Study the Strength Properties of Concrete by Varying Percentage of Silica Fume and Steel Fiber

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ABSTRACT:

Several mechanical parameters of concrete specimens have been examined in this experimental study. The investigation purpose of present experimental work is to create a ductile and high-stable cementitious materials by adding silica fume and steel fibers. In this experiment work, two sorts of steel-F were utilized, taking aspect ratio (L-F / Dia.-F) of 52 and 72, with 0.44%, 0.88%, and 1.76% by mass of cement content. The percentages of SF were added to concrete 8.5% by mass of cement. A W/C ratio of 0.42 was used, slump was considered to be 100 mm. On fresh concrete slump for workability test, unit weight for density tests were conducted. On hardened concrete, compressive-stress, tensile-strength, flexural-strength, elastic-modulus were destined. Cement replacement with SF exceeds both mechanical qualities as well as elastic-modulus of concrete. But, inclusion of steel-F into cementitious materials greatly enhances the flexural-strength, and tensile-strength of high-stable concrete. As silica-F & steel-F percentage increase, the compressive strength also increases, but the aspect-ratio of S-fiber inverse effects on C-S, at low values aspect ratio presented higher compressive strength, and so on. As the silica-F and steel-F percentage increase, the splitting tensile, flexural strength also increases, aspect ratio direct effects on both mentioned strength, and high aspect ratio presented higher tensile and flexural strength. It was finally discovered mechanical qualities of cementitious materials depend upon silica-F, steel-F content, and the aspect ratio of the steel-F.

KEYWORD – *High strength concrete, Mechanical properties of concrete, Silica fume, Steel fiber aspect ratio, Density.*

1. INTRODUCTION:

Concrete is a water-based combination of cement and gravel to construct a solid regular shape. Concrete has been increasingly popular in recent years as a result of its extensive application. For innovation, design, and building approaches, there is a significant need for concrete. Concrete has been transformed into a good building material due to its use in many different areas. Due to advanced technology, cementitious materials taking on various fields' stability, persistency, flu ability and further characteristics of conventional concrete-mixture require proper modification to obtain suitable concrete under suitable conditions. As we know better, cementitious materials is a breakable material also feeble in micro cracks. The inclusion of steel-F to the cementitious materials, this problem is eliminated. Adding steel fiber to concrete-matrix can increase stability properties of cementitious materials & prevent micro-cracks development [1].

The inclusion of 1 percent to 3 percent straight steel fibers improved C-S & flexibility manner significantly; nevertheless, it's deliberated optimal fibre dose for UHPC stability features. Fibers reinforcing and hardening effectiveness became restricted once the steel fiber concentration topped 2% [2, 3, and 4]. When steel fiber is mixed with concrete, the compressive strength is equal to compressive-S of conventional concrete-mix, and the amplification of steel fiber has a greater result on the tensile & flexural strength of concrete [5, 6, 7, and 8]. If the amount of steel fiber in the concrete exceeds 1.5 %, there will be a momentous reduction in mechanical properties of cementitious materials, especially in compressive strength [9, 10]. So currently, the demand for reinforced concrete for steel fiber is around one percent [11, 12, and 13]. Steel fibers that have a significantly larger length and higher yang elastic modulus than other steel fibers, lead to the development of flexural resistance and have higher potential for crack control, despite the great volumetric density [14, 15].

Silica fume, a silicone, and Ferrosilicon alloy have been recognized in the industry as a by-product. Due to its fine and high ($Si\ O_{2)}$ concentration, SF is a highly reparative pozzolana substance. SF is made up of small particles less than one-millimeter micro, with good adhesive strength between cement-past and aggregate [16, 17, 18]. If silica fume mixes directly with concrete, it will increase the water demand. Therefore SF is manipulate simultaneously through a super-plasticizer to maintain flu ability of concrete [19, 20]. The incorporation of silica-F into concrete enhances the resistance of concrete against chloride attacks. The consequence of SF on the binding strength of fibre into cementitious materials was investigated [21, 22, 23, and 24]. In spite of high-stable cementitious materials is more brittle than regular concrete, the use of high-stable cementitious materials is therefore severely limitation [25, 26]. We also know that silica fume is an important material for high-strength concrete due to its high pozzolanic activity, although in this case, the concrete structure is very brittle [27, 28]. Therefore, the development of concrete ductility is one of the main goals that every researcher must take into consideration. To increase the flexibility of cementitious materials we use different types of fibers in mixing with concrete and especially steel fiber [29]. The previous author [30] the final thoughts concerning, the combined use of SF & stil-F with high-strength concrete further enhances in a high-temperature ambient and the C-S of advanced cementitious materials. The purpose of present experiment is to explain how silica-F, steel-F content, and aspect-ratios effects on mechanical characteristics of high-stable concrete-mix.

