Compressive Strength Studies on Recycled Binder Concrete

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Abstract-Recycled materials are gradually utilized in concrete. This paper examines the use of recycled binder in concrete. The compressive strength tests on concrete incorporating recycled binder instead of cement were carried out after 7, 14, and 28 days of curing. Cement was replaced by the recycled binder in ratios of 10%, 20%, and 30% by weight. The results show that the compressive strength of concrete is strongly affected by the percentage of the recycled binder. It has been found that the compressive strength decreases linearly with the increasing content of recycled binder. The recycled binder does not affect the strength development of concrete. In order to apply recycled waste to concrete as a binder, it is necessary to perform supplement research with appropriate additives to compensate for the loss of the compressive strength.

Keywords-compressive strength; recycled concrete; fine aggregates

I. INTRODUCTION

Recycled aggregates can become a new source of material, replacing natural aggregates in concrete [1-3]. Authors in [1] examined the use of crushed concrete produced from waste concrete as fine aggregates regarding the modulus of elasticity, pulse velocity, and long-term properties such as drying shrinkage and creep. They found that the detrimental effects of crushed concrete can be mitigated by a partial replacement of crushed concrete fines with pulverized fuel ash. Another study replaced fine aggregates in concrete with recycled fine aggregates [2]. The authors found that fine recycled aggregates can be used to up to 10% ratio for producing C30 concrete and between 20-50% ratio for producing C25 concrete. Thus, by using recycled fine concrete aggregates in concrete application, environmental impact and consumption of the natural resources can be significantly reduced. The replacement of fine recycled aggregates in concrete had also been investigated in [4-6]. The obtained results indicate that the recycled concretes have a suitable resistant and durable behavior, according to the limits indicated by different international codes for structural concrete [5].

The investigation on using recycled coarse aggregates instead of natural coarse aggregates in concrete has also been carried out by numerous authors [2, 6-10]. Authors in [11] investigated the influence of the amount of recycled coarse aggregates on the properties of concrete, in which 4 different recycled aggregate concretes were produced with the same design compressive strength. The ratio of recycled coarse aggregates replacement had been used up to 100% [11]. Authors in [12] conducted research on the influence of recycled aggregate types, including unbound stone, crushed concrete, crushed brick, to the properties of concrete [12]. The results showed that the performance of concrete containing each type of recycled aggregates was largely influenced by the aggregate nature and quality, in addition to the attached mortar content. The analysis above shows that using recycled aggregates from demolishing works as coarse and fine aggregates for concrete has been studied extensively. However, to the best of our knowledge, there is no research on the application of recycled aggregates as substitute for the binder, i.e. cement, in concrete. In this paper, an investigation on the compressive strength of concrete with partially replacement of cement with recycled fine aggregates is performed. The results will help understanding more about recycled concrete and may give recommendations for further studies.

II. COMPOSITION OF REYCLED CONCRETE

A. Recycled Concrete

The concrete obtained after the demolition of a project was crushed. The crushed old concrete was then screened with a 0.14mm sieve. The resulting fine-grained mixture is shown in Figure 1.

Fig. 1. Recycled fine-grained mixture obtained from crushed old concrete.

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In order to investigate the influence of the replacement rate of the recycled fine-grained aggregates to the compressive strength of concrete, a reference mixture was selected. Cement was then replaced by recycled fine-grained mixture, crushed and screened from old concrete, at various replacement rates, namely 10%, 20%, and 30% by weight. After casting, the samples were stored under normal conditions and were tested for compressive strength at 7, 14, and 28 days of curing.

B. Sand

The sand used in the experiments has the following mechanical properties:

- Density 2.65g/cm^3.
- Modulus of magnitude 2.50.
- Volumetric mass 1660kg/m^3.

C. Cement

Commercial Portland cement in Vietnam, namely PCB40, with the following mechanical properties was used:

- Actual strength of cement 40MPa.
- Density 3.1g/cm^3.

