AKADÉMIAI KIADÓ

Pollack Periodica • An International Journal for Engineering and Information Sciences

17 (2022) 3, 71–76

DOI:
10.1556/606.2022.00600

ORIGINAL RESEARCH PAPER

Effect of using crushed glass on shear strength parameters of poorly graded sand

Tawfek Sheer Ali[1*], Nassr Salman[2] and Mohammed K. Fakhraldin[2]

[1] Department of Structures and Resource, Faculty of Engineering, University of Kufa, Al-Najaf, Iraq

[2] Department of Civil Engineering, Faculty of Engineering, University of Kufa, Al-Najaf, Iraq

Received: January 15, 2022 • Revised manuscript received: March 27, 2022 • Accepted: April 28, 2022
Published online: August 8, 2022

ABSTRACT

This paper presents an experimental work of using crushed glass mixed with the poorly graded sandy soil to investigate the possibility of shear strength parameters improvement using the direct shear test. The crushed glass is sieved and prepared for seven sets of percentages, the collected percentages of crushed glass represented a mix of glass retained on sieves No. 4, No. 8, No. 30, No. 100, and No. 200 and were added as a weight ratio of the sample for many cases. The main results of this work show that the mixing 10% of crushed glass for sieves No. 8, No. 200, and No. 50 increase the angle of internal friction of poorly graded sand (Ø°) about 15%, 3%, and 29% respectively, and mixing 10% of crushed glass retained on sieve No. 4 decrease Ø° about 40%.

KEYWORDS

sandy soil, crushed glass, waste materials, direct shear test

1. INTRODUCTION

The countries of the world throw large quantities of waste materials, whether from the utilize or from factories, for example, cement kiln dust, rubber factory waste, electric power plant waste, paper mill waste, water bottles, glass juices and other waste materials. These materials cause environmental hazards and it is best to dispose of them in multiple ways. Many researchers have made numerous studies for the use of waste materials in civil engineering and to improve soil properties.

Paper [1] preformed a wide test to evaluate the stabilization the sandy soil using crushed glass and cement. They used two percent 5% and 7% of cement while used three percentages of crushed glass were 20%, 40% and 80% of weight of sample. The stabilization the sandy soil with two percent of cement was cured with two periods 7 and 28 days. The results showed the optimum percent determined with 7% cement cured 28 days and mixed with 40% crushed glass, which obtained unconfined compression strength 26.8 kg cm^{-2} also California Bearing Ratio (CBR) also showed the high values with 60% crushed glass mixed with 7% cement and finally the cohesion of soil reached to peak values with 60% crushed glass mixed with 7% cement.

Paper [2] conducted a series of CBR tests using granular materials lining with cement kiln dust as a layer into the soil for different depths from the top of the mold. The results founded that the best position layer at 0.2 H, where H is a thickness of granular soil in CBR mold. The results also showed that the CBR increase about three times when using Cement Kiln Dust (CKD) layer at depth 0.2 H compared with granular soil without CKD.

Paper [3] presents methods to investigate the potential of liquefaction due to earthquake. The paper explains that there are many empirical methods commonly used to estimate stress. The shortcomings and benefits of strain and energy-based methods have been discussed.

*Corresponding author.
E-mail: tawfeeq.shubber@uokufa.edu.iq

A comparative analysis was conducted for the site of the Paks Nuclear Power Plant to contribute the safety assessment of it with respect to liquefaction effects.

Paper [4] investigated the effect of adding reclaim powder (waste materials of tires production) to sandy soil using CBR test. The tests performed by adding different ratios of reclaim to sandy soil as 0.5, 1, 2, and 4% from weight of soil. The tests accomplished into two stages dry and wet conditions, the wet include soaking sample for four days before test. The results showed that the dry unit weight of sand increase with the percent of reclaim increase. The increase is significant up to 2% reclaim and the increment decrease gradually up to 4% reclaims, also the values of CBR decreases with increase of the reclaim ratio increase.

