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New Job Mix Formula To Increase The Compressive Strength Of Concrete With Recycled Coarse Aggregate

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ABSTRACT

Concrete is a form of construction in the form of a composite material consisting of a mixture of fine aggregate, coarse aggregate, cement, and water. However, in certain cases, the concrete application is often a problem, especially the lack of a minimal amount of coarse aggregate material, increasing material prices. Recycled concrete aggregate (RCA) is an embodiment of concrete composed of recycled materials. Recycled material is obtained from fragments or remnants of the demolition of unused concrete. The method used to make concrete from the constituent materials using concrete waste as coarse aggregate per the rules of science is experimental. The tests are the aggregate moisture content test, the mud content test, the coarse aggregate abrasion test, the slump test, and the concrete compressive strength test at 28 days of treatment. The compressive strength results showed that the normal concrete sample could reach F_c' 18.53 MPa. The concrete sample using recycled coarse aggregate reached F_c' 23.79 MPa, so using recycled materials for manufacturing concrete can achieve the planned target.



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1. Introduction

Concrete is a form of construction in the form of a composite material consisting of a mixture of fine aggregate, coarse aggregate, cement, and water [1]. Concrete is one of the basic construction materials with high compressive, flexural, and tensile stress characteristics. Concrete is used as a building construction material for foundations, columns, beams, and building plates [2]. The problem that often occurs when applying concrete is the minimal amount of constituent material, which increases material prices [3]. The survey results concluded that the price of coarse aggregate material (coral) had increased every period. This encourages researchers to conduct experiments to modify the need for coarse aggregate using more environmentally friendly materials [4].

Recycled concrete aggregate (RCA) is a concrete embodiment composed of recycled materials [5]. Recycled material is obtained from new concrete fragments or remnants [6]. Coarse aggregate resulting from the demolition of concrete is expected to be able to be used as a material for making re-concrete. The readiness of the material must, of course, pass several tests to get the material's feasibility category [7]. The use of coarse aggregate from the demolition of unused concrete as a constituent material to manufacture re-concrete must be researched to achieve quality results using several modified methods.

The method used to make concrete from the constituent materials using concrete waste as coarse aggregate per the rules of science is experimental [8]. The tests include the aggregate moisture content test [9][10]. The next test is a mud content test [11]. Performing a coarse aggregate abrasion test to determine the percentage of wear on the coarse aggregate material [12]. After all the aggregates are declared feasible, the concrete mixture with a planned target of $F_c' 21.7$ MPa can be determined. Slump testing can be carried out in the concrete job mix process to determine the control of the new concrete mix calculation [13]. The final achievement is to test the compressive strength of concrete at 28 days of treatment [14]. From all the methods, recycled coarse aggregate is expected to be used constituent of concrete structures according to the planned target.

2. Research Method

This study used experimental methods with core topics discussing the feasibility of materials, job mix formulas, and compressive strength. The sample making of the test specimens carried out was normal concrete and concrete with modified aggregates in the form of the remaining demolition of concrete material with a planned target of $F_c 21.7$ MPa.

2.1 Material Feasibility

The material used in manufacturing concrete in this research is used in general, with a classification that will be reviewed in the following sub-chapter.

A. Coarse Aggregate

Coarse aggregate in concrete in the form of coral / crushed stone with the size used according to the plan is 20 mm. In general, coarse aggregate material fills the substitute for concrete specimens with as much as 60% of the total material used [15]. This study also plans to use the remaining unused concrete demolition as coarse aggregate material [16]. A sampling to obtain coarse aggregate is by crushing the remaining concrete from the compressive strength test in the concrete laboratory of Kadir University. The results of the destruction of the material are carried out by grading a 20 mm pass sieve as a modification of the coarse aggregate used.



Source: Practical documentation (2022).

Figure 1. Coarse Aggregate from Remaining Concrete.

Testing the feasibility of coarse aggregate carried out is by conducting a water content test, a mud content test, and an abrasion/wear test. Coarse aggregate moisture content testing is used to determine coarse aggregate's water absorption ability (absorption) as a waterproofing service of concrete specimens [17]. The absorption ability of coarse aggregate can also be used to determine the job mix formula for concrete [10]. The test carried out is to determine the water content factor contained in the coarse aggregate (concrete lumps). The required water content does not exceed 2% of the total weight of the test object.

Sludge content testing determines the percentage of sludge contained in coarse aggregate. The test carried out is by dissolving the coarse aggregate that has undergone a gradation process in a measuring cup so that the mud contained can be separated during the deposition process. The results of testing the content of coarse aggregate slurry can be carried out as a percentage. The full mud content required should not exceed 1% of the total number of test specimens.

