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# PROPERTIES OF GLASS FIBER REINFORCED SELF COMPACTING CONCRETE

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**Abstract:** Self Compacting Concrete (SCC) is a concrete that is able to flow under its own weight and completely fill the formwork, even in the presence of congested reinforcement, without any compaction, while maintaining homogeneity of the concrete. The elimination of compaction for SCC is beneficial in solving difficult casting conditions and reduction in manpower required. SCC was added with relatively short, discrete, and discontinuous glass fibers to produce Glass Fiber Reinforced Self Compacting Concrete (GFRSCC). Water-cement (w/c) ratio of 0.40 was used in concrete mix proportions. The fiber used was alkaline-resistance glass fiber. Three volume percentages of fiber were added to the mix, i.e. 0.5%, 1.0%, and 1.5% by volume of concrete. Workability and mechanical properties of the concrete were evaluated. SCC and GFRSCC were highly workable than normal concrete (NC). The dosage of superplasticizer required increment as fiber content increase. SCC exhibits higher compressive strength than NC and GFRSCC. Inclusion of fibers does not give positive effect to the compressive strength of GFRSCC. The splitting tensile strength of NC was higher than SCC and GFRSCC due to the negative influence of superplasticizer added. Results indicated that the flexural strength of NC was slightly higher than SCC. The flexural strength of GFRSCC was higher than SCC. The optimum fiber content for GFRSCC, determined during the study was 1.0% by volume of concrete. GFRSCC slab developed higher first crack load and ultimate load compared to NC and SCC slabs.

**Keywords:** *Self compacting concrete; fiber reinforced concrete; glass fiber reinforced self compacting concrete; workability; alkaline-resistance glass fiber; flexural strength, tensile strength.*

## 1.0 Introduction

Self Compacting Concrete (SCC) is a type of concrete that does not require compaction, and is able to flow under its own weight and completely filling the formwork, even in presence of dense reinforcement. The homogeneity of the concrete is maintained without any compaction (EGSCC, 2005; Choo, 2003). SCC was originally initiated in

Japan in the mid-1980s to offset the growing shortage of skilled labour and manpower in construction industry (Choo, 2003; EFNARC 2002).

The crucial characteristics of SCC are filling ability, passing ability, and segregation resistance (Choo, 2003; Shetty, 2006). The filling ability of the fresh concrete is related to the mobility of SCC. Fresh SCC with good filling ability will be able to change shape and flow under its own weight to completely filling the moulds or formworks in place without compaction (Choo, 2003). Passing ability is the ability of fresh concrete to pass through obstructions within moulds or formworks, such as reinforcement and narrow space. SCC mixes should be sufficiently viscous and stable to avoid segregation of the aggregates, without any compaction (Torrijos *et.al.*, 2007). Generally, SCC with good workability aspect can be achieved through low water-cement ratio and optimum dosage of chemical admixture used such as superplasticizer (Ken, 2006).

Fiber Reinforced Concrete (FRC) can be defined as a concrete incorporating relatively short, discrete, and discontinuous fibers (Mindness *et. al*., 2003). Inclusion of fibers in concrete improved the tensile properties, flexural strength, impact strength, toughness, and the failure mode of concrete (Choo, 2003; Mazaheripour *et. al*., 2010; Awal *et al*., 2013; Maca *et al*, 2013). The principal role of fibers is to control cracking of the FRC by bridging across the cracks and subsequently provide post-cracking ductility to the concrete (Mindness *et. al*., 2003). Different types of fibers are used to produce FRC with different properties and characteristics. The fibers used included steel fibers, glass fibers, polypropylene fibers, carbon fibers, and natural organic fibers.

