STUDY OF THE RELATIONSHIP OF MOISTURE AND COMPACTION ON THE MODULUS OF RESILIENCE OBTAINED BY CYCLIC CBR TESTING IN LOCAL SOILS FOR A QUALITY RURAL TOURISM

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Abstract
Low Volume Roads are a key part of both rural and urban life and an accurate study of the parameters involved in their design is fundamental at an environmental level. In nature, due to the passing of the seasons, with changes in humidity and temperature, the density and compaction of the soil changes notably, giving rise to cracks and defects that directly affect their users and entail both economic and environmental costs in terms of vehicle efficiency and repair costs. Furthermore, this type of defect hinders the practice of outdoor activities and sports, which are essential for the development of rural tourism. For this reason, in this study, the Resilience Modulus of a nearby material has been analysed by cyclic California Bearing Ratio tests, thanks to Mendelu's specialised software, under different compaction and humidity conditions.

Key words: Humidity, Density, Soil, Recreation, Low Volume Roads

Introduction

The recreational use of the natural environment in the Czech Republic is a fundamental part of life in the Czech Republic for its inhabitants and many tourists. Furthermore, they are an integral part of the constructive elements - constructions - works - that complete the landscape, connecting and facilitating movement for both economic and recreational activities. Construction for these purposes must meet the criteria, not only in terms of carrying capacity, but also minimise impacts on the surrounding ecosystems. Therefore, proper preservation of rural roads is fundamental and one of its key points is the precise design of rural roads (CSN 73 6108, 2016), known in the world as Low Volume Roads (LVR) already defined by the American Association of State Highway and Transportation Officials (AASHTO, 2011).

These roads have a low traffic flow of less than 400 vehicles on average per day. These types of roads make up long networks of rural roads linking small towns and villages and providing access to various routes in natural environments. Moreover, in larger cities, although they are not so frequent, they can be seen in parks or accesses to peripheral areas. In summary, it can be said that LVR are a key part of many people's lives, both for freight transport and for purely leisure and rural tourism.

In order to design them and simulate their behaviour during deformation, the most significant parameter is the Resilient Modulus (M_r), which is fundamental to be able to define whether the material will be able to support the necessary load under the conditions of each zone and the deformations that are within the permitted limits. M_r is a fundamental material property used to characterize unbound pavement materials. It is a measure of material stiffness and provides a mean to analyse stiffness of materials under different conditions, such as moisture, density and stress level. In order to obtain M_r and to determine the elastic behaviour, it is proposed to perform them in a cyclic manner by simulating repeated traffic loading. This parameter is usually obtained by Cyclic Load Triaxial Tests (ČSN EN 13286-7, 2004). However, these tests are generally very time-consuming and expensive and not all countries can afford them. For this reason, the validity of cyclic tests on California Bearing Ratio (CBR) device, which are much cheaper and would allow an optimal design at a very low laboratory cost, began to be studied.

In addition, the materials used must be taken into account; economical design does not have to come before sustainable design, especially when it comes to infrastructure in a natural environment. Therefore, the aim is to use local materials as much as possible in order to preserve the landscapes that form the rural environment. The consequences of poor design affect society in many ways.

First, a damaged road increases both fuel and repair costs for the vehicles that travel on it, increasing the carbon footprint generated. On the other hand, poor roads and paths can easily hinder the practice of many outdoor sports and transit for people with reduced mobility. These kinds of things are key to

generate good quality and attractive "adventure" tourism. Finally, as previously discussed, a poor choice of material can damage and even destroy local ecosystems (Arias, 2020).
Thus, the University of Mendel, in collaboration with the geotechnical laboratory Geostar, has developed its specialised software (SW) on CBR cyclic test to obtain the Resilience Modulus M_r (PUV 304642, 2014). This software can carry out two types of tests. The first one penetrates the sample until one constant depth, generating high stress levels. For the second test a maximum constant stress value is set in order to simulate the weight of the vehicles. Both tests end when a constant elastic deformation is obtained according to the AASHTO guide, as alternative to Cyclic Load Triaxial Test (MEPDG, 2008).
This SW was key in the presented experiment to analyse the behaviour of M_r under variable natural conditions. These study focuses on local materials and analyses the effect of compaction, soil density and humidity. This is important as, during the year, the seasonal cycle generates abrupt changes in the roads and can damage them.

