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Comparing and evaluating influence of nylon fiber and fly ash in self compacting concrete

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Abstract

Self-consolidating concrete (SCC) is a special concrete that is highly flow able, non-segregating and self-expanding. Self-compacted concrete (SCC) is poured into the formwork without compaction and fills the formwork by its own weight. SCC is considered to have many advantages. Compared with conventional concrete as improved Construction quality, faster construction activity, lower cost etc. This project was carried out to evaluate the effects of addition of nylon fiber and fly ash on the fresh and hardened properties of SCC mixes. In this project, concrete mixes with nylon fiber of 0.5%, 1.5%, 2.5%, and fly ash with 0%, 15%, 30% and 45% were used to determine its permeability, flow Capacity, evaluated on the basis of and separation resistance, slump flow, L-box and V-funnel tests. After 3 days, 14 days, 28 days of curing SCC cylinders, compressive and splitting tensile strength were tested. The test results show that nylon fibers increase permeability but decrease the filling capacity and segregation resistance of SCC. Furthermore, it can be concluded that after 3 days, 14 days, 28 days of curing, the test of concrete samples showed that the addition of nylon fiber up to 2.0% of cement by volume increased the compressive strength of SCC. Strength, improves tensile strength but 2.5%. Nylon fiber reduces the compressive strength, tensile strength of hardened SCC.

Keywords: Aggregates; Nylon fiber; Fly ash; Self compacting concrete; Compressive and tensile strength

1. Introduction

SCC was first introduced in Japan in the 1980s as a means of producing ordinary quality concrete and overcoming problems caused by labor shortages. In addition, the list of issues such as complex design, density of reinforcement in structural members, etc., reduces skilled workforce, rapid growth of the construction industry and the need for quality construction, SCC is introduced to overcome these problems. Concrete is a composite material consisting of water, coarse-grained materials (fine and coarse aggregates or fillers) embedded in a rigid matrix of materials (cement or binder) that fills the space between the aggregate particles and binds them together. Self-compacting concrete (SCC) has been described as "the most revolutionary development in concrete construction in decades". Originally developed to meet the growing shortage of skilled labor, it has proven to be economically beneficial due to a number of factors, including: faster construction, reduced site manpower, better surface, better Durability, more freedom in design, thin concrete sections, low noise level, absence of vibration, safe working environment, convenient location. SCC has resulted in reduced concrete placement, faster development times. The properties of SCC will help to further improve the nature of concrete structures and open up new areas of application of concrete. It can also provide rapid acceleration of solid state, with short development Times and compacts each side of the formwork. Hajime Okamura introduced the concept of Self Compacting Concrete (SCC) in 1986 [1]. The main advantages of SCC application are ability to flow to parts of the mold that cannot be compacted, in particular; Crowded reinforced areas, which give it an advantage over conventional concrete [2]. SCC is a concrete that, due to its own weight, flows easily in different parts of the mold and creates significant consolidation within the directional shape of the mold, it does not require any external vibration and offers

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fewer defective parts due to no leakage or separation [3].Fiber reinforcement is increasingly used in structures subject to bending loads and impacts. Fiber reinforced concrete (FRC) is concrete containing fibrous materials that increase its structural integrity. It consists of short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers - each of which imparts different properties to concrete [4]. To increase resistance Fibers with different geometries and chemical compositions are used in construction practice, to structure bending, tensile, and impact loads. Fiber reinforcement made of fiberglass that is resistant to alkalis can significantly increase the physical and mechanical properties of reinforced concrete [5]. Ozawa and his co-workers developed SCC in 1986, which provided a significant technological advance in concrete construction. The development of SCC not only provided better quality concrete, but significantly more Enhanced productivity and working environment. To maintain High amount of fluid, binders and admixtures are required; this increase in required admixture and binder content can lead to increased product costs, increased CO2 emissions, and risk of shrinkage [6]. Mostly The studies used durable pozzolanic materials such as fly ash, silica fume and limestone powder as partial substitutes for cement [7]. Additionally, incorporation of Silica fume, limestone and fly ash improves stability and improvability. Viability of SCC. Although the increase in them, Materials in SCC will increase durability and compressive strength, yet SCC will fail in a brittle state [8]. Adding fibers to SCC improves the properties of hardened concrete. There are several advantages to applying fibers to concrete such as, protection against sudden failures, improved the fracture energy decreases as the crack width decreases, Shrink, increase flexural and tensile strength and hardships [9]. However, while some researchers reported that the increase in fiber was not significant. The compressive strength and modulus of elasticity of concrete have pointed out that the rate at which concrete strength increases depends on the type and percentage of fibers added [10]. The above discussion of the existing literature demonstrates the many studies that researchers have done in the field of fiber-reinforced SCCs, especially for different fibers. This research conducted for investigating and comparing effect of fly ash and Nylon fiber addition on four main characteristics of SCC in the fresh state: flow ability, viscosity, passing ability and segregation resistance.

