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Micro Steel Fiber Concrete Using Ultrasonic Pulse Velocity Method

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Abstract: Concrete is a prevalent compound that has been used to advance human civilization all over the world. One of the ways to increase durability and sustainability for concrete is to use fiber as an additive and reinforcement in concrete. For information, fiber has been used in cementitious matrices for over 4500 years. Micro steel fiber, MSF, is one of the most often utilised fibers in concrete. Apart from that, structure health monitoring is one of the best ways that can be used to identify defects that occur in concrete structures. Among the method, ultrasonic pulse velocity, UPV, which is the non-destructive testing is the good method compare to others. The objective of this research is to determine the mechanical properties such as strength and wave velocity of micro steel fiber concrete due to the different percentages of micro steel fibres 0%, 0.5%, 1.0% and 1.5% using the ultrasonic pulse velocity method. Then, the optimum percentage of micro steel fiber in concrete will be decided according to the ultrasonic pulse velocity result. The first procedure of this research were preparing the concrete mixing material according to calculation using Department of Environmental, DoE, method. Then, the materials mixed and been curing for 7 days and 28 days. The ultrasonic pulse velocity test and compressive strength test has been carried out after the curing. Finally, the data has been analyse. In conclusion, the optimum percentage of micro steel fiber in concrete that has been obtain was 1.5% as it achieved the highest result for ultrasonic pulse velocity test and compressive strength test compared to control concrete..

Keywords: Concrete, Micro Steel Fiber, Compressive Strength, Ultrasonic Pulse Velocity

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1. Introduction

Concrete is a prevalent compound that has been used to advance human civilization all over the world. The combination of materials such as cement, course aggregate and fine aggregate in one mixture forms a material called concrete. Furthermore, concrete provides a structure that has high compressive strength but low in tensile strength [1]. The demand for building materials has risen dramatically as a result of the enormous increase in construction activity. In addition, there are several new types of reinforcement has been prove can assist the concrete to become more strong and sturdy and can be applied to building construction. Concrete structures are prone to defects that can lead to failure due to the several factors such as aging, chemical reaction and constant stress from load [2].One of the ways to increase durability and sustainability is to use fiber as an additive and reinforcement in concrete. Fiber has been used in cementitious matrices for over 4500 years [3]. For the recent study, natural fibers from jutes, hemp, coir, corn, straw, or pines, as well as coconut are also widely applied in concrete. For the non-natural fiber , micro steel fiber, also known as MSF, is one of the most often utilised fibers in concrete [4].

Along with the rapid advancement of technology, various methods or techniques that can be used in the construction industry to improve the quality of work. Building materials that use concrete face a risk where the durability of the concrete structure is deteriorating due to several factors that cannot be avoided while in service. Hence, structure health monitoring is one of the best ways that can be used to identify defects that occur in concrete structures. Process of implementation on early damage detection and characterization for engineering structures is the mainstay in structure health monitoring [5]. Cracking is the one example of the defect that always occur in all structure. In addition, lack of human ability cause the cracking that occurs in a building cannot fully identify and it desperately needs help in this regard. Non-destructive testing seems to be more suitable for use on building structures because it does not need to make a single damage toward the part of the building to be inspected and is easier to implement. Ultrasonic pulse velocity seem the best method among the NDT. It is easy to implement and the data can be analyse easily. For information, the quality of concrete has been successfully assessed by using this UPV method more than 60 years [6].

The objective of this research is to determine the mechanical properties such as strength and wave velocity of micro steel fiber concrete due to the different percentages of micro steel fibers 0%, 0.5%, 1.0% and 1.5% using the ultrasonic pulse velocity method. Second objective is to identify the optimum percentage of micro steel fiber in concrete according to the ultrasonic pulse velocity result.

2. Materials and Methods

2.1 Materials

The accomplishment in this research as using the materials as below:

i. Ordinary Portland Cement (OPC) Type 1
ii. Water
iii. Fine aggregate that screen through the 5mm sieve and the retain on 75 μm (BS 882:1992)
iv. Course aggregate screen through the 20mm sieve and the retain on 5 mm (BS 882:1992)
v. Micro steel fiber

Figure 1: Micro Steel Fiber Material

2.2 Design Mixing

Design mixing is the process of selecting the optimum materials for producing concrete and determining their relative proportions to achieve the required strength. The concrete was designed using a method of the Department of Environment (DoE) proportions in this study. The proportion of materials required shown in the Table 1.

