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Original Research Paper

Experimental Study on Self Compacting Concrete (M25) with 25% Fly ash Incorporating 10% Replacement of Coconut-Shell as Coarse Aggregate

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ABSTRACT

This paper aims to focus on the possibility of using 10% of coconut shell aggregate (CSA) replaced for coarse aggregate in self compacting concrete (SCC) containing 25% fly ash (FA) prepared using additives of super plasticizer and viscosity modifying agent. The SCC with normal aggregate containing FA 25% is taken as (SCC), a reference and in the same mix, 10% of coconut shell aggregate is replaced for coarse aggregate. The fresh and hardened properties in both the SCC (M25) and SCC-CSA are studied in laboratory experiments. The possibility of potential use of coconut shell being one of the major agro-wastes in South India, as partial replacement of coarse aggregate in making a special concrete such as SCC-FA-CSA in structural component is verified and discussed. The research encourages potential use of the agro-waste known as CSA. It instantaneously reduces the consumption of normal natural stone aggregates apart from serving as a means of combining the CSA with abundantly available fly ash from thermal power stations and in turn help protect our mother earth and its environment by the precious minimised use of normal aggregate.

INTRODUCTION

Self compacting concrete: Self compacting concrete as indicated by name itself, has easy flowability without any vibrating gadget or any other means to compact it. One SCC mix is essentially to possess good passing ability, filling ability and at the same time releases air voids without any segregation. Because every basic material of concrete has got its own specific gravity, to offer very uniform mix with desired flowability, a careful design proportion is inevitable. It is known that in a green mix of concrete larger aggregates will have a tendency of settling down at lower strata by adapting itself as layered rack instead of being a homogenous flowable fluid. So, for the property of flowablity, higher powder content and super-plasticizers known as high range water retarders either with or without viscosity modifying agents are required. The addition of such water reducing agents, may often lead to substantially sensitive or stiff concrete mix. Those sensitive mixes are then highly prone to objectionable segregation of basic ingredients in places where redundant vibration is effected. Viscosity is an important property of concrete, it is taken care by the addition of VMA, which keeps the concrete suspension and also clears off the segregation effects. The fundamental principle underlying in preparing SCC is that by increasing the viscosity, sedimentation velocity of flowing particle is reduced. VMA in SCC offers larger shear resistance to the static contents rather than the one in motion. Structures like large span bridge components, off shore structures, etc., piers in the form of concrete filled tubes need to be provided with SCC.

Earlier studies: Hajime Okamura et al. (2003), established the rational mix-design methods proportioning coarse aggregate and mortar as 50% and 40% respectively of the total aggregate volume. Wenzhong Zhu et al. (2003) tested SCC and normal vibrated concrete of each cube strength of 40MPa and 60MPa on permeation properties and concluded that SCC mix using viscosity agent to maintain stability of the fresh mix had the highest permeability, sorptivity and chloride diffusivity. Brouwers (2005) analysed the combinations of three sands, gravel, SP and slag blended cement resulting in lowest powder (cement, lime stone powder) content and concluded that the use of plasticizer could be limited to 1% of powder content, and the use of viscosity modifying agent could be avoided. Mustafa Sahmaran (2006) having evaluated the effectiveness mineral additives among fly ash (FA), brick powder (BP), lime stone (LS), kaolinite (K) and also chemical admixtures of three super plasticisers (SP) and two viscosity modifying agents (VMA), concluded that the use of FA and LP improved workability and fly ash increased the setting time of mortar. Domone (2006) conducted a case study of almost all published research reports from 1993 to 2003 which reflected the geographical progression of SCC and its applicability to almost all types of construction, and reported that 90% of the cases used