2. Material and methods

Material used in this project are Fly ash, nylon fiber, coarse and fine aggregate, admixtures are superplasticizer, VMA and water, also includes material testing required for mixing design.

- Fibers

We used textile fibers which are nylon to replace fine aggregate. The nylon used in the project is generally available in the market and the length of the fibers Varies from 1 inch to half an inch.

- Cement

STM C150 TYPE 1 Ordinary Portland cement used in the project. The chemical content of cement is given below in the table-1

Table 1 Different chemical percentage

S. No	Chemical	Percentage
1	L.O.I	2.80
2	SiO_2	20.75
3	Al_2O_3	5.56
4	Fe_2O3	3.34
5	CAO	62.30
6	MgO	1.48
7	SO_3	2.55
8	I.R	0.68
9	C3A	9.07
10	L.S.F	0.90

Super Plasticizer (Chemrite 520BA)

Since the water-cement ratio is kept low in SCC to achieve higher strength, the Superplasticizers are used to increase its fluidity or slump for easy compaction because Self-weight, without any agitation, SCC mixture can pass through easily Congested reinforcement. It used 0.6% to 3.0% but we used 1.3% by weight of cement.

- Viscosity Modifying Admixture (Chemrite 303SP)

It is a white liquid based on carboxylic acid derivatives. The main function of using VMA is used to avoid separation of the SCC mixture. With the increase of superplasticizer the workability of the SCC mixture avoids or stops segregation. By adding the VMA We increased its cohesion to control separation and bleeding.

- Water

According to the standard, the water used in SCC is 160 kg/m3 to 200 kg/m3 Durability is required. The W/C ratio used in SCC is 0.3 to 0.4, but to achieve the desired strength and workability, we used 0.4 W/C.

- Aggregates

Gravel and crushed rock can be used as course aggregate in SCC. The maximum size of course aggregate is 20 mm and the smallest size of aggregate used in SSC is up to 10 mm. Course aggregate with similar grading Can be used in conventional concrete. Course Aggregate of (Margalla hills Pakistan) with the size of 12 mm was used in the project.

Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. A fine aggregate used in all types of concrete having a fineness modulus of 2.4 to 2.6 for SCC. Fine aggregate (Nizampur, Pakistan) with the fineness modulus of 2.4 was used in this project.

2.1. Gradation of Coarse aggregate by sieve analysis

Sieve analysis was performed to determine the particle size of the course aggregate. The purpose of sieve analysis is to check whether coarse aggregate is used in the project full fill the requirement or not. In the table-2, the sieve analysis of aggregates also showed the maximum number of aggregates present in the sample. Maximum size of the coarse aggregate used in this project is 12mm. Get an electronic balance and set the scale to read zero. First, measure the weight of the pan. Measure out the coarse aggregate and 2000g, without weighing the pan. Take a sample in an ASTM standard coarse aggregate sieve and start shaking until there is no more grain could easily escape it or for 15 minutes. Use an electronic balance to measure the weight placed on the sieve.

