Experimental Study of Concrete Compressive Strength Using Lightweight Concrete Debris Waste as a Substitute for Coarse Aggregate

Wihardi Tjaronge, Abd.Madjid Akkas, Andi Sri Ulvah

***Abstract:** At present, ready-to-use concrete is rampant adopted in building construction, but it is often excess supply and the rest is sometimes discarded in any place which could directly reduce the soil fertility and damage the balance of the ecosystem. Thus, recycle concrete waste is a solution to overcome the problem. However, the utilization of waste as recycled aggregate needs to be studied more deeply, by conducting experimental testing and analysis of the characteristics possessed. The methods and procedures for the implementation of recycled aggregate testing are carried out with reference to ASTM standards. In this study, the concrete base material which is coarse aggregate in the form of split is replaced with light concrete debris waste (LPBR) with composition (50% LPBR and 50% Split) and the average compressive strength is measured. The composite samples are tested on 28th day, the concrete compressive strength and modulus of elasticity results indicated 17.740 MPa and 20024.43 MPa respectively.*

***Keywords:** Building construction, Concrete Compressive Strength, Recycle concrete waste*

I. INTRODUCTION

Concrete is defined as a set of mechanical and chemical interactions from its constituent material[1]. Concrete is made by mixing Portland cement or other hydraulic cement, coarse aggregate, fine aggregate (sand), and water which becomes one unit, then hardens for a certain period [2]. Concrete properties that are often observed are generally compressive strength, tensile strength and flexural strength. These properties are very dependent on several factors including the quality of the basic ingredients of the concrete maker, the composition of the mixture, age and weather conditions or environmental factors. Many researches on concrete have been carried out regarding the impact of environmental conditions especially in used construction rubbish as recycled aggregate for green building, environmental protection and sustainable development of society [3-5]. Through research and experimentation, concrete technology is now advancing rapidly. One of the objectives of the development of concrete technology is to obtain optimal mechanical properties at a relatively cheap price [6].

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In this case, the use of additional materials in concrete mixtures becomes less economical and the use of recycled aggregate concrete makes the value of concrete more economical and environmental friendly [7, 8].Recycled concrete is a design of a concrete mixture using materials resulting from the destruction of finished concrete which is then used as an aggregate material [9, 10].

Some differences in quality, physical and chemical properties of recycled aggregates cause differences in the properties of the concrete material produced. This is due to the presence of other mixing materials contained in the aggregate granules, namely the mortar layer attached to the aggregate [11]. The mortar layer itself consists of aggregate and cement paste used in the previous concrete mixture. Based on this, this study was carried out in an effort to find an alternative substitute for concrete base material in this case coarse aggregates in the form of crushed stones were replaced with lightweight concrete debris waste and also determine the average compressive strength and modulus of elasticity.

II. METHODOLOGY

This research was conducted at the Structure and Material Laboratory of the Civil Engineering Department of the Faculty of Engineering, Hasanuddin University. This research was carried out for 3 months (January - March 2012). The material used in this study consisted of coarse aggregate (split) and fine aggregate (sand) from the Bili-biliGowa area, the waste of light concrete debris from the Zigel Block brand and the Portland Composite Cement (PCC) from Tonasa brand and tap water. The average compressive strength required in this study is f'cm = 25 MPa with the composition of the waste studied is 50% and 100%, and the cement water factor is a maximum of 0.5.

The average compressive strength test was carried out on 27 samples in the form of concrete cylinders with a diameter of 15 cm and 30 cm high for 3 categories, which is 100% split concrete, 100% LPBR and composition of waste 50% split and 50% LPBR. The compressive strength test of concrete carried out at the age of 3^{rd} day, 7th day and 28^{th} day usingCompression Testing Machine with a capacity of 1500 kN, while testing the modulus of elasticity of concrete was carried out at 28 days.The testing standard in this study refers to the ASTM (American Society for Testing and Materials).