The inclusion of fibers into SCC mixes will certainly enhance the properties of the concrete produced. The combination of SCC and FRC together will produce Fiber Reinforced Self Compacting Concrete (FRSCC) with enhanced properties in both fresh and hardened state. The obvious effect of fiber addition is the enhancement of load resistance due to ductility improvement compared to non fibrous concrete (Ding *et. al*., 2009). In this study, glass fiber was incorporated with three different volume percentages into self compacting concrete, leding to the development of Glass Fibre Reinforced Self Compacting Concrete (GFRSCC). This study involves three major phases; the development of GFRSCC mix design with an optimum contet of glass fibre, the evaluation and comparison of physical and mechanical properties among NC, SCC and GFRSCC; and the application of selective GFRSCC mix design i structural testing.

## 2.0 Materials and Methods

### *2.1 Material*

The raw materials used in this study were cement, coarse aggregate, fine aggregate, superplasticizer, alkaline-resistance glass fiber (A-R glass fiber), water, and steel bars.

The cement used is *Holcim* brand Ordinary Portland Cement (OPC) and conformed to BS EN 197-1: 2000. The coarse and fine aggregates used are crushed granite with 10mm nominal diameter and crushed sand. The mixing water was obtained from fresh tap water in the laboratory. The materials are available in Structure and Material Laboratory in Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM). The A-R glass fiber used was obtained from the manufacturer in roving form and then cut to short fibers of 12mm length. The glass fiber has diameter of 15μm and density of 2400 $kg/m^3$.

### *2.2 Mix Design Method and Proportions*

The standard DOE mix design method is used and modified to produce the mix proportions for NC, SCC, and GFRSCC. SCC and GFRSCC mix design were modified based on NC mix design with the incorporation of suerplasticiser and glass fiber, respectively. All mixes were designed to achieve design strength of 40 MPa at 28 days with fixed w/c ratio of 0.40.

Three volume percentages of fibers were utilized in this study, i.e. 0.5%, 1.0%, and 1.5% by volume of concrete. Table 1 shows the mix proportions for NC, SCC, and GFRSCC mixes. Different dosage of superplasticizer was added to GFRSCC due to different content of glass fiber. Higher amount of fibres requires higher dosage of superplasticiser in order to maintain the workability. The dosage of superplasticizer was determined from trial mixes and measured by percentage of cement weight. The optimum fiber content in GFRSCC mix was then selected for the casting of concrete slab. The selection of optimum mi design was based on the highest flexural tensile strength test.

Table 1: Mix proportions for control concrete, SCC, and GFRSCC mixes (per $m^3$)

| | *Control concrete* | *SCC* | *GFRSCC* |
|---|---|---|---|
| Cement (kg) | 550 | 550 | 550 |
| Water (kg) | 230 | 230 | 230 |
| Coarse aggregate (kg) | 860 | 860 | 860 |
| Fine aggregate (kg) | 740 | 740 | 740 |
| Superplasticizer (L) | - | 7.92 | 12.32 (0.5%)<br>14.96 (1.0%)<br>29.76 (1.5%) |
| Glass fiber (kg) | - | - | 13.0 (0.5%)<br>26.0 (1.0%)<br>39.0 (1.5%) |

### *2.3 Specimen Preparation*

The concrete specimens were prepared, cured and tested at the ages of 3, 7, and 28 days. For NC and SCC, three cubes, one cylinder, and one prism were prepared for each curing age. For GFRSCC, three sets of specimens of different fiber contents (0.5%, 1.0%, and 1.5% by volume), were prepared for each curing age. Upon the determination of an optimum fibe content, one reinforced control concrete slab, one reinforced plain SCC slab, and one reinforced GFRSCC slab were cast.

All specimens were casted using 100 x 100 x 100 mm cube moulds, 100 mm diameter x 200 mm height cylinder mould, and 100 x 100 x 500 mm prism mould. The interior surfaces of the moulds was coated with a layer of oil before placing the fresh concrete. All the concrete were mixed using a mechanical pan mixer. The concrete mix was placed into the steel mould in three layers, with compaction for each layer is made by vibrating table for control concrete. No compaction applied to SCC and GFRSCC mixes. After 24 hours, the specimens were demoulded and submerged in a curing tank for curing.

