The Influence of Fly Ash on the Compressive Strength of Recycled Concrete Utilizing Coarse Aggregates from Demolition Works

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Abstract- The compressive strength of recycled concrete with coarse aggregates with and without fly ash was studied in this paper. The recycled concrete was designed to have a compressive strength of R_n=15Mpa. The ratio of conventional aggregates and recycled coarse aggregates was 50-50. Fifteen samples for each recycled concrete aggregate had been cast and were tested 7, 14, and 28 days after curing. The experimental results indicate that the strength development of the two recycled concrete mixes is relatively uniform. Fly ash increased the compressive strength of recycled concrete by 11% for 7-day aged samples. The recycled concrete with fly ash had 7% less compressive strength than the concrete consisting of natural aggregates.

Keywords-fly ash; recycled concrete; demolishing work

I. INTRODUCTION

Nowadays, reuse of solid waste from demolition works is a common issue, especially at developing cities. Construction solid waste is hardly reused due to various reasons such as the lack of solid waste treatment plants and concentration areas, strict environmental regulations, etc. In fact, many investors dump solid waste from demolition works to save time and money, which has a negative impact on the environment and the locals. Reusing construction solid waste will contribute to satisfy the growing demand for stone materials in construction industry.

Thermal power plants are generating a huge amount of fly ash and slag waste, which, if not treated and reused, cause serious environmental pollution. The burial of waste, such as fly ash, from thermal power plants causes long-term harm to the environment (polluting groundwater sources, damaging cultivated lands, etc.). The reuse of this type of waste is being widely supported and, in fact, fly ash has been used in many applications of construction material production such as the production of unburnt bricks. The problem of recycling concrete from demolition works has been studied extensively. Often, the structure of recycled concrete is similar to conventional concrete and even better in some cases.

There have been many scientific publications about recycled concrete and its uses [1-8]. The most recent research aspects can be seen in [9], in which the authors investigate the effect of the strength of recycled concrete waste on the mechanical properties of recycled concrete. The results show that the reused concrete waste has almost no significant effect on compressive, flexural, and tensile strength of the recycled concrete. Authors in [10] assess the mechanical properties and environmental impacts of self-compacting concrete using recycled aggregates. Authors in [11] evaluate the use of recycled materials from waste concrete to self-compacted concrete. Although the use of recycled concrete is a much studied issue, according to our understanding, there are limited studies evaluating the use of fly ash to increase the efficiency of recycled concrete using construction solid waste [12-14]. Therefore, in this paper the effect of fly ash on the compressive strength of concrete with recycled aggregates from demolition works is studied.

Fig. 1. Construction waste dumped on the side of the road and into a drainage canal.

II. EXPERIMENTAL SETUP

A. Fly Ash

The used fly ash came from the Duyen Hai Thermal Power Plant (Tra Vinh province – Viet Nam). The fly ash belongs to type F because its total content of oxides $SiO_2 + Al_2O_3 + Fe_2O_3$ is bigger than 70%. The technical parameters of the fly ash are shown in Table I.

B. Sand

The sand used in the experiments has the following mechanical properties: density 2.65g/cm^3, modulus of magnitude 2.50, and volumetric mass 1660 kg/m^3. Density is

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the mass per unit volume of a material in a completely solid state and volumetric mass is the mass per unit volume of material in its natural state.

TABLE I. TECHNICAL PARAMETERS OF FLY ASH

Nam of indicator	Results (%)	Standard 10302:2014 (%)
Total content of SiO_2+Al_2O_3+Fe_2O_3	82.9	≥ 45
The content of sulfur and sulfur compounds converted to SO_3	0.03	≤ 6
Free calcium oxide content CaO	0.02	≤ 4
The loss content when heated	8.3	≤ 15
Harmful alkali content (soluble alkali)	< 0.01	≤ 0.1

C. Cement

Nghi Son Portland cement PCB40 was used with the following mechanical properties: actual strength 40Mpa and density 3.1g/cm^3.

D. Coarse Aggregates

1) Natural Coarse Aggregates

Natural coarse aggregates were mixed with the recycled materials. In this study, aggregates of the most common size used in construction (20mm) have been used. The aggregates have the following mechanical properties: 2.61g/cm^3 density and 1430kg/m^3 volumetric mass.

2) Recycled Aggregates

The obtained concrete waste after the demolition of a project was crushed. The resulting coarse aggregates were washed, dried, and pre-screened to remove dust particles. Raw aggregates were screened to classify the particle sizes, then mixed again to be graded as standard for concrete in accordance with the provisions of Vietnamese standard No. 11969: 2018. The recycled coarse aggregate composition according to sieve analysis can be seen in Table II. To avoid strongly absorbing recycled aggregates, affecting the setting of recycled concrete, the coarse aggregates before being mixed were soaked in water in order to absorb it. These aggregates were then let to dry under normal conditions.

