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# Weak rocks of varying strength as earthworks materials

## Roches faibles de force variable en tant que matériau réutilisé

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**ABSTRACT:** Considering the existing sustainability and resource efficiency programs the use of less suitable materials as earthworks materials should increase. Even weak rocks of varying strength belong to these materials cause of their varying strength after exposure which may change within construction time through weathering processes. Generally, changes in the water content accelerate their decay processes that may lead to their complete disintegration with a deterioration of the soil mechanical properties. Due to these weathering influences, there may be variable strength properties, which at first may lead to sagging or swelling and, in consequence of progressive weathering during lifetime of the earthwork, to lasting deformations.

To investigate these variable strength properties, when using them as earthworks materials, it was necessary to analyze their deformation properties depending on their degree of decay, their initial conditions and their degree of saturation. The results of the compression tests in large scale oedometers with a diameter of 30 cm are shown representativly for one of the four investigated soils, the clay marl stone. Cause of their weathering sensitivity, which can lead to a decay into a fine grained soil, higher installation requirements are necessary. Therefore, an initial air void content ≤ 6 Vol.-% leads to relatively lower deformation rates. Furthermore, an intermediate storage without additional protection measures should be avoided.

**RÉSUMÉ:** Compte tenu des programmes existants en matière de durabilité et d'utilisation des ressources, l'utilisation de matériaux moins appropriés comme matériaux de construction devrait augmenter. Même les roches faibles de différentes résistances appartiennent à ces matériaux en raison de leur résistance variable après exposition qui peut changer dans le temps de construction en raison des processus de vieillissement. En règle générale, les changements dans la teneur en eau accélèrent leurs processus de décomposition ce qui peut conduire à leur désintégration complète avec une détérioration des propriétés mécaniques du sol. En raison de ces influences atmosphériques, il peut exister des propriétés de résistance variables qui peuvent, dans un premier temps, conduire à un affaissement ou à un gonflement et, en conséquence de l'altération progressive pendant la durée de vie du terrassement, à des déformations durables.

Pour étudier ces propriétés de résistance variable, il était nécessaire d'analyser leurs propriétés de déformation en fonction de leur degré de dégradation, de leurs conditions initiales et de leur degré de saturation, lors de leur utilisation en tant que matériaux de terrassement. Pour ces essais de compression, on a utilisé des oedomètres à grande échelle d'un diamètre de 30 cm. Les résultats sont présentés de manière représentative pour l'un des quatre sols étudiés, la pierre de marne argileuse. En raison de leur sensibilité aux intempéries, qui peut entraîner une dégradation dans un sol à grain fin, des exigences d'installation plus élevées sont nécessaires. Par conséquent, une teneur initiale en vide d'air ≤ 6 Vol .-% conduit à des taux de déformation relativement plus faibles. En outre, un stockage intermédiaire sans mesures de protection supplémentaires doit être évité.

**Keywords:** weak rocks; varying strength; decay; compression

## 1 INTRODUCTION

With the aim of improving sustainability and resource efficiency, the amount of less suitable geological materials as earthworks materials must be increased to avoid the consumption of natural mineral earthworks materials. Weak rocks of varying strength, which can be found in a significantly extent near the surface, belong to these materials, cause they can lose their strength after exposure to temperature and moisture changes within construction time. Generally, repeated changes of the water content or rather drying-wetting cycles, which can take place during the construction period and the associated earthmoving processes and are often unavoidable, lead to variable strength properties, which can accelerate the decay processes and lead to the complete disintegration of the rock into a soil. During the lifetime of the earth structure, these weathering processes at first may lead to sagging or swelling and, in consequence of progressive weathering during lifetime of the earthwork, to lasting deformations.

Already in previous research studies (e.g. R. Stiegeler et al., P. Möller & D. Heyer, C. Bönsch) it was found that the soil mechanical properties strongly depend on their composition and the internal binding forces as well as the initial conditions and the degree of decay.

Therefore, in order to judge the usability of weak rocks as construction materials, it was necessary to investigate the change of deformation behaviour of this material during weathering processes.

## 2 CHARACTERISATION OF THE VARYING STRENGTH

Weak rocks of varying strength are rocks that only under atmospheric influence, especially by changes in the water content but in particular by repeated drying and moistening processes lose their inner, usually diagenetic bonds and strength. As a result, the rock disintegrates irreversibly to a fine- to mixed-grained soil. These different decay stadiums, which develop through drying-wetting cycles, are exemplary shown in Figure 1. Beside these required drying-wetting cycles, a pure water storage does not necessarily lead to decay processes.

