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Examining the Variability of Recycled Concrete Aggregate Properties

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Abstract: *Agencies concerned with the maintenance of concrete structures in the UAE are aware of the substantial increase in repair work in recent years. This can be attributed to the fact that many structures are now either reaching the end of their design life or the rapid deterioration due to loading and harsh environmental conditions. Such cases usually result in huge amount of concrete rubbles that are routinely discarded. Hence, there is a need to study the potential of using recycled concrete in new construction projects. This may lead to lower construction costs and savings in natural resources.*
Using Recycled Aggregates (RA), as a partial or full replacement of natural aggregates, may improve the sustainability of constructed projects. However, properties of the RA depend on the source of the parent aggregate, loading and exposure conditions. Such variability is a major concern to most of the contractors, governmental agencies, aggregate providers, and professional engineers. Therefore, this study focuses on the variability in the properties of RA produced from recycled concrete. Samples were collected from different batches, which are produced by a local recycling plant, over 1 year to monitor the variability in physical and mechanical properties of RA. One sample of natural aggregate was evaluated to serve as a bench mark for comparing the results obtained for RA. Properties included in the experimental work are variability in aggregate size (20 mm and 10 mm), shape and texture, gradation, specific gravity, water absorption, and crushing value. The conclusions based on the results from different batches showed some variation in the RA properties. The specific gravity was in the range of 2.35 to 2.47, the water absorption varied from 2.8% to 5.9%, the loss in the Los Angeles (LA) abrasion test showed a range of 25% to 35%, and the crushing value was almost (19%-26%). The obtained results are comparable with results reported in other studies in different parts of the world.

Keywords: *Recycled Concrete, Recycled Aggregate, and Aggregate Properties*

1. Introduction

A large number of structures that were built in the Gulf region during the 1970s are now in need of either major repairs or replacement. The main reasons for repairing or replacing a building can be attributed to the fact that the building is reaching the end of the design life, may not have been constructed according to the specifications, or did not receive the required maintenance while in service. New zoning laws in large urban areas have also contributed to the premature replacement of adequately performing buildings. The repair and replacement activities, as well as precast plant rejected units, result in large quantities of construction waste that are usually dumped in landfills or sent to a waste management facility. Fig. 1 shows construction rubble dump site in Sharjah.

Fig. 1 Construction rubble dump site in Sharjah.

Concrete rubbles generated from demolition works constitute a substantial proportion of the waste quantity. They yield fragments in which the aggregate is contaminated with hydrated cement paste, gypsum, and minor quantities of other substances. Since aggregate makes up most of the concrete by volume, utilizing concrete waste as aggregate in new concrete will contribute to preservation of natural resources, in addition to lower environmental pollution and reduction in valuable landfill space.

One of the key issues that obstruct the introduction of recycled aggregate into the construction industry is the difficulty of having a steady source that provides recycled aggregate with comparable characteristics. However, aggregate properties depend on the demolished structures, which are exposed to different loading and environmental conditions. Therefore, it is necessary to establish procedure to evaluate the aggregate properties for concrete production.

2. Literature Review

Past experience has shown that crushed concrete is an important resource that can be reliably recycled back in construction. Crushing of concrete yields dust, fines and chunks of concrete, which can be utilized in various applications. For example, the recycled concrete can be utilized in base and sub-base layers under pavements, in the making of curb blocks and parapets, or for structural applications based on the gradation and quality of the recycled aggregate. Sharjah's Bee'ah Waste Management Complex produces dust, fines and masses of concrete. Previous studies on the possible usage of such material in nonstructural and structural applications are summarized below.

2.1. Physical Properties of Recycled Aggregate

The use of recycled aggregate has been considered by several researchers. For example, Poon [1] reported that the absorption level is significantly affected by the amount of mortar surrounding the recycled aggregate. On the other hand, the quantity of mortar around the recycled aggregate was indirectly proportional to density. According to Ravindrarajah et al [2], the water absorption in recycled aggregate was about 6.35% whereas in natural aggregate it was 0.9%, based on tests conducted on 15 samples. Furthermore, another research claims that the recycled concrete aggregate used in Australia was found to have lower specific gravity (2.44 – 2.46) and higher water absorption (4.5-5.4) than most natural aggregates [3]. According to Yehia et al. [4], concrete produced with recycled aggregate can be affected by the variations in the recycled properties due to many factors. These factors include different environmental conditions, the type of loading and the process of crushing the concrete underwent, and the availability of the contamination. The study by Yehia et al. [4] revealed that the mortar attached to recycled aggregate resulted in lower density, high absorption, and high L.A. abrasion loss.

