

Modification of roadbed soil by crushed glass wastes

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ABSTRACT

This study aims to use the crushed glass obtained from waste flasks to improve the properties of the weak roadbed soil. The study included crushing and powdering waste flasks. Afterward, the crushed glass was sieved and separated into three classes depending on the particle size: class A contains particles with diameter less than 4.75 mm and more than 1.18 mm, class B contains particles with diameter less than 1.18 mm and more than 0.08 mm, and class C contains particles with diameter less than 0.08 mm. For each of these classes, 6 different crushed glass contents were mixed with a weak roadbed soil to study their influences on its engineering properties. To attain this objective, four laboratory tests were applied: California Bearing Ratio (CBR), which determines the bearing value and the swelling ratio, triaxial compression test under cyclic loading, which determines the resilient modulus (M_R), and the Oedometer test, which determines the compressibility coefficients (C_c and C_r). The results showed that increasing the crushed glass content enhances the tightness of the roadbed soil and reduces its volume changeability. Nevertheless, the use of class C showed the highest enhancement compared to the other two classes. Compared with original roadbed soil, CBR values and resilient modulus (M_R) values of the roadbed soil samples mixed with 18% of class C of the crushed glass were increased to more than 8 times and 4 times respectively. In addition, swelling ratio, C_c , and C_r were reduced to 53%, 50%, and 35% respectively.

Keywords: Glass wastes, Resilient modulus, Swelling ratio, California bearing ratio

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1. Introduction

The pavements are the most important components of road construction [1,2,3,4]. In general, the roadbed soil characteristics govern the structure of the pavement [5,6,7,8,9]. In the construction of roadbed layer, the use of all kinds of natural materials is often considered inevitable [10,11,12,13,14,15,16,17]. As a result, improvement of the roadbed soil can improve the paving layers structure and minimize the construction costs [5,6,9]. Though the fact that soil replacement is a popular practice, it is costly and difficult [5,7,18]. Improving the weak roadbed soil with conventional materials is a useful action [19,20,21]. Nevertheless, the use of such materials is mostly costly [22,23,24,25]. At present, there is a trend in the usage of waste materials in the construction projects [8,26,27,28,29,30]. Every year around the world, huge amounts of glass wastes amass [26]. Accumulated wastes of glass are used to modify the properties of building materials [8]. However, few studies were conducted to modify the soils using glass waste; whereas, this study focus on roadbed soils. In addition, the effects of particle size of the crushed glass waste on the properties of soils were not covered to the best knowledge of the authors. Therefore, this study is novel in this field as it focus on roadbed soil layer (which was not considered in this domain) and considers the effect of the particle size of crushed glass used to modify the roadbed soil properties. This approach can assist the sustainable construction. This study aims to

investigate the influences of crushed glass obtained from wastes on the properties of weak roadbed soil. The study includes the use of three classes of crushed glass depending on predetermined particle size: class A contains particles with diameter less than 4.75 mm and more than 1.18 mm, class B contains particles with diameter less than 1.18 mm and more than 0.08 mm, and class C contains particles with diameter less than 0.08 mm. For each of these classes, 6 different preselected contents of crushed glass were mixed with a weak roadbed soil to study their influences on engineering properties. The preselected contents are 3%, 6%, 9%, 12%, 15%, and 18% from the weight of the roadbed soil.

2. Material and methods

Soil used in this research was obtained from a worksite in Baghdad, Iraq. Table 1 presents the properties of the obtained soil. From this table, we can indicate that the soil is poor to be used as a roadbed, and has high swelling potential. Therefore, modifying its properties is crucial. The crushed glass used in this study was produced from waste flasks amassed from trashes. The amassed flasks were crushed using mechanical grinders. Afterward, the crushed glass was sieved and separated into three classes (A, B, and C). A number of samples for the original soil and ones mixed with the predetermined contents of the crushed glass of the three classes (Class A, Class B, and Class C) were prepared according to the standards to investigate the influences of these contents on the properties of the modified roadbed soil. These samples were tested by the tests presented in Table 2. These adopted tests concentrate to explore the roadbed soil strength (1 and 2), and volume changeability (3, 4, and 5).

