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The effect of ceramic shards waste material with the addition of variations of coconut fiber on compressive strength and UPV test in fiber concrete

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ABSTRACT

Waste of coconut fiber (coco fiber) and ceramic shards has the potential that has not been maximally utilized. Using waste as a building material for concrete, can contribute to environmental sustainability and make buildings that are environmentally friendly (green building concepts) and economical. The study aimed to determine the effect of compressive strength and UPV test values produced by waste by ceramic shards of 25% as a substitute for coarse aggregate and coconut fiber as added concrete with variations of 0%, 0.50%, 1.0%, and 1.50% and good variations of concrete. The research method obtained from the results of testing of coarse aggregate, fine aggregate, cement, water, ceramic waste, and coconut fibers are used to determine the calculation of the concrete mix design, then make concrete samples. Based on the test results, the highest compressive strength at the age of 28 days was found in the 4th variation concrete (1.50% with 25% ceramic shard) of 32.95 MPa. From the results of the UPV test, the average velocity of the concrete was 3.5-4.5 m/s. From the results of the study, it was found that the result of the larger test was the UPV test because it looked at the density (velocity). Based on two test methods, the results obtained are increasing the compressive strength of concrete. Variations in the addition of coconut fiber and ceramic shard waste, it has an impact on the quality of the concrete that can achieve the quality of the concrete and the density between the aggregates binds to each other.

ABSTRAK

Limbah serat sabut kelapa (*coco fiber*) dan pecahan keramik memiliki potensi yang belum maksimal digunakan. Dengan mempergunakan limbah sebagai material penyusun beton maka hal ini dapat berkontribusi terhadap kelestarian lingkungan dan menjadikan bangunan yang ramah lingkungan (*green building concept*) dan ekonomis. Penelitian bertujuan untuk mengetahui pengaruh nilai kuat tekan dan tes UPV yang dihasilkan limbah oleh pecahan keramik sebesar 25% sebagai substitusi agregat kasar dan serat sabut kelapa sebagai bahan tambah beton dengan variasi 0%, 0.50%, 1.0% serta 1.50% dan variasi beton yang baik. Metode penelitian yang diperoleh dari hasil pengujian agregat kasar, agregat halus, semen, air, limbah keramik, dan serat serabut kelapa digunakan untuk menentukan perhitungan mix design beton, kemudian dilakukan pembuatan sampel beton. Berdasarkan hasil pengujian hasil kuat tekan tertinggi pada umur 28 hari terdapat pada beton variasi ke-4 (1.50% dengan 25% pecahan keramik) sebesar 32.95 MPa. Dari hasil tes UPV didapatkan rata-rata hasil velocity beton 3.5-4.5 m/s. Dari Hasil penelitian didapatkan bahwa hasil pengujjian yang lebih besar yaitu tes UPV dikarenakan melihat dari kerapatan (velocity). Berdasarkan dua metode pengujian, didapatkan hasil meningkatkan kuat tekan beton. Dengan variasi penambahan serat serabut kelapa dan limbah pecahan keramik memberikan dampak kualitas mutu beton yang dapat mencapai mutu beton dan kerapatan antar agregatnya saling mengikat satu sama lain.

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1. Introduction

Every concrete construction plan is always determined by the quality of the concrete. Calculations are carried out based on the concrete quality that has been determined. Coco fiber has a tenacious characteristic that is able to absorb water and has durable properties if it is not directly related to the weather [1]. In terms of concrete, coco fiber has the property of absorbing water which is the weakness of the material properties, so it is necessary to consider the countermeasures by looking at the quality and condition of the material. However, the advantage of coco fiber has become the relevant choice considering the availability, low price, high specific strength, and lightweight. In this research for the compressive strength decreased the higher fiber content such as concrete containing 0.6% coco fiber is stronger than the concrete that contains 1.8% fiber [2], for the tensile strength has increased the two fibers [3]. However, the dose of coco fiber should be low, not exceeding 1.8% of binder volume, because of the weakness of its natural degradation. This research recommends that coco fiber should be under the treatment before being applied to concrete to protect it from degradation [4]. Looking at the potential of the waste coco fiber and ceramic shards that have not been utilized optimally, this waste has the advantage that it is used as an added fiber material in concrete mixtures. Especially as a fiber-added material and a substitute for coarse aggregate in manufacturing concrete. Using this waste as a concrete constituent material then can contribute to environmental sustainability and make buildings that are environmentally friendly (green building concept) such as residential and high–rise buildings.

