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ORIGINAL RESEARCH
PAPER



Flexural behavior of external reinforced concrete beams by using waste aggregate concrete

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ABSTRACT

The influence of utilizing waste concrete aggregates on the flexural behavior of external reinforced concrete beams has been studied. Seven mixtures were prepared for this investigation where the concrete mixtures had different waste concrete percentages and admixtures. Also, seven beams were modeled by Ansys program and the properties of the seven mixtures have been used in the models to study their effects. It was found that using waste concrete aggregates has decreased the load bearing capacity and concrete ductility. It was found that the beam bearing capacity was decreased by 10.7% when using only waste concrete. Using admixtures have enhanced the concrete properties where the load capacity of beams has been increased by 39% when using silica fume and superplasticizer and the load capacity has increased by 44.6% when multi-admixtures have been used. Besides, it was found that using additives has enhanced the beam ductility significantly.

KEYWORDS

waste aggregate concrete, concrete beams, flexural behavior, load capacity

1. INTRODUCTION

Concrete reinforced with steel is considered as a high durable product that is commonly utilized in the structures. The wide expansion of buildings has led to consuming more concrete subsequently more natural materials have been exploited such as sand, gravel and stone. The consumption of these natural materials can cause sedimentation, abrasion and erosion, besides, the high energy that is utilized in the process of cement production would affect the environmental quality due to the CO₂ gas resulting from it. In order to decrease the cost of concrete and the consumption of the natural materials, many methods can be applied. One of them is the use of waste materials with concrete as coarse or fine aggregates. The use of waste materials can be beneficial and has diverse effects on concrete when it is used with it [1–7]. Batayneh and Marie showed that the compressive strength of concrete can be increased when waste glass is used with concrete while waste plastics decreases the compressive strength of concrete [8]. Some studies revealed that about 20%–53% of the compressive and tensile strength of concrete has been lost when using crushed concrete from old building as coarse aggregate with new concrete [9–12]. On the other hand, the use of crushed waste concrete as aggregate with new concrete would give strength similar to the conventional concrete strength and this depends on the original waste concrete type [13]. Besides, Ghanem H. et al. have proved in their research that the ductility and flexural toughness of concrete beams have improved when using plastic sheets in the concrete of the beams [14]. Another method of decreasing the use of concrete is eliminating the concrete from tension zones of the cross section of beams. Djamaluddin has studied the flexural behavior of beam that had no concrete at tension zones (External reinforced concrete beam,

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ERCB) [15]. In this research the flexural behavior of ERCB has been studied by using waste concrete with multi admixture such as styrene butadiene rubber, silica fume and super plasticizers.

2. MATERIALS AND METHODS

- a. **Mixture Properties and Molds:** the mixture ratio of 1:2:3 (cement: fine aggregate: coarse aggregate) has been used for both reference and waste concrete aggregate mixtures. 50% and 100% replacement of coarse recycled aggregate has been used instead of normal gravel. The w/c ratio was 0.42 for the reference mixture and then decreased to 0.3 for mixtures containing super plasticizer and styrene butadiene rubber liquid. In improved mixtures, 10% silica fume by weight of cement was used, super plasticizer was used as 1 L for each 100 kg of cement, and SBR was used as admixture of 5% by weight of cement. 100 × 100 × 100 mm cubes have been utilized, 3 for each test of compressive strength, and 100 × 200 mm cylinders for tensile strength test as splitting test. 100 × 100 × 400 mm beams have been utilized for flexural strength test.
- b. **Materials:** the properties of the fine and coarse aggregates were listed in Fig. 1 and Tables 1–3 where fine aggregates confirming zone 3 were utilized in all mixtures. The maximum size of gravel and for crushed waste concrete was specified by 10 mm for all mixtures.

