The strength change characteristics of weathering soil due to repeat freezing-thawing and drying-wetting

Les caractéristiques de changement de résistance du sol aux intempéries suite aux repetitions de la congélation-décongélation et du séchage-amortissement

Kim Y.S., Seong J.H.
Korea Infrastructure Safety and Technology Corporation, Republic of Korea
Kim S.S.
The Land and Housing Institute, Republic of Korea

ABSTRACT: Most researches are concentrated on sedimentary soil, and focused on the mechanical behavior of weathered soil from the viewpoint of sedimentary soil. Weathered soil shows great difference in engineering properties as the progression of weathering including the properties of parent rock. In this study, repeated freezing and thawing, drying and wetting test is conducted to recreate the effect of moisture and temperature, which might be considered as important for occurrence and efficacy on weathering among various factors in nature. In addition, to evaluate the strength changed by weathering degree, uniaxial test is conducted on sample with repeated freezing/thawing and drying/wetting. The specific gravity of the sample with the drying and wetting repeated decreased bigger than that with the freezing and thawing performed. In general, as the repetition number of freezing-thawing and drying-wetting increase, the compression stress of each sample decreased by a similar ratio. Especially, the strength change in the beginning by the repetition was significant. The uniaxial compression strength by the change of weathering degree decreases similarly for all the samples, but the axial deformation rate increases as the repetition numbers of the freezing and thawing and the drying and wetting increase.

RÉSUMÉ : La plupart des recherches se concentrent sur les sols sédimentaires et mettent l'accent sur le comportement mécanique des sols altérés du point de vue du sol sédimentaire. Le sol soumis aux intempéries montre une grande différence dans les propriétés mécaniques comme la progression de l'altération dont les propriétés de la roche mère. Dans cette étude, des tests de répétitions de congélation et de décongélation, de séchage et de mouillage sont effectués pour recréer l'effet de l'humidité et de la température, ce qui peut être considéré comme important pour l'apparition et l'efficacité sur l'altération des différents facteurs dans la nature. En outre, pour évaluer la résistance aux intempéries changée par degrés, l'essai uniaxial est effectué sur un échantillon répétés de congélation/ décongélation et séchage/humidification. Le poids spécifique de l'échantillon avec l'humidification et de séchage répétés diminution plus importante que celle de la congélation et la décongélation effectuée. En général, comme le nombre de répétitions de gel-dégel et séchage-mouillage augmente, la contrainte de compression de chaque échantillon a diminué dans une proportion similaire. Surtout, le changement de la force au début de la répétition est important. La résistance à la compression uniaxiale par le changement de degré intempéries diminue de même pour tous les échantillons, mais le taux de déformation axiale augmente à mesure que le nombre de répétition de la congélation et la décongélation et le séchage et de mouillage augmentation.

KEYWORDS: strength change characteristics, weathering soil, freezing/thawing, drying/wetting

1 INTRODUCTION

For weathering soil different from general deposit soil, its engineering properties sharply differ depending on the progress of weathering along with the characteristics of parent rock, which makes the study on this field difficult prior to an engineering research. In order to grasp the engineering properties of weathering soil, it is not enough to make a study from the dynamic view but a comprehensive investigation should be made from geological mineralogy, physics, chemistry, and dynamics. Through this, it is necessary to present how the properties of the soil from these views are expressed as a dynamic property and used in an engineering aspect.

Therefore, this study is to clarify the change of characteristics of granitic weathering soil due to the changes of temperature and water set by examining the existing studies on the effect of weathering factors on granitic weathering soil and considering the frequency and effect among the factors existing in the natural world. And for this, we are to promote the weathering artificially to express the weathering feature and weathering degree caused by weathering progress exponentially and consider correlations with the changes of soil's engineering characteristics so that a useful result may be drawn to accurately clarify the characteristics of granitic weathering soil in the future.

2 WEATHERING CHANGE TEST

For the weathering occurring in the real natural environment, various factors work together composite and the time scale of weathering is big that the effect of specific weathering factors on weathering and weathering acceleration are required in the study on weathering of soil. Thus, a test that controls the weathering speed and factors artificially by creating an extreme environment is suggested and it is necessary to identify the changes of soil's characteristics due to weathering in a quantitative aspect.

The most important thing in the weathering change test is to draw out the relation between testing environment and real environment as well as the relation between the weathering generated in the testing process and that in the real environment.

