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ENGINEERING PROPERTIES OF MONUMENTS IN THE GALLIPOLI PENINSULA, NORTHWEST TURKEY

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ABSTRACT:

Many monuments were built on the Gallipoli Peninsula by governments in memory of the servicemen after the World War I (1915-1918). There are seventy seven monuments in total, thirty one of which were built by the governments of Great Britain, Australia and New Zealand, one by the French and forty five by the Turkish government in 1926.

SiO_2-rich rhyolites known as Azmak and Ilgardere stones and oolitic limestones were usually used for the monuments on the Gallipoli Peninsula. However, freezing and dissolving events increased in Çanakkale province due to sudden climate variations and monuments in this area became subject to weathering. Thus, rhyolites and oolitic limestones used in monuments were replaced with marbles (known as Fenike stone) and micritic limestones.

In this study, a series of mechanical and physicochemical tests have been conducted on both rhyolite and marble to determine their susceptibility to weathering and their long-term behavior in sudden climate variations. XRD, mineralogical and chemical analyses have been performed on both rhyolite and marble. Mineralogical and chemical compositions have been observed if they have an effect on the slake durability of both rocks types. Additionally, the physical and mechanical properties of rhyolites, oolitic limestones, micritic limestones and marbles, such as density and unit weight, have been determined. The results show that marble and micritic limestones are more resistant than rhyolite and oolitic limestone.

Key words: *Canakkale battle, Gallipoli peninsula, monuments and slake durability*

ÖZET:

1915'te başlayan ve 1918'e kadar devam eden I.Dünya Savaşı'nın Gelibolu cephesinde şehit olanlar anısına hükümetler tarafından kamplar ve siperlerde anıtlar yapılmıştır. İngiliz, Avustralya ve Yeni Zelanda hükümetleri tarafından 1926'da yapımları tamamlanan 31 adet, Fransa hükümeti tarafından 1 adet ve Türk hükümeti tarafından 45 adet olmak üzere toplam 77 anıt yapılmıştır.

Bu anıtlarda genellikle Azmak ve Ilgardere taşı olarak bilinen SiO_2 zengin Riyolitler kullanmıştır. Ancak Çanakkale yöresinde ani iklim değişim nedeniyle donma çözünme çok hızlanmıştır. Bunun sonucunda yöredeki anıtlar ayrışmaya maruz kalmaktadır. Bunun sonucu olarak yörede bulunan kayaçlar Finike taşı olarak adlandırılan kayaçlarla değiştirilmiştir.

Bu çalışma kapsamında riyolit, oolitik kireçtaşı, mikritik kireçtaşı ve mermer örnekleri üzerinde birtakım mekanik ve fiziko-kimyasal testler yapılmıştır. Böylece kayaların bozulmaya karşı dayanımları ve ani iklim değişimlerinde göstermiş oldukları davranışlar saptanmıştır. Ayrıca riyolit ve mermer örneklerinin XRD, mineralojik ve kimyasal analizleri yapılmıştır. Buna ek olarak riyolit ve mermerlerin yoğunluk, birim hacim gibi fiziksel ve mekanik özellikleri de saptanmıştır. Sonuçta mermerlerin ve mikritik kireçtaşlarının oolitik kireçtaşı ve riyolitten daha dayanımlı olduğu belirlenmiştir.

Anahtar Kelimeler: *Çanakkale savaşı, Gelibolu Yarımadası, anıtlar ve slake durability*

