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Technical Note:

Characteristics of PVC Coated Welded Wire Mesh Fiber Reinforced Concrete

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Abstract: Introducing fibers into concrete aims to improve the low tensile strength of concrete and its brittle properties. In this research, readily available PVC coated welded wire mesh with diameter of 1 mm was used as fibers in concrete. There are several variations of concrete samples prepared for this study, i.e. based on the fiber's volume fraction, length and interlocking schemes. Concrete samples were subjected to tensile and compressive strength, and elastic modulus tests. The results show that the incorporation of PVC coated welded wire mesh slightly increases the tensile strength of concrete, with the optimum fiber volume fraction of 1.5%; with the fiber length of 3.6 cm, and with the interlocking of 1.2 cm. However, the concrete compressive strength is slightly reduced, compared to the normal ones. The presence of PVC coated welded wire mesh as fiber also tends to reduce the elastic modulus of fiber reinforced concrete.

Keywords: Fiber; PVC coated wire mesh; concrete; tensile strength; compressive strength.

Introduction

Concrete has been widely used in construction due to its high compressive strength, excellent workability and easily moulded into any shape. However, several problems attached to ordinary concrete, i.e. possesses low tensile strength, low ductility, and low resistance to cracking, which could lead to failure of concrete. Therefore, there are needs to improve the performance and durability of concrete, as well as reducing the defects in concrete. One of the effective methods is by adding pieces of short fibers to the concrete mixing process [1-3]. Ismail et al. reported that the use of fiber in concrete can improve its resistance to pull out or stress to rupture [4]. Rambo et al. found that some properties of fiber control the dry and plastic shrinkage cracking, thus reduces bleeding of water [5]. Behaviour of various types of fibers, e.g. steel, glass, rubber, synthetic and natural fibers, in reinforcing concrete, has been studied widely. The concrete is known as fiber reinforced concrete (FRC).

The inclusion of fibers affects the performance of concrete. Fibers possess high elastic modulus that improves the mechanical properties of concrete, e.g. tensile strength, flexural strength, creep behaviour, ductility, impact resistance and toughness [6].

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Thomas and Ramaswamy [7], stated that the use of interlocking fiber cause aggregate particles to entangle, and thus reduces the workability. It may lead concrete to be more cohesive and less prone to segregation. The use of various steel fibers when incorporated into concrete has been widely researched to investigate the tensile, compressive, and shear strength capacity, as well as the durability and the influence of parameters, such as temperature, interlocking, and shape [8]. However, in many cases, steel fibers are expensive and the inclusion of fiber in concrete, in the range of 0.5-2% of concrete, by volume, would lead to excessive cost. Therefore, as an alternative of steel fiber, polyvinyl chloride (PVC) coated welded wire mesh might become a low cost solution. PVC coated welded wire meshes are widely available with various sizes and prices.

The inclusion of PVC coated welded wire mesh in concrete has been investigated by Yazici et al. and other researchers [9-12], with the grid size of 10 mm x 10 mm, the diameter of 0.5 mm, specific length, and interlocking. The result indicated that the introduction of 0.7% PVC coated welded wire mesh in volume fraction improved the compressive strength of concrete for 8.6% compared to those of conventional concrete. However, the effect of fiber interlocking and length have not been clearly understood. Therefore, this study aims to investigate the use of PVC coated welded wire mesh as FRC with various fractions, lengths and interlocking to understand concrete strength characteristics.

Materials

Cement, Fine, and Coarse Aggregate

This study used locally manufactured ordinary Portland cement (type 1) with specific gravity of 3.15.

Natural river fine sand was used as fine aggregate with the specification is shown in Table 1. The properties of crushed stone as coarse aggregate can be seen in Table 1 as well.

Table 1. Aggregate Properties

Properties	Unit	Aggregate	
		Fine	Coarse
Gradation zones	-	2	max. 10mm
Unit weight	kg/m^3	1613	1588
Specific gravity	-	2.713	2.302
Water content	%	4.24	3.64
Water absorption	%	2.67	1.48

Fiber Material

PVC coated welded wire mesh were used as the fiber reinforcement. Figure 1 shows the PVC coated welded wire mesh before it was cut in various shapes and sizes. Geometrically the grid of wire mesh is 12 mm x 12 mm as shown in Figure 2.