Ceramic waste is the building materials that cannot be recycled anymore, because of that, the ceramic waste that has been used or defective at the manufacturing and marketing stages makes ceramic waste unusable and discarded, it is the same with the demolition of buildings, and the rest of the materials cannot be reused and must be discarded because if it is not removed, it will become solid waste which in quantity always increases with the number of building demolitions. According to research [5], based on the previous study, using the ceramic waste the highest compressive strength is achieved by concrete with 25% replacement from natural coarse aggregate with ceramic waste, meanwhile, the compressive tensile strength of concrete is lower when the percentage replacement of natural coarse aggregate by ceramic waste exceeds 30% [6]. Ceramic waste by 25% effects on the highest compressive and tensile strength, so this study used the ceramic waste by 25% for large aggregate substitution. Besides, the ceramic waste aggregate is determined to be finer in texture compared to ordinary crushed stone aggregates because the waste ceramic maintains appropriate characteristics that are used as a pozzolan material so it is suitable for use in the manufacture of concrete based on [7].

Based on the result of the study about the coco fiber that has been done, it can be concluded that the use of coco fiber can increase the tensile strength of concrete, but it caused the compressive strength decreases and this material absorbs water. Meanwhile, the waste of ceramic shards can increase the compressive strength. Therefore, a study was conducted on the effect of using the waste ceramic shards and the addition of coco fiber on the strength of fibrous concrete, the researchers are expected to produce an eco–friendly concrete that can be seen from the mixed composition so that it can be strong toward the compressive strength and can increase the effect of environmental pollution from coco fiber and ceramic shards. This study aims to determine the effect of compressive strength and UPV Test values produced by ceramic shard waste by 25% as a substitute for coarse aggregate and coconut fiber as a concrete added material with variations of 0%, 0.50%, 1.0%, and 1.50%, also a good variety of concrete.

2. Methodology

Looking at the potential of the waste coco fiber and the ceramic shards that have not been used optimally, meanwhile, this waste has the advantage that can be used as added material in the concrete mixture. Especially as a fiber-added material and as a substitute for coarse aggregate in the manufacture of concrete. Using waste as a building material for concrete, can contribute to environmental sustainability and make environmentally friendly buildings (green building concept) such as residential and high–rise buildings. It is also expected to produce economical concrete, to minimize the impact of environmental pollution caused by coco fiber and piles of ceramic shards.

2.1. Definition of Concrete

According to SNI 2847:2013 Concrete is a composition of Portland cement or other types of hydraulic cement, coarse aggregate (split), and fine aggregate (sand), and includes water, with added mixtures (admixture) [8]. Sorts of concrete are classified as heavy contents, divided into 3 types, namely normal concrete, heavy concrete, also lightweight concrete. Normal concrete has a density from 2200 kg/m^2 to 2500 kg/m^3 and heavy concrete is a type of concrete that has a density greater than 2500 kg/m^3. Meanwhile, the type of lightweight structural concrete is concrete that used lightweight aggregate in the form of coarse sand or with light coarse aggregate and natural sand which is a substitute for fine lightweight aggregate with provisions not exceeding the maximum weight requirement of 1840 kg/m^3 and should be fulfilled the specified compressive strength and split tensile strength of lightweight concrete to achieve structural objectives [9].

