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Research Article

Strength and Durability Performance of Clayey Soil Stabilized with Lime and Marble Powder

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ABSTRACT

This paper investigated the effect of freezing-thawing and wetting-drying cycles on the strength and durability of clay soil stabilized with lime and marble powder. The test samples were prepared by adding 5%, 10%, 15% and 20% of marble powder, without and with 6% lime to the soil which is a high plasticity clay (CH) according to the Unified Soil Classification System. Unconfined compressive strength tests were performed after 7 and 28 days of curing periods. The durability behavior of the samples was examined by applying freezing-thawing and wetting-drying cycles to the prepared samples. The results of this study show that the presence of marble powder in the soil mixture has an important role in the improvement of strength. An increase in the number of wetting-drying cycles does not decrease the volumetric stability of the samples stabilized with marble powder. The use of lime and marble powder together increased the strength values compared to the natural soil and the use of lime only. It was concluded that the co-use of lime and marble powder had a positive effect on the strength and durability behavior of high plasticity clayey soil.

Keywords: Soil stabilization, lime, marble powder, freezing-thawing, wetting-drying

Kireç ve Mermer Tozu ile Stabilize Edilmiş Killi Zeminlerin Dayanım ve Durabilite Performansı

ÖZET

Bu çalışma, donma-çözülme ve ıslanma-kuruma çevrimlerinin kireç ve mermer tozu ile stabilize edilmiş kil zeminin dayanım ve durabilitesi üzerindeki etkisini araştırmıştır. Birleşik Zemin Sınıflandırma Sistemi'ne göre yüksek plastisiteli bir kil (CH) olan zemine kireçsiz ve %6 kireçli olarak %5, %10, %15 ve %20 mermer tozu eklenerek test numuneleri hazırlanmıştır. 7 ve 28 günlük kür sürelerinden sonra serbest basınç dayanımı testleri yapılmıştır. Numunelerin durabilite davranışı, hazırlanan numunelere donma-çözülme ve ıslanma-kuruma çevrimleri uygulanarak incelenmiştir. Bu çalışmanın sonuçları zemin karışımında mermer tozunun varlığının, dayanım artışında önemli bir rol oynadığını göstermektedir. Islanma-kuruma çevrimlerindeki artış, mermer tozu ile stabilize edilen numunelerin hacimsel kararlılığını azaltmamıştır. Kireç ve mermer tozunun birlikte kullanılması, doğal zemine ve sadece kireç kullanımına kıyasla mukavemet değerlerini arttırmıştır. Kireç ve mermer tozunun birlikte kullanılmasının, yüksek plastisiteli killi zeminin dayanım ve durabilite davranışı üzerinde olumlu bir etkisi olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Zemin stabilizasyonu, kireç, mermer tozu, donma-çözülme, ıslanma-kuruma

I. INTRODUCTION

Chemical stabilization is one of the cheapest technique for the stabilization of soils. It is familiar to use lime as an additive in soil stabilization. The use of lime improves the engineering properties of soils, especially clayey soils. Lime stabilization is one of the most applied methods in airport and highway pavement [1]. In the light of literature studies, it was found that lime reduces the plasticity index of the soil when applied to clayey soils [2]. As the ratio of lime increases, the liquid limit value decreases and the plastic limit value increases [3]. In the literature, it was determined that the addition of more than 10% lime to the soil had no significant effect on strength values [4]. In the study conducted by Bell (1996), the optimum lime ratio was found to be between 4-6% [5].

The method of improving clay soils with lime has been widely used for many years and is preferred primarily in railway, road, parking and building constructions in many countries [6-10]. Lime stabilization increases the permeability of the clay while swelling parameters decrease [11,12].

Marble is a rock with a high amount of CaCO_3 in its structure. The marble, which is a pure calcium carbonate composition, is white and translucent [13]. Due to the very small structure of marble powder particles and similarity with lime, it can be preferred instead of lime for the stabilization of fine-grained soils. [14]. In this study, the usability of marble powder and lime under freezing-thawing and wetting-drying cycles in soil stabilization was investigated.

II. MATERIALS AND METHODS

The materials used in the study are high plasticity clayey soil, lime and marble powder. In this study, the index, strength and durability properties of the soil with these additives were examined. The soil used in this study was taken from a research pit located in Demirözü District of Bayburt Province. Material taken from this region with an altitude of 1975 m was brought to Bayburt University Geotechnical Laboratory. The material was taken from a depth of approximately 2 m from the soil surface. Test samples were prepared by adding lime and marble powder to natural soil. In all experiments, samples were prepared after the natural soil was kept in the oven for 24 hours.