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Materials

The characteristics of fine and coarse aggregates are tasted prior sample preparation and the Portland cement is not included as it meets the SNI standard. The aggregate characteristics are tasted based on ASTM standard. The testing characteristics are sieving analysis based on ASTM C136-01, specific gravity and absorption checks based on ASTM C128-01, volume weight checks based on ASTM C 29M-97, water content checks based on ASTM C566-97, sludge examination based on ASTM 117-95, Organic content based on ASTM C40-99 and abrasion examination / wear based on ASTM C131-03. The test result is shown in Table 1.

The test result indicated fine aggregate (sand) filters obtained a maximum of 4.75 mm but not less than 0.125 mm, which is included in the zone gradation of sand zone III. The maximum size of coarse aggregate (split) used is 37.5 mm and minimum is 4.75 mm. For coarse aggregates of lightweight concrete debris waste (LPBR) obtained a maximum size of 37.5 mm and a minimum of 4.75 mm in accordance with coarse aggregate sieve analysis.

Table. 1 Test result of Fine Aggregate (Sand), Coarse Aggregate (Split) and Coarse Aggregates (LPBR)

	Fine Aggregate (Sand)			**Coarse Aggregate (Split)**			**Coarse Aggregates (LPBR)**		
Aggregate Characteristics	**Interval**	**Test Results**	**Notes**	**Interval**	**Test Results**	**Notes**	**Interval**	**Test Results**	**Notes**
Modulus of Fineness	1.5 - 3.8	2.31	Good	6.0 - 7.1	7.05	Good	6.0 - 7.1	7.10	Good
Specific density									
a. Actual	1.6 - 3.3	2.63	Good	1.6 - 3.3	2.74	Good	1.6 - 3.3	1.26	Poor
b. Dry base	1.6 - 3.3	2.56	Good	1.6 - 3.3	2.57	Good	1.6 - 3.3	0.79	Poor
c. Dry surface	1.6 - 3.3	2.59	Good	1.6 - 3.3	2.64	Good	1.6 - 3.3	1.16	Poor
Water absorption	Max 2%	1.01%	Good	0.2% - 4%	2.35%	Good	0.2% - 4%	47.06%	Poor
Water Content	2% - 5%	4.53%	Good	3% - 5%	4.40%	Good	3% - 5%	6.80%	Poor
Mud Level	Max 5%	3.20%	Good	0.2% - 1%	0.73%	Good	0.2% - 1%	0.53%	Good
Organic Content	<No. 3	No. 2	Good						
Wear				15% - 40%	27.60	Good	15% - 40%	64.80%	Good

Based on Table 1, the characteristics of sand and split meet the criteria as a concrete constituent material. The test of lightweight concrete debriswaste LPBR as a substitute for coarse aggregate demonstrated some characteristics that do not meet the criteria as concrete constituent materials. However, LPBR is used in this study in order to determine the characteristics of concrete compressive strength that uses waste of lightweight concrete debris. The samples are prepared according to the standard procedure and each category consists of 9 samples.

Compressive Strength and Modulus of Elasticity test

The compressive strength test was carried out using Compression Testing Machine with a capacity of 1500 kN, this test was carried out based on SNI. The compressive strength and the modulus of elasticity of the concrete can be determined from the formula.

1. Press Strength

Based on SNI 1974: 2011 standard [12], the compressive strength of concrete is calculated by dividing the maximum compressive strength received by the test sample during the test with a cross-sectional area.

$$f'ci = P / A \qquad (1)$$

Where:

$f'ci$ = compressive strength of concrete (N / mm^2)

P = axial compression force (Newton, N)

A = cross sectional area of the test sample (mm^2)

2. Modulus of elasticity

Based on SNI 03-4169-1996 standard [13], it provides the following formula:

$$E = (\sigma_2 - \sigma_1) / (\varepsilon_2 - \varepsilon_1) \qquad (2)$$

Where:

E = elastic modulus of concrete (MPa)

σ_2 = tension when it reaches 40% of the maximum load (MPa)

σ_1 = tension during longitudinal strain ($\varepsilon 1$) equal to 0.00005 (MPa)

ε_1 = longitudinal strain generated by tension σ_1

ε_2 = longitudinal strain generated by tension σ_2

The test of compressive strength and modulus of elasticity aims to determine the implied concrete quality and elasticity modulus of concrete samples at 28 days. This test is done using a cylindrical sample measuring 15 cm x 30 cm in 3 pieces.

