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# Strength study on fiber reinforced self-compacting concrete with fly ash and GGBFS

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**Abstract:** In this Investigation the strength studies of fibre reinforced self-compacting concrete was studied and the characteristics are compared. The mix proportion is obtained as per the guidelines given by European Federation of producers and contractors of specialists' products for structure (EFNARC). Self-compacting concrete (SCC) mixes are produced by replacing the cement with 30%, 40% and 50% of ground granulated blast furnace slag, fly ash and with addition of polypropylene synthetic fibre of 0.05% and 0.10% to the SCC concrete. The water-powder (w/p) ratio used in this investigation is 0.4. Super plasticizer used in this study is Glenium B233 and its dosage is 2% to obtain the required SCC mix. Fresh concrete Specimens such as cubes, cylinders and prisms were casted and tested for various mix proportions to study the mechanical properties such as compressive strength, split tensile strength and flexural strength at different ages of concrete such as 7 days, 14 days and 28 days.

***Keywords:*** *Fiber reinforced self-compacting concrete, SCC, Ground Granulated Blast Furnace slag, polypropylene synthetic fibre, Super plasticizer, fresh property, compressive, flexural and split tensile strength*

## 1. Introduction:

### 1.1 Background of Study:

Self-Consolidating concrete (SCC), also known as self compacting concrete, is a highly flowable, non-segregating concrete and by its own weight spread into place, completely fill the formwork even in the presence of dense reinforcement and then encapsulate the rebar without the need of any additional compaction. Development SCC is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. Due to its high deformability and resistance to segregation, it has the capacity to completely fill the formwork, easy to flow in complex forms with congested reinforcement and encapsulate the reinforcement without any influence of the workers skills. This is in contrast to traditional concrete, where the difficulties in compaction could cause entrapped air voids and reduce the strength and durability of concrete. SCC can be defined as an engineered material consisting of cement, aggregates, water, filler, and chemical admixtures to take care of specific requirements, such as, high flowability, passing ability, adequate viscosity, and segregation resistance. In the fresh state, this type of concrete should be able to flow, spread and consolidate under its own weight. SCC must satisfy the following workability performance criteria: 1) Flowability: The ease of flow of fresh concrete when unconfined by formwork and/or reinforcement; 2) Viscosity: The resistance to flow of a material (e.g. SCC) once flow has started; 3) Passing ability: The ability of fresh concrete to flow through tight openings such as spaces between steel reinforcing bars without segregation or blocking; and 4) Stability: the ability of SCC to remain homogenous by resisting segregation, bleeding, and air popping during transport, placement, and after placement. Due to its characteristics, SCC provides several benefits, such as: greater freedom in shape design, easier pumping and placing, improved consolidation around reinforcement, higher bond strength with reinforcement, uniform and complete consolidation, better surface finishes, improved durability, reduced noise levels caused by absence of vibration, labor savings, faster construction and also more spacious and safe working environment. Those characteristics of SCC can be achieved by implementing following basic principles in the mix design process; 1) lower coarse aggregate content, 2) increasing paste content, 3) lower water/powder ratio, (powder is defined as cement added with filler, such as: fly ash, silica fume, etc.), and 4) the use of superplasticizer. Considering lower water-cement ratio and higher content of cementitious materials compared to conventional concrete, SCC should have improved durability and strength. However, similar with other types of cement-based materials, SCC also has a brittle characteristic. This characteristic can be improved by adding fibers in to the concrete mix. The term fiber added concrete can be defined as concrete containing dispersed randomly oriented fibers. Inherently concrete is brittle under tensile loading and mechanical properties of concrete may be improved by randomly oriented discrete fibers which prevent or control initiation, propagation, or coalescence of cracks. Fiber added concrete properties and performance change, depending on the properties of concrete and the fibers. The properties of fibers that are usually of interest are fiber concentration, fiber geometry, fiber orientation, and fiber distribution. Moreover, using a single type of fiber may improve the properties of fiber added concrete to a limited level. Shortcut type of fiber can be added to bridge microcracks of which growth can be controlled. This leads to a higher tensile strength of the composite. Unlike its effects to hardened concrete, the presence of fibers in concrete mixes can cause significant deterioration to the concrete workability. On the other hand, workability is very important for SCC to achieve its requirement to flow, pass through tight openings without blocking, and completely consolidate by its own weight. Based on those reasons, this research was designed to investigate effects of polypropylene fiber addition on some fresh and mechanical properties of SCC.

