EFFECT OF CURING CONDITIONS ON THE MECHANICAL PROPERTIES OF STEEL FIBER REINFORCED SELF COMPACTING CONCRETE

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ABSTRACT

Fiber-reinforced self compacting concrete (FRSCC) is a type of concrete mix that can mitigate two opposing weaknesses: poor workability in fiber reinforced concrete and cracking resistance in plain SCC concrete. This research investigates the influence of curing conditions and effect of steel fiber on shrinkage and mechanical properties of self compacting concrete. Test results showed that water cured specimens always give the highest values followed by this cured as in dry condition irrespective of type and age of concrete and test methods. For flexural, splitting tensile strength and modulus of elasticity tests, the SCC concrete with steel fiber reinforced gives the highest values than plain SCC for all curing conditions. Steel fibers in the early stage, didn't show any improvement in shrinkage.

KEYWORDS: Self Compacting Concrete, Steel Fiber, Curing, Shrinkage, Compressive Strength.

تأثير طرق المعالجة على الخصائص الميكانيكية للخرسانة ذاتية الرص المقواة بألألياف الحديدية

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الخلاصه

تعد الخرسانة ذاتية الرص المسلحة بالألياف نوع من الخلطات الخرسانية ، وهذه الخلطة مع استخدام الألياف المسلحة تعاني من ضعف في قابلية التشغيل وبدونها تعاني من ضعف مقاومتها للتشقق . لقد سلط هذا البحث الضوء على تأثير طرق المعالجة وتأثير ألألياف الحديدية على الخصائص الميكانيكية للخرسانة ذاتية الرص ، وبينت نتائج الفحص أن معالجة النماذج بالماء ذات قيم عالية مقارنة بطرق المعالجة الجافة ، بغض النظر عن عمر وطريقة فحص النموذج . وأن الخرسانة ذاتية ألرص المسلحة بالألياف أعطت قيم عالية لكل من مقاومة ألانثناء وألأنشطار ومعامل المرونة مقارنة بالخرسانة ذاتية الرص لكل طرق المعالجة . وان ألياف الحديد في المراحل المبكرة لم تعطي أي تحسن في ألانكماش .

INTRODUCTION

Self compacting concrete (SCC) offers a number of important advantages. Because of its excellent workability and self-compacting ability, labor for vibration is not needed and the construction period in addition which is directly related to construction costs, can be shortened. For this reason, SCC mix is being widely used in practice (**Khayat, 2002, Sharendahl, 2001, Vachon, 2003**). If fiber is added to SCC mix, many mechanical benefits can be achieved. One difficulty in adding fiber, however, is that it can hinder the flowabl rheological property of fresh SCC mix. A few studies have been carried out on optimization of the mix proportion for the addition of steel or polypropylene to SCC (**Grunewld, 2001, Grunewald, 2004, Ferrara et al, 2007**). Numerous experimental works have verified that the addition of fiber is an effective means of reducing the crack width (**Share Dahl, 2001, Kwon and Yilmaz, 2007**). Meanwhile there is a defect of research on the mechanical properties of fiber reinforced SCC.

Proper curing plays a significant role in achieving optimum performance and full potential from given concrete mixture (**BCA, 1993**). The research carried out by (**Bentz et. al., 1997**) shows that curing conditions have significant effect on the degree of hydration of cement. They showed that for specimens (initially cured at 100% RH for 6 or 12 hr) exposed to 90% RH ,hydration process discontinued as all remaining capillary water was lost due to evaporation , whilst curing under sealed condition , in particular for concrete with w/c of 0.4 or over , or keeping the surface as saturated were adequate . As there are significant differences between conventional concrete and SCC, SFRSCC, knowledge of engineering properties of SCC, SFRCC under different curing environments need to be explored. The main purpose of our research is to investigate the influence of steel fiber on shrinkage and mechanical properties of SCC in dry and water condition.