Within the scope of the study, the effects of marble powder on strength and durability were prepared separately with and without lime samples. The study started with the addition of marble powder directly to the soil. The data obtained required the presence of a primary binder and lime was chosen as the primary binder. Literature studies [15-18] were examined and it was found appropriate to add lime to the mixture at the rate of 6%. Samples were prepared by adding marble powder in 5%, 10%, 15% and 20% ratios with/without 6% of lime to the soil. The notation of test samples is given in Table 1. The properties of natural soil are presented in Table 2.

Table 1. The notations of test specimens

Mixing ratios of test samples	Notation
Natural soil	S
Natural soil and 5% marble powder	SM/5
Natural soil and 10% marble powder	SM/10
Natural soil and 15% marble powder	SM/15
Natural soil and 20% marble powder	SM/20
Natural soil and 6% lime	SL
Natural soil, 6% lime and 5% marble powder	SLM/5
Natural soil, 6% lime and 10% marble powder	SLM/10
Natural soil, 6% lime and 15% marble powder	SLM/15
Natural soil, 6% lime and 20% marble powder	SLM/20

Table 2. Natural soil properties

Liquid limit, LL (%)	60,81
Plastic limit, PL (%)	30
Plasticity index, PI (%)	30,81
Specific gravity, G_s	2,6
Optimum water content, w_{opt} (%)	22,5
Maximum dry density, ρ_{kmax} (Mg/m ³)	1,63
Color	Flavescent

Sieve analysis has shown that the soil class is high plasticity clay (CH) according to USCS. The granulometry curve of the fine-grained soil is shown in Figure 1. Atterberg limit tests were conducted in the scope of this study. Atterberg limits are mainly liquid limit and plastic limit [19]. Cone penetrometer method was used for the liquid limit test. In addition to sieve analysis and Atterberg limit tests, other experiments performed in this study were compaction, unconfined compressive strength, freezing-thawing, and wetting-drying tests. The dimensions of the samples used in the experiments were 50 mm in diameter and 100 mm in height. The standards taken as reference in the conduct of the experiments are presented in Table 3.

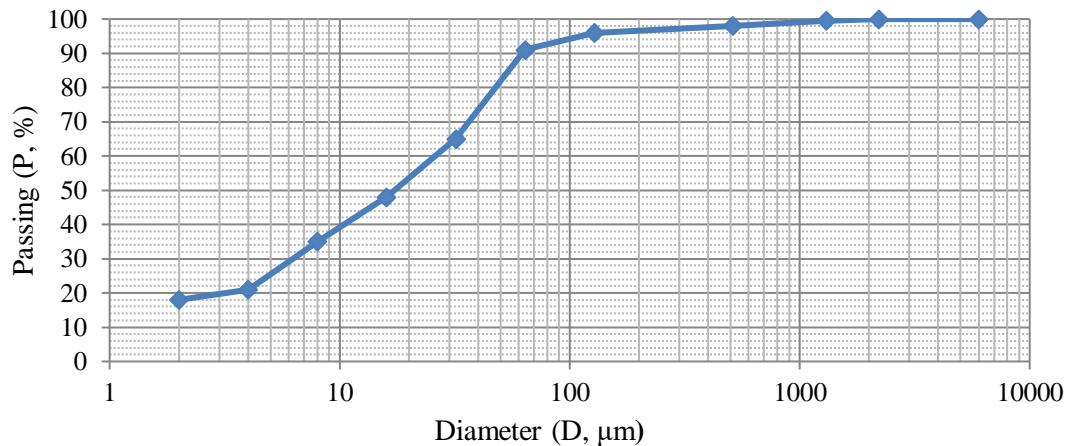


Figure 1. Grain size distribution of the soil

Table 3. Reference standards in experiments

Experiment	Reference Standard
Specific gravity test	ASTM D 854 [20]
Sieve analysis	ASTM D 422 [21]
Consistency limits	ASTM D 4318 [22]
Compaction test	ASTM D 698 [23]
Unconfined compressive strength test	ASTM D 2166 [24]
Freezing-thawing test	ASTM D 560 [25]
Wetting-drying test	ASTM D 559 [26]

III. RESULTS

The consistency limits values obtained in the study are presented in Table 4. The lowest liquid limit value was determined in SLM/20 sample and the highest plastic limit value was observed in the SLM/10 sample as a result of liquid limit tests. When marble powder was added to SL samples, a decrease in

liquid limit values was detected and an increase in plastic limit values was observed. While liquid limit values of SM samples are higher than SLM samples, plastic limit values are lower.