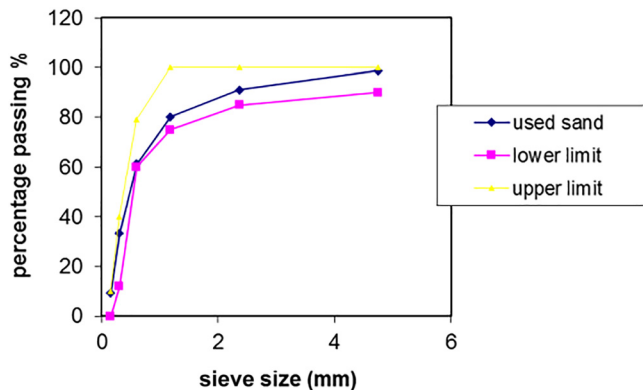


Fig. 1. Particle size distribution curve

Table 1. Fine aggregates sieve analysis confirm Indian Standards IS-383 zone 3

Sieve size	% passing by weight	Zone 1	Zone 2	Zone 3	Zone 4
10 mm	100	100%	100%	100%	100%
4.75 mm	98.7	90–100	90–100	90–100	95–100
2.36 mm	91.1	60–95	75–100	85–100	95–100
1.18 mm	80.3	30–70	55–90	75–100	90–100
600 μm	61.2	15–34	35–59	60–79	80–100
300 μm	33.3	5–20	8–30	12–40	15–50
150 μm	9.3	0–0	0–10	0–10	0–15

Table 2. Sieve analysis of normal coarse aggregates confirming 10 mm maximum size, IS-383 Indian specification

Sieve size, mm	% passing	% passing by weight, IS-383 Standards specifications
12.5 mm	100	100
10 mm	90.8	85–100
4.75 mm	13.6	0–20
2.36	3.7	0–5

Table 3. Sieve analysis of waste coarse aggregates confirming 10 mm maximum size, Indian Standards, IS-383

Sieve size, mm	% passing	% passing by weight, IS-383 specifications
12.5 mm	100	100
10 mm	89.3	85–100
4.75 mm	13.1	0–20
2.36	3.5	0–5

Super plasticizer of type IWP was utilized in improved mixtures. Silica fume with 2.2 specific gravity and grey color besides SBR liquid polymer with 1.1 specific gravity and white color were adopted in the mixtures.

- c. **Specimens:** In order to examine the effect of using waste concrete on the flexural behavior of ERCB, seven beams have been modeled in Ansys program software and then loaded till failure to study their behavior under loading. The properties of beams that Djamaluddin used in his research in 2013 have been adopted in this research where he has tested three normal beams with 2,700 mm in length and 200 × 150 mm as a cross section and he also has tested three ERCB with the same length and cross section of the normal beams with no concrete at the tension zone as illustrated in Fig. (2b and d). Reinforcement steel bars have been used in tension zone and steel stirrups have been used as shear reinforcement to avoid shear failure. Before modeling the seven models of this research, the tested ERCB in Djamaluddin research has been modeled and loaded then its results compared to the laboratory results obtained from Djamaluddin to validate the theoretical program. Figure 2 illustrates the specimens for normal and ERBC beams.
- d. **Testing Procedure:** After 28 days of curing, the cubic specimens have been tested to find the compressive strength by taking the average strength for the three specimens for each mixture type. The tensile strength was specified by using indirect test method and then by using Equation (1) below. The flexural strength was using four points load test and Equation (2) was applied. Figure 3 illustrates the four points load test and Fig. 4 illustrates the compression test.

