

Performance of Recycled Concrete Made from Railway Sleeper: Experimental Study

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(Received: September 22nd 2021 ; Accepted: October 6th 2021)

Abstract: Concrete railway sleeper has been used in Indonesia since about 1990's. It has more advantage that is less maintenance, stabile, good quality, shapeable, onsite raw material, and higher loading ability [9-10, 20 - 22]. But It is prone to damage such as cracking and breaking during construction, so it is often thrown away as a solid waste that can contaminate the land and reduce soil fertility. Therefore, it should be utilized in order to be more useful that is used as recycle aggregate. The concrete waste that is taken from broken concrete railway sleeper will be crush as an aggregate as raw material in the concrete to substitute part or all of the normal concrete. It is called recycled aggregate and concrete that is made from recycled aggregate is called recycled concrete. Base on the testing of raw material, the recycled aggregate can be met to the specification as ASTM [1], so it can be used for concrete raw material. The compressive strength of recycled concrete results in a lower compressive strength of normal concrete at the same initial compressive strength. The strength value of recycled concrete decreased by about 1 – 17% for 25 MPa, and 10 – 18% for 30 MPa. Likewise, the tensile strength of recycled concrete decreased by around 2 – 13% for 25 MPa and 7 – 22% for 30 MPa.

Keywords: concrete railway sleeper; compressive strength; recycled aggregate; recycled concrete; tensile strength

1. Introduction

In Indonesia, the railway was designed by Netherland government as a colonialist, but the realization of construction was built since 1864 in Java that is Solo-Yogyakarta [19 – 21, 24]. The railway was made by steel and the sleeper was produced by wood (Figure 1.a) or steel (Figure 1.b). The wood must be selected material that is elastic and good wooden grain, and the steel is common material that is mill steel. The wood is very difficult to find now, because the jungle has been cleared and looted by community, and the other placed has protected by government. And the steel price has very expensive, so the railway construction will become high price. Base on the both problems they are wood scarcity and steel rail high price sleeper material, the alternative railway sleeper material must be found the solution. It is concrete railway-sleeper (Figure 1.c) that is precast concrete [9-10, 19-21, 24].

Precast concrete railway sleepers have been used since the 1990s, the first being the Bandung-Jakarta route [20 – 22, 24]. The precast concrete is usually pre-tension prestressed system that is fabricate in workshop [26, 30]. The companies that produce the precast concrete railway sleeper in Indonesia are WIKA Beton, Waskita Beton Precast, PT. Tjagrindo Mas, and other companies. The company must be produced and followed to code or standard [30], and other code [19-21].

The minimum concrete strength of precast concrete sleeper is K-500 (about $f'_c = 41$ MPA) and the minimum tensile strength of prestressed tendon is 17,000 kg/cm² (about 1,700 MPA) [21, 26].

The precast concrete railway sleeper that has produced in workshop will be mobilized to site by truck or trailer transportation. It also will be loading and unloading by crane or other lifting equipment that compatible in the field conditions. The precast concrete is often crack, break or damage when it is arrived on the field. The damage precast concrete is rejected, because it is not proper to the requirement and it became waste material. It usually throw out from the field and it affect to the fertility soil that is solid waste or land contamination. The concrete solid waste is also only land fill that is not economical. Base on the both problems, the concrete waste that takes rom damaging precast concrete railway sleeper will be used for aggregate in the concrete. The aggregate is called recycled aggregate as substitute a part of normal coarse aggregate or crush rock because the concrete is classified high strength concrete. The aggregate can be predicted high strength aggregate caused by high strength resources. It should be tested to verify the actual strength of recycled concrete. Furthermore, experimental study will be execute the research. The implication of this research is a reduce and increasing economic value the solid waste (concrete waste).