Figure 1. PVC Coated Welded Wire Mesh

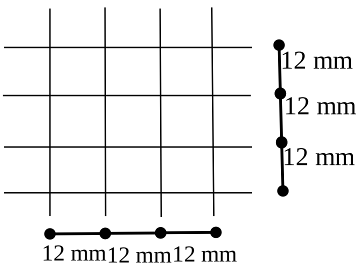

Figure 2. Geometrical Grid of PVC Coated Welded Wire Mesh

Wire mesh was cut into several types with specific fiber length and fiber interlocking. The first type (Figure 3(a)), with the dimension of 36 mm in length and 12 mm in interlocking, was used to examine the effect of various fiber fractions, i.e. 0.5%, 1%, and 1,5% of concrete, by volume, in concrete mixture. The second type was grouped based on the fiber length as shown in Figure 3(b). In this group, fiber was cut with the length of 12 mm, 24 mm and 36 mm, with the specimen code of Lt1, Lt2, and Lt3, respectively. The third type was cut into three groups, based on the interlocking of fiber, as shown in Figure 3(c). For this type, fibers were cut with the interlocking of 6 mm, 12 mm, and 24 mm, which were coded as Il1, Il2, and Il3, respectively.

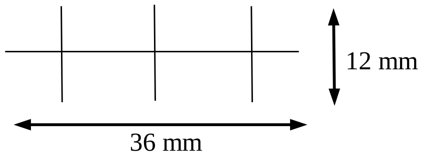

Figure 3(a). Geometrical Dimension of PVC Coated Welded Wire Mesh for Various Fraction Purposes

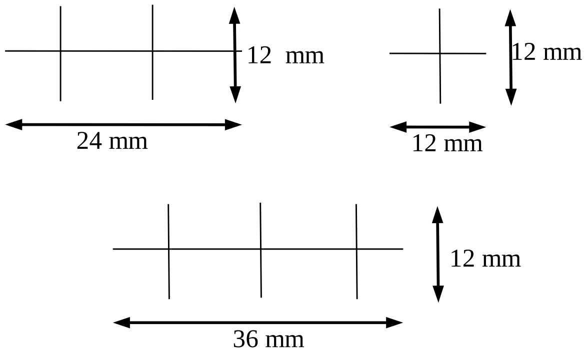

Figure 3(b). Geometrical Dimension of PVC Coated Welded Wire Mesh with Different Length

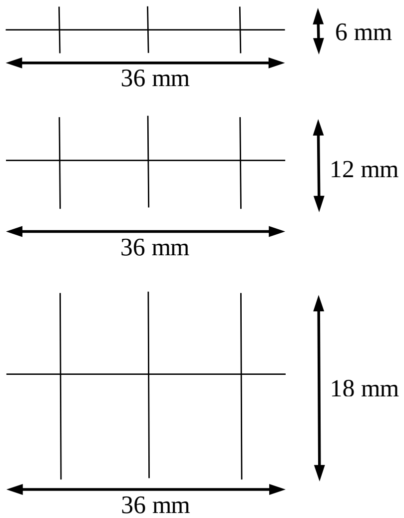

Figure 3(c). Geometrical Dimension of PVC Coated Welded Wire Mesh for Different Interlocking Schemes

Method

Concrete Mix Design

In this study, the concrete mix design was aimed for f'c = 21 MPa at 28 days. Therefore, the concrete mix proportion (cement: fine aggregate: coarse aggregate) was set at 1 : 1.8 : 2, by volume, with the water-to-cement ratio of 0.5. Slump cone method was conducted on freshly prepared concrete to examine the workability of specimen.

Experimental Programs

In this study, 60 cylindrical concrete specimens with diameter of 150 mm and height of 300 mm were casted. PVC coated welded wire mesh were added in 24 concrete specimens, with 4 different percentages of fiber volume, starting from 0% as the reference specimen, and increasing up to 1.5%, with the increment of 0.5%. The specimens were coded as Fr1, Fr2, and Fr3, respectively. In addition, 36 specimens were casted with 1% of fiber volume, with various fiber interlocking schemes and various fibers length.

As seen in Table 2, there were six specimens for each specimen code, in which three specimens were subjected to tensile splitting test and three specimens were subjected to compressive test.

Table 2. Fiber Properties

S.Code	Amount (specimen)	Fraction (% Vol)	Length (mm)	Interlocking (mm)
Norm	6	0	0	0
Fr1	6	0.5	36	12
Fr2	6	1	36	12
Fr3	6	1.5	36	12
Ll1	6	1	36	6
Ll2	6	1	36	12
Ll3	6	1	36	18
It1	6	1	12	12
It2	6	1	24	12
It3	6	1	36	12

Test Results and Discussion

Fresh Properties

At the early stage, workability of concrete mixture was investigated. Slump tests were carried out on the freshly concrete mixtures in 3 repetitions. The result of slump tests is shown in Figure 4.