2. PROGRAM FOR EXPERIMENTATION:

2.1. Substances to be used as raw materials:

In present experiment work Ordinary Pozzolanic Cement (OPC) grade 43, along a special gravitation of 3.15 & choiceness 325 square meter/Kilogram, conforming by IS: 8112: 1989 was manipulated [31]. Table: 1, describes structure of the cement. SF through a special-area of 13 square/gram, and partial-size 0.11–0.15 millimeter micro was utilized. Its chemical details are also itemize in Table: 1. Two sort of fibers to have more than 2000 N/sqmm tensile strength with straight, round cross-section and aspect-ratios of L-F/Dia.-f = 18/0.25, L-F/Dia.-f = 13/0.25 were operated. Fine aggregate (river sand) was selected, through particle size "of 2.36" millimeters. C-gravel was utilized, with a maximum particle size 20 millimeters. Conplast WL polycarboxylic-basis super-plasticiser (SP) through a water-reduction competence of more than 30 percent of the overall was employed. It has a solid composition of 20 percent.

Table 1: Cement and SF elemental creation and density.

Elemental creation	Ca-O (%)	Si-O_2 (%)	AL_2-O_3 (%)	Fe_2-O_3 (%)	S-O_3 (%)	Mg-O (%)	Na_2-Oeq (%)	K_2-O (%)	Density (Kg/sqm)
Cement	57.02	21.77	2.59	0.65	2.41	2.71	-		1760
Silica-F	0.6	94	0.8	0.4	-	0.4	0.5	1.5	550 to 700

2.2. Proportions in the mixture:

According to the results of the previous research [20], as described in Table 2, a mixed proportion of concrete trough a water to-cement (W per C) rate = 0.42 was utilized. 1% of superplasticizer was added to the mixture by mass of cement content. Cement was substitute with SF at a rate of 8.5 percent by mass of cement contented, respectively. %-age of steel-F 0.44%, 0.88%, & 1.76% by weight of cement content, with straight and round cross-section were used. As listed in Table: 3.

Table 2: Mix proportion for M30 concrete (Kilogram/cub meter).

S.No	Descriptions	W/C	Cement	Water	Silica-F	Steel-F	C.A	F.A	SP
1	C – concrete	0.42	361	152	-	-	1308	707	3.6
2	SF 8.5%, 0.00%	0.42	331	152	31	-	1308	707	3.6
3	SF 8.5%, 044%	0.42	331	152	31	2	1308	707	3.6
4	SF 8.5%, 0.88%	0.42	331	152	31	3.18	1308	707	3.6
5	SF 8.5%, 1.76%	0.42	331	152	31	6.36	1308	707	3.6

Table 3: Properties of steel fibers.

S.No	Shape	Density (Kg/m^3)	Melting Point (C)	Appearance	Cross section	Length (mm)	Dia. (mm)	Aspect-ratio (L-F/Dia.-F)	Tensile-Strength (N/sqmm)
1	Straight	7850	1500	Brass coted	Round	18	0.25	52	> 2000
2	Straight	7850	1500	Brass coted	Round	13	0.25	72	> 2000

2.3. Procedure for mixing and specimens preparation:

Eight different concrete mixes (8.5% silica fume and 0.44%, 0.88%, and 1.76% of steel fibres with aspect-ratio L-F/Dia.-F = 18/0.25, L-F/Dia.-F = 13/0.25) were cast in total. Up to 28 liters of water was required for each concrete mix. To achieve a satisfactory dispersion, firstly all the dry components were mixed for 4 minutes. After that, water containing the superplasticizer was amplification to dry matrix & mixed for 5 min. After that fibers were added through passing from a sieve with a 5-millimeter mesh size, and the mixture was mixed again for 6 minutes until uniformly dispersed. When the concrete mixture was ready, were made 9 cubs (150 millimeter × 150 millimeter × 150 millimeter) for C-S, 9 beams (100 millimeter × 100 millimeter × 500 millimeter) for F-S, 9 cylinders (150 millimeter diameter × 300 millimeter in a length) for tensile strength, and 9 cylinders (150 millimeter diameter and 300 millimeter in a length) for elastic modulus test. Each mold was filled in 3 thicknesses each thickness was condensed 40 times by a compaction rod. And then compacted by electronic vibration for up to 5 seconds. For 24 hours, the specimens with molds were maintained at tem of room. 24 hours letter, opened the mold and put the specimens in water for 1 & 4 weeks of curing time.

