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Evaluating the Effect of Nylon Fibers in Self-Compacting Concrete

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Abstract: **This project has been conducted to evaluate the effects of nylon fiber addition on fresh state characteristics of SCC mixes, and investigate the effects of nylon fiberon some hardened properties of SCC. In this project, concrete mixes were added with Nylon fiber of 0.5%, 1.5%, 2.5%, Fresh characteristics were evaluated based on its passing ability, flow ability, and segregation resistance using, 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. Tests results indicate that nylon fibers tend to increase the passing ability but will decrease filling ability and segregation resistance of SCC. Furthermore, it can be concluded after 3 days, 14 days, 28 days of curing, concrete specimen's tests indicate that Nylon fiber addition up to 2.0% of volume cement tend to improve the compressive strength, tensile strength, of hardened SCC but the 2.5% of nylon fiber decreases the compressive strength, tensile strength, of hardened SCC. It can also be suggested that Nylon fibers allowed to be added into SCC mixes up to 2.0 % fiber by volume of cement.**

Keywords: Self Compacting Concrete, Nylon Fiber, SCC, Fiber Reinforced Concrete, High performance concrete

INTRODUCTION:

Concrete is a blend of granular materials like fine and coarse aggregate plus cement and water. There are different types of concrete used in the construction works. Self-compacting concrete (SCC) is also an important type of concrete that is nowadays commonly used in the construction of buildings and road pavements. Self-compacting Concrete (SCC) is creative concrete that does not require any type of vibration and agitation for placing and compacting the concrete. This special type of concrete is able to flow under its own weight completely filling and achieving full compaction even in heavily reinforced structure. Self-Compacting Concrete (SCC) provide speedy rate of concrete placement at site. The SCC provides the ability to pass through the congestion, and occupy complete space in the form. The fluidity and the segregation resistance of SCC assure the high level of homogeneity and minimize the voids and gives the uniform concrete strength.

At the beginning, self-compacting concrete was named as High Performance concrete which means that a concrete with high durability with low water cement ratio but later on its name is changed to High performance Self Compacting Concrete (SCC), which can flow under its own weight without requiring any vibrator [1]. The difference between conventional concrete and self-compacting concrete(SCC) according to material are Limited aggregate content, Low water-powder ratio and Use of superplasticizer. Fiber-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fiber that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fiber, synthetic fiber and natural fiber – each of which lend varying properties to the concrete. The flow properties of concrete e.g: viscosity, filling capacity, time of flow in orifice are required to characterize flow in SCC [8].The self-compacting concrete is also be used in places where the machine of vibration are agitation does not reaches their such as columns or wall of heavily reinforced concrete. The high flow ability of SCC makes it possible to fill the formwork without vibration [2].

LITERATURE REVIEW:

[1] Okamura (1997), in his research study has fixed the coarse aggregate content to 50% of the solid volume and the fine aggregate content to 40% of the mortar volume, so that self-compactability could be achieved easily by adjusting the water to cement ratio and superplasticizer dosage only. However, it was found that the anti washout underwater concrete was not applicable for structures in open air for two reasons: first, entrapped air bubbles could not be eliminated due to the high viscosity; and second, compaction in the confined areas of reinforcing bars was difficult. Thus, for the achievement of self-compact ability, a super plasticizer was vital. With a super plasticizer the paste can be made more flow able with little decrease in viscosity, compared to the drastic effect of the water, when the cohesion between the aggregate and the paste is weakened.

[2] Khayat's (1997), did a research and investigate that the uniformity of in situ mechanical properties of self-consolidating concrete used to cast experimental wall elements. Eight optimized SCC mixtures with slump flow values greater than 630 mm and a conventional concrete with a slump of 165 mm were investigated. The water-cement ratio ranged from 0.37 to 0.42. Experimental walls measuring 95 cm in length, 20 cm in width, and 150 cm in height were cast. After casting, no consolidation was used for the SCC mixtures, while the medium fluidity conventional concrete received thorough internal vibration.