**1.2 Objectives:**

This research conducted to investigate effect of polypropylene fiber addition on four main characteristics of SCC in the fresh state: flowability, viscosity, passing ability and segregation resistance. Effect of polypropylene fiber addition on compressive strength, splitting tensile Strength h, and impact resistance of SCC also wanted to be known. Based on the results of fresh and hardened SCC tests, prediction of optimum volume fraction of polypropylene fiber in SCC mixes can be determined.

**2. Experimental Work:**

**2.1 Materials and Mix Proportion:**

Polypropylene was chosen, because it is not expensive, inert in high pH cementitious environment and easy to disperse. In this research, monofilament polypropylene with 18 µm diameter, and 12 mm length, which having 0.91 g/cm3 density were used. The mixtures investigated in this study were prepared with Ordinary Portland Cement which is fulfilled the requirements in the Indonesian Standard SNI 15-2049-2004. Well graded crushed granite, with Saturated Surface Dry (SSD) density of 2.48, was used as coarse aggregate. A maximum aggregate size of 20 mm was chosen for coarse aggregates, as it is commonly used for SCC mixes. Coarse aggregates were washed to remove fine sandy particles that can hinder rheological properties. Well-graded natural sand, with SSD density of 2.65, and maximum size 5 mm, was used as the fine aggregate. Ground granulated blast furnace slag, fly ash used as mineral admixture while polycarboxylate based superplastisticizer also added in to the mixes. Concrete mixes were prepared containing 0%, 0.05%, 0.10%, and 0.15% of polypropylene fibers (measured by fibers volume in concrete volume). Detail of mixes proportion for this research can be observed in following Table 1

**2.2 Details of Experimental Tests**

It has been noticed that all super plasticizers are not showing the same extent of improvement in fluidity with all types of cements. Some super plasticizers may show higher fluidizing effect on some type of cement than other cement. There is nothing wrong with either the super plasticizers or that of cement. The fact is that they are just not compatible to show maximum fluidizing effect.

Table 1.Detailed mix proportion

| Mix proportions | Cement Kg/m3 | Mineral admixtures Kg/m3 | F.A Kg/m3 | C.A Kg/m3 | w/b | SP (% by weight of cement) | PPF (% by weight of concrete) |
|---|---|---|---|---|---|---|---|
| CM | 500 | 0 | 900 | 600 | 0.4 | 2 | 0 |
| FFSCC-1 | 350 | 150 | 900 | 600 | 0.4 | 2 | 0.05 |
| FFSCC-2 | 300 | 200 | 900 | 600 | 0.4 | 2 | 0.05 |
| FFSCC-3 | 250 | 250 | 900 | 600 | 0.4 | 2 | 0.05 |
| FFSCC-4 | 350 | 150 | 900 | 600 | 0.4 | 2 | 0.1 |
| FFSCC-5 | 300 | 200 | 900 | 600 | 0.4 | 2 | 0.1 |
| FFSCC-6 | 250 | 250 | 900 | 600 | 0.4 | 2 | 0.1 |
| GGBS-1 | 350 | 150 | 900 | 600 | 0.4 | 2 | 0.05 |
| GGBS-2 | 300 | 200 | 900 | 600 | 0.4 | 2 | 0.05 |
| GGBS-3 | 250 | 250 | 900 | 600 | 0.4 | 2 | 0.05 |
| GGBS-4 | 350 | 150 | 900 | 600 | 0.4 | 2 | 0.1 |
| GGBS-5 | 300 | 200 | 900 | 600 | 0.4 | 2 | 0.1 |
| GGBS-6 | 250 | 250 | 900 | 600 | 0.4 | 2 | 0.1 |

Optimum fluidizing effect at lowest dosage is an economical consideration. Giving maximum fluidizing effect for a particular super plasticizers and cement is very complex involving many factors like composition of cement, fineness of cement. Workability requirements of successful casting of SCC include high deformability, passing ability, filling ability and resistance to segregation.

Deformability refers to ability of SCC to flow into and completely fill all spaces within the formwork, under its own weight. Deformability is the property most commonly associated with SCC and provides the justification of acceptance of technology. Optimum mix water/cement ratio of 0.4 is chosen from EFNARC guidelines and following workability studies slump flow, V-funnel, L-Box test, T50 were carried out to assess the workability characteristics.