Abrasion/wear testing is used to determine the loss of part of the volume on the surface of the coarse aggregate due to the frictional force caused by the loss Angeles abrasion machine [18]. The test was carried out by rotating the coarse aggregate and 12 steel balls for 500 rounds on an abrasive tool. The maximum required abrasion/wear value should not exceed 40% of the total number of test specimens.

B. Fine Aggregate

The fine aggregate used in manufacturing concrete is in the form of natural sand with granular form according to its designation [19]. This building material functions as a cementing medium that fills the gaps in the coarse aggregate arrangement. The sand passed the No. sieve gradation—10 in a dry state [20].



Source: Practical documentation (2022).

Figure 2. Fine Aggregate (Natural Sand).

The fine aggregate feasibility test is almost identical to the coarse aggregate material feasibility test. Still, the fine aggregate test does not carry out a wear test. The value of the criteria for water and mud content required for fine aggregate material doesn't exceed 5%.

C. Portland Cement

Cement is one of the mixed ingredients for making concrete which functions as an adhesive. Cement contains chemical substances such as calcium, silica, iron, and aluminum which are useful as adhesives between aggregates and concrete reinforcement [21]. The use of cement in this test is with a level of fineness that passes the No. 40 sieve in the form of type 1 portland cement with the trademark Semen Gresik.

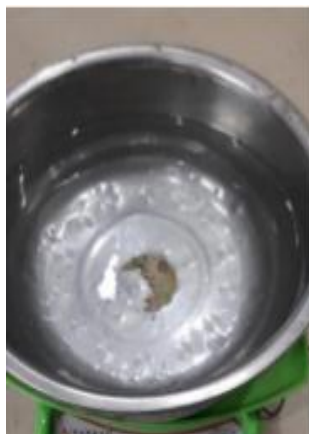


Source: Practical documentation (2022).

Figure 3. Portland Cement

D. Water

Water is one of the constituents of concrete that functions as a chemical reactor in other constituent materials and a lubricant for concrete mixtures to facilitate molding [21]. The water used is clean water taken from the Civil Engineering Laboratory of Kadirri University.



Source: Practical documentation (2022).

Figure 4. Water

2.2 Job Mix Formula

The job mix formula is a mixed plan used in manufacturing concrete test objects [13]. The concrete mix plant used in the following research follows the quality of the F_c' 21.7 MPa. Concrete is as many as three cylindrical specimens with a size of D 15 Cm Height 30 Cm. provided that the amount of material is as follows.

Table 1. Details of the Composition of Concrete Ingredients

Job Mix	Amount	Unit
Coarse Aggregate	19.820	gr
Fine Aggregate	13.200	gr
Portland Cement	7.178,5	gr
Water	3.700	gr

Source: Data Processing (2022).

Based on the calculation results of the table above, it can be seen that the value of a coarse aggregate is 19,820 gr. The total coarse aggregate is planned to modify the aggregate from the rest of the demolition of the concrete.

2.3 Slump Test

The slump test is carried out to analyze the mixture calculations that have been planned according to the job mix formula. The results of the slump calculation are used as quality control for the implementation of making concrete [22]. Measurement of yield stress and viscosity of self-compacting concrete can be known by measuring slump [23] [24]. The settlement value of the fresh concrete mixture in the slump test is planned at a line spacing of 7 cm to 14 cm.

2.4 Compressive Strength Test

The parameter value used to evaluate concrete is the compressive strength of concrete (Megapascal) [25]. The test is carried out by pressing the specimens that have undergone concrete treatment for 28 days [17].

3. Results and Discussion

The results and discussion presented include achievements in the water content test, mud content test, coarse aggregate abrasion test, slump test, and concrete compressive strength test during the 28-day treatment period of the test object. The following provisions can discuss the results.

3.1 Material Feasibility Test Results

In testing the feasibility of the material obtained, the results of the tested aggregate material's water content, mud content, and Abrassions.

A. Coarse Aggregate

The test results obtained in testing the feasibility of coarse aggregate are as follows.

Table 2. Coarse Aggregate Test

Coarse Aggregate	Test Object	Result			
		Normal Concrete		RCA Concrete	
		Weight (gr)	Percentage (%)	Weight (gr)	Percentage (%)
Water Content	2000	18	0,91	19	0,96
Mud rate	1000	3	0,3	4	0,4
Abrassions	5000	1400	38,89	1340	36,61

Source : Data Processing (2022).

