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Effects of concrete ages and reinforcement at the measurement of ultrasonic pulse velocity (UPV)

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Abstract. Knowing the compressive strength of a reinforced concrete structure that has been casted can use non-destructive test that is Ultrasonic Pulse Velocity (UPV). Where the wave propagation velocity will be the main variable on the equation in estimating the value of compressive strength. UPV wave velocity is strongly influenced by the density of the object under test. Research to get compressive strength of a reinforced concrete structure with UPV measurement has been done. The study immediately found the value of concrete compressive strength without considering the effect of reinforcement. It is also based on the fact that concrete and reinforcing steel are different characteristics. Therefore, this research was conducted to determine the effect of concrete age and reinforcement on ultrasonic wave propagation velocity on UPV testing. The ultrasonic wave velocity in UPV test with concrete test object should be performed after the concrete is 28 days or in dry conditions. The reinforcement sequence within the reinforced concrete structure do not have a significant effect on the ultrasonic wave velocity.

1. Introduction

Knowing the compressive strength of concrete in a reinforced concrete structure can be done by Ultrasonic Pulse Velocity (UPV) test. The data obtained from this UPV test is the wave propagation velocity by determining the distance of the transducer and the travel time. The velocity of the wave is strongly influenced by the density of the object under test. The more dense objects are tested, the wave velocity will be higher. This speed data becomes the main variable in determining the value of compressive strength of reinforced concrete.

Concrete compressive strength research with UPV test has been done. Fajar Surya Herlambang conducted concrete compressive strength test on building structure for capacity improvement analysis using Hammer, UPV and Core drill test. The result obtained by compressive strength of 205.74 kg / cm2. Estimates of compressive strength of reinforced concrete structures were also performed on buildings with age above 25 years. This study aims to assess the feasibility of reinforced concrete structure in accordance with its current function. Measurement of compressive strength using the Hammer and UPV methods. The result is obtained by compressive strength of 152.24 kg / cm2 and there is a spread of compressive strength on the elements under test but the structure is still feasible according to its current function [1] [2]. The same is also done by L. Chandrakanthamma, et al who do concrete compressive strength test using Hammer, UPV and Core Drill. Tests are conducted on structural buildings that are damaged by earthquakes or other natural disasters. Test results obtained by compressive strength of 33.2 - 42.2 N / mm2. This happens because the damage suffered by the building is quite light [3]. Aswin S. Balwaik measured the age of the building with UPV. This is done because the concrete is made from a mixture of cement, aggregate and water that is strongly affected by the

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surrounding environmental conditions. The sample of this study is the structure that has been damaged and then retrofitted. Testing done before and after repair. The test results showed an increase in strength after the repair [4]. Jason Maximino C. Ongpeng conducted a study using UPV to find out the compressive strength of the concrete that was affected by the reinforcement. Where the reinforcement is rusted at 8 mm per year. The results showed that UPV can detect the occurrence of rust on the reinforcement. The sensitivity of UPV measurements especially when the transducer is placed between the two reinforcing bars. This also indicates the occurrence of cracks in the concrete around the reinforcement due to rust on the reinforcement. Concrete compressive strength results in a 20% decline in reinforced rust and down 15% in areas where there is no reinforcement [5].

The similarity of all previous studies of concrete compressive strength was obtained from the UPV test but in the study [1] [2] [3] [4] did not review the effect of reinforcement within the concrete that may affect ultrasonic wave velocity so that the compressive strength of the concrete is not compressive strength of pure concrete but already affected by reinforcement. In research [5] the influence of reinforcement has been taken into account but the reinforcement used is rusted and placed in the concrete not in the form of a sequence of reinforcement.

Based on these descriptions, it is necessary to conduct research to determine the influence of reinforcement in concrete against ultrasonic wave velocity measurement on UPV test. In this research, the reinforcement is placed in the concrete in the form of a series of reinforcement and in non-corrosive condition because concrete damage can occur before there is rust on the reinforcement. Given the concrete and steel reinforcement has different characteristics then, also reviewed the influence of concrete age on ultrasonic wave velocity.

2. Methodology

This research is experimental. This study compared the ultrasonic wave velocity on concrete without reinforcement with reinforced concrete. The velocity of the wave at the concrete without reinforcement is the comparator while the speed on the concrete with the reinforcement is the speed that is affected by the reinforcement. Another variation of this study is the age of concrete because the concrete hardened over time while the reinforcement is not. Thus it will be known the influence of concrete age and the influence of reinforcement on wave velocity.

