mm, Class C fly ash, high range water reducing admixture Glenium B233, Internal curing chemical PEG 400 and potable tap water. The specific gravity of cement, fly ash, fine aggregate (F.A) and coarse aggregate (C.A) are 3.15, 2.30, 2.71 and 3.02, respectively. The chemical properties of cement and fly ash are shown in Table 1.

Table 1.*Chemical Properties of Cement and Fly ash*

Constituents/ Material	Cement	Fly ash
SiO2	19.79	35.4
Al2O3	5.67	17.5
Fe2O3	4.68	5.3
CaO	61.81	26.1
MgO	0.84	4.6
SO3	2.48	2.8

2.1.1. Concrete Mix and Casting of Concrete Specimens

The mixing and compacting of concrete are done according to IS 516: 1959 and casting of the specimens is done as per IS:10086-1982. The conventional cubes are cured for 7 and 28 days in water pond and the specimens with PEG400 are cured for 7 and 28 days at room temperature. The mix of M25 for Conventional, Self-Curing and SelfCompacting Concrete is designed and the material required per cubic meter of concrete is shown in Table 2. The PEG400 @ 0.5%, 1%, 1.5% and 2% by weight of cement is added for the Self-Curing Concrete.

Table 2.*Mix Proportions of Concrete Materials*

Mix	Cement (kg/m3)	Fly Ash (kg/m3)	F.A. (kg/m3)	C.A. (kg/m3)	Water (kg/m3)	Admixtures
Conventional Concrete	384	-	636	1138.8	192	-
SC	384	-	636	1138.8	192	0.5, 1.0, 1.5, 2.0% PEG
SCC	315	135	850	1030.2	196	0.6% Glenium B233
SCSCC	315	135	850	1030.2	196	0.6 Glenium and 1.0% PEG

2.1.2. Casting of Beam-Column Joint

One of the objectives is to know the performance of the developed SCSCC at the region of congested reinforcement i.e at the beam-column joint. Therefore two beam-column joints are casted; one with conventional concrete and another with SCSCC. The reinforcement details are shown in Fig. 1. The casted beam-column joints are de-moulded after 24 hours, the beam-column joint with conventional and SCSCC are kept in water pond and room temperature for curing, respectively.

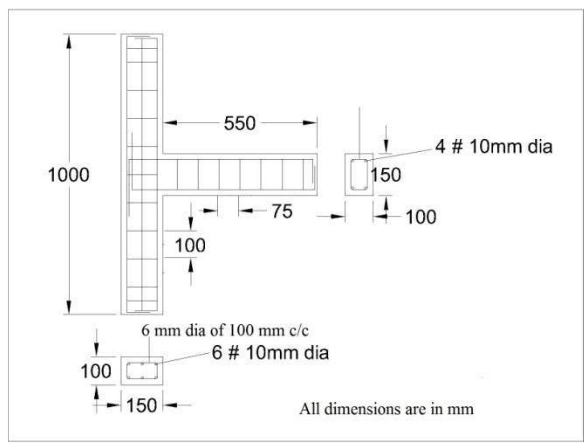

Fig. 1.*Reinforcement detail of Beam-Column joint*

3. Results and Discussion

3.1. Fresh Properties of Self-Compacting Concrete (SCC)

The fresh property tests such as slump flow test, T50 slump flow in sec, U – box test, V- funnel and L-box

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test are conducted and the results are compared with the requirements as specified in EFNARC-2005.

The comparison is given in Table 3 and it is observed that the concrete with 0.6% Glenium B233 shows appreciable self-compaction performance.

Table 3.*Fresh Properties of SCC*

Test Methods	Unit	Test Results	Typical range of values (As per EFNARC-2005)	
			Min	**Max**
Slump flow	mm	670	650	800
T50 cm Slump flow	sec	5	2	5
V – funnel test	sec	6	6	12
U – box test	mm	10	0	30
L – box test	h2/h1	0.87	0.8	1.0

3.2. Compressive Strength of Self-Curing Concrete (SC*)*

Compression test is conducted using compression testing machine of capacity 100 T. The 7 and 28 days compressive strength obtained for the various mixes of Conventional, Self-curing Concrete with 0.5%, 1.0%, 1.5%, and 2.0% replacement of PEG is shown in Fig. 2. It has been found that 1.0% replacement of PEG 400 for SC shows higher strength and is taken as optimum dosage for making SCSCC.