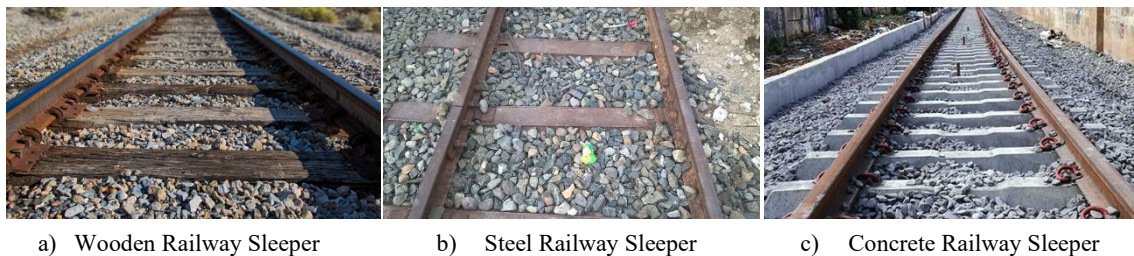


Fig. 1. Type of Railway Sleeper [21, 26]

2. Literature Study

Recycled concrete aggregate is an aggregate that is made from concrete waste material to become aggregate as replacing or substitute the normal or crush rock aggregate and fine aggregate. The concrete waste will be crushed as aggregate in order to make a concrete [2-8, 11-13, 23, 27-29, 31-37]. The concrete that makes from recycle aggregate is called recycle concrete [2-8, 11-13, 23, 27-29, 31-37]. Base on the several researches, the compressive strength result of recycled concrete have lower then normal concrete (that use normal aggregate). Decreasing of recycled concrete compressive strength are about 5 - 45% then normal concrete [2-5,11-12, 31] and it depends on the recycled aggregate as resources of recycled concrete. If the recycled aggregate as a row material of recycled concrete are low strength, so the concrete recycled compressive strength result are low strength [2-5,11-12, 31].

Test result of compressive strength recycled concrete that the recycled aggregate is taken from high strength concrete are obtained a compressive strength decreasing about 13.1-67.2% for 25%, 17.6-72.0% for 50%, 24.3-74.6% for 75% and 6.5-71.1% for 100% recycled aggregate content. [5, 31]. The other tests result of research that is 30 MPa for the initial compressive strength design are decreasing 10 % for 25%, 22% for 50%, 32% for 75% and 45% for 100% recycled aggregate content [31,37]. Usually, the researches of recycled concrete represent a similar result that the compressive strengths decrease from the normal concrete initial design. It may be caused by weak bonding and interlocking between aggregate and cement paste, so the advance research needs to be done to find out the interlocking in the micro cracking or internal bonding [31].

3. Experimental Program

3.1. Concrete Raw Material Testing

Raw material of normal and recycled aggregate should be tested to get a characteristic of it. All raw materials testing will refer to standard that is ASTM C-136-06 [3]. The normal aggregates are coarse and fine aggregate and the recycled aggregate is only coarse aggregate. All of aggregates should be attend to specification in order to able for concrete material because the mix design of concrete strength needs a special characteristic such as gradation, specific gravity, water content and others to get a weight proportion in the concrete.

One of the test is sieve analysis that will be presented in the figure 2. It is illustrated distribution of granular that will be filled all of the space in the concrete volume in order to be solid. The others testing are presented in the Table 1, they are specific gravity, water content, abrasion percentage, and other characteristic. Those are used for proportion weight calculation in the concrete that is called concrete mix design. The test result all aggregates can be used for raw material of concrete, because they meet to ASTM specification that a standard of concrete no exception for recycled aggregate.