The specimens in this research are concrete beams without reinforcement and with reinforcement. Dimensions of beam 150x150x600 mm. The reinforcement used is non-deformed and deform. The diameter of the reinforcement is 10 mm and the stirrup is 6 mm. The reinforcement sequence is shown in Figure 1 below.

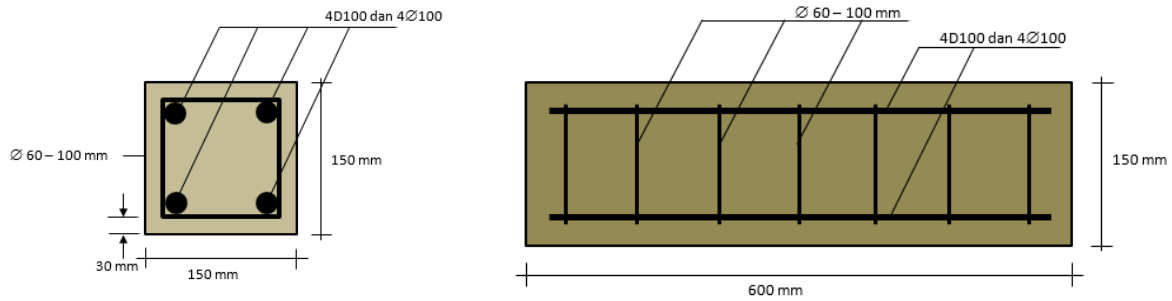

Figure 1. Plan of concrete beam

UPV test method used is direct as shown in Figure 2 below. UPV setting is to set the length of wave path (L), number of pulse and weight of concrete volume. Thus measured is the wave velocity from the transducer to the receiver.

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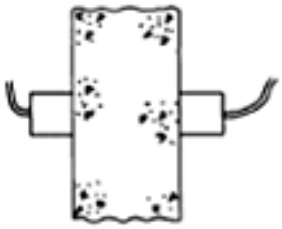

Figure 2. UPV direct method

3. Discussion

The research was started by designing the concrete mixture and the resulted concrete weight of volume 2245 kg / cm3 and the quality of f'c 30. The result of compressive strength test by press machine on the mixture design was obtained result of average 30.52 MPa. The sequence of reinforcing steel is shown in Figure. 3 whereas the preparation for pouring fresh concrete is shown in Figure 4. The sequence of reinforcement according to plan is in Fig. 1 above.

Figure 3. Reinforce sequence

Figure 4. Preparation of pouring fresh concrete

UPV test is done by setting the length of wave path is (L) 150 mm, weight of concrete volume is 2245 kg / cm3, and the number of pulse 5. Each beam is done 4 times UPV test. The tests were performed at 7, 14, 28, 42 and 56 day concrete ages.

Figure 5. UPV test with direct method

From the UPV test series the following results are obtained,

Table 1. Ultrasonic wave velocity on UPV test

Concrete Age	UPV Velocity (m/s)		
	With no bar	With deform bar	With undeform bar
7	3575.81	3624.53	3680.44
14	3662.48	3606.49	3688.73
28	3641.10	3695.65	3668.53
42	3759.93	3737.88	3734.27
56	3756.78	3514.20	3662.32

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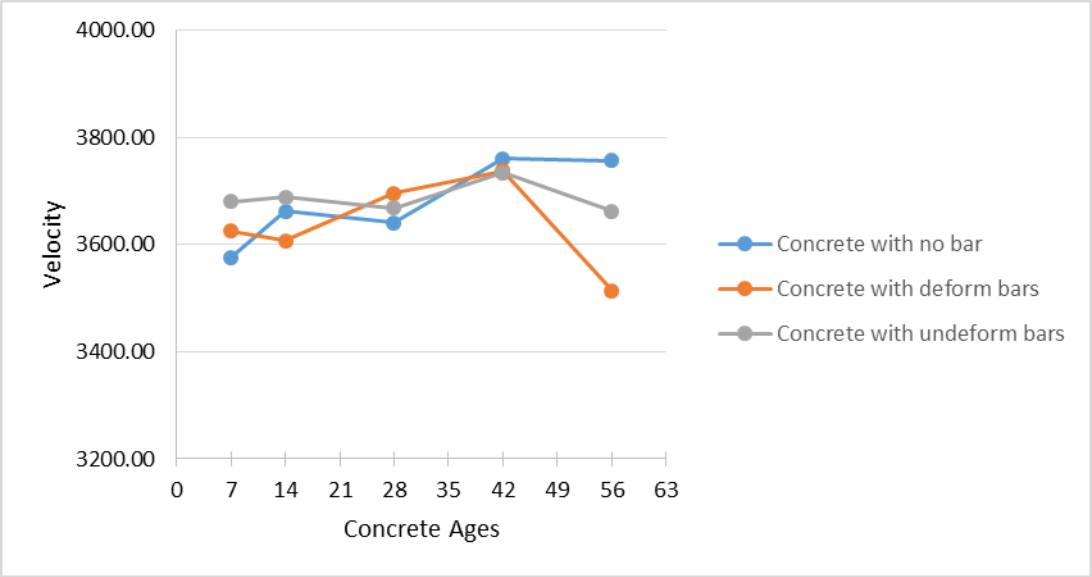