Paper [5] submitted a new method to improve sandy soil using CKD as layers reinforced sand, this method including using of CKD as layers in sand to improve shear strength parameters. The direct shear test was used to perform the study. The parametric study represented by five tests to investigated the best layer position. The five cases are reference tests (natural sand) and four cases of CKD layers in sand as 0.15 *B*, 0.2 *B*, 0.25 *B*, and 0.5 *B*, where *B* is the width of the shear box apparatus and the thickness of CKD layers were constant in all case was 0.1 *B*. The results showed the best location of layer was 0.5 *B* was increase the angle of internal frication about 2.41 times the natural angle of internal friction of sand soil.

Paper [6] studied the additive of CKD and Palm Kernel Ash (PKA) materials to soft clay soil to improve the physical and shear strength parameters of soft clay. The additive waste materials used as ratio of dry weight soil and additive in two stages isolated and combined. Using the optimum percent for each stage of two waste materials then using combined percent of CKD and PKA to investigate the effect of the new percent on soft clay properties. The optimum present of CKD and PKA were found 8% and 2% of weight of soil. The new percent 10% represent 8% of CKD plus 2% of PKA were mixing with soft clay to conduct physical and CBR tests. The results recorded that the addition of 8% of CKD decrease the Liquid Limit (LL), Plastic Limit (PL) and Placidity Index (PI) about 49%, 41% and 37.5% respectively also increase maximum dry density and CBR about 15.7% and 725% respectively while the combined percent 10% of two materials (8% CKD +2% PKA) showed the decreases of LL, PL and PI about 3%, 8.6% and 3% respectively and increase the CBR 938% times from reference test.

Paper [7] investigated the effect of adding various percentages of crushed glass to fine grain soil on unconfined compression strength and shear strength parameters. The crushed glass was sieved on sieve No. 8 and retained on No. 16 and used various percentage of crushed glass start with 10%–50% mixed with fine soil then tested to evaluate optimum percentage of crushed glass. The results appeared the unconfined compression strength increase about 171% while the cohesion of soil increase from 3.23 to 8.76 kPa at 50% of using crushed glass respectively.

Paper [8] studied the effect of using paper sludge ash comparing with cement in improving the properties if subcase, which is used in roads construction. The properties were investigated by CBR. The results showed that the use of 4% paper sludge ash is the optimum ash content at which the CBR value increased 173% and 111% with the comparison with the reference sample and 6% cement respectively. In addition, by means of the compressive strength, the subbase using 6% cement has a compressive strength smaller than those with 4% percentage of sludge ash.

The aim of this paper is to study the effect of using a crushed glass to modify the mechanical properties of a sandy soil by improve the shear strength parameters.

2. MATERIALS

2.1. Used soil

The sand used in this study was classified as poorly graded sand according to the Unified Soil Classification System (USCS), the grain size distribution is shown in Fig. 1. A series of laboratory tests were made to perform physical and chemical properties of soil sample, the results summarized in Table 1.

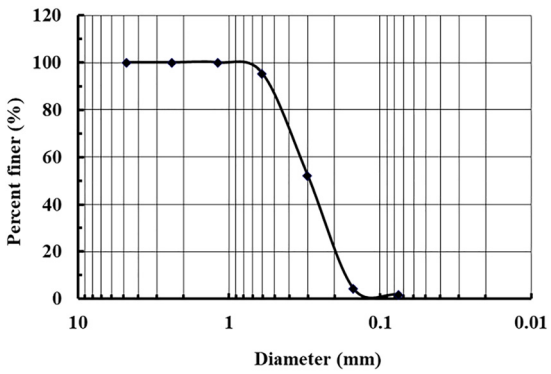

Fig. 1. Grain size distribution of used soil

Table 1. Physical and chemical properties of used soil

The physical properties		Spec.
w.c (%)	1.05	[9]
Gs	2.41	[10]
Minimum density kN m^{-3}	12.26	[11]
Maximum dry density kN m^{-3}	16.52	[11]
Optimum water content%	13.70	[12]
D_{60}	0.34	
D_{30}	0.23	
D_{10}	0.18	
C_u	1.89	
C_c	0.864	
Chemical properties		
Gypsum content	2.7%	[13]
SO_3	1.26%	[14]
Total Dissolved Solids (TDS)	1,150 mg l^{-1}	[15]

