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The Effect of Mortar Mixture Variations on the Compressive Strength and Ultrasonic Pulse Velocity

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ABSTRACT

This paper examines the correlation between compressive strength, porosity, and ultrasonic pulse velocity (UPV) in mortar. The research was conducted at the Yogyakarta State University Building Materials Laboratory. The research was an experimental method; mortar was made with variations in the ratio of cement and fine aggregate 1:3;1:4;1:5;1:6, and 1:7 with a phase of 0,48—the manufacture of test objects in the form of a cube measuring 5x5x5 cm. Tests were carried out at 3, 7, 14, 21, and 28 days with three samples per test age. The data was processed by a quantitative descriptive method to determine the relationship between the variables, especially the relationship between ultrasonic pulse velocity and compressive strength, as well as its relationship with the porosity value. The results of compressive strength and ultrasonic pulse velocity are directly proportional to the age of the test. With the results of the compressive strength at 1:3, 1:4, 1:5, 1:6, and 1:7 variants, respectively, 31.12 MPa, 19.83 MPa, 12.25 MPa, 5.38 MPa, and 3.89 MPa and ultrasonic pulse velocity of 3827.67 m/s, 3641.7 m/s, 3561.3 m/s, 2019.0 m/s, and 1691.0 m/s. Then the porosity values are 11.12%, 12.88%, 16.36%, 17.60%, and 22.06%. The compressive strength has a correlation that is directly proportional to the logarithmic ultrasonic pulse velocity. The higher the value of the compressive strength, the higher the UPV value, and inversely proportional to the porosity value as well as the speed of the wave propagation, which is inversely proportional to the porosity value. The higher the porosity value, the lower the compressive strength value and the UPV value.

1. Introduction

Walls have a vital role as shaper building. Wall is a barrier space in a horizontal direction that separates rooms by function [1] . In Indonesia, many materials are used as Wall covers, brick, adobe, and brick light. Element masonry uses mortar as the adhesive; the Wall will usually be coated again with stucco, so those who also use mortar, mortar obtained from cement mix, aggregate smooth, and also water. Wall could experience damage if it does. Wall is not durable or fast damaged. Among other things is Wall wet, damp and mottled (mold). So, from that needed possible solution resolve frequent problems that happened to the Wall, for one with knowing the optimum ratio of mortar mix.

Besides the ratio mixture, mortar quality is also affected by the proportion of water to cement. The proportion of water to cement is significant, and for the cement to react, it only takes 25-30% of the water from the cement weight [2] . Generally, the mark water-cement factor (FAS) used in practice making regular concrete usually uses a cement water factor of at least 0.4 and a maximum of 0.65.

To know quality, elements in buildings must be tested with Destructive Test and Non-Destructive Test

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methods. Non-Destructive Test (NDT) is testing without damaging an object in a manner that contacts direct, testing with a method this capable of knowing the condition, quality, and durability of something object without ruining it mainly first. One Non-Destructive Test testing can be done with Ultrasonic Pulse Velocity (UPV). Ultrasonic Pulse Velocity (UPV) is a method of testing many Non-Destructive Tests used in inspection testing on project construction besides using the hammer test. Method UPV testing is frequently used to detect internal cracks and defects other, including changes in concrete like declining quality concrete consequence environment aggressive chemicals or freezing and thawing [3] [4] [5] .

Strong results press from concrete is significantly influenced by the constituent materials, several factors primarily influence compressive strength concrete that is character aggregate (stiffness, hardness and density), maximum diameter aggregate, gradation, water-cement factor, and quality artistry (mixing and compaction process is, good will produce concrete with minimal rate pores). [6]

Study this using five variations of different mixes reviewed from ratio mixture between cement and aggregate smooth. Five variants of the shared Become ratio, a mix of 1:3, 1:4, 1:5, 1:6, and 1:7. Tests performed include a robust test press and ultrasonic pulse velocity on age testing 3, 7, 14, 21, and 28 days as well as testing porosity and tensile split at 28 days..

Strong value mortar press obtained from magnitude style maximum unity working area on Portland cement mortar test specimens shaped cube with size and age-specific [7] Big potent calculated mortar press use formula implicit:

$$f'_c = \frac{P}{A} \quad (1)$$

Description :

f'_c = Compresive Strength (N/mm ^{2})

P = Load (N)

A = Area (mm^2)

Figure 1 . Strong test press

Testing compressive strength use UTM machine with capacity of 10 Ton (Figure 1). Specification or different types of mortar to 4 based on compressive strength it among them type M, S, N, and O [8] , specifications Mortar types are presented in Table 1.