The reinforced concrete slab specimens, dimensioning 1000 x 500 x 100 mm (length x breadth x thickness) were prepared for casting the reinforced concrete slabs. The interior surfaces of plywood formworks were coated with a layer of oil. The NC mix was compacted by using poker vibrator; while SCC and GFRSCC mixes require no compaction. After 7 days, the samples were demoulded and exposed to wet curing by means of gunny sacks.

## 3.0 Laboratory Testing of Fresh and Hardened Concrete

### *3.1 Fresh Concrete Testing*

#### *3.1.1 Slump Test and Slump Flow Test*

Slump test was performed on NC mix as stated in BS EN 12350-2: 2009 – Slump-test. The slump of the concrete was measured and recorded. Meanwhile, slump flow test was conducted on fresh SCC and GFRSCC mixes. Figure 1 shows the measurement of slump flow during experimental. The apparatus required and testing procedures are stated in EFNARC Specification and Guidelines for Self Compacting Concrete (EFNARC 2002). The time taken for the concrete to achieve 500mm spread circle ($T_{50}$) and final diameter of the concrete spread were also recorded and measured.

Figure1: Slump flow test

### *3.1.2 L-Box Test*

L-Box test was conducted on fresh SCC and GFRSCC mixes. The purpose of this test was to assess the passing ability of fresh concrete. The testing procedures are based on the EFNARC Specification and Guidelines for Self Compacting Concrete (EGSCC, 2005; EFNARC 2002). The L-box test apparatus is shown in Figure 2. Plywood was used to produce L-Box test apparatus and formwork for casting reinforced concrete slabs. Steel bars of diameter 12mm were installed at the outlet of L-Box test apparatus. The clear spacing between these bars is 80 mm, which is more than the length of glass fiber (12 mm). Steel bars of diameter 6mm were used as reinforcement for concrete slabs.

### *3.1.3 Sieve Segregation Resistance Test*

Sieve segregation resistance test or GTM screen stability test was conducted on all fresh SCC and GFRSCC mixes. This test was used to assess the segregation resistance of fresh concrete; i.e the separation of coarse aggregate fron the cooncrete paste. The apparatus required and standard procedures are stated in EFNARC Specification and Guidelines for Self Compacting Concrete (EGSCC, 2005; EFNARC 2002). The test apparatus used is shown in Figure 3.

Figure 2: L-box

Figure 3: Sieve for segregation resistance test

### *3.2 Hardened Concrete Testing*

#### *3.2.1 Density*

All the concrete specimens were weighed using weighing machine after achieving the specified curing age. The density of the concrete cubes was determined at different curing ages.

#### *3.2.2 Ultrasonic Pulse Velocity (UPV) Test*

UPV test was conducted to measure the time taken for the pulse or wave to travel through the hardened concrete. This test was carried out on the concrete cubes, cylinders, and prisms according to BS 1881-203:1986 – Recommendations for measurement of velocity of ultrasonic pulses in concrete. UPV test was carried out at three positions on the side of the specimen, i.e. bottom, middle, and top of the side.

#### *3.2.3 Compressive Strength Test*

Compressive strength test was done by using compression test machine, ADR 2000. The concrete cubes were loaded to failure in compression test machine. The maximum load sustained and compressive strength of the sample was recorded and calculated. The testing procedures are in accordance to BS EN 12390-3: 2009 – Compressive strength of test specimens. The failure mode of the concrete cube was observed.

#### *3.2.4 Splitting Tensile Strength Test*

Tensile splitting strength test was conducted for all cylinder specimens. The testing procedures are in accordance to BS EN 12390-6: 2009 – Tensile splitting strength of test specimens. The maximum load indicated by the machine was recorded. The tensile splitting strength was calculated using the formula given in the standard. The splitting and fracture condition of the specimens was also observed and recorded.

