CLASSIFICATION OF ROCKS ON THEIR CREEP BEHAVIOUR AT LOW STRESS LEVELS

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Abstract

In this study, it is aimed to classify rocks on their time-dependent properties. Bending creep tests on cantilever beam specimens are carried out at low stress levels. Four different rock types, namely Marble (Afyon), Marl (Tunçbilek - Kütahya), Sandstone (Beytepe - Ankara) and Tuff (Incehisar – Afyon) are used in these creep tests. Each rock type was tested four times at five stress levels, namely, at 10%, 20%, 30%, 40%, and 50% of their average instantaneous bending strengths. The test results are analyzed with the percent deformation criterion using ternary diagrams.

1. INTRODUCTION

The study of time-dependent deformation or creep in rocks is of great significance to mining engineering. The strength and deformation behavior of rocks are time-dependent [1]. Therefore, while designing structures in rock, time-dependent behaviour of rocks should be considered seriously. Time-dependent tests are useful not only in rock mechanics but also in structural geology. Creep tests are relevant in the design of underground openings, the study of failure mechanisms in rocks and in determining rheological properties of rocks. Creep studies were conducted under different stress systems. Most of the researchers have used the compression test, in particular uniaxial compression test [2]. Work in bending, torsion and direct shear were limited [3]. Research on the creep behavior of rocks was carried out by many investigators and reviewed by many others [4-8].

A classification based on time-dependent rock properties would be helpful in differentiating the rock which requires a comprehensive study with emphasis on the predominant property [9]. What is actually required from the classification is some indication as to whether, under a given stress system, the material remains intact, deforms a little and stops, or deforms continuously. Rock material behaves in neither of perfectly elastic nor plastic manner and it is necessary to determine which of these properties are prevalent [10-14]. In this study, four different rock types were tested in bending type creep tests at five stress levels, namely, at 10 %, 20 %, 30 %, 40 %, and 50% of their average instantaneous bending strengths. Each rock type was tested four times for each stress level.

Key Words: Components of Deformation, Creep Tests in Bending, Rock Classification

2. SPECIMENS

To prepare the specimens, a large marble cutting machine with various diameter diamond saws was utilized. Intact blocks of rock were cut to obtain regular blocks with smooth orthogonal faces, paying attention to the specimen length and bedding if present. The largest dimension should be at least 370 mm and parallel to the bedding. These blocks were cut to 35 mm width slabs from which 10 mm thick (15 mm for tuff) cantilever beams were obtained. The sections to be loaded were to be 320 mm from one end and marked all around the specimens. 20 identical beam specimens were prepared for each rock type to perform the required experiments.

3. METHODOLOGY

Based on the idea put forward by Klingmueller and Wallace [3], two identical rigs were designed and constructed by Özgenoğlu [6] in the workshop of the Mining Engineering Department of Middle East Technical University, Ankara, to carry out creep tests on twenty cantilever specimens concurrently with ten specimens on each rig. This setup was used to carry out the creep experiments in this study. Creep tests were performed on rectangular beam specimens measuring 370-390 mm in length, 35 mm in width and 10 mm in thickness. In creep tests, these rock specimens were subjected to constant loads at one end and the resulting end displacements of the cantilever beams were noted with the time. In other words, consideration was given to the measurement of time-dependent load-deflection behavior of rock specimens. The schematic diagram of the deflection measurement system was shown in Figure 1. Tests were conducted in a temperature and humidity controlled room. The mean temperature of the room was about 20°C and the relative humidity was within 50±10 %. The instantaneous bending strengths of the rock types tested in this study were obtained from the study by Özgenoğlu [6].

The deflection readings were taken at 0.5, 2, 5, 10, 15, 20, 30, 45, 60, 75, 90, 120, 180, 240, 360, 480 and 600^{th} minutes and in the morning and evening of the following two days. The last reading was made in the morning of the 4^{th} day prior to unloading. To evaluate the components of deformation in a creep test, recovery of the beam after unloading was necessary. Thus, similar measurements were achieved to determine the recovery of the beam after removal of the loads. Thus, it took seven days to complete a whole loading and unloading cycle for the creep tests. In this study, the total deformation produced as a result of the creep tests were analyzed by separating it into four components such as elastic, plastic, viscoelastic and viscous as suggested by Kidybinski [2]. It is reasonable to express the components of deformation in percentages rather than absolute values. The total deformation undergone by a specimen was assumed to be 100 % and the proportion of the elastic, plastic, viscoelastic and viscous deformations in the total were determined. The components of deformation were obtained from the instantaneous and time-dependent deflection and recovery measurements.