Hardened properties include Strength studies such as Compressive strength test, Split tensile strength test, Flexural strength test.

## 3. Results and Discussion:

### 3.1 Fresh Characteristics:

Effects of polypropylene fibers addition on the fresh characteristics of Self-Consolidating Concrete need to be measured to evaluate its workability performance criteria.
Comparison of the measured flowability, viscosity, passing ability and segregation ratio of the fresh SCC mixes can be observed in the following Tables 2

Table 2 Marsh cone test for various superplastizers by cement

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| SP % by cement | Time in sec (T) SP1 | Time in sec (T) SP2 |
|---|---|---|
| 0.1 | 168 | 109 |
| 0.2 | 104 | 117 |
| 0.3 | 77.30 | 83 |
| 0.4 | 62.45 | 67 |
| 0.5 | 50.38 | 58.23 |
| 0.6 | 40.56 | 52.56 |
| 0.7 | **38.54** | 47.12 |
| 0.8 | 38.57 | **41.03** |
| 0.9 | 38.61 | 40.67 |
| 1 | 38.89 | 39.96 |

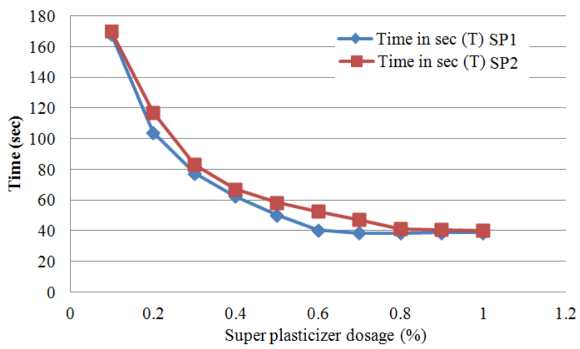


*Fig 1 Marsh cone test for various superplastizers by cement*

Table 3 Workability test results

| Mix Proportions % | $T_{50}$ (sec) | Slump (mm) | V-FUNNEL test Flow timing (sec) | L-BOX test (H2/H1) | U-BO test (H2-H |
|---|---|---|---|---|---|
| CM | 5 | 660 | 12 | 0.920 | 28 |
| FFSCC-1 | 4 | 675 | 11 | 0.925 | 21 |
| FFSCC-2 | 3 | 685 | 10.2 | 0.931 | 20 |
| FFSCC-3 | 3.8 | 681 | 9.8 | 0.929 | 20.5 |
| FFSCC-4 | 4.6 | 685 | 11.2 | 0.928 | 22.5 |
| FFSCC-5 | 4.2 | 683 | 10.6 | 0.935 | 20.3 |
| FFSCC-6 | 4 | 679 | 10 | 0.931 | 21.7 |
| GGBS-1 | 4.2 | 676 | 11.4 | 0.926 | 21.5 |
| GGBS-2 | 3 | 684 | 10.8 | 0.932 | 21 |
| GGBS-3 | 3.6 | 679 | 9.6 | 0.930 | 20.5 |
| GGBS-4 | 4.8 | 682 | 11.4 | 0.928 | 22.6 |
| GGBS-5 | 4.4 | 680 | 10.6 | 0.934 | 20.5 |
| GGBS-6 | 4.2 | 676 | 10.2 | 0.930 | 21 |

