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Correlation of concrete by using small core diameter

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Abstract. One of the causes of limited sampling on concrete structures is that there is reinforcement in the concrete structure so that when using a large diameter drill core, can damage the concrete structure. Therefore, a study of small diameter concrete was conducted to predict the compressive strength of cylindrical concrete. Test specimens in the form of concrete cylinders with dimensions 10 cm x 20 cm, two concrete plates with dimension 45cm x 45cm x 13cm, and four concrete beams with dimensions 70 cm x 30 cm x 15 cm by taking concrete using a drill core diameter of 2" and 1". Two concrete slabs and two concrete beams with concrete strength (f'c) 20 MPa (MSA 20mm and 10mm) while two concrete slabs and two concrete beams with concrete strength (f'c) 30 MPA (MSA 20mm and 10mm). Types of tests carried out include testing the compressive strength of concrete, core concrete normality test, modulus of elasticity and compressive strength of the core concrete. From test results, can be concluded that the compressive strength of core concrete with sample in the direction of casting for a diameter of 2 inches and concrete strength of 20 MPa (MSA 20 mm and 10 mm) meets the requirements and can be recommended with number samples of 25, whereas for diameter 1" the number of samples must be added.

1. Introduction

Understanding of concrete according to ASTM C125-06a "Standard Terminology Relating to Concrete and Concrete Aggregates" is defined as a composite material with its main constituent in the form of aggregates shaped particles or fragments that are binding and attached [1]. The quality of concrete is influenced by many things, including by constituent materials, mix composition, workmanship, and maintenance. in ASTM C42-16 the "Standard Test Method for Obtaining and Testing Drilled Core and Sawed Beams of Concrete" set the standard size of core concrete Samples which are a minimum diameter of 4 inches (100 mm) [2].

Smaller diameter core concrete is often used because it is easier to work on, maintain and store, and is faster than standard sizes. Small-diameter core concrete also minimizes structural damage such as not cutting reinforcement in a structure with tight reinforcement and producing smaller holes for repairs. The problem that arises then is the compressive strength of small diameter core concrete having a large variation coefficient value so that it is rather difficult to determine the actual compressive strength value [3, 4, 5, 6].

Based on research conducted, the use of small diameter core concrete specimens on the test strength of structural elements is a technology that gives a little damage to the structure when sampling is carried out [7, 8]. However, the variation of the compressive strength test results of small diameter core concrete is large and difficult to evaluate precisely the compressive strength values [7,

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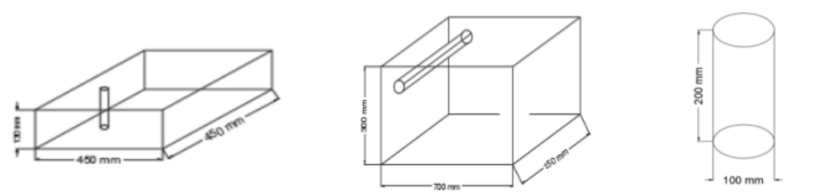
8]. The compressive strength of small-diameter cores tends to be greater if the volume of coarse aggregate from the specimen higher.

2. Materials and Methods

2.1. Research Sites
Sampling and making samples using core drilled tests were carried out at the Structure and Materials Laboratory of the Civil Engineering Department of Hasanuddin University.

2.2. Research Design
Test objects made in the Structure and Material Laboratory of the Department of Civil Engineering, Faculty of Engineering, Hasanuddin University are plate size 450 x 450 x 130 mm, beam size 700 x 300 x 150 mm and cylinder size 200 x 100 mm with 2 (two) quality different (fc 20 Mpa and f'c 30 Mpa) and 2 (two) coarse aggregates with the maximum size of aggregate (MSA) 10 mm and 20 mm. Figure 1 shows the test object design



slab sample
450 x 450 x 130 mm

beam sample
700 x 300 x 150 mm

cylindrical sample
200 x 100 mm

Figure 1. Test object design.

2.3. Experimental Method
Test specimens of core drills Ø2 "and Ø1" are obtained by core plates with a direction parallel to the casting direction and perpendicular to the direction of casting on the beam [1, 2]. Testing of compressive strength, normality test and modulus of elasticity was carried out to evaluate the compressive strength of core concrete by looking for correlation factors between core concrete and cylindrical concrete. Samples taken in the laboratory were divided into four variations: variation A (f'c 20 MPa and MSA 20 mm), Variation B (f'c 20 MPa and MSA 10 mm), Variation C (f'c 30 MPa and MSA 20 mm), Variation D (f'c 30 MPa and MSA 10 mm).