EXPERIMENTAL PROCEDURE

Materials and Mix Proportion

Two different steel fibers – reinforced SCC mixes and one plain SCC mix were designed. **Table 1** shows the mix proportions. Steel fiber was added to two mixes (FRSCC-I, FRSCC-II). The performance of steel fibers reinforced self compacting concrete have been examined with respect to relevant properties of plain self compacting concrete. Details of the fibers are given in **Table 2.** The binder composition of all mixes was prepared using Type I Portland cement with 38% limestone powder (substituted by mass).

For every mix the water to binder ratio was 0.35. The maximum coarse aggregate size was 14 mm. The amount of steel fiber added to the concrete mix was 0.5% and 1% of the total mix volume.

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Details of Specimen and Conditions

The inverted slump-flow test was first conducted to examine if the designed fiber-reinforced SCC mixes have enough flow ability , in which the time required to reach a diameter of 500 mm (T50) and the final diameter of the concrete were recorded .

The test method and the configuration of the slump cone as described in EFNARC (**EFNARC, 2000**), were carried out. The results obtained from these test showed that every mix satisfies the minimum requirement , concrete flow diameter are (700,670,635) and T_{50} second are (3,3.6,4.4) for SCC , FSRSCCI , FSRSCCII respectively .

SHRINKAGE

Shrinkage measurement are done according to Iraqi standard specification (IQS 54:1970), using prisms of (75x75x300) mm, which is measured by apparatus with diagonal of 0.002 mm accuracy.

The shrinkage in water condition means the specimen is cured in water for one week. In dry condition no curing at all after de molding of the specimen is done.

Compressive Strength, Splitting Tensile Strength and Modulus of Elasticity

Cylinder with 150 mm diameter and 300 mm length were tested for each compressive strength according to ASTMC39-86, static modulus of elasticity according to ASTMC469-87a and splitting tensile strength according to BS1881: part 117.

In water condition, the specimen is placed in water after de molding until the time of test. In dry condition the specimen is cured only for one week.

FLEXURAL STRENGTH

For flexural strength specimens with dimensions (100x100x500) mm are tested according to ASTMC78 (3) using ELE testing machine.

In water condition, the specimen is placed in water after de molding until the time of test. In dry condition the specimen is cured only for one week.

RESULTS AND DISCUSSIONS

Compressive Strength

The results obtained from compressive strength test for plain SCC, FSRSCCI and FRSCCII for 4 weeks and 6 weeks duration in water and dry conditions are given in **Figure 1.**

Differences of strength for 4 weeks and 6 weeks are relatively small less than 5%. The improvement of the compressive strength with time in early age for self compacting concrete is larger than normal concrete mixes; test (**Tvikstal, 2000, Holschemacher and Klug, 2002**) showed that, the compressive strength in early age is high due to the use of limestone powder as filler which gives higher compressive strength at the beginning of ardent process.

Figure 1 indicated that the highest compressive strength values from water cured specimens followed by the dry cured specimens , this shows the rule of curing method on the early age compressive strength of concrete i.e. the higher the moisture level were exposed to the compressive strength was achieved . Effect of 1% of steel fiber on compressive strength of self compacting concrete is very limit, regardless of curing condition. This results confined that fibers usually only minor effect on compressive strength slightly increasing or decreasing the test results.

FLEXURAL STRENGTH

The flexural strength test is based on three point loading condition using the ELE testing machine .The results are shown in **Figure 2** for water and dry conditions.

Based on the graph, the flexural strengths are mixed. Differences in 4 weeks and 6 weeks are less than 15% in water condition .The flexural strength in water condition are generally higher than dry condition both in the 4 weeks and 6 weeks tests. Wet SCC with steel fibers is register higher strength than dry ones. It is shown that the addition of 1% steel fibers resulted in noticeable increase in flexural strength, regardless of curing conditions. The failure mode is also improved; it is more gradual than without fibers. Members are still together even there are cracks developed.

MODULUS OF ELASTICITY

The graph of the modulus of elasticity is shown in **Figure 3**, for water and dry curing condition.

It is shown that the addition of 1.0% by volume of steel fibers resulted in noticeable increase in modulus of elasticity, the modulus of elasticity increased with a percentage increase of about 26% in water condition. This enhancement is mainly due to the interlocking action of fibers , where fibers lack the large , aggregate together in the matrix and prevent propagation and the opening of micro cracks and thus inhibiting cracks growth .Results of wet and dry conditions are almost the same in 4 weeks and 6 weeks tests .

