

ANALYSIS OF COMPRESSIVE STRENGTH OF CONCRETE BY USING *SLAG CIRCUM* AS A CONCRETE AGGREGATE MIX

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ABSTRACT

Currently, a lot of research has been carried out on the utilization of manufacturing industry products, one of which is steel slag as a mixed material for construction and the agricultural industry. One of the uses of steel slag in the construction sector is the manufacture of cement slag, as a mortar mixture, or as a mixture of sub-base layers for road pavement construction. The purpose of this study was to analyze the compressive strength of normal concrete compared to concrete added with *slag circum waste* as a partial replacement for fine aggregate with variations in the addition of 10% and 20% waste . This study uses an experimental method of planning normal concrete $f_c' 20$ and concrete $f_c' 20$ with variations of 10% and 20% slag circum as a substitute for fine aggregate by comparing the results of the compressive strength of concrete at 7, 14, and 28 days. In this study, it was found that the compressive strength of normal concrete without the addition of circum slag at the age of 7, 14, and 28 days was still better than the compressive strength of concrete at the age of 7, 14, and 28 days with the addition of 10% circum slag, and 20% .

Keywords : slag, circum, concrete, compressive

PRELIMINARY

The modern era is developing very rapidly, both from the development of the manufacturing industry and the development of infrastructure [1] . With the rapid economic growth as well, the need for the provision of steel LPG cylinders in the community is very necessary [2] . The manufacturing industry for making LPG cylinders continues to increase its production to meet the needs of the community [3] .

Not apart from the manufacturing process, these activities also encourage the production of waste, one of which is *slag circum*, waste resulting from the steel welding process using the submerged arc *welding method* (*submerged arc welding*) . The waste from the welding process is a mixture of *steel slag with flux granules* [4] [5] [6] . These flux granules are made of various basic materials such as limestone, silica, manganese oxide, calcium fluoride, and others [6] .

Steel slag is a by-product formed in the steelmaking process. Broadly speaking, the steel-making process is divided into three processes, namely: the iron-making process, the steel-making process, and the product-shaping process [7] [8] [9] [10] .

Currently, a lot of research has been carried out on the utilization of manufacturing industry products, one of which is steel slag as a mixed material for the construction and agricultural industries [11] [12] [13] . One of the uses of steel slag in the construction sector is the manufacture of cement slag, as a mortar mixture, or as a mixture of sub-base layers for road pavement construction.

Concrete is a material that comes from mixing coarse and fine aggregates then tied with cement which reacts with water as an adhesive, it must be mixed and stirred

properly and evenly in order to achieve good concrete quality [14] [15] . In general, mixing of concrete ingredients is done with a mixer machine, except if only to get low quality concrete, mixing can be done manually. The viscosity of the concrete mix must be monitored and controlled by checking the slip test for each new concrete mix [16] .

Concrete is also one of the construction materials that has strength and durability which is a function of various factors, including the comparative value of the mixture and the quality of the stacking material, the method of casting execution, the final execution, temperature, and the condition of the concrete treatment itself [17].] [18] . The value of the compressive strength of concrete is relatively higher than its tensile strength, the value of its tensile strength is only around 9% -15% of its compressive strength [19] .

Concrete is a composite material (mixture) and several materials whose main ingredients consist of a mixture of fine aggregate, coarse aggregate, water and or without other additives in a certain ratio [20] [21] . Because concrete is a composite, the ductility of concrete is highly dependent on the quality of each of the formers.

Concrete is defined as a mixture of constituent materials consisting of hydraulic cement (portland cement), coarse aggregate, fine aggregate, and water with or without the use of added materials (admixture or additive). DPU-LPMB provides a definition of concrete as a mixture of portland cement or other hydraulic cement, fine aggregate, coarse aggregate and water, with or without additional admixtures that form a solid mass [22] .

One of the materials used to form concrete is Portland cement. Portland cement is a hydraulic adhesive made from a mixture of materials containing calcium, silica, alumina, and iron oxides which are the main oxides. In general, Portland cement is made with the right composition settings so that its quality is guaranteed. However, different composition settings and storage of Portland cement for a long time will allow the occurrence of impurities and a reduction in cement quality [23] .

The function of cement is to react with water to form a cement paste. Cement paste serves to attach the aggregate grains to become a compact/solid mass unit. In addition, cement paste fills the voids between the aggregate grains. Although the volume of cement is only about 10% of the volume of concrete, but because it is an active adhesive material and has a high price compared to other concrete base materials, it is necessary to pay attention/study well [24] .