Table 1. Properties of the original soil

Property	Value	Indication
Liquid Limit	40	High swelling potential
Plastic Limit	25	
Plasticity Index	15	
Max. Dry Density	1887 kg/m ³	Reasonable
Optimum moisture content	13.95	Reasonable
Particles passing sieve No. 200	50%	Clay soil
AASHTO class	A-7-6	Poor to be used as a roadbed layer

Table 2. Tests adopted in the study

Number	Parameter	Standard	Indication
	Resilient Modulus (M_R)	AASHTO T307	Roadbed soil strength
	CBR Value	AASHTO T193	
	CBR Swelling	AASHTO T216	Roadbed soil volume changeability
	Compressibility Coefficient (C_c)		
	Recompression Coefficient (C_r)		

3. Results and discussions

3.1. CBR

CBR test can expose the capability of the roadbed soil to withstand the vetches tire stresses which control the thickness of the layers above the roadbed in the light of their elastic modulus. The test was applied in its standard form to the samples of the original roadbed soil as well as modified ones to explore the influence of the three classes (A, B, and C). The results exhibited crucial increase in CBR values in the modified samples with the increase in crushed glass content (see Figure 1). From the figure, we can discover that the finer the

particle size of the crushed glass the better the results; Class C provides the best results. When the roadbed soil is modified with 18% of class C, the CBR value heightens from 3.33% to 27.3%. This is about 8 times of the original; it is a jump in the strength of the roadbed soil enables it to support the pavements layer above it, which requires smaller thicknesses of these layers. This can vitally minimize the cost of pavements construction. The trend presented in Figure 1 can be related to four causes. First, the samples mixed with class C is denser than that mixed with the other two classes (A and B) due its relative fineness; the denser the roadbed soil the tighter the one. Second, as class C particles distributes in the soil sample in way better than those occur in the other two classes (A and B), these particles can create tighter structure. Third, because of its fineness and its uniform size of its particles, class C creates consistence soil-modifier structure. Fourth, class C increases the friction between the roadbed soil particles more than the other two classes do as a result of the larger surface area it provides compared to them.

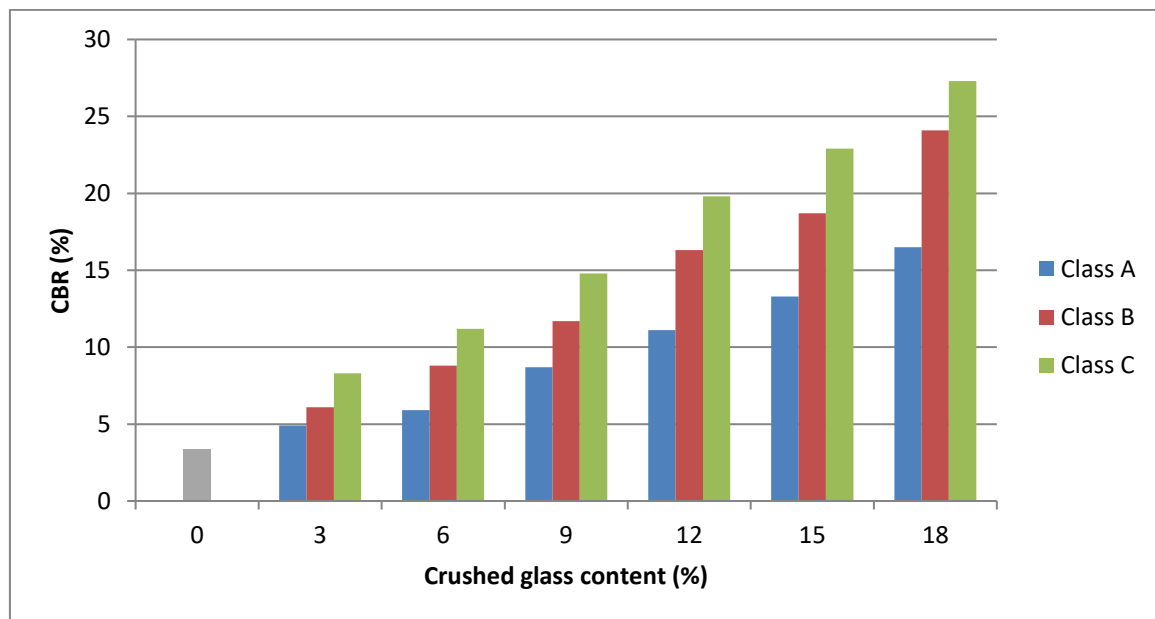


Figure 1. Influence of different contents of the crushed glass on CBR values

3.2. M_R

A sufficient number of triaxial tests under cyclic loading were applied on the samples of the original roadbed soil and samples mixed with different contents of the three class of crushed glass to explore their influences on the M_R of the roadbed soil. Figure 2 presents the results of these tests. From the figure we can notice that the M_R values follow trends similar to the ones noticed in CBR. These results can be attributed to causes similar to what explained for the CBR. As mentioned in subsection 3.1 (CBR), increasing of M_R values reflect a vital modification in the roadbed soil to withstand the traffic loading and to resist miscellaneous types of pavements distresses.