2.2. Properties of Concrete Produced by Recycled Aggregates

The effect of recycled aggregates on concrete properties has been evaluated in different parts of the region. The majority of the studies considered the concrete strength, durability of concrete, and failure mechanism. Such studies were conducted in Saudi Arabia [5], Kuwait [6 – 8], and UAE [9]. In general, the use of recycled aggregate in concrete has a negative effect on the strength of the produced concrete, as indicated in most of the studies. However, the results of the mentioned studies indicated that an acceptable concrete strength, according to the ACI standards, can be achieved, even when using 100% recycled aggregate [5 – 9]. Some other studies [10, 11] concluded that the use of admixtures or silica fume can improve the concrete strength, when using recycled aggregates. The concrete strength, after using admixtures, showed values that are very close to those of the concrete made with natural aggregates. However, the results showed by Gull [12] were in contradiction with this conclusion. Another study, in UAE, considered the combined effect of using recycled aggregate and recycled water on concrete strength and durability [13]. The conclusions showed that the effect of using recycled aggregate and recycled water has higher effect on durability, which can be improved through adding more components to the concrete mix; such as blast furnace slag and fly ash [13]. Some other studies investigated the possibility of using recycled aggregate as a subbase layer in road construction [14, 15]. The authors concluded that the recycled aggregate resulted in a lower deflection. In Kuwait, some research efforts [16, 17] proposed using recycled aggregate in producing sand lime brick. These studies showed that the produced bricks, produced from recycled aggregate, can achieve the required standards.

3. Experimental Program

The main goal of the experimental program is to evaluate the variability in coarse recycled aggregate properties as compared to natural aggregate. Fig. 2 summarizes the various physical and mechanical properties to be examined for recycled and natural aggregates according to ASTM specifications. The recycled aggregate samples were collected from a local recycling plant in Sharjah (Bee'ah recycling plant). In order to investigate the variability in recycled aggregates, eight patches were obtained from the recycling plant during different times of the year. Four of the batches contained a maximum size of 20 mm and the rest contained a maximum of size 10 mm aggregate.

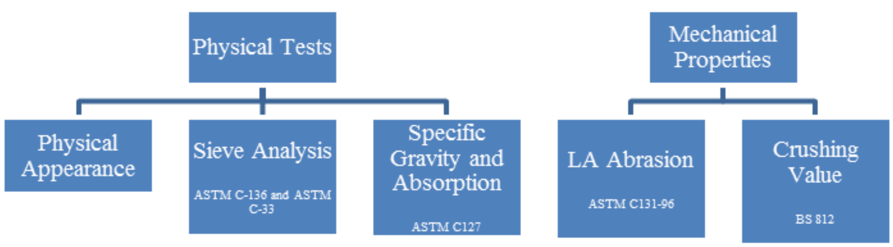
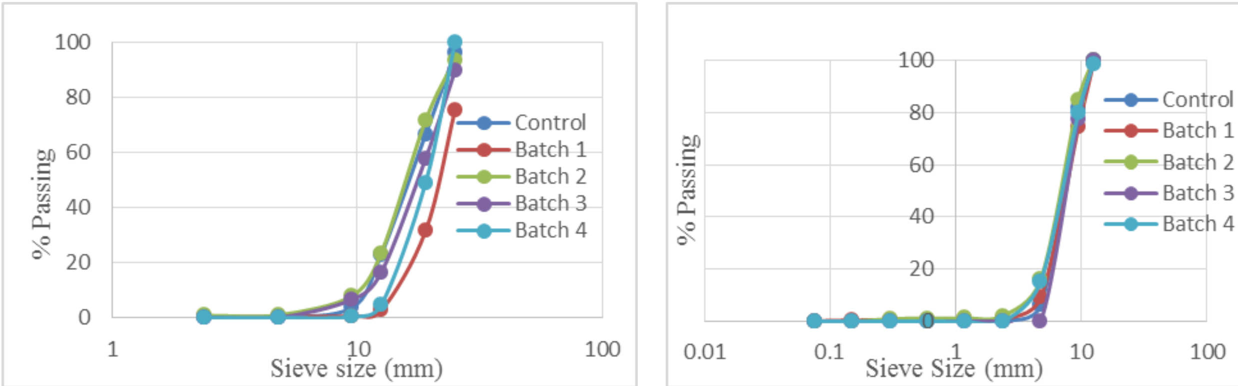


Fig. 2 Experimental Program

4. Results, Analyses, and Discussion

All the collected batches were manually checked to exclude any contaminants (such as; plastic, wood… etc.). The percentage of contaminants ranges from 1.4% to 2.6 % for the collected batches.