$$F_t = 2P / \pi.D.L..... \tag{1}$$

$$F_b = P.L / b.d^2..... \tag{2}$$



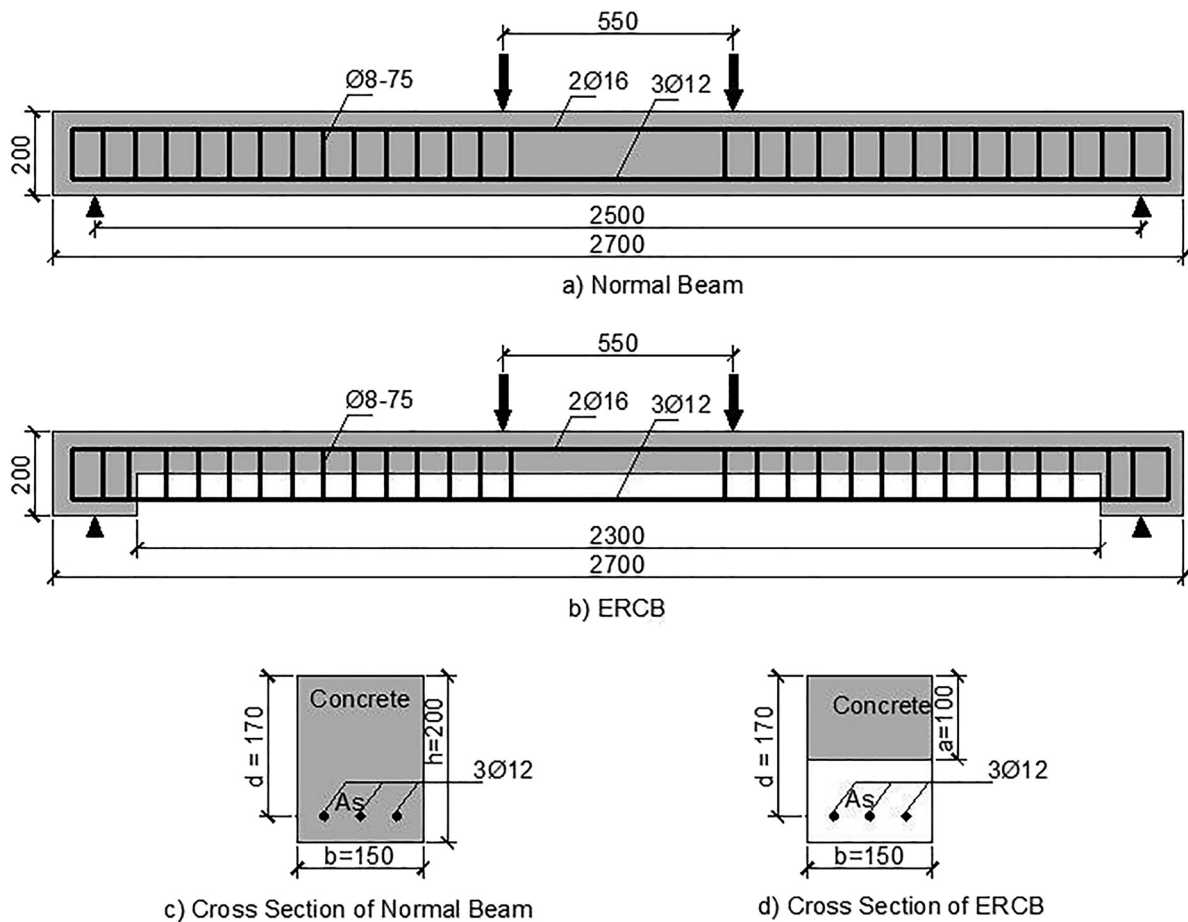


Fig. 2. Details of specimens



Fig. 3. Four points load test

3. RESULTS

The results obtained from testing the concrete cubes and cylinders have been used to find the concrete properties of the different mixture types then these properties have been used in Ansys program to examine the flexural behavior of external reinforced concrete beams by using waste concrete. Table 4 contains the obtained concrete properties.

4. DISCUSSION

The tested external reinforced concrete beam in Djama-luddin's research has been modeled in Ansys program by using the same concrete properties and loaded till failure then compared to the results obtained from Djama-luddin's laboratory work. Table 5 contains the validation results.

After the theoretical model has been validated, the concrete properties in Table 4 were used in Ansys program to model the beams then to examine their behavior. Figure 5

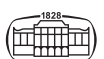




Fig. 4. Compression test

illustrates the relationship between the load and the deflection for the Ansys models.

By looking at testing results in Table 4, an increase can be noticed in concrete compression, tensile and flexural

Table 5. Validation results

	Compressive strength (Mpa)	Modulus of elasticity (Mpa)	Beam load (kN)	Mid-beam deflection (mm)
Lab. results from Djamaluddin	25	24,800	24.5	15.5
Ansys results	25	24,800	24.5	15