The reference for testing the maximum coarse aggregate moisture content is 2%, the maximum mud content is 1%, and the maximum coarse aggregate Abrassions is 40% of the total test object. Thus the coarse aggregate material used as a constituent of the concrete test object can be categorized as feasible.

B. Fine Aggregates

In the fine aggregate feasibility test, the test results obtained are as follows.

Table 3. Fine Aggregate Test

Fine Aggregate	Test Object	Normal Concrete		RCA Concrete	
		Result	Percentage (%)	Result	Percentage (%)
Water Content (gr)	500	20	4,17	19	3,95
Mud Rate (cm)	3	0,1	3,33	0,14	4,7

Source : Data Processing (2022)

The reference for the maximum water content and mud content in the fine aggregate test required does not exceed 5% of the total number of test objects. Thus the fine aggregate material used as a constituent of the concrete test object can be categorized as feasible.

3.2 Slump Test Results

The slump test is carried out on fresh dough from a mixture of concrete constituent materials. The results of the slump test can be presented in the image below.



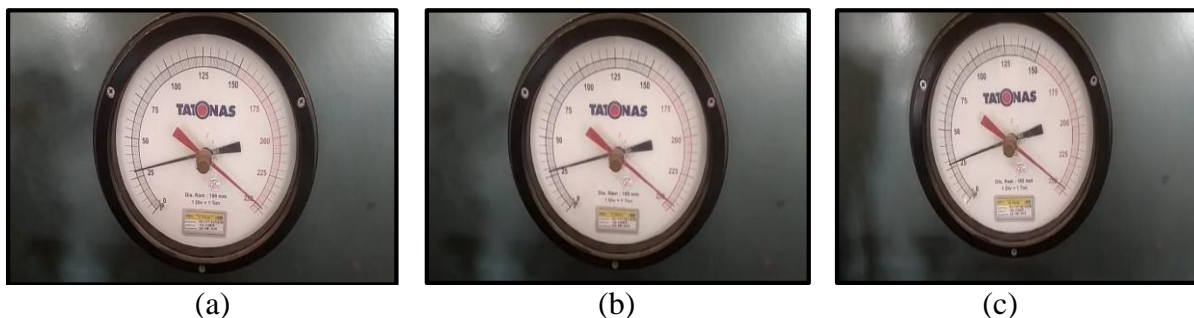
Source: Practical documentation (2022).
Figure 5. Slump Test (a) Normal Concrete, (b) RCA Aggregate Concrete.

The slump test value required in the test is at a drop point of 8 cm to 12 cm. The results of the slump test on normal concrete decreased by 7 cm, and in the test of concrete with RCA, it was 4.4 cm. The slump test results concluded that the two test objects had a low level of workability.

3.3 Compressive Strength Test Results of Concrete

Compressive strength testing was carried out on concrete specimens after experiencing 28 days of treatment. The results of the test are as follows:

A. Normal Concrete Compressive Strength



Source : Practical documentation (2022).

Figure 6. Normal Concrete Compressive Strength Test
(a) Test Object 1, (b) Test Object 2, (c) Test Object 3

The compressive strength test results of test object 1 reached a value of 32 DIV. Test object 2 reached a value of 30 DIV, and test object 3 reached a value of 29 DIV. The test results can be calculated according to the table below.

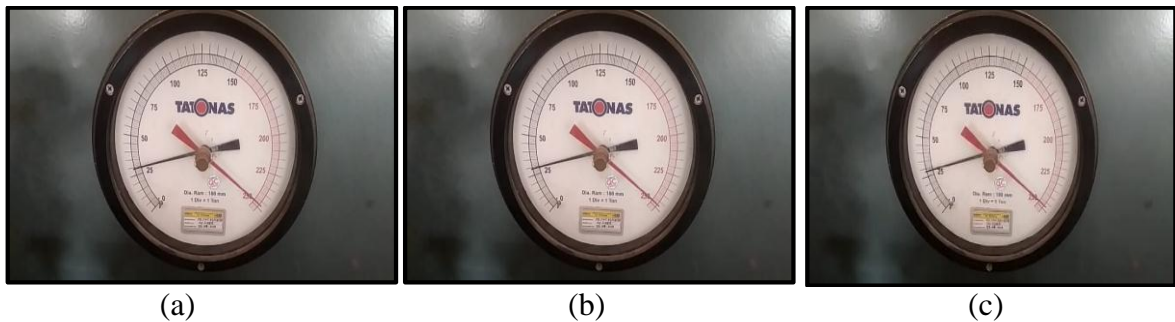
Table 4. Compressive Strength Test Normal Concrete

No	Age	Cross Sectional Area	Dial Reading			Concrete Quality Fc'
Sample	Day	Cm ²	(DIV)	(Correction DIV)	(Kg)	(MPa)
1	28	176,625	32	33	33.400	18,532
2	28	176,625	30	31	31.400	17,422
3	28	176,625	29	30	30.400	16,867

Source : Data Processing (2022)

The test results show that the compressive strength of one test object is 32 DIV, two test objects are 30 DIV, and three are 29 DIV. The test results can be calculated according to the table below.