#### *3.2.5 Flexural Strength Test*

Flexural strength test was conducted for all the concrete prisms. The testing procedures used are as stated in BS EN 12390-5: 2009 – Flexural strength of test specimens. The test performed is known as four-point loading test. Flexural strength test of concrete prisms were done by using the flexural strength testing machine.

### *3.3 Small-scale Slab Testing*

Small-scale slab flexural test was performed for three reinforced concrete slab specimens, i.e. NC, SCC, and 1.0% GFRSCC slabs. The purpose of the test was to assess the structural performance and cracking pattern of each slab. The slabs were tested as simply supported slabs by using the Magnus frame and other equipments, such as hydraulic jack, data logger, and Linear Variable Differential Transducer (LVDT). The setup of the small-scale test is shown in Figure 4. Failure load, mid-span deflection and strain distribution across the depth are among the measurement recorded durring the test.

Figure 4: Setup of small-scale slab test

## 4.0 Results and Discussions

### *4.1 Workability*

The slump value for NC mix was 20 mm, indicating a dry concrete mix with water-cement ratio of 0.40. For plain SCC and GFRSCC, the dosage of superplasticizer increases as the fiber percentage by volume increase. The dosage was stated in percentage by cement weight. The dosage of superplasticizer used were 1.44% for plain SCC, 2.24% for 0.5% GFRSCC, 2.72% for 1.0% GFRSCC, and 5.41% for 1.5% GFRSCC. The workability of GFRSCC decreases as the fiber content increases. Therefore, more dosage of superplasticizer are required to maintain the self-compactability of SCC and GFRSCC. Superplasticiser work in such that the molecules in superplasticizer wrapping themselves around the cement particles and induce highly negative charge on the surface. Inter-particle repulsion leads to deflocculation and dispersion of cement particles. Thus, more water is available to improve the workability of the concrete mix (Mindness *et. al.*, 2003; Neville, 1995).

Accoring to EFNARC (2002), concrete mix can only be classified as SCC if it has fulfilled the three workability parameters, i.e. filling ability, passing ability, and segregation resistance. In this study, filling ability, passing ability, and segregation resistance are assessed through slump flow test, L-box test, and sieve segregation resistance test, respectively. Table 2 shows that SCC and GFRSCC mixes have fulfilled the requirements as stipulated in EFNARC (2002).

Table 2: Requirements for Self Compacting Concrete [1, 3, 17]

| *Test* | *Unit* | *Measured values* | *Typical range of values* |
|---|---|---|---|
| Slump Flow | mm | 670 | 550 – 850 |
| $T_{50}$ Slump Flow | sec | 4 | 1.8 - 5 |
| L-box | - | 0.95 | 0.8 – 1.0 |
| Sieve Segregation Resistance | % | 15 | 0 - 20 |

### *4.2 Density of Hardened Concrete*

The mass of the all concrete cubes were weighed after achieving the specific curing age. The density of the concrete was determined by the division of mass over the volume of concrete. There is no significant difference in the density for NC, SCC, and GFRSCC cubes since all specimens are prepared using the same materials. The mass of added glass fiber were found to be very low (in weight), hence does not influence much on the density of the hardened concrete. The range of density recorded was between 2350 $kg/m^3$ to 2450 $kg/m^3$.

### *4.3 Ultrasonic Pulse Velocity Test*

UPV test was conducted at three positions on the side of the specimens, i.e. bottom, middle, and top. All the UPV readings show no significant difference for the three positions indicating uniform mix of the concrete. In addition, observations were made on the fracture surface of concrete specimens and the distribution of aggregate is uniform within the hardened concrete.

### *4.4 Compressive Strength*

The compressive strength test results of all concrete mixes for different curing ages are presented in Table 3. The relation of compressive strength with curing age is shown in Figure 5.