Figure 6. UPV velocity of the beam with ages and bar variation

From the test results shown in Table 1 and Figure 6 it can be seen that ultrasonic wave velocity in UPV test is always changing. Changes are not always faster sometimes slower. This, of course, is less suited to the concrete theory that concrete is getting stronger with age. The strength of concrete increases very quickly before 14 days and then slows down to tend to flat (Figure 7) [6].

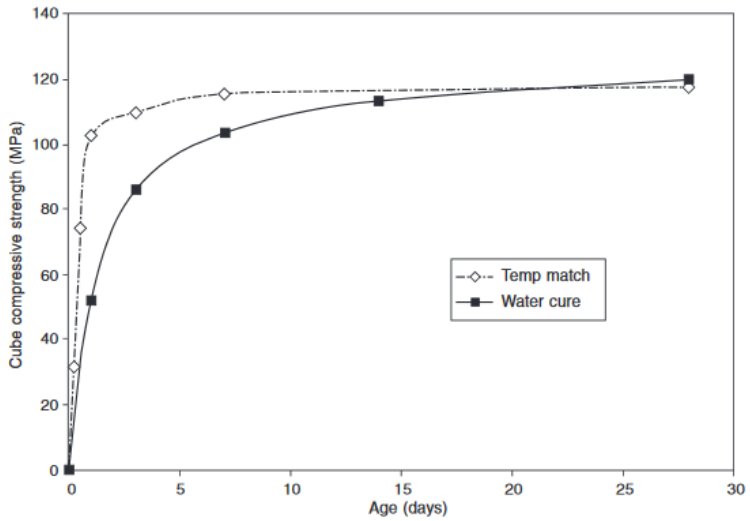

Figure 7. Strength development of a high strength concrete slab
(John Newman and Ban Seng Choo, 2003)

In the graph "concrete with no bar" it can be seen that the wave velocity has a corresponding trend of concrete theory, where the speed trend increases with age. This speed increase is quite large and can be said to be significant but tends to remain at age above 28 days ie 42 and 56.
In the "concrete with deform bars" graph, an increase in wave velocity also occurs and has a tendency to rise slowly. But on 56 days there are things that can not be explained yet because the sudden speed decreased very drastic.

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For the "concrete with undeform bars" graph, the relative speed increases are smaller than others. Fluctuations in speed tend to be small. At 56 days decreased speed as well as "concrete with deform bars".

According to the above conditions it can be seen that at the concrete age of less than 28 days the speed changes can not increase regularly. It is possible to estimate the influence of water that may still exist in the concrete and each specimen does not have the same evaporation rate. It is therefore advisable not to test UPV on concrete age less than 28 days. For the influence of reinforcement in concrete, wave velocity is almost the same for all test specimens and in general the presence of reinforcement within the concrete does not have a significant effect on the UPV test, in this case the age of 28 and 42 days. However, research is still needed in longer timeframes because UPV testing is often applied to existing and decades old structures.

Another thing that can be delivered on this occasion is that the UPV test must be done very carefully because the test equipment needs a fixed setting during the test and should always be adjusted if changing the test method. Included here is a calibration. When placing the transducer and receiver on the surface of the specimen it is necessary to note the consistency of measurement because very small motion makes the speed changeable. This makes it very difficult to determine the right and constant speed. This condition makes space for research to create a tool to hold the transducer and receiver so that it does not move.

4. Conclusion

The ultrasonic wave velocity in UPV test with concrete test object should be performed after the concrete is 28 days or in dry conditions. Because if the concrete is still contains water or wet, it is feared to affect ultrasonic wave velocity.

The reinforcement sequence within the reinforced concrete structure do not have a significant effect on the ultrasonic wave velocity. Thus the value of compressive strength obtained by UPV test can be directly used.

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