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Influence of coarse aggregate properties on specific fracture energy of steel fiber reinforced self compacting concrete

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Abstract. Fracture properties of concrete depend on the mix proportions of the ingredients, specimen shape and size, type of testing method used for the evaluation of fracture properties. Aggregates play a key role for changes in the fracture behaviour of concrete as they constitute about 60-75 % of the total volume of the concrete. The present study deals with the effect of size and quantity of coarse aggregate on the fracture behaviour of steel fibre reinforced self compacting concrete (SFRSCC). Lower coarse aggregate and higher fine aggregate content in SCC results in the stronger interfacial transition zone and a weaker stiffness of concrete compared to vibrated concrete. As the fracture properties depend on the aggregates quantity and size particularly in SCC, three nominal sizes (20 mm, 16 mm and 12.5 mm) and three coarse to fine aggregate proportions (50-50, 45-55, 40-60) were chosen as parameters. Wedge Split Test (WST), a stable test method was adopted to arrive the requisite properties. Specimens without and with guide notch were investigated. The results are indicative of increase in fracture energy with increase in coarse aggregate size and quantity. The splitting force was maximum for specimens with 12.5 mm size which is associated with a brittle failure in the pre-ultimate stage followed by a ductile failure due to the presence of steel fibres in the post-peak stage.

Keywords: concrete fracture; steel fiber reinforced concrete (SFRC); self-compacting concrete; aggregates; concrete crack

1. Introduction

Concrete is the second largest consumed materials, and an enormous amount of research has been carried out commensurate with various practical applications. Concrete being a composite, heterogeneous and quasi-brittle material with multiphase characterisation, the failure mechanism of concrete is neither brittle as glass nor ductile as steel. The crack propagation is complex and mainly depends on component phases, bond between phases, internal micro cracks and material characterisation. The presence of internal flaws makes the concrete more vulnerable to macro cracks under service loads (Shah 1997, Giaccio and Zerbino 1998). Material failure of concrete depends on the energy dissipated to split and is quantified as the fracture toughness (Energy required per unit area of the crack surface to open) (Giaccio 1993, Zhang *et al*. 2016, Rama *et al*. 2017).

The fracture properties viz., fracture toughness, fracture energy, fracture process zone (FPZ) and characteristic length are influenced by material properties, specimen size, test method and test control parameters i.e., displacement or deformation control (Brühwiler and Wittmann 1990, Tasemir and Karihaloo 2001, Korte *et al.* 2014, Akay *et al*. 2016, Khalilpour *et al.* 2019). Usually, fracture properties for Mode I type of failure are evaluated by Three Point Bend Test (TPBT), Wedge Split Test (WST) and Uniaxial Tensile Test (UTT) (single notched and double notched plate test) (Østergaard and Olesen 2004, Xiao *et al.* 2004, Skarżyński and Tejchman 2016, Kumar *et al.* 2017, Reddy and Subramaniam 2017, Guan *et al.* 2018, Ince and Cetin 2018). The uniaxial tensile test procedure is time consuming and requires highly sophisticated equipment. The fracture properties obtained through UTT are affected by machine specimen interaction. Among these three tests, TPBT is the most widely used method for determining fracture properties on notched beams (RILEM FMC 50, 1985). But, the drawbacks with TPBT is that the test has to be executed under well controlled circumstances because the great extent of elastic energy stored in the sample can snap-back during loading; furthermore specimens are heavy and the influence of self weight on fracture properties is significant. Also, the test cannot be used to evaluate fracture properties of existing structures. All the limitations in UTT and TPBT can be overcome by WST method. The difference between TPBT and WST may be attributed to the dissimilar specimen size, shape and self weight, a diverse length of the fracture process zone a varying stress state near the crack and the potential storage of elastic energy during testing (Korte *et al.* 2014). WST was first recommended by Linsbauer and Tschegg (1986) and advanced by Bruhwiler and F.H. Wittmann Bruhwiler (1990). WST specimens involves standard cubes used for laboratory purpose or core samples obtained from existing structures. For determining fracture properties, the descending branch for a load- deformation curve plays a