Splitting Tensile Strength

The results of the splitting tensile strength (f_t) tests in dry and water condition are shown in **Figure 4**, in compression with the plain self compacting concrete , steel fiber reinforced self compacting concrete mixes have greater splitting tensile strength for all curing condition .

It is shown that the addition of 1% steel fibers resulted in noticeable increase in splitting tensile strength, regardless of curing condition. In water condition, splitting tensile strength is increasing by about 29.6% when 1% of steel fibers are used.

Shrinkage

The axial expansion and shrinkage of SCC with steel fibers in dry and water conditions are shown in **Figure 5** and **Figure 6** respectively.

The axial expansion and shrinkage of SCC with and without fibers, for the same duration in dry condition is greater than the one in water condition since there is no curing at all for the specimens. Curing therefore can lower the shrinkage (**Hindy, 1994**).

Additional steel fiber did not reduce the shrinkage of SCC except for the first few days in water condition since it has increased its absorption capacity. However at later age it incurred more shrinkage than plain SCC. Fibers caused more swelling of SCC concrete since water penetrates through the fibers; it is gained more weight while in water. However the absorbed water is easily lost after removing the specimens from the curing tank loosing more water can lead to more shrinkage of SCC. In dry condition with steel fibers, it is consistent to have more shrinkage of SCC than in water condition also with fibers.

CONCLUSIONS

On the basis of the experimental investigation carried out the following conclusions can be drawn:

1-For all concrete the water cured specimens gave the highest compressive strength values, then, dry cured specimens. Effect of 1% of steel fiber on compressive strength of self compacting concrete is very limit, regardless of curing.

2-The influence of steel fibers on the tensile strength are better than their influence on the compressive strength, the improvements on strength up to 29.6% when 1% of steel fiber are used.

3-The use of steel fibers improve the elastic modulus of self compacting concrete for all testing ages and for all curing conditions; where the modulus of elasticity increased about 26% in water condition when 1% of steel fiber was used.

4-The axial expansion and shrinkage of self compacting concrete with and without fiber in dry condition is greater than the one in water condition. The effect of one week curing tends to reduce the shrinkage of self compacting concrete, moreover it can cause swelling to self compacting concrete with high absorption capacity.

5-The steel fibers did not show any improvement in the reduction of shrinkage of self compacting concrete. It is effect may be released after a longer period since fibers are used to counteract and reduce shrinkage.

6-The steel fibers increase the flexural strength of self compacting concrete in water and in dry condition; where the flexural strength increased by about 21.1% when 1% of steel fiber are used. The failure mode is more gradual rather than abrupt for plain self compacting concrete

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Table 1 Mix proportions of concrete used during the experiments.

Mix	Cement kg/m^3	Limestone powder (LSP) kg/m^3	Sand kg/m^3	Gravel kg/m^3	W/P*	Superplastilizer Liter/m^3	Steel Fiber% by volume
SCC	310	194	754	891	0.35	3.21	0
FRSCC-I	310	194	745	883	0.35	3.71	0.5
FRSCC-II	310	194	745	884	0.35	3.71	1.0

*W/P is water to binder ratio

Table 2 Fiber properties.

Fiber type	Fiber length (mm)	Ultimate strength(Mpa)	Aspect (L/D) ratio
Steel fiber hooked end(Dramix type)	30	1118	60