Fig. 2. Recycled coarse aggregates.

E. The Recycled Concrete

It is difficult to design high-grade recycled concrete. Therefore, in this study, the designed recycled concrete has design compressive strength of R_n=15Mpa, equivalent to grade 150 concrete. The design slump is 7cm. The composition of the mix of 1 batch of 1m^3 of concrete is shown in Table III.

TABLE II. GRANULAR COMPOSITION OF THE RECYCLED COARSE AGGREGATES

Sieve size	Quantity of sample per sieve (g)	Separate amount of residue on the sieve (%)	Amount accumulated on the sieve (%)	The amount accumulated on the sieve according to the standard
40mm	0	0	0	0
20mm	780	7.8	7.8	0-10
10mm	4930	49.3	57.1	40-70
5mm	3740	37.4	94.5	90-100
>5mm	550	-	-	-

TABLE III. CONCRETE COMPOSITION

Mixing compositions (1m^3)			
Cement (kg)	**Sand (kg)**	**Coarse aggregates (kg)**	**Water (kg)**
243.8	674.9	1231.1	195.0
Cement (kg)	**Sand (m^3)**	**Coarse aggregates (m^3)**	**Water (lt)**
243.8	0.407	0.861	195.0

In this study, fly ash was added to the concrete composition. To find out the effect of fly ash on the compressive strength of recycled concrete, the aggregate composition of concrete was fixed. The coarse aggregates consisted of natural and recycled aggregates in 50%-50% ratio. The amount of fly ash for each sample was:

- Sample 1 (CP1): Fly ash was not used (0%).
- - Sample 2 (CP2): Fly ash with a 5% content was used.

The Laryee UH5130 (6~300kN) universal hydraulic compressor was used to measure the compressive strength of the concrete samples (Figure 3).

Fig. 3. The Laryee UH5130 universal hydraulic compressor.

The compressive strength of concrete was tested according to the Vietnamese standard No. 3118:1993. Cylindrical samples with size of D150×H300 were cast and cured in water before being compressed to determine their compressive strength. The loading speed was set to 0.5kN/s. The compressive strength after curing of the concrete samples was investigated after periods of 7, 14, and 28 days. For obtaining accurate results, the minimum number of test samples was 3 for each type (Table III).

TABLE IV. SAMPLES USED IN THE COMPRESSION TEST

No.	Description	7 days	14 days	28 days
1	CP1: 50% recycled aggregates, 0% fly ash	3 samples	3 samples	9 samples
2	CP1: 50% recycled aggregates, 5% fly ash	3 samples	3 samples	9 samples

III. RESULTS AND DISCUSSION

Table V shows the critical load values recorded in the compressive test. The compressive strengths were then calculated and the results are shown in Table VI. In order to evaluate the effect of fly ash on the compressive strength of recycled concrete, the average value, shown in Table VII, will be used.

TABLE V. CRITICAL LOAD RECORDED IN THE COMPRESSION TESTS

No.	Critical load (kN)				
	7 days	14 days	28 dasy (9 samples)		
CP1	174.77	195.80	212.23	227.96	231.67
	177.07	204.46	222.13	220.54	250.05
	173.18	211.70	230.61	213.47	259.77
CP2	191.74	229.55	248.28	251.11	259.24
	195.27	230.61	249.70	271.08	270.02
	195.80	227.25	245.99	239.45	244.22

TABLE VI. CALCULATED COMPRESSIVE STRENGTH

No.	Compressive strength (Mpa)				
	7 days	14 days	28 days (9 samples)		
CP1	9.89	11.08	12.01	12.9	13.11
	10.02	11.57	12.57	12.48	14.15
	9.80	11.98	13.05	12.08	14.7
CP2	10.85	12.99	14.05	14.21	14.67
	11.05	13.05	14.13	15.34	15.28
	11.08	12.86	13.92	13.55	13.82

TABLE VII. AVERAGE COMPRESSIVE STRENGTH

No.	Description	Compressive strength (Mpa)		
		7 days	14 days	28 days (9 samples)
CP1	50% recycled aggregates, 0% fly ash	9.90	11.54	13.00
CP2	50% recycled aggregates, 5% fly ash	10.99	12.97	14.33

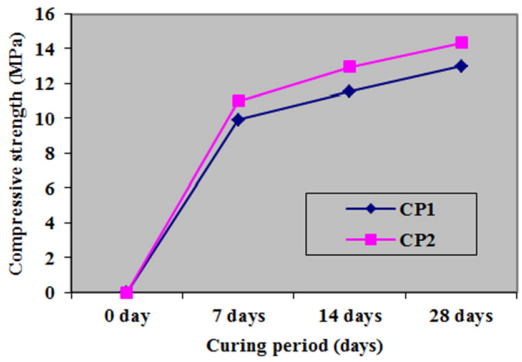

Fig. 4. Strength development of the recycled concrete.

