A Classification of Weak Rocks for their Use in Road Embankments

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INTRODUCTION

Weak or soft rocks are defined as those materials whose geomechanical behavior is between hard rocks and soils. According to Giambastiani (2014), weak rocks are classified as i) primary detrital, metamorphic or volcanic rocks; and ii) secondary or evolving rocks, after the physical-chemical alteration of former hard rocks. Furthermore, weak rocks are critical geological materials since they may present undesirable behaviors, such disaggregation, fissures by cracking, crumbling, low strength and stiffness, high plasticity, slaking, fast weathering, and irreversible volume, textural and mineralogical changes (e.g., Alonso and Alcoverro, 2004). These unfavorable behaviors hinder and, in many cases, prevent their utilization in road embankments. Nevertheless, there are extensive areas in the world dominated by weak rocks, where civil construction companies need to deal with them (Kanji, 2014), as occurs in the Gipuzkoa Province (Basque Country, N of Spain), especially in the GI-632 highway stretch sector (Fig. 1).

Currently the definition of weak rocks, in the design of civil engineering projects, is based on the uniaxial compressive strength test (UCS), which distinguishes between hard and weak rocks at ~20 MPa, and soils at ~2 MPa (Afrouz, 1992). However, experience has shown that frequently, rocks classified as hard rocks according to UCS, can evolve to weak rocks once installed in the road embankment. Therefore, other tests are needed for a better identification. To this aim, we propose a new classification of detrital weak rocks for their use in road embankments, based on the combination of different geomechanical tests that take into account their evolution and durability. We illustrate this new approach applying it to the rocks of the GI-632 highway sector.

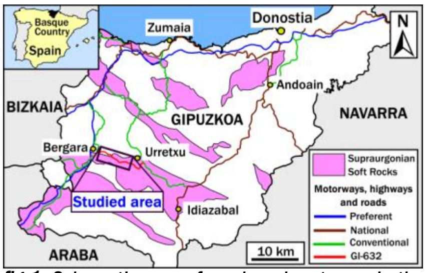

fig 1. Schematic map of weak rock outcrops in the Gipuzkoa Province, showing the location of the studied area (modified from EVE, 2003).

METHODOLOGY

37 samples were obtained from 10 core holes, which were drilled (12-25 m) in excavated slopes and embankments of the GI-632 highway stretch sector (Fig. 1). 19 selected samples were examined in thin section petrographic microscopy. The bulk mineral composition was determined by XRDP. Mineral phase quantification was obtained by point counting analysis in thin sections. The geomechanical parameters applied were: the Uniaxial Compressive Strength (UCS; Afrouz, 1992), the abrasion percent loss under Micro-Deval (MDI; UNE-EN 1097-1), the Slake Durability Index on the intact samples (SDI_{IS}), and on the aged samples (SDI_{AG}) by 15 wetting-drying and 15 freeze-thaw cycles (see Martínez-Bofill, 2011 for the detailed procedure description).

PETROGRAPHICAL CHARACTERIZATION

In the GI-632 highway sector, materials are fine laminated black claystones and siltstones with scarce decimetric to metric interbedded sandstones of the Supraurgonian Complex (Lower to Upper Cretaceous). Texturally, the studied detrital weak rocks are constituted by: i) clastic frameworks of quartz (11-44%), muscovite (<18%), feldspar (<17%), calcareous bioclasts (<8%), sulfurs as pyrite (1-6%), lithic fragments (<5%), and altered chlorite (<4%); ii) matrix of fine-grained mud (5-80%) and/or carbonate (<24%); and iii) cement, either carbonatic (<34%), ferruginous (<14%) and/or siliceous (<14%).

The three different rock types sampled were classified following their relationship between clasts, cement and matrix (Fig. 2). According to the textural classification of detrital rocks proposed by Corominas et al. (2015), 4 samples of

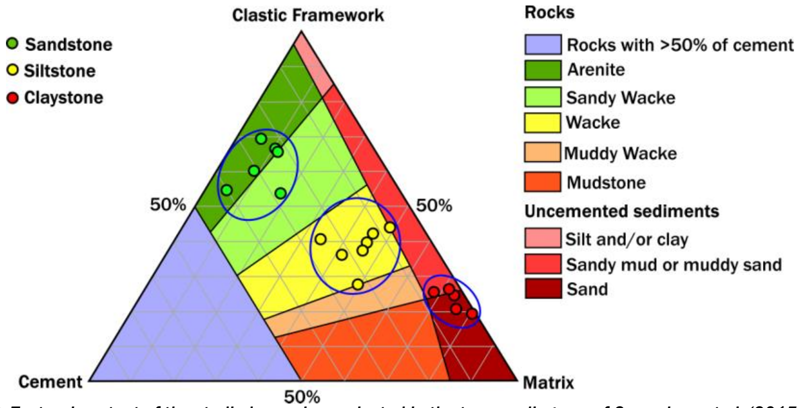

fig 2. Textural content of the studied samples projected in the ternary diagram of Corominas et al. (2015).

palabras clave: Rocas Blandas, Terraplenes, Clasificación. | **key words:** Weak Rocks, Road Embankments, Classification.

