The Feasibility of Applying Waste Concrete as Coarse Aggregates in New Concrete

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Abstract-This paper presents a study on the possibility of replacing natural coarse aggregates with recycled aggregates in concrete in terms of strength, namely compressive strength and flexural strength. The concrete was designed to have a 25MPa compressive strength and an 8cm slump. The replacement rates of natural aggregates with recycled coarse aggregates were 0%, 10%, 15%, and 20%. The test samples were compressed to determine their strength value after 28 days of curing. The research results give a more complete assessment of the efficiency of the use of recycled raw aggregates instead of natural aggregates in concrete. The results indicate that using recycled aggregates is feasible due to the small decrease in concrete strength. The experiment shows that up to 20% replacement, the recorded reduction in the strength of concrete is lower than 15%. However, it is indispensable that the strength of concrete should be enhanced when recycled aggregates are used. According to previous works, fiber reinforcement may be an effective solution. Therefore, to further develop research using recycled aggregates, it is necessary to consider using different fibers to strengthen the concrete. The fiber content can be used in the range of 0-1% of the weight of concrete.

Keywords-compressive strength; flexural strength; waste concrete; demolishing work

I. INTRODUCTION

Recycling of waste construction materials from demolishing works in order to reduce the environmental impact has been investigated by numerous researchers [1-5]. The use sustainable construction materials coming from demolishing works, like recycled concrete, could help produce sustainable materials with advantages such as good quality and low cost while reducing the environmental impact. Besides, the growth in population in big cities leads to continuously rising in the demand of construction materials, which leads to a negative impact on the environment.

Aggregates in concrete are prepared by crushing rocks into different sizes, then sieving and classifying particle sizes according to standards, and mixing to ensure a standard grading curve. This process poses many serious health and environmental hazards, and disrupts ecosystems, necessitating the search for alternative sources of aggregates. On the other hand, the volume of waste concrete generated from the dismantled works is very large and the produced materials are considered waste. As a hard material like stone, waste concrete can be used as aggregates for new concrete. The possibility of replacing natural coarse aggregates with recycled aggregates in concrete has been evaluated by many authors on many aspects. Authors in [2] found that recycled coarse aggregates and natural aggregates can be mixed in a proportionate ratio to be used in pavement and building construction. Various strength tests, including compressive and tensile strength tests of cylinder with 0, 25, 50, 75, and 100% recycled coarse aggregate replacement were performed. Authors in [1] investigated the use of recycled concrete in improving the quality and enhancing the mechanical and microstructure properties of concrete [1]. The designed concrete strength is 35MPa with a fixed water to cement ratio of 0.48. Various characteristics of concrete, including density, workability, temperature, compressive strength, split tensile strength, flexural strength, and microstructural analysis, were investigated. In [6], the authors fully replaced natural coarse aggregates with recycled coarse aggregates and they investigated the bulk density and the compressive strength of concrete for various curing durations. The results show that bulk density and compressive strength of concrete with recycled coarse aggregates were lower than those of concrete using natural coarse aggregates. Authors in [7] carried out various experiments to determine the properties of concrete made with crushed concrete as coarse aggregates. It was found that the recycled coarse aggregates have lower specific gravity

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and higher absorption capacity than the original crushed granite aggregates. The use of recycled coarse aggregates leads to reduced compressive strength up to 25%, reduced modulus of elasticity up to 30%, improved damping capacity up to 30%, and higher amounts of drying shrinkage and creep.

To summarize, it is possible to produce concrete with recycled aggregate as coarse aggregates. The quality of the original concrete from which the recycled aggregates are produced seems to have little influence upon the properties of the produced concrete [7]. However, the study and evaluation of the feasibility of using recycled aggregates in concrete needs to be further studied in terms of strength, including compressive strength, split tensile strength, and bending strength.

II. EXPERIMENTAL SETUP

Before casting, slump measurement was performed to determine the slump of concrete in fresh state. Concrete with slump values that are too low or too high can be identified and corrected prior use. Compression test was carried out on cubical specimens. In the present research, cube specimens with size 15×15×15cm were used. Compression experiments were conducted by loading the cube specimens between two plates, and then applying force by moving the crossheads together. During the test, the specimens were compressed and the applied load was recorded. The yield strength and compressive strength of concrete were then measured. Flexural strength is a measure of the tensile strength of concrete. Unreinforced concrete beams sized 10×10×40cm were used. The peak force when the beam specimen begins to appear failure in bending was measured.

