The Swelling Properties of Modified Expansive soil with pine tree Sawdust

Necmi Yarbaşı[1], Ekrem Kalkan[2*]
[1,2]*Ataturk University, Oltu Earth Sciences Faculty, Geological Engineering Department, Erzurum, Turkey*
[*]*Corresponding author*

***Abstract*: In this study, the swelling properties of stabilized expansive soil samples were investigated under laboratory conditions. The pine tree sawdust was used as additive material for this experimental study. The pine tree sawdust is waste and organic material in terms of eco-friendly additive materials for soil stabilization. For this purpose, the consistency limit tests and vertical swelling tests were carried out under the laboratory conditions. According to the results of experimental study showed that the swelling behavior of pine tree sawdust-stabilized expansive soil samples positively changed. As a result, the pine tree sawdust played an important role in improving the swelling behavior of the expansive soils. Consequently, it was concluded that the pine tree sawdust can be successfully used to improve the swelling characteristics of expansive soils as an eco-friendly additive material.**

***Keywords*— Soil, Expansive soil, pine tree sawdust, soil stabilization, swelling percentage**

I. INTRODUCTION

The expansive soil changes in volume in relation to changes in water content. This occurs as swelling upon wetting, and shrinkage upon drying. These soils have poor volume stability in the presence of water (Jones and Jefferson, 2012; Li et al., 2014). The expansive soil containing rich hydrophilic minerals is a kind of clay soil formed in the natural geological process. These soils are characterized with expansion, shrinkage and consolidability, which is significantly different from general clay (Liu et al., 2019; Miao and Liu, 2001).

Clayey soils are generally classified as expansive soils and these soils are known to cause severe damage to structures resting on them. However, these soils are very important in geology, construction, and for environmental applications, due to their wide usage as impermeable and containment barriers in landfill areas and other environmentally related applications (Erguler and Ulusay, 2003; Harvey and Murray, 1997; Kayabali, 1997; Keith and Murray 1994; Murray, 2000; Sabtan, 2005; Kalkan and Akbulut, 2004; Kalkan et al., 2019; Indiramma et al., 2020; Yarbaşı and Kalkan, 2020).

The expansive soils, frequently encountered in arid and semi-arid regions of the globe, are known to exhibit large volume changes. These soils have significant volume change associated with changes in water contents (Nelson and Miller, 1992; Ito and Azam, 2010; Jones and Jefferson, 2012). These soils primarily composed of expansive clay minerals exhibit high water absorbing and water retention abilities (Ito and Azam, 2009). These types of soil widely distributed throughout the world (Huang and Wu, 2007; Sabtan, 2005) are especially abundant in arid zones, where conditions are suitable for the formation of clayey minerals of the smectite group such as montmorillonite or some types of illites (Avsar et al., 2009; Nowamooz and Masrouri, 2008; Sabtan, 2005). These clays are characterized by having a very small particle size, a large specific surface area (SSA) and a high Cation Exchange Capacity (CEC) (Nalbantoglu and Gucbilmez, 2001; Nalbantoglu, 2004; Fityus and Buzzi, 2009; Seco et al., 2011). The mica-like group including illites and vermiculites can be expansive but generally does not cause significant problems (Zhang and Cao, 2002).

The improvement of soil properties is necessary to solve many engineering problems. Soil improvement techniques can be classified in various ways, for example, mechanical, chemical, and physical stabilization (Ingles and Metcalf, 1977; Lambe and Whitman, 1979; Naeini and Mahdavi, 2009; Kalkan et al., 2020). In the mechanical stabilization, the soil density is increased by the application of mechanical forces in the case of surface layer compaction. Chemical stabilization includes incorporation of additives such as natural soils, industrial by-products or waste materials, and cementitious and other chemicals. Physical stabilization includes changing the physical conditions of a soil by means of heating or freezing (Naeini and Sadjadi, 2008; Arab, 2019; Yarbaşı and Kalkan, 2019).

There are various methods of stabilization including either mechanical stabilization or chemical stabilization. Mechanical techniques densify the soil expelling air from the voids. Chemical techniques incorporate additives that improve the properties of problematic soils and the chemical stabilizers are characterized as traditional and non-traditional additives. Traditional stabilizers include calcium-based stabilizers such as lime and cement (Tingle et al., 2007; Pooni et al., 2019; Kalkan, 2020).