4. RESULTS AND DISCUSSIONS

The components of deformation at various stress levels for each rock type are given in Tables 1, 2, 3, and 4. The overall average deformation components are also given in Table 5. As shown in Table 5 and in Figure 2, the highest elastic deformation occurred with marble with 92.7 % and sandstone and tuff followed marble with 78.9 % and 78.0 % respectively. Marl has shown the lowest elastic deformation with 57.9 %. The highest plastic deformation was suffered by marl with 23.4 % and sandstone and tuff followed marl with 10.1 % and 8.9 % respectively. Marble has shown the lowest plastic deformation with 3.5 %. Tuff has shown the highest viscoelastic deformation with 5.7 % and sandstone and marl followed the tuff with 5.4 % and 4.1 % respectively. Marble has shown the lowest viscoelastic deformation with 2.9 %. Marl has shown the highest viscous deformations with 14.6 % and tuff and sandstone followed marl with 7.4 % and 5.8 % respectively. Marble has suffered the lowest viscous deformation with 1.1 %. Marl, tuff and sandstone have shown viscous components greater than their viscoelastic components, while marble has shown the opposite.

Rocks can be classified according to the type of deformations they experience with the help of ternary diagram. Ternary diagrams can be divided into sections and rocks can be assigned to the classes accordingly. In this study, the rock samples tested were assigned to the classes according to the criterion that the components of deformation less than 10 % were assumed to be insignificant. That is, 10 % lines defined the boundaries of the sections on the ternary diagram. In defining the point representing each specimen, 1 % division ternary diagram is used. Marble has shown the minimal time-dependent deformation components of the order of 3.85 % and elastic deformation was in excess of 90 %. This rock was classified as elastic. The time-dependent deformations for marl, sandstone and tuff were in excess of 10 % and they can be classified as elasto-viscous rocks.

Table 1. Components of Deformations at Various Stress Levels for Marble.

Stress Level	Average Deformations (%)			
	Elastic	Plastic	V. Elastic	Viscous
10 %	91.56	2.51	5.48	0.45
20 %	90.68	4.49	4.16	0.67
30 %	92.97	2.12	3.71	1.22
40 %	93.00	2.15	2.84	2.00
50 %	94.65	3.00	1.18	1.17

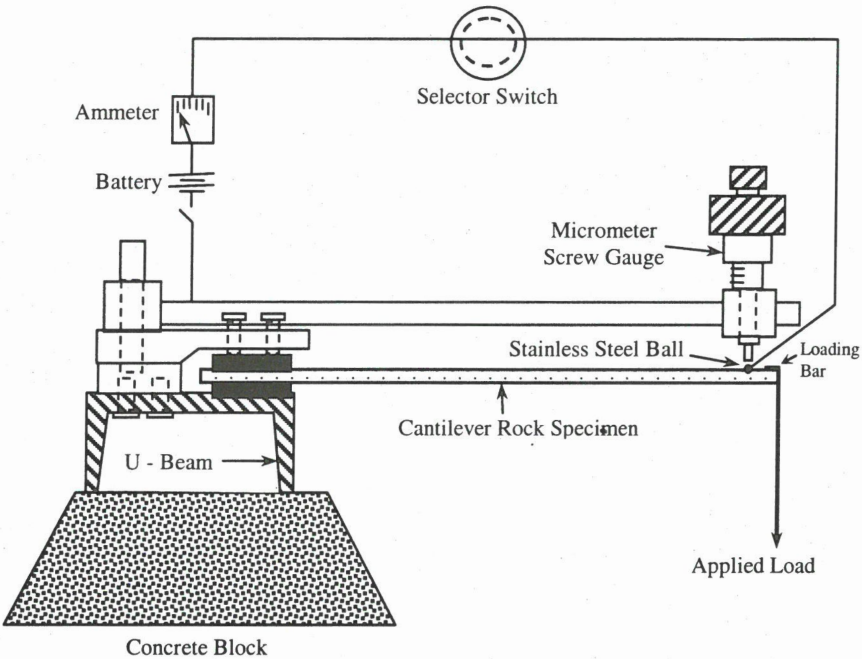

Figure 1. Deflection Measurement with Electrical Circuit System. [6]

Table 2. Components of Deformation at Various Stress Levels for Marl.

