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Potential of Using Recycled Aggregate with Treated Wastewater as Road Base Material

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Abstract. Demolition of old or unsafe concrete buildings is a common practice in many countries which results in a huge volume of aggregate wastes. The disposal and dumping of the produced waste aggregates in the open land resulted in several negative environmental impacts. Also, urban expansion has resulted in the production of large volumes of wastewater which is usually treated for non-domestic uses such as for irrigation and agricultural purposes. The treated wastewater (TWW) may also be used in civil engineering projects to replace millions of gallons of fresh water that are used in many applications. This paper compares between the effect of using tap water and treated waste water on some mechanical properties of recycled aggregates to be used as a potential road base material. Treated waste water was obtained from a waste water treatment plant in Sharjah, UAE, and regular tap water was obtained from SEWA (Sharjah Electricity and Water Authority). The recycled aggregate was obtained from Sharjah recycling site, and was sieved and mixed to obtain target gradation to meet ASSHTO and ASTM specifications. It was found that the CBR value of recycled aggregate prepared using TWW was slightly higher when compared with sample prepared using tap water. Additionally, the maximum dry unit weight of recycled aggregate prepared using TWW was higher than that prepared using tap water. The research result revealed the potential use of recycled aggregate with treated waste water as a road base material.

Keywords: treated wastewater, CBR, proctor compaction, recycled aggregate

1. Introduction

Water shortage is one of the most critical problems in the world. In the Middle East, the average amount of fresh water available per person is less than 50 m^3 per year (Silva and Naik, 2010), and due to the excessive consumption of fresh water, it is expected that countries of the Middle East and North Africa will suffer from chronic water scarcity by 2025 (Barceló and Petrovic, 2011). As a result, millions of gallons of wastewater are produced annually which cause environmental and health problems when disposed in the sewer system and finally to the natural environment. Worldwide, more than 368 km^3 of wastewater are collected every year out of which only 160 km^3 are treated before disposal and 7.1 km^3 are reused. Therefore, several countries have started to reuse treated wastewater as an alternative water source. The most common water reuse practices are in agriculture, landscape irrigation, groundwater recharge, non-potable urban uses for fire protection, air conditioning, toilet flushing, industries for cooling, boiler feed, and heavy construction (Barceló and Petrovic, 2011). In the UK, the construction industry contributes to half of the water consumption (HM Government, 2008) and over one trillion gallons of water are used in concrete making alone worldwide, excluding wash water and curing water (Silva and Naik, 2010). Consequently, in an attempt to reduce the impact of the construction industry on water scarcity and to help minimize the negative impacts on the environment, some research has been conducted on the potential of reusing treated wastewater in concrete making and for other construction purposes. Several studies have shown that concrete prepared using recycled water or treated wastewater exhibits the same characteristics as concrete made with fresh water (Chini and Mbwambo, 1996, Rickert and Grube, 2003, Al-Ghusain and Terro, 2003, Silva and Naik, 2010). However, there is very limited research on the use of treated wastewater in the construction of pavements. A study by Mahdy and Kandil (2012) indicated that reclaimed water is suitable for use in the compaction of unbounded road materials and it was shown that the reclaimed water enhanced the California Bearing Ratio of the compacted materials, in some cases. Another study by Chola et al. (2015) showed that concrete mixed with the effluent from wastewater treatment plants for use in pavements had compressive strengths that are not statistically different from the compressive strengths of the control specimens, at 95% confidence interval.

2. Objective

The objective of this study is to examine the effects of using treated wastewater on the properties of recycled aggregates for potential use as road base material.

3. Laboratory Testing Program

3.1. Properties of used water samples

The wastewater samples used in this study were obtained from wastewater treatment plants in Sharjah and Dubai Emirates and a regular sample of tap water was obtained from SEWA municipal water. Chemical analyses tests were conducted on the water samples and the results are summarized in Table 1. Overall, it can be noted that the two treated wastewater samples met all the specification of ASTM C 94 and the United States Environmental Protection Agency (EPA) guidelines.

Table 1: Chemical Analysis Test Results on Water Samples

Test	**Test Method**	**Tests Results**		**USEPA Guidelines**	**ASTM Specifications**
		Tap Water	**Sharjah TWW**		
Total Dissolved Solids (mg/L)	APHA 2540 C	170	670	-	< 50000
Total Suspended Solids (mg/L)	APHA 2540 D	12	14	≤ 30	
Chloride Content (%)	BS1377:1990 Part 3 CI. 7.2	0.01	0.01	-	< 0.05
Sulfate Content as SO_4 (g/L)	BS1377:1990 Part 3 CI. 5.5	0.03	0.1	-	< 3
pH Value at 22.3 °C	BS1377:1990 Part 3 Cl. 9	7.9	8	6-9	-
Chemical Oxygen Demand (mg/L)	APHA 5220 B	< 10	< 10	-	-
BOD 5 Days (mg/L)	APHA 5220 B	6	7	≤ 30	-
Ammonia Nitrogen as $NH_3 - N$ (mg/L)	SALICYLATE METHOD	0.01	0.01	-	-
Total Hardness (mg/L)	APHA 2340 B / IHTP 17	64	172	-	-
Calcium Carbonate as CaCO3 (mg/L)	APHA 3120 B	48	69	-	