Table 2 Sieve analysis

Sieve #	Retained gram	Cumulative weight retained	%Cumulative weight retained	%Passing	Criteria For % Passing
¾	9.4	9.4	0.75	99.25	100
½	127.6	137	11.07	88.93	90-100
3/8	319.7	456.7	36.91	63.09	50-85
#4	780.3	1237	100	0	0-10

2.2. Gradation of fine aggregate by sieve analysis

This test is performed to recognize the particle size distribution of the fine aggregate shown in table-3. In simple concrete the modulus of fineness must be in the range 3.2 to 3.1. The fine aggregate used in SCC is 2.4-2.6. The fineness modulus is 2.4 was used in the project. Take electronic balance and set scale reading to zero. Weigh the pan first and take a 1000 g fine aggregate sample. Place the sample in an ASTM standard sieve for coarse aggregate Shake in a sieve shaker for 5 minutes. Measure the weight retained on the sieve with the help of an electric balance.

Table 3 Fine aggregate by sieve analysis

Sieve #	Sieve size	% passing	Weight Retained	% Retained	% Passed	Accumulation % Retained
#4	4.75	95-100	16.2	3.24	96.73	3.24
#8	2.36	80-100	66.3	13.26	83.5	16.5
#16	1.18	50-85	100.6	20.12	63.38	36.62
#30	0.6	25-60	96.5	19.3	44.08	55.92
#50	0.3	10-30	110.1	22.02	22.06	77.94
#100	0.15	2-10	96.4	19.28	2.78	97.22
Pan	----------	----------	15.2	3.04	0	100

2.3. Moisture content of coarse aggregate

Course aggregate is tested for moisture content. Water in the voids of the pre-existing coarse aggregate represented by a sample of 1000 grams of coarse aggregate is placed in the percentage test in an Oven at 110°C for 24 hours.

2.3.1. Dry rodded bulk density of coarse aggregate

This test is done to find out the unit weight of coarse aggregate. The units of dry rod unit weight are Kg/m3 or (lb/ft3). In this test the cylinder is filled with Coarse aggregate in three layers and evenly layer with 25 blows.

2.3.2. Ratio of Mix design

The ratio of mix design used in this project are list in table-4.

Table 4 Mixed design ratio

Name	Fine aggregate (kg)	Coarse aggregate (kg)	Water (liters)	Cement (kg)
Amount (kg)	320	366	90	216
Ratio	0.354	0.406	0.40	0.239
Mix design ratio	1.48	1.70	0.40	1

2.4. Casting of cylinders

The casting of the cylinder block is the most important stage of the project. During the casting process of the cylinder block, the cylinder block is carefully cast. The cylinder is filled with self-compacting concrete without any movement or vibration. Self-compacting for filling up to 13 kg on mold Concrete is required. Lubricate the mold properly before filling it. Cast 12 cylinders for Normal with no fiber, 0.5% fiber, 1.5 % of fibers, and 2.5% of fibers respectively for self-compacting concrete. Four out of these 12 concrete cylinders were cast for 3 days curing, other four cylinders were casted for 14 days and remaining 4 days were casted for 28 days. Among these cylinders, two Cylinders is casted for to know the compressive strength and two for split tensile Strength of hardened self-compacting concrete.

Figure 1 Casting of cylinders

For curing the method used in this project is immersion of cylinder in water for 7, 14 and 28 days and the tests are carried on after curing.

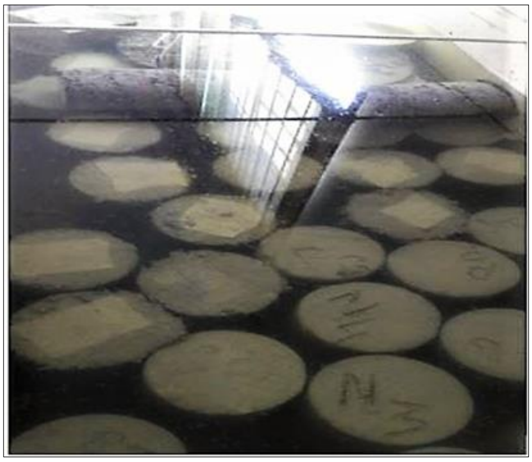

Figure 2 Curing of cylinders

2.5. Fly ash

Fly ash was obtained from ICI Pakistan, Soda Ash Plant, Khewra. Class-F fly ash having specific gravity 2.10 and dark brown color is used. The properties the Fly ash were obtained from the source, from where it is obtained. The chemical composition and properties of fly ash are list in the table-5 and table-6.

