# Uniaxial compressive strength test before and after standard fire test on rock mass

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## ABSTRACT

The paper presents uniaxial compressive strength test according to SRPS EN 1926. Uniaxial compressive strength test was performed on 12 identical cube-shaped specimen's dimensions 70 mm x 70 mm x 70 mm, which are made of sandstone. Samples were brought form Laz tunnel and were divided into two groups of six samples. First group of samples consists of 6 samples tested for uniaxial compressive strength. Second group of samples consists of 6 samples exposed to standard fire test according to SRPS EN 1363-1, with the intention to test uniaxial compressive strength after standard fire test. The aim of this study was to examine the uniaxial compressive strength of the rock, before and after standard fire test on the rock mass. The paper presents the strengths of the specimens tested before and after standard fire test.

## KEYWORDS

Rock; Uniaxial compressive strength; Standard fire test.

## 1. INTRODUCTION

Uniaxial compressive strength testing is a parameter that is determined experimentally. It depends on the structure of the rock mass, grain size and orientation, number and arrangement of cracks and fissures. For the same rock, strength may be different, depending on physical characteristics. Heat of environment can affect structure of rock mass, which results in a change in uniaxial compressive strength of rock after fire.

Uniaxial compressive strength is an important parameter of rock material in the field of rock mechanics. It is the basic parameter for determining strength and classification of rock mass. It is determined experimentally, by laboratory strength testing.

Determination of uniaxial compressive strength is necessary, both in rock mechanics and in the field of application of obtained results during the construction of various underground structures and tunnels. If strength of the rock is lower, it will have an impact on the tunnel structure, different measures will be required to ensure the excavation and a larger amount of material needed for construction of tunnel structure. Incidental actions in tunnels, such as fire, can also affect strength of surrounding rock. Due to structure of rock mass, it is necessary to conduct thermal tests on samples that must be formed and prepared in accordance with standard.

A sample of rock material-sandstone was brought from location where traffic tunnel is being built. It is the Laz tunnel, length 2.850 meters, on the section of highway E-763 Miloš Veliki, from Preljina to Požega. Currently, section from Pakovraće to Požega is being built, within which this tunnel is located. Tunnel is being built by Chinese company CCCC, which is drilling and blasting material. Such material was delivered. The characterization of the rock material was performed.

## 2. EXPERIMENTAL RESEARCH

### 2.1. Material characterization, microscopic description

Rock has a clastic, psammitic texture. It is made of quartz clast, fragments of rock minerals and mica (muscovite and chlorite) which are bound with a limonite clay cement. Quartz clusters dominate, building about 60% of the rock mass. They occur in grains of different sizes, from 0.05 to 0.5 mm. The grains are mostly sub-rounded and partly un-rounded. Some have undulatory extincion due to the effect of pressure, which tells us that they are at least partly of metamorphic origin. The different size of this mineral, poorly sorted indicates a relatively short transport of the material.

Crystal fragments are less presented, mostly small and sub-rounded. Feldspars, orthoclase and plagioclase, which originate from a granitoid rock, are dominated in rock. Let us mention that some of these grains are poorly altered, replaced by fine-grained sericite, which was most likely formed by alteration of this mineral during transport. The rock fragments are rounded, sometimes jagged, up to 0.1 mm in size. There are also fragments of carbonate rocks, which do not differ from other grains in size and shape. The mentioned diversity indicates a wider area of erosion from different types of rocks which, due to various factors, disintegrated, giving the mentioned clasts.

Muscovite is less presented in the rock. Of the mica minerals chlorite is also present. These mica appear in sheets from 0.05 to 0.6 mm in size. They are often banded and deformed during the diagenesis process. The iron is presented in cemnet with a clayey component, and fine-grained quartz which can be seen in some parts. The rock color (black) is most likely a consequence of the presence of divalent (ferro) iron.

In Figure 1 is shown a microscopic image of rock sample.