3. Research Result

3.1. Compressive Strength Test
The compressive strength of concrete is influenced by cement water factors, the nature, and type of aggregate, type of mixture, workability, concrete curing and age of concrete. The compressive strength of core concrete test objects is calculated using the formula:

$$fc' = \frac{P}{A} \qquad (1)$$

Where: f'c = compressive strength (MPa)
P = maximum test load indicated by the press test machine (N).
A = cross-sectional area of the test object (mm²).

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From the results of the average test, the compressive strength values of cylindrical concrete aged 28 days with the values in each variation are as follows: variation A 21.25 MPa, variation B 24.27 MPa, variation C 33.82 MPa variation D 34.67 MPa.

Table 1 shows of the results of compressive strength of concrete casting parallel alignment with a diameter of 2 inches and 1 inch are as follows for a 2-inch diameter variation A 22.18 MPa, variation B 26.98 MPa, variation C 31.70 MPa, variation D 33, 06 MPa while for 1 inch diameter variation A 20.06 MPa, variation B 24.00 MPa, variation C 27.15 MPa, variation D 28.61 MPa and the results of compressive strength of concrete sampling core perpendicular to the direction of casting with a diameter of 2 inches and 1 inch are as follows for a 2 inch diameter variation A 20.44 MPa, variation B 26.27 MPa, variation C 29.25 MPa, variation D 30.36 MPa while for a 1 inch diameter variation A 17.94 MPa, variation of B 23.94 MPa, variation C 24.92 MPa, variation D 27.70 MPa.

Table 1. Compressive strength of core concrete and cylindrical concrete.

Sample	Cylindrical Concrete (Mpa)	Concrete Core (Mpa)			
		Alignment of Casting Directions		Straight Upright Casting Direction	
		Ø 2 inci	Ø 1 inci	Ø 2 inci	Ø 1 inci
A	21.25	22.18	20.06	20.44	17.94
B	24.27	26.98	24.00	26.27	23.94
C	33.82	31.70	27.15	29.25	24.92
D	34.67	33.06	28.61	30.36	27.70

3.2. *Core Concrete Test*

Table 2 shows of the results of the core concrete test can be seen whether it can be sufficient or not the number of tests as many as 25 Samples in each variation to determine the value of compressive strength.

Table 2. Variable of core concrete test.

Sample	Concrete Core (Mpa)			
	Alignment of Casting Directions		Straight Upright Casting Direction	
	Ø 2 inci	Ø 1 inci	Ø 2 inci	Ø 1 inci
A	√	√	√	x
B	√	x	x	x
C	√	√	x	x
D	√	x	√	x

3.3. *Modulus of Elasticity Testing*

The concrete elasticity modulus, according to ASTM C469-02 is the stress-strain stress value inelastic condition, when the voltage becomes 40% of the compressive strength maximum. The testing of the modulus of elasticity aims to determine the concrete quality required by the elastic modulus of the concrete Sample at 28 days. The formula for modulus of elasticity is experimentally calculated by the formula:

$$E_C = \frac{S_2 - S_1}{\varepsilon_2 - 0{,}0005} \quad (2)$$

Where: Ec = Modulus of elasticity of concrete (MPa)
S1 = Voltage at longitudinal strain Ɛ1 = 0.00005 (MPa)

S2 = Voltage at 40% maximum load (MPa)
Ɛ2 = Longitudinal strain generated during S2

The formula for elastic modulus is theoretically calculated by the formula:

$$Ec = 4700 \sqrt{f'c} \quad (3)$$

Where: Ec = Modulus of elasticity of concrete (MPa)
f'c = Concrete compressive strength of 28 days (MPa)

The weight of concrete various from 1442 kg/m^3 to 2563 kg/m^3, calculated by the formula :

$$Ec = Wc\ 1{,}5\ \ 0{,}043\sqrt{f'c} \quad (4)$$

Where: Ec = Modulus of elasticity of concrete (MPa)
f'c = Concrete compressive strength of 28 days (MPa)
Wc = weight of concrete volume (kg/m^3)

Table 3 shows of the result of testing the modulus of elasticity is to see the experimental modulus of elasticity, whether it is smaller or larger than the modulus of elasticity theoretically in a way alignment of casting directions.

Table 3. Modulus of elasticity.

Sample	Alignment of Casting Directions			
	Ø 2 inch		Ø 1 inch	
	Theoretically	Experimentally	Theoretically	Experimentally
A	18,029.46	20,505.74	20,060.37	22,607.79
B	21,963.27	23,141.00	20,441.29	24,481.08
C	23,500.80	25,150.04	22,443.55	27,197.69
D	24,509.61	26,382.03	23,795.06	28,202.56

Table 4 shows of the result of testing the modulus of elasticity is to see the experimental modulus of elasticity, whether it is smaller or larger than the modulus of elasticity theoretically in a way straight upright casting direction.

