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Experimental Investigations on Lightweight self-compacting concrete produced with Sintered fly ash aggregate

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Abstract— **The present research work explores the use of sintered fly ash aggregate (SFA) as a partial replacement to natural coarse aggregate (NCA) for the development of sustainable structural lightweight concrete (LWC). In this regard, the natural aggregates are partially replaced by the sintered fly ash aggregates, i.e.,0%, 10%, 15%, 20%,25% and 30% of its volume. To find out its performance, In the present research work, 40MPa concrete has been prepared and performed the Mechanical properties (such as Compressive strength and split tensile strengths) and Durability properties (like water absorption test and permeability) Based on the obtained results, The 20% of sintered fly ash aggregates based LWSCC has got higher strength (i.e., 56.88MPa) than others mixes, which was considered as optimum mix in the present research work. However, 20% sintered fly ash aggregates replaced mix has high strengths and durability performance.**

Keywords— **Chloride ions permeability, compressive strength, Lightweight Self-Compacting Concrete, Sintered fly ash aggregate, Workability.**

I. INTRODUCTION

Concrete is one of the most widely used building materials in modern constructions and infrastructures needs. Lightweight self-compacting concrete aims to combine the benefits of both Lightweight concrete (LWC) and Self-Compacting Concrete (SCC), which can offer engineers greater freedom when it comes to designing efficient concrete structures with respect to project cost and time. Self-compacting concrete (SCC) does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement, without segregation of material constituents. In plain concrete, there is a weakness due to the presence of microcracks in the motor–aggregate interface. It is used as a construction material because it can be moulded into any structural form and shape. The density of regular concrete ranges from 2200 to 2600 Kg/m3. Self-weight occupies a huge load coming on the structures critically in weak soils and tall structures. Lightweight concrete plays a major role in reducing the density of concrete. It is used worldwide in many construction projects where the soil is weak and heavy constructions are to be done, and Lightweight concrete density varies from 300 to 1800Kg/m3. LWSCC can be produced by using lightweight materials like sinter fly ash aggregate, Lightweight Expanded Clay Aggregate, Pumice stone, expanded shale, Perlite etc.

II. LITERATURE REVIEW

Okamura and Ouchi, 1998 [1]: Self-compacted concrete was developed in 1988 to achieve compaction without vibrations. Such that the author started the investigation for establishing rational method mix design. It is concluded that the rational mix design method is suitable for SCC at the work site. By using this method, we can analyse and introduce new structural design techniques.

Nan Su, Kung-Chung Hsu, His-Wen Chai, 2001 [2] proposed a new mix design method for self-compacting concrete (SCC) called NAN SU Method. The amount of aggregates, binders and mixing water, as well as type and dosage of superplasticizer (SP) to be used, are the major factors influencing the properties of SCC. Slump flow, V-funnel, L-box, 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 successful SCC of high quality. They introduced the Packing Factor (PF) of aggregate which is defined as the ratio of mass of aggregate of tightly packed state in SCC to that of loosely packed state.

Thomas Paul, Habung Bida, Bini Kiron (2016) [3]: Study was to determine and compare the differences in properties of normal concrete, SCC with steel fibres at different proportions. The experimental investigation was carried out to study the compressive strength, flexural strength, split tensile strength of steel fibres reinforced concrete containing fibres of 0%,0.4%, 0.8%, 1.2% volume fraction of end hooked steel fibres. Steel fibre of aspect ratio 75 was used. The result data obtained has been analyzed and compared with a specimen having 0% steel fibre. The workability of SCC is significantly reduced as the fibre dosage rate increases. The research paper proposes that due to these properties of steel fibre reinforced self-compacting concrete, it can be used at places where compaction is not possible and for the design of curvilinear forms.

Siddharth Anand, Mohammad Afaque Khan, Abhishek Kumar (2016) [4]: Addition of Steel fibre at a certain limit improve compressive strength and not only suppress the formation of cracks but provides more strength. Steel Fibers have been added to the hardened state. Fibre-reinforced concrete becomes necessary whenever durability that is limited crack widths or safety considerations are design criteria. Compressive strength increases with the increment of steel fibre in SFR-SCC. Workability slightly decreases with an increase of steel fibre in SFR-SCC. Flexural strength increases with the increment of steel fibre in SFR-SCC. Tensile strength increases with the increment of steel fibre in SFR-SCC 5. Self-compacting concrete is simple and user friendly.