Table 4. Consistency limits

Specimen	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
S	60,8	30	30,8
SM/5	57,4	32,1	25,3
SM/10	58,6	32,8	25,8
SM/15	58,1	31,6	26,5
SM/20	57,8	30,9	26,9
SL	54,9	34,5	20,4
SLM/5	54,1	34,9	19,2
SLM/10	53,9	35,7	18,2
SLM/15	53,0	34,8	18,2
SLM/20	51,6	34,5	17,1

The results of the compaction tests in which the maximum dry densities and optimum water contents of the test specimens are determined within the scope of the study are given in Table 5. Considering the compaction results of the SL sample, the optimum water content increased and the maximum dry density decreased. While the maximum dry density of SM samples in general compared to the natural soil increased, there was a slight decrease in the optimum water contents. In this study, the highest maximum dry density and lowest optimum water content values were determined in SLM samples. In the light of compaction test results, the highest maximum dry density was determined in the SLM/20 sample.

Table 5. Proctor test results

Specimen	Maximum dry density (Mg/m³)	Optimum water content (%)
S	1,63	22,5
SM/5	1,62	22,3
SM/10	1,66	22,8
SM/15	1,65	22,4
SM/20	1,65	22,3
SL	1,50	26,0
SLM/5	1,62	19,0
SLM/10	1,59	20,0
SLM/15	1,64	20,0
SLM/20	1,68	19,0

Table 6 shows the results of the unconfined compressive strength test applied after 7 and 28 days curing of samples. When Table 6 was examined, it was found that the addition of lime to the natural soil increased the unconfined compressive strength approximately 5 times. It was observed that limeless samples show ductile mechanical behavior while limy samples break brittle. Maximum strength in SM mixtures that occurred in the SM/10 sample. In SLM mixtures, the SLM/10 sample gave maximum strength. The SM/10 sample showed 2 times in strength compared to natural soil. While the SL sample showed 5 times increase in strength compared to natural soil, the SLM/10 sample increased 8 times. These results clearly demonstrate the positive effect of marble powder on strength. It is thought that the marble powder combines with the active CaO in the lime to increase the strength. The strength data of the test samples are presented in Figure 2.

Table 6. Unconfined compressive strength test results

Specimen	Strength (kPa)	
	Curing period	
	7 days	28 days
S	115,2	120,3
SM/5	134,0	162,1
SM/10	212,2	254,8
SM/15	174,8	192,0
SM/20	146,5	176,5
SL	560,2	657,0
SLM/5	621,0	672,0
SLM/10	778,3	981,2
SLM/15	710,4	937,5
SLM/20	685,3	861,2