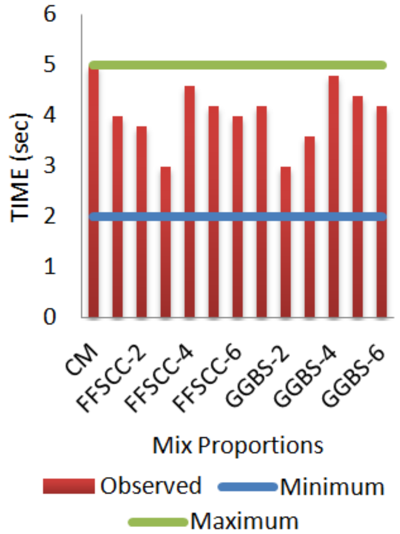


*Fig 2 $T_{50}$ vs mix proportions*

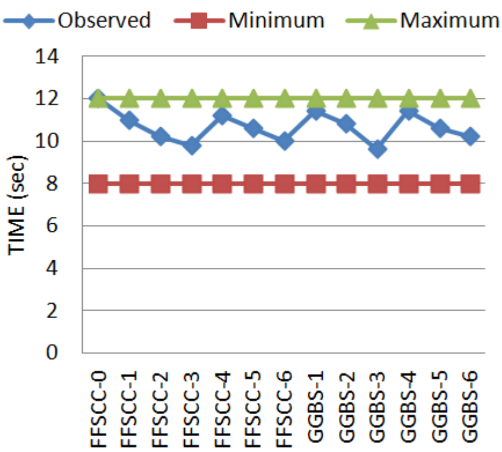


*Fig 3 Slump vs mix proportions chart*

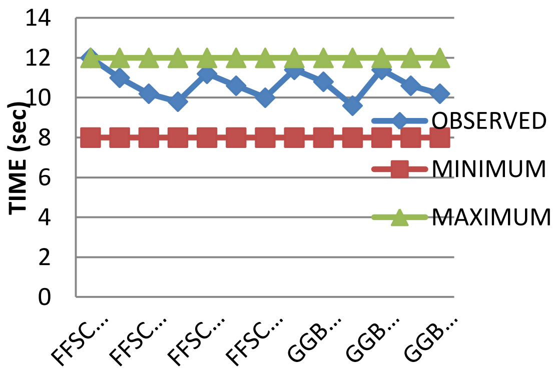


*Fig 4 V-Funnel vs Mix proportions chart*

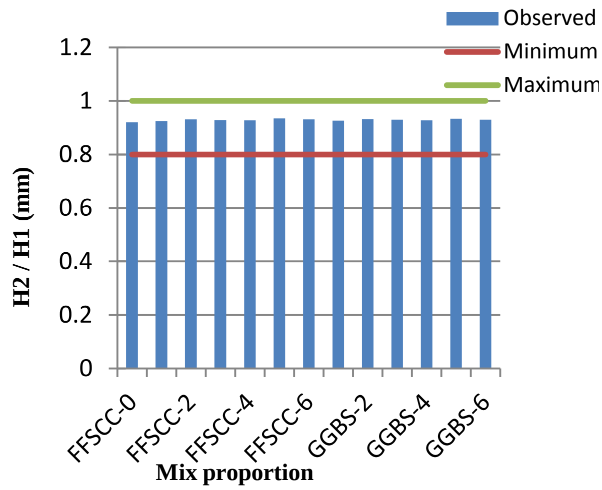


*Fig 5 L-BOX height ratio ($h_2/h_1$) vs mix proportions*

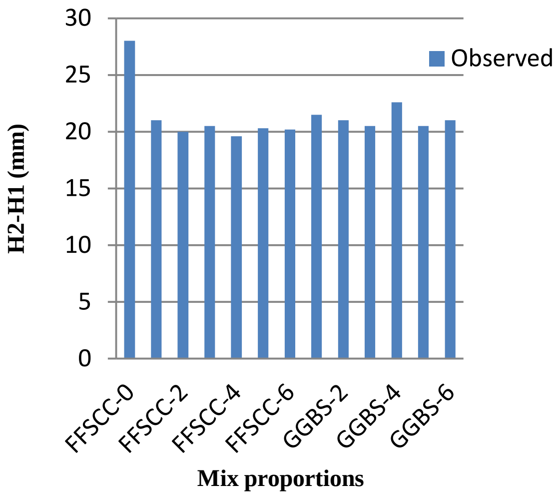


*Fig 6 Mixes vs U-BOX height ratio ($h_2$-$h_1$)*

### 3.2 Strength studies

Table 4 strength test results

| SNo | Mix proportions | 28-Days | | |
|---|---|---|---|---|
| | | Compressive | Split tensile | flexural |
| 1 | FFSCC-0 | 38.2 | 1.74 | 3 |
| 2 | FFSCC-1 | 42.13 | 2.27 | 5.47 |
| 3 | FFSCC-2 | 39.18 | 2.16 | 4.92 |
| 4 | FFSCC-3 | 41.88 | 2.01 | 4.40 |
| 5 | FFSCC-4 | 49.33 | 2.36 | 5.8 |
| 6 | FFSCC-5 | 41.34 | 2.2 | 5.2 |
| 7 | FFSCC-6 | 40.25 | 2.06 | 4.7 |
| 8 | GGBS-1 | 39.2 | 1.98 | 5.65 |
| 9 | GGBS-2 | 40.4 | 2.05 | 5.21 |
| 10 | GGBS-3 | 38.4 | 2.14 | 4.92 |
| 11 | GGBS-4 | 43.4 | 2.26 | 5.81 |
| 12 | GGBS-5 | 41.2 | 2.21 | 5.12 |
| 13 | GGBS-6 | 43.1 | 2.18 | 4.87 |

