The effect of pine tree sawdust on the freeze-thaw resistance of expansive soils

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

***Abstract*:The expansive soils in areas with seasonal frost are exposed to at least one freeze-thaw cycle every year. As a result of this affect, these soils lose their durability's. To prevent the strength, loss of expansive soils, it is necessary to improve the freeze-thaw resistance of them. In this study, it was investigated the effects of pine tree sawdust on the freeze-thaw resistance of expansive soils as alternative additive material. For this purpose, the natural and stabilized expansive soil samples were exposed to the freeze-thaw cycles under laboratory conditions. Then, the samples unexposed and exposed to the freeze-thaw cycles were subjected to the unconfined compressive tests. The experimental results showed that the pine tree sawdust-stabilized samples with have higher freeze-thaw resistance as compared to unstabilized expansive soil samples. Consequently, it was concluded that pine tree sawdust can be successfully used as an additive material to improve the freeze-thaw resistence of expansive soils.**

***Keywords*:Expansive soil, waste material, pine tree sawdust, soil stabilization, freeze-thaw resistance**

I. INTRODUCTION

The 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).

In the cold regions, soils in areas with seasonal frost are exposed to at least one freeze-thaw cycle every year. In the freezing period, subsoil moisture moves towards the frozen layer because of a temperature gradient. Void spaces of soil gradually increase due to frost heave and moisture move to the interstices of the soil and then freezes. In the thawing period, thawing of the frozen layer begins from the top and the bottom at the same time. The maximum soil moisture content appears above the frozen layer and becomes temporarily-perched water. Additionally, the soil moisture content under the frozen layer is more than it was during the prefrozen period (Zhang and Shijie, 2001; Yarbaşı et al., 2007).

The geotechnical properties of natural and stabilized soils change due to the effects of freezing-thawing cycles. For this reason, the strength and force of these soils are affected negatively. In cold regions, freezing–thawing damage is one of the major problems in road construction and earthwork applications. Cracking and spalling are the most common results of freezing–thawing damage in stabilized soils. The design and construction of earth structures influenced seasonally by subzero temperatures requires the determination of the mechanical properties of the construction materials under appropriate thermal conditions (Cruzda and Hohmann, 1997). The strength properties and the stress–strain behavior of soils influenced by subzero temperatures, under natural and laboratory water conditions, are well analyzed and the parameters of the strength and strain rates for many of these soil types have been investigated (Andersland, 1989; Zaman et al., 1992; Cruzda and Hohmann, 1997; Ma et al., 1999; Viklander and Eigenbrod, 2000; Grechishchev et al., 2001; Kozlowski, 2003; Talmucci, 2003; Akbulut and Saglamer, 2004; Hansson and Lundin, 2006; Wang et al., 2006).

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; Yarbaşı and Kalkan, 2019a; 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, 2019b).

In the soil stabilization application, there are some methods such as removal and replacement, precompression, vertical drains, in-situ densification, grouting, stabilization using admixtures and reinforcement. Each of these methods is appropriate for certain soil types and applied to the suitable soil types. In the geotechnical applications, it is very important to select the right and suitable stabilization method for the soil type to achieve success in the soil stabilization (Kalkan, 2020). The methods are needed that could offer enhanced soil stability, without the problem's current approaches face. Some stabilizer materials offer an alternative soil stabilization approach and, if applied properly, can be a cost efficient, long term, and a relatively environmentally friendly approach (Ivanov and Chu, 2008; Anbu et al., 2016; Kalkan, 2020).

There are various methods of stabilization including either mechanical stabilization or chemical stabilization. Mechanical techniques densify the soil expelling air from the voids. The 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).

Among the various building materials, 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). There is relatively limited experimental data on the use of sawdust for stabilization of fine-grained soil. Sawdust, which has a little cementitious value, 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).

In this study, the pine tree sawdust (PTS) was used as environmentally and eco-friendly additive material for the stabilization of expansivesoils. The PTS was added to the expansive soil material at the different contents to obtain stabilized expansive soil samples. The natural and stabilized with PTS additive material were subjected to the freeze-thaw and unconfined compressive tests. The test results were evaluated in terms of freeze-thaw resistance of stabilized expansive soil samples.

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 of expansive soil was given in the Fig. 1.