III. RESULTS AND DISCUSSION

The compressive strength testing in this study refers to ASTM C 39 / C 39 M - 01 (Standard Test Method for Compressive Strength of Cylindrical Concrete Samples) and contained in SNI 1974: 2011. The results obtained are presented in Table 2.

All sample dimension high of 300mm, diameter of 150mm and area of 17662.5mm^2.

The compressive strength test aims to determine the compressive strength of concrete with cylindrical samples made and cured in the laboratory after 28 days. Tests were carried out on three different concrete mixtures with each consisting of three samples. Test samples in the form of cylinders measuring 15 cm in diameter and 30 cm in height are mounted on centric press machines. The load is applied until the test sample is destroyed and unable to withstand the given load, so that the maximum load is determined. Then calculate the compressive strength of concrete is the amount of load per unit area.

The composition of the concrete constituent material has an influence on the compressive strength. From Figure 1, the relationship of compressive strength to the age of concrete in accordance with the predetermined composition. At 28th days, the average compressive strength of normal concrete (100% split) is 28,309MPa, concrete with 100% LPBR is 14.909 MPa, while concrete with 50% LPBR and 50% split is 17,740 MPa.

Table. 2 Concrete Strength Testing Results of 100% Split, 100% LPBR and 50% LPBR and 50% Split

		100% Split			100% LPBR			50% LPBR and 50% Split		
Test sample number	Day	Mass (g)	Press force (kN)	Compressive strength (N / mm^2)	Mass (g)	Press force (kN)	Compressive strength (N / mm^2)	Mass (g)	Press force (kN)	Compressive strength (N / mm^2)
S1	3	12143	170	9.625	8328	110	6.228	10745	130	7.360
S2		12490	290	16.419	8271	110	6.228	10233	160	9.059
S3		12320	280	15.863	8212	140	7.926	11024	140	7.926
Average compressive strength				**13.966**			**6.794**			**8.115**
S1	7	11145	340	19.250	9305	190	10.757	11285	220	12.456
S2		11763	410	23.213	8538	200	11.323	11565	220	12.456
S3		12027	380	21.515	8893	220	12.456	10062	230	13.022
Average compressive strength				**21.326**			**11.512**			**12.644**
S1	28	12524	470	26.610	9320	220	12.456	11335	290	16.419
S2		12205	530	30.007	8860	270	15.287	11575	310	17.551
S3		12455	500	28.309	8395	300	16.985	11515	340	19.250
Average compressive strength				**28.309**			**14.909**			**17.740**

