STUDY OF MODULUS ELASTICITY OF PVC COATED WELDED MESH FIBER CONCRETE

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ABSTRACT: Modulus elasticity is an important parameter that shows the ability of concrete to deform elastically. Data analysis to obtain that value of modulus elasticity can be done with several approaches. To compare some of these approaches and to study the effect of fiber to the modulus elasticity of concrete, an experiment on the addition of PVC coated welded wire mesh fiber to the concrete mixture has been conducted. The specimen in this experiment was a cylindrical specimen with a diameter of 150 mm and height 300 mm. There are 3 variations in this experiment : (1) variations in the fraction of percentage of wire fiber; (2) fiber's length variation and (3) length interlocking variation. Extensometer was installed onto the specimens to measure stress-strain of concrete while the compressive strength was conducted. The data obtained and then analyzed. The result of the analysis showed that the higher the fiber's fraction added to the concrete mixture, the greater the modulus elasticity resulted. However, PVC coated welded mesh fiber concrete has a less value of modulus elasticity when it compared with normal concrete due to the slip effect between fiber and concrete. Furthermore, there are some approaches with good agreement and some indifferent results.

Keywords: Fiber concrete, Modulus elasticity, Stress-strain, PVC coated welded wire mesh

1. INTRODUCTION

Fibers concrete is concrete made of cement, aggregates, water and discrete fibers (steel fibers, glass fibers, synthetic fibers, etc.). According to ACI Committee 544.1R-96 [1], the length and diameter of the fibers used for fibers concrete should not exceed 76 mm and 1 mm respectively. The addition of fiber to the concrete has a purpose to fix the weakness of the concrete that has a low tensile strength.

There are a variety of fibers used for fibers concrete. Iwan R. [2] used fibers made from waste cans with variation fraction and water-cement ratio 0.45. The width, length, and thickness of the fibers are 3 mm, 50 mm and 0.2 mm respectively. The result of the research is that the addition of fiber with a fraction 0.6% increased the compressive strength of 30.65% and the tensile strength of 49.69%. Another research done by Kampa R. [3] use coca-cola can waste as fiber, the width and length of the waste tin fibers are 2 mm and 20 mm respectively. The fibers manually twisted by 180^0 to improve bondage between cement, aggregates, and fibers. The addition of waste tin fibers shown an insignificant change in compression and tensile strength. Waste carpet fibers with the length of the fibers are 20 mm and the variation of the fraction is between 0 – 1.25% were used by Hossein M, Jamaluddin M. Y., Abdul R. M. S., and A. S. M. Abdul Awal [4] as a fibers concrete. In addition to used waste carpet fibers, Hossein also added palms

oil fuel ash (POFA). The interaction between carpet fibers and POFA subsequently led to the lower drying shrinkage of the concrete. Ankur C. B. and Narendra K. A. [5], used metalized plastic waste fibers were shredded into 5 mm, 10 mm and 20 mm long fibers. The fraction variation is from 0% to 2% of mix design volume. The results of his research are that metalized plastic waste fibers did not significantly affect the compressive strength and flexural strength but it increased tensile strength and ductility. From these studies, the results obtained that the addition of fiber can increase tensile strength where the magnitude of the increase is influenced by the type of fibers. Swammy and Al-Noori (in Haryanto Y. W. and Recky S. G., pp.3 [6]) state that the shape of fibers affects the bonding and the properties of the concrete. Concrete using fibers with interlocking will increase its bonding and structural properties rather than the fibers without interlocking.

The addition of fibers can increase tensile strength wherein concrete generally has a low tensile strength and has a brittle nature. Determining the tensile strength is important to determine the crack load where a crack is a form of tensile failure. To have a better understanding of fibers concrete and its influence on tensile strength, it is necessary to know the modulus elasticity of fibers concrete.

Modulus elasticity is one of the strength parameter of a material, which is to measure the resistance of elastic deformation when the material

under the load. It can be said that modulus elasticity is a measure of the stiffness of a material so that it can affect the strength of a material. There are several approaches used to obtain modulus elasticity of concrete. Emi M. [7] calculated modulus elasticity of concrete used the equation of Wang and Salmon. Wang and Salmon predict the modulus elasticity based on the stress-strain of concrete. H. Z. Cui, Tommy Y. L., Shazim A. M., F. Xing and X. Shi [8] used the empirical model from ACI and institute of structural to predicted the modulus elasticity of lightweight concrete, which is influenced by compressive strength and weight of concrete. Turhan B. [9] used several empirical models such as Euro Code 2, TS500, Norwegian Code, etc. , and used composite material models such as Voigt model, Reuss model, Popovics Model, etc. to predicted modulus elasticity of high-quality concrete.