2.4. Experiment techniques:

2.4.1. Workability of new concrete:

The workability of concrete was measured according to IS: 1199: 1959 [32] in fresh concrete. From everyone mixture of concrete taken the sample and done the workability test.

2.4.2. Compressive strength test (C.S):

As indicated in Fig. 1 (a), C.S test were carried out on cub specimens as per IS: 516: 1959[33]. Manipulating a universal compression-test-machine (HEICO, New Delhi) with a 2000-kN load capacity. 0.10 KN per second was the loading rate. The Indian Standard: 516: 1959, with dimensions of 150 millimeters × 150 millimeters × 150 millimeters was used to conduct the test. As a result of the test, an average of three specimens were taken from each mix.

(a) (b)

Figure 1: Testing machine setup.

2.4.3. Splitting tensile strength (S.T.S):

The S.T-tensile strength test was followed by IS: 5816: 1999 [34]. The S.T-strength test was destined on cylindrical models, through dimensions of 150 millimeters diameter × 300 millimeters in a height. Using the universal compression test machine (HEIO, New Delhi) with a 2000-KN load capacity. 0.10 KN per second was the loading rate. As a result of the test, mean of 3 models were taken from each mix.

2.4.4. Flexural strength (F.S):

The F.S-test was followed by IS: 516: 1959 [33]. A flexural strength test was done in two points load mechanism. A Motorized, Aimil, Ltd machine through 100 kilonewtons load ability was manipulated. Loading space of the machine 0.2 kilonewtons per minute was shown. The F.S-test was determined on beam model, with dimensions 100 millimeters × 100 millimeters × 500 millimeters. To evaluate flexure strength, three beams were tested from everyone mixture then were taken the average three specimens.

3. RESULT & ANALYSIS:

3.1. Fresh characteristics of concrete

SF and steel-F inverse impact on the slump of fresh concrete, when increasing %-age of S.F & steel-F the slump of concrete decreases, more aspect ratio also decreases the slump value. It was verified that the silica fume has an inverse impact on the relative density of new cementitious materials when %-age of silica fume increases relative density of new cementitious materials decreases, but steel-F have a direct relationship with the density of fresh made concrete when %-age of steel-F increase the density of fresh made concrete directly develop.

Table 4: Density and slump of fresh made concrete.

S.No	Descriptions	Aspect Ratios	Density (Kilogram/cubic meter)	Slump (millimeter)
1	Conventional – concrete	-	2441	100
2	Silica-F 8.5, Steel-F 0.00%	-	2428	92
3	Silica-F 8.5%, Steel-F 0.44%	52	2432	90
		72		85
4	Silica-F 8.5%, Steel-F0.88%	52	2435	80
		72		75
5	Silica-F 8.5%, Steel-F1.76%	52	2438	70
		72		60

3.2. Compressive strength (C.S):

By adding SF & steel-F there are rise in C.S of concrete. This conclusion is clearly dependent on the filling action of SF improving binding stability of cementitious material connection. Amplification of both steel fiber as well as SF to cementitious material, their S.C is much higher than just added silica-F to cementitious material. With-out adding silica-F plus steel fibers the C.S at 7 days & 28 days are 23.43 N/sqmm & 33.40 N/sqmm respectively. When the %-age of silica fume & steel-F were 8.5% & 0.44%, with aspect ratio of 52, the compressive strength was 29.67 N/sqmm & 39.47 N/sqmm at 7 & 28 days respectively, and for same %-age of silica fume & steel fibre with aspect ratio 72, the compressive strength is 28.92 N/sqmm & 38.15 N/sqmm at 7 & 28 days respectively.

