Rock Mechanics in Civil and Environmental Engineering – Zhao, Labiouse, Dudt & Mathier (eds)

Shear strength of artificially weathered marl

P. Miščević & G. Vlastelica
Faculty of Civil Engineering and Architecture, University of Split, Split, Croatia

ABSTRACT: One of the main soft rock characteristics are relatively rapid deterioration and degradation of strength when soft rock is exposed to atmospheric agents. In the investigation of strength degradation caused by weathering, wetting-drying process (as a part of weathering) is the factor that has most influence. Deterioration of shear strength due to weathering simulated by wetting-drying is tested on marl samples from Eocene flysch formation. Measurement is carried out with a portable shear apparatus, and a modified process of the sample preparation is implemented. Weathering of samples was simulated in laboratory conditions. Groups of five samples were subjected to 2 to 8 cycles of this process. The results provided the conclusion that the magnitude of the strength degradation depends on the strength of unweathered material and the number of simulated weathering cycles. However, with the increase of wetting-drying cycles, the changes become insignificant.

1 INTRODUCTION

Weathering of soft rocks is well known phenomenon that causes many problems in geotechnical constructions. Marl from Eocene flysch strata found in Dalmatia region in Croatia, is just one example of these soft rocks. Excavations in these strata such as those for construction pits or cuttings for roads, have considerable problems with durability. Durability problem is caused with marl strength degradation induced by the weathering. Excavation in these materials can be performed only with use of heavy machinery (rock breaker) or explosives, as well as in any other rock. However, in relatively short time after excavation, about few months, in which period excavated slope in marl is exposed to influence of atmospheric agents, weathering process starts on the slope surface. Repeated cycles of wetting and drying, heating and cooling, freezing and thawing, as parts of weathering process can cause marl to deteriorate into soil like materials. For an example, as a consequence of weathering, a cut that was stable after excavation even with almost vertical inclination, could become instable in the engineering time scale (i.e. a period ranging from a few years to a few decades, in which construction is in use).

In general, weathering includes two dominant processes (Fookes 1988), physical and chemical weathering. Physical weathering results in the disaggregation of rocks without mineralogical change, and chemical weathering results in the decomposition of the constituent minerals to stable or metastable secondary mineral products. The weathering process on marl and marly materials from flysch layer can be described as mainly physical weathering, combined with chemical weathering on the surface of material and on the crack walls inside the material, meaning all surfaces of material that can be in the contact with water (Miščević & Roje-Bonacci 1995; Miščević 1997). Deterioration caused by the weathering can be described in two forms of degradation process (Fig. 1).

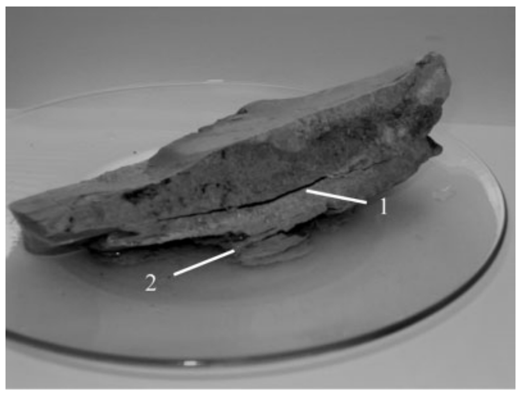

Figure 1. Two forms of deterioration on marl (1-disintegration in smaller parts with the development of the cracks system; 2-an exfoliation from the surface into depth).

Depending on the characteristics of unweathered material, marl can simultaneously undergo both forms of deterioration process. As a result, material is usually broken into smaller parts which have a larger surface area that can be in contact with water and the process of degradation is accelerated.

For the analysis of this situation two basic pieces of information are needed. First one is the depth of degraded layer on the surface of a slope, or the rate of the weathering through the depth. Second one is the rate of strength degradation compared to the strength of intact material. To provide data about the strength deterioration, there should be a possibility to test degraded materials. As it was described previously weathering process fragment marl samples into smaller pieces. Fragmented sample is very difficult to operate with and install into a testing device. For the solution of this problem additions to the standard test procedure were used (Miščević & Vlastelica 2009). Additions refer to the standard procedure of a direct shear test method (ISRM Suggested methods for determining shear strength, 1974) in order to enable testing of deteriorated samples.

2 PREPARATION OF SAMPLES

Samples are collected as blocks with approximate side dimensions between 10 and 20 cm, extracted using stone cutting saw without use of water, hammer and chisel from freshly excavated slopes or from about 0.5 meters beneath the surface of outcrops.