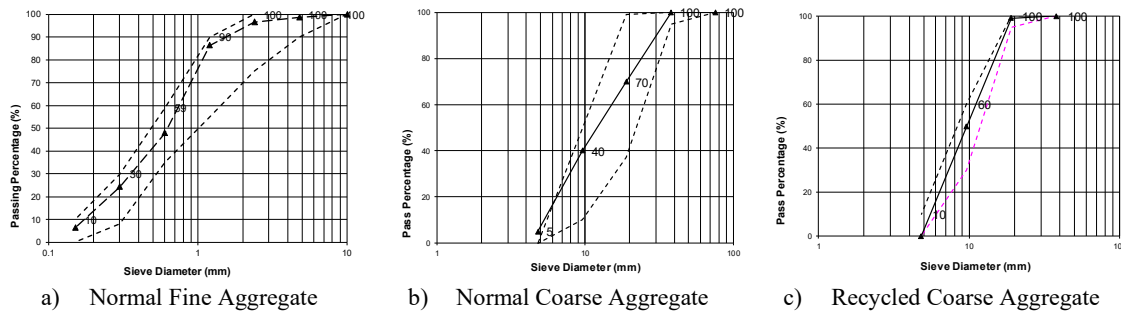


Fig. 2. Sieve Analysis of Fine and Coarse Aggregate

Table 1. Aggregate Characteristic

Description of Testing	Normal Fine Aggregate	Normal Coarse Aggregate	Recycled Coarse Aggregate
Apparent specific gravity	2.77	2.87	2.68
Bulk specific gravity (dry)	2.40	2.43	3.01
Bulk specific gravity (SSD)	2.53	2.45	2.43
% absorption of water	6.78	7.46	7.97
Weight of compact volume (kg/ltr)	1.56	1.41	1.39
Weight of loose volume (kg/ltr)	1.40	1.28	1.23
Maximum aggregate size (mm)	4.75	25.00	25.00
Fineness content (%)	2.20	0.70	0.10
Fineness modulus	2.40	6.50	4.564
Water content (%)	12.30	1.39	-
Soundness (%)	7.60	17.60	19.800
Alkali Reactive	Nil	Nil	Nil
% Abrasion	-	23.40	31.20

3.2. Preparation of Specimens

The first activity of concrete specimen testing is mix design in order to get a proportion of raw material such as fine and coarse aggregates, cement, and water. The proportion result can be seen in the Table 2 and 3.

Table 2. Raw material proportion of concrete for 25 MPa compressive strength

Raw Material	Normal Concrete	Recycled Concrete			
		25%	50%	75%	100%
Cement	413.46	413.46	413.46	413.46	413.46
Water	275,36	280,07	284,77	289.48	294,18
Fine Aggregat	617.31	617.31	617.31	617.31	617.31
Coarse Aggregate	1,073,86	279.38	558.76	838.14	1,117.52

Note: Normal coarse aggregate content in the recycled concrete is depend on percentage of recycled aggregate content.

Table 3. Raw material proportion of concrete for 30 MPa compressive strength

Raw Material	Normal Concrete	Recycled Concrete			
		25%	50%	75%	100%
Cement	438.78	438.7	438.7	438.7	438.7
Water	224.88	227.93	230,97	234.02	237.07
Fine Aggregat	677,66	677,66	677,66	677,66	677,66
Coarse Aggregater	1,034,01	269.01	538.02	807.03	1,076.04

The specimen of concrete is cylinder that dimension is dimeter 150 mm and height is 300 mm. The testing of cylinder is crushing and indirect tensile (splitting) test. The crushing test will be compressed at 3, 7, 14, 21, and 28 ages, but splitting test is only at 28 age. The crushing test in the several age aims to monitor and check the development of concrete strength. Total number of specimens are 180 pieces.

The name of several specimens as above mention are:

- 25MPa-0 for normal concrete strength 25 MPa
- 25MPa-25 for recycled aggregate content 25% in the concrete strength 25 MPa
- 25MPa-50 for recycled aggregate content 50% in the concrete strength 25 MPa
- 25MPa-75 for recycled aggregate content 75% in the concrete strength 25 MPa
- 25MPa-100 for recycled aggregate content 100% in the concrete strength 25 MPa
- 30MPa-0 for normal concrete strength 30 MPa
- 30MPa-25 for recycled aggregate content 25% in the concrete strength 30 MPa
- 30MPa-50 for recycled aggregate content 50% in the concrete strength 30 MPa
- 30MPa-75 for recycled aggregate content 75% in the concrete strength 30 MPa
- 30MPa-100 for recycled aggregate content 100% in the concrete strength 30 MPa

3.3. Equipment Devices

The equipment devices of the testing is compressive test machine (Figure 3) and splitting apparatus (Figure 4). Those equipment are available in the Wiralodra University of Civil Laboratory.