Several soil stabilization methods are available for stabilization of expansive clayey soils. These methods include the use of chemical additives, rewetting, soil replacement, compaction control, moisture control, surcharge loading, and thermal methods (Chen, 1988; Nelson and Miller, 1992; Yong and Ouhadi, 2007). Many investigators have studied natural, fabricated, and by-product materials and their use as additives for the stabilization of clayey soils.

In the construction of building, the wood is one of the oldest and most common materials in terms of areas of use. Theoretically, it is a natural material that can be obtained from all the trees and has its own quantity and quality characteristics within the scope of the various uses that social life and technological applications require (Bozkurt, 1986). Sawdust reacts chemically and forms cementitious compounds attributed to the improvement of strength and compressibility characteristics of soils in the presence of moisture (Abdulnafaa and Al-Khashab, 2009; Koteswara et al., 2012; Ogunribido, 2012; Jasim and Çetin, 2016). Also, there is also a study the behavior for sawdust after burning it and use it as ash (Khan and Khan, 2015).

In this study, the pine tree sawdust (PTS) was used as an eco-friendly additive material for the stabilization of expansive soils. The aim of this study was to investigate the effect of PTS on the swelling properties of expansive soils. To achieve this objective, the PTS-stabilized expansive soil samples was subjected to the lobotomy test in terms of the vertical swelling and the standard odometer tests.

II. MATERIAL AND METHOD

2.1. Expansive soil

The expansive soil was supplied from the calyey deposits of Oltu-Narman sedimentary basin, Erzurum, NE Turkey. The expansive soil material is inorganic clay with high plasticity (CH) in according with the United Soil Classification System. This material has high expansion potential as a result of over-consolidation, high-very high plasticity, and montmorillonite clay content (Kalkan, 2003; Kalkan and Bayraktutan, 2008). In this figure, a and b represent the expansive soil and PTS, respectively. The grain-size distribution and XRD pattern of expansive soil were given in the Figs. 1 and 2, respectively.

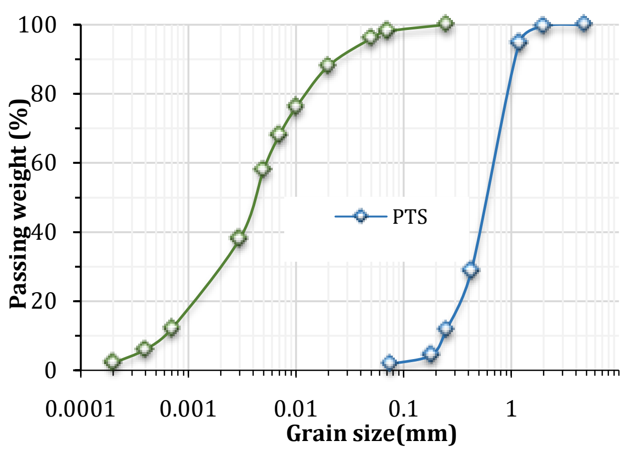

Fig. 1. The grain-size distributions of the expansive and PTS

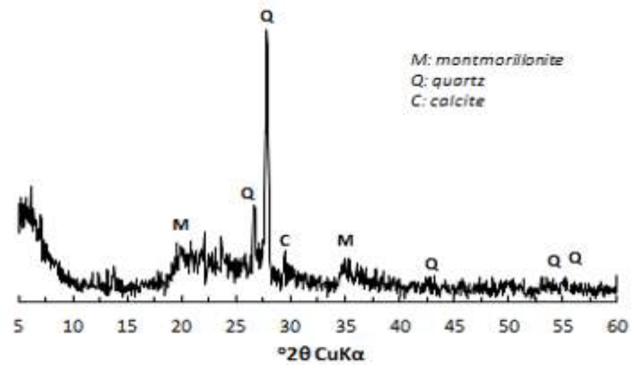

Fig. 2. XRD pattern of the expansive soil

2.2. PTS

The wood cutting factories generates a by-product known as sawdust. The PTS waste material was obtained from the carpenters in the industrial zone of Oltu (Erzurum), NE Turkey (Fig. 1). PTS is an organic waste resulting from the mechanical milling or processing of timber (wood) into various standard shapes and useable sizes. Consisting of soil-like particulate materials that are lighter than soil, sawdust inexpensive and environmentally safe (Rao et al., 2012; Oyedepo et al., 2014). The SEM image of PTS sample was given in the Fig. 3.