The significance of this procedure is that some of the outer material from the exposures was removed in order to obtain intact samples. For some kinds of marl, especially those with clay content greater than 40%, sampling is difficult because of its weak nature and frequent fractures. Before transportation, in order to minimize both the effects of vibration on the samples and desiccation, the samples were encased within layers of paraffin and thin plastic grid.

Collected samples were prepared in the laboratory for testing. Smaller pieces of approximate dimensions $10 \times 10 \times 8$ centimetres were cut with stone cutting saw from the field samples, without use of water in order to prevent the degradation. To prevent the deterioration of samples with overheating, cutting was performed very slowly with an interruption periods. After a described preparation, samples with the level of moisture as close as possible to a natural level of moisture, were used to form testing series.

The main problem in an investigation of the strength degradation caused by deterioration of the material (i.e. weathering) is to acquire samples that can be tested after deterioration. The main idea of the addition that is used (Miščević & Vlastelica 2009) is to enfold the sample with thin metal net before testing. Purpose of this net is to prevent the sample breaking into smaller pieces during the simulation of weathering. The metal net can be easily enfolded around the sample without any problem to form it in a shape of the sample.

In this paper investigation of strength deterioration is performed with analysis of the shear strength. Shear strength is measured with a portable shear apparatus for rock. For the purpose of the testing, sample is placed in heavy duty plaster to form two separated part in the shape of a testing cell.

3 LABORATORY SIMULATED WEATHERING

Laboratory simulated weathering is used in order to analyse the influence of weathering on the strength deterioration. The weathering is thus simulated with cycles of wetting and drying of samples in laboratory conditions consisting of three phases:

- drying of samples in an oven at temperature of 105°C over a period of 24 hours,
- cooling the samples at laboratory air temperature over a period of 24 hours,
- immersing the samples in water for a period of 24 hours.

After every weathering cycle weights of samples are measured and compared with weights of samples on the beginning of process. Comparing the two weights during testing is to ensure that loses of sample mass through net apertures are small enough not to have influence on the values of strength. Namely some kind of soft rock materials can deteriorate completely into a soil like material which can then easily pass through the net apertures during the process of wetting and drying.

For the purpose of testing several sets were formed, each comprising of five samples. Each sample was enfolded with a net before the start of. procedure. One set of samples is always tested with laboratory preserved moisture. Results of that test are used as the main data for the comparations in strength degradation analysis. Weathering is simulated with two to eight previously described cycles of wetting and drying.

4 TEST RESULTS AS CONCLUSIONS

Using proposed additions to shear test procedure marl from two locations in Split, Croatia were tested. Samples of marls for this study are taken from the sides of the slopes at construction sites close to each other. Test results obtained by this procedure are presented.

First group formed with marl from the first location has 47.2% carbonate content. Slake durability index after the second cycle of this material is $I_{d2} = 64.2\%$. Second group formed with marl from the second location has 54.6% carbonate content. Slake durability index after the second cycle of this material is $I_{d2} = 76.0\%$.

From each group four sets comprising of five samples were made. First set is tested with moisture preserved in laboratory conditions and without simulated weathering. Second set of samples is tested after two cycles, third set after four cycles, and finally the fourth set of samples is tested after eight cycles of simulated weathering. Both groups are subjected to three phase weathering, however with one slight difference. Testing of the first group follows the phases in wetting, drying and cooling order, while the second group follows drying, cooling and wetting order. Figure 2 represents a sample from second group that was subjected to 4 cycles of weathering.

Weight of all samples is measured after each cycle of simulated weathering. The loss of mass is less than 1% for all samples. At the same time visual inspection confirmed that the samples broke down into smaller pieces.

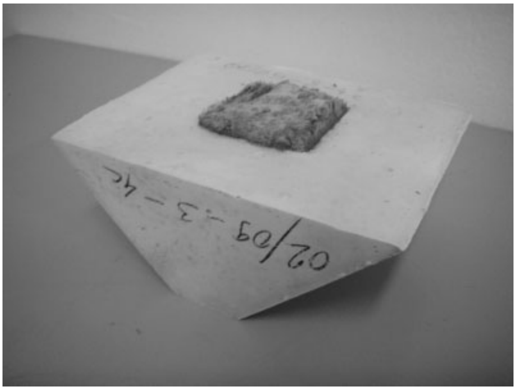

Figure 2. Example of sample from second group after shearing.

