# Analytical Study For Determination Of The Sandstone Strength Properties

M. Boudiaf, Fateh Mebarek-Oudina, Talhi Korichi,

**Abstract:** Using a servo-controlled testing machine, stress-strain curves were obtained from which the uni-axial compressive strength, Young's modulus and the brittleness index were measured for specimens prepared from a single block of Sandstone from Hadjar Soud quarry, Algeria. To see how the strength properties were affected by changes in absorption content such as are likely to occur on site, the specimens were divided into three groups which were prepared for testing under different conditions of absorption equilibrium.

**Index Terms**: Servo-control, Sandstone, Young's modulus, Equilibrium, Excavation. Analysis steady, uniaxial compressive strength, Hadjar Soud quarry.

## 1 INTRODUCTION

In For both excavation and stability problems, knowledge of ground properties is essential so that excavation and stability system can be matched to the ground (Bhasim, and al.1996) [1]. The uni-axial compressive strength is one of the most widely used for these properties and the purpose of this research was to study the variation in the compressive strength and the correlation of sandstone strength with other properties. Using a servo-controlled testing machine, complete stress-strain curves were obtained for specimens. Because specimen failure was controlled, brittleness of the sandstone could be studied from the form of the stress-strain relation after the peak load had been reached. Specimen preparation and the testing technique are described and stress-strain results are presented. The strength and brittleness values are then correlated with absorption contents.

## 2. SITE AND SAMPLE DETAILS

A large, intact block of sandstone was obtained from Hadjar Soud quarry which is situated 7 kilometers on the outskirts of Azzaba and is an opencast site (see fig.1). Lithologically, the rock is red, medium-grained, weakly cemented sandstone. A sample of the rock was disaggregated by gentle pressure with a pestle and mortar, taking care not to crush individual grains, and the particle size distribution and the particle specific gravity were determined. It was found that 85 per cent of the particles fell in the medium sand range (0.2-0.6mm) and ten per cent in the fine sand range (0.06-0.2mm) and that the particle specific gravity was 2.66.

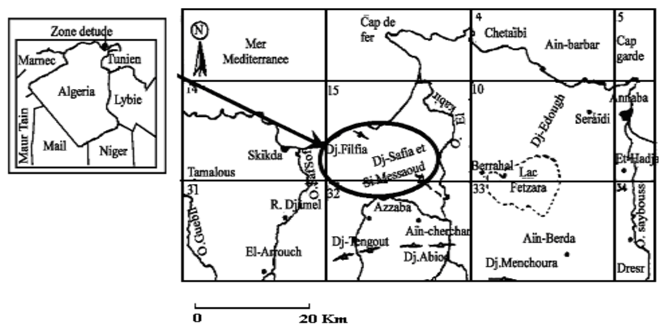


**Fig.1.** Location map of the study area (Azzaba region)

## 3. EXPERIMENTAL PROCEDURE

### 3.1. Specimen Preparation and Testing

The representative cores for use in the experimental work are obtained from block quarry sample. Coring of the block samples was accomplished by diamond core drills. The original core of 95 mm was plugged with a diamond cores drill having 38 mm as nominal diameter. All core samples were cut to length/diameter ratio of 2.5:1. The ends of cores were ground flat and parallel. The diameter and length of each specimen were measured with a vernier to the mearsest 0. 01 mm. The specimen were divided into three groups, one group was saturated by using a vacuum –saturation process, similar to that suggested by the U.S. Bureau of reclamation (1953)[2],this process consists of :

1. Oven- drying the specimen for a period of 24 hours **à** 105°c,
2. Placing the specimen in a bell joir under a vacuum exceeding 50. 80 cm for 24 hours.
3. Immersing, the specimen in water while continuing with vacuum for another 24 hours.
4. Removing the vacuum and exporing the water containing the immersed specimen to the atmosphere for at least 48 hours.

This procedure eliminates air from rock pores and de–airs the water, atmospheric pressure. Then drives water into the rock, thus assuming saturation repon completion of the 5 day cycle, the specimen is removed from the water surface dried, and then weighed .the absorption content is computed. The second group of specimens was immersed in water. The third group was allowed to air dry conditions because the oven-drying may sometimes cause erratic changes in the physical property. The mass of each specimen was determined immediately before testing, and