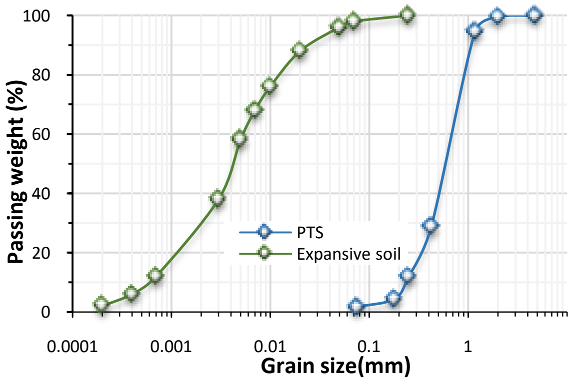

Fig. 1. The grain-size distributions of the expansive and PTS

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). The SEM image of PTS waste material was given in the Fig. 2. 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).

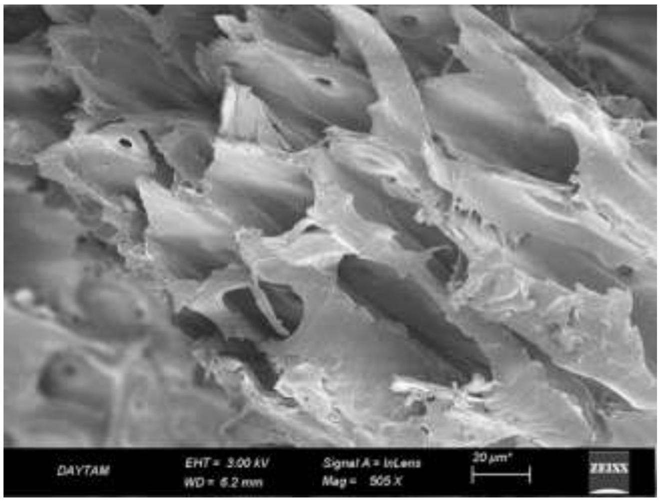

Fig. 2. The SEM image of PTS waste material

2.3. Preparation of expansive soil-PTS mixtures

Before mixing, expansive soil and PTS were dried at the oven. Then, the amounts of PTS were selected to be 0,5%, 1% and 1,5 % of the total dry weight of the mixtures (Table 1). After the mixing of expansive soil and PTS, the water at the optimum content was added and well blended. Then, natural and stabilized samples were obtained by carrying out compaction procedure.

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. Unconfined compression test

The unconfined compressive strength (UCS) values of natural and PTS-modified expansive soil samples were determined from the unconfined compression test in accordance with ASTM D 2166. The unconfined compression test was carried out on the cylindrical samples compacted at optimum moisture content. All of the samples had 35 mm in diameter by 70 mm in length. In this study, three cylindrical samples were prepared and tested for each combination of mixtures. The unconfined compression test was performed at a deformation rate of 0,8 mm/min. Before this test, the samples were cured at the curing time of 1, 7, 28 and 90 days.

2.5. Freeze-thaw test

To obtain the freeze-thaw resistance of the natural and stabilized expansive soil samples with PTS, all of the samples were exposed to the freeze-thaw cycles. Before this test, the samples were cured at the curing time of 1, 7, 28 and 90 days. This process was carried out by freeze-thaw tests under laboratory conditions. In the freeze-thaw test, firstly all samples were frozen at −21°C for 24 hours. Then, they were transferred from the freeze–thawapparatus into a test room at +21°C to allow the samples to thaw for 24 hours. This operation named as cycle 1 and this process was repeated 10 times.The freezing-thawing tests were performed by a programmable deep-freezer apparatus in accordance with ASTM D 560.

III. RESULTS AND DISCUSSION

3.1. Effects of PTS on the UCS of expansive soils before freeze-thaw cycles

The natural and stabilized expansive soil samples were subjected to the unconfined compressive strength test after curing of different curing period and results were illustrated in the Fig. 3. The results of experimental studies showed that the addition of PTS to the expansive soil increased the UCS values of stabilized expansive soil samples. The UCS values increased at the all of the PTS contents but the maximum improvement was obtained with the addition of 0.5% PTS content. The maximum raise at the UCS values was obtained at the end of 90 days curing time. At the all of curing time, the MIX1 was the best PTS-stabilized expansive soil sample. Similar results were reported by Udoeyo and Dashibil (2002), Okagbue (2007), Okunade (2008), Mageswari and Vidivelli (2009) and Oyedepo et al. (2014).