2.2. Crushed glass

In the many countries of the world throw, large quantities of glass are used for various purposes, as these materials are considered as waste and have a harmful environmental impact. In this paper, the thrown glass containers in the waste were used after crushed by the electric mill and then sieved on sieves of different sizes for the purpose of separating the particles of crushed glass and mixing them with the sandy soil. Several attempts were performed for different percentages depending on the grain distribution curve of the used soil, whereby the grain size compensation was made for the missed sand particle or a little by the same size from the crushed glass in order to investigate the effect on the shear strength parameters of the used poorly graded Sandy Soil (SP). The percentage of added crushed glass is 10% of soil sample weight. The percentage divided into 5% for glass retained on sieve No. 4 and 5% for glass retained on sieve No. 8 and mixed to be 10%. The 5% of crushed glass retained on sieve No. 100 and 5% of crushed class retained on sieve No. 200 were mixed to be 10% also. A 10% of crushed glass of the sample weight retained on sieves No. 4, No. 8, No. 30, No. 50, and No. 200 respectively were added separately. The direct shear test was made on the soil without any additive as a Reference Sample (RS), and then

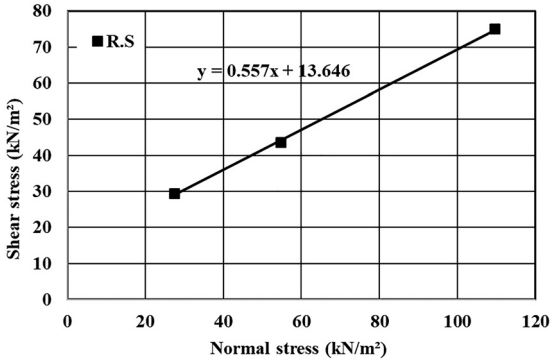

Fig. 2. Direct shear results of reference sample

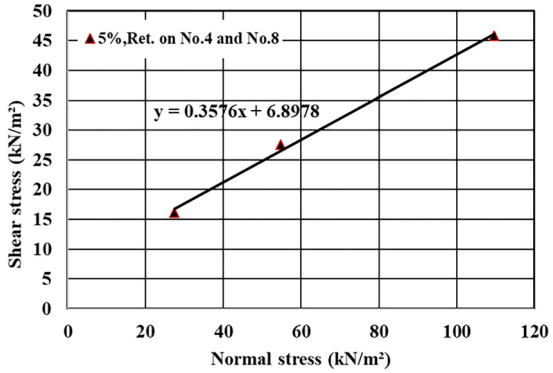

Fig. 3. Direct shear results of sand mixed with 5% crushed glass retained on sieve No. 4 and 5% on sieve No. 8

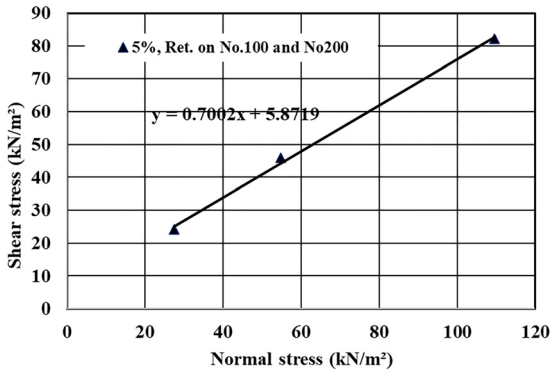

Fig. 4. Direct shear results of sand mixed with 5% crushed glass retained on sieve No. 100 and 5% on sieve No. 200

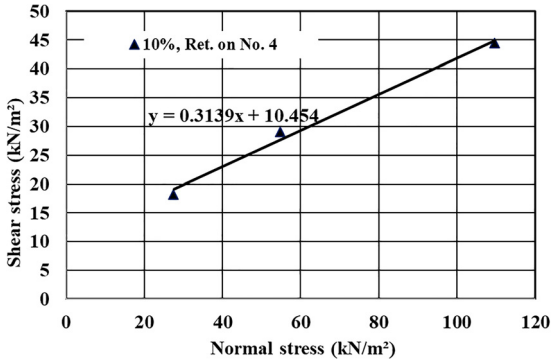

Fig. 5. Direct shear results of sand mixed with 10% crushed glass retained on sieve No. 4