Table 3: Compressive strength of NC, SCC, and GFRSCC samples

| *Curing age (days)* | *NC (MPa)* | *SCC (MPa)* | *GFRSCC (MPa)* | | |
|---|---|---|---|---|---|
| | | | *0.5 %* | *1.0 %* | *1.5 %* |
| 3 | 26.8 | 23.4 | 28.8 | 27.8 | 27.4 |
| 7 | 34.1 | 41.6 | 38.9 | 41.0 | 30.2 |
| 28 | 47.4 | 53.3 | 51.1 | 49.6 | 34.9 |

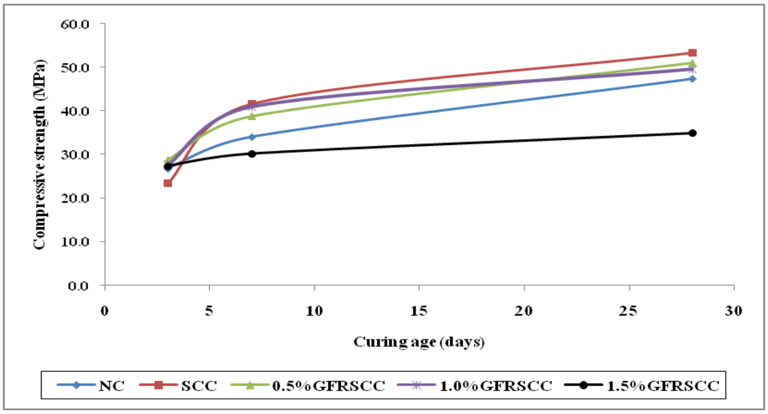

Figure 5: Relation between compressive strength and curing age for each type of concretes

In general, the plain SCC exhibits higher compressive strength than control concrete (NC). The dispersion of cement particles by the addition of superplasticizer results in better distribution of cement particles and consequently, better hydration within the concrete (Neville, 1995). In addition, when normal concrete is vibrated, water will tend to bleed upward causing the formation of bleeding channels as well as porous interfacial zones (Choo, 2003; Parra *et.al*, 2011). The weak phases formed will consequently reduce the strength of concrete. Besides, the lower compressive strength of NC is probably due to insufficient degree of compaction.

Comparing with GFRSCC, SCC exhibits higher compressive strength than GFRSCC for ny volume percentage of glass fibre. The study conducted by Sivakumar and Santhanam (2007) indicated that concretes with individual non-metallic fibers (polypropylene, polyester and glass) did not show any increase in strength compared to control concrete. The maximum increase in strength was about 15% only (Sivakumar and Santhanam, 2007). The inclusion of non-metallic fibers will not impart positive influence on the compressive strength of concrete. The results show that GFRSCC can achieve high compressive strength more than 40 MPa at 28 days. This is due to the high workability of concrete mix which permits the glass fibers to be distributed uniformly within the mix. The glass fiber is categorized as flexible fiber and can be easily distributed within the concrete mix as compared to rigid fiber, such as steel fiber (Bartos, 1992).

GFRSCC with 0.5% of glass fiber exhibits the highest 7-days and 28-days compressive strength among the GFRSCC specimens. GFRSCC with 1.5% of glass fiber possess relatively lower compressive strength as compared to the others. Weak phases or zones may be formed within the concrete due to the addition of high fiber content, which lower the strength of the concrete. There were many small voids observed on the fracture surface of the concrete cube which may indicate the weak zones within the concrete.

### *4.5 Splitting Tensile Strength*

The result of splitting tensile strength test of concrete cylinders is shown in Table 4. The relation of splitting tensile strength and curing age of all concrete samples is presented in Figure 6. The splitting tensile strength of GFRSCC samples is shown in Figure 7.