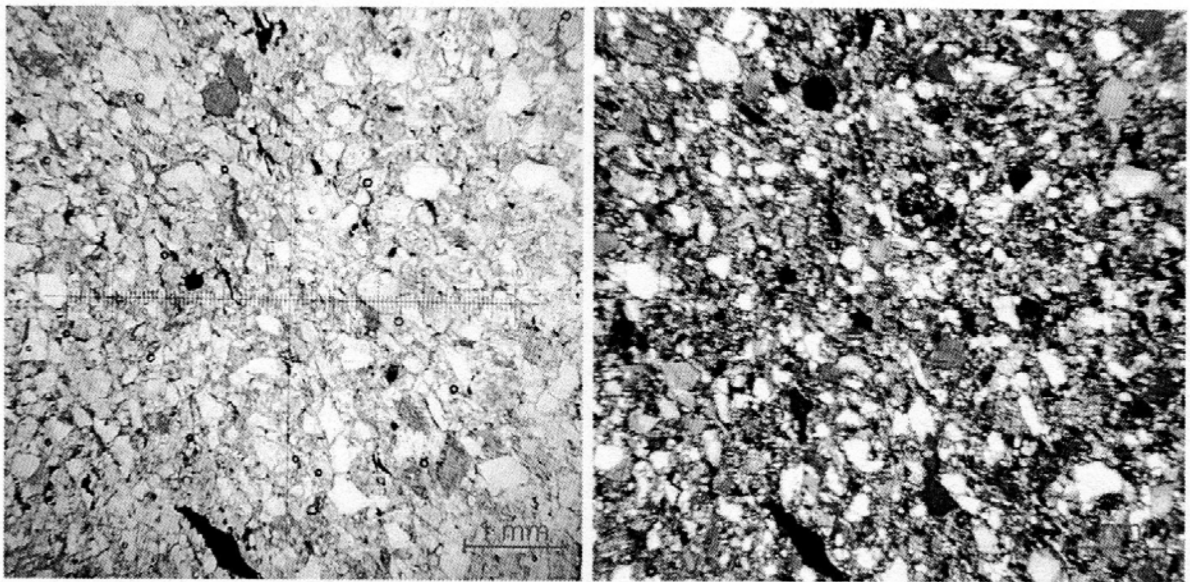


Figure 1. Microscopic image of a rock sample; picture left in plane polarized light, picture right in cross polarized light

### 2.2. Material sampling

Two groups of 6 samples are tested according to SRPS EN 1926. First group of samples consists of 6 samples tested for uniaxial compressive strength. Second group of specimens consists of 6 samples exposed to standard fire test with intention to test uniaxial compressive strength after standard fire test.

diameter and height equal to 70 ± 5 mm or 50 ± 5 mm. For practical reasons, test was performed with a total of 12 samples of a cube with an edge length of 70 ± 5 mm. Preparation of surfaces affected by load is performed according to SRPS EN 1926. Surfaces must be flat with the appropriate tolerances prescribed. Sides of pattern must be smooth and straight, with no bumps. Samples must be dried at 70 ± 5 ° C to constant weight before testing. A constant mass is considered to have been reached when the difference between two consecutive weight measurements, performed at 24 ± 2 h intervals, is not greater than 0,1% of mass of test sample. After drying, and before testing, samples are stored at room temperature. Load on test specimen must be applied continuously, at a constant pressure increase of 1 ± 0,5 MPa/s. Maximum load must be accurately recorded.

In Figure 2 samples prepared for uniaxial compressive strength test according to SRPS EN 1926 are presented.

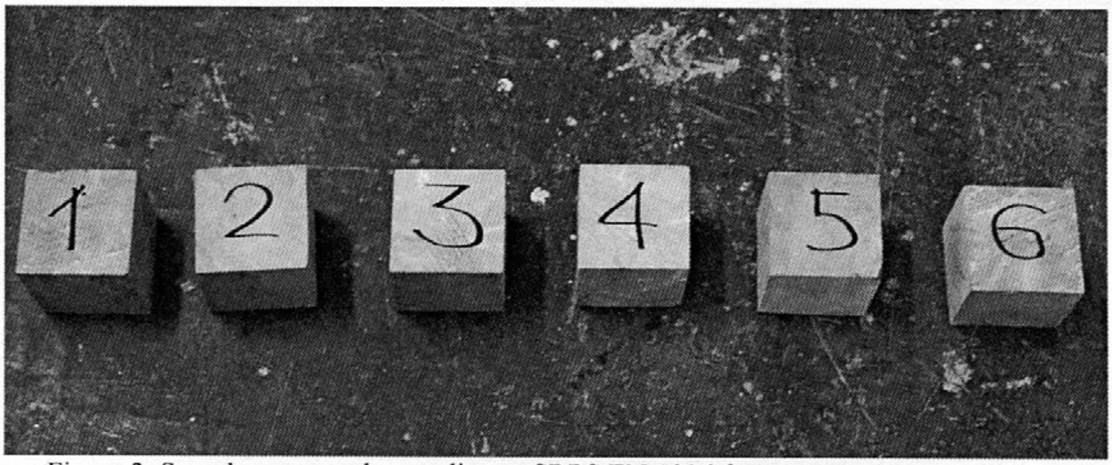

Figure 2. Samples prepared according to SRPS EN 1926 for compressive strength test

In Figure 3 samples prepared for standard fire test according to SRPS EN 1926 are presented.