Based on previous studies, this research used PVC coated welded wire mesh fibers and investigated its influence on modulus elasticity of fiber concrete. This research also studied and compared the modulus elasticity from several empirical models.

2. EXPERIMENTAL INVESTIGATION

PVC coated wire is a modified type of wire bend. It is also known as PVC *coated welded wire mesh*, is high-quality stainless steel wire with stainless resistance much better than ordinary iron wire. This wire consists of galvanized wire (diameter 0.8 mm) coated by PVC (thickness 0.2 mm). The advantages of this wire are high rust resistance, easy to get, great savings in time, effort and money.

The specimen in this research is a cylinder with a diameter 150 mm and height 300 mm with 3 variations :
(1) Variation of fraction (0.5 %, 1 %, 1.5% of cylinder volume) with fiber length 36 mm and interlocking length 12 mm (Fig. 3.b)
(2) Variation of fiber's length (12 mm, 24 mm, 36 mm) with a fraction 1% and interlocking length 12 mm (Fig. 4)
(3) Variation of fiber's interlocking length (6 mm, 12 mm, 18 mm) with a fraction 1% and fiber length 36 mm (Fig. 5)
The specimen was tested with a compressive test machine and an extensometer to measure concrete strain. (Fig.1). To prepare the materials, it is necessary to know the density of the wire mesh. After 3 experiments, the density of PVC coated welded wire mesh as shown in Table 1.

After knowing the density, then calculate the need for each fraction. For example the calculation for one cylinder with a fraction 1%.

$W_{wire\ mesh}$
$= \%fraction\ x\ V_{cylinder}\ x\ density_{wire\ mesh}$
$= 1\%\ x\ 5298.75\ cm^3\ x\ 0.371\ gr/cm^3$
$= 19.658\ gr$

Fig. 1. Test model with the compressive test machine
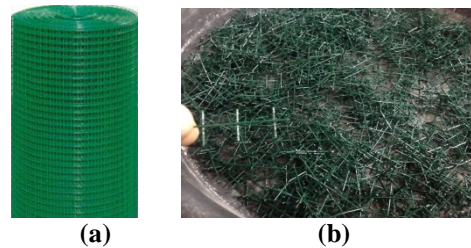

| **(a)** | **(b)** |

Fig. 2. (a) PVC coated welded wire mesh, (b) PVC coated welded mesh fiber

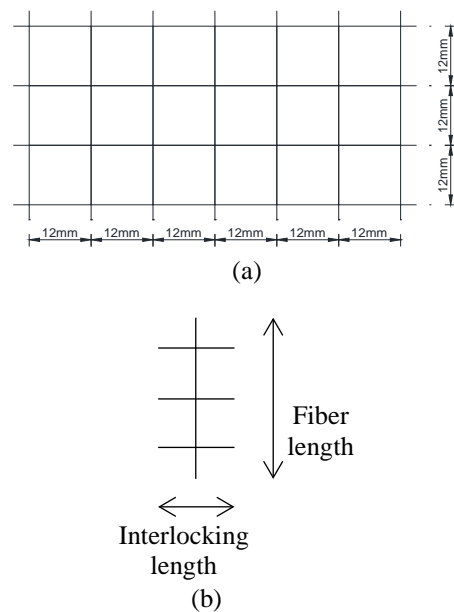Fig. 3. (a) PVC coated welded wire mesh before cut, (b) PVC coated welded wire mesh after the cut.

Table 1 PVC coated welded wire mesh density

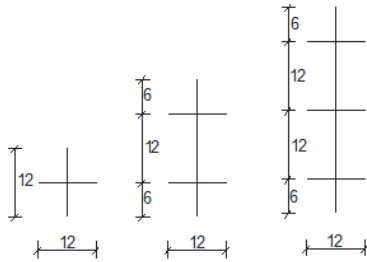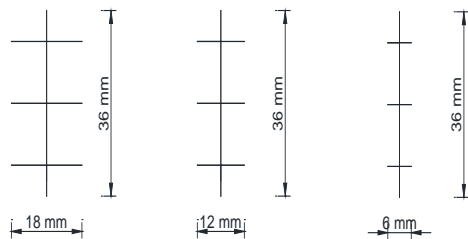|	Density (gr/cm³)
Experiment A	0.373
Experiment B	0.351
Experiment C	0.388
Average	**0.371**

Fig. 4. Variation of fiber's length

Fig. 5. Variation of fiber's interlocking length

Mix design in this research refers to SNI 03-2834-2000 [10]. From the calculation obtained ratio of actual proportion (in kg).