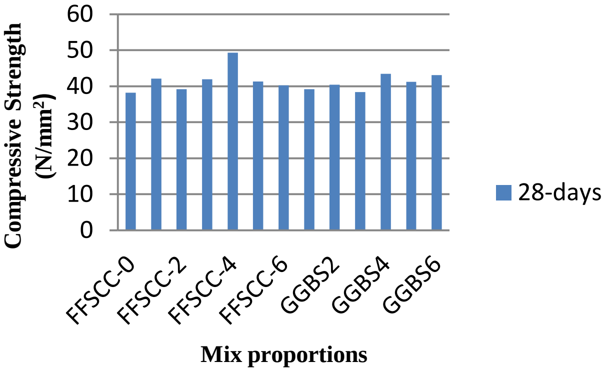


*Fig 7 Compressive strength test results*

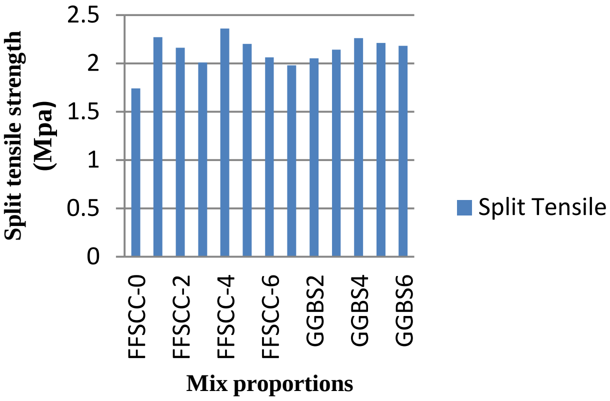


*Fig 8 Mix proportions vs split tensile test results*

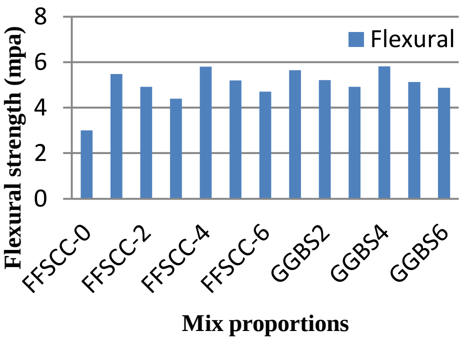


*Fig 9 Mix proportions vs flexural strength*

### 3.3 Discussion:

The results of the determined fresh properties shows that mix which has 50% mineral admixture and 0.05% fibre additive give good workability results but in case of 30% mineral admixture and 0.1% fibre additive gives less workability results but it gives under permissible limits. The deformability of SCC reduces with the presence of polypropylene fiber. This could be caused of more surface area that should be lubricated by the cement paste and water. In the same time, polypropylene fibers also reduce the potential energy that needed by the fresh concrete to be able to flow by its own weight due to the increase of friction between aggregates and the fibers in the mixes.

The results of the determined strength properties shows that which has 50% mineral admixture and 0.05% fibre additive give less strength results but in case of which have 30% mineral admixture and 0.1% fibre additive gives high strength results. This could be achieved, due to the fact that polypropylene fiber bridges micro cracks of which growth can be controlled.

## 4. Conclusions:

- From the above experimental work, it is concluded that when the coarse aggregate content is reduced better flow in SCC can be achieved due to the less blocking effect. The volume of coarse aggregate content was reduced to 46% instead of 50% to avoid segregation.
- In this study it has been found that with increase in super plasticizer dosage the workability is increased. So that the required slump value can be obtained thus full filling the criteria of EFNARC.
- For 50% mineral admixture and 0.05% fibres added, the fresh properties observed were good as compared to other mix proportions replacement.
- The mix with 0.1% fibre content and 30% mineral admixture gave less workability but under permissible limits
- For 30% mineral admixture and 0.1% of fibres added considerably gave high mechanical properties than other various mix proportions replacement.
- The entire rheological test can be concurrently used to predict the flow behaviour of the concrete made with different composition.
- Suitability of self-compacting concrete mixture proportion was verified through displacement trials in a complicated mould and field trials.
- Mineral admixture substitution generally results in favourable outcomes and is highly recommended for all SCC mixes.

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