B. Recycled Concrete Aggregate (RCA) Compressive Strength



Source: Practical documentation (2022).

Figure 6. Recycled Concrete Aggregate (RCA) Compressive Strength Test (a) Test Object 1, (b) Test Object 2, (c) Test Object 3

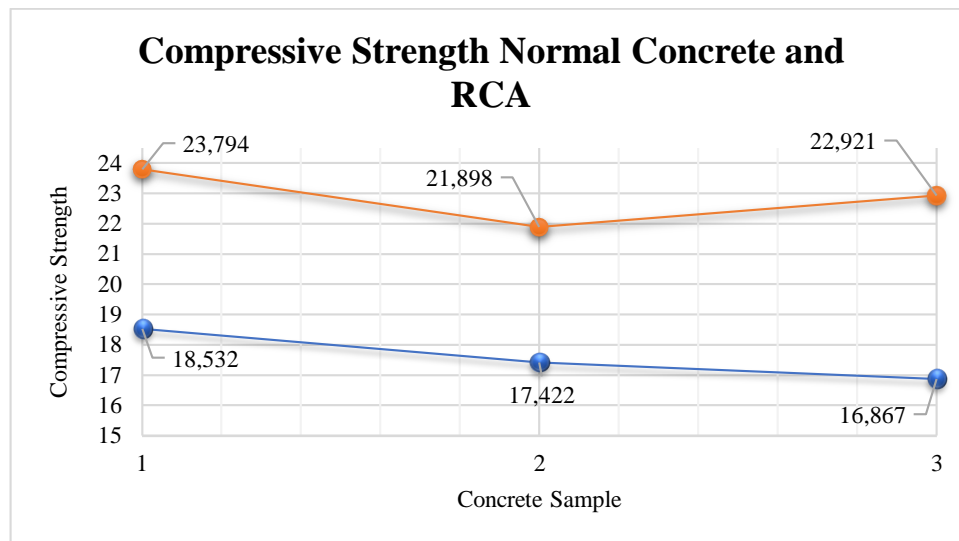
The test results of the compressive strength of the test object 1 reached a value of 43 DIV. Test object 2 reached a value of 39 DIV, and test object 3 reached a value of 41 DIV. The test results can be calculated according to the table below.

Table 5. Compressive Strength Test Recycled Concrete Aggregate (RCA)

No	Age	Cross Sectional Area	Dial Reading			Concrete Quality Fc'
Sample	Day	Cm ²	(DIV)	(Correction DIV)	(Kg)	(MPa)
1	28	176,625	43	43	42.884	23.794
2	28	176,625	39	39	39.467	21.898
3	28	176,625	41	41	41.310	22,921

Source : Data Processing (2022)

The compressive strength test of concrete specimens with recycled coarse aggregate results shows that the average value is 22.871 MPa. The following graphic image can illustrate the results of the two test samples.



Source: Practical documentation (2022).

Figure 7. Result of Compressive Strength Test

Figure 7 shows that the highest value of normal concrete compressive strength (blue line color) is in sample 1, which is worth FC 18,532 MPa. In contrast, the results for concrete specimens with modified materials use Recycled Concrete Aggregate (RCA) as coarse aggregate (orange line). The highest concrete compressive strength value was obtained in the first sample with an FC value of 23,794 MPa.

4. Conclusion

The research results on concrete with recycled coarse aggregate as the base material can achieve the planned target value. This is shown from the results of the average compressive strength of RCA concrete that can exceed the target value of FC 21.7 MPa. The highest value of the compressive strength of RCA concrete is FC 23.79 MPa. For ordinary concrete objects, it only reaches FC 18.53 MPa with the use of the material at the same feasibility.

5. Suggestions

The slump test results are planned for the concrete test object to decrease at a distance of 8 cm to 12 cm. The slump test results showed that the normal concrete specimens decreased by 7 cm, and the concrete specimens with RCA material only decreased by 4.4 cm from the tip of the Abrams cone. Thus, it is suggested that practitioners and academics apply further research better to consider the job mix formula in manufacturing concrete.

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