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claystones are classified as silts and 2 as sandy muds, 6 siltstones samples are classified as wackes *sensu strictu* and 1 as muddy wacke, and 5 sandstone samples are classified as arenites and 1 as sandy wacke (Fig. 2).

GEOMECHANICAL CHARACTERIZATION

Claystones show a USC range from 6.6 to 8.5 MPa, and MDI values of 46 to 100%, which corresponds to typical values of evolutive weak rocks. Furthermore, the SDI_{IS} values are between 1.6 and 87.7%, indicating a durability range from very low to high. Nevertheless, the values of SDI_{AG} are lower than 67.2%, which are consistent with a very low to medium durability grade (Fig. 3a). Consequently, the Slake Durability Test in aged samples is more representative of the durability grade.

Siltstones are characterized by 11.1 to 34.4 MPa of USC, which are comprised between hard and weak rocks. Furthermore, siltstones show 99 to 100% of MDI, corresponding to evolutive rocks. The SDI_{IS} and SDI_{AG} ranges from 31.7 to 94.9% and from 11.2 and 95.2% respectively. These values indicate very low to very high durabilities (Fig. 3a). Therefore, the SDI_{AG} separates better the durability behavior.

Finally, an arenite sample shows a UCS of 70.6 MPa, which may be classified as hard rock. Nevertheless, the MDI is in the range of 47 to 50%, which correspond to evolutive rocks. The sandstones SDI_{IS} and SDI_{AG} are from 78.3 to 99.2%, indicating a durability range from high to very high (Fig. 3a).

ROCK CLASSIFICATION FOR USE IN ROAD EMBANKMENTS

The proposed detrital rock classification for their use in road embankments (Fig. 3b) is partly based on the previously exposed results. Three types of rocks are defined: non-evolutive hard rocks (NEHR), evolutive weak rocks (EWR) and inadequate soils (IS).

Non-evolutive hard rocks

Non-evolutive hard rocks (NEHR) are characterized by uniaxial compression strengths higher than 20 MPa and abrasion percent losses lower than 18%. If the abrasion percent loss is higher than 18%, the tested sample will be considered as EWR. In addition, NEHR must also show SDI_{IS} and SDI_{AG} higher than 90% (Fig. 3b).

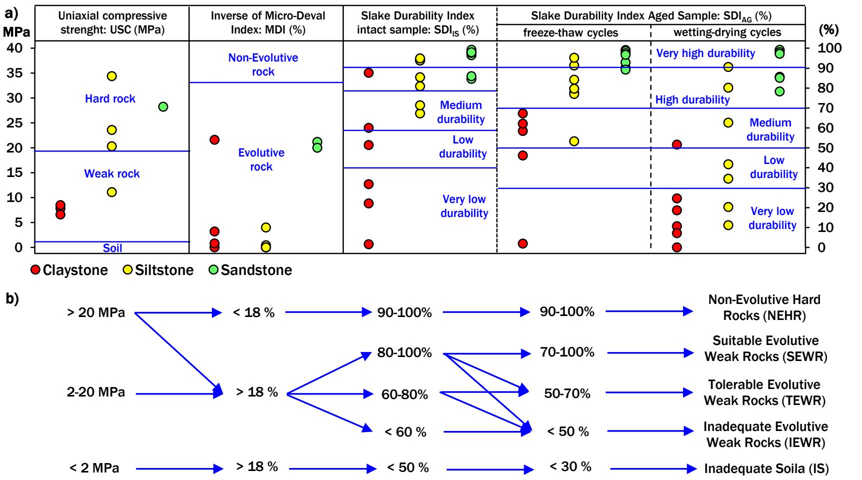

fig 3. a) Geomechanical results of studied samples. b) Weak rock classification for use in road embankments.

Evolutive weak rocks

Evolutive weak rocks (EWR) show UCS between 2 and 20 MPa and MDI values higher than 18% (Fig. 3b). According with slake durability indexes, three different subcategories are defined: suitable (SEWR), tolerable (TEWR) and inadequate (IEWR).

Suitable evolutive weak rocks are defined as those materials whose SDI_{IS} and SDI_{AG} are higher than 80 and 70%, respectively (Fig. 3b). On the other hand, tolerable evolutive weak rocks are characterized by 60 to 80% of SDI_{IS} and by 50 to 70% of SDI_{AG} (Fig. 3b). Finally, inadequate evolutive weak rock will shows SDI_{IS} and SDI_{AG} lower than 60% and 50%, respectively (Fig. 3b).

Inadequate soils

Materials that have UCS values lower than 2 MPa and abrasion losses higher than 18% are classified as inadequate soils (IS). Typically, these materials must show SDI_{IS} and SDI_{AG} lower than 50 and 30%, respectively (Fig. 3b).

CONCLUSIONS

Petrography and geomechanical data from the detrital rocks (claystone, siltstone and sandstone) outcropping in the GI-632 highway stretch sector put constrains on the evolution, durability and quality degree of weak rocks for use in road embankments. Even though more work is needed, five types of materials have been defined: non-evolutive hard rocks (NEHR), suitable weak rocks (SEWR), tolerable weak rocks (TEWR), inadequate weak rocks (IEWR) and inadequate soils (IS). Furthermore, the studied claystones can be classified as TEWR and IEWR, and siltstones and sandstones as TEWR and SEWR.

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