S. Ramesh Reddy,I.Krisharchana, Dr V.Bhaskar Desai (2017)[5]: an attempt is made to prepare ions material lightweight concrete by replacing 100% natural aggregate with sintered fly ash aggregates and also to use cement with partial replacement of cement (11%) with three numbers of pozzolanic materials like silica Fume, Slag and Fly ash in equal proportions along with varying percentage of Nano Aluminium Oxide at 0,0.5,1,1.5 on 11% of cement. The target mean strength of M20 concrete is 26.6N/mm2. This modified concrete rises to 42.80N/mm2. Increase in flexural strength and young's modulus when increased up to 1% of Nano Al2O3. Cement consumption is reduced by 11%, and sintered fly ash aggregate can be used as coarse aggregate

Dilip Kumar, Arvind Kumar, Ashish Gupta (2014) [6]: In the present study, A mix design has been done for M25 Grade of concrete by IS method. Ordinary Portland cement of 43 Grade is selected, and sintered fly ash aggregates were prepared by mixing them with cement and water to make low-cost concrete, which is a waste material of coal firing Thermal power plants (TPPs) and its accumulation near the power plant. In this paper, the author investigates the concrete's Compressive Strength and Flexural strength test at 28 days. Sintered Fly Ash Aggregates were replaced 10%, 20%, 30%, 40% and 50% in the place of Corse aggregate. Its utilization as a raw material for the cube (Brick) making will be a useful solution in our economic and environmental aspects. The maximum compressive strength of 43.12N/mm is found at 30% replacement of Sintered fly ash aggregate in concrete while the minimum strength of 26.24 N/mm is found at 50% replacement of Sintered fly ash aggregate in concrete, at 10 % replacement, increased the value 37.98 N/mm and 30% increased the value 43.12N/mm the highest increased the value. The maximum flexural strength9 of 11.16 N/mm is found at 30% replacement of Sintered fly ash aggregate in concrete. In comparison, the minimum strength of 2.10 N/mm was attained at 50% replacement of Sintered fly ash aggregate in concrete. To increase the speed of construction, enhance the green construction environment, we can use lightweight concrete. The possibility exists for the partial replacement of coarse aggregate with Sintered fly ash aggregate to produce in thermal power plants waste materials.

III. MATERIALS AND METHODS

A. Materials

The present work used Type I cement conforming to ASTMC150-19 [7]. The specific surface area of cement was 330 m^2/kg, evaluated by Blaine's air permeability method, and the specific gravity of cement was 3.12, assessed according to IS 4031-1996 [8]. Class-F fly ash was used for the preparation of sinter fly aggregates, which was procured from the Indian mart ltd. The crushed granite stones of 20 mm well-graded were used as coarse aggregates (CA), and natural river sand was used as fine aggregates (FA) conformed to Zone-II as per IS 383:2016 [9]. Table I represents the properties of aggregates. Superplasticizer was used as a high-water reduction agent; sulfonated naphthalene-based polymers, according to ASTM C 494:2019 [10]. Table II represents the chemical composition of cement and fly ash.

TABLE I
PHYSICAL PROPERTIES OF AGGREGATES

Property	Fine aggregates	Coarse aggregate
Fineness modulus	2.83	6.41
Specific gravity	2.59	2.43
Bulk density	1570 kg/ m3	1420 kg/ m3
Water absorption	1%	0.6%

TABLE II
CHEMICAL COMPOSITION OF CEMENT AND FLY ASH

	Cement	Fly ash
Cao	65.29	3.37
Al2O3	4.73	26.12
Fe2O3	3.95	4.7
SiO2	20.93	59.05
Na2O	0.29	0.41
MgO	1.43	1.25
K2O	0.36	0.83
TiO2	-	0.81
Others	3.02	3.46

B. Sintered fly ash aggregates

Sintered fly ash lightweight aggregate substitutes natural stone aggregate in concrete, reducing dead weight. The sintered fly ash aggregate concrete is spherical in shape, possessing 5-20 mm size and light grey colour. Water absorption is 15-20% in uncrushed material and 40-50% in crushed material; bulk density: 640-750 kg/m3, aggregate crushing strength: 5-8.5 t. Fig.1 shows size variations of sintered fly ash aggregates.