2.2. Coconut Fiber (coco fiber)

Based on coco fiber is a fiber material that has a thickness of about 5 cm, and is the outmost layer of the coconut [10]. While part of a coconut consists of a mixture of 35% coco fiber, 12% of coconut shell, 28% of coconut flesh, and 25% of coconut water. Meanwhile part of coconut husk consists of 78% in the form of cell walls and 22.2% in the form of cavities. Besides, the fibers that can be extracted are 40% downy fibers and 60% mattress fibers.

2.3. Ceramic Shards Waste

Ceramic waste is a type of waste obtained from ceramic production and the repair work of a construction building. Ceramic materials are made of clay through the hardening method with a high-temperature combustion process [11]. The availability of the ceramic shards if it is not used properly will accumulate and be difficult to recycle. Ceramic waste is used with a diameter of 20-25 mm by passing a 25.4 mm sieve with a percentage of 25% by weight of gravel.

2.4. The Test Results of Compressive Strength of Concrete

It should be noted that the value of suat fc' or equal to the compressive strength of concrete by using a cylindrical test object if there is a value of K, so the result of compressive strength needs to be converted. The value of compressive strength of concrete can be obtained from testing by standard methods on cylindrical specimens. Meanwhile, the dimensions of the test object are 30 cm with a diameter of 15 cm. If the result of compressive strength of concrete with the test objects with different dimensions can convert the multiplier results that have been found in SNI 1974:2011 [12].

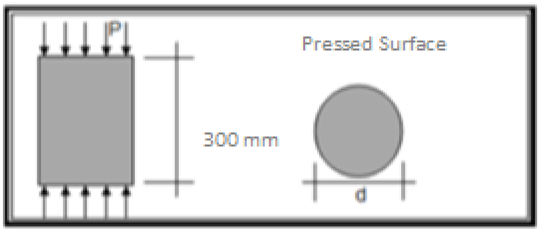

Figure 1. The example of compressive strength test for cylindrical concrete test objects

The equation to calculate the compressive strength of concrete as follow.

$$fc' = \frac{P}{A} \tag{1}$$

Description:

P : The maximum force on concrete press machine, (N)
A : Cross–sectional area of the test object, (mm²)
fc' : The result of compressive strength, (N/mm²)

2.5. UPV Test

Ultrasonic Pulse Velocity Test (UPVT) is to predict the value of the hardness of concrete by connecting the wave speed UPV of the medium used for the concrete sample with the result of the compressive strength of the concrete itself [13]. The travel time (T) required propagating the wave on the concrete path along (L) so it can be measured, so that the speed of the wave can be found by the formula below [14].

$$V = \frac{L}{T} \tag{2}$$

Description:

V : Ultrasonic wave speed (m/s)
L : Traversed concrete track (m)
T : Ultrasonic wave travel time along the path(s)

Standard used to measure the velocity to compressive strength namely ASTMC597-09 Standard Test Method for Pulse Velocity through Concrete and ACI 318 Building Code Requirements for Structural Concrete [15]. The results of the velocity above will be correlated with the quality of the concrete based on the formula ASTMC597-09 [16].

$$V = \sqrt{\frac{E(1-\mu)}{\rho(1+\mu)(1-2\mu)}} \tag{2}$$

Description:

E : Dynamic elastic modulus value (MPa)
ρ : Density of concrete (kg/m^3)
V : Ultrasonic wave speed value (m/s)
μ : Dynamic poisson ratio value (0.1-0.2)

Table 1. The concrete quality level through the UPV test [17].

Ultrasonic wave speed (km/s)	**Concrete quality**
>4.5	Excellent
3.5-4.4	Good
3.1-3.4	Fair
2.1-3.0	Poor
< 2.0	Very poor

This research used SNI 7656:2012 as a parameter in making concrete, meanwhile the material followed the National Standard such as coarse aggregate, fine aggregate, and cement [18].