Table 5 Chemical Composition of Fly ash

Chemicals	Percentage
Sio2	56.55
Fe2o3	6.13
Al2o3	26.20
Cao	9.23
Mgo	0.32
So3	0.07
Nao	0.9
K2o	0.6

Table 6 Properties of Fly ash

Properties	Values
Colour	Brown
Specific gravity	2.6
Type	F Class

2.5.1. Admixture

High range water reducing admixture obtained from 'imp orient chemicals' having a density of 1.18±0.05 kg/liter is used 1% by weight of total binder content.

2.5.2. Preparation of Cylinders:

48 cylinders were casted in the order of 12 cylinders at a time for same percentage. 12 cylinders were casted and cured for each percentage of Fly ash. The tests that are described further were also performed before casting of the cylinders. 2 cylinders were casted for each test and the average value was calculated.

Table 7 Mix Proportion of concrete

% Fly Ash	Fine Aggregates kg/m³	Coarse Aggregates kg/m³	Cement kg/m³	Fly Ash kg/m³	Water kg/m³	Admixture kg/m³
0	735.3	980.4	490.2	0	220.59	4.90
15	735.3	980.4	416.7	73.6	220.59	4.90
30	735.3	980.4	343.2	147	220.59	4.90
45	735.3	980.4	269.61	220.6	220.59	4.90

2.6. Influence of Nylon fiber on Workability, Filling ability and Passing ability

Based on the above experimental work we conducted different types of tests. We mix the concrete in a mixer to get the standard consistency. After mixing concrete casting is done and finally Harden property test is done. Slump test is one of the most widely used SCC tests at present. The difference between the slump flow test and the conventional slump test is that the slump flow test measures the "spread" or "flow" of the concrete sample after the cone is lifted, rather than the "slump" (decrease in height) of the concrete sample. . Slump flow values of about 24 to 30 inches or 650-800 mm are within acceptable limits for SCC.

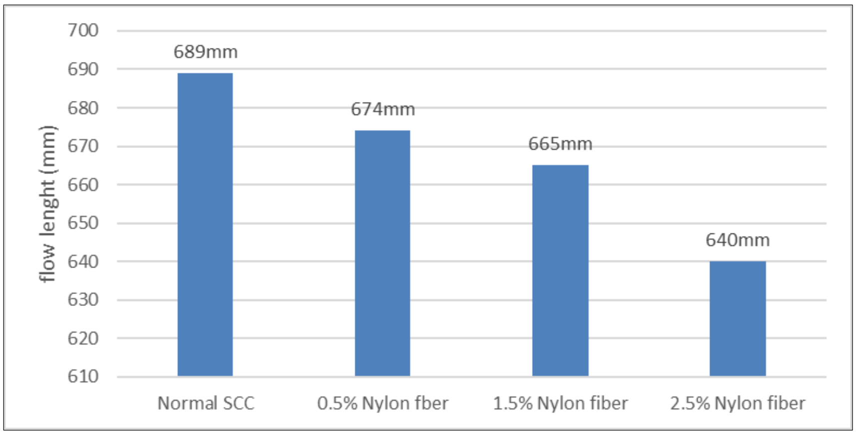

Figure 3 Slump flow test

When nylon fiber is added with percentages of 0.5%, 1.5%, 2.5% to conventional concrete, the slump is in the range of 650mm - 800mm as per ASTM standards. But when the fiber content increases by 2.5%, this decrease will not be within the range of ASTM standards. Hence it indicates that fiber content suitable for slump test is not more than 2.5% by weight of cement.