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major role as it varies with the stability in test method. The wedge split test can be conducted with or without deformation control machine at a constant displacement rate (Shaowei *et al.* 2016). The crack development is very stable because of the compressive stress field at the crack tip and minimum amount of energy stored. The slope of the wedge contributes precise displacement control and the wedge angle multiplies the effect of vertical force transferred by the machine (Skoček and Stang 2008). Wedge split test method has been extensively used of late for fracture and fatigue studies of high strength concrete, fiber reinforced concrete and the numerical simulation can be done using ABAQUS (Sitek *et al.* 2014, González *et al.* 2018). With the experimentation using WST, the bilinear stress-crack opening relationship was determined through inverse analysis (Löfgren *et al.* 2008, Zhang *et al.* 2010a, Jin *et al.* 2014).

Many authors investigated the influence of CA size and volume on fracture properties of different types of concrete using TPBT. Zhang *et al*. (2010) noticed the increase in fracture energy and characteristic length with increase in coarse aggregate size. Beygi *et al*. (2014) observed that fracture energy calculated through work of fracture method (WFM) and size effect method (SEM) resulted an increase in fracture energy with the increase in aggregate size and volume. Ghasemi *et al*. (2018) concluded that for maximum size of 12.5 mm aggregate and for different steel fiber percentages SFRSCC exhibited better behaviour than 9.5 mm and 19 mm aggregate size in both WFM and SEM.

The best advantage of SCC can be achieved using higher content of fine particles (Okamura and Ouchi 2003, Zarrin and Khoshnoud 2016, Bideci *et al.* 2017, Djelloul *et al*. 2018). The occurrence of higher fine particles escalates the strength of ITZ resulting in path through aggregate leading to transgranular failure (Amparano *et al.* 2000, Zhang *et al.* 2010a, Cifuentes and Karihaloo 2013, Nikbin *et al.* 2014, Alyhya *et al.* 2016, Karamloo *et al.* 2016). Hence, The fracture properties of SCC needs to be investigated in view of the change in the size and CA/FA ratio which seems to be different compared to vibrated concrete. In view of limitation with TPBT, the fracture properties must be studied with a stable test method i.e., Wedge Split Test (WST) method.

2. Research significance

The internal flaws present in hardened concrete prior to loading proliferate to form macro cracks, which leads to fracture/failure of the member. Crack proliferation occurs through the weak zone and may occur in paste phase, aggregate phase or interfacial transition zone (ITZ) depending on the strength in each phase relative to one another. The inclusion of fibers in concrete arrests the crack propagation at ITZ, paste phase and converts the nature of failure from quasi brittle to ductile. Self compacting concrete, by virtue of its mix design contains higher fines concrete and strong ITZ compared to normal vibrated concrete. With these changes in material type, mix proportions, and/or addition of fibers, there would be a change in mechanical and specific fracture energy of self compacting concrete. As stated by (Bretschneider *et al.*, 2011) the specific fracture energy is effected by the ligament dimensions and aggregate sizes. For the present study two types of notches were adopted i.e., with and without guide notch to study the variation of the ligament dimensions. By considering the scant research on effect of aggregate on Steel Fibre Reinforced Self Compacting Concrete (SFRSCC) using wedge split test method, an investigation is carried out to determine fracture behaviour of SFRSCC with special reference to size and quantity of coarse aggregates based on wedge split test.

Table 1 Properties of hooked end steel fiber

Length (mm)	35
Diameter (mm)	0.5
Aspect Ratio (l/d)	70
Density (kg/m^3)	7850
Tensile Strength (MPa)	1100
% Elongation	2

3. Experimental program

The experimental investigation includes testing of specimens (SFRSCC) with three different coarse aggregate size (20 mm, 16 mm and 12.5 mm) and three different CA-FA content (50-50, 45-55, 40-60). The proportions of fine and coarse aggregates were varied keeping all other constituents of mix constant. This is to enable the study of influence of aggregate on fracture properties of SFRSCC.

