Influence of Adding Demolition Wastes on the Mechanical Properties of Concrete in Sultanate of Oman

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Abstract

Nowadays the global trend in construction industry is to reduce the cost, saving energy and preserving the environment. Using other industries' waste material as a construction material is one of several methods followed to meet these trends. Management of solid waste is considered as one of the most significant environmental issues not only in a country like Oman, but globally as well. Around 1.7 million tons of solid waste is yearly generated in Oman. More than 120 million tons of constriction demolition waste is yearly generated over the world. Besides, 10-30 % of solid wastes produced from construction field (concrete wastes and aggregate) in Oman is just dumped in the landfill area without any further use. In this paper, the influence of replacing the demolition waste with coarse aggregate on the mechanical properties of concrete was studied in terms of compressive, flexural, and tensile strengths, and workability. The concrete properties were evaluated by replacing of 20, 30 and 40% of coarse aggregates with demolition waste in the mix proportion of C-35 concrete and the experiment's results were compared with each other as well as with the conventional one, based on two different periods of 7 and 28 days. The results were satisfactory so it could be concluded that replacing of up to 40% of coarse aggregates with construction and demolition waste is still safe and not causing dramatic reduction in the concrete strength.

Keywords: Oman; Concrete; Recycling; Construction waste; Demolition

1 Introduction

Nowadays in the developed countries, the demolition waste from construction has become a real problem and major portion of the solid waste. In addition, there is a need for several methods that either reduce the use of natural resources, reuse them, or recycle them to other materials that can be used for the same purpose or another purpose due to the continuous consuming of natural resources on the planet. Besides, there are more than 120 million tons of construction demolition waste, which is yearly generated over the world (Elchalakani, 2012; Akter & Samah, 2018). However, 10-30 % of Oman solid wastes produced from construction field (concrete wastes and aggregate) is dumped in the recognized landfill area without any further use. Besides, management of solid waste is considered as one of the most significant environmental issues not only in Oman, but globally as well. Around 1.7 billion tons of solid waste is yearly generated in Oman, which is expected to reach 2.2 billion tons

by 2025 due to the increase in Oman's population (Ithraa, 2016). Moreover, construction industry consumes huge amounts of material, water, and energy, but unfortunately, all of these resources are non-renewable natural resources such as water and rocks. In addition, the process of producing aggregate is consuming a huge amount of diesel to generate the crusher and the screen as well as the gas emission due to that (Al-Manthari, 2018). Therefore, it becomes extremely necessary to find a useful method to recycle the demolition waste (Annual sustainability report, 2020).

In this research, the influence of replacing the demolition waste with coarse aggregate on the mechanical properties of concrete will be studied in terms of compressive, flexural, and tensile strengths, and workability will be discussed.

Fig. 1: Examples of Demolition Waste from Al-Masnaah- Al Batanah Region – Oman

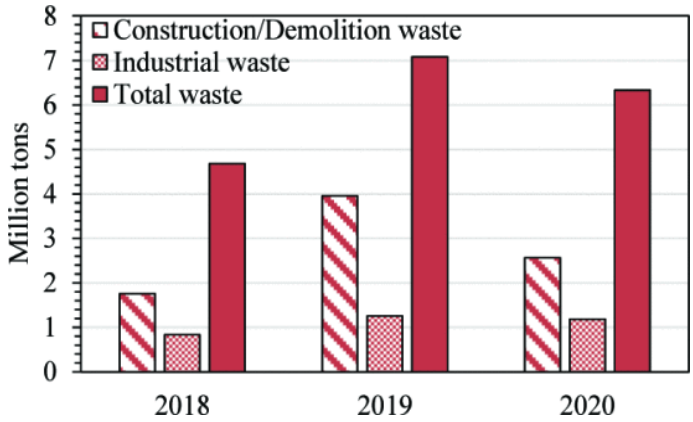

Fig. 2: Industrial and Construction Waste in Oman according to be'ah

2. Methodology

In order to complete this research and achieve its objectives, the experiments of compressive, flexural, and tensile strengths, and workability tests were performed on the concrete grade C-35 with replacement percentages of 0, 20, 30 and 40% and specimens ages are 7 and 28 days. Potable water, fine aggregate with 4.75mm particle size, 20mm crushed coarse aggregate, grade 53 ordinary Portland cement and demolition waste were crushed and sieved to obtain 20mm particles size, which are the materials used in this research. Later on, the findings were compared with the results of previous literature.