3.3. Swelling ratio

The swelling ratios of the unmodified samples and the ones mixed with class A, class B, and class C (with different contents) were specified based on standard method to explore the different in volume changeability between the different samples (see Figure 3). From the figure we can notice that the swelling ratios vitally recede when the crushed glass content is increased. The samples mixed with the three classes (A, B, and C) of the crushed glass exhibited similar manner. This manner can be related to the reduction in the clay proportion comparing to glass proportion in the mixture knowing that the clay particles with high plasticity cause the swelling in contrary with glass ones. Furthermore, the increased friction in the soil-glass mix generates further bonding that may interfere with the swelling action. The reduction in swelling ratios by adding the crushed

glass reflect the capability of the modified roadbed soil to resist the volume change which indicate a reduction in probable damages in the road pavements.

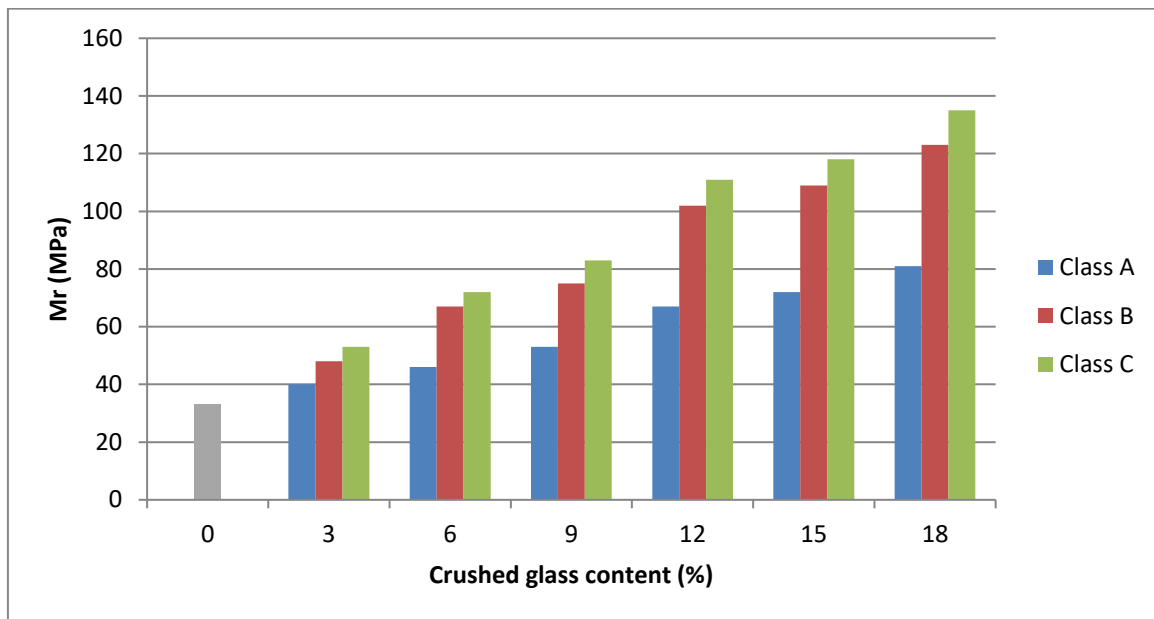


Figure 2. Influence of different contents of the crushed glass on M_R values

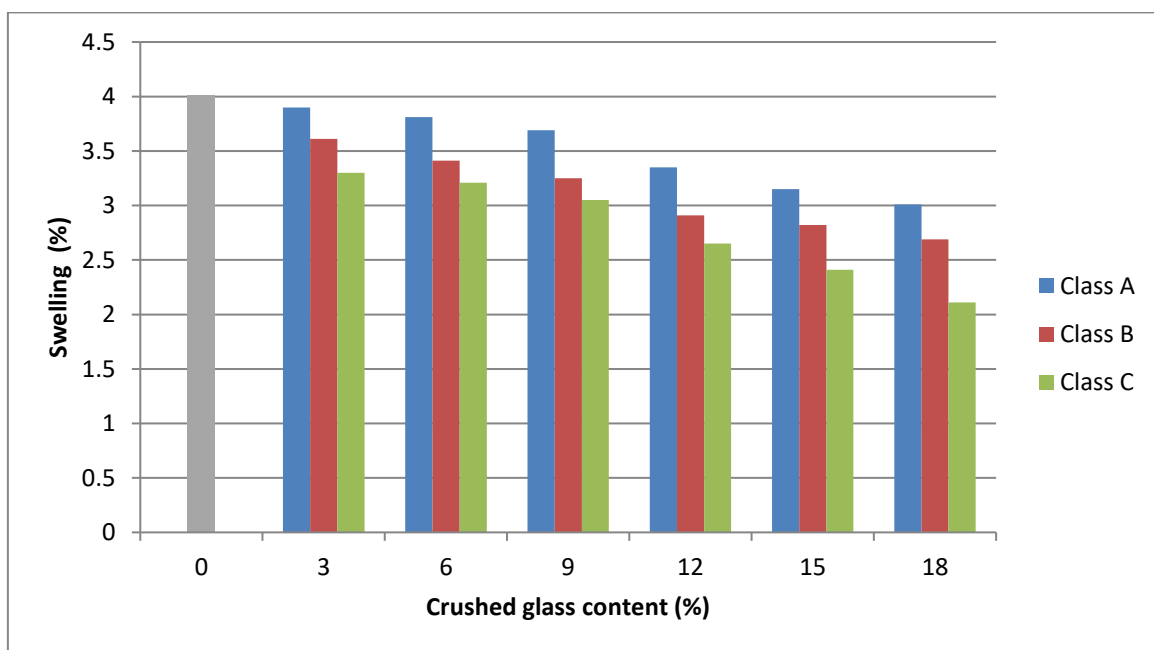


Figure 3. Influence of different contents of the crushed glass on swelling ratios values

3.4. Compressibility parameters

One-dimensional compression test was applied on the samples of the original roadbed soil and samples mixed with different contents of the three class of crushed glass to explore their influences on the compressibility of the roadbed soil. The results showed that the C_c and C_r values vitally decreased with increasing the crushed glass content as shown in Figure 4 and Figure 5 respectively. The reduction in the C_c and C_r values may relate to the properties of the glass material as it is incompressible material in contrary with the clayey soil. In addition, modification of the soil tightness as well heightening of the friction forces between the particles can reduce the compressibility of the soil. Figure 4 and Figure 5 also exhibit that the samples mixed with the finer

class of the crushed glass (class C) produced soil mixture with lowest compressibility. Two possible reasons are behind that. First, the glass particles in class C can fill the voids between the clay particles as this class has similar particles size; this action greatly decreases the compressibility which depends on voids. Second, the crushed glass in class C is more distributable than the other two classes as a result of greatest fineness which strengthen the soil. The reduction in the roadbed soil compressibility reflects a great modification in its engineering properties in terms of volume changeability which eliminates probable pavements damages as mentioned in subsection 3.3.