The inclusion of fiber has been known to reduce the slump value and to decrease the density of concrete mixture, as indicated in Figure 4. Therefore, higher fraction of fiber content in concrete reduces workability, and the fresh concrete becomes much harder to mould that may lead to porosity. Consequently, the optimum amount of fiber fraction is essential to be determined, to produce dense and smooth concrete surface.

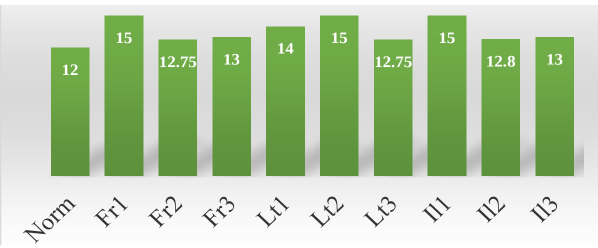

Figure 4. The Average Slump Value of Each Specimen Category (unit: cm)

Mechanical Properties

Concrete Specimens with Various Fiber Fractions

Referring to Figure 5, among the various fractions of fiber volume that were added, concrete with 1.5% fiber addition tends to have better tensile strength. However, further increasing the fiber content would decrease the tensile strength, when compared to theose of normal concrete. Meanwhile, the elastic modulus of the concrete was significantly reduced due to the elastic characteristics of coated welded wire mesh. Coated welded wire mesh tends to increase the strain of concrete, while maintaining the stress, which lead to lower elastic modulus.

The optimum fiber fraction was acquired on concrete with 1.5% fiber fraction, of concrete, by volume (Fr3). This fiber addition tends to increase the concrete tensile strength, while maintaining its compressive strength. The increase of tensile strength was considered minor (0.57%). It is mainly due to the polyvinyl chloride (PVC) layer coating on the welded wire mesh, that creates smooth and slippery surfaces. This coated layer prevents an active interaction between wire mesh and concrete. As the consequences, during the tensile test, welded wire mesh losts its ability to carry friction and to maintain the solidity of concrete.

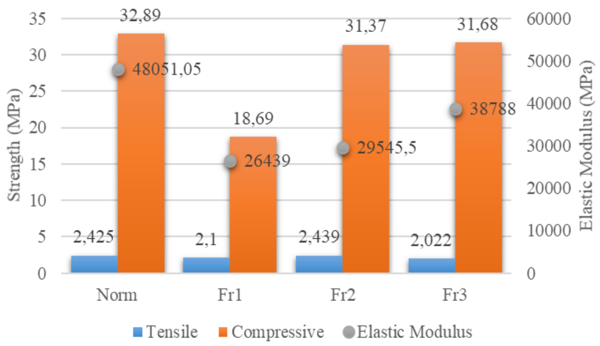

Figure 5. Mechanical Properties of Concrete Specimens with Different Fiber Fractions

The residual specimens after tensile test, as can be seen in Figure 6, shows some of the PVC coated welded wire mesh were sticking out from the surface of concrete cloven part. The full-sized length of sticking-out-wire-mesh indicates that there was a slip mechanism during the tensile test.

Specimens with Different Fiber Length

Figure 7 shows the influence of fiber length on the mechanical properties of concrete specimens. As indicated in Figure 4, the longer the length of fiber tends to lower the slump value of fresh concrete. Meanwhile, the compressive and tensile strength are highly associated with the slump value. Too high slump tends to reduce the mechanical properties of concrete due to the hardening issue. However, longer fiber tend to maintain the higher compressive strength. As can be seen in Figure 7, concrete specimens with the longest fiber produce the highest compressive strength, while those with the shortest fiber length produce better tensile strength.