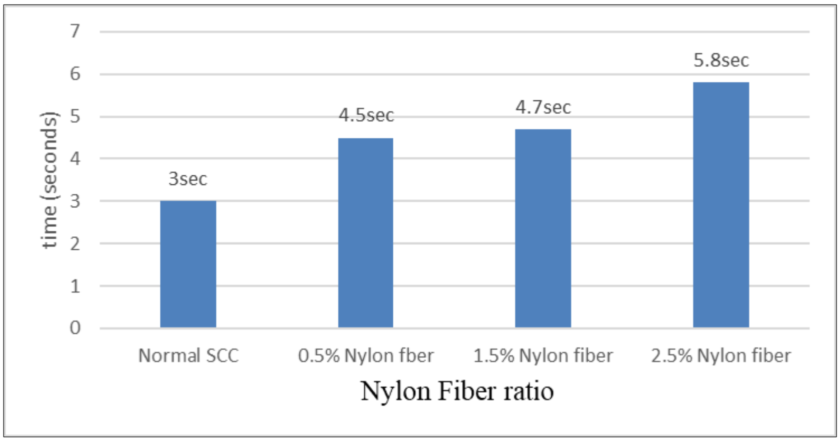

Figure 4 T50cm flow test

When nylon fibers are added to conventional concrete with percentages of 0.5%, 1.5%, 2.5%, the time taken for the concrete to expand is 3 seconds. But when the fiber content is increased by 2.5%, the slump flow time is 6sec which will not be within the range of ASTM standards. So it shows that the fiber content suitable for slack flow is not more than 2.5% by weight of cement.

2.6.1. V-funnel test

The flow ability of fresh concrete can be tested by V-funnel test, by which flow time is measured. The funnel is filled with about 12 liters. The time taken to flow through the concrete and its equipment is measured. Further, T 5min is also measured with a V-funnel, which indicates a tendency for Separation.

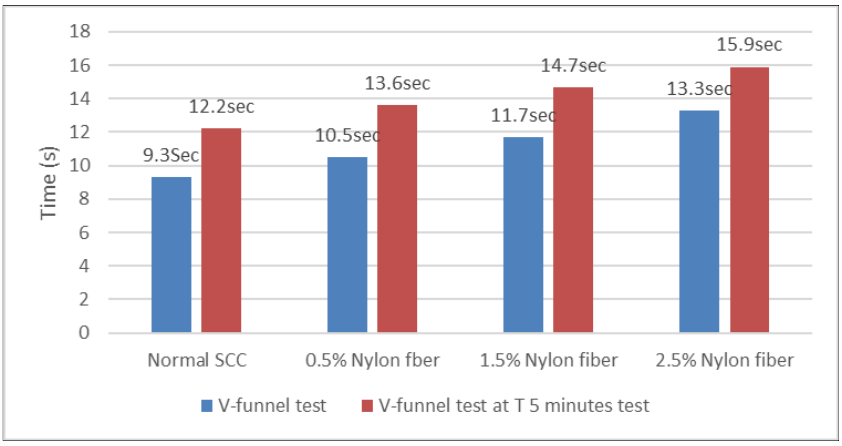

Figure 5 V-funnel test

The concrete time for conventional concrete is 9.3 seconds. When nylon fiber is added to conventional concrete with percentages of 0.5%, 1.5% and 2.5% the concrete takes time to flow which indicates that the fiber in the concrete affects its flow ability. The graph shows that nylon fiber concrete takes less time to flow down due to gravity but when nylon fiber is added with percentages of 0.5%, 1.5%, 2.5% to conventional concrete, the concrete takes less time to flow down.

2.7. Compressive Test of self-compacting concrete by adding Nylon fibres

The graph shows that the compressive strength of the concrete samples improved proportionally with the addition of nylon fibre up to 2.0% by volume of cement, and then tended to decrease with the addition of nylon at 2.5%.