Table 1 .Mortar Type [8]

No	Type	Compressive Strength (MPa)
1	M	17,2
2	S	12.5
3	N	5,2
4	O	2,4

UPV equipment is tool tester characteristic concrete nondestructive (NDT). Principle method work UPV tools deliver vibration longitudinal waves through fluid or some kind of gel already smeared on the surface concrete before test . later energy wave electricity generated by generators the sending transducer pulse (T) becomes energy wave next mechanic propagate on the concrete material after pass wave the displayed time travel in digital form. Then natural its use UPV equipment has 3 tests among them method indirect , semi direct , and direct [9] , as shown in Figure 2, Figure 3 and Figure 4 .

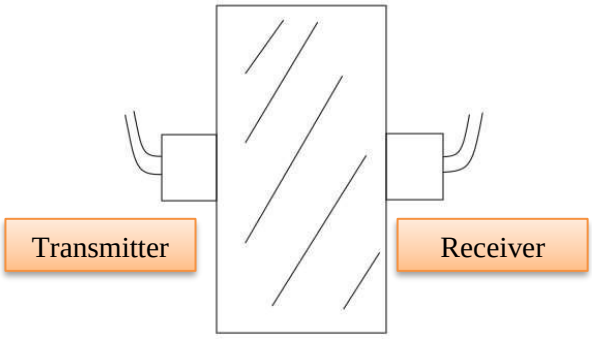

Figure 2 . Method *direct* [9]

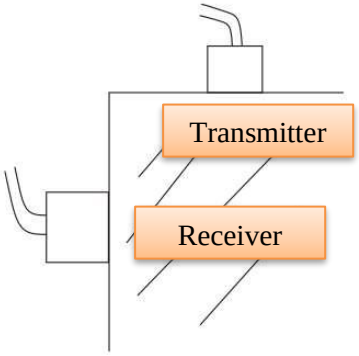

Figure 3 . Method *semi-direct* [9]

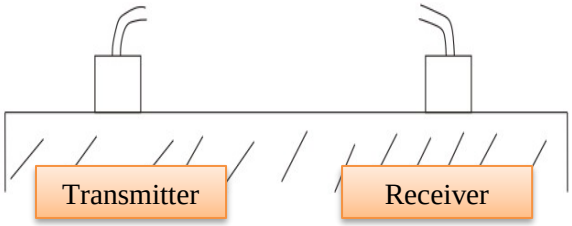

Figure 4 . Method *indirect* [9]

Beside that there is a number of influencing factors _ results UPV testing including temperature concrete , long trajectory , shape and size , influence reinforcement , and uniformity concrete . For measurement fast vines ultrasonic propagates through the concrete material could applied for knowing uniformity quality concrete , measure changes to concrete from age , search correlation Among wave ultrasonic and compressive strength concrete , and know the modulus of elasticity from concrete and change poison ratio in concrete materials [9] .

The test results obtained from speed wave as well as time propagation waves in the mortar test object media. Evaluation quality test object against results ultrasonic pulse velocity ultrasonic could see in Table 2. Meanwhile for look for speed ultrasonic waves can used formula as following :

$$V = L/T \quad (2)$$

Description :
V = Speed wave (m/s)
L = Distance (m)
T = Time (s)

Speed wave can display from based UPV test equipment time already traveled counted. So that speed wave could counted with formula [10] . Besides testing compressive strength and UPV testing in research, this also does testing porosity. Porosity is marked rate pores owned by mortar or concrete. The porosity value shows the total rate of pores in mortar and concrete and tests the porosity function to know how much water is adsorbed on the mortar. For calculation, mark porosity can use the formula equality following:

$$\text{Porosity} = \frac{\text{A-B}}{\text{B}} \text{ x } 100\% \quad (3)$$

Description :
A = weight wet / saturated (grams)
B = weight dry (grams)

Table 2. Evaluation Quality Concrete based on Pulse Velocity [9]

No	Pulse Velocity (m/s)	Evaluation Quality Concrete
1	>4500	Very Well
2	3500-4500	Well
3	3000-3500	Currently
4	3000-2000	Doubtful
5	<2000	Bad

2. Method

In research, this used approach method in a manner experiment laboratory. The aim is to investigate the connection because consequence Among one variable with another variable to gain something conclusion. Study this using a shaped mortar test piece cube with a size 5 cm x 5 cm x 5 cm and a cylinder size 10 cm x 20 cm, with five variations ratio different mixes between cement and aggregate smooth. Flow chart study presented in Figure 5.