Table 2. Results of direct shear tests

Crushed glass percentage	*c* (kPa)	Difference in *c* from reference sample (%)	Ø°	Difference in Ø° from reference sample (%)
Sand alone	13.6	0.0	29.1	0.0
5% retained on No.4 and 5% on No.8	6.9	−32.3	19.7	−49.3
5% retained on No.100 and 5% on No.200	5.9	20.3	35	−56.6
10% crushed glass retained on No.4	10.5	−40.2	17.4	−22.8
10% crushed glass retained on No.8	6.4	15.5	33.6	−52.9
10% crushed glass retained on No.30	24.6	−18.2	23.8	80.9
10% crushed glass retained on No.50	0.45	28.9	37.5	−96.7
10% crushed glass retained on No.200	10.9	3.1	30	

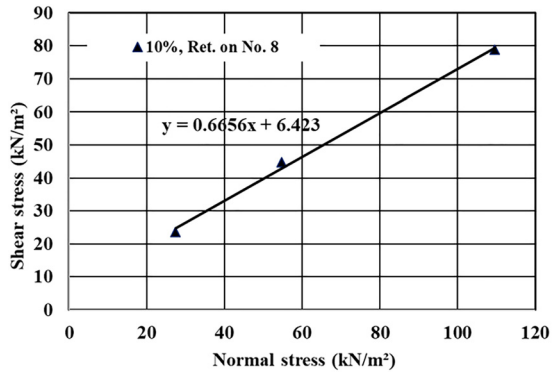

Fig. 6. Direct shear results of sand mixed with 10% crushed glass retained on sieve No. 8

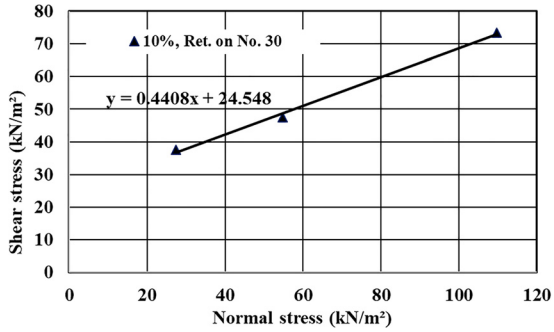

Fig. 7. Direct shear results of sand mixed with 10% crushed glass retained on sieve No. 30

the test was performed for each percentage to investigate the shear strength parameters of soil, which are cohesion (c), and angle of internal friction (Ø).

3. RESULTS AND DISCUSSION

The results obtained from the direct shear test according to ASTM D3080 [9] to depict the effect of using the crushed glass to improve shear strength parameters (c and Ø). The first test conducted on sand alone to show the possibility of increasing shear strength parameters of sand soil, after mixing with crushed glass, the results of reference sample is shown in Fig. 2.

The value of c and Ø of natural sand (reference sample) obtained from Fig. 2 can be known from the fitting line equation $y = 0.557x + 13.646$. The value of Ø equals to $\tan^{-1}$ (0.557) and the intersection of the line with y-axis (at $x = 0$) equals to 13.646 kPa. The value of cohesion c is considered very little because of the soil classified as a sandy soil with little fines. The results of all cases were listed in Table 2. Figures 3–9 shows the direct shear results for seven cases of study

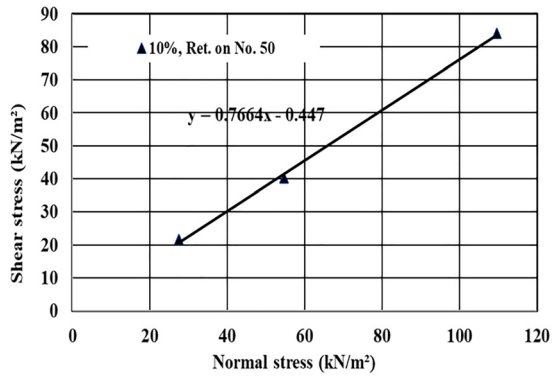

Fig. 8. Direct shear results of sand mixed with 10% crushed glass retained on sieve No. 50