Table 1: Mix Proportions

W/C Ratio	Concrete Constituents (kg)			
	Cement	Fine Aggregate	Coarse Aggregate	Demolition Waste
0.51	411.8	698.7	889.4	0
0.51	411.8	698.7	711.52	177.88
0.51	411.8	698.7	622.88	266.82
0.51	411.8	698.7	533.64	355.76

3 Results and Discussion

The experiments had been done to find the differences between the normal concrete and replacing demolition waste as coarse aggregates or it can be called Recycled Aggregate Concrete (RAC). The demolition waste was taken from Al-Masnaah and Barka- North of Al Batinah Region – Oman. However, four experiments done are compressive strength, splitting tensile strength and flexural strength, as well as the workability (slump cone) test. The results are matching with the findings of other researches such as (Ramadevi & Chitra, 2017; Wahih, El-Karmoty, Ebid & Okba, 2013).

3.1 Compressive Strength

Test cubes were prepared for different concrete mixes with 0, 20, 30 and 40% replacement of coarse aggregates with recycled aggregates taken from demolition waste. Then universal compressive strength test was applied to the concrete cubes after 7 and 28 days. The results are shown in Table 2 and 3 and Figure 3. There is a slight decrease between normal concrete and 20% of the replacement ratio of demolition waste and there is more decreasing in 30% and 40% of replacement ratio of concrete waste. The reduction percentage after 7 days of curing was 2% between normal concrete and the 20% RAC. The normal concrete was 30 MPa and for 20% RAC was 29.4 MPa. In addition, the 30% of RAC was 24.2 MPa after 7 days of curing, and 22.9 MPa for 40% of RAC.

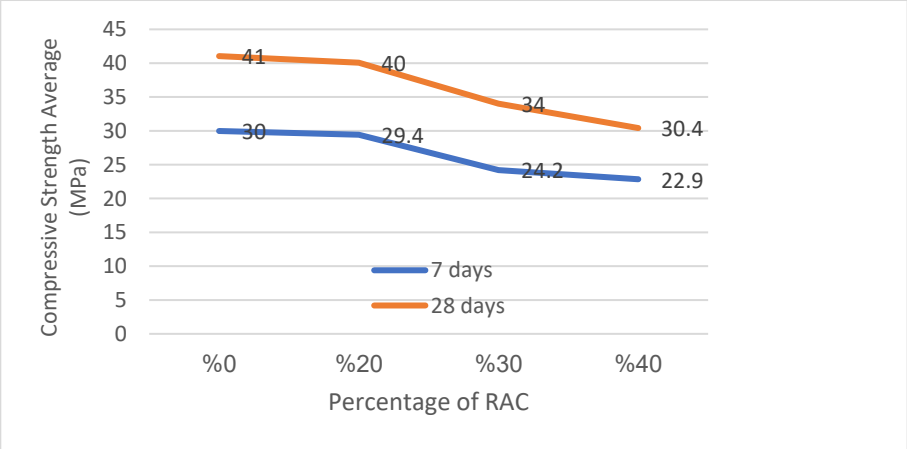

Fig. 3: Compressive Strength Results for 7 & 28 days

Table 2: Compressive Strength Results

% Demolition Waste	Testing age	Maximum Load (KN)	Compressive Strength (MPa)	Average Compressive Strength (MPa)
0%	7 Days	590.1	29.4	30
		576.7	28.8	
		583.6	30.7	

% Demolition Waste	Testing age	Maximum Load (KN)	Compressive Strength (MPa)	Average Compressive Strength (MPa)
	28 Days	689.8	39.1	41.0
		909.7	41.5	
		916.5	42.6	
20%	7 Days	680	30.2	29.4
		672.4	29.9	
		634.1	28.2	
	28 Days	900.5	40.2	38.4
		815.9	36.3	
		871.4	38.7	
30%	7 days	422	18.8	24.2
		605.2	26.9	
		606.9	27	
	28 days	773.9	34.4	34.0
		781.6	34.7	
		741.3	32.9	
40%	7 Days	517.6	23	22.8
		509.9	22.6	
		512.4	22.8	
	28 days	714.5	31.7	30.4
		662.5	29.4	
		689.5	30	

Moreover, the results after 28 days were 41.0 MPa for normal concrete, 38.3 MPa for 20% of RAC, 34.0 MPa for 30% and for 40% was 30.4 MPa. Therefore, it can be said that the results were nearly to achieve the goal of the compressive strength, which is C35, and the best percentage was20 %, which was 38.4 MPa, for 30% it was 34.03, which is close to 35 MPa. The 40% percentage of replacement ratio of demolition waste was 30.4 MPa, which is not bad and can be used for C30 concrete and lower. The quality of the concrete decreased when the percentage of the demolition waste replacement increased and by this experiment the differences of the compressive strength results for all percentages were shown, that there is a minor difference between normal concrete and other percentages of replacement ratio of demolition waste. The results show that demolition waste can be used as coarse aggregate in the concrete, especially for lower grades of concrete.