2.6. The Place of Research and the Location of Material

This study was conducted in the Concrete Laboratory of Mercu Buana University and the source of material such as split type of crushed stone, the type of sand namely Bangka sand meanwhile the cement used is Portland type I that obtained from PT. Plant Pionir Beton Kamal.

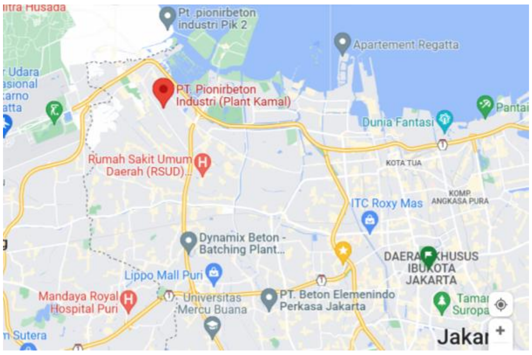

Figure 2. The maps of the place of the research and the location of the material.

2.7. Sample Testing

This research was conducted by making 40 test samples. The sample test data is presented in Table 2.

Table 2. Sample testing.

No	Sample testing	Testing			Total testing
		Compressive strength (sample testing)		UPV test (sample testing)	
		7 days	28 days	28 days	
1	Normal Concrete (NC)	3	3	2	8
2	Concrete 0.50 CF	3	3	2	8
3	Concrete 0.50 CF + 25%	3	3	2	8
4	Concrete 1.0 CF + 25%	3	3	2	8
5	Concrete 1.50 CF + 25%	3	3	2	8
	Total				**40**

Notes: NC = Normal Concrete, CF = Coconut Fiber (coco fiber), and CSW = Ceramic Shard Waste

Sample testing table carried out in this study were 40 pieces. For the sample testing that made by making a variety of mixtures in the form of coconut fiber (coco fiber) and ceramic shard waste. The testing used compressive strength test on 7 days and 28 days in each mixture varieties and UPV test on 28 days.

3. Finding and Discussion

3.1. Test Result of All the Concrete Variations

The following figure is the compressive strength of all variations of concrete in MPs units.

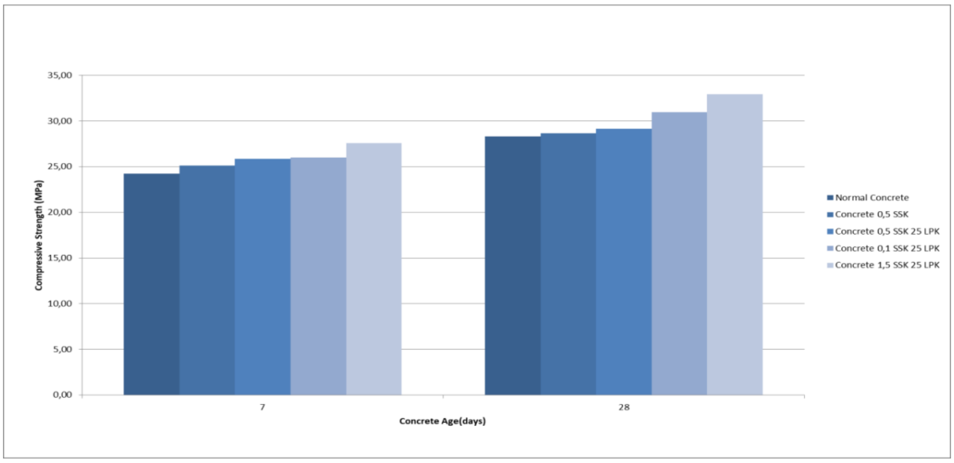

Figure 3. The results of graph concrete compressive strength in all variations.

Compressive strength of normal concrete plan and the composition of the mixture used is 20 MPa. The result obtained by adding the coco fiber and ceramic shards in this study have increased from the quality of the plan. For comparison of the increase in compressive strength of concrete, showed in Table 2.

Table 2. Increased compressive strength of fiber concrete.