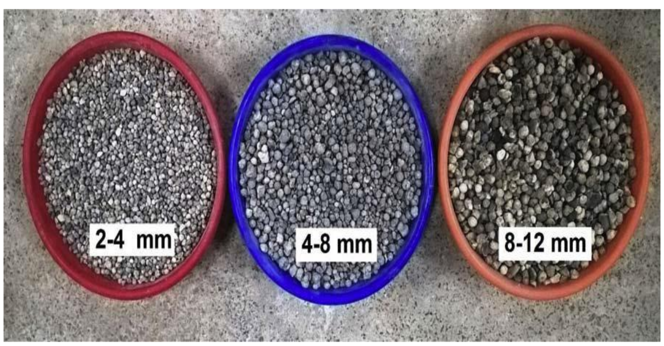

Fig. 1 Sintered fly ash lightweight aggregate samples of different sizes

C. Mix calculations

Table III represents the mix calculations of the present study prepared as per IS 10262-2019 [11]. The control mix was considered with 0% replacement of sintered fly ash aggregates, and further six mixes were considered with the level of replacement as 5%, 10%, 15%, 20%, 25% and 30% by volume of normal coarse aggregates.

TABLE III
MIX PROPORTIONS

Materials / Mixes		NWSCC	5SFCA	10 SFCA	15SFCA	20SFCA	25SFCA	30SFCA
cement		470	470	470	470	470	470	470
Fly ash		349	349	349	349	349	349	349
Fine aggregates		942	942	942	942	942	942	942
Coarse aggregates	NCA	700	666	617	595	549	526	480
	SFCA	0	9	18	27	36	45	54
Water		258	258	258	258	258	258	258
SP		11	11	11	11	11	11	11

D. Mechanical properties

The dimensions of the concrete cubes and cylinders used for compressive strength and split tensile strength measurements were 150 × 150 × 150 mm3 and 150 mm (diameter) and 300 mm (height) according to IS 516-2013 [12] and IS5816-1999 [13], respectively. The compressive strength of the concrete samples was measured using a compressive testing machine at a loading rate of 140 kg/cm^2/min. The split tensile strength was measured at a loading rate of 1.2 N/mm^2·min according to IS 5816-1999 [13]. All the samples were cured in regular water for the specified curing time of 28 days according to IS 9013-1978 [14]. The reported results are based on the average values of three samples.

E. Durability properties

As per IS 1124-1974 [15], water absorption test was performed; the specimens were dried in an oven for 105 ^{0}C for 72 h, later weigh the sample and considered it as dry weight (Wd). Further, the samples are immersed in water for 24 h to take the samples wet weight (Ww) after wiping the surface dry.

Samples prepared using sintered fly ash aggregates based on concrete mixes were subjected to the rapid chloride permeability test (RCPT) to evaluate the resistance of the concrete to chloride ion penetration. This test was conducted according to ASTM C1202 [16], and test samples 100 mm in diameter and 50-mm thick were sliced from a concrete cylinder of100 mm in diameter and 200 mm in height. The test samples were inserted between a 3% sodium chloride reservoir and a 0.3-M sodium hydroxide reservoir. A 60-V direct current was applied to the test sample for 6 h. The total charge passed through the concrete was measured in coulombs, and the degree of chloride ion penetration of the concrete was determined.

IV. RESULTS AND DISCUSSION

A. *Compressive strength*

Fig.2 shows the variations in compressive strength of lightweight self-compacting concrete when sintered fly ash aggregates are partially replaced in Normal coarse aggregates up to 30% of its volume was measured at 28days. The compressive strength of the controlled concrete specimen has shown 49.27MPa. The compressive strength has increased with increases in the replacement of sintered fly ash aggregates up to 20% in LWSCC. Whereas, the compressive strength increased 3.47% in 5SFCA, 8.91% in 10SFCA, 12.62% in 15SFCA, 15.45% in 20SFCA, 8.52% in 25SFCA and 5.64% in 30SFCA as compared to the control concrete mix. The complicated interplay between inferior SFA quality and superior interfacial transition zone (ITZ) features may account for the aforementioned strength difference [17].