Variation ratio the mixture is made among others, namely 1:3, 1:4, 1:5, 1:6, and 1:7. Test object that has been made will be soaked in a bucket of working water for care for mortar during wait age testing. After the mortar is done, enter-age testing on days 3, 7, 14, 21, and 28 days will do testing in a Non-Destructive Test with Ultrasonic Pulse Velocity (UPV) testing to measure ultrasonic pulse velocity [11] . After that, well did testing in a Destructive Test with, do testing compressive strength using a UTM machine [7]. Besides, it is also done testing porosity in mortar as well testing pull split for shaped mortar test piece cylinders tested at the age of 28 days.

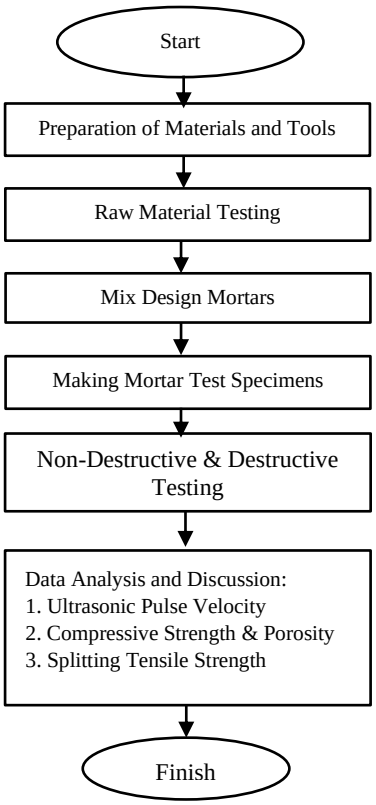

Figure 5 . Experimental Works Procedure

Figure 6. Mortar Mixer

Materials pre-mixed mortar has tested for know specifications contained in the material to be used in making test objects [7] . For necessary tools that is machine stirrer (Figure 6) is equipped mortar mixer capacity of 2500 cc. Mold shaped test object cube with long side 5 cm (Figure 7), mold cylinder diameter of 10 cm, as well tools supporters form digital scales, glasses measure, stopwatch, tool compactor, spoon average, term slide, basin, and bucket for immersion test object. Mortar test object that has been made will soaked until approach time testing at the age of 3, 7, 14, 21, and 28 days. Testing first thing to do is testing ultrasonic pulse velocity using UPV next done destructive testing.

Figure 7. Mortar Mold

3. Results and Discussion

Aggregate material testing and cement were analyzed later in the laboratory to get results such as water content, absorption, density, and another test. Aggregate material test results smooth and cement can be seen in Table 3 and Table 4.

Table 3. Test results aggregate fine

No	Type testing	Test results
1	Water content (%)	1.83 %
2	Organic content	Color 2
3	Sand content	1.08 %
4	Density	2.45
5	Absorption (%)	3.59 %
6	MKB	1,775
7	Fill weight	1.60 kg/ lt
8	Weight content congested	1.78 kg/ lt

Table 4 . Semen test results

No	Type testing	Test results
1	Density	2.62
2	Cement fineness	99.82%

Once material testing is used in making the test object, the calculation mix design for making the mortar test object is next. Mix design created based on mortar variant to be made. The calculation results mix design for mixture 1 m^3 can see in Table 5.

To know dose mix design for once mixed so need count Return results in mix design in Table 5 multiplied with the volume of the test object to be made and added safety factor by 20%

a. Mixing Measure (TM) = Volume of Test Object X Material
b. Dose Final (TA) = TM + 20 % TM
c. Example:
   TM Cement = 0.001875 x 491.1 = 0.920 kg

TA Cement = 0.920 + 0.184 = 1.104 kg

d. Mixing volume of cube test object = 0.001875 m^3

e. Mixing volume of cylinder test object = 0.001570 m^3

Table 5. Mix design Each Mortar Variant

Variant	Material Requirements for 1 m^3 (kg)		
	Water	Cement	Sand
1 :3	235.7	491,1	1473,2
1:4	192.7	401.5	1605.8
1:5	163.0	338.5	1697,5
1:6	141.2	294,1	1764.7
1:7	124.5	259,4	1816,0