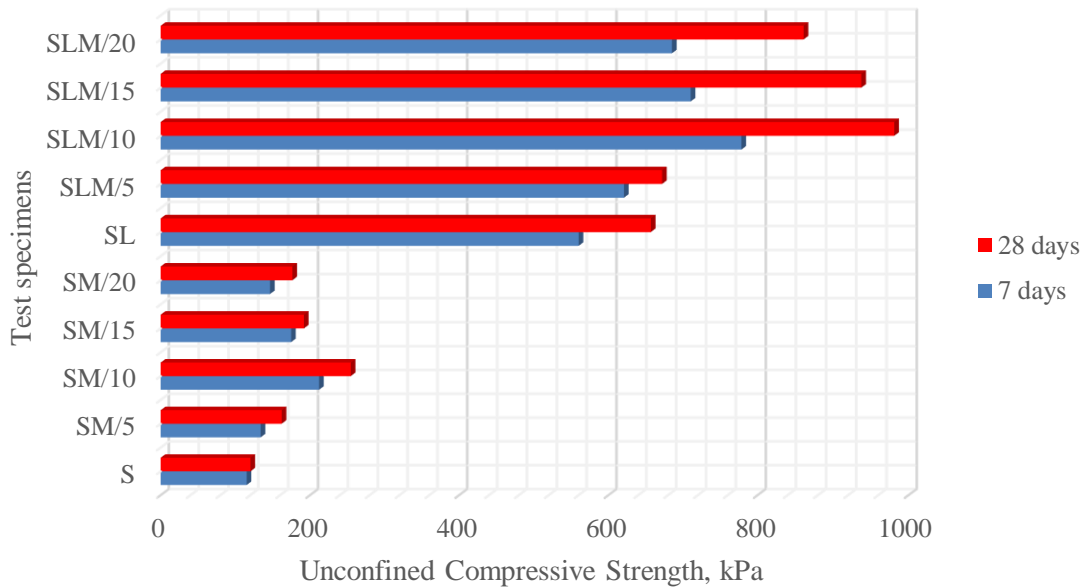


Figure 2. Strength test results

18 test specimens with 50 mm diameter and 100 mm height were prepared for the wetting-drying tests. After the curing period for 28 days, 12 wetting-drying periods were performed. Wetting and drying results of S and SM samples and S, SL and SLM samples are presented in Figure 3 and Figure 4, respectively. As can be seen from the figures, the natural soil has completely lost its volumetric integrity at the end of the third cycle. SL sample lost its volumetric integrity after 7 cycles of wetting-drying. Samples containing marble dust have preserved their structural integrity against the wetting-drying period.