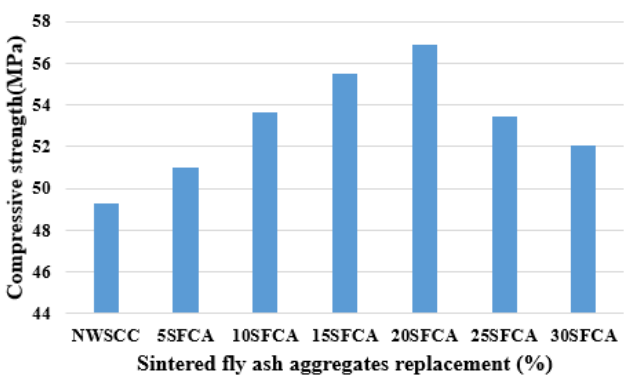

Fig.2 compressive strength of LWSCC

B. *Split tensile strength*

Fig.3 depicts the split tensile strength of sintered fly ash based lightweight self-compacted concrete. Based on the results, the replacement of sintered fly ash aggregates in the LWSCC has shown a positive effect on the split tensile strength of concrete. However, 20.32% of strength increment was observed in the LWSCC consists of 20% of sintered fly ash aggregates. Whereas 5.02MPa, 5.38 MPa, 5.59 MPa, 5.88 MPa, 6.04 MPa, 5.62 MPa and 5.4 MPa in NWSCC, 5SFCA, 10SFCA, 15SFCA, 20SFCA, 25SFCA and 30SFCA.

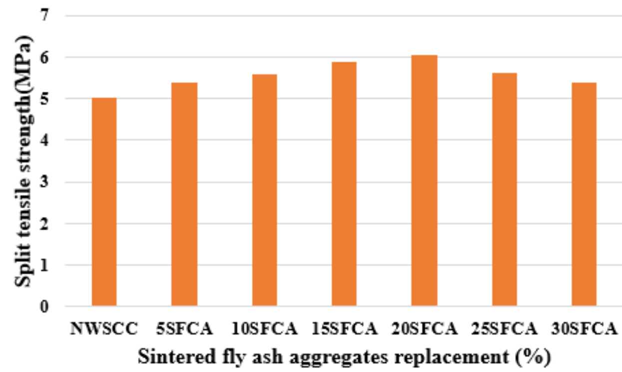

Fig.2 compressive strength of LWSCC

C. *Chloride ions permeability*

In the present research work, chloride ions permeability test has been conducted on sintered fly ash based lightweight self-compacting concrete and results are represented in Table IV. In the control concrete (NWSCC) 3030 Coulombs of charge has passed through it and which was confirmed moderate permeability as per ASTMC 1202-2016. Similarly, the remaining all mixes have shown moderate permeability except the 20SFCA mix. The sintered fly ash aggregates replaced LWSCC has the passage coulombs as follows; 2915 C, 2537 C, 2147 C, 1945 C, 2174 C and 2344 C.

Table IV

CHLORIDE IONS PERMEABILITY

Mix	Coulombs passage	Condition
NWSCC	3030	Medium
5SFCA	2915	Medium
10SFCA	2537	Medium
15SFCA	2147	Medium
20SFCA	1945	Low
25SFCA	2174	Medium
30SFCA	2344	Medium

D. *Water absorption*

Fig.3 shows the water absorption of sintered fly ash aggregates based on lightweight self-compacted concrete. More resistance was observed in the sintered fly ash aggregates replaced LWSCC against water absorption. However, 7.6% of water absorption has been observed in the control mix (NWSCC), but it was reduced to 4.1% in case of sintered fly ash aggregates are replaced at a level of 20%. The water absorption of sintered fly ash aggregates based lightweight self-compacting follows ; 7.07%, 6.5%, 5.12%, 4.1%, 4.98% and 5.87% in 5SFCA, 10SFCA, 15SFCA, 20SFCA, 25SFCA and 30SFCA.

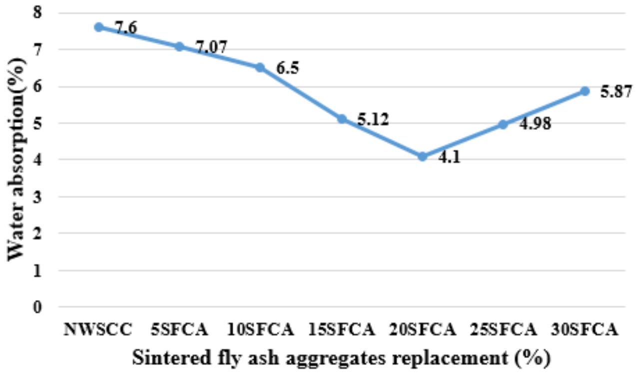

Fig. 3 Water absorption

V. Conclusions

In the present research, sintered fly ash aggregates are partially replaced in the normal coarse aggregates up to 30% of its volume to prepare the lightweight self-compacting concrete. In order to determine its performance, various fresh properties, mechanical and durability properties are evaluated. Based on the experimentation and results from the analysis, the following conclusions were made.