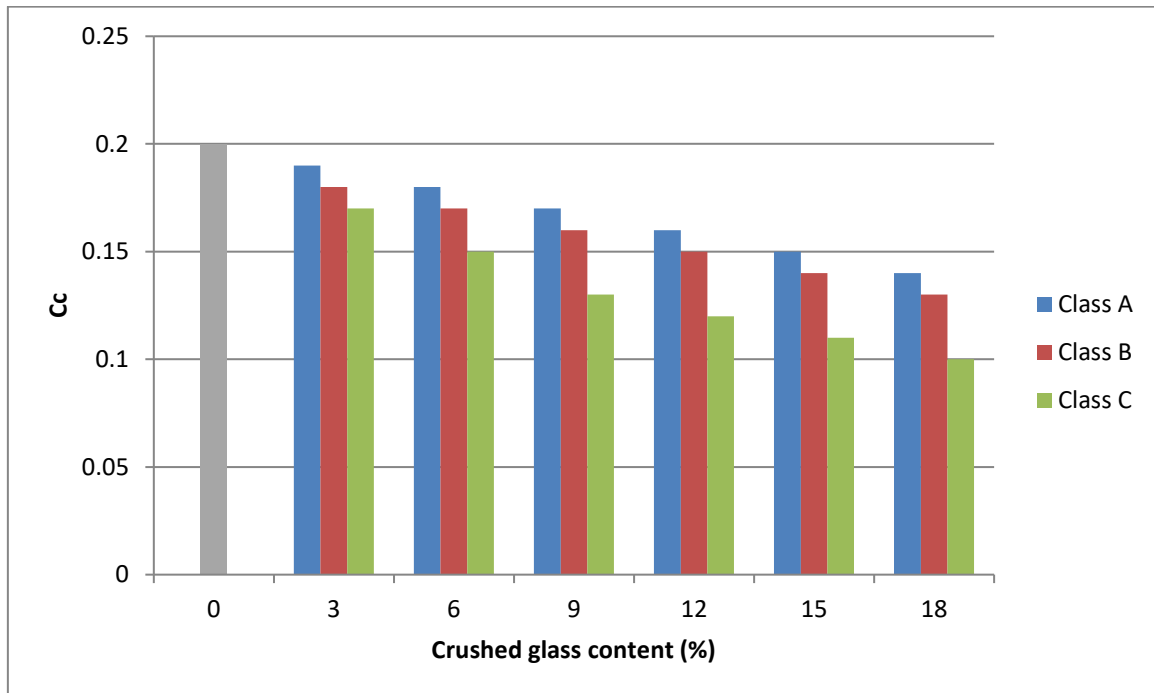


Figure 4. C_c values against crushed glass content

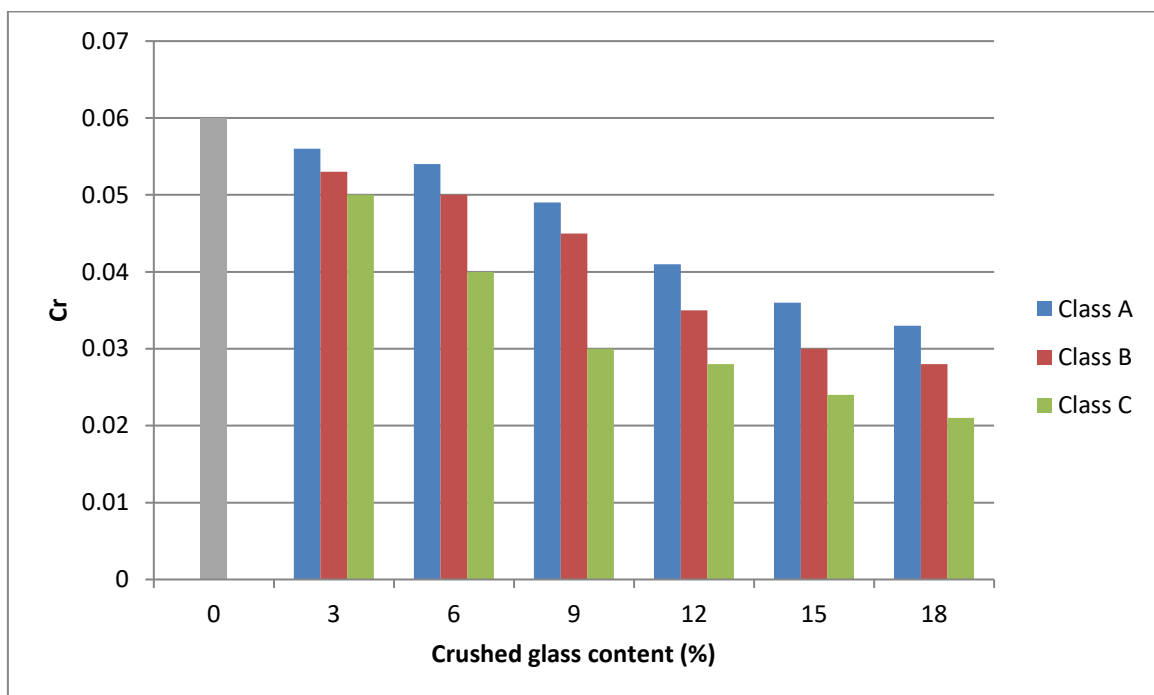


Figure 5. C_r values against crushed glass content

4. Conclusions

Using waste glass in roadbed construction can improve the environment and support sustainability. Mixing crushed glass wastes can modify the properties of roadbed soils. The flasks wastes from trash were amassed, crushed, and sieved into three classes depending on particle size; class A is the coarser whereas class C is the finer, and class B is intermediate one. Six different contents (3%, 6%, 9%, 12%, 15%, and 18%) were mixed with original soil. Generally, by increasing the content of the crushed glass, the properties were greatly improved in terms of increase in soil tightness and decrease in volume changeability. In addition, the finer class gives the best results. Regarding the samples mixed with 18% of class C (which is the best one), the following conclusions can be drawn. Compared with the original soil,

1. The values of CBR and M_R related to the modified soil were heightened to 820% and 409% respectively.
2. The values of C_c and C_r related to the modified soil were reduced to 50% and 35% respectively.
3. The swelling ratio related to the modified soil was reduced to 53%.

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