Table 2 Ratio of mix design

Cement	Water	Fine aggregate	Coarse aggregate
1.00	0.5	1.18	2.02

3. MODELING APPROACH

Modulus elasticity is the ratio of the stress and strain of the material as seen in the Eq.(1).

$$E = \frac{\sigma}{\varepsilon} = \frac{P \, x \, L}{A \, x \, \Delta L} \qquad (1)$$

According to Wang and Salmon [11], modulus elasticity depends on the age of the concrete, materials properties, the loading rate, the type and size of the specimen. The empirical model used in this research can be seen in Table 3. According to the theory of elasticity, the slope of the curve in the early stage illustrates the modulus elasticity of concrete (Fig.6).
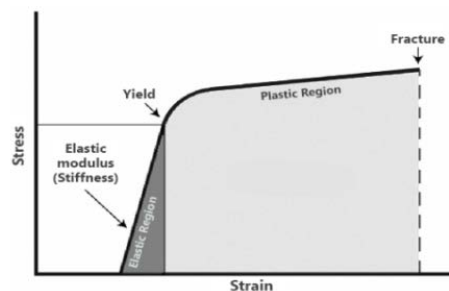

Fig. 6. Stress-strain curve [12]

Elastic proportional limits (ASTM C 469 and Eurocode 2 - 1992) in predicting modulus are important because the nature of the concrete is an elasto plastic, where as a result of a fixed loading, the material exhibits the elastic ability of the material and also exhibits permanent deformation. The modulus elasticity based on the material resistance to the compressive strength test (deformation) is called modulus elasticity static. In addition, there is also an empirical model of elastic modulus containing the concrete compressive strength factor (SNI 03-2847-2002 and TS 500).

Table 3. Summary of an empirical model to estimate the modulus elasticity

Empirical model		Parameters	Ref. source
$E = \dfrac{0.4 f'c}{\varepsilon(0.4 f'c)}$	(2)	E is the modulus elasticity static (MPa), f'c is compressive strength (MPa), ε is an axial strain	Eurocode 2 - 1992
$E = \dfrac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1}$	(3)	E is the modulus elasticity static (MPa), σ_1 is axial stress when the axial strain is 0.00005, σ_2 is axial stress at 40% f'c, $\varepsilon_1 = 0.00005$, ε_2 is an axial strain when σ_2	ASTM C 469
$E = 0.043 \, x \, W_c^{1.5} \, x \, f_c^{0.5}$ (4) $(1500 \leq Wc \leq 2500 \text{ kg/m}^3)$		E is the modulus elasticity (MPa), W_c is unit weight (kg/m³), f'c is compressive strength (MPa)	SNI 03-2847-2002 (Indonesian Standart)

Continue of Table 3. Summary of an empirical model to estimate the modulus elasticity

Empirical model	Parameters	Ref. source
$E = 4700\,fc^{0.5}$ (5) (Wc ± 2300 kg/m³)	E is the modulus elasticity (MPa), W_c is unit weight (kg/m³), f'c is compressive strength (MPa)	SNI 03-2847-2002 (Indonesian Standart)
$E = \left(3250\,x\sqrt{f'c}\right) + 14000$ (6)	E is the modulus elasticity (MPa), f'c is compressive strength (MPa)	TS 500 (Turkey Standart)

4. RESULT AND DISCUSSION

In Table 4, 5 and 6 are shown the results of modulus elasticity calculations using the empirical model contained in Table 3. It can also be seen the percentage values of the difference for each calculation method of modulus elasticity. Eurocode 2 - 1992 (eq.2) and ASTM C 469 (eq.3) are similar to each other and the value of modulus elasticity also close to each other, they have the smallest percentage of the difference between empiric formulas (2.3% - 2.6%), this is because both formulas consider the value of strain-stress that occurs in the concrete. If Eurocode 2 - 1992 (eq.2) is compared with TS 500 (eq.6) and

ASTM C 469 (3) compared with SNI 2002 (eq.4), where as TS 500 and SNI 2002 related to compressive strength as the parameter of elastic modulus, then the percentage difference is quite large (average more than 50%).