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1. Introduction

One of the bloodiest fronts during the World War I (1915-1918) was the Gallipoli front, where the Turkish soldiers fought against the troops of Australia, New Zealand and France (Figure 1). A notable and most tragic war, namely Canakkale Battle, consists of four phases. In the first phase, naval operations commenced in early 1915, culminated on 18 March in an unsuccessful attempt by battleships forcing the Dardanelles. The second phase began on 25 April: the British and French armies on Cape Helles, and the Australian and New Zealand Army Corps (the Anzacs) began landings on the Anzac beach. In the third phase, further British landings on the north of Anzac and at Suvla Bay on 6 August occurred simultaneously with attacks mounted from both Cape Helles and Anzac beach. These nearly succeeded, but after this failure to achieve a breakout, the opposing armies remained deadlocked in trench warfare. In the fourth phase, troops withdrew [1,2,3]. As a result of this bitterly battle in the Gallipoli Peninsula, fought especially in Seddülbahir, Cape Tekke, Cape Hisarlık, Morto and Ertugrul Bay, Alçıtepe, Kerevizdere, Arıburnu, Conkbayırı, Kocaçimen, Kanlısırt and Anafartalar districts, 262000 servicemen of Australia, New Zealand, British and France, and 252300 servicemen of Turkish troops died [1,2,3]. Many monuments were built by governments in memory of the servicemen on the Gallipoli Peninsula. There are seventy seven monuments in total, thirty one of which were built by the governments of Great Britain, Australia and New Zealand, one by the French and forty five by the Turkish government in the battle area (Figure 2 and 3).

Weathering conditions affected the physical and mechanical properties of the rock mass used in monuments, and caused a reduction in their strength and an increase in the deformation and permeability of the rock mass and rock material (Figure 4). In this paper, rhyolites samples have been used in some monuments and physical, mechanical, mineralogical, XRD and chemical properties have been determined in laboratory. Impaired parts of monuments have been restored by marbles brought from Fenike (Antalya). The goal of this study is to determine the slaking behavior and the effect of climate variation on the deterioration of rhyolite and marble used in monuments in the Gallipoli Peninsula. Thus, several laboratory tests have been carried out in order to designate the physical and mechanical features of both rhyolite and marble samples taken from the monuments and also a unit compressive strength test has been conducted to determine their strength. XRD and chemical analyses have been made to investigate their weathering grades and the impact of compositional variation. Slake durability tests have been used to determine their weather ability and durability and the degree of degradation and the resistance of rock samples against drying and soaking.

2. Methods and sampling

Twenty samples were evaluated to determine the physical and mechanical properties of the rocks. These analyses were conducted in soil and rock mechanic laboratory in Canakkale Onsekiz Mart University, while the chemical, XRD and mineralogical analyses were carried out in Kale Maden laboratories. Rhyolite and marble samples were prepared for laboratory tests. These rocks used for monuments in the Gallipoli Peninsula were studied in the laboratory by a series of tests to determine their mechanical, physical, mineralogical and chemical properties.

During field studies samples were also collected to determine the physical properties of rocks used for monuments in the Gallipoli Peninsula such as water content, unit weight, and uniaxial compressive strength test as well as slake durability tests. The material properties such as unit weight, water content and unit weight were determined in accordance with [4]. Slake index tests were carried out according to [5].

3. Mineralogical and chemical properties of monuments

Mineral characteristics influence the engineering properties of a rock, especially when the mineral forms a significant part of the rock. The engineering properties of a rock generally depend not only on the matrix structure formed by the minerals but also on imperfections in the structure such as pore space, cracks, inclusions, grain boundaries, and weak particles.

Rhyolite and marble samples used for the monuments were studied on the base of XRD, chemical and mineralogical analyses. Rhyolite samples consist mainly of nearly 10 % phenocrystals of sanidine, plagioclase, biotite and quartz and 90 % glassy groundmass according to thin section studies. The sanidine phenocrystals reach up to 1 mm in size, euhedral and subhedral. The plagioclase phenocrystals are as much as 0.3-0.4 mm in size, which are unzoned and subjected to deterioration. The biotite phenocrystals are subhedral and mostly oxidized. They are characterized by brown color and conspicuous pleochroism. The quartz phenocrystals occur either as subhedral or euhedral. The groundmass is mainly vitrophyric.

Based on the thin section studies, marble samples are mainly composed of calcite and minor quartz. Marble samples comprise different sizes and shapes of cracks that are filled by the secondary calcite minerals, which are 0.03-0.09 mm in size. The minerals that are present in both rhyolites and marbles were also determined by XRD analyses. It was difficult to identify all of the minerals by thin sections, thus XRD and chemical analyses were used to determine the composition of the rhyolite and marble samples. Minerals that were identified by XRD analyses of rhyolites were found to be sanidine, plagioclase, quartz, biotite and kaolinite (Figure 5). Kaolinite minerals have resulted from the alteration of sanidine and plagioclase phenocrystals.