The variations of cocofiber	Ceramic variations	Compressive strength test	Increased percentage (%)
0%	0%	28.29	-
0.50%	0%	28.66	1.31
0.50%	25%	29.12	1.61
1.0%	25%	30.96	6.32
1.50%	25%	32.95	6.43

It could be seen from variation without mixture there is an increase of 1.31% by adding the coco fiber about 0.50% + 25% of ceramic variations. Meanwhile, the fixed coco fiber variation by 0.50% and the addition of 25% ceramic shard waste has increased slightly due to the nature of the ceramic that replaces gravel and the various granular shapes. For variations of 1.0% coco fibers and 25% ceramic variations, there was a considerable increase because of the nature of coco fiber that can bind cement paste. From the results of the increase in the compressive strength of concrete obtained from this study, it can be concluded that by adding a variety of coco fibers, a fairly good increase was obtained due to the nature of the coco fibers that fill the pores of the concrete and increase the bonding value of the cement binding capacity to produce a high strength maximum. The results obtained for maximum results are variations in coco fiber of 1.50% + 25% Ceramic Shard Waste with a compressive strength value of 32.95 MPa.

Figure 4 describes the compressive strength test with ceramic composition according to previous studies and the results of this study. The results obtained from this study are quite good because they still exceed the planned quality limit of the concrete plan, which is 20 MPa. It should be understood that the substitute for coarse aggregate, namely gravel with ceramic shards, can provide an increase in compressive strength and environmentally friendly concrete and reduce costs more economically.

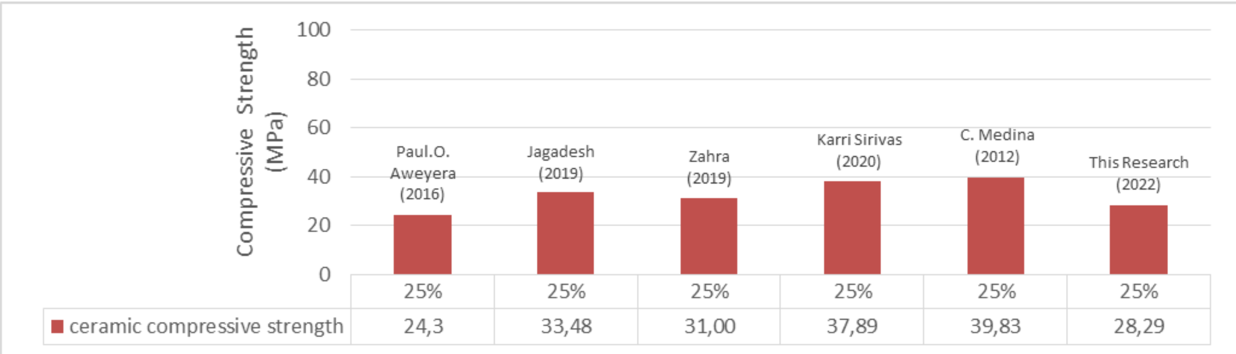

Figure 4. Graph of compressive strength testing of concrete with ceramics in previous study (1).