Table 1: Mix Design Concrete

Quantities	Cement (kg)	Water (kg)	Fine Aggregates (kg)	Course Aggregates (kg)	Micro Steel Fiber (kg)
Per m^3	325	160	610	1300	860
0.001 m^3	0.325	0.160	0.610	1.306	0.86
0%MSF	0.325	0.160	0.610	1.306	0
0.5%MSF	0.325	0.160	0.610	1.306	0.004
1.0%MSF	0.325	0.160	0.610	1.306	0.009
1.5%MSF	0.325	0.160	0.610	1.306	0.013

2.3 Specimen and Test

In this research, a total of 24 specimens has been mixed using the fraction 0%, 0.5%, 1.0% and 1.5% of micro steel fiber as an addition based on the design mix calculation. The fresh concrete then went through the slump test to measure the fresh concrete workability. After that, the fresh concrete poured into a cube's mould (100× 100×100 mm) for hardening. According to BS 1881: Part 111: 1983, the specimens went through curing period of 7 and 28 days in the water tank. The temperature of the water in the tank was 26 to 29°C. After the curing period finished, the concrete has been test using ultrasonic pulse velocity to get the velocity value of every specimens. Lastly, all of the specimens went through the compressive strength and the result has been obtained.

3. Results and Discussion

The outcomes of the 24 laboratory specimens were discussed and the comparison of the results offered in the form of tables and graphs.

3.1 Slump Test

The slump value that varies according to the fraction of MSF percentage in the concrete mixture. The required slump test estimate based on the calculations in the DoE method is in the range of 10 mm - 30 mm. The slump value obtained in this study is within this ranged. In addition, the values obtained show that when the friction MSF percentage used in the mixture increases, the workability of concrete based

on the decrease in slump value also increases. Based on previous studies, [7] also have identified that workability decreases as the MSF fraction increases. Table 2 show the slump test value and Figure 2 show the graph of workability of the mixture.

Table 2: Slump Test Value

Micro Steel Fiber Percentage (%)	Slump Value (mm)
0%MSF	30
0.5%MSF	26
1.0%MSF	15
1.5%MSF	11

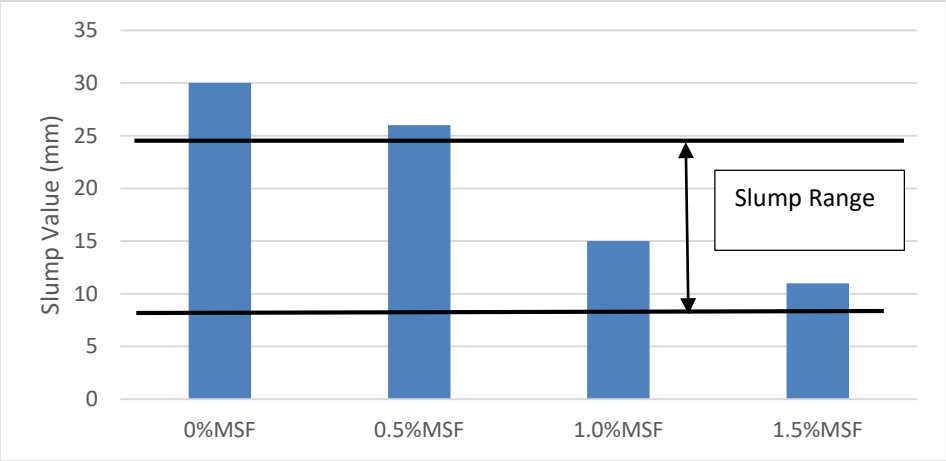

Figure 2: Slump Test Value

3.2 Ultrasonic Pulse Velocity test

The velocity obtained in a direct transmission UPV test on concrete specimens with MSF fiber at 7 days increase 8.28%, 6.25% and 10.22% for the specimen containing 0.5%, 1.0% and 1.5% respectively compare to control specimen. Apart from that, the velocity obtained in a direct transmission UPV test on concrete specimens with MSF fiber at 28 days increase 3.43%, 2.58% and 4.18% for the specimen containing 0.5%, 1.0% and 1.5% respectively compare to control specimen.