Value of modulus elasticity from SNI 2002 formula for concrete weight ± 2300 kg / cm3 (eq.5) and for concrete weight between 1500 s.d 2500 kg / cm³ (eq.4) has not too much different (4.1% - 4.6%). This is because the normal concrete and fiber concrete has a specific gravity and compressive strength for each variation that not too much different.

Table 4. Modulus elasticity of PVC coated welded mesh fiber-concrete with a variation of fiber's fraction

No.	Specimen code	f'c (MPa)	Modulus elasticity (MPa)					difference between empiric formulas (%)				
			2 Eurocode 2 – 1992	3 ASTM C 469	4 SNI 2002 (1500 ≤ Wc ≤ 2500 kg/m3)	5 SNI 2002 (Wc ± 2300 kg/m3)	6 TS 500	(2) & (3)	(3) & (4)	(4) & (5)	(2) & (6)	(4) & (6)
1	N.A1	32.75	38158.5	37391	28326.8	26897.6	32599.4	2.1	32	5.3	14.6	15.1
2	N.A2	33.03	62778	58705	28448.8	27013.5	32679.5	6.9	106	5.3	47.9	14.9
3	F.0.5.A1	19.40	10924.5	10757	21672.3	20702.4	28315.5	1.6	50	4.7	159.2	30.7
4	F.0.5.A2	17.99	41827.4	42121	20493	19933.7	27783.9	0.7	106	2.8	33.6	35.6
5	F.1.A1	30.32	16970	16970	27581	25879.5	31895.4	0.0	38	6.6	88	15.6
6	F.1.A2	32.41	41957.6	42121	26843.2	26757.9	32502.8	0.4	57	0.3	22.5	21.1
7	F.1.5.A1	31.68	40600.7	38788	27360.2	26452.6	32291.7	4.7	42	3.4	20.5	18
	Average % difference between empiric model							2.3	61.6	4.1	55.2	21.6

Table 5. Modulus elasticity of PVC coated welded mesh fiber-concrete with a variation of fiber's length

No.	Specimen code	f'c (MPa)	Modulus elasticity (MPa)					difference between empiric formulas (%)				
			2 Eurocode 2 – 1992	3 ASTM C 469	4 SNI 2002 (1500 ≤ Wc ≤ 2500 kg/m3)	5 SNI 2002 (Wc ± 2300 kg/m3)	6 TS 500	(2) & (3)	(3) & (4)	(4) & (5)	(2) & (6)	(4) & (6)
1	N.A1	32.75	38158.5	37391.0	28326.8	26897.6	32599.4	2.0	24.2	5.0	14.6	15.1
2	N.A2	33.03	62778	58705.0	28448.8	27013.5	32679.5	6.5	51.5	5.0	47.9	14.9
3	L.1.2.A1	28.91	13319.7	13346	26452.6	25268.8	31473.11	0.2	98.2	4.5	136.3	19.0
4	L.1.2.A2	30.60	56253.8	58645	27545.3	25987.7	31978.71	4.3	53.0	5.7	43.2	16.1
5	L.2.4.A1	22.91	18840.1	18683	23832.8	22495.8	29555.62	0.8	27.6	5.6	56.9	24.0
6	L.2.4.A2	23.42	67726.1	63636	24096.2	22744.4	29727.51	6.0	62.1	5.6	56.1	23.4
7	L.3.6.A1	30.32	16970	16970	27581	25879.6	31895.37	0.0	62.5	6.2	88.0	15.6
8	L.3.6.A2	32.41	41957.6	42121	26843.2	26757.9	32503.04	0.4	36.3	0.3	22.5	21.1
	Average % difference between empiric model							2.5	51.9	4.7	58.2	18.6

Table 6. Modulus elasticity of PVC coated welded mesh fiber-concrete with variation of fiber's length interlocking