For 8.5% silica fume & 0.88% steel fibre the compressive strength is 35.42 N/sqmm & 48.17 N/sqmm for 7 & 28 days with aspect ratio 52, and 34.06 N/sqmm & 47.16 N/sqmm with aspect ratio 72 for 7 & 28 days respectively. For 8.5 % silica fume and 1.76 % steel fibre the compressive strength was determined about 33.58 N/sqmm & 45.68 N/sqmm respectively with 52 aspect ratio, same percentage of silica fume and steel-F through aspect-ratio of 72 the C.S was recorded 32.72 N/sqmm & 44.58 N/sqmm at 7 & 28 days respectively.

The C.S increase when the % age of silica fume & steel fiber increases from 8.5%, 0.44% to 8.5%, 0.88% respectively, and then decreases when the percentage of silica-F plus steel-F increases. Therefore it gives the optimum result at 8.5% silica fume & 0.88% steel fiber. In general, the compressive stability of cementitious material through steel-F has an aspect-ratio of 52 was higher than concrete through a steel fiber aspect-ratio of 72. The connection b/w the C-S as well as SF content plus steel-F several percentage and aspect ratios are given in Table 5.

Table 5: Compressive stability result (N/mm^2):

S.No	% age of Silica fume	Aspect ratio	% age of Steel fiber	7 Days (N/sqmm)	28 Days (N/sqmm)
1	-	-	-	23.43	33.4
2	8.5	-	-	26.51	36.31
3	8.5	52	0.44	29.67	39.47
4	8.5	72	0.44	28.92	38.15
5	8.5	52	0.88	35.42	48.17
6	8.5	72	0.88	34.06	47.16
7	8.5	52	1.76	33.58	45.68
8	8.5	72	1.76	32.72	44.58

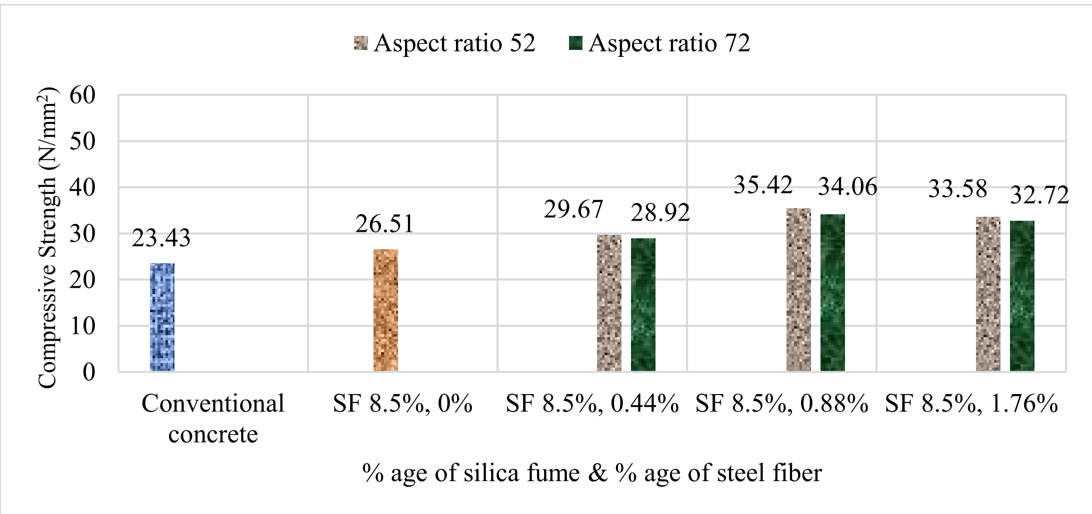

Figure 2: Result of C.S after one week of curing.