Another material is aggregate, aggregate is mineral granules which are the result of natural disintegration of rocks or also the result of stone crushing machines by breaking natural stone. Aggregate is one of the fillers in concrete, however the role of aggregate in concrete is very important. The aggregate content in concrete is approximately 70% - 75% of the volume of concrete. Aggregates are very influential on the properties of concrete, so the selection of aggregates is an important part in the manufacture of concrete. Aggregate is divided into 2 types, namely fine aggregate and coarse aggregate which can be naturally or artificially [25] .

Table 1 Fine Aggregate Gradation Limit

Sieve Hole (mm)	Percent of Grains Passing Sieve			
	Zone I (Coarse Sand)	Zone II (Slightly Coarse Sand)	Zone III (Slightly Fine Sand)	Zone IV (Fine Sand)
10	100	100	100	100

5	90-100	90-100	90-100	90-100
2	60-95	75-100	85-100	95-100
1	30-70	55-90	75-100	90-100
1	15-34	35-59	60-79	80-100
0	5-20	8-30	12-40	5-50
0	0-10	0-10	0-10	0-15

Source: SNI 03-2834-1993

In the test used Slag Circum. The welding process using damped arc welding produces slag or slag. According to the Ministry of Environment and Biodiversity, Slag Steel itself is categorized as hazardous and toxic waste. This circum slag is produced from the submerged arc welding (SAW) process in the manufacturing process of making LPG cylinders by combining the top and bottom plates called circums. In contrast to Slag Steel or slag, Slag Circum consists of a mixture of steel slag with flux granules. These flux granules are made of various basic materials such as limestone, silica, manganese oxide, calcium fluoride, and others. The composition of the slag circum consists of welding wire and flux in the form of sand, with a list of the compositions of each material as follows:

Table 2 Welding Wire Material Composition

No	Chemical Composition	Percentage
1	Iron	60-100%
2	Magnesium	1-5%
3	Silicone	0.5-1.5%

Source: Safety Data Sheet Noriweld ER70s-6

Table 3 Material Composition of Flux Sand

No	Chemical Composition	Percentage
1	Silicon Dioxide	10-20%
2	Titanium Dioxide	15-23%
3	Magnesium	5-15%
4	Aluminum Oxide	10-25%
5	Magnesium Oxide	10-25%
6	Iron	2-5%

Source: Material Safety Data Sheet Flux for Submerged Arc Welding

THEORETICAL FRAMEWORK

A. Definition of Concrete

Concrete is a product resulting from the mechanical and chemical interactions of the constituent materials [26].

B. Definition of Cement

Cement is cement obtained by mixing materials containing lime, burning it at a temperature that results in the formation of clinker and then grinding the clinker with plaster as an additive [27].

C. Cement Function

The function of cement is to glue the aggregate grains to form a solid mass and the cement is also useful for filling the cavities in the aggregate grains [27].

D. Aggregate

Aggregates are mineral grains which are the result of the natural disintegration of rocks or also the result of stone crushing machines by breaking natural stone. Aggregate is one of the fillers in concrete, however the role of aggregate in concrete is very important. The aggregate content in concrete is approximately 70% - 75% of the volume of concrete. Aggregates are very influential on the properties of concrete, so the selection of aggregates is an important part in the manufacture of concrete.

METHODS

The method applied in this research is the experimental method of planning normal concrete $f_c' 20$ and concrete $f_c' 20$ with variations of 10% and 20% slag circum as a substitute for fine aggregate by comparing the results of the compressive strength of concrete at 7, 14, and 28 days. In the research carried out several stages, including;

Table 4. Research stages

Stage 1	✓ At this stage, the provision of tools and materials used in the implementation research is carried out
Stage 2	✓ Specific gravity test on aggregate ✓ Test passed the filter ✓ Aggregate sieve testing ✓ Abrasion Testing
Stage 3	✓ It is called the concrete mix planning stage (mix design) based on the SK SNI method 03-2834-2000
Stage 4	✓ Normal concrete variation without the addition of slag circum. ✓ Variation of concrete with the addition of slag circum as a substitute for sand as much as 10%. ✓ Variation of concrete with the addition of slag circum as a substitute for sand as much as 20%.
Stage 5	✓ The slump test (Slump Test) refers to SNI 2439-2011
Stage 6	✓ The concrete treatment (curing) was carried out by immersing the cylindrical specimen after being removed from the test specimen mould.
Stage 7	✓ The compressive strength test of concrete was carried out after the concrete 7 days, 14 days, and 28 days.
Stage 8	✓ At this stage the data that has been obtained from the test results will be analyzed to get the value of the compressive strength of each variation and compare the value of the compressive strength
Stage 9	✓ At this stage the data that has been analyzed must be made a conclusion related to the research objectives.