3.1 Materials

Ordinary Portland cement (OPC) 53 grade meeting the requirements of IS 12269 (2013) with specific gravity and specific surface area of 3.14 and 225 m^2/g respectively was used in the present investigation. The fine aggregate (FA) confining to zone II as per IS 383 (2016) was used and the specific gravity and bulk density were 2.64 and 1.45 g/cm^3. The coarse aggregate (CA) was crushed granite obtained from local crushing unit according to IS 383 (2016) and the specific gravity and bulk density were 2.8 and 1.5 g/cm^3. Fly ash from a nearby National Thermal Power Station, was used as a cementitious material in SCC. It confirms to IS 3812 (2013) and the specific gravity was 2.11. Polycarboxylic ether based chemical admixtures conforming to ASTM C494 (ASTM 2017), was used as super plasticizer. The steel fibers of hooked end type were added at 0.5% by volume of concrete during dry mixing of the ingredients. The properties of hooked end steel fibers are shown in Table 1.

3.2 Mix proportions

The mix proportions of SCC were obtained using modified Nansu method (Nansu 2001) and the mix quantities were fixed after trial mixes by ensuring fresh properties of SCC according to EFNARC specifications (2005). The mix compositions for the three coarse

Table 2 Quantities of materials in Kg/m^3

Constituents	Mix A (50-50)			Mix B (45-55)			Mix C (40-60)		
	A_1 (20 mm)	A_2 (16 mm)	A_3 (12.5 mm)	B_1 (20 mm)	B_2 (16 mm)	B_3 (12.5 mm)	C_1 (20 mm)	C_2 (16 mm)	C_3 (12.5 mm)
Cement (kg/m^3)	450	450	450	450	450	450	450	450	450
Fly ash (kg/m^3)	150	150	150	150	150	150	150	150	150
Water (l/m^3)	190	190	190	190	190	190	190	190	190
FA (kg/m^3)	771	771	771	835	835	835	945	945	945
CA (kg/m^3)	(800)	(800)	(800)	(710)	(710)	(710)	(630)	(630)	(630)
20-16 mm	160	-	-	142	-	-	126	-	-
16-12.5 mm	160	240	-	142	213	-	126	189	-
12.5-10 mm	240	320	560	213	284	497	189	252	441
10-4.75 mm	240	240	240	213	213	213	189	189	189
Admixture (l/m^3)	4.6								

aggregate sizes and the three volumes of aggregates are shown in Table 2. The fresh properties of steel fiber reinforced self compacting concrete (SFRSCC) viz., flowability, passing ability, filling ability and resistance to segregation were checked based on slump flow, T_{50} cm, *V* funnel, V_5 min, *J* ring, *L* box test and the values were satisfying the EFNARC guidelines (EFNARC 2005).

4. Test methods

4.1 Compressive strength and split tensile strength tests

Standard cubes of dimensions 150 mm×150 mm×150 mm for compressive strength and cylinders with 150 mm diameter and 300 mm height for split tensile strength were cast and tested at the end of 28days of curing periods. The compressive strength test was conducted as per IS 516 (2013) while the split tensile strength test was done as per IS 5816 (2013). The average value of the three specimens was taken.

4.2 Wedge split test

Wedge split test is a Mode I (opening) failure type of fracture testing. Splitting force is applied on cubical or cylindrical specimens with a cast groove to divide the specimen partially into two. The size of the specimen depends on the maximum fiber length or maximum size of aggregate used. Recommended specimen dimensions should be at least 3.5 times larger than the maximum fiber length. For short fibers of 35mm long, specimens of 150 mm×150 mm×150 mm were used with a cast groove of 30mm wide and 22 mm deep made during casting using a wooden piece placed on the one the faces of cube. A total of 54 specimens were cast for 9 mixes which includes specimens with and without guide notch for the present study. The schematic diagram of the test specimens and test setup of Wedge split test are shown in Figs. 1(a) and 1(b). A starter notch and a guide notch were sawed to the cast groove using concrete cutter. The depth of the starter notch shall be half of the height of the specimen depth. The starter notch of 53 mm deep was sawed to ensure crack propagation and a guide notch of 25 mm deep was cut on the two opposite faces of the cube to prevent from occurring of horizontal cracking. The guide notch also minimises the influence of wall effect at the formwork surfaces. The effect of change in area of ligament differs in the energy consumption to split the specimen into two parts (change in ligament dimensions can change the crack propagation direction) (Hu and Wittmann 1992, Abdalla and Karihaloo 2003, Vydra *et al.* 2012, Cifuentes *et al.* 2013). Two steel plates with roller bearings are placed on top of the specimen. The vertical compressive load (F_v) is transferred as splitting force F_{sp} through the wedging device and roller bearing. A roller support is provided at the bottom of the cube as it acts as a hinge support. The rate of loading applied should be less than or equal to 0.25 mm/min for crack mouth opening displacement (CMOD) between 0.2-2 mm and for CMOD greater than 2 mm, the rate of loading may be increased to 0.5 mm/min. The WST was conducted on a displacement controlled testing machine with a constant rate of loading of 0.2 mm/min. The linearly varying displacement transducers (LVDTs) were attached horizontally to measure the horizontal deformation i.e., CMOD Fig. 2. The Splitting force (F_{sp}) was calculated from compression load (F_v) using Eq. (2) and F_{sp} vs CMOD graphs were plotted by considering the average of three specimens (NT Build 511 2005).