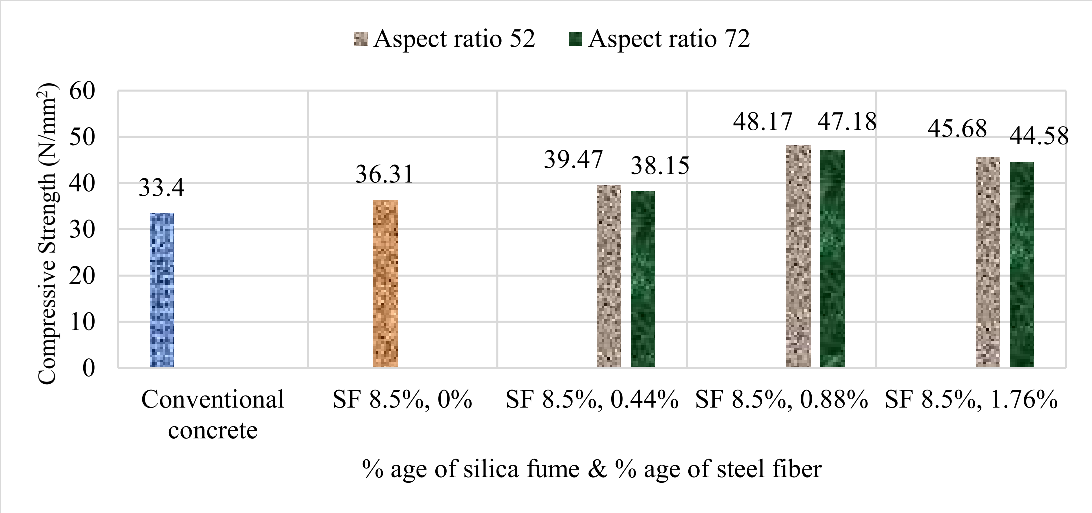

Figure 3: Result of C.S after four week of curing.

3.3. Splitting tensile-strength (S.T.S):

The tensile strength increased when the % age of SF plus steel-F was increased from 8.5%, 0.44% to 8.5%, and 1.76% respectively. Therefore it gives the optimum result at 8.5% of silica-F & 1.67% of steel-F with strength of 3.84 N/sqmm & 4.97 N/sqmm at 7 and 27 days respectively for 52 aspect ratio, and same percentage of silica-F and steel-F with tensile strength of 4.10 N/sqmm & 5.35 N/sqmm at 7 & 28 days respectively for 72 aspect ratio. The T-strength of concrete with steel fiber has an aspect-ratio of 72 was higher than concrete through a steel fiber aspect-ratio of 52. Connection b/w S.T.S, silica-F plus steel-F several percentage and aspect ratios are given in Table 6.

Table 6: Splitting tensile-strength result (N/sqmm):

S.No	% age of Silica-F	Aspect ratio	% age of Steel-F	7 Days (N/sqmm)	28 Days (N/sqmm)
1	-	-	-	2.9	3.36
2	8.5	-	-	3.10	3.58
3	8.5	52	0.44	3.34	3.91
4	8.5	72	0.44	3.53	4.23
5	8.5	52	0.88	3.69	4.44
6	8.5	72	0.88	3.75	4.76
7	8.5	52	1.76	3.84	4.97
8	8.5	72	1.76	4.10	5.35

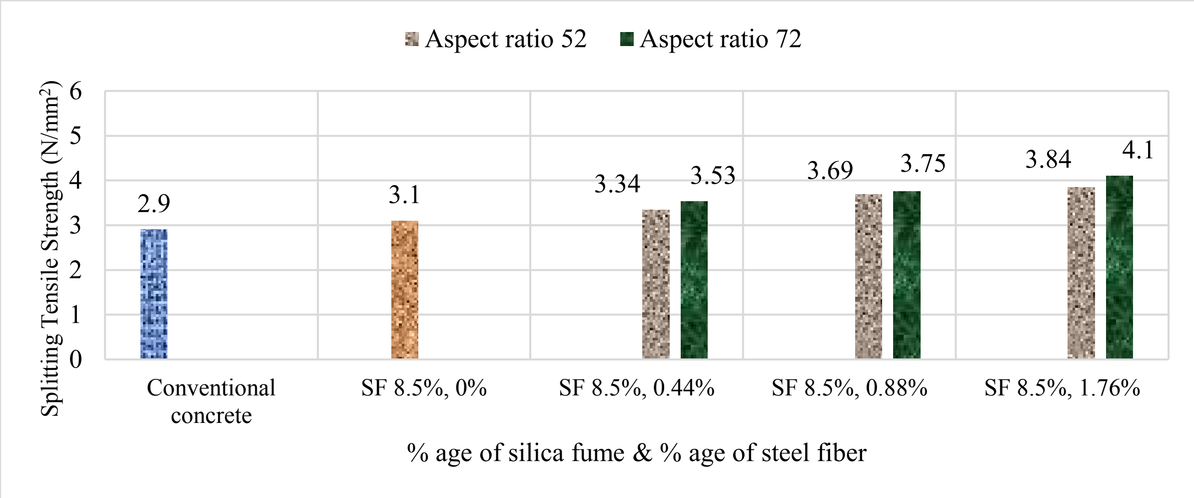

Figure 4: Result of S.T.S after one week of curing.