Table 5. Research sample

No.	Sample Test Item	7 days	14 days	28 days	Number of Test Items
1.	Normal Concrete Variations	3	3	3	9
2.	Variation of Slag Circum 10 %	3	3	3	9
3.	Variation of Slag Circum 20 %	3	3	3	9
Amount					27

Source : Researcher

The stages of carrying out a laboratory study on the properties of concrete using slag circum as an aggregate mixture can be seen in Figure 1 below.

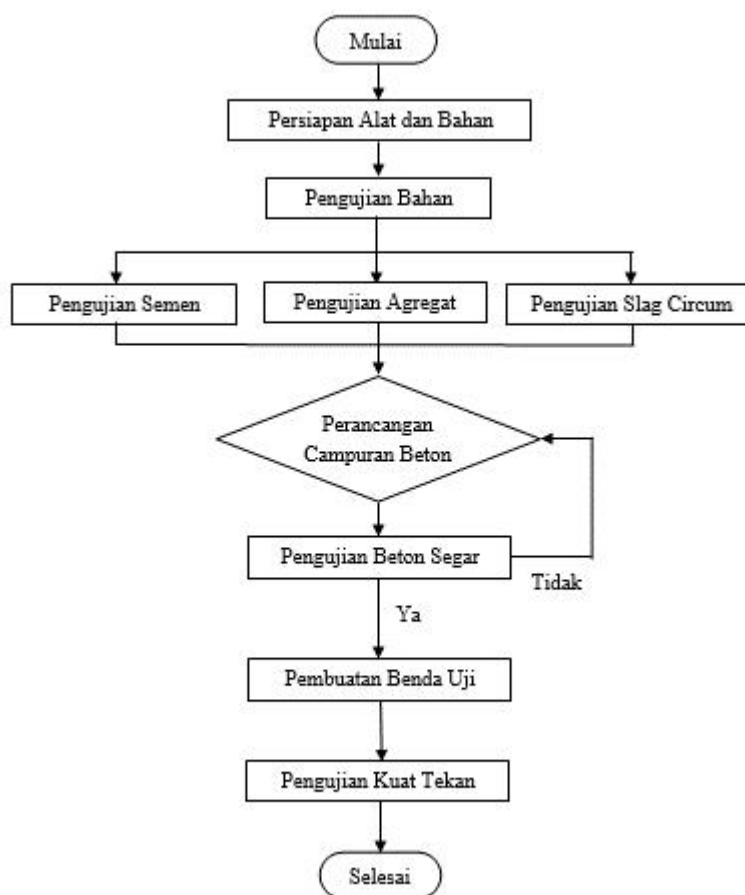


Figure 1 Laboratory Study Flowchart

RESULTS AND DISCUSSION

A. Results

1. Testing of Hydraulic Pressing Materials (Cement)

Portland cement is a hydraulic adhesive made from a mixture of materials containing calcium, silica, alumina, and iron oxides which are the main oxides. In general, Portland cement is made with the right composition settings so that its quality is guaranteed.

Table 6. Comparison of Compressive Strength of Concrete with Type of Test Object

Test Object	Compressive strength comparison
Cube 15 x 15 x 15 cm	1.0
Cube 20 x 20 x 20 cm	0.95
Cylinder 15 x 30 cm	0.83

Table 7. Multiplier factor for the number of test objects < 20 pieces

Number of Test Items	Multiplier
8	1.37
9	1.29
10	1.23
11	1.19
12	1.15
13	1.12
14	1.10
15	1.07
16	1.06
17	1.04
18	1.03
19	1.01
20	1

The steps for testing the compressive strength of concrete are as follows:

- Take the test object from the soaking tub, then wipe it with a damp cloth. Then mark (number) using chalk/marker;
- Weigh the weight, and measure the dimensions of each test object, Put the test object on the centric press machine,
- Run the pressing machine with a loading speed of 4 kg/cm² / sec until it reaches the maximum load,
- Repeat the steps in points 1 to 4 for all the test objects made.
- Record all data in the format that is already available,
- Calculate the compressive strength, average compressive strength, standard deviation, and characteristic compressive strength (specific compressive strength) .