Materials and methods
The presented analysis was carried out on a pavement constructed in the vicinity of the city of Brno. The deformation behaviour of natural base materials was determined in soils taken from the active zone of the forest roadway at a depth of about 500 mm below the construction layers. From the roadway subgrade, soil classification analysis was performed according to the Unified Soil Classification System (USCS) according (ČSN EN ISO 14688-2, 2005 and ČSN EN ISO 14689-1,2004*)*. In addition to the classification tests, a standard Proctor test (ČSN EN ISO 13286-2, 2015) was performed to define the optimum moisture and maximum dry density. Resilient Modulus was measured on the CBR device which allows the application of cyclic loading (PUV 304642, 2014) in order to obtain Resilient Modulus according to MENDELU methodology.
To detect the changes produced by humidity and compaction, the following methodology has been followed, using the second test-type of the SW. First, a sample is compacted according to the CBR test standards (ČSN EN ISO 13286-47, 2015) and a CBR cyclic test is carried out on each side of this sample to check the effect of different levels of compaction ($M_{r,max1}$ and $M_{r,min2}$). After this, a sample is compacted again and the same tests are carried out but switching the order surfaces ($M_{r,max2}$ and $M_{r,min1}$). In addition to the influence of the degree of compaction on M_r, the influence of increasing humidity was also monitored.
The moisture content of the sample was increased gradually from 2% to the maximum allowed by the material itself. Finally, ten samples have been tested with the optimum moisture content of the material.

Results
<u>Geotechnical Result</u>
The analysed material was classified following (ČSN EN ISO 17892-4, 2017) as a F4 CS compound by a 21.6% of gravel, a 29.1% of sand and a 49.4% of thin material. That thin material following (ČSN EN ISO 17892-1, 2015) y (ČSN EN ISO 17892-12, 2018) as clay (sasiCl) sandy silty clay. Laboratory Reference Density 1820 kgm^3 and Water Content 8.5 % from the Proctor Compaction test.
In total 54 cyclic tests were carried out with increasing and optimum humidity. The humidity was progressively increased and a constant tension was applied with a maximum of 210 kPa, the value expected in subgrade. (Fig.1).

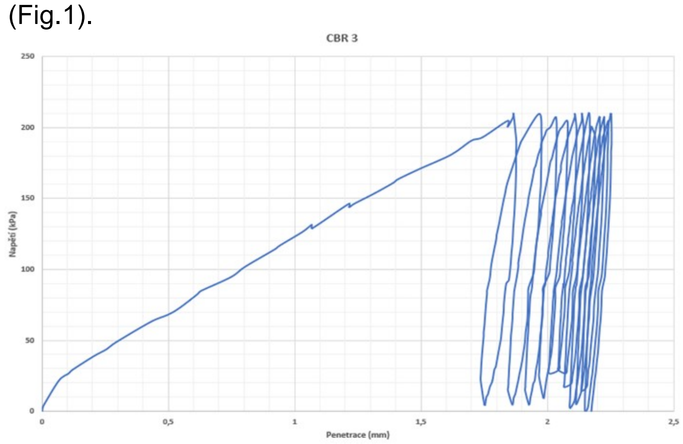

Fig. 6: Cyclic CBR test result under a set maximum stress level.

For each moisture content two measurements were carried out. On the most compacted surface, resp. least compacted, and the Modulus of Resilience Mr,max, resp. M_r,min was calculated.
The moisture values for the most compacted surface were found to be between 2.84 % and 17.03 %, for the least compacted surface between 2.11 % and 17.82 %.
Dry density values for the most compacted surface were found to range from 1408.71 kgm3 to 1837.50 kgm3, for the least compacted surface from 1413.41 kgm3 to 1823.63 kgm3.
The density values are averages over the whole sample and are therefore not representative of the actual density on each surface. They serve to control and verify the performance of the test and for the preparation of the results.
The Resilient Modulus values for the most compacted surface were found to range from 77.0 MPa to 1000 MPa, for the least compacted surface from 48.57 MPa to 848.14 MPa.
The trends of the M_r values related to dry density can be seen in Fig. 2. The values of the two Modulus, $M_{r,min}$ and $M_{r,max}$, increase from the lowest density and culminate near the maximum dry density obtained from the proctor test. Modulus $M_{r,max}$ archives higher values.

