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# Effect of granular waste glass on soil properties

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ABSTRACT: Glass constitutes a major component of solid waste both developed and developing countries. Relatively easy to separate from the general solid waste stream and owing to its physical and chemical properties, it is an important candidate for using as an additive material into soil. Waste glass are widely used in the industry, however its use in geotechnical engineering is quite new. There is no detailed research about effects of waste glass on mechanical and physical properties of soils. In this experimental study, it was investigated usability of fine sand sized waste glass as an additive material into soil. For this purpose, grinded waste glass in different content was added to clay and sand soils, then after consistency limits, compaction and shear box tests were carried out. According to test resalts, liquid and plastic limits of the clay soil were decreased with increasing of waste glass content. Also waste glass caused an increase in the maximum dry unit weight and caused a decrease in the optimum water content of the clay soil in the compaction test. Waste glass exhibited similar behaviour to sand in clay. The grinded waste glass has not significant effect on the sand properties. Internal friction angle of the sand samples was not affected by the grinded waste glass. According to tests, grinded waste glass did not cause any declination of the soil properties. The waste glass can be used as an additive material for the soils.

## 1 INTRODUCTION

This work explores the crushed and grinded waste glass as reusing disposable materials for beneficially manner in geotechnical engineering. Waste glass has high proportion in the solid waste, for example in the United State range of the waste glass is about 27-percent in solid waste (Meyer, 2002). The glass industry has developed in immense degree in last few decades. As a result of intensive development, cost of the producing glass materials especially as a container is very low today. This low cost of the production cause a diminish reusing of the waste glass materials. Each day, amount of the waste materials has rapidly increasing in the world. Cost of the deposition or disposal of the waste materials has increasing everyday. Waste materials should be reuse with economically and beneficially manner. Waste glass materials do not harm the environment when it is used with properly technique and way.

Glass materials are processed for into new glass materials after being colour-separated. Recycled glass may contain contaminants including organic (paper label, food, etc.) and inorganic (concrete, ceramics, metal, etc.) materials. Most of the contaminations found in glass cullet from paper label (Landris, 2007). Contaminants must be separated before recycling process. Each process in the recycling process plays a role as a determinative factor for the cost of remanufacture. Beside remanufacture, glass is tried to be used as a bound aggregate substitute in concrete and

asphalt. A lot of researcher studied on the using of the glass material as supplementary material for the concrete or cement (Shao et all., 2000; Chidiac and Mihaljevic, 2011; Topçu and Canbaz, 2012; Park et all., 2004; Shi and Zheng, 2007). There are some significant works on the glass using as aggregate or pozzolanic material in the concrete and asphalt technology (Shayan and Xu, 2006; Taha and Nounu, 2008; Su and Chen, 2002). However, glass cullet is not widely used as a concrete aggregate because of alkali-silica reaction (Polley et all, 1998). Main component of the manufactured glass is siliciumdioxid (SiO2) (Landris, 2007). Researcher in the concrete technology concern with alkali-silica reaction of the waste glass and they try to overcome this problem. Waste glass material does not contribute significantly to strength of concrete. Conversely some researches (Topçu and Canbaz, 2012) assert that additive waste glass materials cause a reduction of strength. Finding out a way for using of the waste glass materials in the concrete technology is main purpose of the most researchers.

Waste glass seems to be easily used in the geotechnical engineering field. The waste glass can be use with only grinding process in soil as an additive material or aggregate substitute in landfill. In the geotechnical engineering, grinding waste glass can be used without separation process for colour or remnant of concrete, paper label, ceramics etc. Obviously clear that, some hazardous contaminants must not to be in glass cullet such as arsenic, mercury, nuclear materials. Glass has high endurance for chemical weathering in the nature. Main compound of manufactured glass is SiO2, and soil materials can contain abundantly SiO2. Consequently, waste glass is useable material in the geotechnical engineering.

## 2 MATERIALS AND EXPERIMENTAL METHODS

In this experimental study glass, clay and sand materials were used as test materials. The clay material was supplied from a construction of the Kuşadası solid waste storage area. The clay was used as impervious layer in the solid waste storage area, and it may be used in the future as a covered material of the storage area. The sand material was supplied from sand vendor in the Menemen (İzmir). The sand is extracted from Gediz River bad. Empty glass bottles were used as waste glass materials. Bottles were firstly crushed and grinded then sieved from No.10 (2 mm) and No.40 (0.425 mm) sieves.