Fig. 3. Concrete compressive test



Fig. 4. Splitting test apparatus

4. Test Result and Discussion

4.1. Compressive strength of concrete

Crushing test of specimen that is cylinder shape as above dimension explanation will be tested under the compressive testing machine (Figure 3) until crush and record the final pressure indicator. The values of concrete compressive strength in the table are average result for three samples testing. The test result will be presented in the Table 4.

Compressive strength of recycled concrete result lower than normal concrete. Decreasing of strength may be caused by quality of recycled aggregate is lower the normal aggregate that is shown an abrasion test which the abrasion percentage value is number of crushed aggregate during los Angeles test. The percentage of abrasion value is higher than normal concrete. Compressive strength decreasing is about 1 – 17% for 25 MPa and 10 – 18% for 30 MPa (Figure 5). It can be seen that the more increase of the compressive concrete strength design, so it will be more great the decrease of compressive strength.

Table 4. Compressive strength result

Concrete Type	Testing Age					% decreasing
	3 days	7 days	14 days	21 days	28 days	
25MPA-0	10.47	15.85	21.80	23.92	25.29	
25MPA-25	9.72	14.53	19.91	23.44	25.01	1.11
25MPA-50	9.62	13.68	18.49	21.80	23.02	8.98
25MPA-75	9.34	12.74	17.93	21.17	22.27	11.94
25MPA-100	8.96	12.36	16.99	19.34	21.04	16.81
30MPA-0	13.21	21.31	26.70	29.88	31.89	
30MPA-25	10.57	17.65	23.67	27.11	28.63	10.22
30MPA-50	9.83	16.65	22.87	26.01	27.86	12.64
30MPA-75	9.40	15.89	22.27	25.76	26.95	15.49

Concrete Type	Testing Age					% decreasing
	3 days	7 days	14 days	21 days	28 days	
30MPA-100	8.96	15.34	21.12	24.56	26.26	17.65

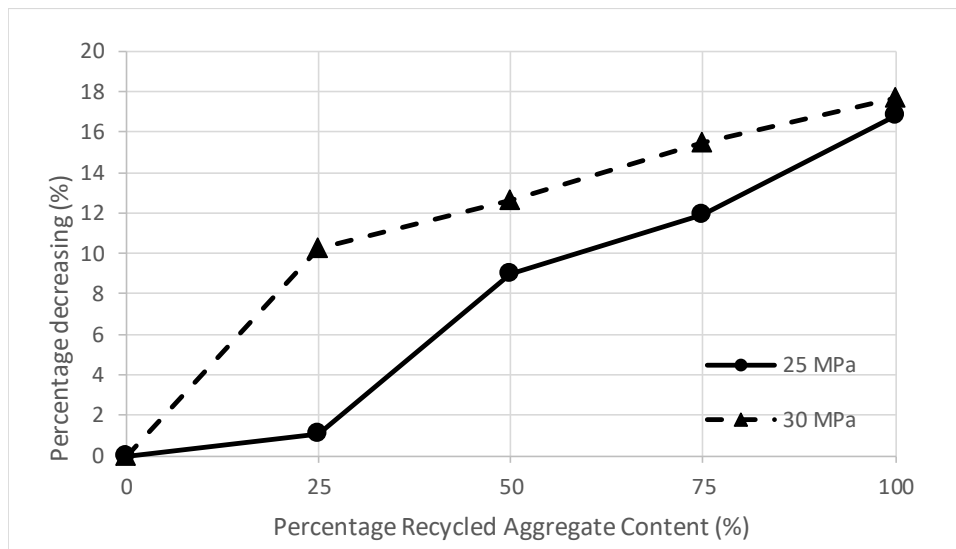


Fig. 5. Percentage decreasing of concrete compressive strength

4.2. Tensile strength of concrete

Tensile test of specimen that is cylinder shape as a compressive strength specimen will be tested under the indirect tensile testing machine (splitting apparatus testing) (Figure 4) until split and record the final pressure indicator. The values of concrete tensile strength in the table are average result for three samples testing. The test result will be presented in the Table 5.