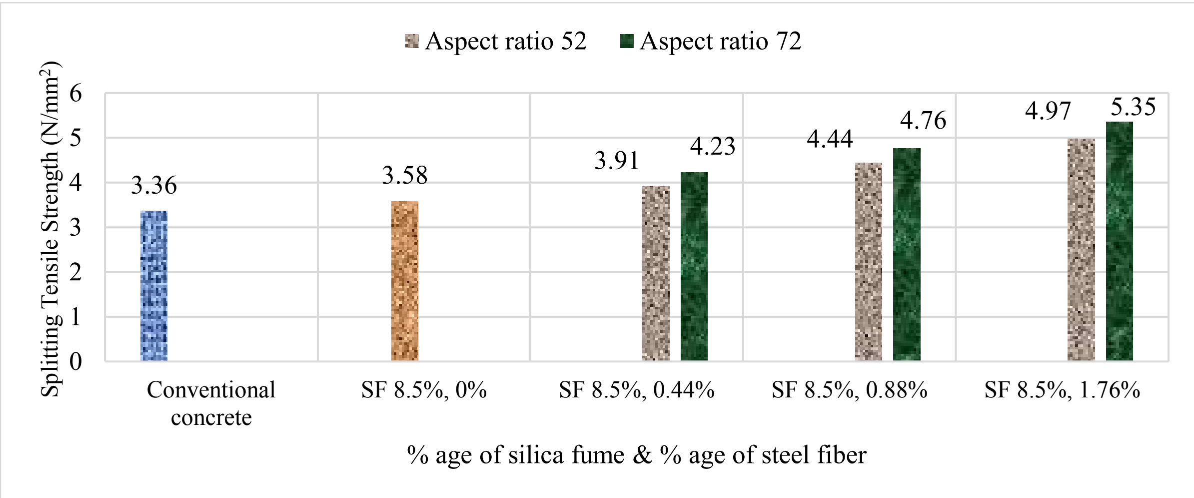

Figure 5: Result of S.T.S after four weeks of curing.

3.4. Flexural strength (F.S):

Same to S.T.S test, adding SF plus steel-F considerably increase flexural stability of cementitious material. F.S come highest, when % age of silica-F and steel-F increases from 8.5%, 0.44% to 8.5%, and 0.88% respectively. Therefore it gives the optimum result at 8.5% of silica-F & 1.76% of steel-F with strength of 7.27 N/sqmm & 8.95 N/sqmm at 7 & 28 days respectively for 52 aspect ratio, and same percentage of silica-F and steel-F with tensile strength of 7.56 N/sqmm & 10.13 N/sqmm at 7 & 28 days respectively for 72 aspect ratio. The F-strength of concrete with steel fiber having an aspect-ratio of 72 was came higher than concrete through a steel fiber aspect-ratio of 52. Connection b/w F.S & SF through steel-F several percentage and aspect ratios are given in Table 7.

Table 7: Flexural Strength result (N/sqmm):

S.No	% age of Silica fume	Aspect ratio	% age of Steel fiber	7 Days (N/sqmm)	28 Days (N/sqmm)
1	-	-	-	4.53	5.33
2	8.5	-	-	4.75	5.60
3	8.5	52	0.44	5.36	6.59
4	8.5	72	0.44	6.02	7.06
5	8.5	52	0.88	6.20	7.25
6	8.5	72	0.88	7.14	7.82
7	8.5	52	1.76	7.27	8.95
8	8.5	72	1.76	7.56	10.13