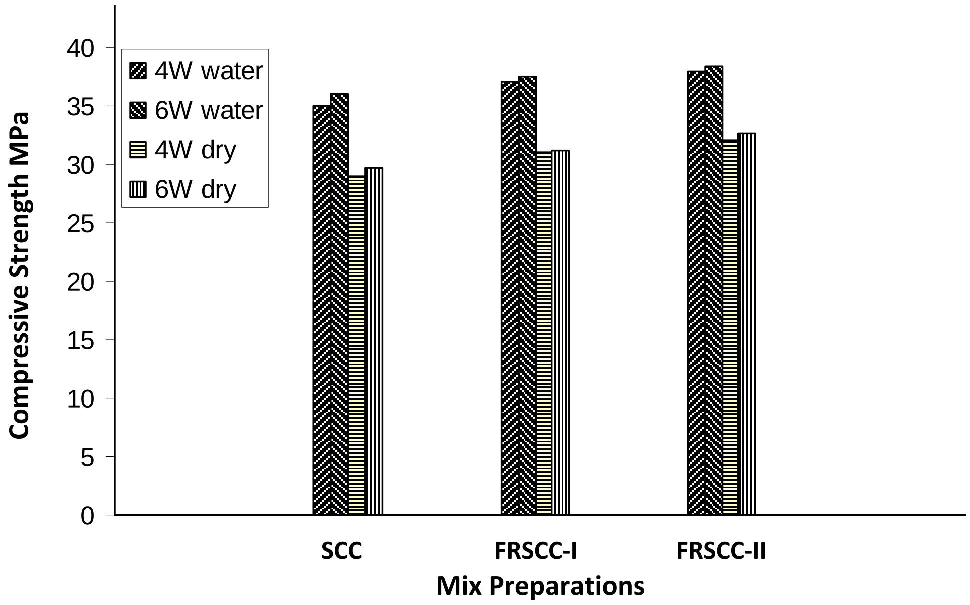

Figure 1 Compressive Strength of Fiber Reinforced Self-Compacting Concrete in Dry and Water Conditions.

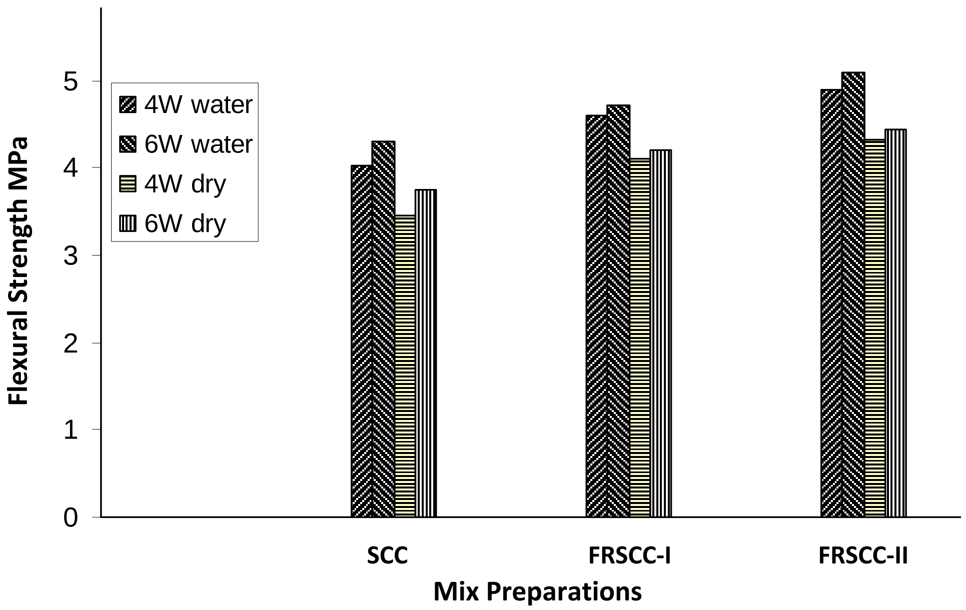

Figure 2 Flexural Strength of Fiber Reinforced Self-Compacting Concrete in Dry and Water Conditions.

