USE OF FIBERS TO IMPORVE THE TENSILE STRENGTH OF CONVENTIONAL CONCRETE

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INTRODUCTION

Concrete is one of the most commonly used civil engineering material in the modern world. It is popular due to its high compression strength, and almost all the shapes can be cast with concrete. However one of the weakest aspects of concrete is its poor tensile capacity. Concrete's tensile strength accounts for barely 6% of its compressive strength (Shetty, 2010).Due to its poor tensile capacity, the construction of thin sections with concrete causes, tensile failures.

The tensile property of concrete can be improved in many ways. According to Purvis (1987) steel fibre additive agents can be added to the concrete to improve the tensile capacity of concrete. Steel fibres are also among these substances and in recent years, it has been commonly used in concrete. As stated by Balendran et al.,(2002) the effects of fibre added to concrete depend on the type, size, density, and distribution of the fibre, as well as the interfacial effort between the concrete and fibres. Their study covers a novel organic modified polypropylene fibre (OMP), with a lower specific gravity and greater anti-corrosive property than steel fibre. Zhou et al.,(2015), showed that at 7 days, the concrete combined with OMP had a significantly higher compressive strength than the plain concrete, and maintained that status at day 28. Durability, physical and mechanical properties of fibre-reinforced concretes at low-volume fraction was investigated by Söylev and Özturan(2014). Their findings showed that the slump value was greatly affected by the addition of fibres that could be again improved by the addition of superplasticizer. However the addition of superplasticizer will increase the unit rate (price) of concrete drastically. The toughness of concrete can be increased by the addition of steel fibres (Mohamad et al, 2015) as they can bridge micro- and macro-cracks formed in the cementitious matrix. Due to this fibre reinforced concrete can show more ductile behaviour compared to the normal concrete adding a lot of favourable properties to concrete. The study carried out by Mohammad et al.,(2015) shows the use of steel fibre in precast pipe fabrication. Their results showed that a fibre dosage of 30 kg/m^3satisfied the strength requirements of ASTM C76 Class V pipe for 450 and 600 mm diameter pipes.

As Slump cone test is incapable of simulating the interaction between the main reinforcement and the secondary reinforcement, different approaches are used in the measuring the workability of concrete.
In this study the properties of fibre concrete at green stage and at the hardened stage were measured. To measure the properties at the green stage two new apparatus were fabricated.

Material and concrete mixtures

As the starting point, the Sri Lankan experience in mix design together with the UK method described by the Department of Environment for concrete mix design, United Kingdom (UK), was used for preparation of concrete mixtures. It was decided to carry out the test for grade 25 concrete as that is the widely used concrete in normal construction fields in Sri Lanka. The OPC content of concrete was kept to340 kg/m^3 (Dias, 2003). The rest of the materials were determined according to the guidelines provided by UK Department of Environment. The target slump of the mixes was 120-150 mm. Although the addition of superplasticizer is common in fibre concrete to improve the workability, it was decided not to use a superplasticizer in the mix as the production cost will increase (Söylev and Özturan, 2014).

Four different types of mixes were prepared by adding different percentage of fibres. Carbon fibre was selected as the fibre in this study (Chung, 1999). Fibre weight was presented as a percentage to cement. The second was selected changing the water content by 10%. In the mix 3, only the maximum size of the aggregate was changed to 10mm compared to mix 2 whose maximum aggregate size is 25mm. M4 mix is a grade 30 concrete that is normally used in in-situ pile casting. No any other adjustment was made in the determination of water content due to the addition of fibre which is common in modified mix design methods.

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Table 1. Mix proportions (kg/m^3) for different concrete mixtures.

Mix type	M1	M2	M3	M4
Water/Cement	0.5	0.5		
Cement (kg)	300	300~~0~~	300	440
Water(kg)	205	225.5	225.5	210
Fine aggregate(kg)	645	645	645	685
Coarse aggregate(kg)	1200	1200	1200	1065
Fibre content(kg)	7.5	7.5	7.5	7.5

Workability of fibre added concrete

The slump cone test is normally used in workability measurement for conventional concrete. However use of slump cone test is not appropriate for fibre concrete as the behaviour of fibre cannot be simulated with slump cone. Fibres in concrete will create barriers for the movement concrete near the main reinforcement. Therefore it is important to reflect this behaviour in workability measurement. To measure the workability of the fibre added concrete two different apparatus were fabricated in the laboratory at the Civil Engineering Department. The U Box test was developed by the Technology Research Centre of the Taisei Corporation in Japan (Tanaka et al., 1993).These two apparatus have been used successfully in other countries (Bartos et al., 2002) to measure the workability of the fibre reinforced concrete and self-compacting concrete. U boxtest apparatus has four reinforcement bars (Figure 1a) that can simulate the real field situation that fibre concrete face in the field. Figure 1b also can represent the real field behaviour of concrete compared to the traditional slump cone test.