In this study, repetition tests of freezing and thawing as well as drying and wetting are conducted in order to reproduce the effect of temperature changes and water which are considered important in the aspect of occurrence frequency and effect among the various weathering factors existing in the natural world.

2.1. Repeat Freezing and Thawing

In the past, strength decrease due to freezing and thawing is thought to be caused by frozen gravitational water or absorption

water in the soil particles with a direct factor, but Aoyama and Fukuda(1990) proved that it can be generated in the closed system without water supply from under the ice layer.

In this study, Italian regulations that set the maximum and minimum temperatures based on real weather, are considered proper and applied to the test. In order to determine a proper temperature range suitable for the domestic weather conditions, the freezing and thawing temperatures are set based on the comparison of 10 years' weather data on Seoul, Icheon, Cheongju, Jeonju, Daegu, Milyang, Yeongju, Yeongwol, Wonju, Jecheon, and Taebaek along with its resulting temperature range of -21.1 to +26.5℃.

Therefore, the freezing and thawing temperatures to reproduce real weather conditions are set at -20℃ and +20℃ respectively, and the temperature duration at 4 hours to carry out a repetition test up to 200 times. For the water supply method, a freezing-induced method by maintaining comparative humidity rather than a flooding method is used, which is to reproduce a general effect occurring under the temperature condition below 0 not under special conditions such as rainfall or underground water.

2.2. Repeat Drying and Wetting

To reproduce the weathering caused by weakened binding power between the particles that compose soil when repeating the flooding and drying process in pure water excluding the effect of temperature, a drying and wetting repetition test was conducted.

For fresh rock or high consolidation rock, deterioration due to drying and wetting repetition does not occur significantly, however weakening of binding power between the particles and chemical weathering are promoted by the water permeated into a gap in the earth and sand state. In other words, chemical effects like reprecipitation of decomposed ions such as dissolution, filteration, deformation and salification change the characteristics of soil.

A method to copy rainfall is yet to be established that a total flooding method is applied to make a continuous contact between water and soil particles in this study. This is because only the surface of the soil particles would be affected if a periodic spraying method is applied.

3 STRENGTH CHANGE CHARACTERISTIC

3.1. Target Sample

The weathering soil sample to identify the strength change is classified into igneous rock, metamorphic rock, and sedimentary rock, and the soil underground has been collected after removing about 1.0m surface layer to exclude the effect of vegetation.

Table 1 shows the test codes by strength test for weathering degree change cycle.

3.2. Physical Characteristic Change

Weathering soil is a type of soil with a very high crushability compared to other types of deposit soil. Fig. 1 and Fig. 2 are representative results performed to know the effect of particle crushing caused by weathering progress.

As shown in the figures above, the grain-size distribution curves move to the left when repeating the freezing and thawing and the drying and wetting compared to that of the test beginning state, which means soil particles become finer and signifies that the distribution effect of weathering soil is very big because of the weathering caused by temperature and water. The previous studies shows that the granulation of quartz and feldspar by the particle change take the most cases of the granulation.

The increase in fine-grained soil due to the 190 time repetition of freezing and thawing and the 180 time repetition of drying and wetting are compared with each other and shown in Table 1. The report of Kim(2002) also pointed out that the shape and feature of the surface among basic structural characteristics have a huge impact on the physical and dynamic features of soil, and among many factors for the change of particle shape, the initial grain diameter, mineral composition of particles, and features for weathering work as important factors and the characteristics change according to the weathering progress.

Table 1. Classification of strength test and test codes

Artificial Weathering Conditions	Estimated Parent Rock	Sample Type	Classification Code	Cycle Times	Direct shear Test Condition	Uniaxial Compression Test Condition
Freezing Thawing (F)	Igneous rock (G)	Seoul	FGS	0 10 25 40 60 80 100 120 150 190	- initial condition 0.95Ydmax -vertical Stress (kg/cm2) 0.35 0.69 1.04 1.39 -shear speed 0.5mm/min -test code (S)	- initial condition 0.95Ydmax -deformation Speed 0.1%/min -test code (U)
		Yuseong	FGY			
		Jeonju	FGJ			
	Sedimentary rock (S)	Cheongdo	FSC			
		Goryeong	FSG			
		Gwangju	FSK			
	Metamorphic Rock (M)	Sabuk	FMS			
		Mungyeong	FMM			
Drying Weting (D)	Igneous rock (G)	Seoul	DGS	0 10 40 60 100 150 180		
		Yuseong	DGY			
		Jeonju	DGJ			
	Sedimentary rock (S)	Cheongdo	DSC			
		Goryeong	DSG			
		Gwangju	DSK			
	Metamorphic rock (M)	Sabuk	DMS			
		Mungyeong	DMM			

After checking the change of water content by weight during drying through a preparatory experiment, it turned out to have deteriorated below the optimum level in about 24 hours, so the repetition test of drying and wetting in this study has been performed with 24-hour cycle.

