World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:17, No:11, 2023

A Study on the Pressure Void Ratio Relationship for Rock Powder Blends with Brick Dust

Aktan Ozsoy, Ali Fırat Cabalar, Eyyub Karakan

***Abstract*—**Climate change is one of the biggest issues facing communities. Increasing population, growing economies, rapid industrialization are the main factors triggering it. On the other hand, the millions of tons of waste have generated by the period of rapid global growth not only harm to the environment but also lead to the use of valuable lands around the world as landfill sites. Moreover, it is rapidly consuming our resources and this forces the human population and wildlife to share increasingly shrinking space. In this direction, it is vital to reuse waste materials with a sustainability philosophy. This study was carried out to contribute to the combat against climate change, conserve our natural resources and the environment. An oedometer (consolidation) test was performed on two waste materials combined in certain proportions to evaluate their sustainable usage. Crushed brick dust (BD) was mixed with rock powder (RP) in 0%, 5%, 10%, 20%, 30%, 40%, and 50% (dry weight of soil). The results obtained revealed the importance of the gradation of the material used in the consolidation test. It was found that there was a negligible difference between the initial and final void ratio of mixtures with BD added.

***Keywords*—**Waste material, oedometer test, environmental geotechnics, sustainability, crushed brick dust, rock powder.

I. Introduction

ALTHOUGH the increase of living creatures except for that of humans is limited by ecosystems, with the intelligence and technology they possess, humans continue their existence in the world with their own will [8]. The global population had reached 8 billion people in 2022 [16], and this is expected to reach 9.7 billion in 2050 [17] and 11 billion in 2100 [16]. Briefly, we are faced with the fact that the world population continues to grow rapidly. Industrialization, urbanization and continued economic developments have also rapidly increased in response to the increasing world population. This has led to the construction of huge dams for energy production, countries to build thousands of kilometers of roads to grow their economy [10], as well as the increase of industrial facilities serving in many areas and the construction of millions of housing units to meet the housing demands. From the environmental perspective, all the natural resources of the world are mobilized to meet the heavy demand caused by the increasing world population. Moreover, all this industrial process has led to a significant increase in the carbon footprint. For example, it is projected that there will be an increase in carbon dioxide emissions of about 16% from 2015 to 2035 [7]. Unfortunately, the world has limited valuable space and natural resources. While the requirements of the crowded population are met, some problems come with it. Increasing environmental pollution, rapid decrease in limited natural resources on the planet, deteriorating biodiversity and ecosystem, and damage to human health are some of these problems. The main issue that should be emphasized here is the global climate change, which is at the top of the public agenda for the past few decades and posing a threat to the future of all creatures. Climate change can be defined as series of problems that occur in the natural balance, with the deterioration of the current average conditions on Earth. The main factor that disrupts the current average conditions is the increase in world surface temperature day by day. Compared to the temperature between 1986-2005, it is envisaged that there will be a temperature increase of 0.4-1.0 degrees between 2016-2035 and 0.2-4.8 degrees between 2081-2100 in the world [15]. It is obvious that this temperature increase will lead to destruction on the earth and living things. Rising sea levels due to melting glaciers, storms, floods, increasing wildfires, collapsing ecosystems, water shortage, and drought are some of the negative effects of climate change on living creatures.

Although efforts are made to draw attention to climate change and increase awareness in the global public, the fact that we need to get quick results in a short time does not change. For this reason, interest in more effective and faster solution methods have been increasing significantly to prevent climate change. At this point, environmental geotechnics is an important platform where innovative and effective solutions can be produced [2]. To elaborate, it is a large-scale research area where geotechnical projects are carried out with the philosophy of sustainability, various waste materials are investigated under laboratory conditions, natural resources are conserved considerably, greenhouse gas emissions and other negative environmental effects are tried to be mitigated. Although the field applications carried out with this philosophy are limited, recently, the interest of scientists in environmental geotechnics has paved the way for new and creative field applications. There are few studies on the use of waste materials in geotechnical projects in the literature [1], [3]-[6], [9], [11]-[14], [18].