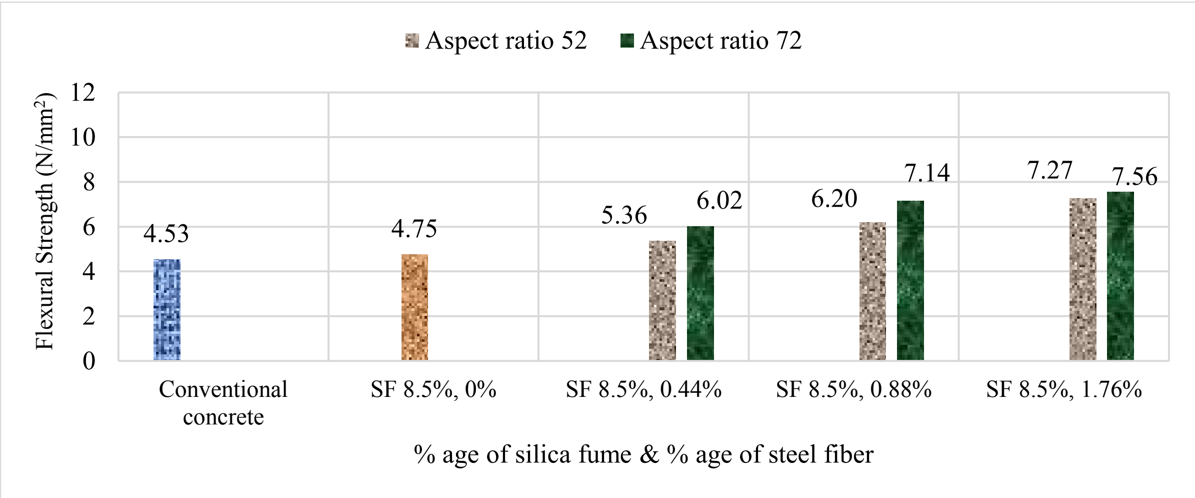

Figure 6: Result of F.S after one week of curing.

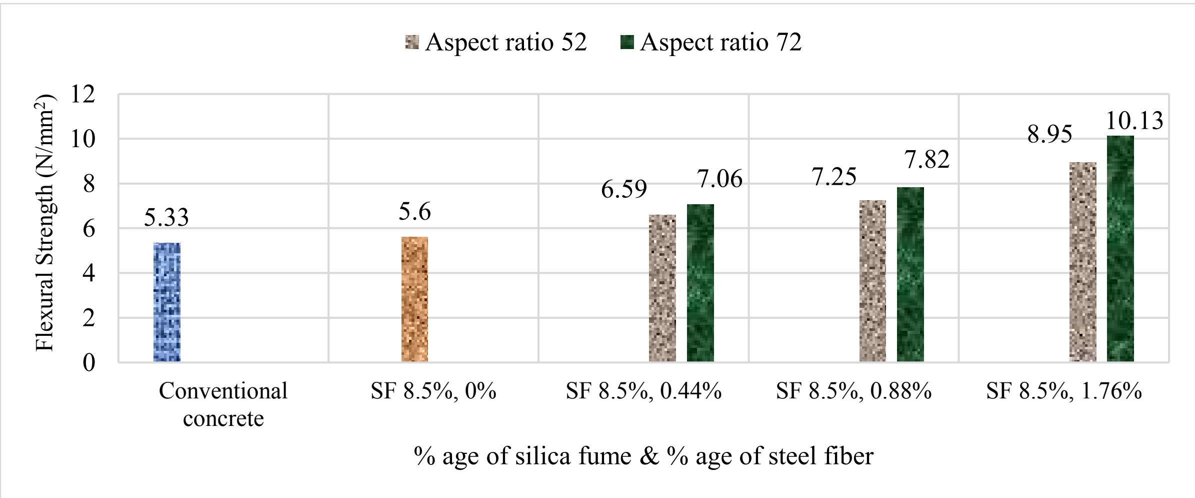

Figure 7: Result of F.S after four weeks of curing.

3.5. Modulus of elasticity (MOE):

As silica-F and steel-F were incorporated into the concrete the elastic modulus was higher than conventional concrete. The MOE of cementitious material came higher, when %-age of SF & steel-F increase from 0.44 to 1.76% respectively. Therefore it gives the optimum result at 8.5% of silica-F & 1.76% of steel-F, the elastic modulus 35.55 N/sqmm & 36.31 N/sqmm at 7 & 28 days sequentially. In general, MOE of cementitious materials through steel fiber has an aspect-ratio of 52 was came higher than concrete with an aspect ratio of 72. Connection between the MOE and the silica-F content with steel-F several percentage and aspect ratios are given in Table 8.