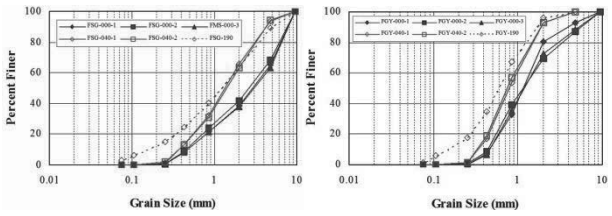


Figure 1. Grain-size distribution change caused by freezing and thawing repetition

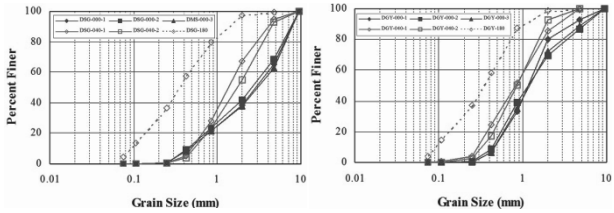


Figure 2. Grain-size distribution change caused by drying and wetting repetition

Table 2. Increase of fine grain by the change of weathering degree (unit : %)

Division	Seoul	Jeonju	Cheongdo	Goryeong	Gwangju	Sabuk
Freezing/ thawing	1.6	1.7	2.5	2.8	2.5	3.5
Drying/ wetting	3.2	5.9	3.3	4.6	1.6	0.8

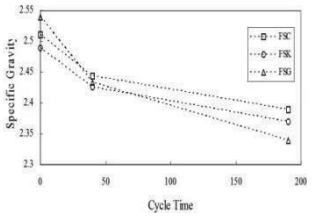
The previous studies suggest that among primary minerals in weathering soil, especially feldspar and mica change selectively as weathering proceeds that it is possible to apply them as an index for weathering degree when distinguishing these components and measuring their specific gravities(Matsuo, 1979). This study is intended to measure the outward specific gravities and understand the changes according to the weathering progress.

First of all, after testing the samples with the freezing and thawing and the drying and wetting repeated 0, 40, and 190(180 for drying and wetting) times respectively according to KSF 2308, it turned out that the specific gravity soil particles decreases as the number of repetitions increases.

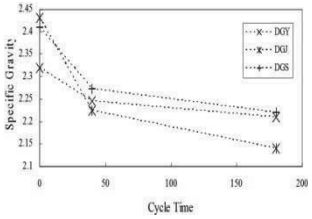
Figure 3 shows the change of specific gravity by the freezing and thawing repetition, signifying the specific gravity change appears high in the beginning of the repetition. Comparing the specific gravities in the beginning by parent rocks, it shows that metamorphic rock has the biggest one followed by sedimentary rock, and igneous rock has the lowest one, but for the decreasing specific gravity from the result of the weathering change test, it shows that sedimentary rock and metamorphic rock have a similar change while igneous rock has a comparatively smaller change.

Next, the change of specific gravity by the drying and wetting repetition are divided by parent rocks and shown in Figure 4, which indicates that the change of specific gravity decreases as the number of repetitions increases just like the freezing and thawing repetition, and the change in the beginning of the repetition appears great.

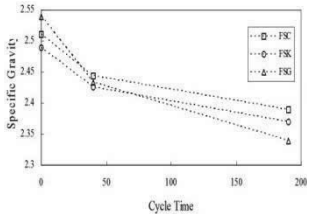
However, when comparing the decreasing specific gravities from the result of the weathering change test, igneous rock takes the highest one followed by metamorphic rock, and sedimentary rock takes the lowest one, which is different from the freezing and thawing case. Therefore, with the effect factors of weathering that causes the change of specific gravity, it is judged that the weathering by water has a more dominant effect on the change of specific gravity than that by temperature change.