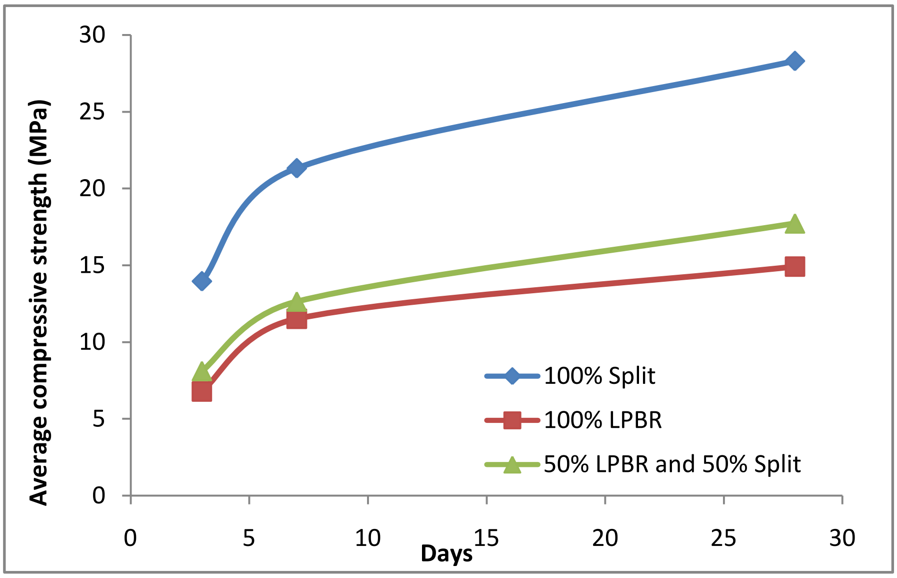

Figure 1. Graph of Correlation of Compressive Strength to Concrete Age

Figure 2 shows the percentage change in concrete compressive strength at the age of 3, 7 and 28 days of the test sample. For normal concrete (100% split), the percentage of increase in compressive strength to the age of the test samples are 49.33%, 75.33% and 100% respectively. For concrete with 100% LPBR an increase of 46.00%, 77.22% and 100%. As for concrete with 50% LPBR and 50% split increase by 45.74%, 71.28% and 100%.

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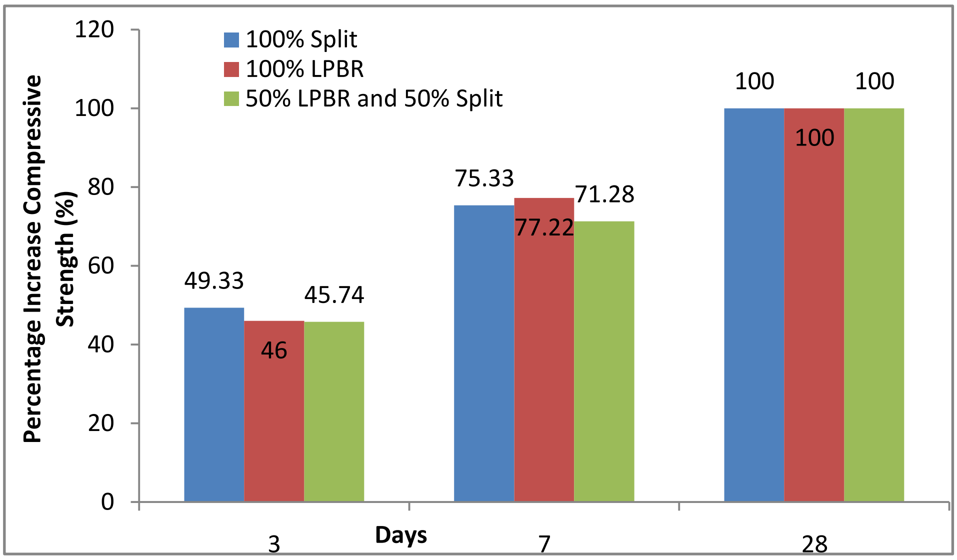

Fig. 2 Diagram of Percentage of Change in Press Strength against Concrete Age

Analysis of Modulus of Elasticity

Table 3 tabulated the modulus of elasticity and maximum deformation on 28th day for 100% Split, 100% LPBR and 50% LPBR and 50% Split Concrete.The result of elasticity testing on concrete using coarse aggregate 100% split on 28th day demonstrated the maximum tension for sample I is 26.610 MPa. When the load reaches 40% of the maximum load, tension (σ2) is 10.6440 MPa, so that the longitudinal strain (ε2) is 0.0004. Then the tension (σ1) is 2.1231 MPa when the longitudinal strain (ε1) is 0.00005.The maximum tension for sample II is 30,007 MPa. When the load reaches 40% of the maximum load, tension (σ2) is 12.0028 MPa, so that the longitudinal strain (ε2) is 0.0004. Then the tension (σ1) is 2.1231 MPa when the longitudinal strain (ε1) is 0.00005.The maximum tension for sample III is 28,309 MPa. When the load reaches 40% of the maximum load, tension (σ2) is 11.3234 MPa, so that the longitudinal strain (ε2) is 0.0003. Then the tension (σ1) is 1.4154 MPa when the longitudinal strain (ε1) is 0.00005.