The splitting force F_{sp} is calculated using the formula in Eq. (1). The fracture energy G_f is calculated from the area under the Load-CMOD curve and area of the ligament. The splitting force F_{sp} is given by

$$F_{sp} = \frac{F_v}{2\tan(\alpha)} \frac{(1-\mu\tan(\alpha))}{(1+\mu\cot(\alpha))} \tag{1}$$

Where,

α - wedge angle (here α=15°)

μ - coefficient of friction for the roller bearing. μ varies from 0.1% to 0.5%.

If friction is ignored

$$F_{sp} = \frac{F_v}{2\tan(\alpha)} = 1.866 \times Fv \tag{2}$$

The specific fracture energy, G_{FCMOD} is determined from the load-CMOD curves obtained from test results.

$$G_{FCMOD} = \frac{W_{FCMOD}}{A_{lig}} \tag{3}$$

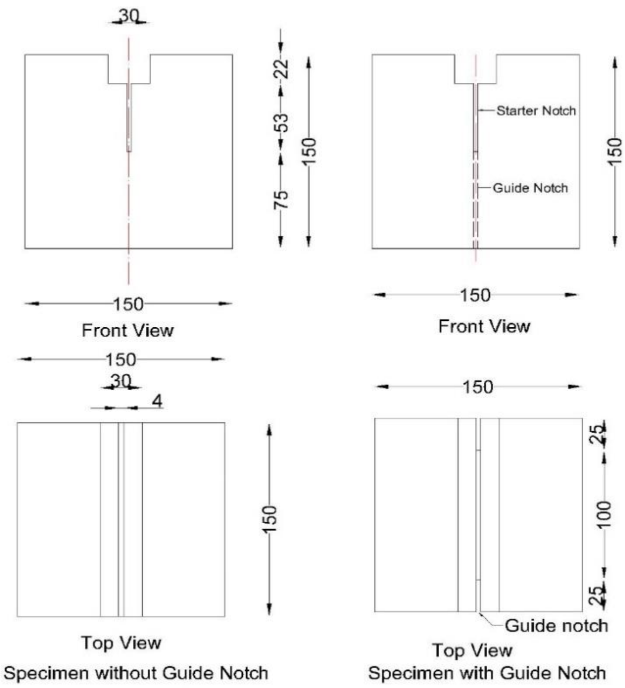


Fig. 1(a) Details of test specimens for Wedge Split Test

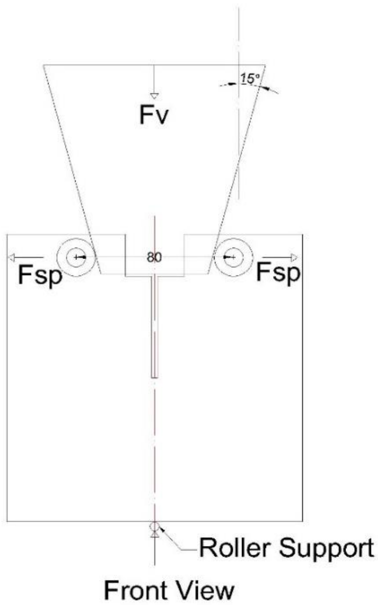


Fig. 1(b) Diagram of test setup for Wedge Split Test

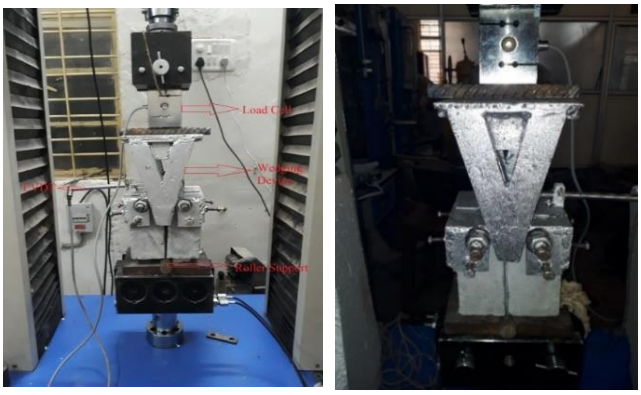


Fig. 2 Experimental test setup for Wedge split test

Where,

$W_{F\,CMOD}$ is the area under F_{split} load- CMOD curve

A_{lig} is the area of the ligament

5. Test results and analysis

5.1 Tests on physical properties of SFRSCC

The details of the fresh properties as per EFNARC guidelines (2005) are represented in Table 3. The results are indicative of improvement in flowability of self compacting concrete with increase in volume and size of coarse aggregate. The increase in flow is due to decrease in specific surface area of aggregates. Further, increase in the fine aggregate content makes the concrete viscous. It was also observed that the mix with higher fine aggregate content and least coarse aggregate size obtained