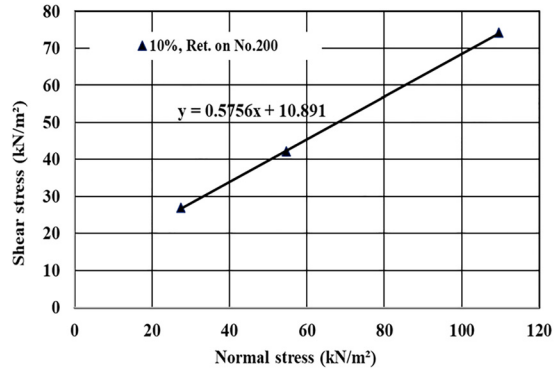

Fig. 9. Direct shear results of sand mixed with 10% crushed glass retained on sieve No. 200

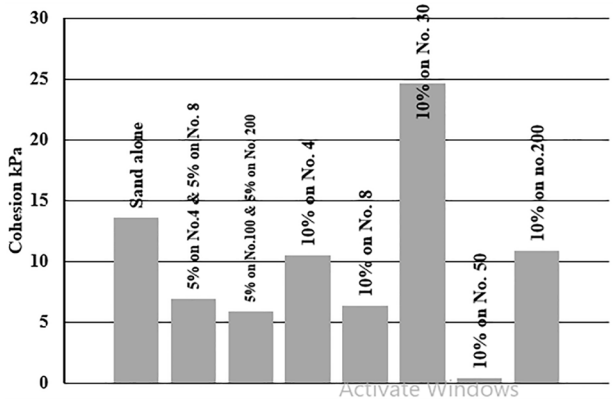

Fig. 10. Effect of added percentages of crushed glass on cohesion

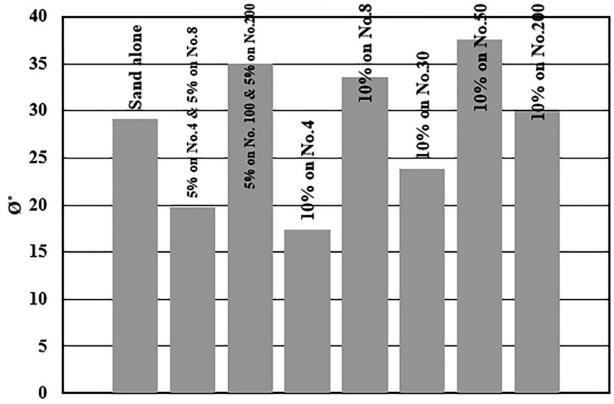

Fig. 11. Effect of added percentages of crushed glass on angle of internal friction

Table 3. Results of soil parameters and bearing capacity

Crushed glass percentage	c (kPa)	Ø°	Bearing capacity (kPa)	Difference in bearing capacity from RS (%)
10% retained on No. 30	24.6	23.8	626	6.8
5% retained on No. 100 and 5% on No. 200	5.9	35.0	601	2.6
Sand alone	13.6	29.1	586	0
10% retained on No. 8	6.4	33.6	537	−8.4
10% retained on No. 200	10.9	30.0	526	−10.2
10% retained on No. 50	0.45	37.5	472	−19.5
5% retained on No. 4 and 5% on No. 8	6.9	19.7	227	−61.3
10% retained on No. 4	10.5	17.4	182	−68.942

represent the effect of adding crushed glass to the sandy soil with different gradation as explained above. The results grouped together into Figs 10 and 11 to show the effect of each added percentage of crushed glass on c and Ø respectively.

4. EFFECT OF ADDED CRUSHED GLASS ON BEARING CAPACITY

To investigate the effect of each percentage of added crushed glass in the bearing capacity, considering a strip footing with $B = 1$ m rests on a ground surface ($D_f = 0$) using Terzaghi bearing capacity equation ($S_c = S_q = S_\gamma = 1$) and $\gamma = 12.26$ kN m^{-3}. The results listed in Table 3 from maximum value to the minimum value of bearing capacity show the crushed glass percentage that gives larger value to smaller value of bearing capacity. It can be concluded that when add 10% crushed glass retained on No. 30 the bearing capacity increase from 586 to 626 kPa, the difference of each added percentage of crushed glass from sand alone RS listed in the table also.