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the absorption content immediately after. The affixing to the specimens of two axially oriented foil strain gauge type (N22-FA-5-120-H). These pairs are placed diametrically opposite each other and located centrally on the specimen. During testing the pairs are connected up with pairs of gauges. on "dummy" sample away from the machine to give temperature variation compensation. This wheastone bridge is formed and strain changes are monitored by changes in the voltage across the bridge. The testing procedure was essentially the same as that described by Hudson and Morgan (1975) [3] and the following account, slightly modified, is taken from their report. The compression tests were carried out in a fart-response, closed-loop, programmable testing machine (Fig.2). This type of machine was used because a constant displacement rate can be achieved throughout the test- i.e. failure is controlled after the maximum load bearing capacity of the specimen has been reached; and because it is programmable and automatic. The closed-loop, servo-control principle is shown in Figure3. A feedback signal (f) representing the actual condition of an experimental variable, in this case the axial displacement, is continually compared with a program signal (p) representing the required experimental condition. The feedback signal corresponding to the displacement between the specimen ends was generated by four displacements transducers located at 90 degree intervals around the specimen. The individual transducer outputs were summed to provide a voltage equivalent to the average specimen displacement. This feedback signal was compared with the program signal produced by a function generator. The program signal increased linearly with tune enabling a constant displacement or strain rate to be achieved. An error signal (e) occurred if there was any difference between the feedback and program signals; this activated a servo-valve causing the hydraulic pressure in the loading ram to be adjusted and the error signal to be reduced. Feedback and program signals were frequently compared and high speed adjustments made so that the experimental condition followed the programmed condition. The control mechanism and advantages are explained further by Hudson, Crouch and Fairhurst (1972) [4]. To carry out a test, the specimen was inserted in the testing machine between platens having the same diameter as the specimen. The program was switched on and the specimen was then displaced at a constant rate of $2x10^{-3}$ mm/sec, corresponding to an axial strain rate of about $3x10^{-3}$ per cent/sec. Displacement was thus the independent variable and force was the dependent variable. Failure was then controlled beyond the peak force because the displacement was programmed to increase at a constant rate regardless of whether this necessitated a rise or fall in applied force. The load was monitored with a pressure transducer and a complete force-displacement curve obtained for each specimen on an X-Y recorder. Axial load was additionally monitored by a remote X-Y chart recorder which was used to monitor the axial displacement detected by the strain.