minimum flow with the same amount of super plasticizer. From *L* box and *J* Ring test values, it can be noticed that the passing ability of concrete decreased with increase in volume and size of coarse aggregate. The higher content and larger size of coarse aggregates obstructed the passing ability of concrete compared to other mixes. However, all the results are within the range of EFNARC guidelines and satisfied the essential fresh properties of SCC.

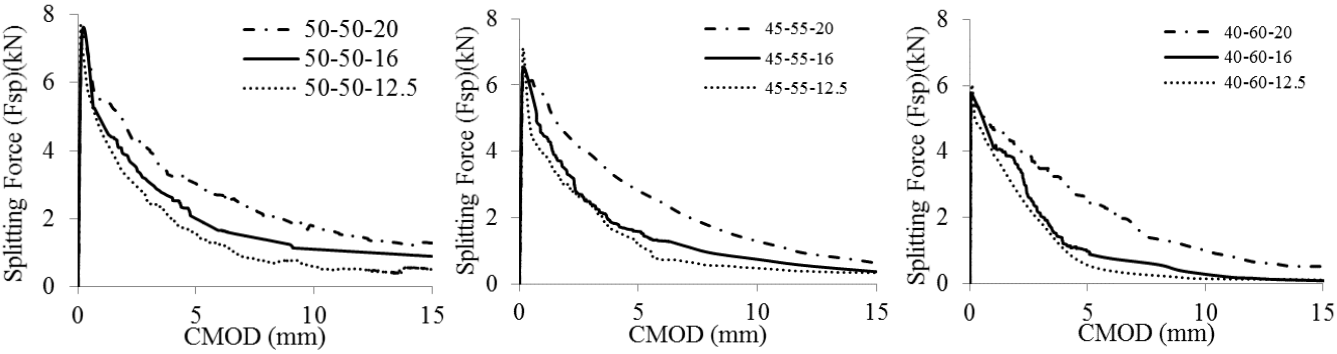
5.2 Mechanical properties of SFRSCC

The compressive strength test was conducted at the end of 28days of curing as per IS 516 (2013) on standard cubes and the average values are shown in Table 4. The results indicated a significant influence with the variation in volume and size of coarse aggregate on compressive strength of SFRSCC. The increase in volume of coarse aggregate increased the compressive strength of concrete and it is noticed for all sizes of aggregates. The increase in coarse aggregate volume by 10% (40% to 50%) enhanced the strength by 5.9%, 5.1% and 6.1% for specimens with coarse aggregate sizes 20 mm, 16 mm and 12.5 mm respectively. It was also observed that for a particular volume proportions of aggregate, the smaller size aggregate specimens attained high values of compressive strength compared to large size coarse aggregate based specimens. The enhancement in compressive strength of concrete with decrease in size of aggregate from 20 mm to 12.5 mm was 3.8%, 2.9% and 3.6% for aggregate volumes 50-50, 45-55 and 40-60 respectively. With the change from 20mm to 16mm, the improvement was 0.8%, 1.1% and 1.7% respectively.