After curing at room temperature for 28 days, the concrete samples were tested for compressive strength and flexural strength. The experimental setup is shown in Figures 1 and 2.

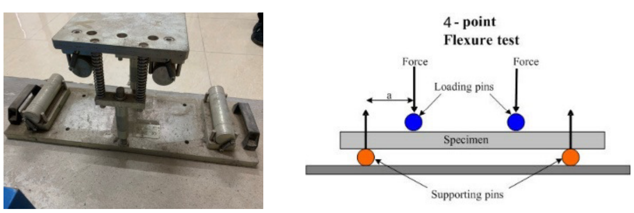

Fig. 1. Four-point bending test.

Fig. 2. Compressive test.

In this study, all concrete sample constituents were acquired from local sources, namely Vietnamese standard Portland cement, river sand used as fine aggregates, local natural-crushed rock used as coarse aggregates with diameters ranging from 5 to 20 mm (Table I).

Four cements sets with 0%, 10%, 15%, and 20% of recycled coarse aggregates were cast. Each set consisted of 5 specimens. The specimens were cast in composite molds and compacted through an external vibration machine. The specimens were demolded at least 24h later.

TABLE I. MIX COMPONENTS OF CONCRETE (PER $1m^3$)

Content of recycled aggregates	Cement (kg)	Sand (kg)	Natural aggregates (kg)	Recycled aggregates (kg)	Water (kg)
0%	292.5	648.3	1216.3	0	195
10%	292.5	648.3	1094.7	121.6	195
15%	292.5	648.3	1033.9	182.4	195
20%	292.5	648.3	973	243.3	195

III. RESULTS AND DISCUSSION

The failure loading values, recorded in the compression test are presented in Table II. These values will be used to calculate the compressive strength of concrete for various percentages of recycled aggregates. The compressive strength values of concrete, calculated according to the Vietnamese standard 3118:1993, are shown in Table II.

TABLE II. FAILURE LOADS IN COMPRESSION TEST

Percentage of recycled aggregates	Specimen	Failure load (kN)	Compressive strength (MPa)
0%	1	505.2	22.45
	2	512.7	22.78
	3	501.3	22.28
	4	499.9	22.22
	5	510.4	22.68
10%	1	497.2	22.1
	2	479.2	21.3
	3	490.5	21.8
	4	489.1	21.74
	5	482.4	21.44
15%	1	455.2	20.23
	2	465.8	20.7
	3	472.4	21.0
	4	477.7	21.23
	5	485.1	21.56
20%	1	460.3	20.46
	2	427.4	19.0
	3	435.5	19.36
	4	418.7	18.61
	5	422.9	18.79

The compressive strength of concrete using different contents of recycled aggregates is plotted in Figure 3. It can be easily seen that using recycle aggregates leads to a decrease of the compressive strength of concrete, although the result arrangement varies in several specimens corresponding to the usage of recycle aggregates. However, the compressive strength of concrete generally decreases with the increasing use of recycled aggregates. This result is in agreement with the results of [3, 5-7].

The drop in percentage of the average compressive strength of concrete using various contents of recycled aggregates was calculated. The result is plotted in Figure 4. We can see that the drop rate of compressive strength of concrete is almost linearly declining with the increase of the using rate of recycled aggregates, with less than 15% reduction in strength when 20% recycled aggregates are used. From this, the use of recycled coarse aggregates can be considered feasible.

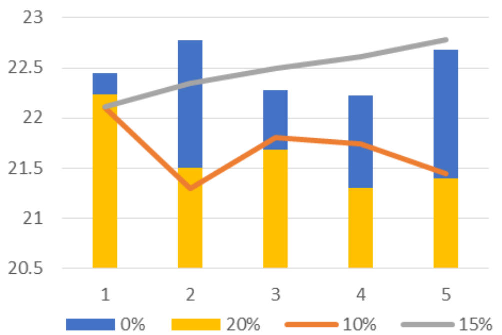

Fig. 3. Compressive strength of concrete samples using recycled aggregates.