Table 4: Splitting tensile strength of NC, SCC and GFRSCC samples

| *Curing age (days)* | *NC (MPa)* | *SCC (MPa)* | *GFRSCC (MPa)* | | |
|---|---|---|---|---|---|
| | | | *0.5 %* | *1.0 %* | *1.5 %* |
| 3 | 2.74 | 1.98 | 2.58 | 3.06 | 2.60 |
| 7 | 3.18 | 2.80 | 2.71 | 3.26 | 2.92 |
| 28 | 4.44 | 3.54 | 3.45 | 4.29 | 3.39 |

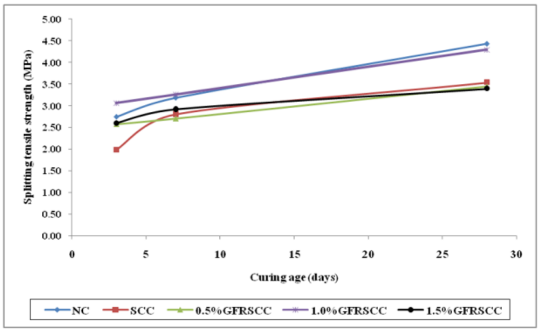


Figure 6: Relation between splitting tensile and curing age

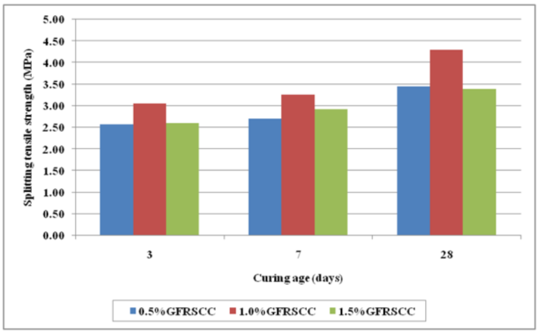


Figure 7: Splitting tensile strength of GFRSCC samples

From the results, the splitting tensile strength of all concrete cylinders increases with the increase in curing age. NC specimen exhibits higher splitting tensile strength than SCC and GFRSCC. There was similar trend from experimental study by Parra *et al.* (2011), which indicated that tensile strength was lower in SCC than in normal vibrated concrete. The results from their study found that the addition of superplasticizer result to negative effect on the aggregate-paste bond (Parra *et. al*, 2011). The failure of concrete in tension is governed by the interfacial region between the cement and aggregate particles, or known as aggregate-paste bond. The aggregate-paste bond plays greater influence on the tensile strength than compressive strength (Mindness *et. al.,* 2003; Parra *et. al*., 2011). Therefore, the weaker of aggregate-paste bond, the lower the tensile strength of concrete. The consequence of adding superplasticizer is the formation of ettringite crystals which are small and nearly cubic in shape rather than needle-like (Neville, 1995). The cubic-shaped ettringite formed will probably consume more growth space and induce internal stresses that may damage the paste.

One of the purposes of inclusion of fibers is to improve the tensile properties of concrete (Choo, 2003). However, for both 0.5% and 1.5% GFRSCC, the values of splitting tensile strength obtained are similar to the plain SCC. Study conducted by Sivakumar and Santhanam (2007) shown that the splitting tensile strength of fiber reinforced concrete with 0.5% fiber content is similar to the control concrete. This may be due to low aspect ratio of glass fiber added into concrete. For 1.5% GFRSCC, obvious voids were found on the fracture surface of the concrete cylinders. The addition of high fiber content (1.5 %) may result in the formation of excess voids that reduce the tensile strength of the concrete. Based on Figure 4.3, GFRSCC with 1.0% of fiber content exhibits the highest splitting tensile strength. The fiber content of 1.0% by volume was then selected as the optimum content for GFRSCC.

### *4.6 Flexural Strength*

Flexural strength test was performed on the concrete prisms and slabs. Four-point loading test was conducted for flexural strength test. The result of flexural strength test on concrete prisms is shown in Table 5. Figure 8 presents the relation between flexural strength and curing age of all concrete samples. Figure 9 shows the flexural strength of GFRSCC samples.