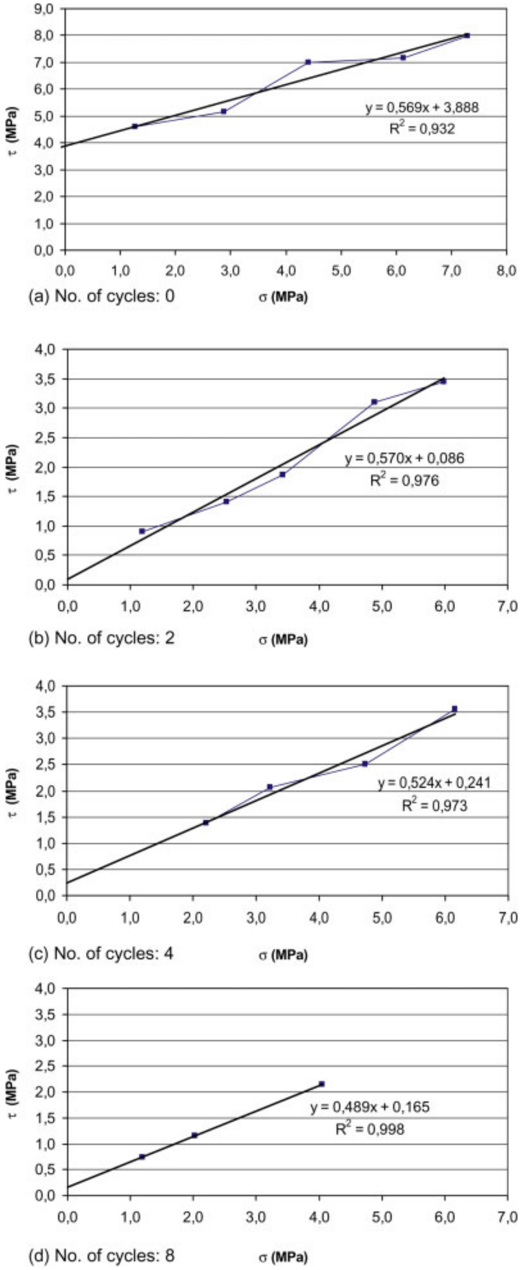

Figure 3. Shear test results of first group of samples (cycle in wetting, drying and cooling order)

Unfortunately, some samples after simulated weathering had such small shear strength that it was not possible to measure it with used equipment. Visual inspection of such samples indicated that the deterioration of sample in a zone of a predestined shearing plane in direct shear apparatus is the possible cause of the problem. In that case results obtained with the rest of samples in the same set were used to determine the shear strength parameters.

Obtained results of shearing resistance and determined parameters of Mohr-Coulomb criterion, i.e. cohesion and angle of internal friction, are presented in Figure 3, Figure 4 and Table 1.

Results of the first group of samples, presented in Figure 3, are acquired by using wetting, drying and cooling order of simulated weathering. Results are not consistent and could even suggest an increase of marl shear strength. Reason for this could be that the samples are tested after drying. So the samples from the second group of marl were tested in wet conditions.

In Figure 4 results of the second group of samples are presented. It can be observed that weathered samples have lower values of cohesions and same value of angle of friction, compared to the values obtained from unweathered sets of samples. It was not possible to use more than 8 cycles of weathering because samples were so deteriorated that it would be very difficult to obtain any results. Even after 8 cycles it was not possible to apply higher vertical forces (Fig. 4 (d)). At this stage of weathering remained material can be treated as soil like material (Roje-Bonacci, 1998).

Comparison of cohesion and angle of internal friction, for both groups of marl, is presented in Table 1. Results obtained from the second group of samples confirm that proposed additions to standard procedure make the measurement of strength degradation after weathering possible to some extent. Crucial factor is the order in which the cycles of weathering should be applied. Similar to field conditions, the unfavourable state of marl is when it is wet, so testing of shear strength should be proceeded in that conditions.

It can be concluded that magnitude of strength degradation depends of strength of unweathered marl, number and order of simulated weathering cycles. With the increase of the number of wetting and drying cycles, changes become insignificant in conditions used in testing.