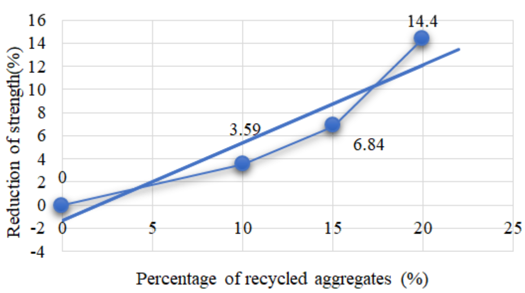

Fig. 4. The drop rate in the compressive strength of concrete using recycled aggregates.

The destructive forces, recorded in the 4-point flexural test, are presented in Table III. The flexural strength, defined as the maximum stress in a material just before it yields in a bending test, was calculated according to the Vietnamese standard 3119:1993.

TABLE III. DESTRUCTIVE FORCES AND FLEXURAL STRENGTH OF CONCRETE

Percentage of recycled aggregates	Specimen	Load (kN)	Flexural strength (MPa)
0%	1	1003.61	3.16
	2	1013.7	3.19
	3	1138.1	3.59
	4	1026.25	3.23
	5	1009.8	3.18
10%	1	987.34	3.11
	2	968.25	3.05
	3	972.21	3.06
	4	979.08	3.08
	5	991.06	3.12
15%	1	932.5	2.94
	2	955.01	3.01
	3	960.23	3.02
	4	934.1	2.94
	5	963.17	3.03
20%	1	872.6	2.75
	2	889.13	2.8
	3	905.74	2.85
	4	919.2	2.89
	5	879.04	2.77

The flexural strength of concrete using different content values of recycled aggregates is plotted in Figure 5. It indicates that using recycle aggregates leads to a slight decrease of flexural strength. The drop in the percentage of the average flexural strength using various content values of recycled aggregates was calculated and the result is plotted in Figure 6. It indicates that the drop rate of compressive strength of concrete is almost linearly declining with the increase of the using rate of recycled aggregates, with less than 15% reduction in flexural strength when 20% recycled aggregates are used. So, the use of recycled coarse aggregate can be considered feasible in terms of flexural strength.

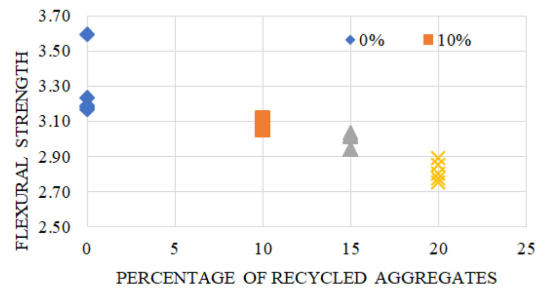

Fig. 5. Flexural strength of concrete samples using recycled aggregates.

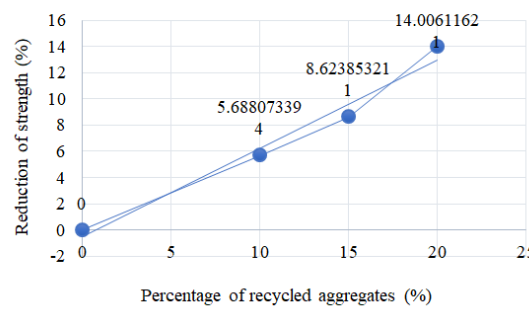

Fig. 6. The drop rate in the flexural strength of concrete using recycled aggregates.

Thus, in order to be able to use recycled aggregates in concrete, it is necessary to find solutions to enhance its compressive and flexural strength. Fiber reinforcement may be considered for the enhancement of the strength of concrete [8-10]. The quantity of fibers has been selected as 0.5% and 1.0% of the weight of concrete [8]. It has been concluded that increased quantity of fibers, improves the flexural strength of concrete beams [8]. Therefore, to further develop the research in the use of recycled aggregates, it is necessary to consider using different fibers to strengthen the cement. The fiber content can be used in the range of 0-1% of the weight of concrete.