Testing compressive strength concrete was performed at ages 3, 7, 14, 21, and 28. The total sample for compressive strength is as many as 15 samples, with three samples used _ for each testing compressive strength. Test results compressive strength can be seen in Table 6 as follows:

Table 6. Compressive Strength Testing

Variant	Compressive Strength (MPa)				
	3	7	14	21	28
1:3	7.96	16.39	26,18	31.61	31,12
1:4	6,44	14.58	19,71	18,42	19.83
1:5	3.68	8,48	9.58	10.77	12.25
1:6	2,19	3.79	4.52	5.70	5,38
1:7	1.73	2.67	2.79	2.72	3.89

Based on the results of table testing the results compressive strength that you always get experience increases with each increase in age testing. That could look at variants increased mortar testing each age testing from 3 days old until 28 days old. However, there are many variants of compressive strength. The average obtained rather occurs decline matter caused by one suspected sample not enough good or no equally When mixing matter, the make strong hit the average on some variant experience decline with age longer test.

Table 7. Test Results Ultrasonic Pulse Velocity

Variant	UPV Testing (m/s)				
	3	7	14	21	28
1:3	3318	3473	3473	3680	3827
1:4	3329	3473	3473	3597	3641
1:5	2256	3285	3561	3555	3561
1:6	1916	2036	2364	2476	2019
1:7	2253	1926	2089	1546	1691

Besides results, a compressive strength test was also carried out, testing ultrasonic pulse velocity with UPV and age testing as well, as the total sample was the same with trying compressive strength. Test results fast vines the waves in Table 7 are UPV testing with method direct because the results obtained have more accuracy good from method indirect and semi-direct. Following results testing ultrasonic pulse velocity:

Based on the results table testing, ultrasonic pulse velocity results in the 1:3 and 1:4 variants, respectively, consistently experience an increase until age 28-day testing. Whereas in the 1: 5 variants, it is a bit of experience decline with the age 21-day test; experience increases Back to testing next. And in the 1: 6 and 1: 7 variants decline enough significance from the results testing the highest variant on test 28 days old. Following is the chart correlation Among ultrasonic pulse velocity with compressive strength:

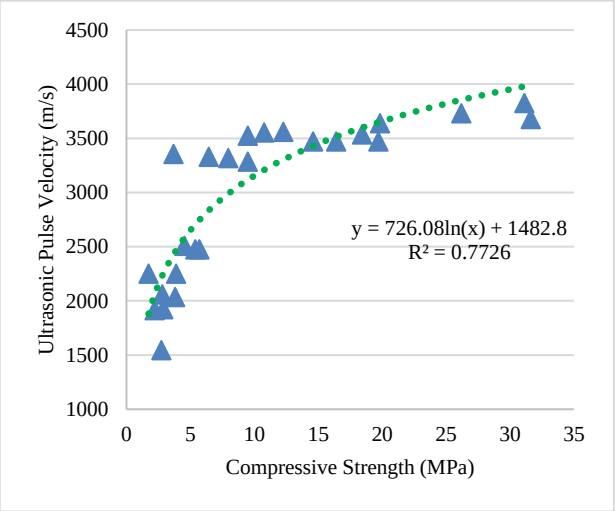

Figure 8. Graph Correlation Compressive Strength with Ultrasonic Pulse Velocity

Correlation results (Figure 8). show that mark ultrasonic pulse velocity has a connection compared straight in a manner logarithmic with compressive strength. The chart shows the tall mark compressive strength, so the more high-value fast vines, the wave. It _ caused the tall mortar density will cause the creeping media in the mortar to increase meeting so the more well, so fast vines the waves are also growing fast.

Testing split tensile strength done at age 28-day testing with shaped test object cylinder 10 cm in diameter and 20 cm high. Testing will be done with three samples the results will be average. Strong average test results pull split mortar can be seen in Table 8 as follows:

Table 8. Testing Spilt Tensile Strength

No	Variant	Split Tensile Strength (MPa)
1	1:3	1.79
2	1:4	1.37
3	1:5	0.70
4	1:6	0.64
5	1:7	0.42

Then next, the testing porosity test aims to know pores or rate air for each variant mortar tested. Testing was done with three samples shaped test object cube with dimensions 5 cm x 5 cm x 5 cm. testing was done by soaking the test object up to saturated (> 24 h), and the saturated test object next weighed heavy saturation, after the oven test object until actual water content already no there is or oven dry and then weighed the weight. Test results porosity can be seen in Table 9 as follows:

Table 9. Test Results Porosity

Variation	Weight Saturated Water (gr)	Weigh Oven Dry (gr)	Porosity (%)
1:3	264.5	238,1	11,12
1:4	262.4	232.5	12.88
1:5	259,1	222.7	16,36
1:6	260.3	221.4	17.60
1:7	249.8	204.7	22.06

Based on the results obtained from tester pull cleavage and porosity that has been done . There is possible correlation _ taken from test data these , follows results correlation Among testing porosity with testing other .