Table 4. Modulus of elasticity.

Sample	Straight Upright Casting Direction			
	Ø 2 inch		Ø 1 inch	
	Theoretically	Experimentally	Theoretically	Experimentally
A	19,242.49	21,230.93	19,666.21	20,213.23
B	21,631.84	18,012.28	21,510.18	43,798.21
C	25,001.87	-	24,582.99	26,395.20
D	20,685.74	31,183.00	26,457.50	39,214.54

3.4. Core Concrete Compressive Strength Test

Evaluation of core concrete compressive strength is done by comparing the compressive strength between the core concrete with a diameter of 2 inches and 1 inch and a standard concrete diameter of 10 cm. ASTM C42-12 regulates the dimensions of core concrete section not less than twice the MSA while in BS-EN 12504-1: 2000, the ratio of MSA in concrete to the diameter of core concrete has a significant effect on compressive strength if the value is greater than 1: 3. Core concrete with smaller MSA has compressive strength, which is closer to the standard concrete compressive strength.

Table 5 shows the test results of the Core Concrete Press Strength Evaluation are to see the core concrete correlation factor against cylindrical concrete.

Table 5. Correlation factors of core concrete compressive strength.

Sample	Alignment of Casting Directions		Straight Upright Casting Direction	
	Ø 2 inch	Ø 1 inch	Ø 2 inch	Ø 1 inch
A	1.0364	1.1801	1.1013	1.3104
B	1.0205	1.1536	1.0815	1.1944
C	1.0364	1.1801	1.1013	1.3104
D	1.0205	1.1536	1.0815	1.1944

4. Discussion

For sampling perpendicularly or parallel to the casting director, it shows that the compressive strength of the core concrete is 1 inch in diameter smaller than the core concrete with a diameter of 2 inches. It shows that a 1-inch diameter core concrete requires a larger correction factor compared to 2-inch diameter core concrete.

For sampling perpendicularly or parallel to the casting director, it shows that the compressive strength of core concrete 1 inch and 2 inches in diameter for aggregate with MSA 20 mm is smaller than the core concrete 1 inch and 2 inches in diameter for aggregate with MSA 10 mm.

For sampling in parallel with the casting direction, shows that the compressive strength of the core concrete with a diameter of 2 inches for quality f'c 20 MPa is greater than the standard cylinder test Ø 10 cm while for core concrete 2 inches in diameter for f'c quality 30 MPa, core concrete with a diameter of 1 inch for quality f'c 20 MPa and f'c 30 MPa is smaller than the standard cylinder test Ø 10 cm.

For sampling in parallel with the casting direction, shows that the compressive strength of the core concrete with a diameter of 2 inches for quality f'c 20 MPa is greater than the standard cylinder test Ø 10 cm while for core concrete 2 inches in diameter for f'c quality 30 MPa, core concrete with a diameter of 1 inch for quality f'c 20 MPa and f'c 30 MPa is smaller than the standard cylinder test Ø 10 cm.

For upright sampling all direction of casting, shows that the compressive strength of core concrete with a diameter of 2 inches for f'c quality of 20 MPa (variation B) is greater than the standard cylinder test Ø 10 cm while for core concrete with a diameter of 2 inches for quality f'c 20 MPa (variation A), core concrete with a diameter of 2 inches for quality f'c 30 MPa, core concrete 1 inch diameter for quality f'c 20 MPa and f'c 30 MPa smaller than the standard cylinder test Ø 10 cm.

For sampling in parallel casting direction, shows that the correlation factor for 2-inch core concrete with 20 mm MSA is 1.0364, for 10 mm MSA is 1.0205, while the correlation factor for 1-inch core concrete with 20 mm MSA is 1, 1801, and for MSA 10 mm equal to 1.1536 to equate with the value of the 10 cm cylindrical concrete compressive strength for concrete quality between 20 MPa to 30 MPa.

For sampling perpendicular to the casting direction, shows that the correlation factor for 2-inch core concrete with MSA 20 mm is 1.1013, for MSA 10 mm is 1.0815, while the correlation factor for 1-inch core with MSA is 20 mm is 1 , 3104, and for MSA 10 mm in the amount of 1.1944, to equalize the value of the 10 cm cylindrical concrete compressive strength for concrete quality between 20 MPa to 30 MPa.

5. Conclusions and Recommendations

Based on the results of the evaluation of compressive strength, it can be concluded that the compressive strength of core concrete with sampling direction in the direction of casting for diameter 2 "and concrete quality f'c 20 MPa (MSA 20 mm and 10 mm) meet normal distribution requirements and are recommended with Sample number of 25, while for diameter 1 "need to add the number of Samples.

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