Table 3: Different between UPV test at 7 days and 28 Days

Micro Steel Fiber Percentage (%)	Ultrasonic Pulse Velocity (m/s)	
	7 Days	28 Days
0%MSF	3777	3993
0.5%MSF	4090	4130
1.0%MSF	4013	4096
1.5%MSF	4163	4168

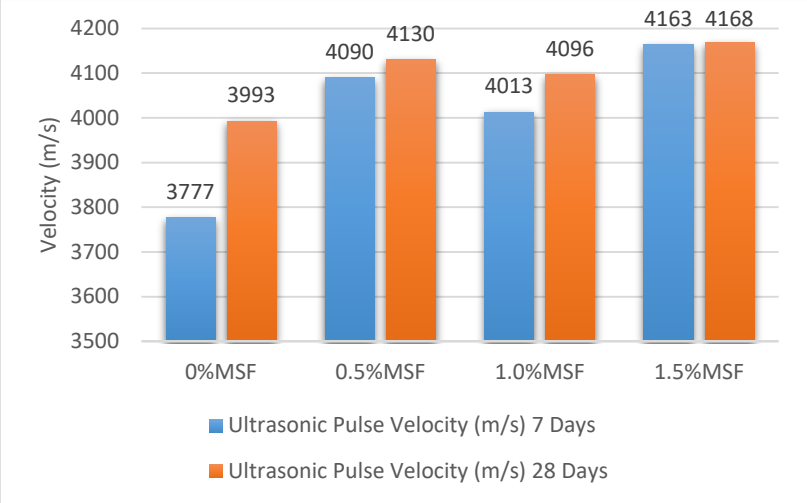

Figure 3: Ultrasonic Pulse Velocity Test Result at 7 Days and 28 Days

Based on Figure 3, it can be declare that all of the results of the ultrasonic pulse velocity test at 28 days are huge than result of ultrasonic pulse velocity at 7 days. Generally, the gradient of the graph started to increase from 0%MSF until 0.5%MSF for both values of UPV at 28 and 7 days. Then, the gradient apparently start to decrease from 0.5%MSF to 1.0%MSF and it increased back for 1.5%MSF. Therefore, the specimens containing 1.5% micro steel fiber had the maximum velocity value, according to the results.

3.3 Compressive Strength Test

The compressive strength of each cube has been determined using the ASTM technique. The total of 24 micro steel fiber concrete specimens were examined.

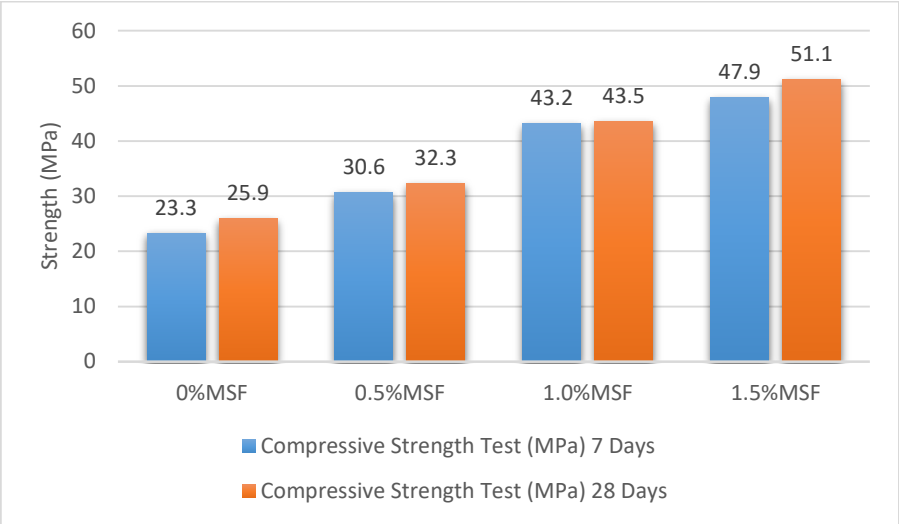

Figure 4: Compressive Strength of Micro Steel Fiber Concrete at 7 and 28 Days

According to Figure 4, it can be observed that the compressive strength of both specimens at 7 days and 28 days were slightly increase from 0%MSF until 1.5%MSF. For the compressive strength of the specimens at 7 days, the result increased by 7.3 MPa, 12.6 MPa and 4.7 MPa for specimens containing 0.5%, 1.0% and 1.5% of micro steel fiber, respectively. In other hand, the result of compressive strength for the specimens at 28 days increased by 6.4 MPa, 11.2 MPa and 7.6 MPa for

specimens containing 0.5%, 1.0% and 1.5% of micro steel fiber, respectively. Therefore, the specimens containing 1.5 % micro steel fiber exhibited the best compressive strength, according to the results.

3.4 Relationship between Compressive Strength and Ultrasonic Pulse Velocity

The relationship between compressive strength and ultrasonic pulse velocity shows encouraging results. It can be concluded that when the ultrasonic pulse velocity result produces high data, the compressive strength of the specimen also produces high data. Both results show a nice improvement in the graphs that have been formed.