No.	Specimen code	f'c (MPa)	Modulus elasticity (MPa)					difference between empiric formulas (%)				
			2 Eurocode 2 – 1992	3 ASTM C 469	4 SNI 2002 (1500 ≤ Wc ≤ 2500 kg/m3)	5 SNI 2002 (Wc ± 2300 kg/m3)	6 TS 500	(2) & (3)	(3) & (4)	(4) & (5)	(2) & (6)	(4) & (6)
1	N.A1	32.75	38158.5	373919	28326.8	26897.6	32599.4	2.0	24.2	5.0	14.6	15.1
2	N.A2	33.03	62778.0	587059	28448.8	27013.5	32679.5	6.5	51.5	5.0	47.9	14.9
3	I.0.6.A1	22.80	27402.6	26428	23632.5	22440.2	29517.2	3.6	10.6	5.0	7.7	24.9
4	I.0.6.A2	22.00	44146.46	43217	23357.3	22047	29245.3	2.1	46	5.6	33.8	25.2
5	I.1.2.A1	30.32	169706	16970	27581	25879.6	31895.4	0.0	62.5	6.2	88.0	15.6
6	I.1.2.A.2	32.41	41957.6	42121	26843.2	26757.9	32502.78	0.4	36.3	0.3	22.5	21.1
7	I.1.8.A1	30.21	18537.2	17755	27366.5	25831.2	31862	4.2	54.1	5.6	71.9	16.4
8	I.1.8.A2	32.07	23258.1	22810	27603.4	26617.4	32405.7	1.9	21	3.6	39.3	17.4
	Average % difference between empiric model							**2.6**	**38.3**	**4.6**	**40.7**	**18.8**

Figure 7 presented that the data regression of Eurocode 2-1992 and ASTM C-469 coincide. Both methods of SK SNI 2002 also produce linear lines that mutually coincide. Although with different models and parameters, it can be seen that compressive strength increased followed by the increase of modulus of elasticity. This statement is similar to the theory of modulus elasticity in Eq. 1.
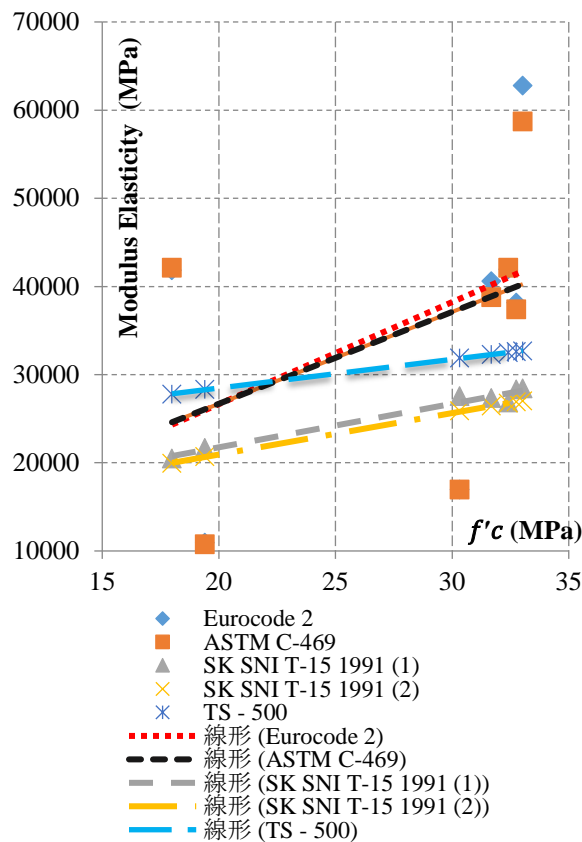

Fig. 7. Regression of modulus elasticity of PVC coated welded mesh fiber-concrete with a variation of fiber's fraction

In this paper, the effect of PVC coated welded mesh fiber as a fiber in concrete will be analyzed based on Eurocode 2-1992 and ASTM C-469. The experimental result (Fiq.8) showed that the higher the fiber's fraction added to the concrete mixture, the greater the modulus elasticity resulted. However, PVC coated welded mesh fiber concrete has a less value of modulus elasticity when compared with normal concrete. The addition of PVC coated welded mesh fiber did not give a positive effect to the compressive strength or it can be said the compressive strength was decreased (decreased by 19.4%.).
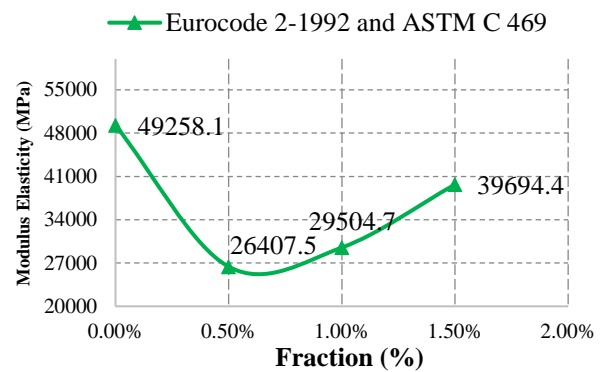