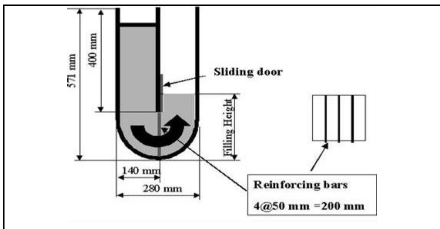

Figure 1a. U tube test

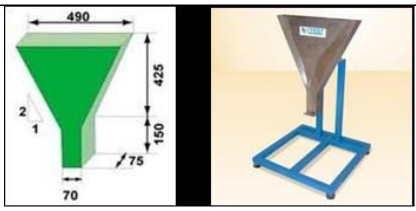

Figure 1b. V funnel test

Plastic shrinkage cracking

This test was carried out using the arrangement as illustrated in Figure 2a. The relevant code is ASTM C1579-06. The test sample is subjected to prescribed conditions of restraint and drying conditions that are severe enough to induce plastic shrinkage cracking in test sample. The severe environmental conditions recommended by ASTM C1579-06 were created inside the laboratory by creating artificial heating (electric bulbs) and wind (electric fans) as illustrated in Figure 2b.

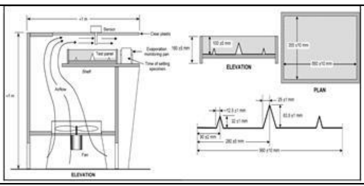

Figure 2a. The test apparatus used for the Plastic cracking

Figure 2b. Arrangement to the plastic shrinkage cracking measurements

Tensile strength test

Normally concrete has a low tensile strength compared to compressive strength. This test was conducted according to the code ASTM D6272. This test provides a quantitative measurement of the tensile strength.

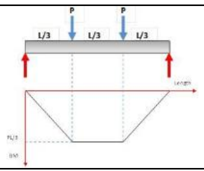	
Figure 3a. The loading arrangement of the four point loading test for the tensile strength measurement	**Figure 3b.** The experimental arrangement of the four point loading test

RESULTS

Fresh properties

The workability measurements are presented in Table 2.

Table 2. Workability measurement

Mix	Slump(mm)	U tube(mm)	V funnel(Sec)
M1	80	Negligible	No flow
M2	165	50	No flow
M3	180	80	9
M4	185	150	7

As illustrated in the Table 1, M1 mix showed very stiff behaviour in the slump test as well as in U box tube and V funnel test. However all the other mixers shows higher slump values. However, by carrying out U box test and V funnel test more information can be obtained about the mixtures. Mix 2 denoted slump value of 165mm. However, the U tube test gave lower value of filling height indicating very low flowablity due to interlocking. Therefore it is important to carry out U box type test to measure the workability of fibre concrete.

Plastic shrinkage cracking

Measurement of the plastic shrinkage cracking indicates lesser number of plastic cracking in fibre added concrete. Only one crack was observed (width is approximately 0.5mm) in all the fibre added concrete whereas in plain concrete several smaller cracking were noticed.

Tensile strength

Figure 4 shows the tensile strength results of hardened concrete. Each of the presented values is the average of three values of three samples for each mix type. As illustrated in Figure, 4 the addition of fibre has caused the improvement in tensile strength. However the addition of fibre should be made carefully as the workability is affected by fibres. As shown in our results, M2 has shown lower tensile strength. One of the reasons for the reduction of strength is that part of water has gone to wet the fibres thus causing lesser water for the chemical reaction. This has affected the strength to go down. In the mix 3 the maximum aggregate size of the mix is 10mm. The smaller aggregates help to increase the total surface area to be wetted. Therefore 10% additional water was added to compensate higher surface area due to the fact of smaller aggregate and fibres. This process gave similar strength to the previous mix (mix 1). The determination of optimum additional water content needs more test to be carried out which is on the way now. The process was hindered due to higher cost of fibres.

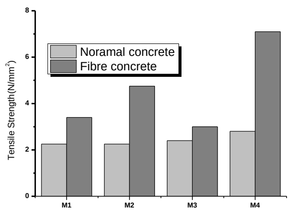

Figure 4. Variation of tensile strength in normal and fibre added concrete

CONCLUSIONS

This study investigated the measurement of workability, plastic shrinkage and tensile strength of fibre added concrete using newly developed apparatus. Workability is greatly affected by the addition of fibre. Plastic shrinkage cracking is controlled by the added fibre. Tensile strength analysis shows higher tensile strength ($5N/mm^2$) gain in fibre concrete compared to normal grade

25 concrete (2N/mm²). Significant tensile strength improvement was obtained in fiber concrete that increased from 3N/mm² to 8N/mm² in comparison to the normal in-situ pile concrete. Modification to the water content in mix design needs more experiments to be carried out with the selected fibre.

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