. **Table 4: Relationship between UPV and Compressive Strength**

Relationship for Ultrasonic Pulse Velocity and Compressive Strength				
Sample of Concrete	7 Days Curing		28 Days Curing	
	Ultrasonic Pulse Velocity (m/s)	Compressive Strength (MPa)	Ultrasonic Pulse Velocity (m/s)	Compressive Strength (MPa)
0%MSF	3777	23.3	3993	25.9
0.5%MSF	4090	30.6	4130	32.3
1.0%MSF	4013	43.2	4096	43.5
1.5%MSF	4163	47.9	4168	51.1

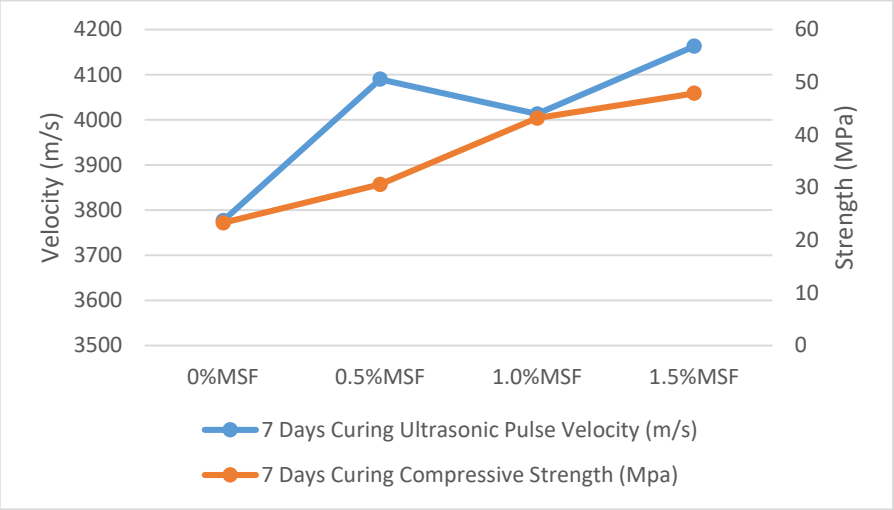

Figure 5: Relationship for Ultrasonic Pulse Velocity and Compressive Strength at 7 days

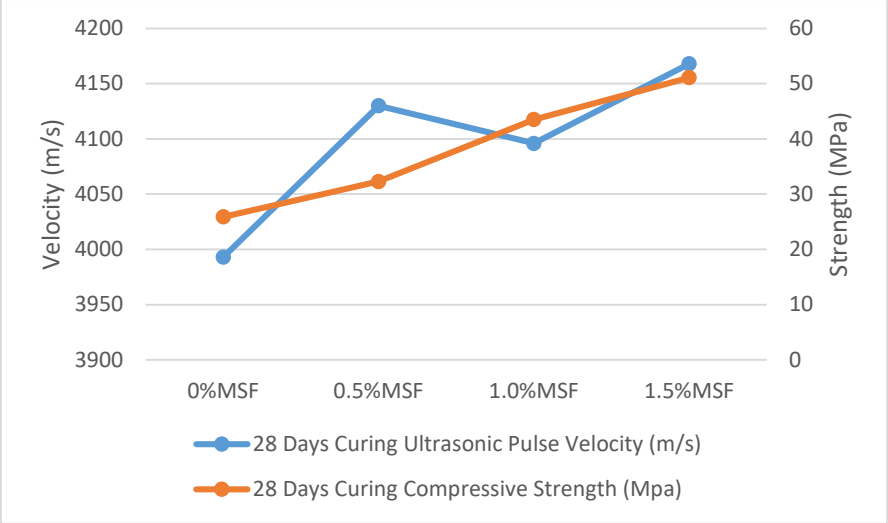

Figure 6: Relationship for Ultrasonic Pulse Velocity and Compressive Strength at 28 days