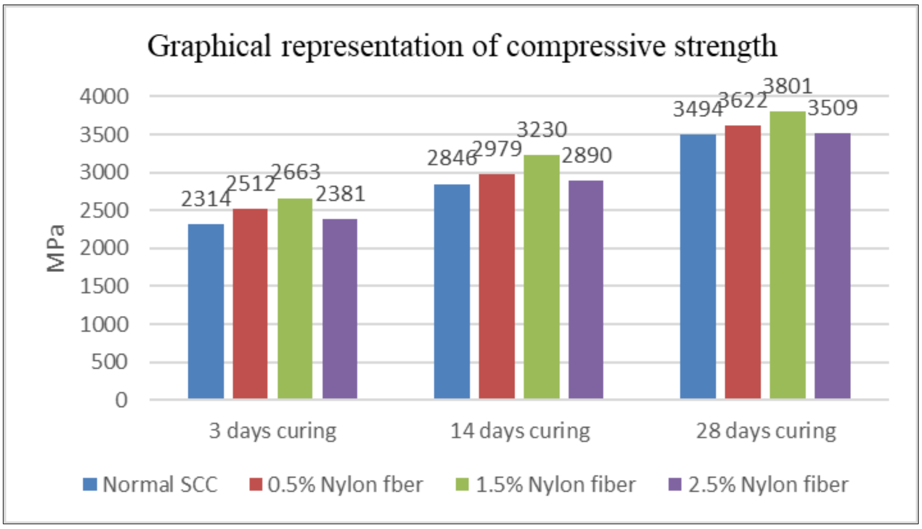

Figure 6 Compressive strength

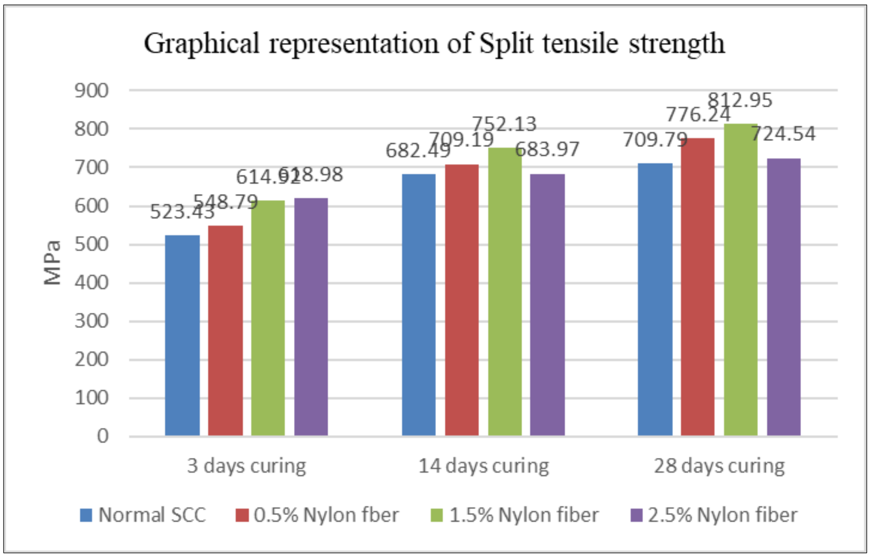

Figure 7 Split tensile test

2.8. Influence of fly ash on Workability, Filling ability and Passing ability

Slump test was performed to check the influence of fly ash on the workability of self-compacting concrete. Results show that when we increase the amount fines in concrete at constant w/b ratio its workability is decreased is shown in fig-6, fig-7 and fig-8. This was also the case with L-box test which was used to check the passing ability of self-compacting concrete. V-Funnel test that was used to check the filling ability of self-compacting concrete also shows the same results.