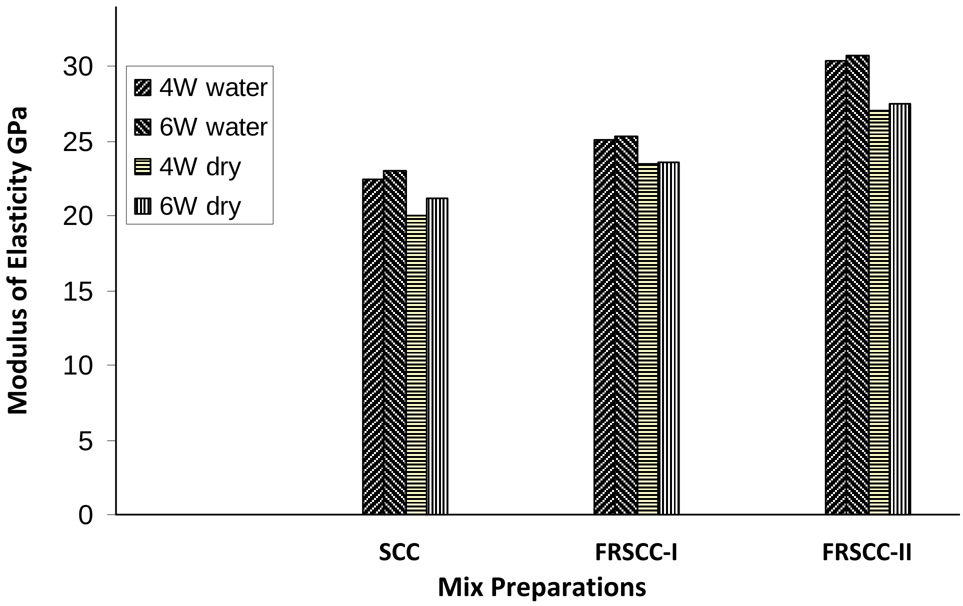

Figure 3 Modulus of Elasticity of Fiber Reinforced Self-Compacting Concrete in Dry and Water Conditions.

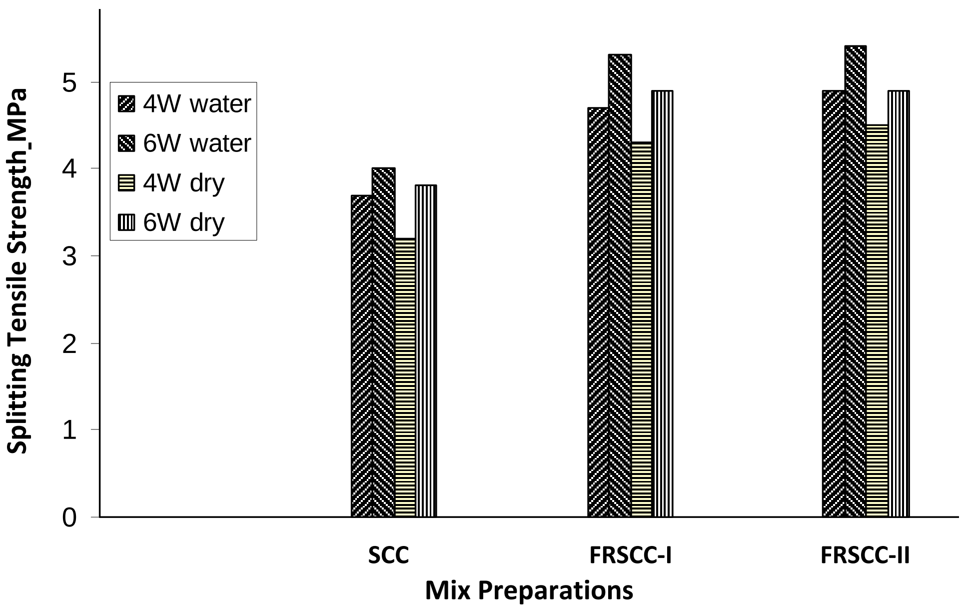

Figure 4 Splitting Tensile Strength of Fiber Reinforced Self-Compacting Concrete in Dry and Water Conditions.