3.2. Properties of road base material

The recycled aggregate was collected from Sharjah recycling site at Al Sagaa landfill which is managed by Bee’ah agency. Four different sizes were collected from the site; 0 to 5 mm size, 0 to 10 mm size, 5 to 15 mm size and 10 to 40 mm size. A grading curve was plotted for each size and used to finalize the mixing percentages of the target gradation. The target gradation was selected to satisfy both ASTM and AASHTO Standards. After trials and errors, the final gradation curve was obtained by mixing 25% of each size.

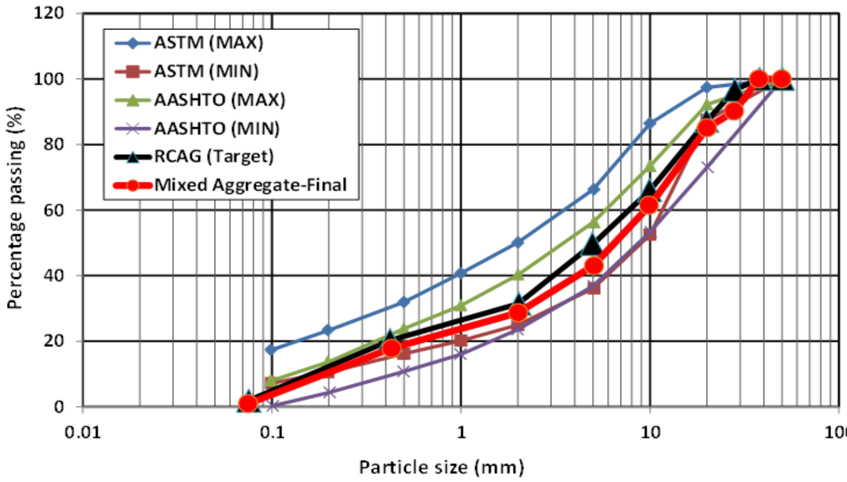

Fig. 1: Particle size distribution of the recycled aggregate

Figure1 shows the grain size distribution of the recycled aggregate used in the current study, and Figure 2 shows part of the recycling process of demolished concrete at Al Sagaa landfill site. Based on the American Association of State Highway and Transportation (AASHTO) classification system the recycled aggregate used is classified as A-1-b. Specific gravity (G_s) and absorption tests were also performed on the recycled aggregate according to ASTM standards D 792 and D 698. The recycled aggregate properties of specific gravity, absorption, angularity, permeability and AASHTO classification are shown in table 2

Fig. 2: Recycled aggregate at Al Sagaa landfill controlled by Bee'ah

Table 2: Properties of the recycled aggregate

Property	Recycled Aggregate
G_s	2.7
Absorption (%)	2.8
AASHTO classification	A-1-b
Coarse aggregate angularity (%)	100
Permeability	3.02 x 10^{-2} cm/s

4. Results Discussion

4.1. Effect of wastewater on CBR of the recycled aggregate

California Bearing Ratio (CBR) tests were conducted on the recycled aggregate prepared using tap water as well as the treated waste water. CBR tests were conducted on unsoaked samples as well as on samples soaked for 96 hours. The results of the CBR tests show that the recycled aggregate compacted with TWW had a higher CBR value than the recycled aggregate compacted with tap water as shown in Figure 3. Also, the CBR values of the tested samples decreased after the 96 hours soaking. However, the reduction in CBR was more pronounced in the samples prepared and soaked using the tap water than the samples prepared and soaked using TWW, as shown in Figure 4. The tap water results of CBR tests on recycled aggregate were also compared with the results obtained by Attom et al. (2016) that were conducted on a virgin road base material for the case of unsoaked condition. . The comparisons showed higher CBR values for recycled aggregate than the virgin road base material as illustrated in Figure 5