Figure 6. The Full-sized Length of Welded Wire Mesh Sticking Out from the Concrete Surface

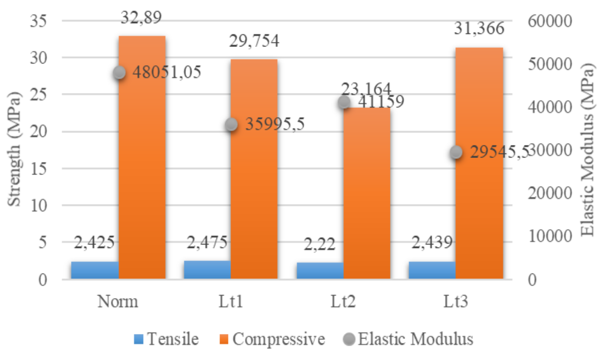

Figure 7. Mechanical Properties of Concrete Specimens with Different Fiber Length

Figure 7 also reveals the use of longer coated welded wire mesh length tends to reduce the elastic modulus of fiber concrete. It seems that the smooth surface of PVC coated wire mesh causes the bonding failure between fiber (wire mesh) and concrete, and resulting in decrease of the elastic modulus of concrete.

Specimens with Different Fiber Interlocking

Figure 8 describes the effect of different fiber interlocking to concrete mechanical properties. The addition of interlocking length does not significantly reduce the compressive strength of fiber concrete, as seen in specimen Il3 (18mm of interlocking length). The reduction was only about 5% compared to compressive strength of the normal specimens. Meanwhile the tensile strength of concrete does not show any significant change due to the addition of PVC coated weld wire mesh. It may due to the effect of irregular fiber direction to the applied load. The addition of interlocking length may be more effective if the direction of fiber are uniformly perpendicular to the applied load during the tensile test. Further, the procedure of fiber and concrete mixing may contribute to the tensile properties of fiber reinforced concrete. The uneven distribution of fiber, as well as its direction, causes the applied load cannot equally be distributed to all areas. In addition, as explained, the smooth and slippery surface reduce bonding mechanism between fiber and concrete, which can be indicated from the Figure 9.

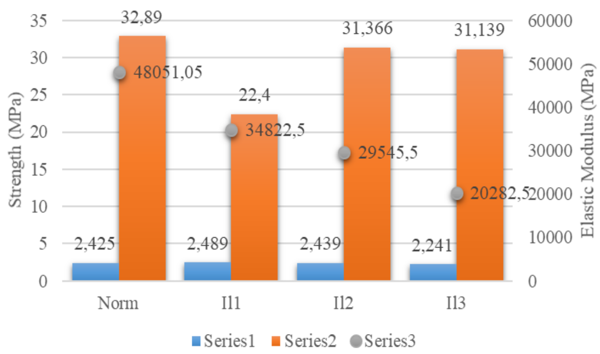

Figure 8. Mechanical Properties of Specimens with Different Fiber Interlocking Length

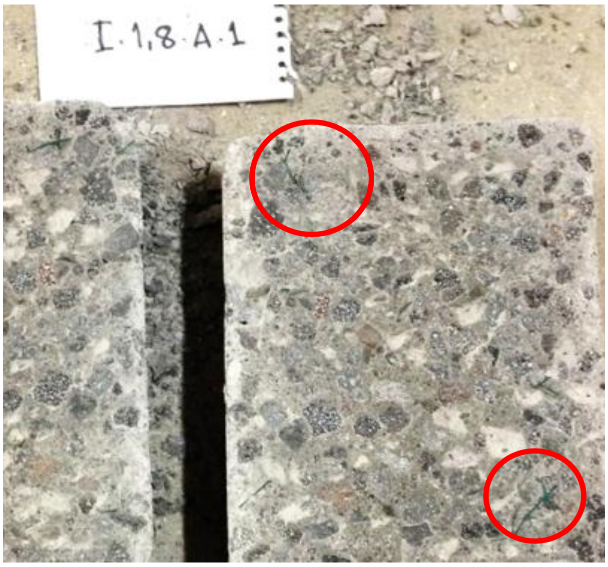

Figure 9. The Uneven Distribution and Irregular Direction of PVC Coated Weld Wire Mesh

However, the longer the fiber interlocking length significantly reduces the modulus elasticity of concrete, as seen in Figure 8.

The elastic modulus of specimens Il3, which has 18 mm of interlocking length, was 55% lower compared to the normal ones. Moreover, there was a good relation between the additions of interlocking length with the reduction of elastic modulus.

Correlations

Slump vs. Compressive Strength

Table 3 shows the slump and compressive strength of the various concrete specimens. Specimen without fiber has the highest compressive strength, while specimen with 0.5% fiber addition has the lowest compressive strength. Thus, slump has significant role on determining the compressive strength of PVC coated welded wire mesh fiber reinforced concrete.