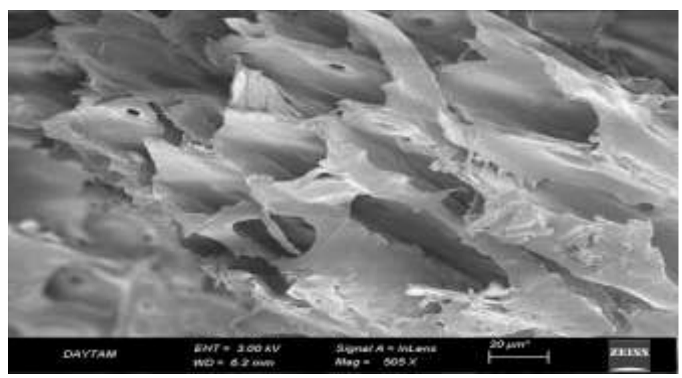

Fig. 3. The SEM image of PTS waste material

2.3. Preparation of expansive soil-PTS mixtures

The expansive soil and PTS were mixed under dry conditions to prepare mixtures of expansive soil-PST. The amounts of PTS were selected to be 0,5%, 1% and 1,5 % of the total dry weight of the mixtures (Table 1). The dry mixtures were mixed with the required amount of water recognized to give the optimum water content. All mixing was done manually and proper care was taken to prepare homogeneous mixtures at each stage.

Table 1. Expansive soil and pine tree rates of samples

Samples	Expansive soil	PTS	Total
MIX0	100	-	100
MIX1	99,5	0,5	100

MIX2	99,0	1,0	100
MIX3	98,5	1,5	100

2.4. Swelling percentage test

The vertical swelling value reported as a percentage was calculated in accordance with ASTM D 4546-14. The samples used for the vertical swelling percentage tests were first compacted at optimum moisture content and then extruded through a cylindrical mold with a 35 mm diameter and 70 mm height. The upper sides of the cylindrical samples in the cylindrical mold were trimmed. The remaining height of the new samples was 55 mm. The upper empty space (15 mm) of the cylindrical mold was filled with water. Afterwards, these samples were left to swell for 72 h. At the end of the tests, the amount of swelling was measured in each sample. The following equation was used for the calculation of vertical swelling percentage.

$$VSP = (L2 - L1)/L1 \times 100 \quad (1)$$

where VSP is the percent vertical swelling percentage in %, $L1$ is the first height of sample in mm before the addition of water and $L2$ is the final height of sample in mm after it had been allowed to swell for 72 h.

2.5. Permeability test

The falling-head permeability tests were carried out to determine the hydraulic conductivity of the samples of expansive soil and expansive soil -PTS mixtures, according to ASTM D 5084-10. The samples were prepared in 102 mm diameter proctor molds. Equation used to calculate the coefficient of permeability (k) is given below:

$$k = \frac{al}{At} ln \frac{h_0}{h_1} = 2.30 \frac{al}{At} \log_{10} \frac{h_0}{h_1} \quad (2)$$

where h_0 and h_1 are primary and secondary elevation of water in the tube, A is tube cross section, a is sample cross section, l is length of sample and t is the time of water flow through sample (water loss form h_0 and h_1) (Saghari et al., 2015).

III. RESULTS AND DISCUSSION

3.1. Effects of PTS on the swelling percentage

The amounts of swelling of natural expansive soil and expansive soil modified with PTS samples are shown in Fig. 4 and Table 2. The addition of PTS decreased in the vertical swelling of expansive soil samples. The vertical swelling percentages of PTS-modified expansive soil samples decreased from 11,55 to 6,60%, 3,86% and 2,18% for the 0,5%, 1% and 1,5%. The decrease in the swelling percentage values of the PTS-modified expansive soil samples is due to the addition of low-plastic materials and the interaction between PTS and expansive soil particles. Similar results were reported by Kalkan (2006), Okagbue (2007), Kalkan (2009a), Kalkan (2009b) and Rao et al. (2012).