The split tensile strength results were obtained as per IS 5816 (2013) using standard cylinder and the values are presented in Table 4. Similar observation was made here also. With the increase in size and quantity of coarse aggregate, the tensile strengths of fiber reinforced SCC

Table 3 Physical properties of steel fiber reinforced self compacting concrete

Mix Designation	Volume of aggregate (CA-FA)	Nominal size of coarse aggregate (mm)	Slump flow (mm)	T_{50cm} (sec)	V funnel (sec)	T_{5min} (sec)	L box (h_2/h_1)	J ring (mm)
	EFNARC RANGE		550-900	2-5	6-12	6-15	0.8-1.0	0-10
A_1	50-50 (Mix A)	20	675	2.84	7.47	8.35	0.8	8
A_2		16	675	2.96	8.12	9.43	0.83	8
A_3		12.5	655	3.12	8.48	9.99	0.84	7
B_1	45-55 (Mix B)	20	655	3.17	8.18	10.24	0.85	7
B_2		16	650	3.56	8.54	11.12	0.87	6
B_3		12.5	640	3.84	8.75	11.22	0.88	6
C_1	40-60 (Mix C)	20	640	3.77	9.82	11.58	0.88	5
C_2		16	635	3.98	10.12	12.34	0.91	5
C_3		12.5	610	4.44	10.51	13.02	0.92	4



(a) Mix A - 50-50 (b) Mix B - 45-55 (c) Mix C - 40-60

Fig. 3 Splitting force vs. CMOD curves for specimens without guide notch of SFRSCC

improved from 20 mm nominal size to 16 mm and the increase was 1.7%, 1.7%, and 2.4%, whereas from 16mm to 12.5 mm this was 4.4%, 2.2% and 3.5% for aggregate proportions 50-50, 45-55 and 40-60 respectively.

5.3 Fracture energy: Effect of CA size and volume

The fracture behaviour of SFRSCC was obtained using Wedge Split Test method as explained in section 4.2. The average splitting force vs. CMOD curves were plotted for three aggregate sizes and volumes for specimens without and with guide notch. The ligament dimension for without guide notch was 150 mm×75 mm and for with guide notch was 100 mm×75 mm.

5.3.1 Specimens without Guide Notch

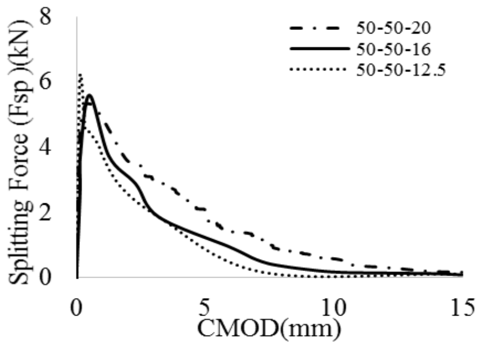
Figs. 3(a)-3(c) show the graphs of CMOD vs. splitting force for different volume and sizes of coarse aggregate. The maximum splitting force for each of the mixes is presented in Table 4. In every case, it was observed that the splitting force obtained was maximum for 12.5 mm aggregates compared to 20 mm and 16 mm coarse aggregate based specimens. The post peak behaviour has significantly improved with large size aggregate based specimens (20 mm). This is because of occurrence of crack propagation around the coarse aggregate i.e., at interfacial transition zone and the load drop after post peak was gradual. In case of 12.5 mm size, the path of the failure was through the aggregate and lead to a sudden drop in the loading curve after reaching the maximum splitting force.

Fig. 4 Failure pattern of specimens without guide notch

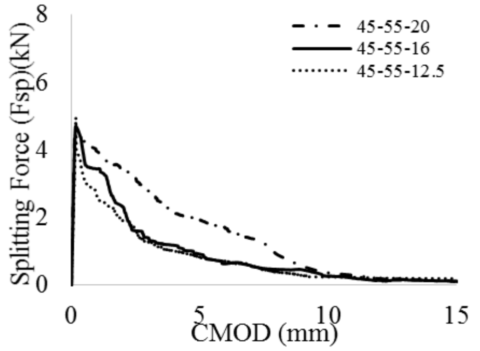
However, the steel fibers resists the crack propagation and thus modifies the nature of failure from brittle to ductile (Amparano *et al.* 2000, Zhang *et al.* 2010a, Siregar, *et al.* 2017).