XRD diffraction studies of marble samples indicate the predominance of calcite and less amount of quartz (Figure 6). The results of chemical analyses of both rhyolite and marble samples are shown in Table 1. Chemical analyses of rhyolites have high alumina (Al_2O_3) and potassium (K_2O) content. High alumina content has resulted from the sanidine and plagioclase phenocrystals. Oolitic limestone is mainly composed of oolite (>70%) and micritic calcite combining these oolites to each other (Figure 7). Secondary quartz as microcrystalline quartz occurs in the core of oolites. Mikritic limestone is dominantly compose of micritic calcite and macroscopically shows compact texture. Finally, when evaluation with petrographical, mineralogical, physical and mechanical features of all rock types, marble and micritic limestones are more resistant than rhyolite and oolitic limestone.

4. Physical analyses

Table 2 presents the water content, unit weight and density of the samples collected from rocks that were used for monuments in Gallipoli Peninsula. The average of the natural unit weights of the rhyolite varies between 19.73 kN/m^3 and 22.29 kN/m^3. These values are low compared to the marbles unit weight of the rocks (Table 2). Water content of rhyolite is found to be more than those of marble. Note that the density of rhyolite is lower than marble samples.

5. Uniaxial strength tests

Table 3 presents the uniaxial compressive strength of the rocks in the monuments of Gallipoli Peninsula. While the uniaxial compressive strength of the marble found to be of average 374.03 MPa, this value for the rhyolite was found to be 324.85 MPa. Note that the uniaxial strength of rocks especially marble, are much higher than rhyolite. Consequently, these rock samples can be classified as low strength rock.

6. Slake durability index, Id

The slake durability test was primarily devised by [6] to estimate the susceptibility of rocks to weathering. The slake durability index test was fulfilled by a procedure suggested by [7]. The slake durability device is composed of a pair of test drums that have a 2-mm meshed exterior, a pair of transparent water tanks positioned on horizontal axis drive shafts, and a motor assembly including a drive that rotates at rpm. The drum was 100 mm in length and 140 mm in diameter with a solid fixed base. The base of the drum is removable to facilitate loading of test samples. 20 test samples were prepared to be used in the slake durability test, each of which is 40 to

60 g. The total sample weighed 450 to 600 g [7]. These rock samples are possibly rounded on, causing no mechanical disintegration.

After prepared samples were placed in two drums, they were dried in the drying oven at 105°C for 24 hours. Thus, their dry weights were determined. Oven-dried samples were placed in the drum and the drum was rotated at 20 rpm for duration of 10 minutes. The samples remained were oven-dried, after weighing the retained samples, the test was repeated for a second cycle. After repeating five times, the slake durability index was obtained [7].

Five-cycle slake durability index was performed in accordance with [7, 5] to determine the weakening and disintegration of the monuments samples. The relations between the slake durability index versus the number of cycles of different rocks of the monuments are presented in Figure 7. The results indicate that monument samples have high slake durability (Id = 95 - 98) according to the classification [8]. However, Rhyolite have lower slake durability index than marble samples. It has been seen that rhyolite which was used in monuments are more erodable than the marbles. This is because of the chemical composition of rocks. Rhyolite consists of biotite and kaolinite, which eroded very easily.

Conclusion

A notable and most tragic war, namely Canakkale battle, occurred in Gallipoli Peninsula. Many monuments were built by governments in memory of servicemen on the Gallipoli Peninsula after the World War I. There are seventy seven monuments in total, thirty one of which were built by the governments of Great Britain, Australia and New Zealand, one by the French and forty five by the Turkish government.

Most of these monuments are subject to the freezing and dissolving events which has increased in Canakkale province due to sudden climate variations. Therefore each year some part of these monuments, which were constructed by rhyolite, is changing because of eroding. Rhyolites used in monuments are replaced with marbles (known Fenike stone). It is important to measure the slake durability of these monuments regularly. The freezing and thawing of the monuments should be measured as well.

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