IV. CONCLUSION

In this paper, the compressive strength and flexural strength of concrete with recycled aggregates have been investigated. The recycled aggregates came from demolition works, and were used at different contents, namely 0%, 10%, 15%, and 20%. The results indicate that using recycled aggregates is feasible because of the low decrease of concrete strength. The experiment shows that for up to 20% of recycled concrete used, the recorded reduction in the strength of concrete is lower than 15%. However, it is indispensable that the strength of concrete should be enhanced when recycled aggregates are used. According to previous studies, fiber reinforcement may be an effective solution. Therefore, to further develop the research on the use of recycled aggregates, it is necessary to consider the use of different fibers to strengthen concrete. The fiber content can be used in the range of 0-1% of the weight of concrete.

REFERENCES

[1] M. T. El-Hawary, C. Koenke, A. El-Nemr, and N. F. Hanna, "Using Recycled Concrete as a Replacement for Coarse Aggregate in the Production of Green Concrete," in *Sustainable Issues in Infrastructure Engineering*, Cham, Switzerland, 2021, pp. 127–151, https://doi.org/10.1007/978-3-030-62586-3_9.

[2] B. Panda, N. T. Imran, and K. Samal, "A Study on Replacement of Coarse Aggregate with Recycled Concrete Aggregate (RCA) in Road Construction," in *Recent Developments in Sustainable Infrastructure*, Singapore, 2021, pp. 1097–1106, https://doi.org/10.1007/978-981-15-4577-1_91.

[3] D. D. Nguyen and V. T. Phan, "Compressive Strength Studies on Recycled Binder Concrete," *Engineering, Technology & Applied Science Research*, vol. 11, no. 4, pp. 7332–7335, Aug. 2021, https://doi.org/10.48084/etasr.4230.

[4] V. T. Phan and T. H. Nguyen, "The Influence of Fly Ash on the Compressive Strength of Recycled Concrete Utilizing Coarse Aggregates from Demolition Works," *Engineering, Technology & Applied Science Research*, vol. 11, no. 3, pp. 7107–7110, Jun. 2021, https://doi.org/10.48084/etasr.4145.

[5] X. H. Vu, T. C. Vo, and V. T. Phan, "Study of the Compressive Strength of Concrete with Partial Replacement of Recycled Coarse Aggregates," *Engineering, Technology & Applied Science Research*, vol. 11, no. 3, pp. 7191–7194, Jun. 2021, https://doi.org/10.48084/etasr.4162.

[6] H. Opara, U. Eziefula, and C. Ugwuegbu, "Experimental study of concrete using recycled coarse aggregate," *International Journal of Materials and Structural Integrity*, vol. 10, no. 4, pp. 123–132, Dec. 2016.

[7] R. Sri Ravindrarajah and C. T. Tam, "Properties of concrete made with crushed concrete as coarse aggregate," *Magazine of Concrete Research*, vol. 37, no. 130, pp. 29–38, Mar. 1985, https://doi.org/10.1680/macr.1985.37.130.29.

[8] A. Namdar, I. B. Zakaria, A. B. Hazeli, S. J. Azimi, A. S. B. A. Razak, and G. S. Gopalakrishna, "An experimental study on flexural strength enhancement of concrete by means of small steel fibers," *Frattura ed Integrità Strutturale*, vol. 7, no. 26, pp. 22–30, Sep. 2013, https://doi.org/10.3221/IGF-ESIS.26.03.

[9] S. T. Kang, B. Y. Lee, J.-K. Kim, and Y. Y. Kim, "The effect of fibre distribution characteristics on the flexural strength of steel fibre-reinforced ultra high strength concrete," *Construction and Building Materials*, vol. 25, no. 5, pp. 2450–2457, May 2011, https://doi.org/10.1016/j.conbuildmat.2010.11.057.

[10] H. binti Hashim *et al.*, "Improving the mechanical properties of polycaprolactone using functionalized nanofibrillated bacterial cellulose with high dispersibility and long fiber length as a reinforcement material," *Composites Part A: Applied Science and Manufacturing*, vol. 158, Jul. 2022, Art. no. 106978, https://doi.org/10.1016/j.compositesa.2022.106978.