5. CONCLUSIONS

Many conclusions of the experimental work of this paper can be drawn as:

1. The use of 10% crushed glass retained on sieve No. 30 decrease the angle of internal friction of poorly graded sand (Ø°) about 18% and increase cohesion c about 81%;
2. Mixing 5% of crushed glass retained on sieve No. 100 and 5% retained on sieve No. 200 together with poorly graded sand increase the angle of internal friction of poorly graded sand (Ø°) about 20% and increase the cohesion c about 130%;
3. Mixing 10% of crushed glass for sieves No. 8, No. 200, and No. 50 increase the angle of internal friction of poorly graded sand (Ø°) about 15%, 3% and 29% respectively and mixing 10% of crushed glass retained on sieve No. 4 decrease Ø° about 40%;
4. Mixing 10% of crushed glass for sieves No. 8, No. 200, No. 50 and No. 4 decrease the cohesion of poorly graded sand c about 53%, 20%, 97% and 23% respectively;
5. Mixing 5% of crushed glass retained on sieve No. 4 and 5% retained on sieve No. 8 together with poorly graded sand decrease the angle of internal friction of poorly graded sand (Ø°) about 32% and decrease the cohesion c about 49%;
6. The use of 10% crushed glass retained on sieve No. 30 increases the bearing capacity of poorly graded sand about 6.8%;
7. The use 5% of crushed glass retained on sieve No. 100 and 5% retained on sieve No. 200 together with poorly graded sand increase the bearing capacity about 2.6%.

REFERENCES

[1] M. Arabani, H. Sharafi, R. Habibi, and E. Haghshenas, "Laboratory evaluation of cement stabilized crushed glass-sand blends," *EJGE,* vol. 17, no. L, pp. 1777–1792, 2012.

[2] A. Al-Hdabi, M. K. Fakhraldin, and R. A. Al-Fatlawy, "A novel granular material stabilization method using cement kiln dust," in *3rd International Conference on New Research Achievement in Civil, Architectural and Urban Management*, Tehran, Iran, September 16, 2016, pp. 1–13.

[3] Z. Ban, T. J. Katona, and A. Mahler, "Comparison of empirical potential evaluation methods," *Pollack Period.*, vol. 11, no. 1, pp. 55–66. 2016.

[4] M. K. Fakhraldin, T. S. Ali, and R. A. Al-Fatlawy, "Effect of reclaim on California bearing ratio of sandy soil," *Int. Adv. Res. J. Sci. Eng. Technol.,* vol. 3, no. 5, pp. 1–6, 2016.

[5] M. K. Fakhraldin and Z. H. Abdulabbas, "Increasing shear strength parameters of sandy soil by lining CKD," *Int. J. Curr. Eng. Technol.*, vol. 7, no. 2, pp. 422–425, 2017.

[6] A. J. Naiem, M. Al-Jumaili, and M. K. Fakhraldin, "Strengthening soft clayey subgrade soil layer using cement kiln dust and palm kernel ash materials," *IOP Conf. Ser. Earth Environ. Sci.,* vol. 856, 2021, Paper no. 012004.

[7] S. T. Amiri, R. Nazir, and A. Dehghanbanadaki, "Experimental study of geotechnical characteristic of crushed glass mixed with kaolinite soil," *Int. J. GEOMATE*, vol. 14, no. 45, pp. 170–176, 2018.

[8] A. Al-Hdabi, M. K. Fakhraldin, R. A. Al-Fatlawy, and T. S. Ali, "Investigate the properties of the granular materials incorporated

paper sludge ash," *Pollack Period.*, vol. 15, no. 3, pp. 73–90, 2020.

[9] *ASTM D2216-10*, Standard test methods for laboratory determination of water (moisture) content of soil and rock by mass, ASTM, 2017.

[10] *ASTM D792-00*, Standard test methods for density and specific gravity (relative density) of plastics by displacement, ASTM, 2017.

[11] *ASTM D7263-21*, Standard test methods for laboratory determination of density and unit weight of soil specimens, ASTM, 2017.

[12] *ASTM D698-12*, Standard test methods for laboratory compaction characteristics of soil using standard effort (12 400 ft-lbf/ft3 (600 kN-m/m^3)), ASTM, 2017.

[13] *ASTM C471M-20*, Standard test methods for chemical analysis of gypsum and gypsum products (metric), ASTM, 2017.

[14] *ASTM C563-07*, Standard test method for approximation of optimum SO_3 in hydraulic cement using compressive strength, ASTM, 2017.

[15] *ASTM D5907-09*, Standard test method for filterable and nonfilterable matter in water, ASTM, 2017.