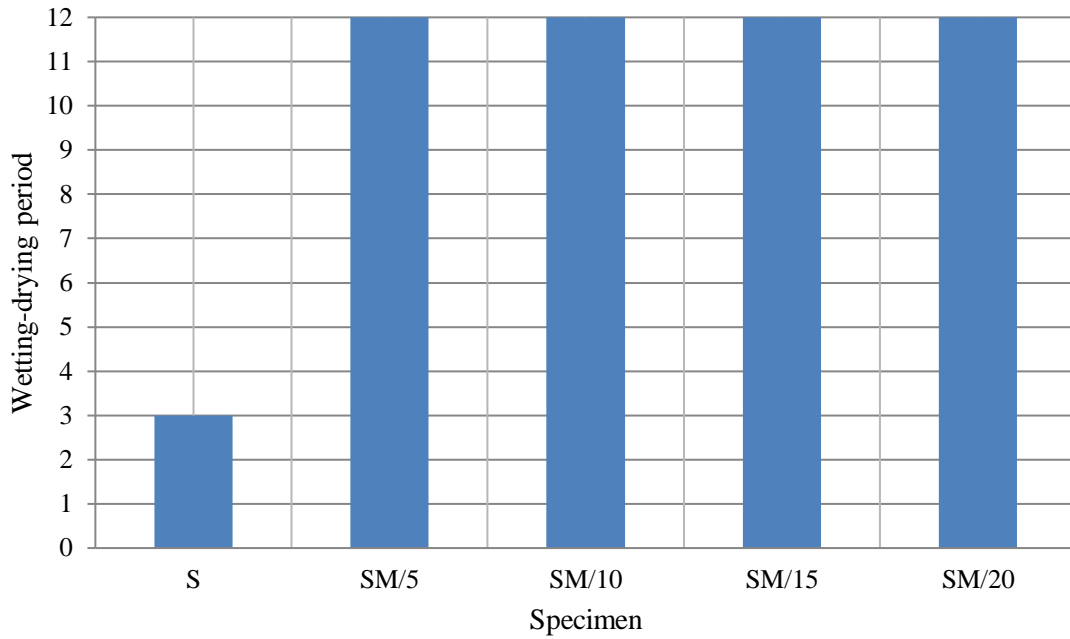


Figure 3. Wetting and drying cycle time of S and SM samples

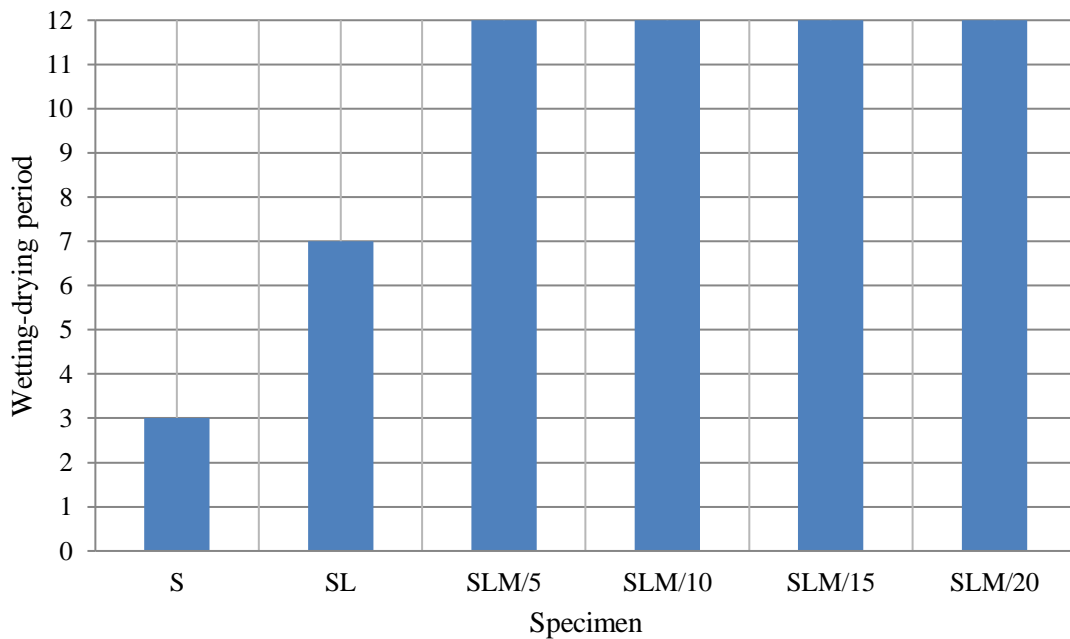


Figure 4. Wetting and drying cycle time of S, SL and SLM samples

For the freezing-thawing experiment 54 test specimens were prepared and after being cured for 28 days, they were subjected to 12 freezing-thawing cycles. Unconfined compressive strength results after freezing-thawing cycles are given in Figure 5. The strength loss of SM and SLM specimens after the freezing-thawing cycle are presented in Figure 6 and Figure 7, separately. When the unconfined compressive strength test values after freezing-thawing were examined, it was observed that there was a decrease in the strength of all mixtures in general. It was observed that the unconfined compressive strength values were higher in SLM mixtures compared to SL mixtures. Similar to the results of unconfined compressive strength test after 28 days of curing, maximum strength was obtained from SL/10 and SLM/10 samples. It was determined that SLM samples are more effective in freeze-thaw than SM samples.