Stress Level	Average Deformations (%)			
	Elastic	Plastic	V. Elastic	Viscous
10 %	-	-	-	-
20 %	55.02	3.87	19.48	21.64
30 %	54.38	5.31	26.61	13.78
40 %	60.63	1.21	22.10	16.05
50 %	57.89	4.09	23.40	14.62

Table 3. Components of Deformations at Various Stress Levels for Sandstone.

Stress Level	Average Deformations (%)			
	Elastic	Plastic	V. Elastic	Viscous
10 %	-	-	-	-
20 %	74.19	7.32	11.90	6.59
30 %	82.25	2.59	8.18	6.99
40 %	78.66	5.42	7.72	8.20
50 %	79.86	6.18	12.72	1.46

Table 4. Components of Deformations at Various Stress Levels for Tuff.

Stress Level	Average Deformations (%)			
	Elastic	Plastic	V. Elastic	Viscous
10 %	61.62	7.77	18.24	12.38
20 %	72.56	11.80	5.11	10.53
30 %	88.49	2.40	7.46	1.65
40 %	85.63	1.49	4.68	8.20
50 %	81.61	5.20	9.12	4.28

Table 5. Overall Average Deformations for Various Components of Deformations.

Rock Type	Overall Average Deformations (%)			
	Elastic	Plastic	V. Elastic	Viscous
Marble	92.57	3.47	2.85	1.10
Marl	57.89	23.40	4.09	14.62
Sandstone	78.82	10.10	5.38	5.80
Tuff	78.00	8.90	5.70	7.40

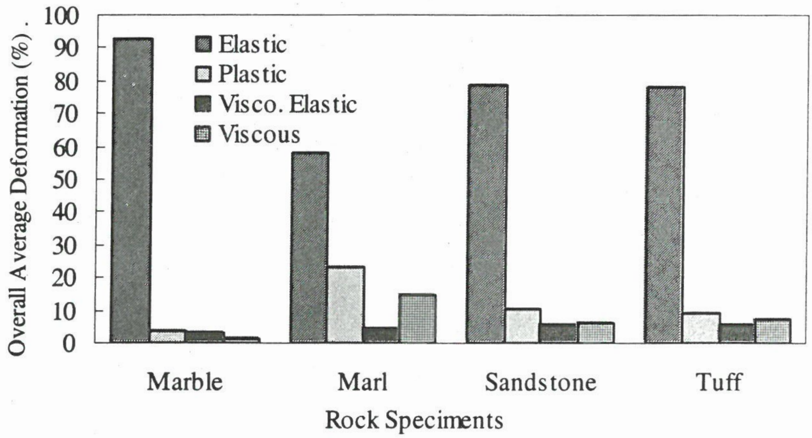

Figure 2. Graph of Overall Average Deformations for Various Components of Deformations.

5. CONCLUSIONS

It can be concluded from Tables 1, 2, 3, and 4 that the components of deformation in percentages are independent of the load applied for the selected rock types at the given stress levels. Thus, a single test at a certain stress level may be sufficient to evaluate the class of rocks with percent deformation criterion for classification purposes. This conclusion was also supported by Özgenoğlu [6] for the high stress levels. Finally, the viscoelastic and viscous components of deformation are dependent on the duration of the creep tests.

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KAYAÇLARIN DÜŞÜK GERİLME YÜKLERİ ALTINDAKİ SÜNME DAVRANIŞLARINA GÖRE SINIFLANDIRILMASI

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Özet

Bu çalışmada, kayaçların sünme davranışlarına göre sınıflandırılması amaçlanmıştır. Bükülme deneyleri, dikdörtgen prizması şeklindeki serbest kiriş numuneleri üzerinde düşük gerilme yükleri altında gerçekleştirilmiştir. Deneylerde, Mermer (Afyon), Marn (Tunçbilek - Kütahya), Kumtaşı (Beytepe - Ankara) ve Tüf (Incehisar - Afyon) olmak üzere dört ayrı kayaç türü kullanılmıştır. Her kayaç türü, ani bükülme dayanımlarının %10, %20, %30, %40 ve %50'sinde olmak üzere beş ayrı gerilme yükü altında dörder defa denenmiştir. Deney sonuçları, üçgen diyagramını kullanarak deformasyon bileşenleri yöntemiyle analiz edilmiştir

Anahtar Kelimeler: Bükülmedeki Sünme Deneyleri, Deformasyon Bileşenleri, Kayaç Sınıflandırması

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