Figure 4 shows the strength development of the experimental concrete samples of CP1 and CP2. The results show that in the first 7 days, the speed of development was very fast and gradually decreased for 7-28 days. At 7 days of age, concrete reaches 76% (CP1) and 77% R28 (CP2) respectively. Thus, it can be seen that the intensity development of the two experimental types of aggregates is relatively uniform.

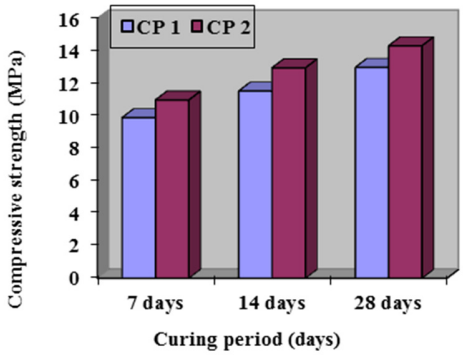

Fig. 5. Comparison of the strength of the two experimental recycled concrete mixes.

Figure 5 shows the result of the comparison of the compressive strength of the two types of the tested graded concrete samples. It can be easily seen that the strength of recycled concrete using 5% fly ash (CP2) is always higher than the compressive strength of recycled concrete without fly ash (CP1). This increase was 11% at 7 days old, 12% at 14 days old and 10.2% at 28 days old. Thus, it can be seen that the use of fly ash increases the strength of recycled concrete by at least 11%. To evaluate the compressive strength of recycled concrete, the compressive strength of recycled concrete using fly ash 5% (CP2) is compared with the compressive strength of conventional concrete by design (R_n=15Mpa). The result is shown in Figure 6.

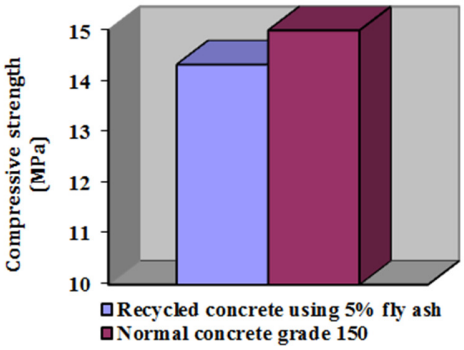

Fig. 6. Comparison of the strength of recycled concrete using fly ash with the conventional concrete.

It can be seen that when using recycled aggregates in a 50% ratio and 5% fly ash, the difference between the compressive strength between the two is not much. According to the experimental results, the compressive strength of recycled

concrete using fly ash is decreased by about 7% when compared to conventional concrete, according to the M150 design. This result is quite consistent with the results of [15], in which the authors conclude with:

- Fly ash content of 5% is the most optimal, giving the best compressive strength results among the experimental recycled concrete mixes.
- The difference in compressive strength between conventional and recycled concrete using 5% fly ash is 11%.

Authors in [12] investigated the use of 30% fly ash as a partial substitute of Portland cement for fly ash concrete production. They found that while embedding high amounts of recycled coarse aggregates could lower the resistance to chloride penetration, the carbonation of the concrete was still comparable and design strength similar to that of the control mix could still be achieved. Combined with the above analysis results, it can be concluded that it is possible to use fly ash at a higher concentration to ensure the compressive strength of recycled concrete.

IV. CONCLUSIONS

In this study, the compressive strength of two recycled concrete aggregates, with and without the utilization of fly ash, was studied. Recycled concrete was designed with compressive strength of *Rn*=15Mpa, equivalent to M150. The ratio between conventional and recycled coarse aggregates from waste concrete was 50-50. Fifteen samples for each recycled concrete aggregate had been casted, 3 were tested at the age of 7 days, 3 at 14 days, and 9 at 28 days. The drawn conclusions from the experimental results are:

- The strength development of these two recycled concrete mixes is relatively uniform. During the first 7 days, the speed of strength development was very fast. In the period of 7-28 days, the speed gradually decreases. At 7 days of age, concrete reaches 76% R28 (with recycled concrete using no fly ash) and 77% R28 (with recycled concrete using 5% fly ash).
- The strength of recycled concrete using 5% fly ash (CP2) is always higher than that of recycled concrete without the use of fly ash (CP1). This recorded increase was 11% at 7 days, 12% at 14 days, and 10.2% at 28 days.
- The compressive strength of recycled concrete using 5% fly ash is about 7% less than the compressive strength of conventional M150 concrete. Thus, it is possible to use fly ash at higher concentrations to ensure the compressive strength of the recycled concrete.

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