3.2 Splitting Tensile Strength

Concrete cylinders were cast also to test the tensile strength of concrete. The splitting tensile test had been done and as it is shown in Tables 4, 5 and Figure 3; that the normal concrete has 14.6 MPa splitting tensile strength after curing 28 days and according to BS 81I0; the concrete tensile strength has good reasonable value as well as the 20% of Recycled Aggregate Concrete, which was 14.3 MPa. Moreover, the results of 30% and 40% were 14.0 MPa and 13.5 MPa, respectively. It can be said that there is a minor decrease between the normal concrete and the other percentages of recycled aggregate concrete.

Table 3: Splitting Tensile Results

Percentage of RAC	Testing Age (Days)	Maximum Loads (KN)	Splitting Tensile (MPa)	Splitting Tensile Average (MPa)
0%	28	249.7	14.1	14.6
		251.9	14.8	
		254	14.8	

Percentage of RAC	Testing Age (Days)	Maximum Loads (KN)	Splitting Tensile (MPa)	Splitting Tensile Average (MPa)
20%	28	250	14.1	14.3
		270.7	15.3	
		234.5	13.5	
30%	28	232.6	13.2	14.0
		264.2	15	
		248.6	14.0	
40%	28	237.5	13.4	13.5
		240.5	13.6	
		238.4	13.5	

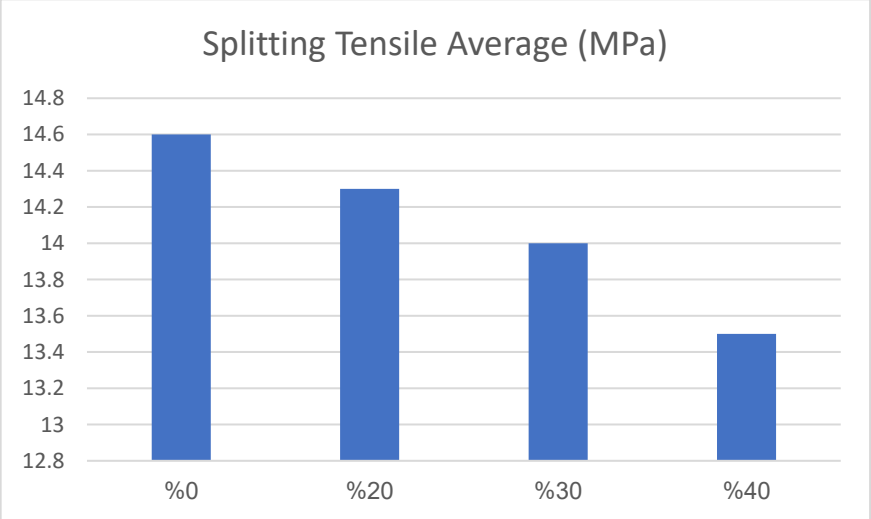

Fig. 4: Splitting Tensile Results for 28 days

3.3 Flexural Strength

In order to determine the flexural strength, 12 prisms, three from each percentage had been cast and cured for 28 days. As it is shown in Tables 6, 7 and Figure 5; the normal concrete has 15.7 MPa of the flexural strength and the 20% of recycled aggregate concrete was 14.4 MPa of the flexural strength. Where for 30% and 40% of recycled aggregate concrete it had a minor difference with normal concrete, the 30% of recycled aggregate concrete has 13.8 MPa of the flexural strength. Figure 5 is clearly showing the drop of the strength of the concrete when the percentage of the recycled aggregate concrete increases. The experiment's results show that the best percentage is 20%, which has 14.4 MPa, that is nearly same to the normal concrete quality, and it can be said that the results were nearly to achieve the goal of the strength. Generally, the results show that demolition waste can be used as coarse aggregates in the concrete especially for grades lower than C30.