Table 8: Result of elastic modulus (KN/sqmm):

S.No	% age of Silica-F	Aspect ratio	% age of Steel-F	28 Days (KN/sqmm)
1	-	-	-	28.72
2	8.5	-	-	30.16
3	8.5	52	0.44	35.64
4	8.5	72	0.44	33.95
5	8.5	52	0.88	36.69
6	8.5	72	0.88	36.23
7	8.5	52	1.76	38.13
8	8.5	72	1.76	37.33

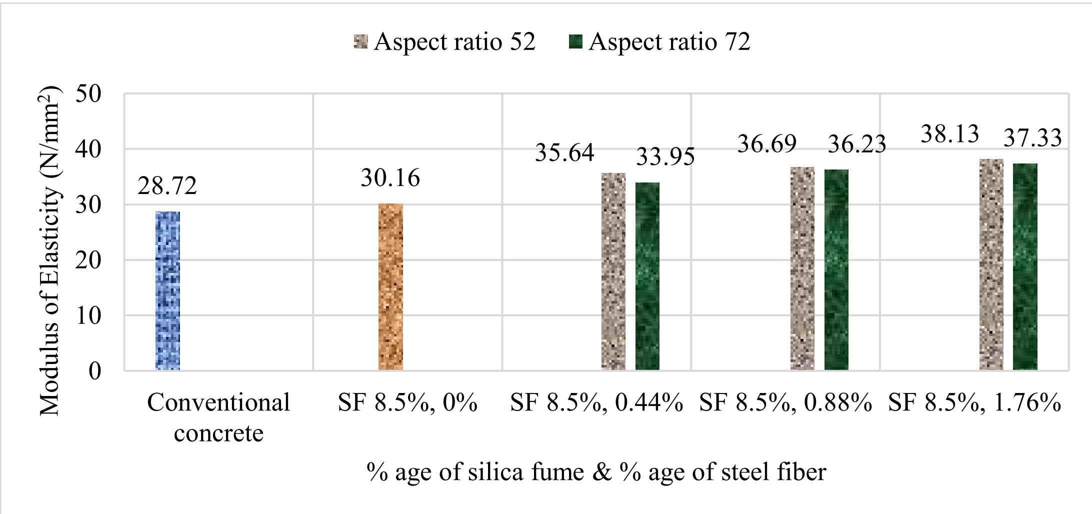

Figure 8: Result of MOE after four weeks of curing.

4. Conclusion:

- The incorporation of silica-F into concrete reduces the density plus flue ability of cementitious materials, as well as steel fiber, has a negative effect on flue ability, but increases density of concreting materials.
- The C-strength of concreting materials increases through amplification of both steel-F plus silica-F to the concrete. The steel-F aspect-ratios have an inverse consequence on C.S of concreting materials, at higher aspect ratios the lower compressive strength has been recorded. The cement was replaced with a percentage of silica-F, and inclusion of steel-F directly to cementitious materials, compressive strength of the concrete increased from 8.01% to 30.67%, while contrasted to regular concreting.
- Significant increases at splitting tensile strength were observed, when silica-F and steel-F were used together in concrete, tensile strength increased as the percentage of silica-F and steel-F increased. The cement was replaced with a percentage of silica-F, and inclusion of steel-F directly into cementitious materials, S-tensile strength of the concrete increased from 6.15% to 37.2%, while contrasted to conventional concreting materials. Steel-F aspect ratios has a direct consequence on S-T-S of cementitious materials, at higher aspect ratios the higher S-tensile strength have been recorded.
- Significant increases in flexural-S were perceived, though SF & steel-F were manipulated together in concrete, flexural strength developed in the manner %-age of silica-F & steel-F raised. The cement was replaced with a percentage of silica-F, as well as inclusion of steel-F directly to the cementitious materials, flexural strength of concrete increased from 19.58% to 47.67%, as competed with conventional concreting materials. Steel-F aspect ratios have a direct sequence on F-S of cementitious materials, at greater aspect ratios the higher flexural strength have been recorded.
- The inclusion of ST-F in cementitious materials gives a flexible concreting materials, but addition of silica fume to cementitious materials enhances its brittleness to achieve greater strengths.
- The strength properties of concrete were directly contacted by weight, aspect-ratio of ST-F, as well as silica fume concentration. To make extra tractile HSC, optimal %-age required to identify perfect ST-F weight plus S-F concentration while think about cost of composition.
- Finally, it should be noted that S-F and ST-F are essential components cementitious materials, their proportions in the mix should be carefully regulated to get the appropriate concrete strength qualities.

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