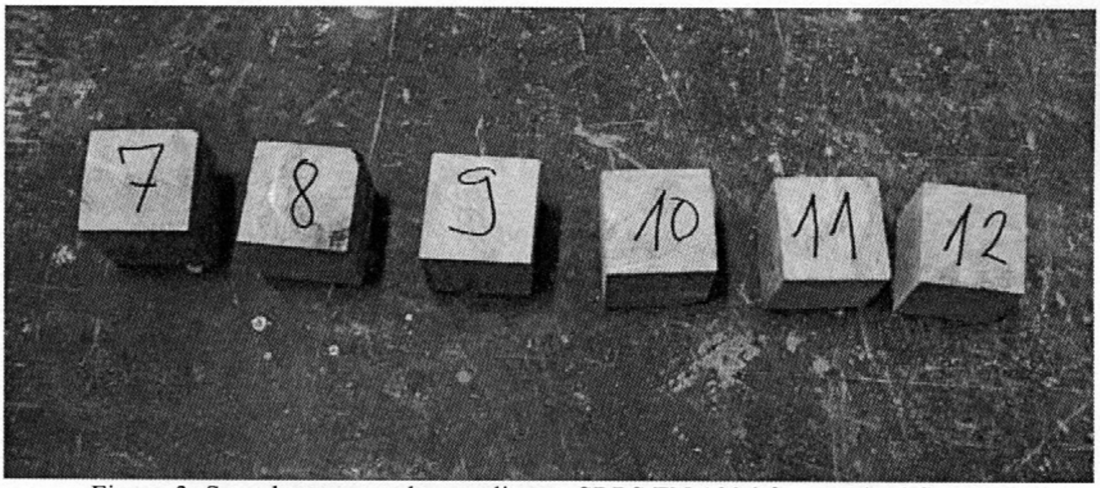

Figure 3. Samples prepared according to SRPS EN 1926 for standard fire test

### 2.3. Description of measuring equipment and experiment

Uniaxial compressive strength test is performed on a hydraulic press. A total of 6 samples (1-6) are tested and uniaxial compressive strength is determined. The same 6 samples (7-12) are placed in a furnace that simulates effect of fire. After that, the compressive strength of 6 samples (7-12) from furnace on a hydraulic press is measured. Goal is to see how fire affects uniaxial compressive strength of the sandstone rock. Uniaxial compressive strength measured in this way is compared with the previously measured compressive strengths.

Wall had dimensions of 3m x 3m, and test was done at IMS Institute, in Laboratory for thermotechnics and fire protection. Standard furnace for structural testing consists of four two-stage liquid fuel burners of the type "Major P25 AB HS TL V.C.", thermal power 296 kW manufactured by ECO FLAM. Two differential pressure transmitters type 6321 manufactured by TESTO (Germany), with a range of ± 100 Pa, inside furnace, were used to measure pressure. Inside furnace, temperature was measured in six places with a type K thermocouple. Measuring ranges of type K thermocouples were -270 ° C to 1372 ° C. Acquisition systems for monitoring standard fire tests in vertical furnace were made completely in Laboratory for thermotechnics and fire protection according to SRPS EN 1363-1. Standard fire development is described by a logarithmic curve. See Equation (1) below.

$$\Theta_g = 345 \log_{10}(8t + 1) + 20 \tag{1}$$

where: $t$ [min] time, and $T$ [° C] temperature inside furnace depending on time t.

In Figure 4 standard fire curve according to SRPS EN 1363-1 is presented.

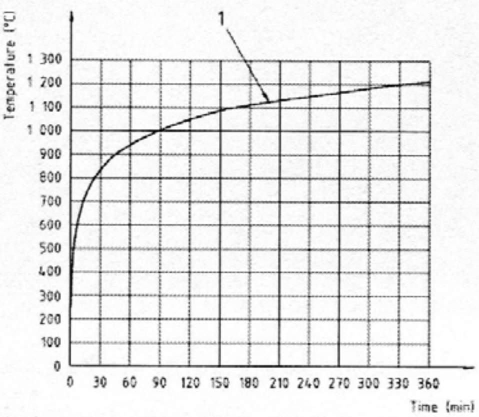


Figure 4. Standard fire curve according to SRPS EN 1363-1

## 3. ANALYSIS OF TEST RESULTS

Uniaxial compressive strength was tested on 6 identical samples (1-6). Samples that were exposed to fire (7-12), in order to test uniaxial compressive strength after standard fire test, disintegrated after standard fire test and it was not possible to test uniaxial compressive strength. Test results are shown in Table 1.