Moreover, the disintegration or decomposition of the rock occurs within a relatively short period of time from days to months (or years). Accordingly, these changes in strength are relevant for the earthmoving processes (loosening, loading, conveying, intermediate storage, installation and compaction) and earthworks in contrast to the long lasting weathering through chemical and biological weathering processes.

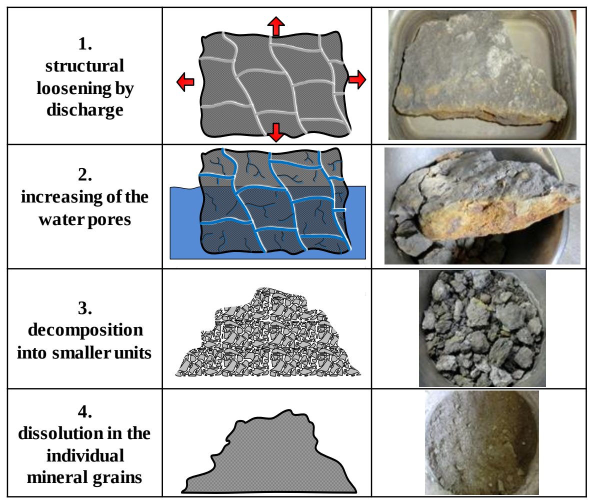


*Figure 1. Decay stadiums of weak rocks of varying strength leaning on P. Möller & D. Heyer*

This relatively fast decay from rock to soil is characterized by variable geotechnical properties. Thus, corresponding materials can not be adequately described with either rock or soil mechanical classification and testing methods.

The interaction between drying und wetting is deciding for the decay of these weak rocks associated with negative effects on stability properties. In order to identifiy and classify these rocks concerning their weathering behavior, in particular with respect to mode and speed of the decay, there are different methods in the literature, for example the Slake Durability Test according to P. Herzel or the drying-humidification test according to M. Nickmann.

## 3 INVESTIGATION RESULTS

### *3.1 Proctor tests depending on the degree of decay*

The aim of the investigations was to analyze the deformation properties of weak rocks of varying strength depending on their degree of decay (V), their initial conditions (initial water content and initial dry density) and their degree of saturation (sat). The results are shown exemplary for one of the four investigated soils, the clay marl stone.

First, to investigate different degrees of decay it was necessary to estimate the specific limit grain distrubtion curve as shown in Figure 2. Based on this limit curve, an intermediate storage should be simulated, where approximately 50 % of the expected decay should have occurred. Therefore, drying-wetting-cycles (DWC) where combined with wet sievings to simulate the disintegration from a weak rock into a more fine-grained soil. After two DWC more than 50 % of the grains were smaller than 2 mm and so corresponds to V2.

For the two different degrees of decay V0 and V2, the proctor curves was determined through proctor tests to define the initial conditions (initial water content and initial dry density). The desired initial conditions as well as the really reached conditions of the samples for the compression tests are shown in Figure 3. With an increasing degree of decay the proportion of fine grains rises and therefore the dry density (proctor optimum) decrease. In addition the proctor area of V0 shows the often existing heterogeneity of weak rocks of varying strength.