Figure 8 Slump flow test

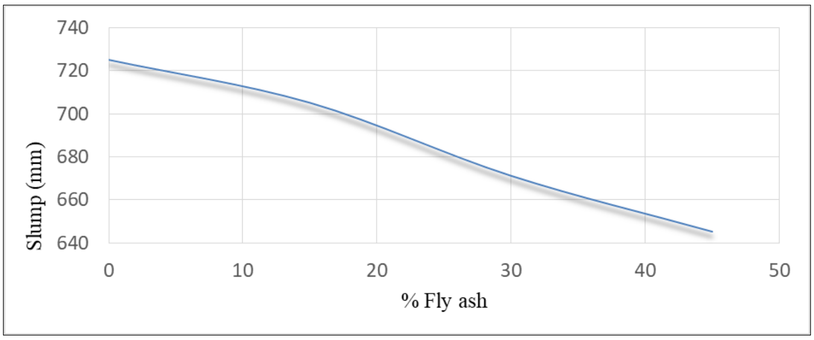

Figure 9 slump graphical test

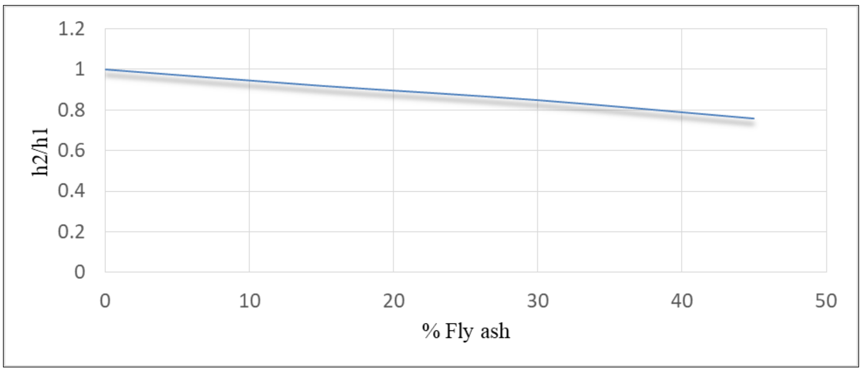

Figure 10 Slump test

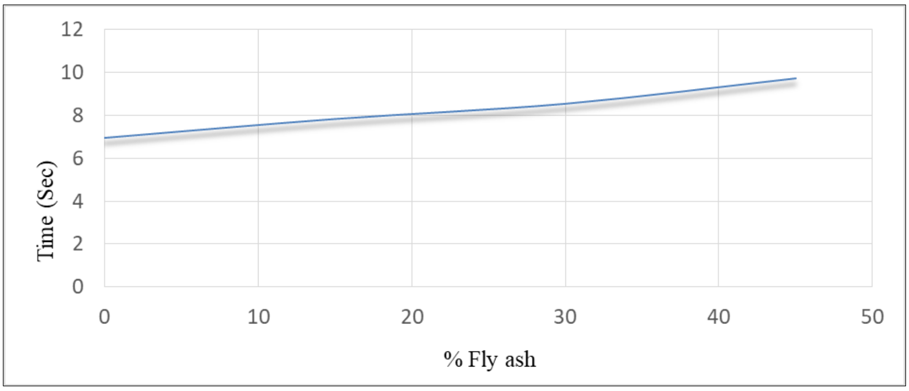

Figure 11 Slump time test

2.9. Influence of Fly ash on Compressive strength of concrete

The compressive strength's test is performed on samples of 0%, 15%, 30% and 45% fly ash which shows that the compressive strength increases with replacement of fly ash up to 30% in cement. Silica from Fly ash react with lime that is produced by cement to form extra cementious compounds i.e. CSH which means strength but as the amount of cement is reduced and that of Fly ash is increased the lime is produced in very low amount and silica remains unreacted so the strength is decreased. This is the reason that strength is increased up to 30% and when the lime available was less i.e. at 45%, strength started to decrease. The maximum compressive strength was found to be 41.94 N/mm2 at 28 days and at 30% replacement of Fly ash which was 9.22% more than the concrete with 0% Fly ash.