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Several cores were obtained in order to evaluate the uniformity of compressive strength and modulus of elasticity along the height of each wall. In his study, he found out that all cores from both types of concrete exhibited little variation in compressive strength and modulus of elasticity in relation to height of the wall, indicating a high degree of strength uniformity. However, compressive strength and modulus of elasticity were greater for SCC samples

[3] Duval R. (1998), prepares a model of water-cementitious materials and silica-cement ratios and he investigated the workability and compressive strength of high performance concrete at low water cement ratios with a naphthalene sulphonate superplasticizer as an admixture is used. After the results, he found out that if 10% silica fume is used in place of cement then it does not reduce the workability of high performance concrete. Moreover, if the percentage of silica fume increased up to 20% then then it produces higher compressive strength than normal concrete.

[4] Kuroiwa (1993), developed a type of concrete, which contained materials normally found in conventional concrete such as Portland cement, aggregate, water, mineral and chemical admixtures. The chemical admixtures were added in order to improve the deformability and the viscosity of the concrete. The newly developed type of concrete was called super-workable concrete and showed excellent deformability and resistance to segregation. It could also fill completely heavily reinforced formworks without any use of vibrators. After the laboratory tests it was found out that the super-workable concrete had superior properties in the fresh state and excellent durability after hardening. Because of its properties, it was considered that it would be suitable for projects involving heavily reinforced areas and was employed in the construction of a 20-story building.

[5] Mindess et al. (2003), conducted a study in which Mineral admixtures are added to self-compacting concrete as part of the total cementitious system. They may be used in addition to or as a partial replacement of Portland cement in SCC depending on the properties of the materials and the desired effect on SCC.

[6] Khayat et al. (1997), evaluated the influence of silica fume blended with cement on some properties like bleeding, slump loss, time of setting and compressive strength of fresh and hardened concrete. A total of 26 commonly used concrete mixtures were prepared. Half of the mixtures were air-entrained and had water-cement ratios ranging from 0.33 to 0.59. The remaining half contained non air-entrained mixtures and the water-cement ratios varied between 0.45 and 0.69. Studies revealed that the addition of small percentages of silica fume, usually under 10%, and proper amount of high range water-reducing admixture (superplasticizer) could decrease the viscosity of the paste, thus reducing the water demand and the risk of bleeding.

MATERIAS AND METHODALOGY:

NYLON FIBER:

Textile fibers that is Nylon is used as a replacement of Fine aggregate. The Nylon used in this research is commonly available in the market and length of fibers varies from 1 inches to ½ inches.

Figure (1), Nylon fibers

CEMENT:

ASTM C150 TYPE 1 Ordinary Portland cement which is mostly available in Pakistan was used. The chemical composition of cement is given below:

Table (1) showing the Chemical Composition of Cement

S. No	Chemical	Percentage

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1	L.O.I	2.80
2	SiO2	20.75
3	Al2O3	5.56
4	Fe2O3	3.34
5	CAO	62.30
6	MgO	1.48
7	SO3	2.55
8	I.R	0.68
9	C3A	9.07
10	L.S.F	0.90

SUPER PLASTICIZER (CHEMRITE 520BA):

As in SCC, the water cement ratio is kept low to achieve the higher strength, the Super plasticizer is used to increase its flow or slump to be easily compacted due to its own weight, without any agitation and SCC mix can easily pass through congested reinforcement. It is used up to 0.6% to 3.0% but we used 1.3% by weight of cement.

VISCOSITY MODIFYING ADMIXTURE (VMA) (CHEMRITE 303SP):

It is white pale liquid based on carboxylic acid derivatives. The main function of using VMA is to avoid the Segregation of SCC mix. As Super Plasticizer increase the workability of SCC mix the Segregation is avoid or stop. By the adding VMA by we increased its cohesiveness to control Segregation and also Bleeding.

Figure (2), Superplasticizer and VMA

WATER:

Water is used in the SCC which is 160 kg/m3 to 200 kg/m3 according to durability required. The water cement ratio used in SCC is 0.3 to 0.4 and we used 0.4 water cement ratio. To achieve the desire strength and workability.

COARSE AGGREGATE:

In SCC the gravel and crushed rock could be used as Course Aggregate. The maximum size of course aggregate is 20 mm and smaller size of aggregates use in SSC is up to 10 mm. The Course Aggregate with a grading similar to that used in conventional concrete may be used. Course aggregate of (Margalla Hills) with size of 12 mm is used in the project.