Fig. 8. Summary of modulus elasticity of PVC coated welded mesh fiber-concrete with a variation of fiber's fraction

Based on previous research, fiber increase tensile strength although it has little effect on compressive strength. However, in this study, it can be seen that the addition of PVC coated welded mesh fiber did not give a positive effect to modulus elasticity of concrete. The wire coated by PVC and give slip effect so that bonding between concrete and fiber did not work well. The addition of fibers are supposed to improve the tensile strength, but the slip effect causes the fiber did not give a good effect to tensile strength. However,

modulus elasticity of PVC coated welded mesh fiber concrete increased as fiber's volume fraction increased, even though modulus elasticity of fiber concrete less than normal concrete.

Figure 9 showed that PVC coated welded mesh fiber-concrete with a variation of fiber's length 24 mm had the highest value of modulus elasticity. However, it decreased by 14.29% from normal concrete.

The effect of PVC coated welded mesh fiber-concrete with a variation of fiber's length shown in Fig. 10. The addition of fiber's length interlocking produced a decreasing effect on the modulus elasticity. Compared with normal concrete, modulus elasticity of PVC coated welded mesh fiber concrete decreased by 24%.
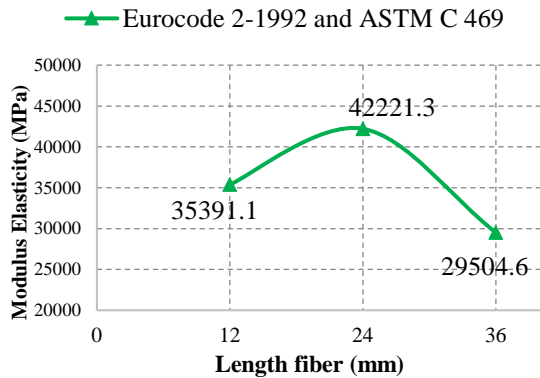

Fig. 9. Summary of modulus elasticity of PVC coated welded mesh fiber-concrete with a variation of fiber's length
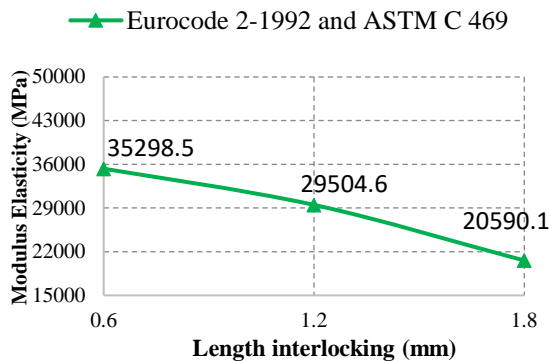

Fig. 10. Summary of modulus elasticity of PVC coated welded mesh fiber-concrete with variation of fiber's length interlocking

5. SUMMARY

1. Modulus elasticity calculated by Eurocode 2 - 1992 and ASTM C 469 is similar to each other because of both of the empirical models related to the stress-strain relationship of fiber concrete.

The other empirical model such as SNI 2002 and TS-500 also similar to each other and related to compressive strength.

2. Although each of empiric models has different parameters, however, have the same pattern that is an increase in compressive strength followed by an increase in modulus elasticity

3. Based on the variation of a fraction, PVC coated welded mesh fiber fraction of 1.5% produced the highest modulus elasticity. However, compared to normal non-fiber concrete, modulus elasticity decreased by 19.4%.

4. Based on the variation of fiber's length, the modulus elasticity produced the highest value on the variation of fiber's length 24 mm. However, compared to normal non-fiber concrete, the elasticity modulus value decreased by 14.29%.

5. Based on the variation of fiber's interlocking length, fiber's length interlocking of 0.6 mm produced the highest modulus elasticity. However, compared to normal non-fiber concrete, the elasticity modulus value decreased by 24%.

6. Less bonding between fibers with concrete may cause the use of PVC coated welded mesh fiber as a fiber material is not effective in increasing the modulus elasticity of concrete.

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