Specific gravity, sieve and consistency limits tests were performed to determine the fundamental properties of the test materials. Specific gravities of the clay, sand and glass materials are 2.71, 2.66 and 2.52 respectively. Sand and glass are non-plastic materials. Liquid ($w_L$) and plastic ($w_P$) limit of the clay are 58% and 24% respectively. Clay material has high plasticity properties (CH). The fundamental properties of the tests materials are given in Table 1. Grain size distributions of the sand and glass materials are shown in Figure 1. Sand and grinded glass materials are poorly graded.

Table 1. Properties of the test materials

| Material | Specific Gravity | Water content of Liquid Limit (%) | Water content of Plastic Limit (%) | Plasticity Index |
|---|---|---|---|---|
| Clay | 2.71 | 58 | 24 | 34 |
| Sand | 2.66 | NP | | |
| Grinded waste glass | 2.52 | NP | | |

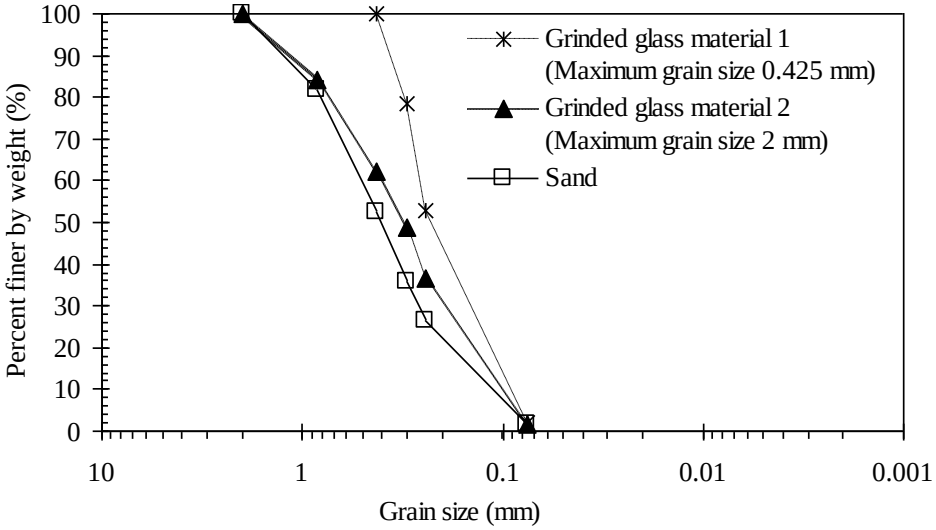


Figure 1. Grain size distribution of the sand and grinded waste glass materials

All test materials were dried in oven at 80°C. Then clay and sand materials were sieved from No.40 sieve (0.425 mm) and No.10 (2 mm) respectively. Sieved from No.40 sieve (0.425 mm) grinded glass material was used in consistency limits tests, and sieved from No.10 sieve (2.0 mm) grinded glass was used in compaction and shear box tests. Consistency limits were determined for 0%, 5%, 10%, 20% grinded glass contents. Procter tests were performed on clay – glass mixtures at 0%, 10% 20% grinded glass contents. Internal friction angle of sand – glass mixtures was determined for the 0%, 20%, 100% glass contents. Prepared clay – glass and sand – glass mixtures for the tests are given in Table 2. Consistency limits, compaction and shear box tests were conducted as described in ASTM D4318, ASTM D698 and ASTM D3080 procedures respectively.