Table 4: Compressive Strength Results

% of RAC	Testing Age (Days)	Maximum Loads (KN)	Splitting Tensile Average (MPa)
0%	**28**	15.76	15.7
		15.89	
		15.53	
20%	**28**	15.57	14.4
		13.03	
		14.73	

% of RAC	Testing Age (Days)	Maximum Loads (KN)	Splitting Tensile Average (MPa)
30%	**28**	14.30	13.8
		13.33	
		13.86	
40%	**28**	13.92	13.3
		13.03	
		12.89	

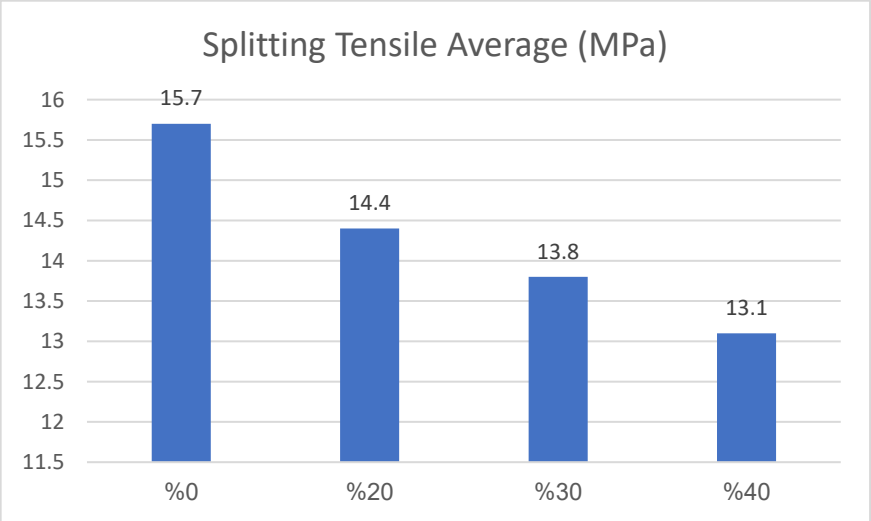

Fig. 5: Flexural Strength Results

4 Conclusion

The aim of this paper was to find a cheap and environmentally friendly concrete by using Recycled Aggregate from demolition waste. In this paper the mechanical properties of the concrete had been discussed such as compressive strength, flexural strength and splitting tensile strength. These experiments were done to check the differences between normal concrete, after replacing Recycled Aggregate Concrete. The demolition waste was taken from Be'ah plant-Barka – Oman.

In compressive strength test, there was a slight decrease between normal concrete and 20% of replacement ratio of demolition waste, which has been used as coarse aggregates and there is a decrease in 30% and 40% of replacement ratio of concrete waste. The quality of the concrete decreased when the percentage of the demolition waste replacement increased and by this experiment, the differences of the compressive strength results for all percentages were shown, that there is a minor difference between normal concrete and other percentages of RAC. The splitting tensile test had been also done and the results were shown that the normal concrete has 14.6 MPa of the splitting tensile strength after curing 28 days and according to BS 8110 the concrete strength has a reasonable quality as well as the 20% of Recycled Aggregate Concrete has 14.3 MPa, which is nearly same. Moreover, the results of 30% and 40% were 14.0 MPa and 13.5 MPa of the splitting tensile strength after curing 28 days. The quality of the concrete decreased when the percentage of the demolition waste replacement increased and by this experiment the differences of the strength results show that the best percentage is 20% which is has 14.3 MPa, which is nearly same to the normal concrete quality.

To test the flexural strength, the prisms had been casted and cured 28 days. The flexural strength of the normal concrete has 15.7 MPa and for the 20% of recycled aggregate concrete was 14.4 MPa, which is nearly same to normal concrete. Moreover, the 30% and 40% of recycled aggregate concrete had a minor difference with normal concrete. The 30% of recycled aggregate concrete has 13.8 MPa of the flexural strength. The results show that demolition waste can be used as coarse aggregates in the concrete. The workability of the concrete was tested using slump test. The result was 50 mm for normal concrete. The workability of the concrete with demolition waste was less than the workability of normal concrete. The result of first percentage which is 20% of recycled aggregate concrete was 42 mm which is less than normal concrete by 8 mm. The concrete which has 30% of recycled aggregate concrete was found 37 mm. There is a dropping in the workability of the concrete between the normal concrete and the re-cycled aggregate concrete. Generally, it can be concluded that 20% of coarse aggregates can be replaced in confidence with demolished grounded waste for C30 and C35 concretes. 30% and 40% can be used also for concrete of grades less than C30. For higher percentages of coarse aggregate replacement or higher grades of concrete, it should be tested before deciding to use such replacements.

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