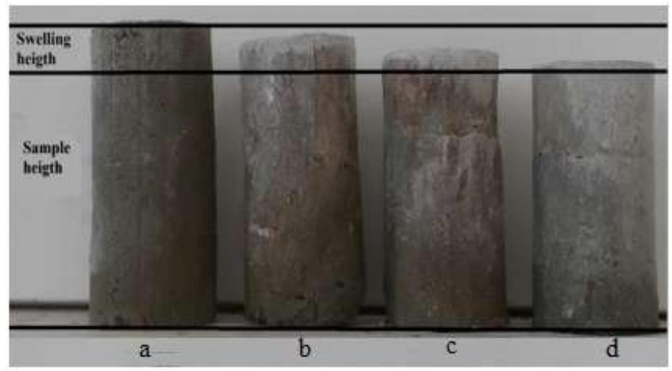

Fig. 4. The change in swelling amounts of the tested samples; a: MIX0, b: MIX1, c: MIX2 and d: MIX3

Table 2. Swelling percentages of natural expansive soil and PTS-modified expansive soil

Samples	Sample heigth (mm)	Swelling heigth (mm)	Total height (mm)	Swelling (%)
MIX0	55	6,35	61,35	11,55
MIX1	55	3,63	58,63	6,60
MIX2	55	2,12	57,12	3,86
MIX3	55	1,20	56,20	2,18

3.2. Effects of PTS on the permeability coefficient

The permeability test using falling-head permeability method was carried out on expansive soil -PTS mixtures with different weight percentage of PTS (0,5%,1% and 1,5%) that the results are summarized in Fig. 5. Permeability test on the PTS-modified expansive soil samples indicate that increasing weight percentage of PTS initially has increasing trend on the permeability coefficient.

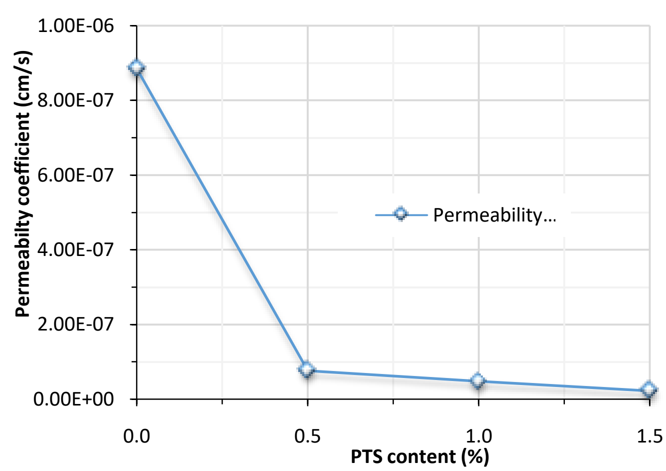

Fig. 5. The change in the permeability coefficients of the tested samples

IV. CONCLUSIONS

In this study, the effect of PTS on the swelling properties of expansive soil was investigated in terms of swelling percentage. The results obtained experimental studies showed that PTS play positively role on the swelling percentage of expansive soils. The addition of the PTS to the expansive soil materials decreased the swelling percentage values. The same positive results were obtained from the permeability tests and the PTS decreased the permeability values of the expansive soils. As a result, the PTS waste material can be used to improve the geotechnical properties of clayey soils in terms of swelling percentage. In addition, the PTS waste material can potentially reduce stabilization costs by utilizing wastes in a cost-effective manner.

REFERENCES

[1] Abdulnafaa, M.T., Al-Khashab, M.N., 2009. The Effect of Organic Matter's Content on the Engineering Properties of Expansive Soils Engineering and Technology Journal 28 (8), 318-334.

[2] Arab, M.G., 2019. Soil Stabilization Using Calcium Carbonate Precipitation via Urea Hydrolysis. Proceedings of the 4th World Congress on Civil, Structural, and Environmental Engineering (CSEE'19), April, 2019, Rome, Italy.

[3] Avsar, E., Ulusay, R., Sonmez, H., 2009. Assessments of swelling anisotropy of Ankara clay. Engineering Geology 105 (1-2), 24-31.

[4] Bozkurt, A.Y., 1986. Wood Technology. Istanbul University Faculty of Forestry Publications, Istanbul, Publication No: 3403/380.

[5] Chen, F.H., 1988. Foundations on Expansive Soils. Elsevier, Amsterdam.

[6] Erguler, Z.A., Ulusay, R., 2003. A simple test and predictive models for assessing swell potential of Ankara (Turkey) Clay. Engineering Geology 67, 331-352.

[7] Fityus, S., Buzzi, O., 2009. The place of expansive clays in the framework of unsaturated soil mechanics. Applied Clay Science 43 (2), 150–155.

[8] Harvey, C.C., Murray, H.H., 1997. Industrial clays in the 21st century: a perspective of exploration, technology and utilization. Applied Clay Science 11, 285-310.