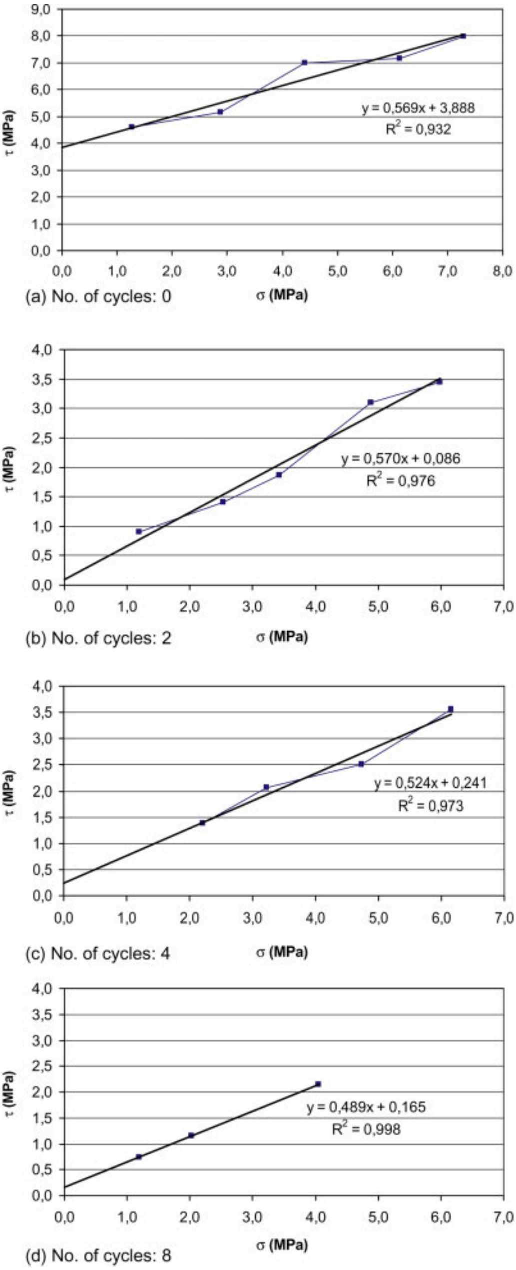

Figure 4. Shear test results of second group of samples (drying, cooling and wetting order)

Table 1. Results of cohesion and angle of internal friction.

Number of cycles	First group		Second group	
	c (MPa)	φ (°)	c (MPa)	φ (°)
0	0.45	21.3	3.89	29.6
2	0.25	38.5	0.09	29.7
4	0.71	24.4	0.24	29.7
8	0.76	32.2	0.16	31.2

ACKNOWLEDGEMENT

The presented results derive from the research project, Development of the Weathering Model for the Design Purpose of Geotechnical Constructions in Flysch, implemented due to support of the Ministry of Science, Education and Sports, Rep. of Croatia.

REFERENCES

Erguer, Z.A. & Ulusay, R. 2009. Assessment of physical disintegration characteristics of clay-bearing rocks: Disintegration index test and a new durability classification chart. Engineering Geology 105: 11–19.

Fookes, P.G., Gourley, C.S., & Ohikere, C. 1988. Rock weathering in engineering time. Quar. J. of Eng. Geol. 21: 33–57.

Hoek, E., Marinos, P.G. & Marinos, V.P. 2005. Characterisation and engineering properties of tectonically undisturbed but lithologically varied sedimentary rock masses. Int. J. Rock Mechanics and Mining Sciences 42: 277–285.

ISRM, 1974. Suggested methods for determining shear strength.

Marinos, P. & Hoek, E. 2001. Estimating the geotechnical properties of heterogeneous rock masses such as flysch. Bull. Eng. Geol. Env. 60: 85–92.

Miščević, P. 1997. The investigation of weathering process in flysch terrains by means of index properties. Marinos et.al. (ed.) Proc. Int. Sym. on Eng. Geology and Enviro., Athens, Greece, Vol. 1: 273–277. Rotterdam: Balkema.

Miščević, P., Števanić, D. & Štambuk-Cvitanović N. 2009. Slope stability mechanisms in dipping conglomerates over weathered marls: Bol landslide, Croatia. Environmental geology 56, Issue 7: 1417–1426.

Miščević, P. & Vlastelica, G. 2009. Shear strength of weathered soft rock – proposal of test method additions. Proc. Reg. Sym. on Rock Eng. in Diff. Gr. Cond. – Eurock 2009, Cavtat, Croatia, 303–308. Leiden: CRC Press/Balkema.

Roje-Bonacci, T. 1998. Parameter changes after weathering of soft rock in flysch, Proc. Int. Sym. on Hard Soils-Soft Rock, Naples, Italy, Vol. 2: 799–804. Rotterdam: Balkema.