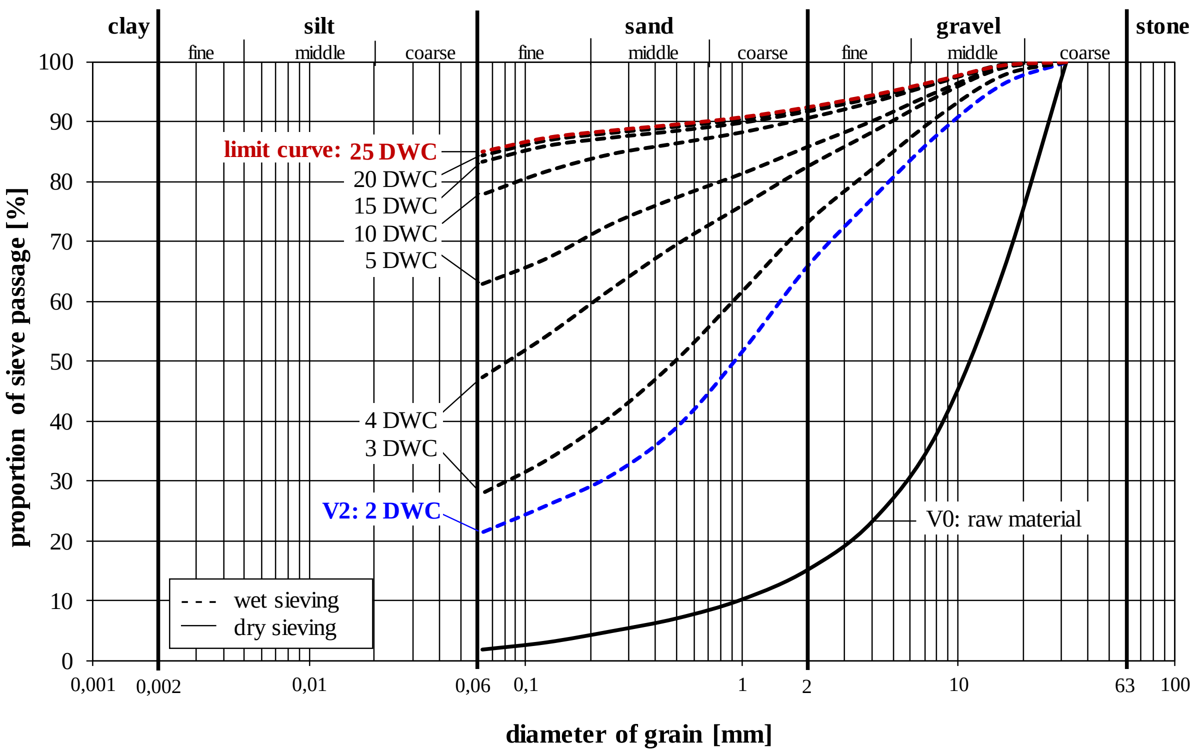


*Figure 2. Grain distribution curves from the V0-state to the limit curve after 25 drying-wetting-cycles (DWC)*

Beside the proctor test, all classification tests, for example the grain distribution, where water have to be used and therefore can have an impact on the weak rock of varying strength are because of that less suitable. Because of their weathering sensitivity the mode of the preparation and the consistency of the sample has an important influence on the test results (P. Möller & D. Heyer).

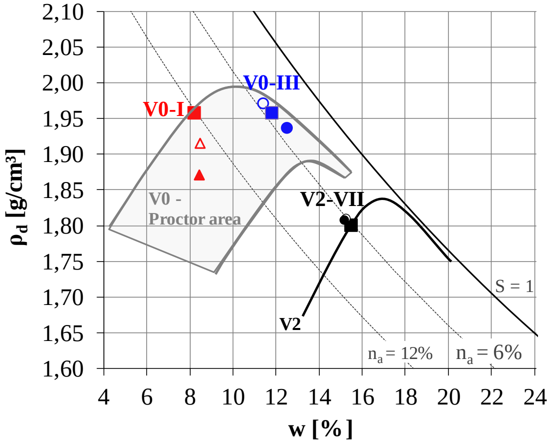


*Figure 3. Proctor curve for V0 and V2 with the desired and actually reached initial conditions*

## 3.2 Compression tests

Beside the degree of decay and the initial conditions, two different saturation times were selected as third factor. In order to investigate a potential bearing capacity deficit by water impact in a loaded condition, water was added after reduction of the settlement in the first (25 kN/m²) or last loading level (400 kN/m²).

The results of the compression tests in large scale oedometers with a diameter of 30 cm and a sample height of 6 cm are shown for the stress-strain behaviour in Figure 4 and for the deformation modulus in Figure 5.

It was observed, that in all tested soils both, an increasing initial water content and the addition of water in the lowest loading level, leads to an enhancement of the settlement and therefore to a reduction of the stiffness. Generally, in all tested soils it was observed, that with an earlier saturation swelling and with a later saturation sagging arise. Thereby, especially the initial condition on the dryer side of the proctor curve has to be considered critically in case of bigger deformations have occurred. Thus, the higher amount of air pores leads to higher saturation and in consequence a higher water content leads to higher deformations cause of the higher specific surface of the finer grains. This leads to the result, that the recommendation of an initial air void content ≤ 6 Vol.-% (ZTV E-StB 2017) has to transform into a mandatory limit.