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Figure (3), Coarse Aggregates

FINE AGGREGATE:

The fine Aggregate used in all types of concrete having Finesses module of 2.4 to 2.6 for SCC. Available natural sand or Fine aggregate (Nizampur) with the fineness modulus of 2.4.

Figure (4), Fine Aggregate

TESTS OF COARSE AND FINE AGGREGATE:

GRADATION OF COARSE AND FINE AGGREGATE BY SIEVE ANALYSIS:

Sieve analysis is performed to know the particle size of coarse and fine aggregate. The sieve analysis of aggregates also tells about the maximum number size of aggregate present in sample. The maximum size of coarse aggregate used in this research study is 12 mm. The fine aggregate used in SSC concrete is 2.4 to 2.6. and fineness modulus of fine aggregate used in this research study is 2.4.

MOISTURE CONTENT OF COARSE AND FINE AGGREGATE:

The moisture content test of coarse and fine aggregate is performed to check the quantity of water already present in the voids of coarse and fine aggregate. It is represented in percentage. During the test, sample of 1000 gram of coarse aggregate or fine aggregate is placed in oven for 24 hours at temperature of 110C.

WATER ABSORPTION OF COARSE AND FINE AGGREGATE:

The Water absorption test means that how much quantity of water can coarse aggregate and fine aggregate absorb. In this test the sample of coarse aggregate or fine aggregate is fully immersed in the water for 24 hours and then taken out of the water and made it dried and then put the dried sample in the oven for 24 hours at the temperature of 110C.

DRY RODDED BULK DENSITY OF COARSE AGGREGATE:

This test is executed in order to check the unit weight of coarse aggregate. The units of dry rodded bulk density are Kg/m3 or (lb/ft3). In this test, cylinder was filled with coarse aggregate in three layers and with 25 blows uniformly.

TESTS OF SELF-COMPACTING CONCRETE (SCC):

MIX DESIGN:

Mix design is a method in which we try to find out the suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is called mix design.

SLUMP FLOW TEST:

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Slump flow is being one of the mostly used SCC tests at the current time. The main difference between the slump flow test and conventional slump test is that the slump flow test measures the “spread” or “flow” of the concrete sample once the cone is lifted rather than the “slump” (drop in height) of the concrete sample. The, slump flow values of approximately 24 to 30 inches or 650-800mm are within the acceptable range for the SSC.

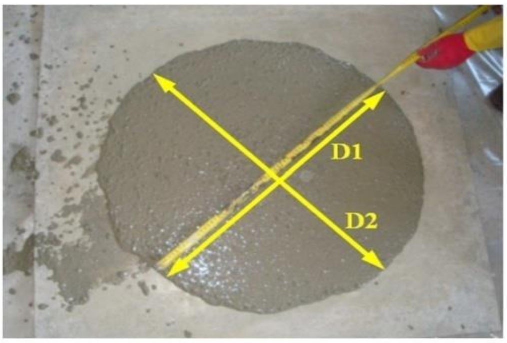

Figure (5), Slump flow Test Specimen

V-FUNNEL TEST:

The V-funnel test is used to check the flow ability of the fresh concrete, whereby the flow time is measured. The funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus is measured. Further, T 5min is also measured with V-funnel, which indicates the tendency for segregation.

L-BOX TEST:

The passing ability of SCC is determined using the L- box test. The vertical section of the L-Box is filled with concrete, and then the gate lifted to let the concrete flow into the horizontal section. The height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (H2/H1). This is an indication of passing ability.

COMPRESSIVE STRENGTH OF SCC CYLINDER:

To determine harden properties of self-compacting concrete for checking compressive strength of the concrete cylinder specimens. In this test the concrete compressive strength is check after 3rd, 14th and 28th days curing in Universal testing machine (UTM). The cylinder is placed under UTM and load is applied until the cylinder is crushed and the reading were noted.

Figure (6), Casting of Cylinders

SPLIT TENSILE STRENGTH:

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A concrete cylinder of size 150mm dia×200mm height is subjected to the action of the compressive force along two opposite edges, by applying the force in this manner. The cylinder is subjected to compression near the loaded region and the length of the cylinder is subjected to uniform tensile stress.