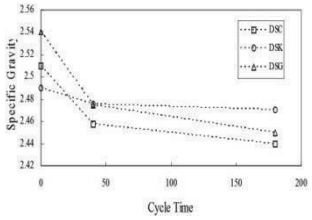
(a) Igneous rock



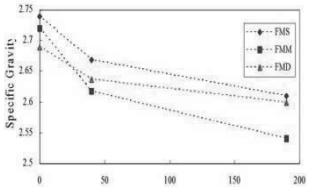
(a) Igneous rock



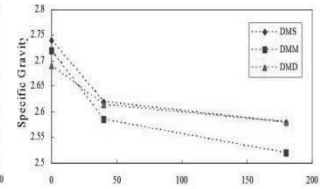
(b) Sedimentary rock



(b) Sedimentary rock



(c) Metamorphic rock



(c) Metamorphic rock

Figure 3. Change of Specific Gravity by Freezing and Thawing Repetition

Figure 4. Change of Specific Gravity by Drying and Wetting Repetition

Nevertheless, the real specific gravity of weathering soil changes very little, but feldspar and mica are changed selectively by the weathering that it is acknowledged that a comprehensive change trend should be traced after measuring the specific gravities of feldspar and mica.

3.3. Strength Characteristic Change

Figure 5 and Figure 6 are the result of an uniaxial compression test after thawing and drying so as to know the progress of strength changes due to the changes in the numbers of the freezing and thawing and the drying and wetting. In general, as the repetition number of freezing and thawing increased, the compression stress of each sample decreased by a similar ratio. The initial stress of each sample appeared different while the compression stress during the 190 time repetitions has a little difference.

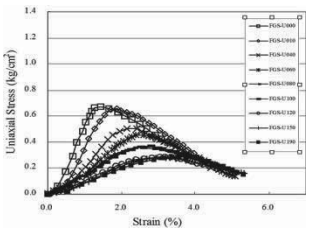
In other words, the strength change in the beginning by the freezing and thawing is significant, which is similar to the study result that Yong et al.(1985) reported the strength decrease by the first repetition is the biggest. Compared with igneous rock, sedimentary rock and metamorphic rock shows a bigger strength decrease by the freezing and thawing repetition.

For the drying and wetting repetition, the strength by the increase of repetition number continued to decrease with a bigger change in the beginning than the overall decreasing tendency. The uniaxial compression strength by the change of weathering degree decreases similarly for all the samples, but the axial deformation rate increases as the repetition numbers of the freezing and thawing and the drying and wetting increase.

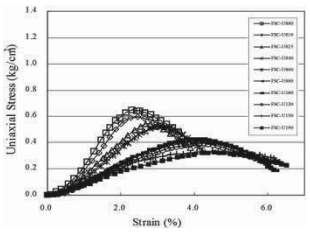
In other words, the softening of deformation rate appears in the initial result of the compression test, while the hardening of deformation rate becomes vivid as the repetition numbers of the freezing and thawing and the drying and wetting.

The reason why the strength decreases as the repetition number of the freezing and thawing increases, is not that the strength rovers completely due to thawing but it turns to the state with a certain degree of strength decrease and back to the

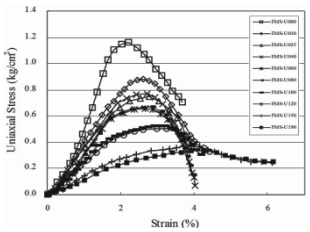
freezing state weakening its strength gradually. In addition, the strength decrease by the drying and wetting repetition is caused by the weakened binding power between soil particles.



(a) Seoul

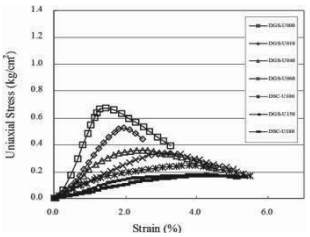


(b) Chenongdo

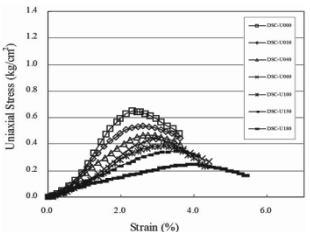


(c) Sabuk

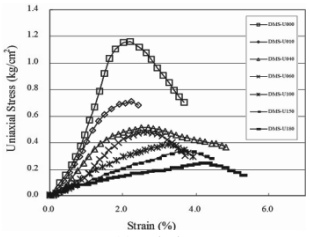
Figure 5. Uniaxial Compression Test Result of Freezing and Thawing Test Conditions



(a) Seoul



(b) Cheongdo



(c) Sabuk

Figure 6. Uniaxial Compression Test Result of Drying and Wetting Test Conditions

The soil particles in the strength recovery and expansion area of the soil in a dense state are oriented to show the maximum contact area perpendicular to the maximum main stress direction, so the expansion motion in a dense state is bigger than that in a loose state and with a bigger initial tangent modulus.