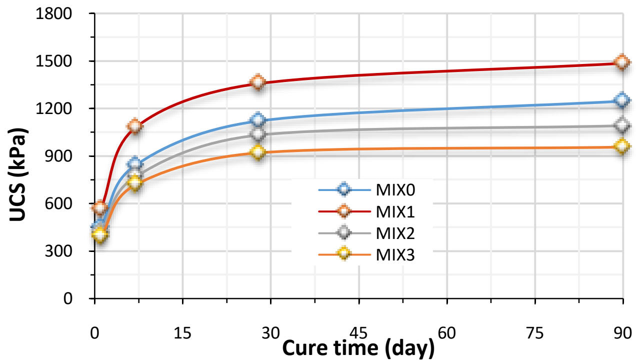

Fig. 3.The change in the UCS value with curing time before freeze-thaw cycles

3.2. Effects of PTS on the UCS of expansive soils after freeze-thaw cycles

The engineering properties of expansive soils exposed to the freeze-thaw cycles of seasonal differences changes negatively. The durability of these soils decreases under the acceptable level. As a result of this, the engineering structures located on the strength falling soils suffer structural damages. To overcome this problem expansive soils, need to the improvement. With for this purpose, expansive soil material was stabilized by using PTS waste material. The natural and PTS-stabilized expansive soil samples were exposed to the freeze-thaw cycles and then subjected to the unconfined compressive strength tests to investigate the changes on thefreeze-thaw resistance of stabilized expansive soils. The results obtained from the experimental studies showed that the soil stabilization by using PTS waste material is effective against to the freeze-thaw cycles of stabilized expansive soils. The change in the UCS value with curing time after freeze-thaw cycles was illustrated in the Fig. 4.

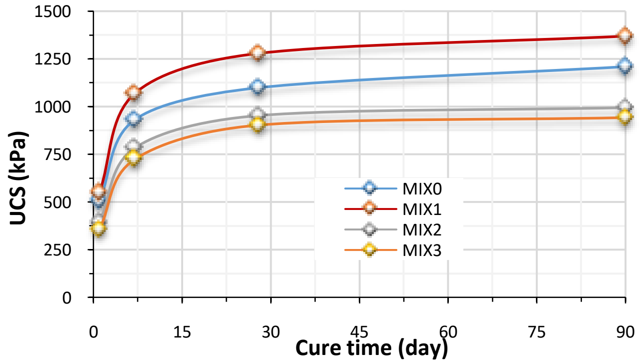

Fig. 4.The change in the UCS value with curing time after freeze-thaw cycles

Consequently, the maximum increase in the UCS values were before and after freeze-thaw cycles in the expansive soil samples stabilized with 0,5% PTS.Similar studies were performed from some researchers and parallel results were reported (Ghazavi and Roustaie, 2010; Yarbasi et al., 2007; Rao et al., 2012; Shawl et al., 2017).

IV. CONCLUSIONS

In this study, the effect of PTS on the freeze-thaw resistance of expansive soils stabilized with PTS waste material was investigated and obtained results were compared with that of the unstabilized expansive soils. The results obtained experimental studies showed that PTS play positively role on the freeze-thaw resistance of expansive soils. The maximum improvement in the freeze-thaw resistance was obtained at the MIX1 in term of soil stabilization.As a result, the PTS waste material can be used to improve the geotechnical properties of expansive soils in terms of freeze-thaw resistance. In addition, the PTS waste material can potentially reduce stabilization costs by utilizing wastes in term of cost-effective and environmentally friendly.

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] Akbulut, S., Saglamer, A., 2004. Modification of hydraulic conductivity in granular soils using waste materials. Waste Management 24, 491-499.
[3] Anbu, P., Kang, C.-H., Shin, Y.-J., So, J.-S., 2016. Formations of calcium carbonate minerals by bacteria and its multiple

applications. Springerplus 5 (1), 250.

[4] Andersland, O.B., 1989. General report on mechanical properties of frozen soil. Proceedings of 5th International Symposium onGround Freezing, I, pp. 433-441.

[5] 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.

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

[7] Cruzda, K.A., Hohmann, M.,1997. Freezing effect on strength of clayey soils. Applied Clay Science 12, 165-187.

[8] 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.

[9] Ghazavi, M., Roustaie, M, 2010. The influence of freeze–thaw cycles on the unconfined compressive strength of fiber-reinforced clay. Cold Regions Science and Technology 61, 125-131.

[10] Grechishchev, S.E., Instanes, A., Sheshin, J.B., Pavlov, A.V., Grechishcheva, O.V., 2001. Laboratory investigation of the freezing point of oil-polluted soils. Cold Regions Science and Technology 32, 183-189.