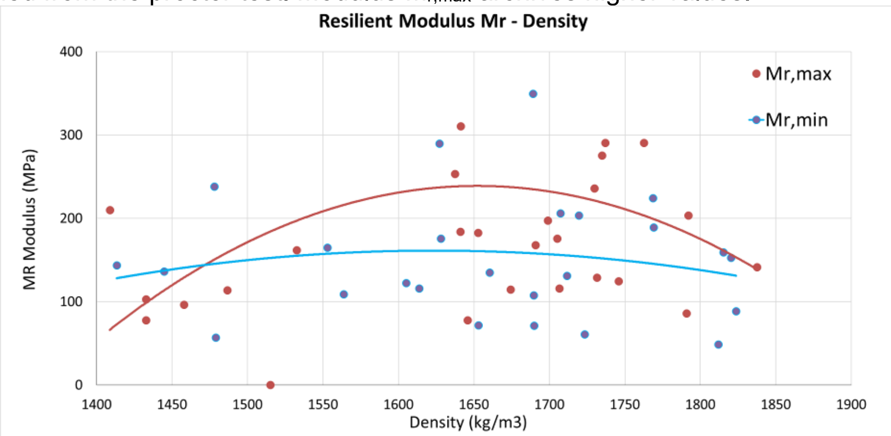

Fig. 7: Relation between the Resilient Modulus and the density of the material

Fig. 3 shows the trends of the Mr values in relation to humidity. The values of the two Modulus, $M_{r,min}$ and $M_{r,max}$, increase from the lowest humidity and culminate at humidity 13 %, slightly above the optimum humidity.

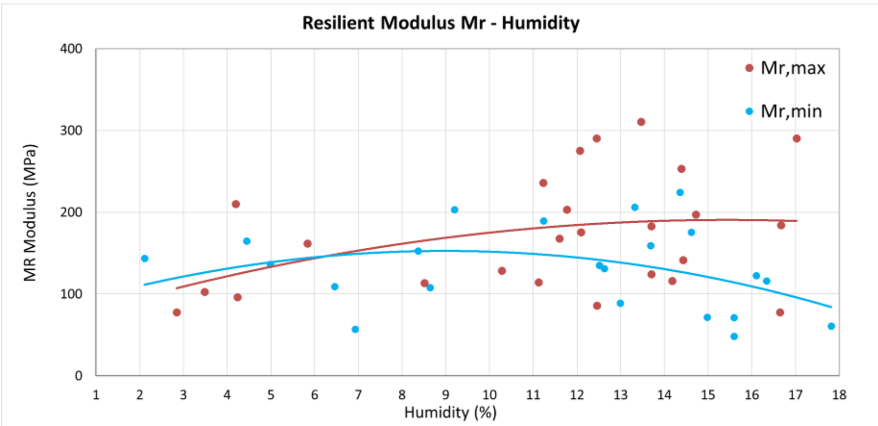

Fig. 8: Relation between the Resilient Modulus and the moisture of the material

Discussion

Analysis showed that the Resilient Modulus reaches higher values in the case of higher compaction, while at the same time shows a clear dependence of the modulus on moisture. They peaked at optimum moisture and after exceeding the maximum dry weight. Although this trend was expected to be fulfilled only in the case of modulus and moisture dependence when the soil is more compacted, the modulus growth stopped after exceeding the maximum dry weight and started to decrease. However, the modulus growth stopped after exceeding the maximum dry weight and started to decrease.

Conclussion

The problem of modulus definition and sample preparation is essential for pavement design. The results obtained from this analysis show the influence of natural conditions on the variety of parameters of construction materials. The modulus varies with humidity and density and the parameters influence the values with similar shape. In both cases the module values increase to the ones obtained from Proctor compaction and even when the density increases the values do not go up.

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Souhrn

V této studii byl analyzován vliv zhutnění, hustoty a vlhkosti na modul pružnosti zemin. Za tímto účelem byly použity cyklické zkoušky CBR a data byla shromážděna a zpracována pomocí specializovaného softwaru Mendelovy univerzity. Výsledky ukazují, že tyto parametry významně mění hodnotu modulu pružnosti. Vždy však dosahuje maxima při optimální hustotě a vlhkosti, které byly dříve získány z Proktorovy zkoušky zhutnění.

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