D. Coarse aggregates

In this study, 20mm aggregates, the most common size of used in construction, have been used, with the following mechanical properties:

- Density 2.61g/cm^3.
- Volumetric mass 1430kg/m^3.

III. EXPERIMENTAL SET-UP

In this test, the push force was applied on both faces of the concrete specimens and the maximum compression that concrete bore without failure was noted (Figure 2). Cylindrical samples with size D150×H300 were cast and cured in normal conditions before being compressed to determine their compressive strength. The loading speed was set to 0.5kN/s. The replacement rates of cement were 0%, 10%, and 20% of the standard sample (reference sample) respectively. Mix components for 1m^3 of concrete are presented in Table I.

TABLE I. MIX COMPONENTS FOR 1m^3 OF CONCRETE

Aggregate by mass	**Cement (kg)**	**Sand (kg)**	**Aggregate (kg)**	**Water (kg)**
	292.5	648.3	1216.3	195.0
Aggregate by volume	**Cement (kg)**	**Sand (m^3)**	**Aggregate (m^3)**	**Water (lt)**
	292.5	0.391	0.851	195.0

TABLE II. EXPERIMENTAL DETAILS OF CONCRETE SAMPLES

No.	**Notation**	**Description**	**Quantity**
1	CP0	Reference sample: Mixture composition as describe in Table I	3 samples for 7 days, 3 samples for 14 days, and 3 samples for 28 days.
2	CP10	Cement replacement rate is 10%	
3	CP20	Cement replacement rate is 20%	
4	CP30	Cement replacement rate is 30%	

Fig. 2. An in-process experiment (CP20-28 days) and the recorded destructive force.

IV. RESULTS AND DISCUSSION

The obtained results of the compression tests (sample destructive force) are shown in Table III. From the value of the destructive force P (kN) of each sample, the compressive strength (MPa) is calculated as follows:

Bearing Area: Sample diameter is D = 15cm, so:

$$S=\pi.R^2=\pi.7.5^2=176.71\text{cm}^2 \quad (1)$$

The compressive strength is then calculated by:

$$R=\alpha\,.\,P/S \quad (2)$$

where P is the destructive load of the sample, S is the compressive area (S=176.71cm^2), α is the coefficient of converting the experimental results when compressing the samples with different sizes from the standard samples (150×150×150mm). With cylinder sample D150×H300, $\alpha = 1.2$.

TABLE III. RECORDED DESTRUCTIVE FORCES

No.	**Replacement rate**	**Sample destructive force (kN)**		
		7 days	**14 days**	**28 days**
1	0 %	171.21	239.11	295.2
2		176.1	225.99	293.5
3		173.51	229.39	294.1
4	10 %	167.09	213.19	288.1
5		163.13	226.09	286.2
6		154.71	219.41	281.3
7	20 %	152.01	199.19	262.1
8		153.04	199.73	259.4
9		151.50	215.29	265.8
10	30 %	153.23	200.96	251.2
11		151.44	196.87	252.4
12		145.46	190.60	250.8

The compressive strength of the experimental samples at 7, 14, and 28 days was calculated and is shown in Table IV. It can be observed that the replacement of recycled binder significantly affected the compressive strength of concrete. The decrease is recorded as 3% at replacement rate of 10%, 10% at replacement rate of 20% and 14% at replacement rate of 30%.The results are presented graphically in Figure 3.

TABLE IV. CALCULATED COMPRESSIVE STRENGTH OF RECYCLED CONCRETE

No.	Replacement rate	Compressive strength (MPa)					
		7 days	Mean value	14 days	Mean value	28 days	Mean value
1	0 %	11.62	11.79	16.23	15.72	20.04	19.98
2		11.95		15.34		19.93	
3		11.78		15.57		19.97	
4	10 %	11.34	10.98	14.47	14.91	19.56	19.36
5		11.07		15.35		19.43	
6		10.50		14.89		19.10	
7	20 %	10.32	10.33	13.52	13.90	17.79	17.82
8		10.39		13.56		17.61	
9		10.28		14.62		18.04	
10	30 %	10.40	10.19	13.64	13.32	17.05	17.07
11		10.28		13.36		17.13	
12		9.87		12.94		17.03	