Table 4 Compressive strength, tensile strength, splitting force and fracture energy results

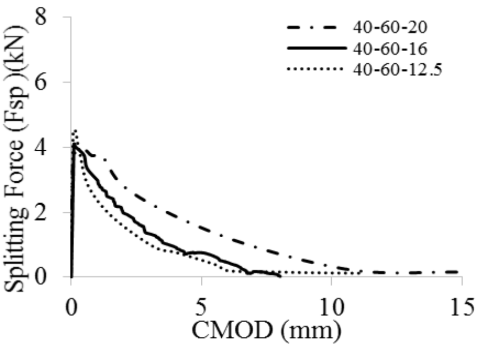
Volume of Aggregate (CA-FA)	Size of CA (mm)	f_c' (N/mm^2)	f_t (N/mm^2)	E (GPa)	Without Guide Notch			With Guide Notch		
					F_{sp} (kN)	W_F (N-m)	G_F (N/m)	F_{sp} (kN)	W_F (N-m)	G_F (N/m)
50-50 (Mix A)	20	82.4	9.05	45.39	7.32	40.67	3615.2	5.22	23.66	3155.0
	16	83.1	9.20	45.58	7.46	30.57	2717.5	5.60	17.36	2314.1
	12.5	85.5	8.95	46.23	7.65	23.77	2113.3	6.07	15.45	2059.2
45-55 (Mix B)	20	80.4	8.80	44.83	5.75	35.92	3192.9	4.35	21.99	2931.8
	16	81.3	8.95	45.08	5.78	23.92	2126.4	4.67	14.15	1886.8
	12.5	82.7	9.00	45.47	5.97	19.53	1736.1	4.94	12.42	1655.6
40-60 (Mix C)	20	77.8	8.50	44.10	5.75	30.91	2747.9	3.92	18.73	2497.7
	16	79.1	8.70	44.47	5.78	18.03	1602.3	4.11	10.48	1397.5
	12.5	80.6	8.80	44.89	5.97	14.97	1330.6	4.52	9.13	1216.9



(a) Mix A - 50-50



(b) Mix B - 45-55



(c) Mix C - 40-60

Fig. 5 Splitting force vs. CMOD curves for specimens with guide notch of SFRSCC

The energy required per unit area of the crack surface to open, defined as fracture energy (G_F) was calculated for mixes with three different volumes and sizes of coarse aggregate. The G_F values are presented in Table 4. For Mix A (50-50) and with 20 mm aggregates, the fracture energy was enhanced from 2113.3 N/m to 3615.2 N/m compared to 12.5 mm size aggregate, while for 16 mm, it was 2717.5 N/m. The similar increase in fracture energy with increase in size of coarse aggregate was observed for the other volumes of aggregates (Mixes B and C). The increase in G_F with increase in size of aggregate is due to the improved area of splitting force. Fig. 4 shows the failure pattern of specimens without guide notch under wedge split test. It can be noticed that the crack propagation doesn't follow a well-defined path during splitting and the crack tends towards horizontal (NT Build 511 2005).

On the other hand, to observe the true fracture energy of the concrete, it is requires a definite crack path. Hence, the concrete specimens were grooved with guide notch and tested using WST method.

5.3.2 Specimens with Guide Notch

The guide notch creates a well-defined vertical path and reduces the ligament area. Therefore, the energy consumption is less compared to specimens without guide notch. Despite having lesser defined area, for lower size aggregates (12.5 mm), the crack follows weaker path through the aggregate leading to a sudden drop in the post peak behaviour. In contrast, specimens with large size aggregates attain gradual decrease in the loading curve after post peak due to the bridging of aggregates.