DISCUSSION

A. Aggregate Gradation Test Results

The sand used in this test is using black sand from the Serpong area. The gradation used is included in the number 2 graph area which is medium sand. Results The fineness modulus for fine aggregate is 4.01 for Serpong black sand and the fineness modulus for split stone is 6.51

Table 8. Gradation Test Results for Fine Aggregate (Sand)

Pass Sieve			Heavy stuck	Total Weight stuck	Total Percentage		cumulative
			(g)	(g)	stuck (%)	Get away (%)	(%)
25.4	mm	(1")					
19.1	mm	(3/4")					
12.5	mm	(1/2")					
9.52	mm	(3/8")	0	0.00		100.00	0.00

4.75	mm	(No.4)	3	3.00	0.60	99.40	0.60
2.38	mm	(No.8)	95.1	98.10	19.02	80.38	19.62
1.18	mm	(No.16)	134.7	232.80	26.94	53.44	46.56
0.6	mm	(No.30)	97.5	330.30	19.50	33.94	66.06
0.3	mm	(No.50)	64.4	394.70	12.88	21.06	78.94
0.15	mm	(No.100)	51.8	446.50	10.36	10.70	89.30
0.075	mm	(No.200)	53.5	500.00	10.70	0.00	100.00
Pan					-	-	
Amount			500.00				
Fineness modulus							4.01

Source: Research results in the laboratory

Table 9. Results of Fine Aggregate Gradation Testing (*Slag Circum*)

Pass Sieve			Heavy	Total Weight	Total Percentage		cumulative
			stuck	stuck	stuck	Get away	
			(g)	(g)	(%)	(%)	
25.4	mm	(1")					
19.1	mm	(3/4")					
12.5	mm	(1/2")					
9.52	mm	(3/8")	0	0.00		100.00	0.00
4.75	mm	(No.4)	5	5.00	1.00	99.00	1.00
2.38	mm	(No.8)	73.4	78.40	14.68	84.32	15.68
1.18	mm	(No.16)	89.6	168.00	17.92	66.40	33.60
0.6	mm	(No.30)	125.9	293.90	25.18	41.22	58.78
0.3	mm	(No.50)	81.7	375.60	16.34	24.88	75.12
0.15	mm	(No.00)	76.1	451.70	15.22	9.66	90.34
0.075	mm	(No200)	48.3	500.00	9.66	0.00	100.00
Pan					-	-	
Amount			500.00				
Fineness modulus							3.75

Source: Research results in the laboratory

Table 10. Data on *Slump* Testing of Concrete Test Objects

Mixed Variations	<i>Slump</i> Value	Unit
Variation 0 (Normal)	11.5	mm
Variation 1	11	mm
Variation 2	10.5	mm

Source: Research results in the laboratory

Based on the table above, the slump test can meet the requirements of 6 cm to 18 cm referring to SNI 03-2834-2000.

B. Hard Concrete Testing (Concrete Compressive Strength)

The test for compressive strength of concrete refers to SNI 1974-2021 concerning Procedures for Testing Compressive Strength of Concrete with Cylindrical Test Objects. Calculation of the compressive strength of concrete using the formula:

Where:

The compressive strength of concrete is expressed in MPa or N/mm² . units

P = Axial compression force (N)

A = Cross-sectional area (mm²)

Concrete compressive strength testing was carried out on specimens aged 7 days, 14 days, and 28 days using a concrete compression tester (Compression Testing Machine) with readings on the device using kN units and a digital display. The results of the compressive strength test of concrete can be seen in the table below.

Table 11. Results of Concrete Compressive Strength Testing Age of Test Objects 7, 14, 28

Test Object	Age Test (Day)	Heavy (Kg)	Reading (kN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)
V0-1	7	11.68	220	12.46	11.25
V0-2	7	11.74	183	10.36	
V0-3	7	11.86	193	10.93	
V0-4	14	11.80	251	14.21	14,17
V0-5	14	11.72	265	15.00	
V0-6	14	11.68	245	13.31	
V0-7	28	11.74	325	18,40	18,61
V0-8	28	11.84	327	18.51	
V0-9	28	11.72	334	18.91	

Source: Research results in the laboratory

Table 12. Test Results of Concrete Compressive Strength Age of Test Object 7, 14, 28 Days Concrete Variation 1 (*Slag Circum 10%*)