Negative pressure in the freezing and thawing boundary is the function of the gap size and on this point. the decrease of gap water pressure increased the effective stress. At this point, if a freezing starts, an ice nucleation is formed and a Cluster in between soil particles and water is discharged from the Cluster that the compression of the soil in the cluster is promoted by the increased effective stress and dehydration. Once the thawing starts, the cluster turns into a over consolidated state than the original soil through the process of re-absorption as a thawing water, leading to a collapse and weakening(Choi, 1996). From this, we can learn that some structural change may have occurred in the soil particles due to the freezing and thawing, and that it is similar to the study result by Kim(2002) that for the solid affected by the freezing and thawing, soil structure and physical and chemical properties change without increases of water content by weight.

4 CONCLUSIONS

For the characteristics of weathering soil, there should always be limits to a minute access because of the particularity of motion due to various weathering environment, weathering degree and effect factors. Especially, the domestic and overseas studies are focused on deposit soil and tend to analyze dynamic motion of weathering soil from the aspect of deposit soil that it is difficult to judge whether these results correspond to the real motion of the weathering soil. Therefore, this study is to clarify the characteristic change of igneous weathering soil by the changes of temperature and water.

The strength change characteristics are identified by promoting the weathering artificially through the freezing and thawing and the drying and wetting processes.

After examining the effect of particle crushing by the progress of weathering, it is identified that the particles become finer through the freezing and thawing and the drying and wetting processes. It is understood that the granulation by water and temperature is caused by the granulation of quartz and feldspar due to the change of grain sizes.

By measuring the outward specific gravity and examining the change by weathering progress, it is understood that the specific gravity of soil particles decreases as the repetition numbers of the freezing and thawing and the drying and wetting increase. The change of specific gravity appeared big in the beginning of the repetition and decreasing as its number increases. The specific gravity of the sample with the drying and wetting repeated decreased bigger than that with the freezing and thawing performed.

And when judging the effect factors of the weathering that causes the change of specific gravity, it is judged that the weathering by water rather than that by temperature has more dominant effect on the specific gravity change.

In general, as the repetition number of freezing and thawing increased, the compression stress of each sample decreased by a similar ratio. Especially, the strength change in the beginning by the freezing and thawing was significant.

However, the initial stress of each sample appeared different while the compression stress during the 190 time repetitions has a little difference. For the drying and wetting repetition, the strength by the increase of repetition number continued to decrease with a bigger change in the beginning than the overall decreasing tendency. The uniaxial compression strength by the change of weathering degree decreases similarly for all the samples, but the axial deformation rate increases as the repetition numbers of the freezing and thawing and the drying and wetting increase.

It is very difficult to draw out the relation between testing environment and real environment as well as the relation between the weathering generated in the testing process and that in the real environment, and to identify this fact from the mere study result, so it is judged that a stored data and analysis for various soil qualities would enable a quantitative distinction in the weathering stage.

5 REFERENCES

Aoyama, K., and Fucuda, M. 1990. Stress-Deformation characteristics of a soil after freezing and thawing. *Proceedings of the ninth Danube-European conference on soil Mechanics and Foundation Engineering.* Budapest. October. 2-5. pp. 393-403

Matsuo, S., /Nisida, K. and Sasaki, S. 1979. Physical properties of weathered Granite soil paticles and their effect on permeability. *soils and foundations*. Japanese Society of soil Mechanics and foundation engineering. vol. 19, No.1, pp.13-22

S.Y. Choi. 1996. A study on the characteristics of the physical and engineering properties of weathered soil of freezing and thawing. Master Thesis, Kang-Won National Univ.

Yong, R. N., Boonsinsuk, P., and Yin, C. W. P. 1985. Alteration of soil behavior after cycle freezing and thawing. *The 4th International Symposium on Ground Freezing*. August. pp.187-195

Y.S. Kim. 2002. Development of the method to determine the weathering degree of decomposed granites soil for the evaluation of the engineering properties. Ph.D Thesis. Chung-Ang Univ.