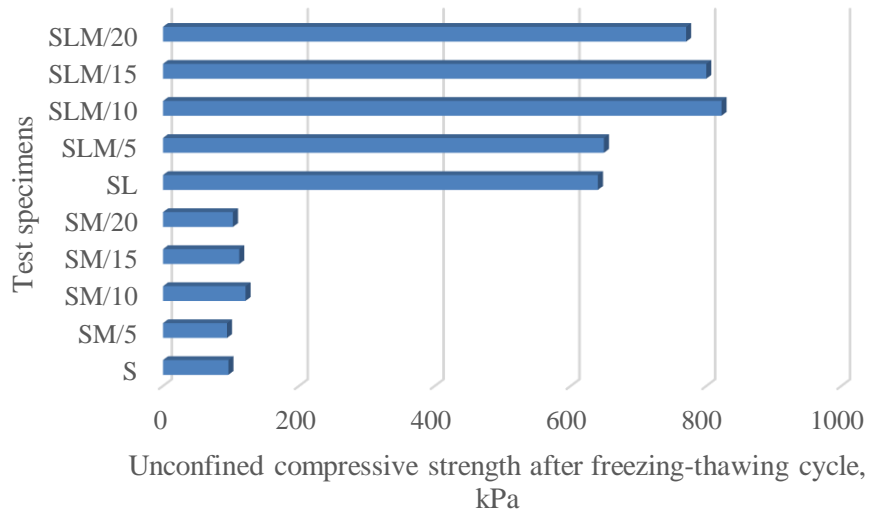


Figure 5. Freezing-thawing test results

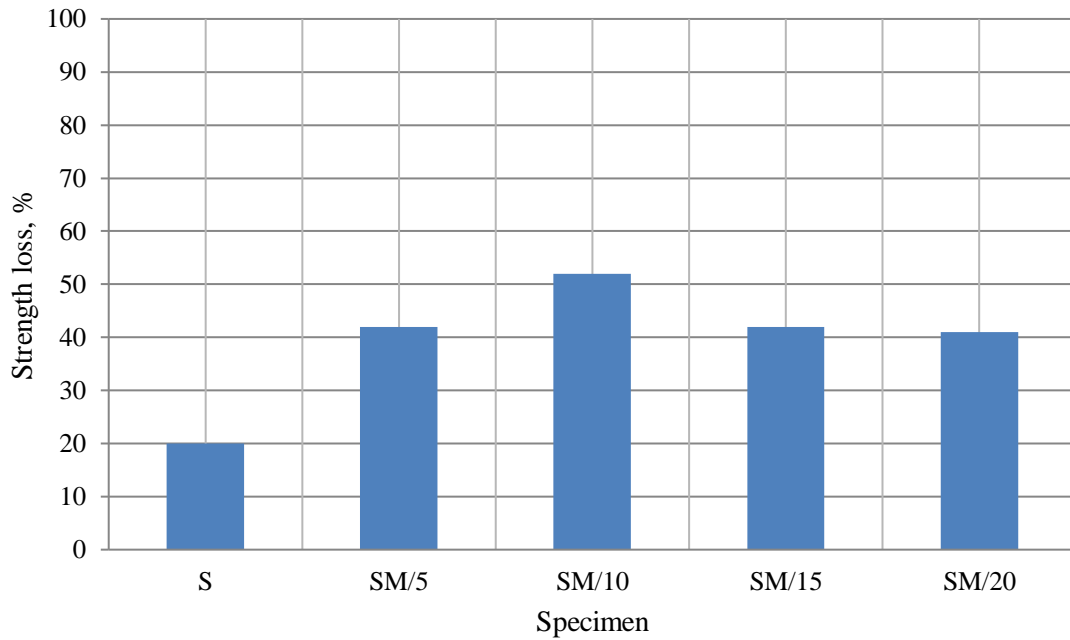


Figure 6. Strength loss of SM specimens after freezing-thawing cycle

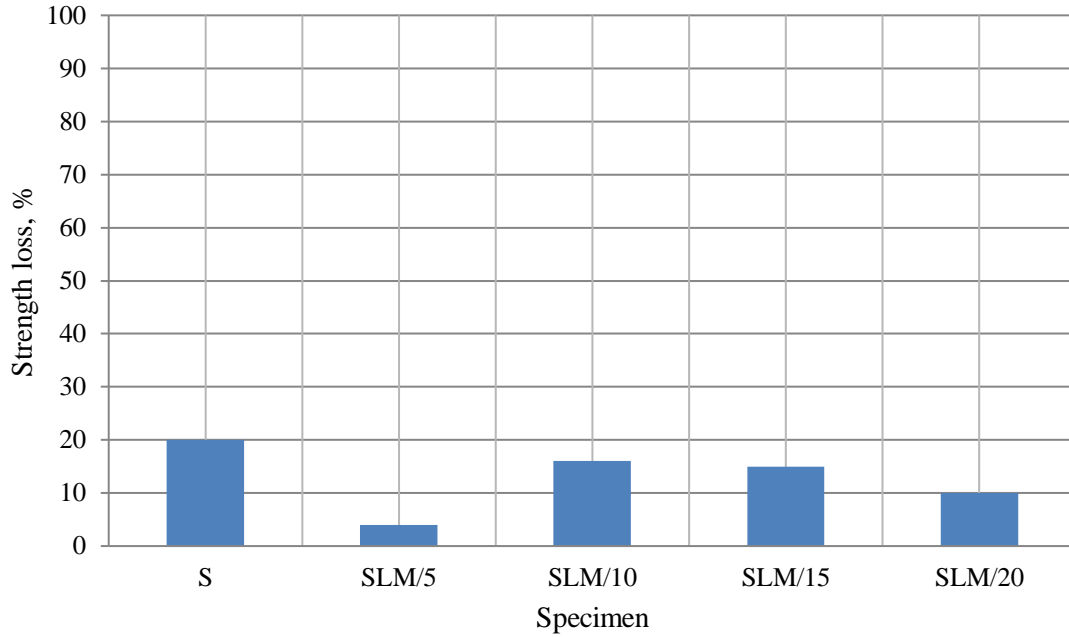


Figure 7. Strength loss of SLM specimens after freezing-thawing cycle

IV. CONCLUSION

In the light of this experimental study which investigated the effect of lime and marble powder on soil stabilization under freezing-thawing and wetting-drying effects, it was determined that the use of lime and marble powder as additives increase the strength data compared with specimens containing only lime. Similar behavior was observed as a result of the freezing-thawing test. Marble powder has enabled the soil to show a stable behavior against wetting-drying cycles. It is concluded that marble powder can be used in combination with lime in the stabilization of high plasticity clay and improves the strength and durability values of the natural soil.

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