To evaluate the size distribution for all batches, the sieve analysis results were obtained as shown in Fig. 3. Each set of batches (10 mm and 20 mm sizes) are compared to the natural aggregate results (control).



a) 20 mm b) 10 mm

Fig. 3 Sieve Analyses Results

As shown in Fig. 3, the gradation for recycled aggregates is very similar to that of the natural aggregate, with few minor difference recognized in the 10 mm size batch 1. However, the difference does not seem to be a significant difference in gradation. For the 20 mm size batches, the gradation is almost identical to that of the control batch (natural aggregate).

In addition to the gradation, the following tests have been carried out to compare the properties of recycled aggregates to the natural aggregate:

Specific Gravity: The recycled aggregate batches resulted in a slightly lower bulk specific gravity than the natural aggregate. The range of the bulk specific gravity for recycled aggregate is (2.3 - 2.6) while the value for the natural aggregate is (2.6). Furthermore, the apparent specific gravity ranged from 2.6 to 2.7 for recycled aggregate, which is also less than the value for the natural aggregate (2.72).

Water Absorption: The water absorption in recycled aggregate showed a higher value than that for the natural aggregate. The water absorption for recycled aggregate ranged from 2.8% to 5.9%, which is significantly higher than the value for natural aggregate, which ranges from 1.4% to 1.7%.

Similar results were reported in previous studies [7, 8], who indicated that the water absorption is considerably higher in recycled aggregate, but the specific gravity is smaller. He also concluded that the percentage of water absorption for recycled aggregate is about 3.5% higher than that of natural aggregates.

LA Abrasion is a value that indicates aggregate toughness and abrasion characteristic. The natural aggregates usually show better performance than recycled aggregates because of the mortar, which is covering the recycled aggregates, as it breaks off easily. The percentage loss for recycled aggregates is about 25% to 35%, which is higher than the range for natural aggregates (19%-25%).

Table I provides a summary of the test results for natural and recycled aggregates.

Table 1: Summary for Physical and Mechanical Properties

Batch	Aggregate		Physical Tests			Mechanical Tests	
	Type	Size	Bulk Specific Gravity	Apparent Specific Gravity	Water Absorption	L.A. Abrasion	Crushing Value
Control	Natural Aggregates	20 mm	2.6	2.72	1.4	19.1	19.6
		10 mm	2.5	2.72	1.7	24.6	19.5
Batch 1	Recycled Aggregates	20 mm	2.4	2.7	4.7	31.9	24.1
		10 mm	2.3	2.7	5.6	27.3	21.6
Batch 2		20 mm	2.5	2.7	5.0	31.3	25.4
		10 mm	2.5	2.7	2.8	24.5	22.7
Batch 3		20 mm	2.3	2.7	5.9	30.8	20.1
		10 mm	2.4	2.7	4.3	20.6	19.2
Batch 4		20 mm	2.6	2.7	4.4	26.4	16.1
		10 mm	2.4	2.7	3.6	35.0	26.3

The values shown in Table 1 indicate that the properties of recycled aggregates are different than those of natural aggregates. However, there are no specification requirements for accepting recycled aggregate, which is the following step of this research effort.

5. Conclusions

Table 2 provides a comparison between the experimental results of the current study and those found in the literature.

Table II Comparison of the results

RA properties	Experimental results	Previous research results [2 – 4, 7, 8]	Conclusion
Physical appearance	Contamination ranges from 0.015% to 0.025%	____	Contamination percentage is less than 0.05%
Sieve analysis	Well graded, but graph shape slightly differs from control unit	Well graded, but graph shape slightly differs from control unit	RA gradation is well graded regardless of location
Specific gravity	Ranges from 2.6 to 2.7	Ranges from 2.44 to 2.46	Slightly higher difference due to sources variation yet
Water absorption	Ranges from 2.8% to 5.9%	Ranges from 4.5% to 5.4%	Larger range, due to sources variation
LA abrasion	Ranges from 25% to 35%	Ranges from 27% to 35%	Within the range
Crushing Value	Ranges from 19% to 26%	Ranges from 15% to 25%	Within the range

It appears from the summary results that the variation in the recycled aggregate properties is not dependent on the batch. Accordingly, the local recycled aggregate is showing consistent properties with the results of previous research. Therefore, there is a need to develop criteria for accepting the local aggregate to replace natural aggregates in some construction projects.

6. Acknowledgements

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