To tackle climate change, to find alternative usage area for waste materials and to conserve limited natural resources, the study of the engineering properties of waste materials under the title of environmental geotechnics is one of our main topics of interest. In line with this purpose, supporting the zero-waste policy, contributing to sustainability, that is, producing fast and

Aktan Ozsoy is with Gaziantep University, 27410 Gaziantep, Turkey (corresponding author, e-mail: ozsoyaktan@gmail.com.tr)
Ali Fırat Çabalar is with Gaziantep University, PhD, 27410 Gaziantep, Turkey (phone: +90-342-3172417, e-mail: cabalar@gantep.edu.tr)
Eyyub Karakan is with Kilis 7 Aralık University, 79000 Kilis, Turkey (phone: +90-348-8141830, e-mail: eyyubkarakan@kilis.edu.tr).

practical solutions for the final disposal of the waste materials, motivates this study. In this study, some data of the consolidation test, which is one of the time-consuming and costly tests of soil mechanics, are presented. Hereby, an attempt has been made in this study to shed light on future studies, to encourage using waste materials on geotechnical applications.

II. Material and Procedure

Two types of waste materials, RP and crushed BD, were used for this study. Brick material was obtained from the dump area where broken materials were thrown at construction sites. The brick was pulverized by using hammer and single-drum roller before it was used in experiments. RP is a waste material that the stone crushing industry inevitably produces in enormous amounts. The RP used in the study were passed through No. 40 (0.425 mm) sieve. Both materials (RP and BD) were dried in the oven at 105 °C for 24 hours before being used.

A. Testing Apparatus and Experimental Procedures

It is a laboratory test that is often used in geotechnical engineering and plays critical role in determining the settlement characteristics of engineering structures. In principle, it is based on the determination of the deformation that occurs when gradually stress loading is applied on a laterally constrained soil. A series of consolidation experiments in this study was undertaken in accordance with ASTM 2435-2011 requirements. The semi-automatic consolidation machine used in tests is shown in Fig. 1. The samples prepared with the optimum ratios obtained from the compaction test results were placed into the steel ring with height of 20 mm and diameter of 50 mm. All materials used in this experiment, i.e., RP and BD, were passed through No. 40 (0.425 mm) sieve. The prepared specimens were compressed with California Bearing Ratio (CBR) machine (0.02 mm/sec). Thus, all sample was placed into steel ring. In addition, a porous stone was placed on the bottom of the consolidation test mold. Subsequently, steel ring was placed on the porous stone. The top and bottom of the steel ring were covered with a filter paper to prevent fine grain particle loss. The sample was saturated with water by filling the consolidation mold with water up to the overflow limit. Then, the specimen was placed in the consolidation test device and incremental loading was applied. Initial loading was initiated at 25.5 kPa and doubled each day until it reached 1630.6 kPa. After the final loading, the unloading was gradually performed, that is, the unload is cut in half each day (1630.6, 815.3, 407.6, 203.8, 101.9, 51 and 25.5 kPa). Since the oedometer device is connected to the control panel, deformation readings caused by the gradual loading and unloading stage in this study were conducted automatically. The time intervals for each loading and unloading stage in the experiment were determined as 24 hours. In addition, after the 25.5 kPa loading, which was the last loading in the unloading phase, was removed, another 24 hours was waited, and the experiment was finished by taking the last reading of deformation.

B. Mix and Proportions

Crushed BD was mixed with different percentages (0, 5, 10, 20, 30, 40, and 50%) of RP by weight. While increase rate of BD added to RP is generally 10%, the reason for using the 5% addition rate is to understand whether there is a change in bearing capacity at lower rates.

III. Result and Discussion

The initial void ratio (e_0) is one of the parameters that play important role in the evaluation of c_c. When a consolidation test is completed, the void ratio is plotted as a function of the logarithm of the pressure (Figs. 2-8). The difference between the initial void ratio-final void ratio of the RP only mixture and the difference between the initial void ratio and the final void ratio of the mixtures added brick powder were compared. Since the difference between the initial and final void ratio of the mixtures added brick powder was negligible, all mixtures could not be shown in a single graph. As seen in Fig. 9, there was no stable trend in the initial void ratios of the mixtures. Overall, the initial void ratios of BD added mixtures possess lower values than the mixture prepared with RP alone. Among the mixtures used in the study, while the 100% rock powder mixture has the highest initial void ratio with a value of 0.764, the mixture with 10% brick dust addition has the lowest initial void ratio with a value of 0.476. This can be attributed to the increase in the water absorption potential of the sample with the addition of BD. The volume of the BD particles will change which will lead to rearrangement of the RP and BD particles in the sample. In addition, the minor difference between the initial and final void ratios in the mixtures with brick powder can be attributed to the particle size distribution of the BD used. Since only the material passing through the No. 40 (0.425 mm) sieve is used, coarse-grained materials may have prevented the mixture from compressing sufficiently under pressure.