[11] 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.

[12] Hansson, K., Lundin, L.C., 2006. Equifinality and sensitivity in freezing and thawing simulations of laboratory and in situ data. Cold Regions Science and Technology 44, 20-37.

[13] 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.

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

[15] Ivanov, V., Chu, J., 2008. Applications of microorganisms to geotechnical engineering for bioclogging and biocementation of soil in situ. Reviews in Environmental Science and Biotechnology 7 (2), 139-153.

[16] 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.

[17] 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.

[18] 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.

[19] 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.

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

[21] 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.

[22] 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.

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

[24] 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.

[25] 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.

[26] Kozlowski, T., 2003. A comprehensive method of determining the soil unfrozen water curves 1. Application of the term of convolution. Cold Regions Science and Technology 36, 71-79.

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

[28] Ma, W., Wu, Z., Zhang, L., Chang, X., 1999. Analyses of process on the strength decrease in frozen soils under high confining pressure. Cold Regions Science and Technology 29, 1-7.

[29] Mageswari, M., Vidivelli, B., 2009. The use of sawdust ash as fine aggregate replacement ın concrete. Journal of Environmental Research and Development 3 (3), 720-726.

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

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

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

[33] Ogunribido, T., 2012. Geotechnical Properties of Saw Dust Ash Stabilized Southwestern Nigeria Lateritic Soils. Environmental Research Engineering and Management 2, (60), 29-33.

[34] Okagbue, C.O., 2007. Stabilization of Clay Using Woodash. Journal of Materials in Civil Engineering 19 (1), 14-18.

[35] Okunade, E.A., 2008. The Effect of Wood Ash and Sawdust Admixtures on the Engineering Properties of a Burnt Laterite-Clay Bricks. Journal of Applied Sciences 8 (6), 1042-1048.

[36] 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.

[37] 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.

[38] 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.

[39] Sabtan, A.A., 2005. Geotechnical properties of expensive clay shale in Tabuk, Saudi Arabia. Journal of Asian Earth Science 25, 747-757.

[40] Shawl, Z.Z., Parkash, E.V., Kumar, E.V., 2017. Use of lime and sawdust ash in soil stabilization. International Journal of Innovative Research in Science, Engineering and Technology 6 (2), 1682-1689.

[41] Talmucci, F., 2003. Freezing processes in porous media: formation of ice lenses, swelling of the soil. Mathematical and Computer Modeling 37, 595-602.

[42] Tingle, J., Newman, J., Larson, S., Weis, C., Rushing, J., 2007. Stabilization mechanisms of nontraditional additives. Transportation Research Record 989-2 (1), 59-67.

[43] Udoeyo, F.F., Dashibil, P.U., 2002. Sawdust Ash as Concrete Material. Journal of Materials in Civil Engineering 14 (2), 173-176.

[44] Wang, D., Zhu, Y., Ma, W., Niu, Y., 2006. Application of ultrasonic technology for physical–mechanical properties of frozen soils. Cold Regions Science and Technology 44, 12-19.

[45] Viklander, P., Eigenbrod, D., 2000. Stone movements and permeability changes in till caused by freezing and thawing. Cold Regions Science and Technology 31, 151-162.

[46] Yarbaşı, N., Kalkan E., 2019a. The Stabilization of Sandy Soils by Using the Plastic Bottle Waste. International Journal of Advance Engineering and Research Development 6 (11), 140-144.

[47] Yarbaşı N., Kalkan, E., 2019b. Freeze-Thaw Behaviors of Sandy Soils Modified by Mixtures of PET Fiber and Marble Dust. International Journal of Latest Technology in Engineering, Management & Applied Science 8 (12), 38-42.

[48] Yarbaşı, N., Kalkan, E., 2020. The Mechanical Performance of Clayey Soils Reinforced with Waste PET Fibers. International

Journal ofEarth Sciences Knowledge and Applications 2 (1), 19-26.
[49] Yarbasi, N., Kalkan, E., Akbulut, S., 2007. Modification of freezing-thawing properties of granular soils with waste additives. Cold Regions Science and Technology 48, 45-54.
[50] Zaman, M., Lagurous, J.G., Sayah, A., 1992. Soil stabilization using cement kiln dust. Proceedings of the 7th International Conference on Expansive Soils, Dallas, TX, pp. 347-351.
[51] Zhang, D., Shijie, W., 2001. Mechanism of freeze-thaw action in the process of soil salinization in northeast China. Environmental Geology 41, 96-100.