Figs. 5 (a)-(c) illustrate the graphs of CMOD vs. splitting force of SFRSCC specimens with guide notch. The fracture energy (G_F) was calculated as per Eq. (3) and shown in Table 4. For Mix A (50-50), the fracture energy values obtained are 3155.0 N/m, 2314.1 and 2059.2 N/m for sizes 20, 16 and 12.5 mm respectively. With the decrease in the maximum size of aggregate from 20mm to 16mm, the decrease in G_F was 26.7% while, with reduction from 16 mm to 12.5 mm aggregates, the drop was 34.7%.

In addition to this, it is also noticed that the decrease in volume of coarse aggregate by 10% (50% to 40%) reduced the fracture energy by 20.8%, 39.6% and 40.9% with sizes 20 mm, 16 mm and 12.5 mm. Similar observation was made in other volumes and sizes of coarse aggregates. Fig. 6 shows the failure pattern of specimens with guide notch under wedge split test.

5.3.3 Comparison of fracture energy of specimens without and with guide notch

From comparison of the fracture energy (G_F) values of

Fig. 6 Failure pattern of specimens with guide notch

SFRSCC specimens without and with guide notch for three different volumes and sizes of coarse aggregate, it is understood that G_F values of specimens without guide notch are on the higher side than specimens with guide notch. This can be attributed to the indefinite failure path in SFRSCC specimens without guide notch. During splitting, the crack initiates at the tip of the starter notch and propagates towards the bottom surface of the specimen. In this process, the crack follows a weak zone to propagate and the crack proliferates in horizontal direction rather than vertical. Therefore, the energy consumption for a crack to reach the bottom is high for specimens without guide notch.

In addition to this, it is also perceived that the variation in fracture energy (G_F) is maximum for 20 mm and 16mm coarse aggregate sizes compared to 12.5 mm aggregate based specimens which attained only marginal difference. In Mix A (50-50), the increase in G_F for specimens without guide notch one those with guide notch specimens is 14.6%, 17.4% and 2.6% for aggregate sizes 20 mm, 16 mm and 12.5 mm respectively. In mixes B (45-55) and C (40-60), the corresponding increase is 8.9%, 12.7%, 4.9% and 10.0%, 14.7%, 9.3% for aggregate sizes 20 mm, 16 mm and 12.5 mm respectively. In small sized aggregates, the fracture path is through the aggregates resulting vertical failure pattern in specimens without guide notch. This is the reason for the marginal difference in fracture energy for both the specimens without and with guide notch. On the other hand, due to the presence of large size aggregates in specimens without guide notch, the crack follows around the surface of the aggregate consuming additional energy to cause failure.

6. Conclusions

The influence of size and volume of coarse aggregate on fracture behaviour of Steel Fiber Reinforced Self Compacting Concrete (SFRSCC) was studied experimentally based on Wedge Split Test. The results are analysed for SFRSCC specimens without and with guide notch. The following major conclusions were drawn from the results.

- All the mixes of SFRSCC satisfied the fresh properties as per EFNARC guidelines. However, the mix becomes viscous in nature with decrease in size and quantity of coarse aggregate. The fresh property values are moderately on lower side for the mix with 12.5 mm size of aggregate and 40-60 CA-FA proportions.
- The increase in size and volume of coarse aggregate improved the compressive strength of SFRSCC. The increase in coarse aggregate volume by 10% (i.e., 40% to 50%) enhanced the compressive strength by 5.9%, 5.1% and 6.1% for specimen with coarse aggregate size 20 mm, 16 mm and 12.5 mm respectively.
- The maximum splitting force was observed for concrete mix with coarse aggregate size of 12.5 mm. This is true for the three quantities of C.A. (40%, 45% and 50%). Among the above three quantities, the splitting force has achieved maximum with 50% volume of C.A.
- The specimens without guide notch attained maximum splitting force compared to specimens with guide notch. This observation is same for all sizes and quantities of C.A. The maximum splitting force in specimens without guide notch can be attributed to indefinite failure path and more ligament area which assisted in attaining better fracture energy.
- Fracture energy was maximum for 20 mm size of coarse aggregate based specimens for all the CA-FA ratios. This is because, the crack proliferates through the aggregate in the smaller size aggregate leading to transgranular failure and in case of large size aggregate crack proliferates around the aggregate leading to intergranular failure.

Conflict of interest

There is no conflict of interest.

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