Fig. 1 Semi-automatic oedometer (consolidation) test machine used in the experiment

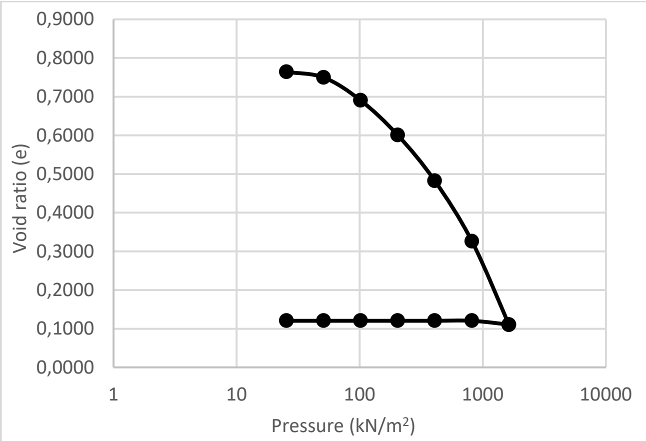

Fig. 2 Compression curve (e-log p) for RP alone or 100% RP

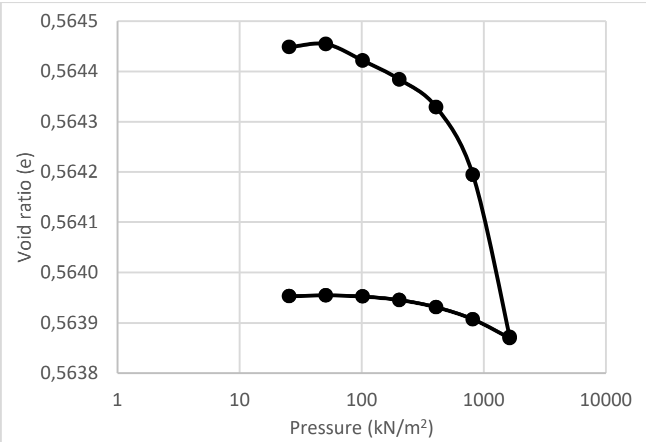

Fig. 3 Compression curve (e-log p) for mixture with 5% BD addition

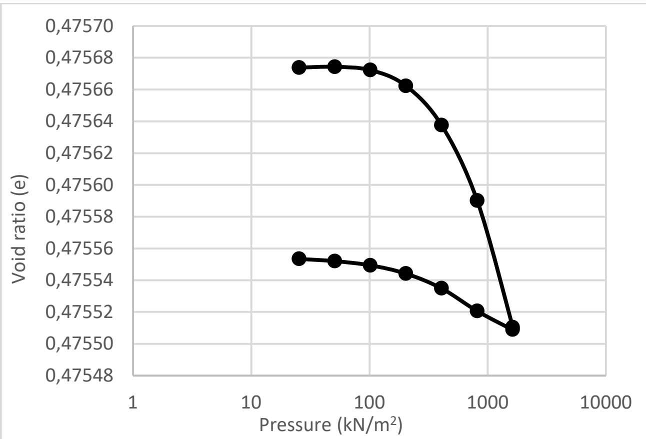

Fig. 4 Compression curve (e-log p) for mixture with 10% BD addition

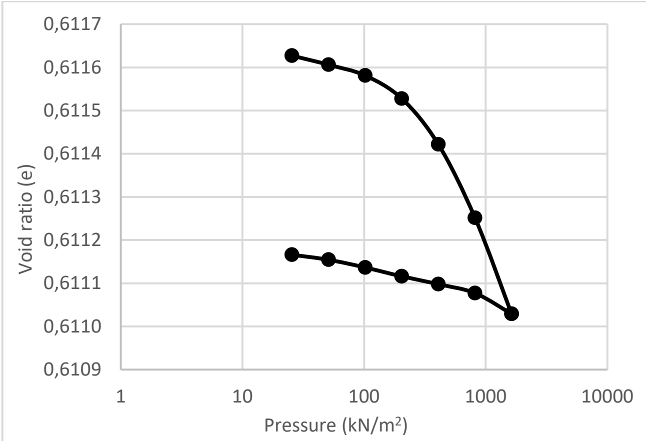

Fig. 5 Compression curve (e-log p) for mixture with 20% BD addition

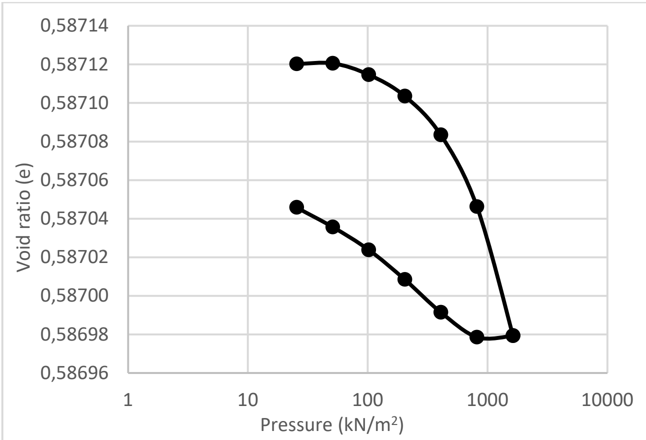

Fig. 6 Compression curve (e-log p) for mixture with 30% BD addition

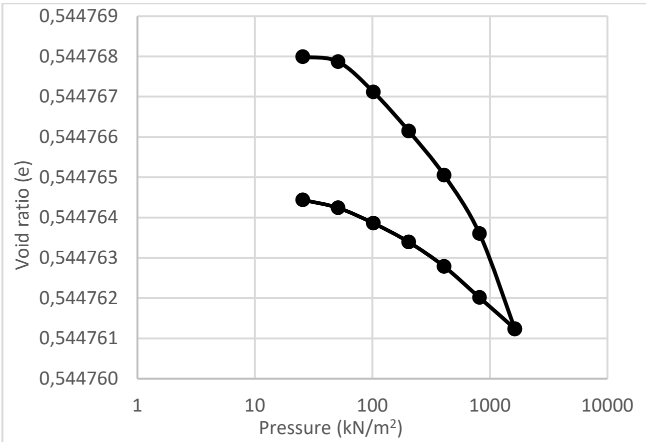

Fig. 7 Compression curve (e-log p) for mixture with 40% BD addition

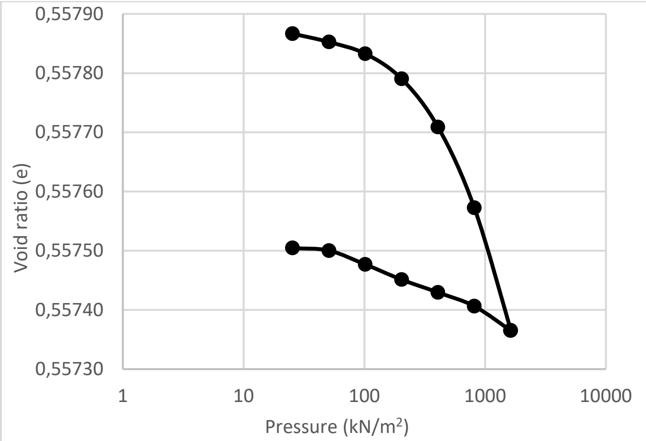

Fig. 8 Compression curve (e-log p) for mixture with 50% BD addition

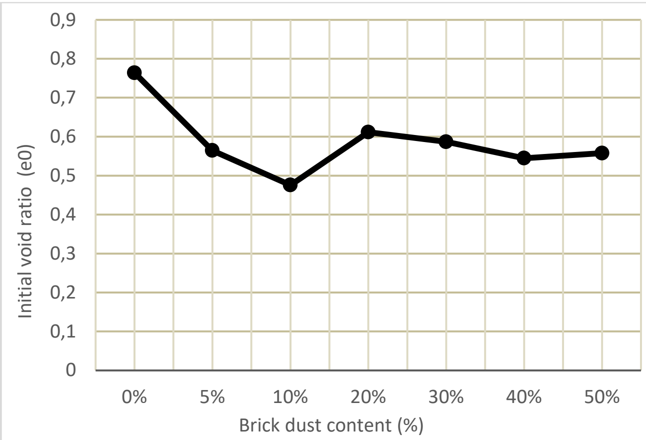

Fig. 9 Variation of e_0 with BD content

IV. Conclusion

In this study, the void ratio-pressure graphs obtained because of the consolidation experiments carried out on the mixtures were evaluated. It is aimed that the results obtained from the consolidation test, which is a time-consuming and costly test, will shed light on future studies to be carried out in this field. In the test results, it was observed that there was a negligible difference between the initial void ratio and the final void ratio in the mixtures with brick powder added. This result indicates that the BD passing through the sieve No. 40 (0.425 mm) sieve used in the mixtures comprise coarse grains in it. For this reason, the expected compression under pressure could not be realized. Here, it is useful to draw attention to the importance of the gradation of the materials used in the consolidation experiment. In addition, from an environmental point of view, the idea of finding alternative usage field by investigating the engineering properties of these two waste materials will benefit to sustainability and waste management. Moreover, the reuse of waste as raw material is a substantial economic profit.