Table 2. Prepared clay-glass and sand-glass mixtures

| Mixtures | Grinded glass content (%) | Maximum grain size of the test materials (mm) | Performed Tests |
|---|---|---|---|
| Clay-Grinded glass | 0 | 0.425 | Consistency Limits |
| Clay-Grinded glass | 5 | 0.425 | |
| Clay-Grinded glass | 10 | 0.425 | |
| Clay-Grinded glass | 20 | 0.425 | |
| Clay-Grinded glass | 0 | 2.0 | Compaction Tests |
| Clay-Grinded glass | 10 | 2 | |
| Clay-Grinded glass | 20 | 2 | |
| Sand-Grinded glass | 0 | 2 | Shear Box |
| Sand-Grinded glass | 20 | 2 | |
| Sand-Grinded glass | 100 | 2 | |

Resalts of the consistency limits tests are given in Table 3. Changing of the plastic and liquid limits water contents of the natural clay with grinded glass can be seen in Figure 2. Both of the plastic and liquid limit water contents decreased with increasing of grinded glass content. Decreasing of the consistency limits was occurred linearly to %20 content of the grinded waste glass. When the grinded glass reached the 20-percent content, a decreasing about 13.2% was

occurred in plastic limit water content of the natural clay ($w_P$=24%). Also, liquid limit water content of the natural clay ($w_L$=58%) was decreased about 22.1%. As expected, the plasticity index was decreased dependently with the consistency limits.

Table 3. The effects of the grinded glass on the consistency limits of the clay

| Consistency Limits | Grinded glass content (%) | | | |
|---|---|---|---|---|
| | 0 | 5 | 10 | 20 |
| Liquid limit (%) | 58.0 | 58.0 | 55.0 | 45.2 |
| Plastic limit (%) | 24.0 | 23.1 | 22.0 | 21.0 |
| Plasticity index | 34.0 | 31.9 | 33.0 | 24.2 |

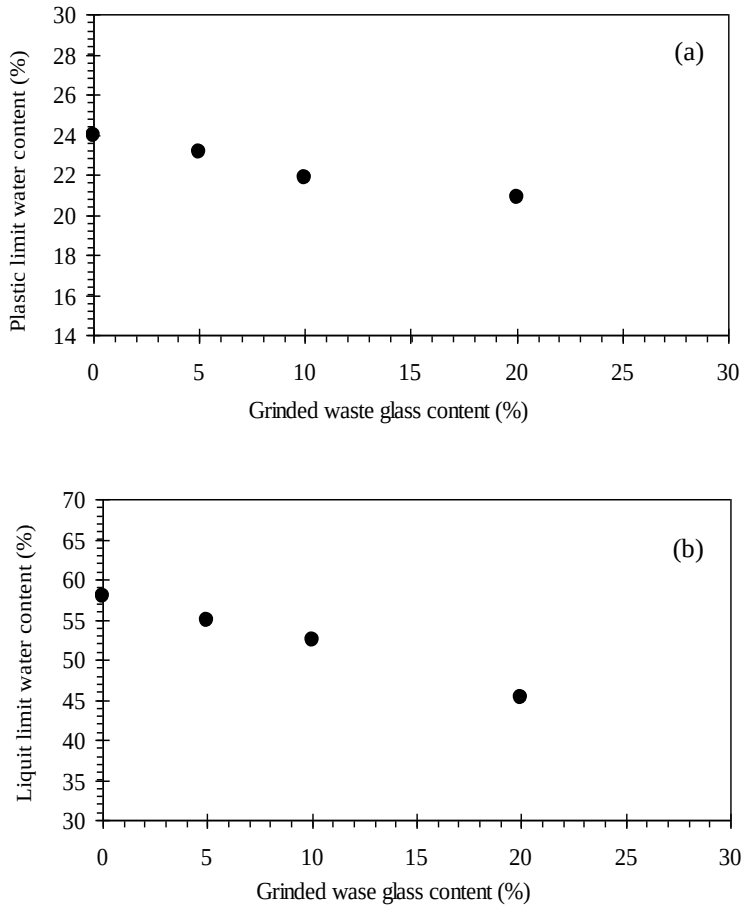


Figure 2. Changing of the liquid (a) and plastic (b) limits of the clay with grinded waste glass content

Effects of the grinded waste glass material on the compaction characteristic of the clay material were investigated with standard proctor tests. The standard proctor tests were performed on three different clay – grinded waste glass mixtures. Maximum dry unit weights and optimum water contents of the clay – grinded glass mixtures are given in Table 4. Compaction curves of the mixtures are given in Figure 3.