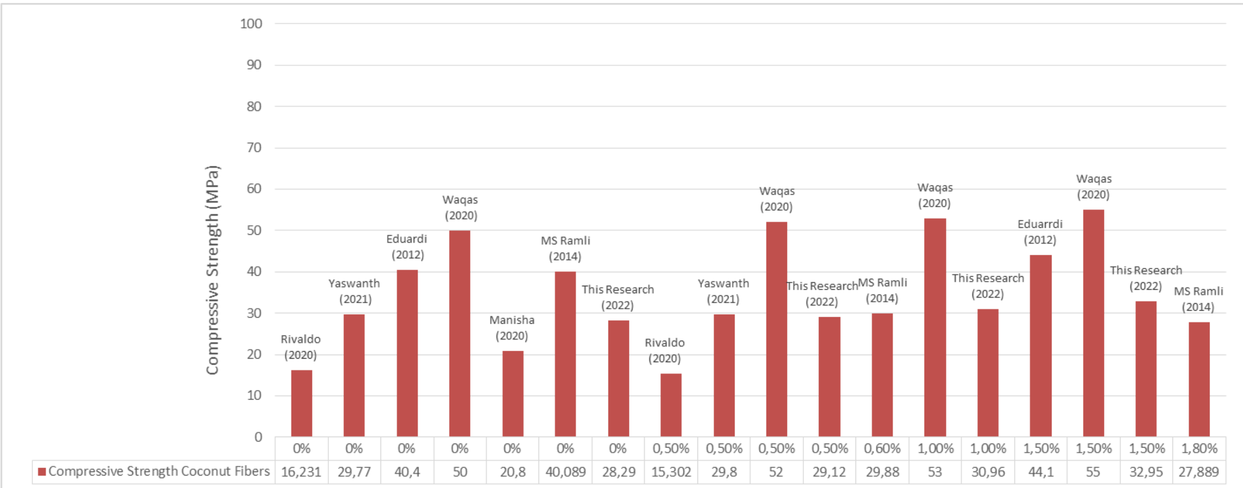

Figure 5. Graph of compressive strength testing of concrete with ceramics in previous study (2).

In Figure 3, it can be seen that the highest compressive strength at the age of 28 days is found in the 4th variation concrete (1.5% with 25% ceramic shard with a compressive strength value of 32.95 MPa). The lowest compressive strength results are found in normal concrete with a compressive strength value of 28.29 MPa. Figures 4 and 5 show the composition of the coconut coir mixture with a mixture of ceramic shards in previous studies and this research is combined with the planned research materials. From research on [19], the nature of ceramic aggregates causes refinement of concrete pores by increasing the volume of capillary pores and reducing macro pores. The more coco fibers increase the compressive strength of concrete this is due to the role of fiber as a barrier to creeping cracks and ceramics which can fill the gaps of the mixture so that the pore volume of the concrete becomes small. According to [20], if the fiber length exceeds 5 cm, it will cause the accumulation of fibers in the mixture of other concrete materials resulting in poor concrete. So in this study, using fibers with a length of 3-5 cm to maintain the strength of the concrete. Things that affect this test are the shape of the uniformity and relative quality of concrete, indicating the presence of voids or cracks, and to evaluate the effectiveness of crack repair and determining changes in concrete properties, and structural surveys, to estimate the extent of damage or cracks, to obtain changes in the condition of the concrete due time to time for the test to be repeated at the same position.

3.2. Scan Concrete Test (UPV Test- Ultrasonic Pulse Velocity Test)

The following table was the result of scan concrete (UPV-Test).

Table 3. Result of UPV test.