RRSULTS AND DISCUSSION:

TEST RESULTS ON COARSE AND FINE AGGREGATE:

Table (2), Showing the results of coarse and fine aggregate

S. No	Tests	Results
1	Sieve analysis of fine aggregate	2.34
2	Specific gravity of coarse aggregate	2.94
3	Specific gravity of fine aggregate	2.65
4	Moisture content of coarse aggregate	11.26%
5	Moisture content of fine aggregate	1.11%
6	Water absorption of course aggregate	3.3 %
7	Dry rodded bulk density of coarse aggregate	1568

MIX DESIGN OF SELF-COMPACTING CONCRETE (SCC):

Table (3), Showing the Result of Mix Design of SCC

Concrete Mix	Water (liter)	Cement (kg)	Fibers (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Super-Plasticizer (%)	VMA (%)	W/C
SCC1(N)	22.5	55	0	80	91.5	1.3	0.8	0.40
SCC2 (0.5% F)	22.5	55	0.4	79.60	91.5	1.3	0.8	0.40
SCC3 (1.5%F)	22.5	55	1.2	78.8	91.5	1.3	0.8	0.40
SCC4 (2.5% F)	22.5	55	2	78	91.5	1.3	0.8	0.40

SLUMP FLOW TEST:

Table 4, Showing the Result of Slump Flow Test

Name of test	Normal SSC	0.5% fibers SSC	1.5% fibers SSC	2.5% fibers SSC
Slump flow test	689mm	674mm	665mm	640mm
T50 cm Slump flow test	3 sec	4.5 sec	4.7 sec	5.8 sec

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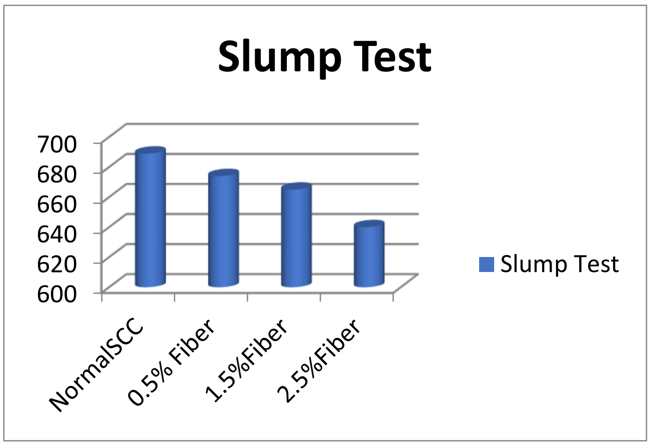
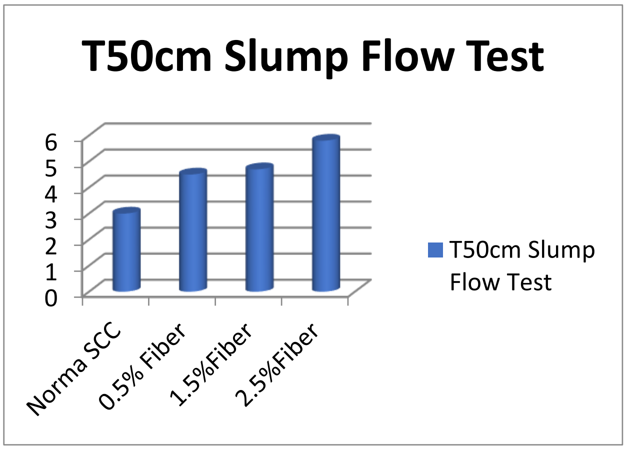
Graph (1), showing the Result of Slump Flow Test and T50cm Slump Flow Test