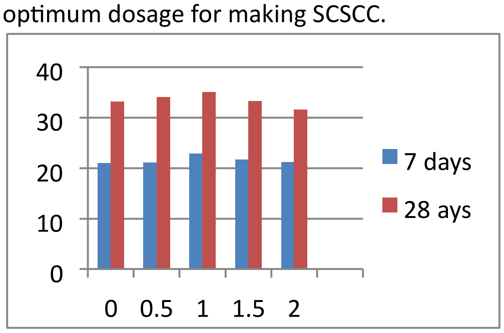

Fig. 2.*Compressive strength of Self-Curing Concrete*

3.3. Compressive Strength of SCSCC

The compressive strength of SCSCC with 0.6% Glenium and 1.0% of PEG is found at 7 days and 28 days curing and is shown in Fig.3. The compressive strength of SCSCC with fly ash and M sand proves to be equivalent to the conventional concrete.

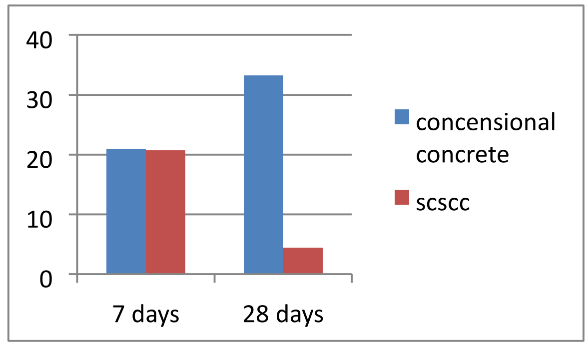

Fig. 3.*Compressive strength of conventional and SCSCC*

3.4. Split Tensile Strength of SCSCC The split tensile strength of the conventional and SCSCC mix at 7 and 28 days curing is shown in Fig.4. It can be seen that the SCSCC can take equal split tensile strength as the conventional concrete.

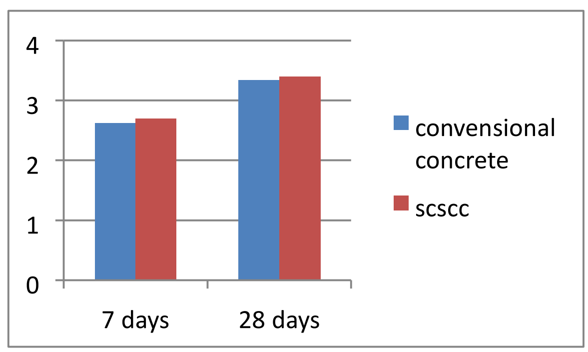

Fig. 4.*Split tensile strength of conventional and SCSCC*

3.5. Rebound Hammer Test on Beam-Column Joint

It is one of the most popular non-destructive testing methods used to investigate the compressive strength of concrete. In this study the rebound hammer test is conducted in the horizontal position at 5 different locations in the beam-column joint. Fig.5 shows the locations for the typical measurement of concrete strength using rebound hammer. The compressive strength obtained at different locations are given in Fig.6 and it is found that the compressive strength of SCSCC is equal to that of conventional concrete which means that the SCSCC is well compacted without vibrators.