References

[1] Abukhettala, M., Fall, M., ''Geotechnical Characterization of Plastic Waste Materials in Pavement Subgrade Applications'', *Transportation Geotechnics*, 27, 100472, 2021.
[2] Arulrajah, A., ''The Importance of Environmental Geotechnics'', *Environmental Geotechnics*, 1(4), 197, 2014.
[3] Arulrajah, A., Disfani, M. M., Suthagaran, V., Bo, M. W., ''Laboratory Evaluation of the Geotechnical Characteristics of Wastewater Biosolids in Road Embankments'', *Journal of Materials in Civil Engineering*, 25(11), 1682-1691, 2013.
[4] Cabalar, A. F., Akbulut, N., Demir, S., Yildiz, O., ''Use of a Biopolymer for Road Pavement Subgrade'', *Sustainability*, 15(10), 8231, 2023.
[5] Cabalar, A. F., Hassan, D. I., Abdulnafaa, M. D., ''Use of Waste Ceramic Tiles for Road Pavement Subgrade'', *Road Materials and Pavement Design*, 18(4), 882-896, 2017.
[6] Cabalar, A. F., Zardikawi, O. A. A., Abdulnafaa, M. D., ''Utilisation of Construction and Demolition Materials with Clay for Road Pavement Subgrade'', *Road Materials and Pavement Design*, 20(3), 702-714, 2019.
[7] Cao, X., Dai, X., Liu, J., ''Building Energy-Consumption Status Worldwide and the State-Of-The-Art Technologies for Zero-Energy Buildings During the Past Decade'', *Energy and buildings*, 128, 198-213, 2016.
[8] Çamurcu, H., ''The Increase of the World Population and the Problems It Causes'', *Balıkesir University Journal of the Institute of Social Sciences*, 8(13), 87-105, 2005.
[9] Gobinath, R., Akinwumi, I. I., Afolayan, O. D., Karthikeyan, S., Manojkumar, M., Gowtham, S., Manikandan, A., ''Banana Fibre-Reinforcement of a Soil Stabilized with Sodium Silicate'', *Silicon*, 12(2), 357-363, 2020.
[10] Kalan, O., ''The Relationship Between Economic Growth and Road Infrastructure: Evidence from Turkey'', *PhD Thesis*. Bogazici University, 2017.
[11] Mohammadinia, A., Arulrajah, A., Sanjayan, J., Disfani, M. M., Bo, M. W., Darmawan, S., ''Laboratory Evaluation of the Use of Cement-Treated Construction and Demolition Materials in Pavement Base and Subbase Applications'', *Journal of Materials in Civil Engineering*, 27(6), 04014186, 2015.
[12] Montepara, A., Tebaldi, G., Marradi, A., & Betti, G., ''Effect on Pavement Performance of a Subbase Layer Composed by Natural Aggregate and RAP'', *Procedia-Social and Behavioral Sciences*, 53, 980-989, 2012.
[13] Rahman, M. A., Imteaz, M. A., Arulrajah, A., Piratheepan, J., Disfani, M. M. ''Recycled Construction and Demolition Materials in Permeable Pavement Systems: Geotechnical and Hydraulic Characteristics'', *Journal of Cleaner Production*, 90, 183-194, 2015.
[14] Saberian, M., Li, J., Nguyen, B., Wang, G., ''Permanent Deformation Behaviour of Pavement Base and Subbase Containing Recycle Concrete Aggregate, Coarse and Fine Crumb Rubber'', *Construction and Building Materials,* 178, 51-58, 2018.
[15] Wang, G., Zhang, J., He, R., Liu, C., Ma, T., Bao, Z., Liu, Y., ''Runoff Sensitivity to Climate Change for Hydro-Climatically Different Catchments in China'', *Stochastic Environmental Research and Risk Assessment*, 31, 1011-1021, 2017.
[16] Wilmoth, M. J., Menozzi, M. C., Bassarsky, M. L., ''Why Population Growth Matters for Sustainable Development'', United Nations Department of Economic and Social Affairs, Policy Brief, 130, (2022). Retrieved from: https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/undesa_pd_2022_policy_brief_population_growth.pdf, 2022.
[17] Wowrzeczka, B., ''City of Waste—Importance of Scale'', *Sustainability*, 13(7), Article Number: 3909, 2021.
[18] Yıldız, Ö., Cabalar, A. F., ''Cyclic Direct Shear Testing of a Sand with Waste Tires'', *Sustainability*, 14(24), 16850, 2022.