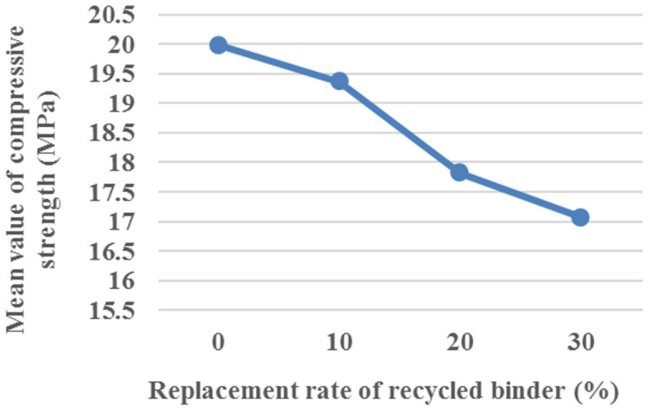

Fig. 3. Compressive strength of concrete at various replacement rates of recycled binder.

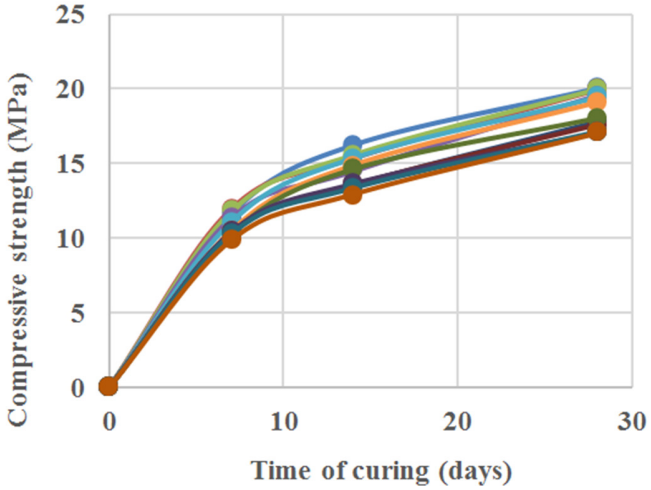

Fig. 4. The development of the compressive strength of concrete.

It can be seen that, basically, the strength development of concrete using recycled binder at a low rate (≤ 30%) is similar to the strength development of ordinary concrete, however the following points should be noted:

- Normal concrete (replacement rate 0%) grows up to 60% of its maximum design strength at the age of 7 days. This growth has slowed down to 56% by 10% replacement, 57% by 20% replacement, and 59% by 30% replacement of the recycled binder. That indicates that the replacement of recycled binder does not affect the strength development of concrete at an early age.
- At 14 days of curing, the experimental concrete achieves about 78% of its maximum design strength. These rates are 77% by 10%, 78% by 20% and 78% by 30% replacement of recycled binder. This means that the replacement of recycled binder does not affect the strength development of concrete.

The diminution of compressive strength of recycled concrete with partially replacement of recycled aggregates has been reported in [2, 3, 7 10, 12]. The present investigation on the influence of recycled binder on the compressive strength of concrete indicates that the compressive strength decreases linearly with the increasing percentage of the recycled binder. Therefore, in order to apply recycled waste to concrete as a binder, it is necessary to perform supplement research with appropriate additives to compensate for the loss of the compressive strength.

V. CONCLUSION

The current paper presented the results of a research on the compressive strength of concrete using recycled binder from demolition works. The rates of replacement were 0%, 10%, 20%, and 30%. The test samples were compressed to determine the values of compressive strength at different ages, namely 7 days, 14 days, and 28 days of curing. The results show that the compressive strength of concrete is strongly affected by the percentage of recycled binder replacement. It has been found that the compressive strength decreases linearly with the increase of the recycled binder content. The presence of recycled binder does not affect the strength development of concrete. In order to apply recycled waste to concrete as a binder, it is necessary to perform supplement research with appropriate additives to compensate for the loss of the compressive strength.

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