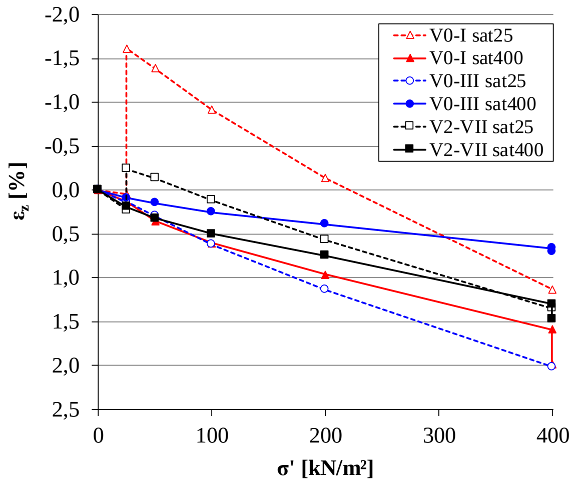


*Figure 4. Stress-strain diagram*

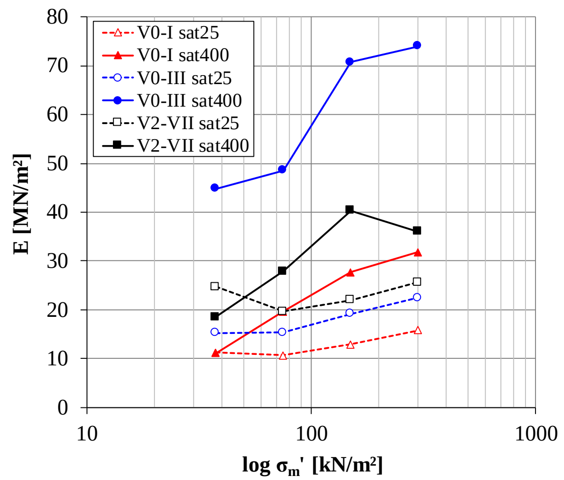


*Figure 5. Elastic modulus*

Moreover, it has been turned out that with a rising degree of decay, the potential of sagging and swelling increases as result of the decreasing of the dry densitiy and increasing of the proportion of fine grains.

### 3.3 Weathering influence at compacted soils

The influence of weathering processes on the deformation behaviour in the compacted state of samples was investigated in the large oedometers for two different initial conditions (see Figure 6). Therefore, the compacted samples were subjected to six drying-wetting cycles under two different constant load stresses of 50 kN/m² and 100 kN/m². The drying was done by means of compressed air and the wetting by adding water through the base of the sample.

In general, there were alternate sagging because of drying and swelling due to water addition. Again, a higher water content leads to higher deformation depending on the load stress. Especially the high proportion of air pores of T-I under a load stress of 50 kN/m² leads to a decreasing of the settlements with rising DWC.

Moreover, that the desired initial conditions could not reached shows also the importance of the homogenization and defining initial conditions near the proctor optimum to minimize deformations cause of too high air pores.