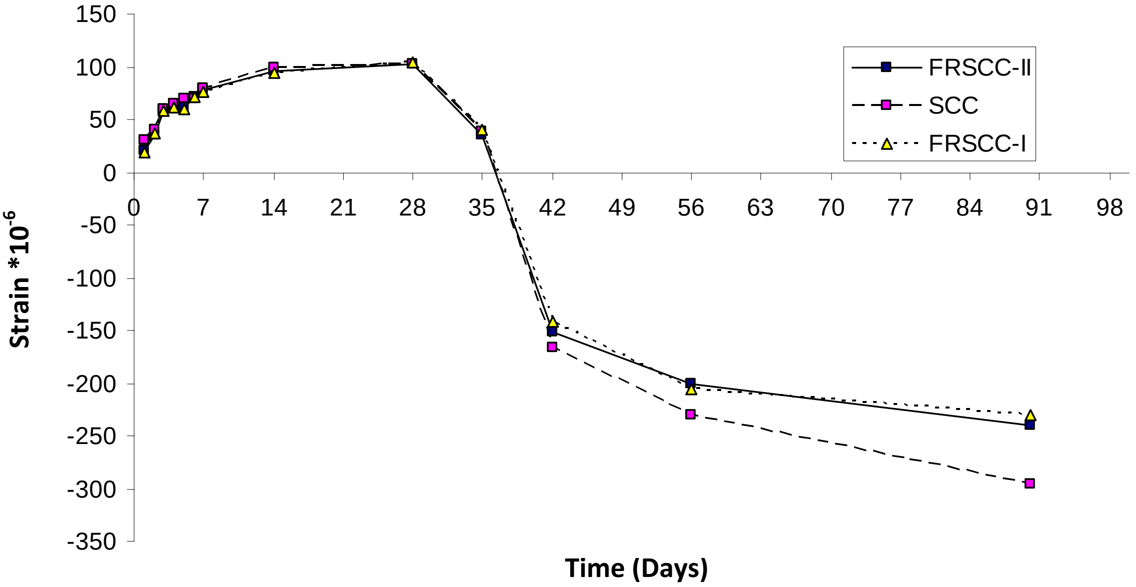

Figure 5 Shrinkage of FRSCC in Dry Condition.

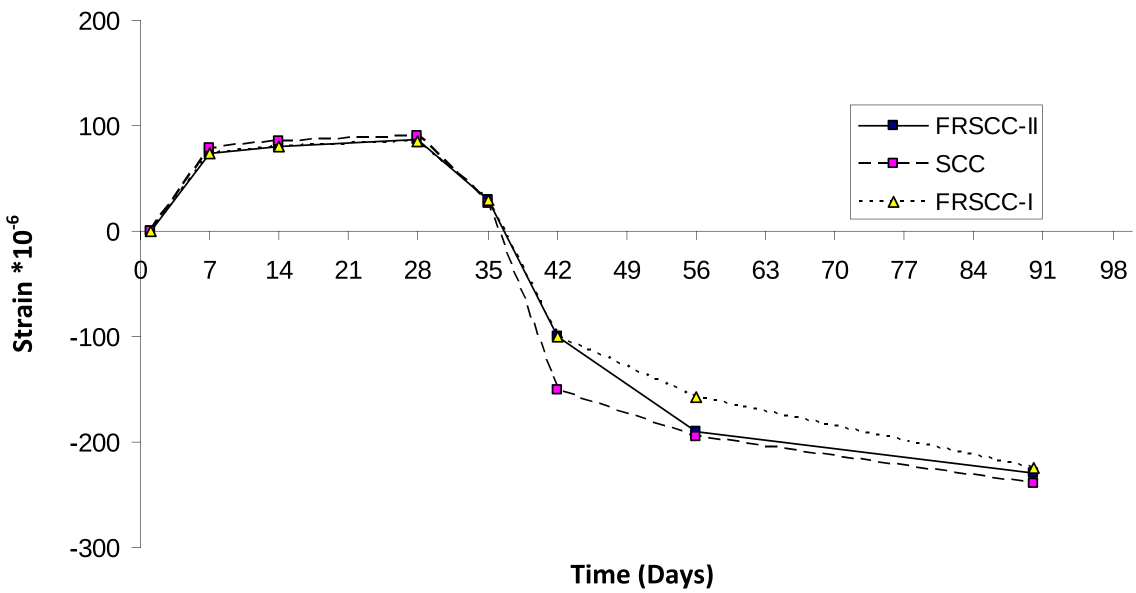

Figure 6 Shrinkage of FRSCC in Water Condition.