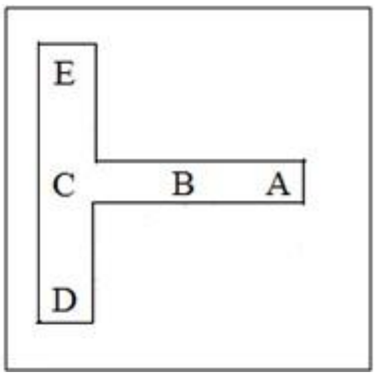

Fig. 5.*Locations for non-destructive testing*

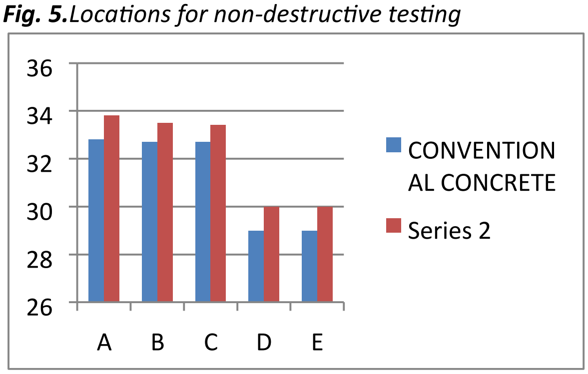

Fig. 6.*Compressive strength of Beam-Column joint using rebound hammer*

3.6. Ultrasonic Pulse Velocity Test on BeamColumn Joint

Ultrasonic Pulse Velocity (UPV) testing of concrete is based on the pulse velocity (PV) method. It provides information on the uniformity of concrete, cavities, cracks and defects. The PV in a material depends on its density and its elastic properties which in turn are related to the quality and the compressive strength of the concrete. The UPV test is conducted at various locations of beam-column joint as in the case of rebound hammer test. The test results as shown in Fig. 7 are compared with IS-13311(part 1):1992 which reveal that the concrete with and without vibrations is of good quality. Therefore it is proved that the developed SCSCC is well sound in terms of quality and strength.

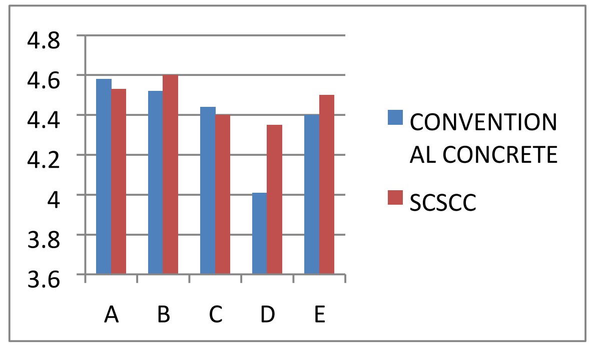

Fig. 7.*Pulse velocity test results*

3.7. Destructive Test on Beam-Column Joint

The destructive test on beam-column joints is carried out in a loading frame of capacity 200kN as shown in Fig.8 and the monotonic loading is applied at the end of beam. Both the ends of the column are fixed in the loading frame. Using *Linear Variable Differential Transducer* (LVDT) the displacement corresponding to the load is noted. Load versus displacement behavior of normal and SCSCC is shown in Fig.9. It is observed that the ultimate load carrying capacity of normal and SCSCC beam column joints are 7.7 and 7.8 kN, respectively. The displacement of the normal and SCSCC beam column joints are 25.1 and 19.8 mm, respectively. The load carrying capacity of beam-column joint with SCSCC is 25 % more than that of conventional concrete beamcolumn joint and the displacement is reduced around 25 % in SCSCC specimen. It is also interesting to note that the initial stiffness of the specimen with SCSCC is nearly four times greater than the conventional concrete beam-column joint.

Fig. 8.Testing on Beam-Column joint

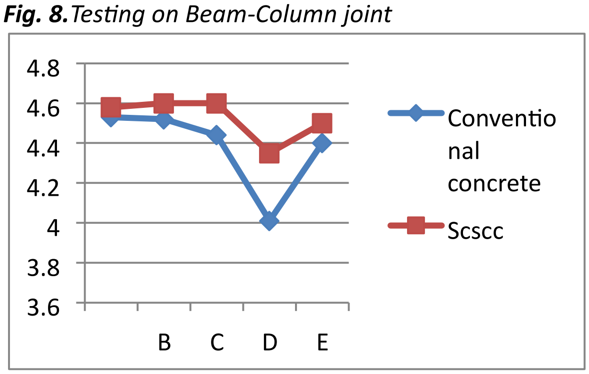

Fig. 9.Load versus Displacement behaviour of BeamColumn joint

4. Conclusion

The following conclusions are drawn based on the experimental results.

1. The optimum dosage of the self-curing admixture PEG 400 is found as 1% by weight of cementitious material for M 25 concrete.
2. The fresh properties of SCC yield satisfactory results as per EFNARC and can be used in structural components.
3. The compressive and split tensile strength of SCSCC is found to be 3 % and 2 % higher than that of conventional concrete.
4. The quality and compaction capability of SCSCC beam-column joint obtained from ultrasonic pulse velocity and rebound hammer tests is found to be on par with conventional concrete.
5. The destructive tests on SCSCC beam-column joint shows better behaviour than the conventional concrete joint. The initial stiffness of the specimen with SCSCC is nearly four times greater than the conventional concrete beam-column joint.
6. The usage of industrial wastes such as fly ash and M sand in SCSCC helps in reducing the demand for conventional concrete materials and making the concrete eco-friendly.

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