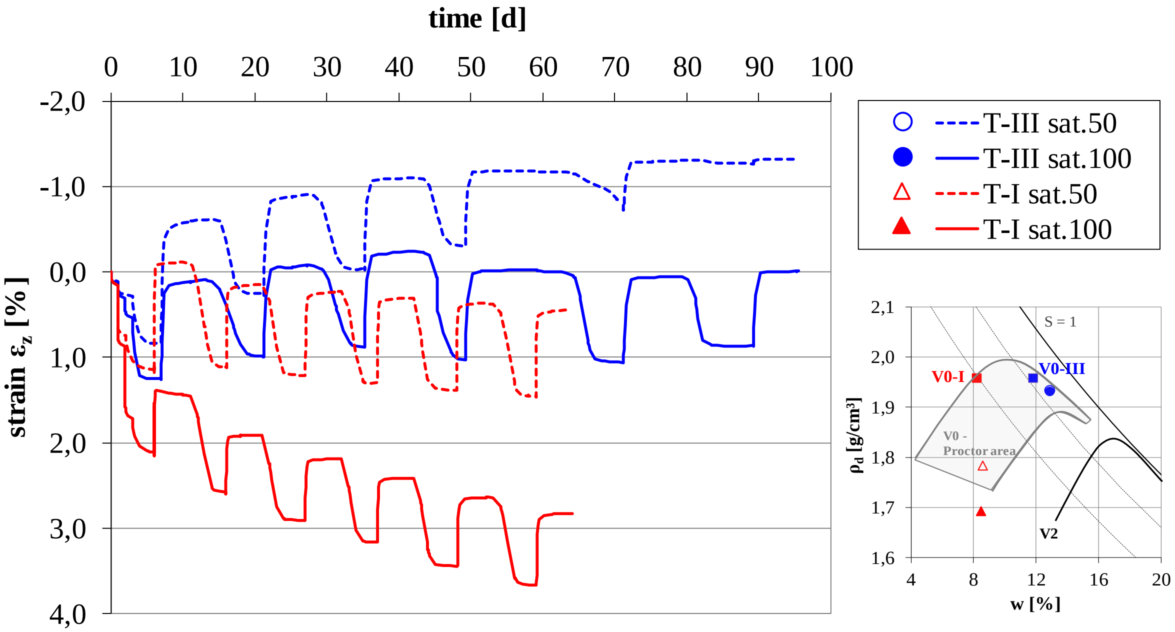


*Figure 6. Drying-wetting cycles at compacted soils*

## 4 CONCLUSIONS

The results of the compression tests have shown, that the reuse of weak rocks of varying strength as earthwork materials is in consideration of their particularities in principle possible against the uncertain attitude because of missing rule works. Cause of their weathering sensitivity, an adaption of the classical laboratory progamm and especially higher installation requirements are necessary.

The problem concerning weak rocks of varying strength is often that during the earthwork processes, including from excavation to reinstallation, changes in the water content can lead to the decay of the rock into a soil with a resulting negative increase of the fine grains. Even the test results shows a decreasing of the deformation with the rising of DWC and therefore the rising amount of fine grains. So, first of all it is important to identify and classify this changing behaviour through specific classification tests (e.g. Slake Durability Test). With knowing their weathering sensitivity, the following requirements will be set better adjusted. In this regard, to minimize the negative increase of the fine grains through changes in the water content, an intermediate storage without additional protection measures should be avoided. Furthermore, especially the installation requirements have to estimate on the material to be reused, thus after intermediate storage.

To reduce the potential of sagging or swelling of weak rocks of varying strength, when using them as earthworks materials, the recommended limit of an initial air void content ≤ 6 Vol.-% has to be set as a mandatory limit. Those higher requirements are also necessary because of their often existing heterogeneity.

## 5 REFERENCES


Bönsch, C. 2006. Auswirkungen der Saugspannungen auf physikalische und mechanische Eigenschaften von überkonsolidierten Tonen und Tonsteinen im Verwitterungsprozess. Dissertation an der Mathematisch-Naturwissenschaftlich-Technischen Fakultät der Martin-Luther-Universität Halle-Wittenberg.

Floss, R. 2017. Zusätzliche Technische Vertragsbedingungen und Richtlinien für Erdarbeiten im Straßenbau, ZTV E-StB, Ausgabe 2017, Kommentar und Leitlinien mit Kompendium Erd- und Felsbau, Kirschbaum Verlag, Bonn.

Herzel, P. 2002. Empfehlung Nr. 20 des Arbeitskreises 3.3 „Versuchstechnik Fels" der Deutschen Gesellschaft für Geotechnik e. V.: Zerfallsbeständigkeit von Gestein – Siebtrommelversuch, Bautechnik 79 (2002), S. 101 – 105, Verlag Ernst & Sohn, Berlin.

Möller, P., Heyer, D. 2014. Verwendung veränderlich fester Gesteine und halbfester bis fester Tone als Erdbaustoff, Schlussbericht zum F&E Vorhaben 09.148/2011/HRB (unpublished).

Nickmann, M. 2009. Abgrenzung und Klassifizierung veränderlich fester Gesteine unter ingenieurgeologischen Aspekten, Münchner Geowissenschaftliche Abhandlungen, Reihe B, Band 12, 2009, Verlag Dr. Friedrich Pfeil, München.

Stiegeler, R., Heyer, D., Baumgärtel, T. 2006. Aufbereitung und Einbau veränderlich fester Gesteine, Forschung Straßenbau und Straßenverkehrstechnik (FGSV), Heft 931, 2006, Bundesministerium für Verkehr, Bau und Stadtentwicklung, Abteilung Straßenbau, Straßenverkehr, Bonn.