Table 4. Maximum dry unit weights and optimum water contents of the clay-grinded glass mixtures

| Grinded glass content (%) | 0 | 10 | 20 |
|---|---|---|---|
| Maximum dry unit weight (gr/cm$^3$) | 1.52 | 1.57 | 1.61 |
| Optimum water content (%) | 26.4 | 23.9 | 22.5 |

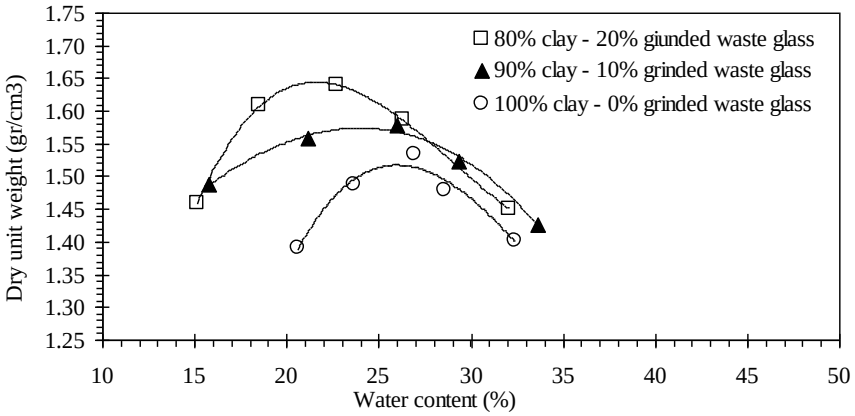


Figure 3. Compaction tests curves of the clay-grinded glass mixtures

When grinded waste glass material is used as additive material for the clay, it causes an increase the maximum unit weight of the clay under the same compaction energy. Maximum dry unit weight of the clay was increased about 9% by 20–percent grinded glass content. Optimum water content of the clay was decreased by grinded glass content for the all mixtures. Optimum water content of the mixture with 20–percent glass content was determined as 20.1% more less then optimum water content of the natural clay.

Effect of the grinded waste glass on the shear strength of the soils was investigated with sandy soils. Shear strength tests were performed with shear box test apparatus. The internal frictional angles of the pure sand, pure cullet and sand–grinded glass mixtures were determined as 38$^o$ and 43$^o$ and 38.4$^o$ respectively. Relative densities of the tests samples are %48 (pure sand), %47 (pure glass cullet) and %46 (sand – grinded glass mixture). The 20–percent grinded waste glass was appeared to have not effect on the shear strength of the sand soils. Shear tests results are given in Table 5.

Table 5. Internal frictional angle of the sand, glass cullet and sand–grinded glass mixture

| Grinded glass content (%) | 0 | 20 | 100 |
|---|---|---|---|
| Internal friction angle ($^o$) | 38 | 38.4 | 43 |
| Relative density (%) | 48 | 47 | 46 |

## 3 CONCLUSIONS

According to literature, waste glass does not improve significantly the engineering properties of the concrete (Shao et all., 2000; Chidiac and Mihaljevic, 2011; Topçu and Canbaz, 2012; Park et all., 2004; Shi and Zheng, 2007). Moreover some researchers (Topçu and Canbaz, 2012; Shayan and Xu, 2006) denoted that waste glass reduces some properties (workability and strength) of the

mortar and concrete. Consequently, waste glass material is not used widely in the concrete technology because of alkali–silica reaction of the glass (Polley et all, 1998).

In this study, beneficial usage of waste glass material in the geotechnical engineering field was investigated with an experimental work. In the study determined that consistency limits and optimum water content of the clay material was decreased with increasing of grinded glass content. Maximum dry unit weight of the clay was increased with increasing of the grinded glass content. Hence, the grinded waste glass showed effects similar to sand on the clay material.

The glass cullet did not cause to reduce or increase of the shear strength of the sand materials. In light of the shear box tests, the glass cullet seems to have not significant effect on the shear strength of the sand materials.

Each year, huge amount waste material comes up in the world, and waste glass has high proportion in the solid waste. The waste glass does not need to separation process for colour or concrete, paper label, ceramics etc. remnant for geotechnical engineering practice. The waste glass can be used with only grinding process as additive material for soils. Consequently, waste glass materials can be used easily in the geotechnical engineering.

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