[9] Huang, R., Wu, L., 2007. Stability analysis of unsaturated expansive soil slope. Earth Science Frontiers 14 (6), 129-133.

[10] Indiramma, P., Sudharani, C., Needhidasan, S., 2020. Utilization of fly ash and lime to stabilize the expansive soil and to sustain pollution free environment - An experimental study. Materials Today: Proceedings 22, 694-700.

[11] Ingles, O.G, Metcalf, J.B., 1977. Soil Stabilization Principles and Practice. 2nd ed, Australia Butterworths.

[12] Ito, M., Azam, S., 2009. Engineering characteristics of a glaciolacustrine clay deposit in a semi-arid climate. Bulletin of Engineering Geology and the Environment 68, 551-557.

[13] Ito, S.M., Azam, S., 2010. Determination of Swelling and Shrinkage Properties of Undisturbed Expansive. Geotechnical and Geological Engineering 28, 413-422.

[14] Jasim, O.H., Çetin, D., 2016. Effect of Sawdust Usage on the Shear Strength Behavior of Clayey Silty Soil. Sigma Journal Engineering and Natural Sciences 34 (1), 31-41.

[15] Jones, L.D., Jefferson, I.F., 2012. Expansive soils. In book: ICE Manual of Geotechnical Engineering. Volume 1, Geotechnical Engineering Principles, Problematic Soils and Site Investigation. Chapter: Expansive Soils, Publisher: ICE Publishing, Editors: J. Burland, pp. 413-441.

[16] Kalkan, E., 2003. The improvement of geotechnical properties of Oltu (Erzurum) clayey deposits for using them as barriers. PhD Thesis (in Turkish), Ataturk University, Graduate School of Natural and Applied Science, Erzurum, Turkey.

[17] Kalkan, E., 2006. Utilization of red mud as a stabilization material for preparation of clay liners. Engineering Geology 87 (3-4), 220-229.

[18] Kalkan, E., 2009a. Influence of silica fume on the desiccation cracks of compacted clayey soils. Applied Clay Science 43, 296-302.

[19] Kalkan, E., 2009b. Effects of silica fume on the geotechnical properties of fine-grained soils exposed to freeze and thaw. Cold Regions Science & Technology 58, 130-135.

[20] Kalkan, E., 2020. A Review on the Microbial Induced Carbonate Precipitation (MICP) for Soil Stabilization. International Journal of Earth Sciences Knowledge and Applications 2 (1), 38-47.

[21] Kalkan, E., Akbulut, S., 2004. The positive effects of silica fume on the permeability, swelling pressure and compressive strength of natural clay liners. Engineering Geology 73 (1-2), 145-156.

[22] Kalkan, E., Bayraktutan, M.S., 2008. Geotechnical evaluation of Turkish clay deposits: a case study in Northern Turkey. Environmental Geology 55, 937-950.

[23] Kalkan, E., Yarbaşı, N., Bilici, Ö., 2019. Strength performance of stabilized clayey soils with quartzite material. International Journal of Earth Sciences Knowledge and Applications 1 (1), 1-5.

[24] Kalkan, E., Yarbaşı, N., Bilici, Ö., 2020. The Effects of Quartzite on the Swelling Behaviors of Compacted Clayey Soils. International Journal of Earth Sciences Knowledge and Applications 2 (2), 92-101.

[25] Kayabali, K., 1997. Engineering aspects of a novel landfill liner material: bentonite-amended natural zeolite. Engineering Geology 46, 105-114.

[26] Keith, K.S., Murray, H.H., 1994. Clay liners and barriers, In: Carr, D.D. (Ed.), Industrial Minerals and Rocks, Sixth Edition. Society for Mining, Metallurgy and Exploration, Littleton, Colorado, pp. 435-452.

[27] Khan, S., Khan, H.,2015. Improvement of Mechanical Properties by Waste Sawdust Ash Addition into Soil. Electronic Journal of Geotechnical Engineering 20 (7), 1901-1914.

[28] Koteswara, R.D, Anusha, M., Pranav, P.R.T., Venkatesh, G., 2012. A Laboratory Study on the Stabilization of Marine Clay using Sawdust and Lime. International Journal of Engineering Science and Advanced 2 (4), 851-862.

[29] Lambe, T.W., Whitman, R.V., 1979. Soil Mechanics. SI version, New York, Wiley.

[30] Li, J., Cameron, D.A., Ren, G., 2014. Case study and back analysis of a residential building damaged by expansive soils. Computers and Geotechnics 56, 89-99.