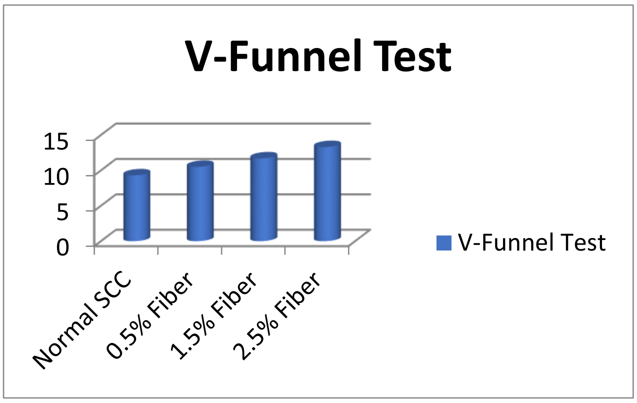


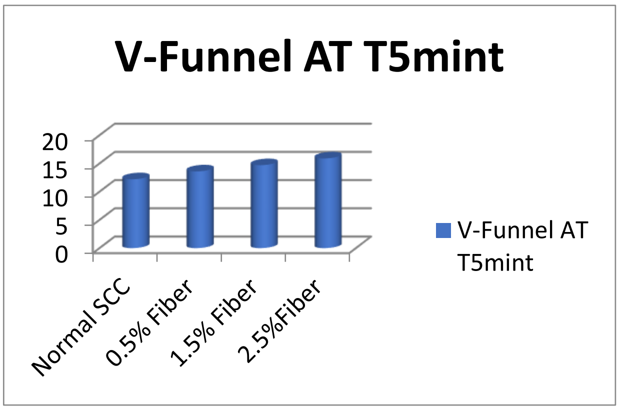
V-FUNNEL TEST:

Table (5), Showing the result of V-funnel and T5 minutes test

Name of test	Normal SSC	0.5% fibers SSC	1.5% fibers SSC	2.5% fibers SSC
V-funnel test	9.3 sec	10.5 sec	11.7 sec	13.3 sec
V-funnel at T5 minutes tests	12.2 sec	13.6 sec	14.7 sec	15.9 sec

Graph (2), Showing the result of V-funnel test and V-funnel at T 5 mint. Test



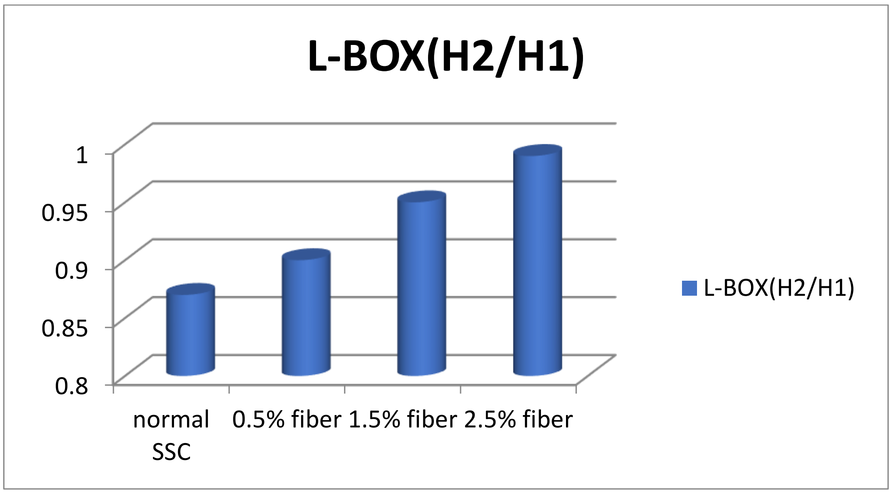


L-BOX TEST:

Table (6), Showing the Result of L-Box Test

Name of Tests	Normal SCC	0.5% Fiber SCC	1.5% Fiber SCC	2.5% Fiber SCC
L-BOX(H2/H1)	0.87	0.90	0.95	0.99

Graph (3), Showing the result of L-Box Test Result

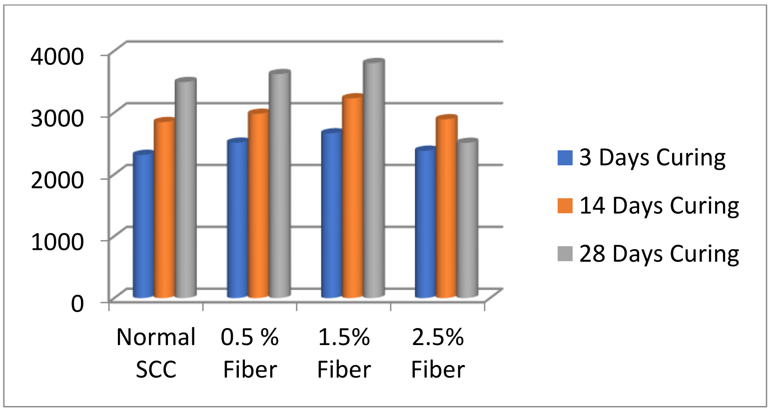


COMPRESSIVE TEST:

Table (7), Showing the result of Compressive test of SCC

After Curing	Normal SCC	0.5 % Fiber SCC	1.5% Fiber SCC	2.5% Fiber SCC
Strength after 3 days (Psi)	2314	2512	2663	2381
Strength after 14days (Psi)	2846	2979	3230	2890
Strength after 28days (Psi)	3494	3622	3801	3509

Graph (4), Showing the result of Compressive Test of SCC



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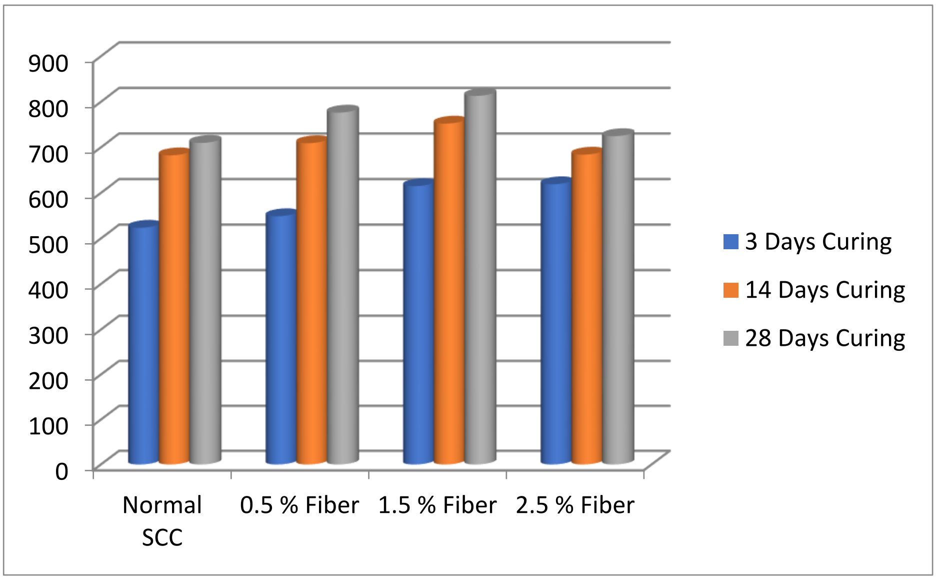
SPLIT TENSILE TEST:

Table (8), Showing the result of Split Tensile test

After Curing	Normal SCC	0.5 % Fiber SCC	1.5 % Fiber SCC	2.5% Fiber SCC
Split tensile Strength after 3 days (Psi)	523.43	548.79	614.92	618.98
Split tensile Strength after 14 days (Psi)	682.49	709.19	752.13	683.97
Split tensile Strength after 28 days (Psi)	709.79	776.24	812.95	724.54

Graph (5), Showing the result of Split Tensile Test



CONCLUSION:

Based on the tests results of the fresh and hardened state of self-consolidating concrete added with polypropylene fiber, the following conclusions can be drawn:

1. In the fresh state of SCC, when the presence of nylon fiber increased it caused lower flowing ability (Slump Flow) of SCC mixes. On the other hand, passing ability and the segregation ratio of the mixes increasing in accordance with the volume fraction of nylon fibers content.
2. The concrete mixes can still meet the requirement of flow ability, viscosity and passing ability of SCC with nylon fiber addition up to 2.0 percent by volume of cement.
3. The compressive strength of concrete specimens improved proportionally with the addition of nylon fiber up to 2.0 percent by cement volume, and then tend to decrease with 2.5percent of nylon addition.
4. The splitting tensile strength of concrete specimens also improved in accordance with the addition of nylon fiber up to 2.0 percent by cement volume, and then tend to decrease with 2.5 percent of nylon addition.
5. According to the evaluation of fresh and hardened properties of SCC, it seems that nylon fibers allowed to be added into the concrete mixes up to 2.0 percent by cement volume.

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