Table 5: Flexural strength of concrete prisms

| *Curing age (days)* | *NC (MPa)* | *SCC (MPa)* | *GFRSCC (MPa)* | | |
|---|---|---|---|---|---|
| | | | *0.5 %* | *1.0 %* | *1.5 %* |
| 3 | 4.49 | 4.85 | 4.97 | 5.23 | 4.51 |
| 7 | 5.41 | 5.47 | 5.53 | 5.62 | 5.27 |
| 28 | 6.16 | 5.34 | 7.20 | 7.70 | 6.61 |

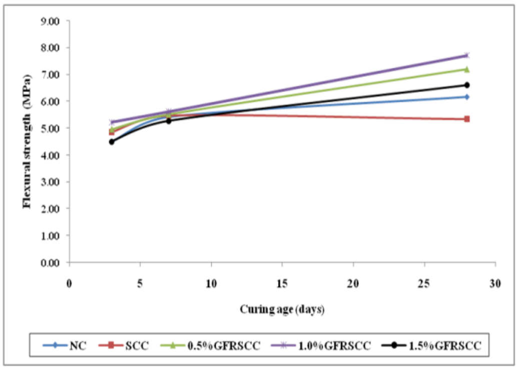

Figure 8: Relation between flexural strength and curing age

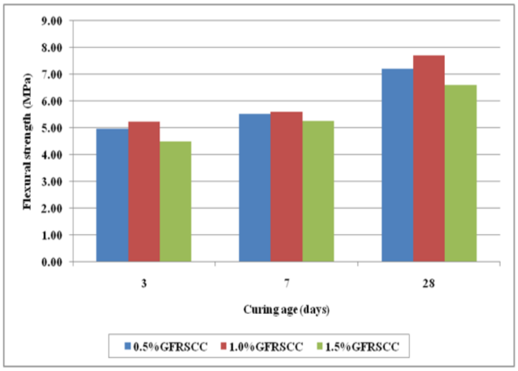

Figure 9: Flexural strength of GFRSCC samples

From the results, the increasing trend is flexural strength is similar to those of compressive and tensile strength. Generally, the flexural strength of NC e is slightly higher than plain SCC, with the difference of 13.0%. All the GFRSCC prisms exhibit higher flexural strength than plain SCC prisms. This finding is in line with the principal role of the fiber in bridging the cracks that developed within the matrix, and therefore, improve the flexural properties of concrete (Choo, 2003; Mindness *et.al*., 2003).

Figure 9 shows the flexural strength of all GFRSCC samples. Increasing fiber content by volume from 0.5% to 1.0% was observed to increase the flexural strength of concrete; however, the flexural strength is reduced for 1.5% GFRSCC samples. A study carried out by Mirza and Soroushian (2002) shows that there was increasing trend for flexural strength of lightweight concrete until fiber volume fraction of 0.625% and slightly decrease for 0.75% fiber content (Mirza and Soroushian, 2002). Therefore, the optimum fiber content for this study was taken as 1.0% by volume of concrete.

The optimum fiber content of 1.0% was used to cast GFRSCC slab. The load-deflection curves at the mid-span for the three reinforced concrete slabs, i.e. NC, SCC, and 1.0% GFRSCC, are presented in Figure 10. Table 6 shows the results of first crack and ultimate loads of all samples tested.