Similar with compressive strength, the tensile strength of recycled concrete result lower than normal concrete. It also may be caused by quality of recycled aggregate is lower the normal aggregate. Tensile strength decreasing is about 2 – 13% for 25 MPa and 7 – 22% for 30 MPa (Figure 6). It can be seen that the increasing of the tensile concrete strength design will be greater the compressive strength decrease.

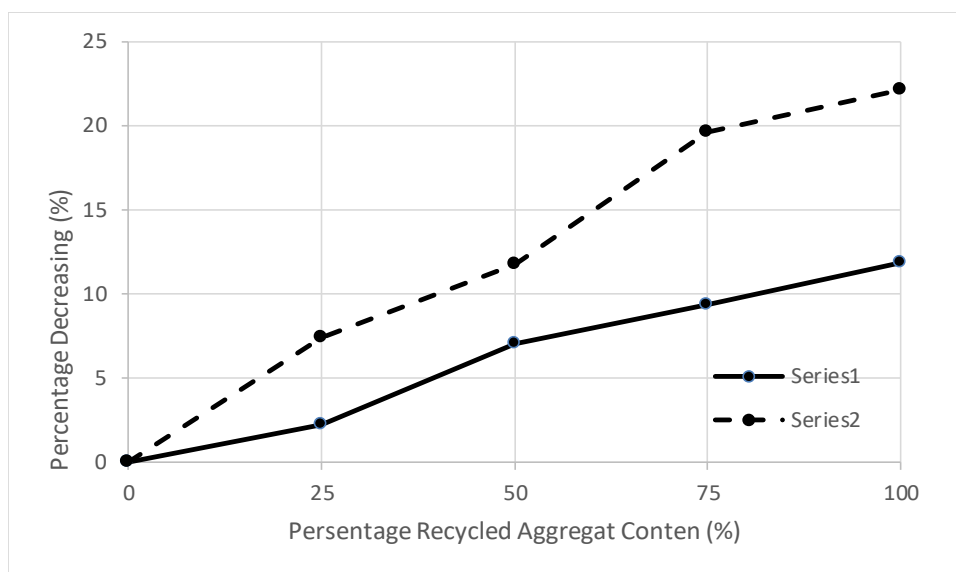


Fig. 6. Percentage decreasing of concrete tensile strength

Table 5. Tensile strength result

Description	Concrete Compressive Strength 25 MPa				
	25MPa-0	25MPa-25	25MPa-50	25MPa-75	25MPa-100
Concrete Type					
Tensile Strength (MPa)	3.96	3.87	3.68	3.59	3.49
% decreasing		2.27	7.07	9.34	11.87

Description	Concrete Compressive Strength 30 MPa				
	30MPa-0	30MPa-25	30MPa-50	30MPa-75	30MPa-100
Concrete Type					
Tensile Strength (MPa)	4.34	4.02	3.83	3.49	3.38
% decreasing		7.37	11.75	19.59	22.12

5. Conclusion

The concrete specimens testing have been done they are compressive and tensile test. The conclusion from the results of testing are :

1. Recycled aggregate that takes from concrete railway sleeper waste can be used as raw material of concrete, because the recycled aggregate specification can meet to the standar of ASTM. The deference of specifications are on the percentage absorpition and abrasion that the values are greater than normal aggregate. They are caused more porosity in the recycled aggregate that affected of the mortar is still adhere around the existing normal aggregate of the recycled aggregate.
2. Decreasing percentage of recycled concrete compressive strength will be greater when the design of compressive strength of concrete is also increase. It may be caused by internal bonding or interlocking.
3. Similar with compressive concrete strength, the tensile strength also decrease. Percentage of recycled concrete tensile strength also will be greater when the design of compressive strength of concrete is increase.

Acknowledgements

This research has been done successfully, so researches aim to say Wiralodra University that has provided a laboratory and other facility such as room, equipment and others..

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