**Fig. 2** Machine with tests servo-control on the test sample

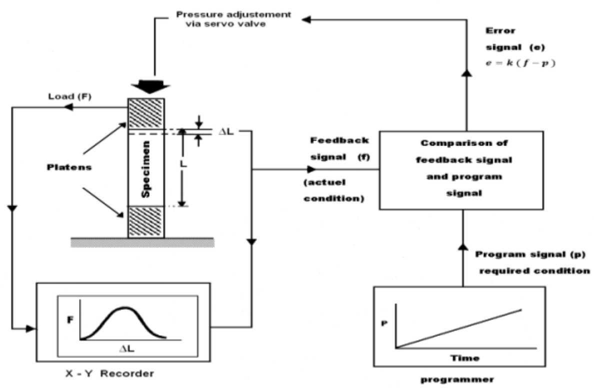


**Fig.3** Closed –loop programmable testing machine control system (after Hudson and Morgan, 1975)

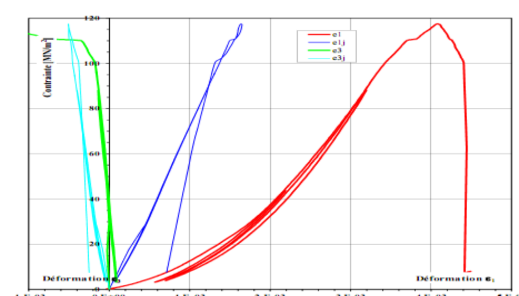

**Fig.4** Stress-strain curve obtained during a test. (after Hudson and Morgan, 1975).

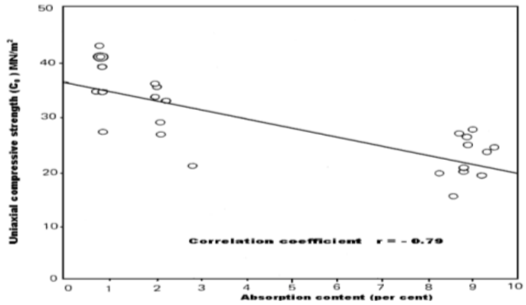


**Fig.5** Effect of absorption on uni-axial compressive strength.

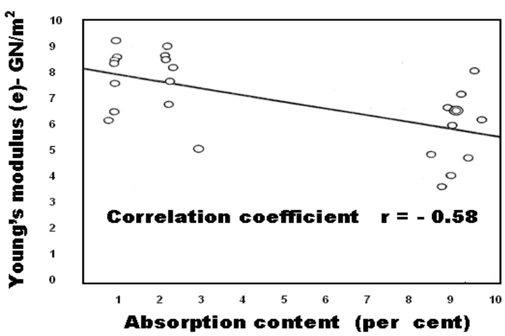


**Fig. 6** effect of absorption content on young's modulus

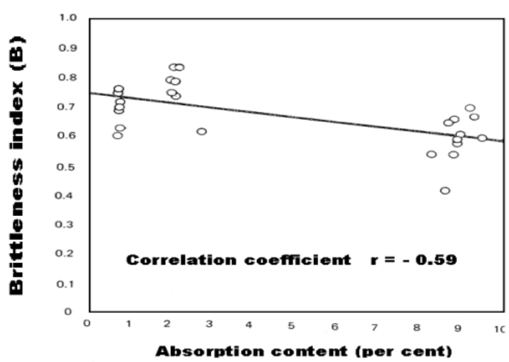


**Fig. 7**effect of absorption content brittleness index

## 4. Results

load displacement curves obtained from the X-Y recorder were converted to stress-strain curves by dividing the load by the original cross- sectional area of the specimen to give stress and by dividing the displacement by the original length of the specimen to give strain; a typical result is shown in Fig.4. The brittleness index (B) defined by Hudson and Morgan (1975)[3] as

$B = A_E/ (A_{E +} A_p)$……………………………(1)

Where $A_E$ is the area beneath the stress-strain curve before the peak stress and Ap is the area beneath the stress-strain curve after the peak stress (see Fig.4) was obtained for each curve by Tamaya Digital Planimeter measurements. The value of B can range from 0 to 1, for perfectly brittle rock with a post-failure curve descending vertically, B is unity since Ap is zero; for perfectly ductile rock with a horizontal post-failure curve, Ap is infinite and B becomes zero. The uniaxial compressive strength ($C_0$) was obtained from the peak of each curve. Young's modulus (E) was obtained from the stress-strain curve. The results for the three groups of specimens are summarised in Table1. To study the effect of absorption content on the strength properties, individual values of uniaxial compressive strength, young's modules and brittleness index have been plotted against individual values of absorption content for each specimen in Figures 5, 6 and 7.

**TABLE 1**
STRENGTH PROPERTIES OF SANDSTONE FROM HADJAR SOUD

| Conditions | Air dried specimens | | Specimens 1m above water | | Saturated specimens | |
|---|---|---|---|---|---|---|
| Values | Mean | Standard deviation | Mean | Standard deviation | Mean | Standard deviation |
| Uniaxial compressive strength ($c_0$), MN/m² | 37.2 | 5.5 | 30.6 | 5.4 | 23.0 | 4.5 |
| Young's modules (E), GN/m² | 7.17 | 0.69 | 7.04 | 1.25 | 5.50 | 1.23 |
| Brittleness index (B) | 0.69 | 0.06 | 0.77 | 0.08 | 0.61 | 0.08 |
| Dry density, Mg/m³ | 2.10 | 0.02 | 211 | 0.02 | 2.09 | 0.03 |
| Absorption content ,per cent | 0.77 | 0.03 | 217 | 0.28 | 8.92 | 0.34 |
| Number of specimens | 7 | | 7 | | 11 | |

## 5. Discussion and Conclusion

Figures 5, 6 and 7 show the effect of absorption content on the uni-axial compressive strength, Young's modulus and brittleness index of the sandstone respectively. There is a general tendency for both the uni-axial compressive strength and Young's modulus to decrease with increasing absorption content. With the brittleness index the trend is not clear and it is not possible from these data to see whether the index is unaffected by absorption content or has a maximum at some intermediate absorption content. On each of the figures a least square regression line for the data is shown together with the value of the computed correlation coefficient (r). A value of $r^2 \geq 0.6$ has been considered in rock mechanics as indicating a reasonable correlation [5, 6]. Judged by this criterion, Figures 6 and 7 show that Young's modulus and brittleness index of the sandstone are not h significantly affected by absorption changes over the range from air dry to saturation. Fig.5. However, shows that the effect of absorption content on uni-axial compressive strength is just significant, the strength of the sandstone decreasing with increasing absorption content. The mean uni-axial compressive strength of the air-dry

Sandstone from Hadjar Soud quarry, 37 MN/ $m^2$ (see Table 1), is almost identical with that of the dry chalk marl studied by Hudson and Morgan (1975)[3]. However, while the mean strength of the saturated Sandstone had fallen to 23 MN/$m^2$ that of the saturated chalk marl had fallen to 2 MN/$m^2$, showing a very different response to increasing absorption content. The mean Young's modulus of the Sandstone varied from 7.2 GN/ $m^2$ for air dried rock to 5.5 GN/ $m^2$ for saturated rock (see Table 1). Even the lower of these values is higher than the maximum value of 3 GN/ $m^2$ reported for the chalk and shows the sandstone is the stiffer of the two rocks. The mean brittleness index of the Sandstone varied from 0.61 to 0.77 (see Table 1). These values are lower than the values of 0.83 to 0.85 reported for the chalk and, shows the sandstone is the less brittle of the two rocks when judged by the criterion of brittleness index.

## 6. Acknowledgements
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