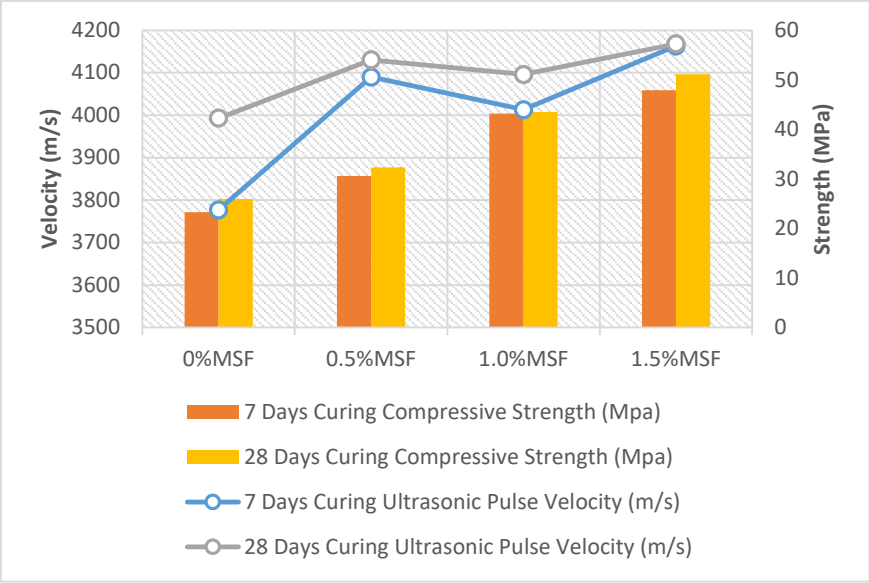

Figure 7: Comparison between Compressive Strength and Ultrasonic Pulse Velocity

Generally, the increases of micro steel fiber fraction in the concrete specimen have been increases the compressive strength of the specimen. Moreover, the addition of micro steel fiber tends to fill up the voids and decreases the risk of forming the critical deformation such as micro cracking in the concrete. The decrease of ultrasonic pulse velocity result at 1%MSF perhaps there was human error factor during concrete mixture procedure. Therefore, the optimum micro steel fiber fraction that can be used in the concrete mixture and increase the compressive strength as well as reduce the deformation in the concrete specimens is 1.5 % of micro steel fiber.

4. Conclusion

Based on the slump test, compressive strength test and ultrasonic pulse velocity test, it is possible to make the following conclusion:

i. The workability of the concrete has been increase when the percentage of micro steel fiber fraction in concrete decrease. The range of the slump value were from 10 mm to 30 mm.
ii. The highest velocity value achieved was concrete containing 1.5% micro steel fiber fraction where 4163 m/s and 4168 m/s for 7 days and 28 days, respectively.

iii. The compressive strength of the concrete increase when the percentage of micro steel fiber fraction in concrete increase. With 1.5 % of micro steel fiber content, the peak compressive strength of 7 days and 28 days specimens was 47.9 MPa and 51.1 MPa, respectively.
iv. Based on the relationship between the compressive strength test and ultrasonic pulse velocity test, when the ultrasonic pulse velocity result produces high data, the compressive strength of the specimen also produces high data.
v. The specimen with 1.5% micro steel fiber content and curing 28 days consider as optimum value because it have the best performance for both ultrasonic pulse velocity test and compressive strength test.

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References

[1] A. F. A. Manaf *et al.*, "Strength Capacity of Concrete Using Micro Steel Fiber: A Review," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1144, no. 1, p. 012023, 2021, doi: 10.1088/1757-899x/1144/1/012023.

[2] K. Ohno and M. Ohtsu, "Crack classification in concrete based on acoustic emission," *Constr. Build. Mater.*, vol. 24, no. 12, pp. 2339–2346, 2010, doi: 10.1016/j.conbuildmat.2010.05.004.

[3] E. Arunakanthi and J. D. C. Kumar, "Experimental studies on fiber reinforced Concrete (FRC)," *Int. J. Civ. Eng. Technol.*, vol. 7, no. 5, pp. 329–336, 2016, doi: 10.9790/9622-0705024044.

[4] S. Iqbal, A. Ali, K. Holschemacher, and T. A. Bier, "Effect of Change in Micro Steel Fiber Content on Properties of High Strength Steel Fiber Reinforced Lightweight Self-Compacting Concrete (HSLSCC)," *Procedia Eng.*, vol. 122, no. Orsdce, pp. 88–94, 2015, doi: 10.1016/j.proeng.2015.10.011.

[5] S. Shahidan and N. Muhammad Bunnori, *Structure Health Monitoring using Acoustic Emission*. Batu Pahat: Penerbit UTHM, 2017.

[6] T. R. Naik, V. M. Malhotra, and J. S. Popovics, *The Ultrasonic Pulse Velocity Method*. 2004.

[7] M. V. Mohod, "Performance of Steel Fiber Reinforced Concrete," *Int. J. Eng. Sci.*, vol. 1, no. 12, pp. 1–4, 2012.