Velocity (m/s)	Quality of concrete	ID	No.Test	Concrete age	Average	
					Velocity (m/s)	Quality of concrete
4533	Excellent	Mercu-Yolanda-BN6-1				
4304	Good	Mercu-Yolanda-BN6-2	U-1	28 Days	4433	Good
4462	Good	Mercu- Yolanda-BN6-3				
4224	Good	Mercu-Yolanda-BS 0.50- no.3-1				
4300	Good	Mercu-Yolanda-BS 0.50-no. 3-2	U-2	28 Days	4275	Good
4300	Good	Mercu-Yolanda-BS 0.50-no.3-3				
4547	Excellent	Mercu-Yolanda-BS 0.50 LPK 25 – no..3-1				
4360	Good	Mercu-Yolanda-BS 0.50 LPK 25- no.3-2	U-3	28 Days	4491	Good
4547	Excellent	Mercu-Yolanda-BS 0.50 LPK 25- no.3-3				
4115	Good	Mercu-Yolanda-BS 1.0 LPK 25- no.3-1				
4127	Good	Mercu-Yolanda-BS 1.0 LPK 25- no.3-2	U-4	28 Days	4136	Good
4167	Good	Mercu-Yolanda-BS 1.0 LPK 25- no.3-3				
4098	Good	Mercu-Yolanda-BS 1.50 LPK 25- no.1-1				
4170	Good	Mercu-Yolanda-BS 1.50 LPK 25- no.1-2	U-5	28 Days	4089	Good
4000	Good	Mercu-Yolanda-BS 1.50 LPK 25- no.1-3				
4065	Good	Mercu-Yolanda-BS 1.50 LPK 25- no.6-1				
4071	Good	Mercu-Yolanda-BS 1.50 LPK 25- no.6-2	U-6	28 Days	4105	Good
4176	Good	Mercu-Yolanda-BS 1.50 LPK 25- no.6-3				
4208	Good	Mercu-Yolanda-BS 0.50 LPK 25- no.7-1				
4231	Good	Mercu-Yolanda-BS 0.50 LPK 25- no.7-2	U-7	28 Days	4233	Good
4231	Good	Mercu-Yolanda-BS 1.0 LPK 25- no.7-3				
4231	Good	Mercu-Yolanda-BS 1.0 LPK 25- no.1-1				
4132	Good	Mercu-Yolanda-BS 1.0 LPK 25- no.1-2	U-8	28 Days	4214	Good
4280	Good	Mercu-Yolanda-BS 1.0 LPK 25- no.1-3				
4354	Good	Mercu-Yolanda-BS 0.50 LPK 25- no.2-1				
4243	Good	Mercu-Yolanda-BS 0.50 LPK 25- no.2-2	U-9	28 Days	4253	Good
4161	Good	Mercu-Yolanda-BS 0.50 LPK 25- no.2-3				
4267	Good	Mercu-Yolanda-BN-No.8-1				
4260	Good	Mercu-Yolanda-BN-No.8-2	U-10	28 Days	4276	Good
4280	Good	Mercu-Yolanda-BN-No.8-3				

Table 4. Result of UPV test (Concrete strength)

Velocity (m/s)	Quality of concrete	Compressive strength	ID	No. Test	Concrete age	Average	
						kg/cm^2	MPa Cylinder
4533	Excellent	455.2	Mercu-Yolanda-BN6-1				
4304	Good	418.7	Mercu-Yolanda-BN6-2	U-1	28 Days	439	36.5
4462	Good	443.7	Mercu- Yolanda-BN6-3				

Velocity (m/s)	Quality of concrete	Compressive strength	ID	No. Test	Concrete age	Average	
						kg/cm^2	MPa Cylinder
4224	Good	406.4	Mercu-Yolanda-BS 0.50- no.3-1	U-2	28 Days	434	34.4
4300	Good	418.1	Mercu-Yolanda-BS 0.50-no. 3-2				
4300	Good	418.1	Mercu-Yolanda-BS 0.50-no.3-3				
4547	Excellent	457.5	Mercu-Yolanda-BS 0.50 LPK 25 – no.3-1	U-3	28 Days	449	37.2
4360	Good	430.6	Mercu-Yolanda-BS 0.50 LPK 25- no.3-2				
4547	Excellent	457.5	Mercu-Yolanda-BS 0.50 LPK 25- no.3-3				
4115	Good	390.0	Mercu-Yolanda-BS 1.0 LPK 25- no.3-1	U-4	28 Days	393	32.6
4127	Good	391.8	Mercu-Yolanda-BS 1.0 LPK 25- no.3-2				
4167	Good	397.8	Mercu-Yolanda-BS 1.0 LPK 25- no.3-3				
4098	Good	367.5	Mercu-Yolanda-BS 1.50 LPK 25- no.1-1	U-5	28 Days	386	33.1
4170	Good	398.3	Mercu-Yolanda-BS 1.50 LPK 25- no.1-2				
4000	Good	373.2	Mercu-Yolanda-BS 1.50 LPK 25- no.1-3				
4065	Good	382.7	Mercu-Yolanda-BS 1.50 LPK 25- no.6-1	U-6	28 Days	389	32.3
4071	Good	383.5	Mercu-Yolanda-BS 1.50 LPK 25- no.6-2				
4176	Good	399.5	Mercu-Yolanda-BS 1.50 LPK 25- no.6-3				
4208	Good	404.0	Mercu-Yolanda-BS 0.50 LPK 25- no.7-1	U-7	28 Days	406	33.7
4231	Good	407.5	Mercu-Yolanda-BS 0.50 LPK 25- no.7-2				
4231	Good	392.6	Mercu-Yolanda-BS 1.0 LPK 25- no.7-3				
4231	Good	415.0	Mercu-Yolanda-BS 1.0 LPK 25- no.1-1	U-8	28 Days	405	33.6
4132	Good	426.5	Mercu-Yolanda-BS 1.0 LPK 25- no.1-2				
4280	Good	409.3	Mercu-Yolanda-BS 1.0 LPK 25- no.1-3				
4354	Good	396.9	Mercu-Yolanda-BS 0.50 LPK 25- no.2-1	U-9	28 Days	411	34.1
4243	Good	413.0	Mercu-Yolanda-BS 0.50 LPK 25- no.2-2				
4161	Good	415.0	Mercu-Yolanda-BS 0.50 LPK 25- no.2-3				
4267	Good	413.0	Mercu-Yolanda-BN-No.8-1	U-10	28 Days	414	34.4
4260	Good	413.0	Mercu-Yolanda-BN-No.8-2				
4280	Good	413.0	Mercu-Yolanda-BN-No.8-3				