Table 1. Uniaxial Compressive Strength

| Sample | Sample Mass [gr] | Dimensions [cm] | Base Area [cm$^2$] | Force [kN] | Uniaxial Compressive Strength [MPa] |
|---|---|---|---|---|---|
| 1 | 889,25 | 6,98x6,99x6,89 | 48,79 | 390 | 80 |
| 2 | 856,58 | 6,85x6,87x6,98 | 47,06 | 184 | 39 |
| 3 | 886,40 | 6,96x6,92x6,94 | 48,16 | 525 | 109 |
| 4 | 889,62 | 6,97x6,94x6,94 | 48,37 | 328 | 68 |
| 5 | 880,34 | 6,92x6,90x6,95 | 47,75 | 281 | 59 |
| 6 | 888,72 | 6,95x6,93x6,97 | 48,09 | 428 | 89 |

Test results show that uniaxial compressive strength of samples that were not exposed to fire depends on internal structure of samples, since dimensions of samples, their weight and surface area are approximately equal.

Testing uniaxial compressive strength of samples (7-12) after standard fire test was not possible because samples cracked so much that they disintegrated even before application of force on the hydraulic press.

In Figure 5 samples after standard fire test are shown.

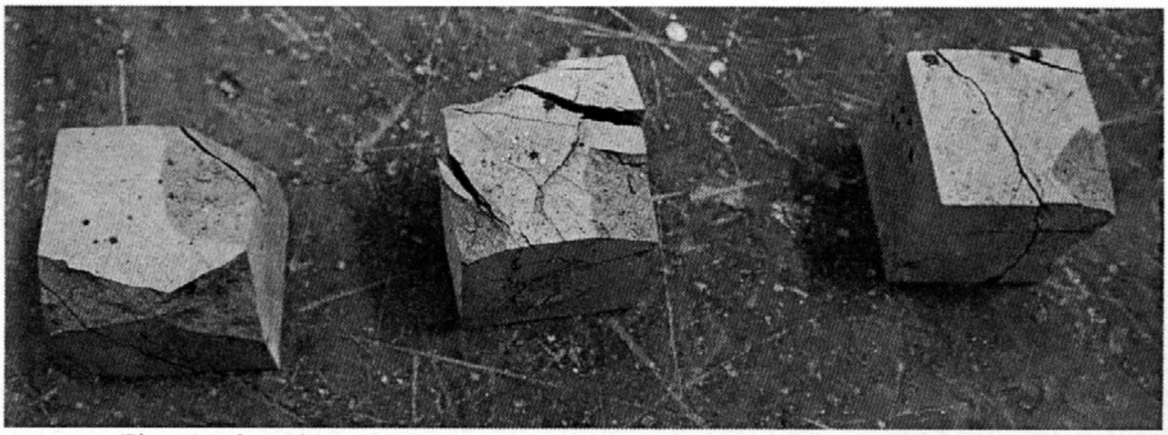

Figure 5. Samples prepared according to SRPS EN 1926 after standard fire test

## 4. CONCLUSIONS

Uniaxial compressive strength test, according to SRPS EN 1926, was performed on 12 identical cube-shaped specimen's dimensions 70 mm x 70 mm x 70 mm, which are made of sandstone. Samples were brought form Laz tunnel and were divided into two groups of six samples. First group of samples consists of 6 samples tested for uniaxial compressive strength. Second group of samples consists of 6 samples exposed to standard fire test according to SRPS EN 1363-1, with the intention to test uniaxial compressive strength after standard fire test. For the sandstone rock mass of determined characteristics, for which it is determined uniaxial compressive strength before standard fire test and obtained results are shown in this paper, it is not possible to determine uniaxial compressive strength after standard fire test. Standard fire test showed that the rock is of such composition, it will disintegrate at high temperatures. For tunnel structure, this significant drop in strength after standard fire test is not dangerous, because due to existence of primary and secondary tunnel structure, the rock itself will not develop as high temperatures in case of fire, as they were in standard fire test.

## REFERENCES

Hoek, E. and Brown, E.T., 1980. *Underground excavations in rock*. The Institution of Mining and Metallurgy, London.
Wittke, W., 2014, *Rock Mechanics Based on an Anisotropic Jointed Rock Model (AJRM)*
SRPS EN 1926:2007, *Natural stone test method - Determination of compressive strength*
SRPS EN 1363-1:2014, *Fire resistance tests - Part 1: General requirements*