- The lightweight self-compacting concrete is greatly influenced by the sintered fly ash aggregates replacement in it.
- The flowability properties of LWSCC reduced with increases the replacement levels of sintered fly ash aggregates.
- The mechanical and durability properties are enriched with the replacement of sintered fly ash aggregates in LWSCC.
- The 20% of sintered fly ash aggregates based LWSCC has got higher strength (i.e., 56.88MPa) than other mixes, which was considered as optimum mix in the present research work.
- Similarly, low permeability was found in the 20% of sintered fly ash aggregates based on LWSCC. The charge passed through this mix is 1945C, and water absorption is 4.1%.

References

[1] Okamura, H. and Ouchi, M., 1998. Self-compacting high-performance concrete. *Progress in Structural Engineering and Materials*, 1(4), pp.378-383.

[2] Nan Su, Kung-Chung Hsu, His-Wen Chai, "A simple mix design method for self-compacting concrete", Cement and Concrete Research 31, January 17, 2001, pp. 1799– 1807.

[3] Thomas Paul, Habung Bida, Bini kiron, Shuhad A K, Martin Varghese, 2016. Experimental Study on Self Compacting Concrete with Steel Fibre Reinforcement. *International Journal of Science, Engineering and Technology Research*, 5(4), pp. 1166-1169.

[4] Siddharth Anand, Mohammad Afaque Khan, Abhishek Kumar 2016. Effect of Steel Fiber on Self-compacting Concrete: A Review. *International Research Journal of Engineering and Technology*,3(3), pp.507-510.

[5] S. Ramesh Reddy, K. Thejakala, V. BhaskaR Desai, 2017. A brief study on the strength properties of concrete modified with sintered fly ash aggregates and silicon dioxide (nano material), International Research Journal of Engineering and Technology, 4(3),pp.1500-1508.

[6] Dilip Kumar, Arvind Kumar, Ashish Gupta,2014. Replacement of Coarse Aggregate with Sintered Fly Ash Aggregates for Making Low Cost Concrete, *International Journal for Scientific Research & Development*,2(8),PP.307-310.

[7] ASTM C150/C150M-16e1 (2016) Standard specification for Portland cement. ASTM International, West Conshohocken, PA.

[8] BIS, IS 4031-I (1996) Specifications for method of physical tests for hydraulic cement. Bureau of Indian Standards, New Delhi.

[9] BIS, IS 383-2016 (2016) Specification for coarse and fine aggregates from natural sources for concrete. Bureau of Indian Standards, New Delhi.

[10] ASTM, ASTM C494 (2019) Standard specification for chemical admixtures for concrete. ASTM, West Conshohocken.

[11] BIS, IS 10262–2019 (2019) Specification for mix design guidelines for concrete. Bureau of Indian Standards, New Delhi.

[12] BIS, IS 516–2013, Specification for Method of Tests for Concrete, Bureau of Indian Standards, New Delhi, India, 2013.

[13] BIS, IS 5816–1999, Specification for Splitting Tensile strength of Concrete – Method of Test, Bureau of Indian Standards, New Delhi, India, 1999.

[14] BIS, IS: 9013–1978, Specification for Method of Curing of Concrete, Bureau of Indian Standards, New Delhi, India, 1978.

[15] BIS, IS 1124–1974 (1974) Specification for water absorption for concrete. Bureau of Indian Standards, New Delhi.

[16] ASTM C1202–19 (2019) Standard test method for electrical indication of concrete's ability to resist chloride ion penetration. ASTM, West Conshohocken.

[17] S.K.Patel, R.K.MajhiH.P.SatpathyA.N.Nayak.,2019. Durability and microstructural properties of lightweight concrete manufactured with fly ash cenosphere and sintered fly ash aggregate. *Construction and Building Materials*, *226*, 579-590.