[31] Liu, Y., Chang, C-W., Namdar, A., She, Y., Lin, C-H., Yuan, X., Yang, Q., 2019. Stabilization of expansive soil using cementing material from rice husk ash and calcium carbide residue. Construction and Building Materials 221, 1-11.

[32] Miao, L.C., Liu, S.Y., 2001. Engineering characteristics of expansive soil and engineering measures. Advances in Science and Technology of Water Resource 48 (2), 37-40.

[33] Murray, H.H., 2000. Traditional and new applications for kaolin, smectite, and palygorskite: a general overview. Applied Clay Science 17, 207-221.

[34] Naeini, S.A., Mahdavi, A., 2009. Effect of polymer on shear strength of silty sand. EJGE 14, 1-11.

[35] Naeini, S.A., Sadjadi, S.M., 2008. Effect of Waste Polymer Materials on Shear Strength of Unsaturated Clays. EJGE 13, 1-12.

[36] Nalbantoglu, Z., 2004. Effectiveness of Class C fly ash as an expansive soil stabilizer. Construction and Building Materials 18 (6), 377-381.

[37] Nalbantoglu, Z., Gucbilmez, E., 2001. Improvement of calcareous expansive soils in semi-arid environments. Journal of Arid Environments 47 (4), 453-463.

[38] Nelson, D.J., Miller, J.D., 1992. Expansive Soils: Problems and Practice in Foundation and Pavement Engineering. John Wiley & Sons, New York.

[39] Nowamooz, H., Masrouri, F., 2008. Hydromechanical behavior of an expansive bentonite/silt mixture in cyclic suction-controlled drying and wetting tests. Engineering Geology 101 (3-4), 154-164.
[40] Okagbue, C.O., 2007. Stabilization of Clay Using Woodash. Journal of Materials in Civil Engineering 19 (1), 14-18.
[41] Ogunribido, T., 2012. Geotechnical Properties of Saw Dust Ash Stabilized Southwestern Nigeria Lateritic Soils. Environmental Research Engineering and Management 2, (60), 29-33.
[42] Oyedepo, O.J, Oluwajana, S.D., Akande, S.P., 2014. Investigation of Properties of Concrete Using Sawdust as Partial Replacement for Sand. Civil and Environmental Research 6 (2), 35-42.
[43] Pooni, J., Giustozzia, F., Roberta, D., Setungea, S., O'Donnellb, B., 2019. Durability of enzyme stabilized expansive soil in road pavements subjected to moisture degradation. Transportation Geotechnics 21, 100225.
[44] Rao, D.K., Anusha, M., Pranav, P.R.T., Venkatesh, G., 2012. A laboratory study on the stabilization of marine clay using saw dust and lime. Internatıonal Journal of Engıneerıng Science and Advanced Technology 2 (4), 851-862.
[45] Sabtan, A.A., 2005. Geotechnical properties of expensive clay shale in Tabuk, Saudi Arabia. Journal of Asian Earth Science 25, 747-757.
[46] Saghari, S., Bagheri, G., Shabanzadeh, H., 2015. Evaluation of permeability characteristics of a polymer fibers-reinforced soil through laboratory tests. Journal of the Geological Society of India 85 (2), 243-246.
[47] Seco, A., Ramírez, F., Miqueleiz, L., García, B., 2011. Stabilization of expansive soils for use in construction. Applied Clay Science 51, 348-352.
[48] Tingle, J., Newman, J., Larson, S., Weis, C., Rushing, J., 2007. Stabilization mechanisms of nontraditional additives. Transportation Research Record 989-2 (1), 59-67.
[49] Yarbaşı, N., Kalkan E., 2019. The Stabilization of Sandy Soils by Using the Plastic Bottle Waste. International Journal of Advance Engineering and Research Development 6 (11), 140-144.
[50] Yarbaşı, N., Kalkan, E., 2020. The Mechanical Performance of Clayey Soils Reinforced with Waste PET Fibers. International Journal of Earth Sciences Knowledge and Applications 2 (1), 19-26.
[51] Yong, R.N., Ouhadi, V.R., 2007. Experimental study on instability of bases on natural and lime/cement-stabilized clayey soils. Applied Clay Science 35, 238-249.
[52] Zhang, J-R., Cao, X., 2002. Stabilization of Expansive Soil by Lime and Fly Ash. Journal of Wuhan University of Technology-Materials Science Edition 17 (4), 73-77.