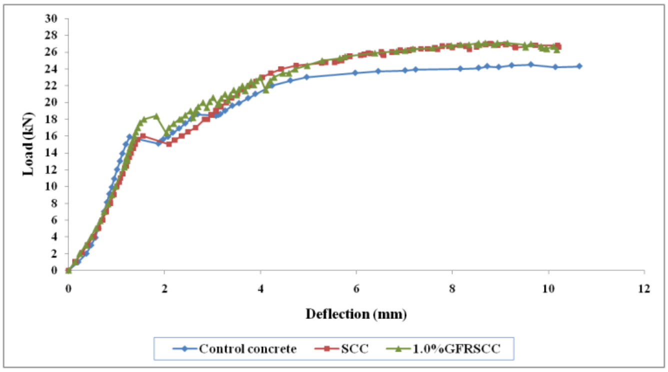

Figure 10: Load deflection curves for control concrete, plain SCC, and 1.0% GFRSCC slabs

Table 6: Load in which first crack developed and ultimate load of concrete slabs

| | *NC* | *SCC* | *1.0%GFRSCC* |
|---|---|---|---|
| First crack load (kN) | 14.0 | 15.5 | 18.5 |
| Ultimate load (kN) | 24.5 | 26.5 | 27.0 |

The trend of load-deflection curves is similar for all the three slabs. From the results, 1.0% GFRSCC slab demonstrated the highest first crack load and ultimate load. The presence of glass fiber in GFRSCC slabs has succesfully delayed the formation of first crack. When fiber reinforced concrete members are subjected to flexure, the load at first crack will increase due to the crack arresting mechanism of the fibers, and subsequently the ultimate load will also increase (Gambhir, 2004). The maximum percentage increment in first crack load and ultimate load of GFRSCC is 20% only as compared to plain SCC. It is probably due to the inability of the non-metallic fibers to sustain high crack widths (Sivakumar and Santhanam, 2007). Figure 11 shows the cracking pattern of all the concrete slabs. 1.0%GFRSCC slab developed closer crack spacing compared to NC and SCC slabs.

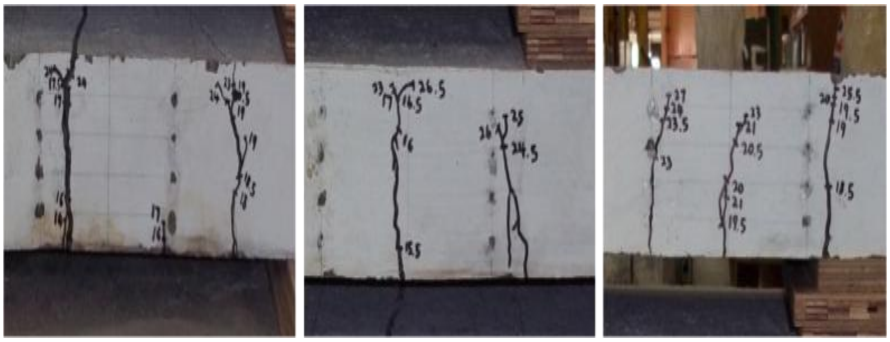
Figure 11: Cracking pattern of concrete slabs (from left to right: NC, SCC, 1.0%GFRSCC)

## 5.0 Conclusions

The following conclusions can be drawn on the basis of test results obtained from the experimental study.

(i). As the fiber content increase, the dosage of superplasticizer required was also increased in order to maintain the self-compactability characteristics.

(ii). The workability is low for NC specimens with water-cement ratio of 0.40. All the SCC and GFRSCC produced very high workability and fulfilling the requirements set by EFNARC.

(iii). SCC demonstrated higher compressive strength than NC; however the percentage increment in compressive strength is very low. For GFRSCC, the compressive strength developed by 0.5%GFRSCC is the highest among all.

(iv). Control concrete exhibits higher splitting tensile strength than SCC and GFRSCC. GFRSCC with 1.0% of fiber content exhibits the highest splitting tensile strength among all the GFRSCC. The flexural strength of control concrete is higher than SCC, with slight strength increment of 13%. Generally all GFRSCC exhibit higher flexural strength than SCC since the fiber added is to improve the tensile and flexural properties of concrete.

(v). The optimum fiber content for GFRSCC is 1.0% by volume of concrete. GFRSCC slab with 1.0% fiber content witnessed higher first crack load and ultimate load than control concrete and SCC slabs.

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