Table. 3 The Modulus of Elasticity and Maximum Deformation on 28th Day for 100% Split, 100% LPBR and 50% LPBR and 50% Split Concrete

	100% Split		100% LPBR		50% LPBR and 50% Split	
No.	Modulus of Elasticity (MPa) (σ2-σ1 / ε2ε1)	Δ max (mm)	Modulus of Elasticity (MPa) (σ2-σ1 / ε2ε1)	Δ max (mm)	Modulus of Elasticity (MPa) (σ2-σ1 / ε2ε1)	Δ max (mm)
1	24252.97	0.43	16660.35	0.48	19617.63	0.36
2	25332.53	0.47	18536.41	0.35	19737.53	0.37
3	34969.40	0.40	19920.84	0.37	20718.14	0.39
Average	**28184.97**	**0.43**	**18372.53**	**0.40**	**20024.43**	**0.37**

The result of elasticity testing on concrete using 100% coarse aggregate LPBR at 28th daydemonstrated the maximum stress for sample I is 12.456 MPa. When the load reaches 40% of the maximum load, tension (σ2) is 4.9823 MPa, so that the longitudinal strain (ε2) is 0.0003. Then the tension (σ1) is 1.0616 MPa when the longitudinal strain (ε1) is 0.00005. The maximum tension for sample II is 15.287 MPa. When the load reaches 40% of the maximum load tension (σ2) is 6.1146 MPa, so that the longitudinal strain (ε2) is 0.0003. Then the tension (σ1) is 2.1231 MPa when the longitudinal strain (ε1) is 0.00005.The maximum tension for sample III is 16.9851 MPa. When the load reaches 40% of the maximum load, tension (σ2) is 6.7941 MPa, so that the longitudinal strain (ε2) is 0.0003. Then the tension (σ1) is 1.4154 MPa when the longitudinal strain (ε1) is 0.00005.

The result of testing the elasticity of concrete using 50% coarse aggregate LPBR and 50% split at 28th day demonstrated the maximum tension for sample I was 16.419 MPa. When the load reaches 40% of the maximum load, tension (σ2) is 6.5676 MPa, so that the longitudinal strain (ε2) is 0.0003. Then the tension (σ1) is 1.0616 MPa when the longitudinal strain (ε1) is 0.00005. The maximum tension for sample II is 17.5513 MPa.

When the load reaches 40% of the maximum load, tension (σ2) is 7.0205 MPa, so that the longitudinal strain (ε2) is 0.0004. Then the tension (σ1) is 0.8493 MPa when the longitudinal strain (ε1) is 0.00005. The maximum tension for sample III is 19.2498 MPa. When the load reaches 40% of the maximum load, tension (σ2) is 7.6999 MPa, so that the longitudinal strain (ε2) is 0.0004. Then the tension (σ1) is 1.4154 MPa when the longitudinal strain (ε1) is 0.00005.

IV. CONCLUSION

1. The average compressive strength of normal 100% split concrete is 28.309 MPa, the average compressive strength of 100% LPBR concrete is 14.909 MPa, and the average compressive strength in concrete is 50% LPBR and 50% split is 17.740 MPa.
2. The average modulus of elasticity for three concrete test items 100% split is 28184.97 MPa, concrete using 100% LPBR is 18372.53 MPa and concrete using 50% LPBR and 50% split is 20024.43 MPa.
3. The compressive strength of concrete with LPBR does not reach the planned strength of 25 MPa and is only 14.909 MPa for concrete using 100% LPBR and 17.740 MPa for concrete with 50% LPBR and 50% Split.

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