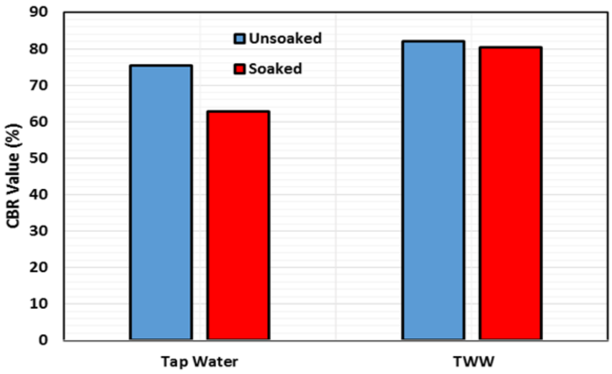

Fig. 3: CBR test results for Tap and TWW water

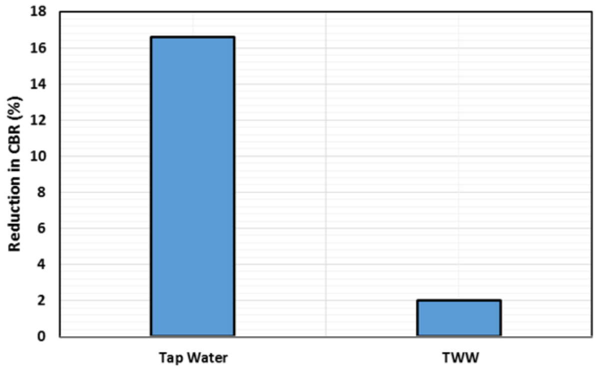

Fig. 4: Reduction in CBR due to soaking

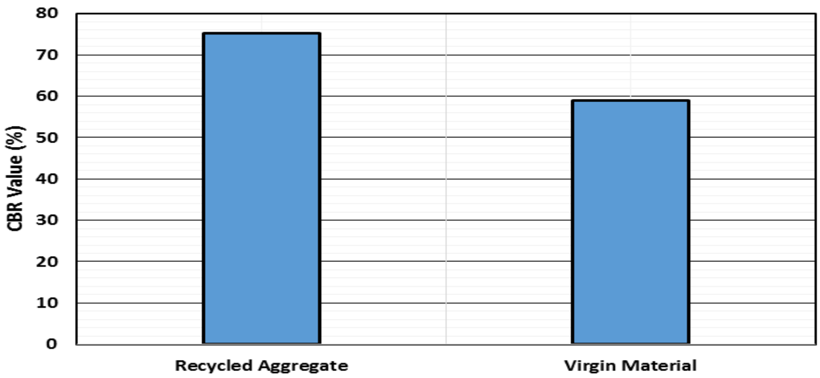

Fig. 5: CBR values of recycled aggregate and virgin material with tap water (unsoaked)

4.2. Effect of wastewater on the compaction characteristics of the recycled aggregate

Modified proctor compaction tests were conducted on recycled aggregate samples using both tap water and TWW. The modified proctor compaction curves are presented in Figure 6. The figure shows that the recycled aggregate with TWW had a slightly higher maximum dry unit weight and a higher optimum moisture content than the recycled aggregate with tap water. The percentage differences between the two different waters were more than 30 % for the optimum moisture content values and less that 5% for the maximum dry unit weigh values as shown in Figure 7.

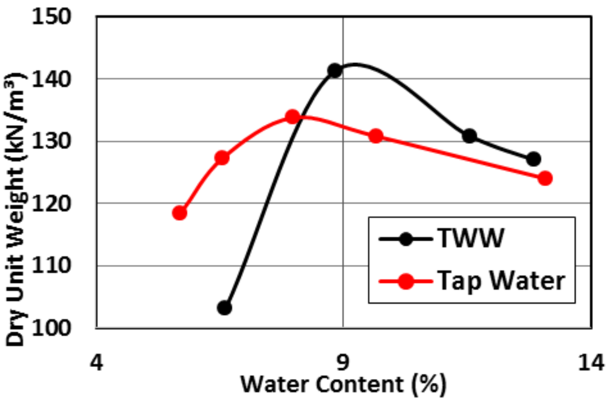

Fig. 6: Modified proctor compaction curves

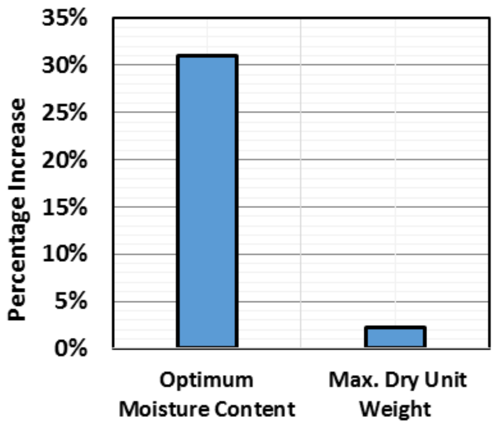

Fig. 7: Difference in optimum moisture content and maximum dry unit weight for tap water and TWW

5. Conclusion

Based on the evaluation of CBR and compaction properties of recycled aggregates treated with both treated waste water and tap water, the following conclusions can be drawn:

- Chemical analysis tests results revealed that both the treated wastewater and the tap water met all the specifications in ASTM C 94 and, therefore, it could be suitable for use in road base materials.
- The recycled aggregate compacted with TWW showed larger maximum dry density and slightly larger optimum water content compared to the samples prepared with tap water.
- The use of treated wastewater resulted in a higher CBR value than the tap water for the road base material made with recycled aggregate.
- The reduction in CBR values due to 96 hours soaking was more pronounced in the road base materials compacted and soaked using tap water than the samples prepared using TWW.
- The maximum dry density, CBR, and permeability values of the tested recycled aggregate were within the standard values specified for the road base material.

The future work proposed for this project is to investigate the effect of treated wastewater on different clay engineering properties as well as the effect of treated waste water on the compressive strength of concrete.

6. Acknowledgements

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