Things that affect this test are the shape of the uniformity and relative quality of concrete, indicating the presence of voids or cracks, and to evaluate the effectiveness of crack repair and determining changes in concrete properties, and structural surveys, to estimate the extent of damage or cracks, to obtain changes in the condition of the concrete due time to time for the test to be repeated at the same position. Things that affect the saturation level of concrete can affect the ultrasonic speed and are one of the factors that must be considered when assessing test results. Velocity speed in the form of saturated concrete does not respond to changes in relative quality. The received signal strength is also affected by the length of the travel path and by the presence and degree of cracking or deterioration in the concrete being tested.

The study conducted for the results of the UPV test with results showing the level of concrete density is in the poor grouping, which propagates around 2.40 km/s, so it can be categorized as excellent, which results in 4.60 km/s [21]. According [22], the test results are categorized as good with a propagation value of 4.35 km/s to the excellent category of 4.93 km/s. According to research, the results obtained are in poor quality concrete with an ultrasonic pulse velocity value of 2.4 m/s to a fair concrete quality value of 3.58 km/s [23]. The category of good concrete quality according to Table 4 is 51 km/s can be accurate if an evaluation is used to show the uniformity of concrete quality [24]. While the results obtained from this study were 4.08 km/s which showed the level of concrete density was in the good category to the excellent category with a propagation result of 4.533 km/s. So that it can be categorized from the quality of the concrete that is feasible. Based on this result, it can be concluded that the higher the value of the compressive strength, the higher the value of the velocity of wave propagation which affects the weight of the mass of the test object which affects the value of the velocity of wave propagation and the higher of compressive strength.

4. Conclusion

Based on the test, it can be concluded such as:

1. The highest compressive strength at the age of 28 days were in the concrete variation 4 (1.50% with 25% of ceramic shards with a compressive strength value of 32.95 MPa. The lowest compressive strength test were in normal concrete with a compressive strength value of 28.29 MPa.

2. The result of UPV Test was higher in normal concrete variations that are in excellent quality with 36.9 MPa concrete qualities with a velocity of 4.433 m/s. While the results of the lowest compressive strength in concrete variations of 1.50% with 25% ceramic shards with a compressive strength of 32.1 MPa.
3. It can be concluded that the maximum result from this study is the UPV Test because this test shows the uniformity value of the concrete quality from the density concrete level by using signal strength.

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