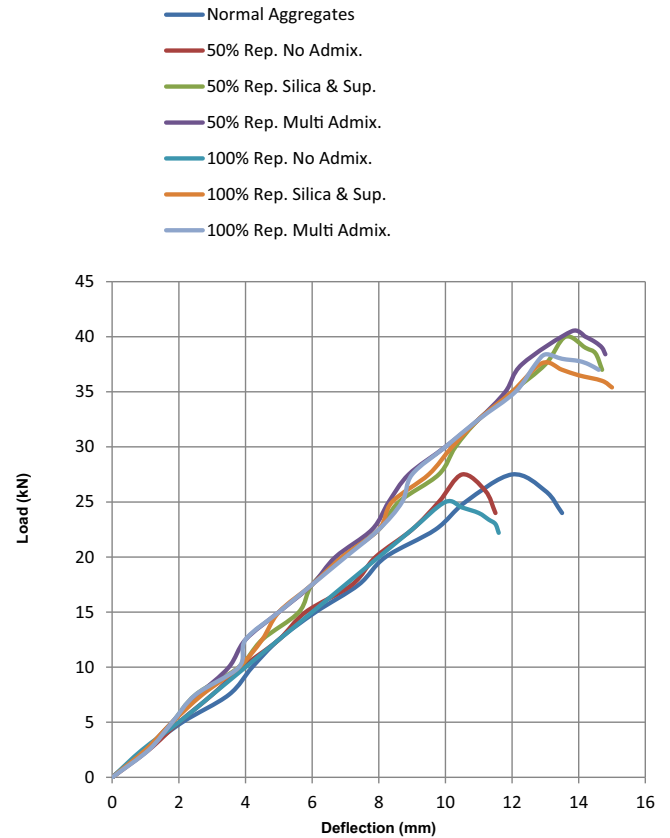


Fig. 5. Load – Deflection for Ansys models

Table 4. Testing results

Mix. No.	Mixture properties	Testing results			
		Compressive strength (Mpa)	Modulus of elasticity (Mpa)	Tensile strength (Mpa)	Flexural strength (Mpa)
Ref. Mix.	Reference mixture (Normal aggregate)	34.83	27,738	2.21	2.87
Mix. 1	Using waste aggregate as 50% replacement of whole aggregate, without additives	32.07	26,616	1.82	2.72
Mix. 2	Using waste aggregate as 50% replacement of whole aggregate with silica fume, and superplasticizer	48.80	32,590	3.37	5.47
Mix. 3	Using waste aggregate as 50% replacement of whole aggregate, and adding multi additives	50.12	33,274	4.52	8.65
Mix. 4	Using waste aggregate as 100% replacement of whole aggregate, without additives	30.20	25,829	1.80	2.54
Mix. 5	Using waste aggregate as 100% replacement of whole aggregate with silica fume, and superplasticizer	46.6	32,084	3.24	5.33
Mix. 6	Using waste aggregate as 100% replacement of whole aggregate, and adding multi additives	47.80	32,495	4.65	7.71



strengths when using additives with the mixture. This enhancement in concrete properties may be attributed to the effect of the additives on the concrete properties where using superplasticizer and SBR liquid polymer lower the water demand and silica fume leads the mixture component to be denser [16, 17]. By examining Fig. 4, it can be seen that using waste concrete aggregate as 50% and 100% replacement instead of normal aggregate without any additives decreased the bearing capacity of the beam by 3.6% and 10.7% respectively, less than the normal beam which has normal aggregate only. Besides, the failure beam deflection was less than the normal beam which means that using waste concrete aggregate decreases the beam ductility specially when replacing all normal aggregate with waste concrete aggregate. This decrease in ductility may be attributed to the small values of tensile strength of the concrete of these two mixtures. This decrease has influenced the concrete behavior under tension negatively by increasing the concrete cracks which led to speeding up the failure.

Adding silica fume and superplasticizer to the concrete mixture has enhanced both the bearing capacity of the beam and the beam ductility when waste concrete aggregate has been used. It is obviously clear that using 50% and 100% of waste concrete aggregate instead of normal aggregate has increased the bearing capacity of the beam by 39.3% and 34.3% respectively. Besides, both beam models have failed at high value of deflection in comparison to the deflection failure of the normal model. All of the testing values for the concrete mixture were high in comparison with the normal mixture which resulted in enhanced behavior of the beam model as mentioned earlier.

The other two beam models had properties of the mixture with multi admixture. These two models had also high values of both bearing capacity and failure deflection. It can be noticed that beam bearing capacity has increased with 44.6% and 37.1% when 50% and 100% of waste concrete aggregate has been used instead of normal aggregate respectively. Although, the flexural strength of the mixture used in these two models were the highest in comparison with the others, the beam behavior was not different from other models as much as the flexural strength differed. This point gives an overview on how the concrete properties affect the beam behavior.

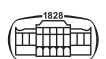
5. CONCLUSIONS

In this research, the effects of using waste concrete as aggregates on the behavior of external reinforced concrete beam have been studied. It was found that when using waste concrete aggregate as 50% replacement from normal aggregate, the tensile and flexural strengths of concrete have been decreased and consequently the load bearing capacity of the beam decreased by 3.5% besides the beam behavior showing less ductility. Adding silica fume and superplasticizer has increased the beam load capacity with a ratio

of 39% and enhanced the beam ductility. The maximum increase in the load beam capacity was 44.6% when multi-admixtures have been used with this mixture. Replacing all normal aggregate with waste concrete for the concrete has decreased the tensile and flexural strengths of concrete more than using waste concrete as 50% replacement from normal aggregate and the load bearing capacity of the beam decreased by 10.7%. Using silica fume and superplasticizer has increased the load bearing capacity of the beam by 34.3% while it was 37.1% when multi-admixtures have been used with concrete and also the tensile and flexural strengths of concrete have been increased with different percentages which resulted in more beam bearing capacity and more ductility.

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