SCC with slump flows in the range 600-750mm, 80% had compressive strengths in excess of 40Mpa, 70% of cases used 16mm to 20mm aggregate, 41% cases used the limestone and 50% used viscosity modifying agent (VMA) in addition to super-plasticiser. The mixes with VMA were considered as more robust mixes than other mixes. Burak Felekoglu (2006) carried out studies on five mixtures with various water/cement ratios and super-plasticizer dosage and brought out that the optimum water/cement ratio for SCC as 0.84-1.07 by volume. The author also found that higher splitting tensile strength and lower moduli of elasticity for SCC mixtures compared to the vibrated concrete. Suresh Babu (2008) investigated on glass fibre reinforced SCC (GFRSCC) and stated that 97% addition of glass fibre has shown higher compressive strength. The split tensile strength increased up to 20%. 30% energy absorption increased by the addition of glass fibres, and ductility improvement obtained at 21% to 27% at 90% to 70% stress levels. The author also arrived at an empirical equation for stress strain responses for SCC, $Y=Ax/1+Bx^2$ where A=2, B=1 for ascending and A=2.24 and B=1.24 for descending portion and that for GFRSCC A=2.61, B=1.61 for ascending and A=1.78, B=0.78 for descending portion of the stress strain curve. Valcuende et al. (2009) tested on eight different concretes including four self-compacting concrete (SCC) and four normally-vibrated (NVC), and concluded that for moderate levels, SCC performs a stiffer behaviour than NVC. Mucteba Uysal et al. (2011) experimented with one control mix and nine mixtures with mineral admixtures by keeping water binder ratio of 0.33, and concluded that among the addition of LP, BP and MP, MP had positive effects on workability and compressive strength. The author also declared that the reduction in cost was approximately 0.1$/MPa/$M^3$ for MP30 among the tested series. Ramanathan et al. (2013) experimented on strength aspects replacing mineral admixtures by 30%, 40% and 50% for Portland cement, and obtained higher compressive strength for silica fume series and 30% replacement of mineral admixtures for Portland cement as optimum for both flowability and mechanical properties. The author also concluded that slump flow test satisfies the robustness and optimum water powder ratio was 0.35 by weight.

MATERIALS AND METHODS

Scope: Researchers extend their work in verifying agricultural wastes such as shell of various dry fruits, rice husks, wheat husk, straws and hemp fibre etc., to prepare several types of modern concrete. There lies a vast choice in identifying and preparing modern bio-based construction materials (Agunsoye et al. 2012). Environmental concerns created a thrust in search of environment friendly materials. Annually, approximately 33 billion coconuts are harvested worldwide (Monteiro et al. 2008), which can reduce this kind of environmental pollution and enhance the efficiency of using natural resources.

Even though SCC was developed more than three decades ago, a basic knowledge on the property and comparative data on using locally available materials, especially with agro waste like coconut shell in SCC as aggregate replacement is uncommon from the literature. Moreover, similar to the other industry, agricultural industry is a major industry in India, wherein the coconut shell is plentiful in South India; especially in Kerala, Tamilnadu, Andra and Karnataka States.

Hence, in this paper SCC normal mix and SCC mix with 25% of fly ash along with 10% of coconut shell aggregate were prepared. The fresh and hardened concrete properties of them were tested and reported. The viability study for preparing SCC and put it in structural use, to help hand in solid waste management and also to protect nature and environment is aimed at. The effects of direct replacement of normal aggregate with 10% coconut shell aggregate is studied in SCC grade M25 containing 25% fly ash in addition to the super-plasticiser and viscosity modifying agent available in local market.

Materials Used

Fine aggregate: Sand conforming to Zone-III was used as the fine aggregate, as per IS: 383-1970. The sand was air dried and free from any foreign material, earlier than mixing. Its properties are given in Table 1.

Coarse aggregates: Crushed granite of size 12 mm and

Table 1: Fine aggregate properties.

Physical property	Test result
Fineness modulus	2.42
Specific gravity	2. 44
Bulk density (kg/m^3)	1517-1620
Water absorption (%)	0.80

Table 2: Coarse aggregates properties.

Physical property	CSA	Normal
Maximum size (mm)	12	12
Fineness modulus	6.26	7.1
Specific gravity	1.53	2.65
Bulk density (kg/m^3)	512-612	1465-1610
Water absorption (%)	22.7	0.10
Aggregate crushing value (%)	2.38	16.40
Aggregate impact value (%)	8.52	10.91
Moisture content (%)	4.18	-
Coconut shell thickness (mm)	3.2 to 4.5	-

a. Breaking b. Broken c. Mixing

Fig. 1: Coconut shell preparation.

a. Flowability b. Casting c. Compression

Fig. 2: Fresh and hardened tests self compacting concrete with 25% fly ash and 10% CSA.

down coarse aggregate as well as broken coconut shell (CSA) passed through 12mm sieve were used. Essential properties of both the aggregates are given in Table 2.