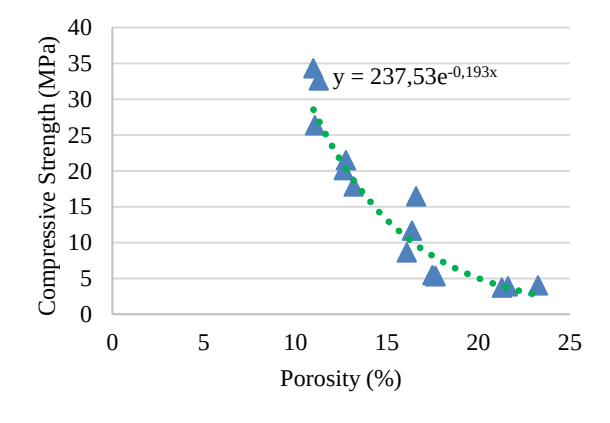

Figure 9. Graph Correlation Compressive Strength with Porosity

Correlation results (Figure 9). showing that mark porosity compared backwards in a manner *exponential* with mark compressive strength what you get. Chart the showing the taller mark porosity so will the lower mark compressive strength it. it caused because the more congested a mortar then will the taller strength in withhold burden.

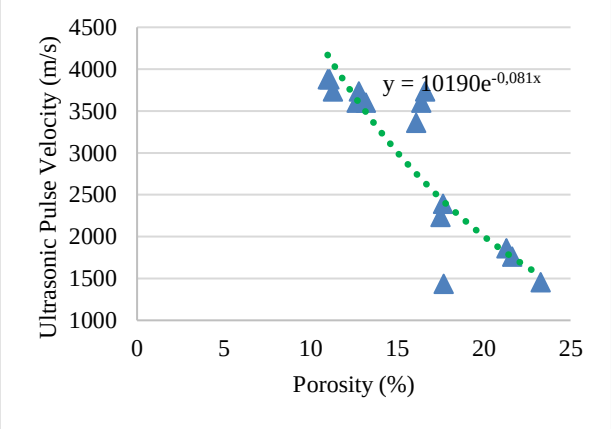

Figure 10. Chart Correlation UPV With Porosity

Correlation among mark ultrasonic pulse velocity (Figure 10) have connection compared backwards in a manner exponential with mark porosity. The chart on showing the tall mark porosity, so the more decreased ultrasonic pulse velocity. It caused mark high porosity to have density or smaller density, so the propagation medium, not both result results ultrasonic pulse velocity decreased

4. Conclusion

Strong value press and fast vines mortar wave vs straight with age the test, the longer the time testing, so mark results test obtained the higher and vice versa.

The porosity value of the mortar is proportional backwards in a manner exponential with mark compressive strength and ultrasonic pulse velocity. Based on the results, the ratio of a material mix with aggregate is more refined. Many have marked more porosity high.

The resulting press's strong value compared straight logarithmic with mark ultrasonic pulse velocity. The tall mark compressive strength, so the more valuable fast ultrasonic pulse velocity on mortar. Statement they could searching for with equality y = 726.08ln(x) + 1482.8.

Value ultrasonic pulse velocity vs backwards in a manner exponential with mark porosity. The tall the mark porosity so, the more decrease fast vines the resulting waves. The correlation could be represented with equation y = 10190e -0.081x. A high porosity value _ show much cavity air in a mortar, so cavities air in

inhibiting the ultrasonic pulse velocity and reduce accuracy results on UPV testing.

The substantial value resulting pressure is compared backwards in a manner exponential with mark porosity: the tall the mark porosity, the more substantial the resulting compressive decreases. Statement they could be searching for with equality y = 237.53e -0.193x. Porosity also matters in mortar density. The tall mark porosity density decreased, so the compressive strength follows decreased.

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