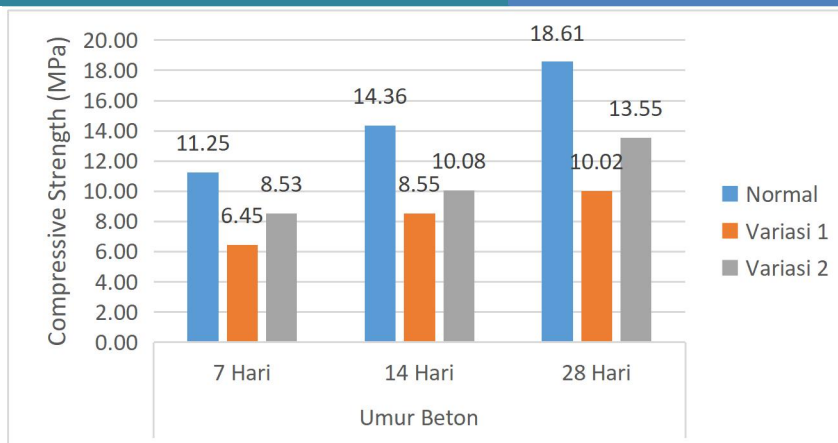
Test Object	Age Test (Day)	Heavy (Kg)	Reading (kN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)
V1-1	7	11.12	122	6.91	6.45
V1-2	7	10.86	102	5.77	
V1-3	7	10.70	118	6.68	
V1-4	14	11.22	149	8.44	8.55
V1-5	14	11.68	165	9.34	
V1-6	14	11.28	139	7.87	
V1-7	28	10.98	168	9.51	10.22
V1-8	28	11.82	177	10.02	
V1-9	28	10.90	186	10.53	

Source: Research results in the laboratory

Table 13. Test Results of Concrete Compressive Strength Age of Test Object 7, 14, 28 Days Concrete Variation 2 (*Slag Circum 20%*)

Test Object	Age Test (Day)	Heavy (Kg)	Reading (kN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)
V2-1	7	11.22	158	8.95	8.53
V2-2	7	11.68	168	9.51	
V2-3	7	11.28	126	7.13	
V2-4	14	11.22	174	9.85	10.08
V2-5	14	11.80	186	10.53	
V2-6	14	11.76	174	9.85	
V2-7	28	11.82	194	10.98	13.55
V2-8	28	11.36	301	17.04	
V2-9	28	11.86	223	12.63	

Source: Research results in the laboratory



Source: Research results in the laboratory

Figure 2. Diagram of Concrete Compressive Strength Test Results

C. Form of Destruction of Normal Concrete Test Objects

Analysis of the shape of normal concrete test specimens at the age of 28 days formed a collapse parallel to the vertical (columnar) axis as shown in the following figure:



Source: Research results in the laboratory

Figure 3. Form of Destruction of Normal Concrete Test Objects

D. Form of Destruction of Concrete Test Objects Variation 1

In the results of the compressive strength of the concrete test specimen variation 1 with the addition of 10% slag circum forming a cone and splitting with crack conditions more crushed than normal concrete which indicates that the concrete with the addition of 10% slag circum is more brittle than normal concrete, as shown in the following figure :



Source: Research results in the laboratory

Figure 4 . Form of Destruction of Test Object Variation 1

E. Form of Destruction of Concrete Test Objects Variation 2

The results of the compressive strength of concrete specimens of variation 2 with the addition of 20% slag circum form a collapse parallel to the vertical axis (columnar) with more crack conditions than normal concrete and concrete variation 1 which indicates that concrete with the addition of 20% slag circum is more brittle than normal concrete. and concrete variation 1, as shown in the following figure:



Source: Research results in the laboratory

Figure 5. Form of Destruction of Test Object Variation 2

CONCLUSION

The results of research conducted at the Jakarta Laboratory using added slag circum as a partial substitute for fine aggregate as much as 10% and 20%, the data obtained were then analyzed and the following conclusions were drawn:

- 1) The normal compressive strength of concrete without the addition of slag circum at the age of 7, 14, and 28 days is 11.25 MPa, 14.36 MPa, and 18.61 MPa.
- 2) The compressive strength of concrete at the age of 7, 14, and 28 days with the addition of 10% circum slag was 6.45 MPa, 8.55 MPa, and 10.02 MPa and with the addition of 20% circum slag it was 8.53 MPa, 10 .08 MPa, and 13.55 MPa. So that when compared with normal concrete, the compressive strength of concrete decreased by 46% and 27%.

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