Cement: Ordinary Portland cement conforming to IS: 8112 has been used. Fly ash from Mettur thermal power plant has been used for this study. Fly ash conforms to the requirements of IS: 3812 Part-1. Coarse aggregate from quarry located at Kanuvai in size of 12mm and down conforming to IS: 383 has been used.

Water: Potable tap water was used for preparing the concrete.

Admixtures: Super-plasticizer and viscosity modifying agents available in the market names of Conplast SP 430 and Gelenium stream 2 were used. The mix proportion is presented in the Table 3.

Coconut shell aggregate (CSA): Coconut shell widely available in Coimbatore was collected from residential hostels, hotels, etc., cleaned dry and broken manually (Figs. 1a and 1b).

Advantages of CSA: Less in weight than normal aggregate and it is strong. The use of this CSA can on one side solve the demand of natural stone chips, and on the other side it can help creating environmental awareness. Overall cost reduction is possible where aggregate is not available in bulk.

Preparation and casting: The mix design was made based on EFNARC (2005) guidelines. By the several trial mixes with the basic ingredients and WRA and VMA, a standard ratio was obtained for SCC (M25) with FA 25% as powder content. The Coconut shell was immersed in water for 24 hours before use to avoid its water absorption. The measured quantities of all the items by weight basis were mixed by hand in dry, and then coconut shell was added as in Fig. 1c. After thorough dry mixing up to uniform colour, water was added and mixed. The WRA was added after ensuring around 75% of mixing is over, to avoid the mix becoming stiff. Then the cubes, cylinders and beams were cast in the standard moulds.

a. Tested cube b. Split cylinder

Fig. 3: SCC-CSA tested samples.

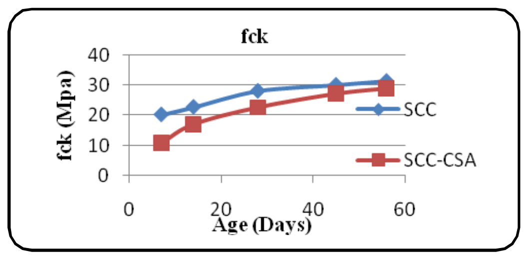

Fig. 4: Compressive strength of SCC and SCC-CSA.

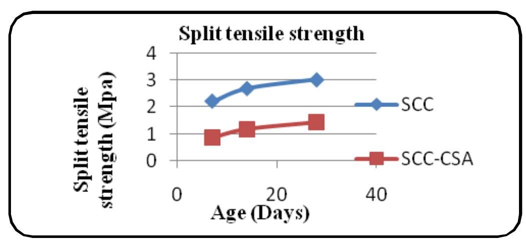

Fig. 5: Split tensile strength of SCC and SCC-CSA.

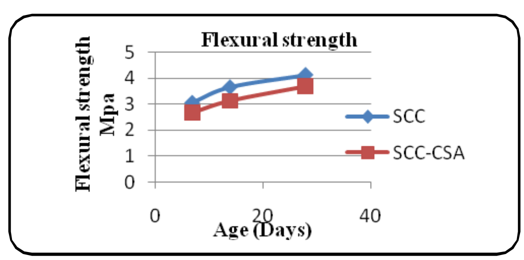

Fig. 6: Flexural strength of SCC and SCC-CSA.

Table 3: Mix design-M25 (per m^3).

Mix	Cement (in kg)	Fine aggregate (in kg)	Coarse aggregate (in kg)	Fly ash (in kg)	VMA (% of powder content)	WRA (% of powder content)	Water (in kg)	W/Cm (Cm=C+FA)
SCC	573.6	756	775	152.25	0.30	5.5	304.82	0.42
SCC-CSA	573.6	756	697.5 + (CSA*) 77.5	152.25	0.30	5.5	306.00	0.42

* Coconut shell aggregate

Table 4: Details of fresh concrete properties of SCC mixes.