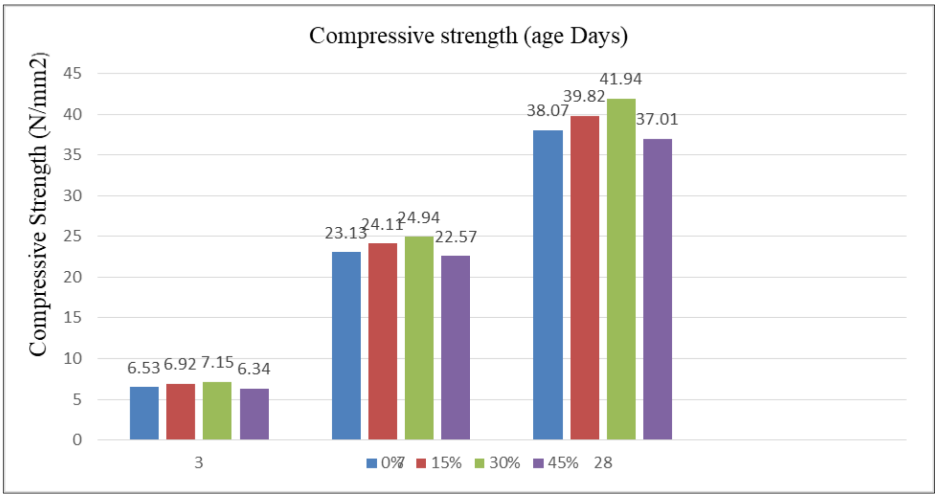

Figure 12 Compressive strength with fly ash

2.10. Influence of Fly ash on split Tensile Strength of concrete

The split tensile strength test was also increased by the replacement of Fly ash with cement up to 30% and then decreased when Fly ash was further increased to 45%. When the fine particles are increased, they fill the voids between the coarser particles and as a result, strength of concrete increases. The maximum split tensile strength was found to be 4.91N/mm2 at 28 days which was 13.84% more than concrete with 0% Fly ash.

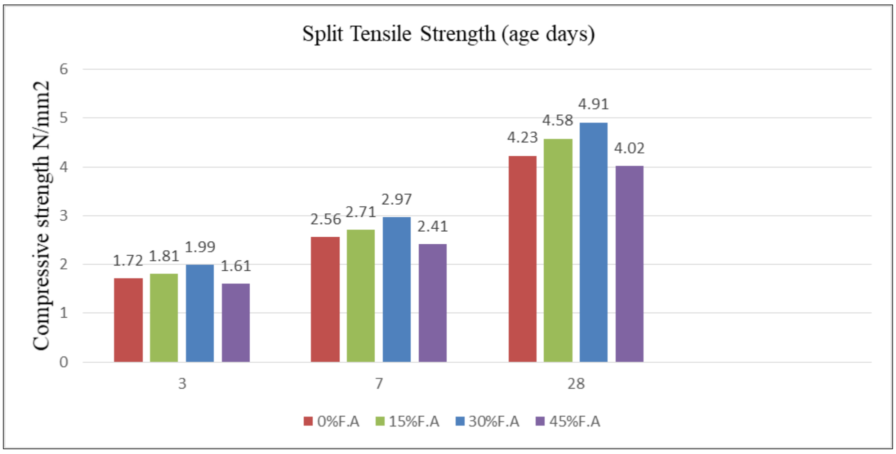

Figure 13 Split tensile strength with fly ash

3. Conclusion

Based on the fresh and hardened state test results of self-compacting concrete mixed with nylon fiber and fly ash, the following conclusions can be drawn. In the fresh state of SCC, when the presence of nylon fiber increased, it resulted in a lower flow ability (slump flow) of the SCC mixes. On the other hand, the permeability and separation ratio of the mixes are increasing according to the volume fraction of the nylon fiber material. On the other hand Flow ability (V-Funnel) decreases as we increase the amount of Fly ash in the concrete at a constant w/b ratio and admixture. Concrete mixes can still meet the flow, adhesion and permeability requirement of SCC with the addition of nylon fiber up to 2.0% by volume of cement. The compressive strength of the concrete specimens improved proportionally with the addition of nylon fiber up to 2.0% by volume of cement, and then tended to decrease with the addition of nylon at 2.5%. Compressive strength increases as we increase the amount of Fly ash up to a certain limit (30%) and then it starts decreasing. The splitting tensile strength of concrete specimens also improved with the addition of nylon fiber up to 2.0% by volume of cement, and then tended to decrease with 2.5% of nylon addition. Split Tensile strength also increases up to 30% and then decreases if we further increase the amount of Fly ash. According to the assessment of fresh and hardened properties of SCC, it seems that nylon fibers are allowed to be added to concrete mix up to 2.0% by volume of cement. Passing ability (L-Box) decreases as well with the increase of the amount of mineral admixture (Fly ash) in concrete while keeping all other constituents constant. The results of concrete with the addition of Fly ash were found to be best at 30% as the V-Funnel, L-Box, and Slump satisfy the criteria and also compressive strength and split tensile strength were found to be maximum at 30% Fly ash.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declared no conflict of interest.

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