As can be seen in Figure 10, the relationship between slump with compressive strength shows a good correlation. Higher slump value correlates with lower compressive strength, as in the case of normal concrete. PVC coated welded wire mesh practically does not absorp any water from the fresh concrete mixtures.

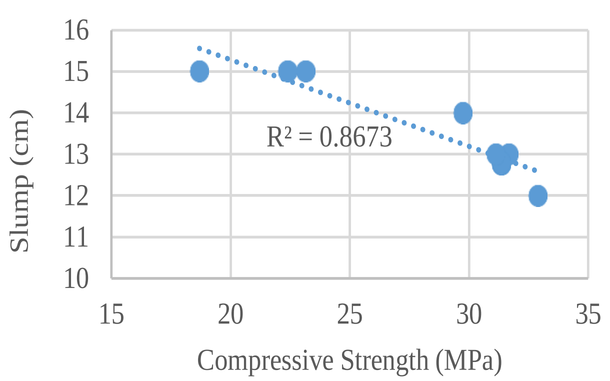

Figure 10. Relationship between Slump and Compressive Strength of PVC Coated Fiber Reinforced Concrete

Table 3. Slump and Compressive Strength of Various Specimens

S.Code	Slump (cm)	Comp. Strength (MPa)
Norm	12	32.89
Fr1	15	18.69
Fr2	13	31.37
Fr3	13	31.68
Lt1	14	29.75
Lt2	15	23.16
Lt3	13	31.37
Il1	15	22.40
Il2	13	31.37
Il3	13	31.14

Unit Weight vs. Elastic Modulus

Table 4 shows the unit weight and elastic modulus of various concrete specimens. The introduction of PVC coated welded wire mesh as fiber tends to lower the unit weight of specimens. The biggest reduction was occurred at the specimen with 18mm of interlocking length.

Figure 11 shows the relationship between the unit weight and the elastic modulus of fiber reinforced concrete. The R value confirms the good correlation between them. The lighter the PVC coated welded wire mesh fiber reinforced concrete, the lower will be the elastic modulus.

Table 4. Unit Weight and Elastic Modulus of Various Specimens

S.Code	Elastic Modulus (MPa)	Unit Weight (kg/m³)
Norm	48051	2368
Fr1	26439	2328
Fr2	29545	2345
Fr3	38788	2351
Lt1	35995	2367
Lt2	41159	2365
Lt3	29545	2335
Il1	34822	2362
Il2	29545	2333
Il3	20282	2321

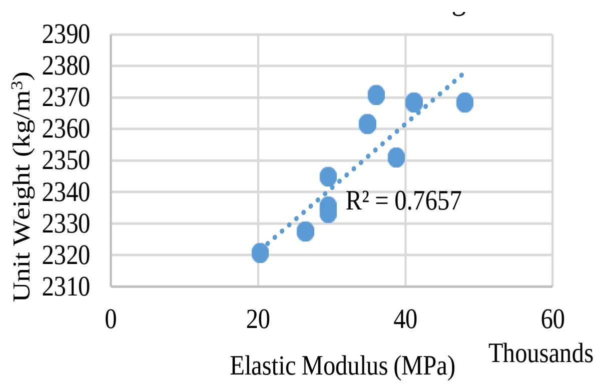

Figure 11. Relation of Unit Weight and Elastic Modulus in PVC Coated Reinforced Concrete

Conclusion

Sixty cylindrical concrete specimens were tested for their compressive and tensile strengths, to determine the effect of using PVC coated welded wire mesh as fiber in the concrete mixtures. Three categories of specimens were prepared, i.e. specimens with different fiber fractions, specimens with different fiber length and specimens with various fiber interlocking length.

Several outcomes can be observed as follows:

1. The optimum value of PVC coated welded wire mesh fiber fraction was found at the 1.5% of the concrete volume. With the incorporation of the fiber, there is a slight reduction in concrete compressive strength compared to those of normal ones, whereas the tensile strength remains practically unchanged.
2. The longer the fiber and its interlocking length tends to improve the compressive strength of fiber reinforced concrete. However, the use of the PVC coated material as fiber, with its smooth and slippery surface characteristics, fails to increase the tensile strength of fiber reinforced concrete.

3. There is a good correlation between slump and compressive strength, and between unit weight and elastic modulus, of fiber reinforced concrete. It is indicated that the higher the PVC coated welded wire mesh fraction and the longer the fiber length or the interlocking length tends to lower the elastic modulus of fiber reinforced concrete.

Acknowledgments

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