Tests	To study	EFNARC-Guidelines	SCC	SCC-CSA
Slump flow	Filling Ability	650-750	670	600
T50 Slump flow (sec)	Filling Ability	2-5	3	4.2
V- funnel (sec)	Viscosity	6-12	8	10
L- box : H2/H1	Passing Ability	0.8-1.0	0.9	0.93
U- box: H2-H1 (m)	Passing Ability	0-30	25	27

Table 5: Compressive strength of SCC and SCC (CSA)-M25 at different ages.

Age (Days)	7	14	28	45	56
SCC	20.17	22.69	28.02	30	31.3
SCC-CSA	10.66	16.96	22.6	27.2	29

Table 6: Split Tensile strength of SCC and SCC (CSA)-M25 at different ages.

Age (Days)	7	14	28
SCC	2.21	2.69	3.02
SCC-CSA	0.84	1.17	1.42

Table 7: Flexural strength of SCC and SCC-CSA-M25.

Age (Days)	7	14	28
SCC	3.05	3.65	4.12
SCC-CSA	2.67	3.14	3.71

RESULT AND DISCUSSION

Properties of Concrete in Fresh State

Slump flow: Slump flow for the concrete mix of SCC (CSA) is shown in Fig. 2a. Details of fresh concrete properties of SCC and SCC (CSA) mixes are as given in Table 4, which satisfies the requirement of European standards.

The 150mm size cubes were filled with fresh concrete as in Fig. 2b. Compression tests were made as shown in Fig. 2c and the results with respect to ages are given in Table 5. The cube concrete tested is shown in Fig. 3a. A graph showing the compressive strength Vs age (days) is presented in Fig. 4. The split tensile tests were made and tested cylinder is shown in Fig. 3b, and the results are presented in Table 6. A graph showing split tensile strength with respect to age (days) is presented in Fig. 5. Flexural strength tested is given in Table 7 and a graph showing the flexural strength with age (days) is presented in Fig. 6.

As far the fresh properties are concerned, both the mixes show acceptable results. In view of the hardened properties, referring to Fig. 4, unlike the normal SCC mix, the SCC-CSA meets the strength requirements of grade M25 at later age, that is after completion of 15 days beyond 28 days. This may be because of the weight based batching, by which for equal weight of coarse aggregate, the volume of CSA will become more compared to the former. This will result in larger surface area, and in turn demand slightly more water content to wet the surfaces to demand more cement slurry to stick with inter-particle bonding. However, there is a positive sign of utilizing the 10% CSA for replacement of normal aggregate in SCC mix, with a limitation that adequate age is maintained for acquiring the designed strength, especially in the SCC where FA, WRA and VMA are used. There is a notable reduction of split tensile strength observed and its reduction from 7 days to 28days is obvious; but, for its growth and results at still longer age, further tests may be necessary. The flexural strength is moderately reduced compared with normal SCC.

CONCLUSION

Within the scope of this paper, the following conclusions can be drawn: The SCC and SCC-CSA (10%) mixes containing fresh properties as per EFNARC guidelines, have satisfied the norms. From this, it can be concluded that achieving fresh SCC properties is possible by incorporating 10% CSA replacement of normal aggregate in SCC. In comparing compressive strength of SCC-CSA and SCC with respect to age, the SCC-CSA has initial strength and final at 28days, lower for around 40% and 20% lesser. However, the SCC-CSA gains the designed compressive strength 15 days after the completion of 28 days of curing. Hence, SCC-CSA concrete when used must be given enough time allowance for the concrete to attain the strength especially when the SCC has fly ash content in addition to WRA and VMA. The Split compressive strength of concrete SCC-CSA is also observed to be lesser than that of the SCC. The flexural compressive strength of SCC-CSA is marginally lesser than that of the SCC. Thus, SCC-CSA with 10% replacement of aggregate resulting in light weight is found feasible for structural use. This study eventually encourages the potential use of a natural material CSA and fly ash being a waste material from thermal power stations causing solid waste disposal, in structural use and hence, would serve to maintain cleaner environment and help protect the nature.

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