COMPARISON OF THE RESILIENCE MODULUS AT DIFFERENT MOISTURE CONTENTS USING THE CYCLIC CBR TEST TO PROMOTE NATURE TOURISM

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Abstract
The detailed and sensitive determination of input characteristics for low volume road design is important especially for the natural environment in conjunction with recreation activities. Existing methodologies for the pavement structure design consider the Resilience Modulus to be the fundamental property to characterize the materials of low volume roads. In order to obtain this modulus the cyclic CBR test has been used. Two different test variants have been carried out, the first one applying a constant 2.5mm penetration repeatedly until the elastic deformation reaches a constant value, and the second one applying a constant stress of 210 kPa. The material examined has been tested at fifteen different moisture contents and for each moisture content two different material compaction levels have been considered. Thus it has been possible to analyze the difference between the Resilience Modulus values obtained from the two different variants of cyclic CBR tests, for different moisture contents as well as for different material compaction levels.

Key words: Natural Environment for recreation, Low Volume Road, Californian Bearing Ratio, Resilient Modulus, Moisture, Density Dry of Soil, Subgrade

Introduction
Low-volume roads (LVR) are roads with lower traffic volume that mainly include forest and country roads. These roads are designed to carry low volumes of traffic and are defined as being in the range of less than 400 vehicles per day, and its design is based on knowledge of the Californian bearing ratio (CBR) value (ČSN EN ISO 13286-47, 2015). These types of roads are essential for the social and economic development of small, often mountainous, or semi-desert human communities where access to basic health and education services is very difficult.
Although LVR have different functions in different countries, they have specific characteristics in common and must meet general criteria for reliability, load capacity and durability. Moreover, their importance for forest management cannot be in contradiction with society's environmental and economic priorities.
LVR are also the main road networks in mountainous areas. Thanks to these roads it is possible to access to these mountainous areas or forests where visitors can go hiking and enjoy nature. It can be said that they are vital to promote nature tourism, as they conserve it to a large extent by using local materials to ensure that the original state of nature is not changed. It is also important that these natural materials are sourced close to where the road is to be built, as the use of other materials, even if they are natural, can have a negative impact on the ecosystem.
In addition, soil is a highly variable material, which makes it very difficult to study. A small change in the basic properties of the soil, such the compaction level or moisture, directly influences the behaviour of the soil. That is why all its properties have to be constantly controlled in order to make a good study and to obtain good results.
The design and evaluation of these pavements requires careful determination of such factors as: material properties, traffic type and volume, environmental conditions, etc. Material properties are one of the most important factors in the structural design of a pavement, as well as in its performance during its life. The current methodology for pavement design used by the AASHTO method (American Association of State Highway and Transportation Officials) (AASHTO, 2003), considers that the fundamental property for characterising the constituent materials of a road section is the parameter called resilient modulus.
This module must be obtained by triaxial tests done in cyclic load condition, however, number of test equipment such as CBR apparatus, is easier to obtain and cheaper to buy than sophisticated cyclic triaxial apparatus. One of solutions of this problem may be cyclic CBR test which is using CBR apparatus in extraordinary way. By CBR test method researchers are able to receive mechanistic factors such as Young modulus (E) or Resilient modulus (M_R).
These tests have been done with different moisture and therefore with different levels of compaction, this is due to the fact that in nature, depending on the season of the year, the conditions will change.

Each year in nature the process of volume increase is repeated, reaching the maximum volume in winter when the rainwater freezes. Thanks to the cyclic CBR tests, these conditions can be simulated and the volume can change as it does in nature.

Material

The first thing that was done before the CBR tests were started was to classify the material. This classification is based on the USCS (Unified Soil Classification System) (ČSN EN ISO 14688-2, 2005), is used in engineering and geology to describe the size and texture of soil particles. Once all the tests for classification have been carried out, it was determined that the soil to be used is a clayey material of medium plasticity (CI).

Methodology

Two modifications of the CBR test were used to analyze the deformation behaviour of the soil, which are being verified and developed in the MENDEL laboratory. One with a constant penetration of 2.5 mm and the other with a constant tension of 210 kPa. The first test ($M_{R,2}$) is based on Molenaar's theory (Molenaar, A.A.A., 2007), where a constant penetration of 2.5 mm will be applied repeatedly until the elastic recovery is zero. The second test ($M_{R,3}$) however, is an innovative test proposed by the Mendel laboratory in Brno, which is based on applying a constant stress of 210 kPa repeatedly (PUV 304642, 2014). This stress simulates the stress that the sub-base layer of a low volume road has to withstand.

These roads are normally composed of four or three layers the first layer is the superficial layer, the second is the base layer, the third is the sub-base and the last is the sub-grade, where the other two are laid. However, on rural roads, the first layer or base layer is usually the same surface due to the lack of any surface material. After an analysis, it has been calculated that the sub-base layer is subjected to a stress of 210 kPa when a vehicle passes through.

In order to quantify the influence of the change in moisture, an experiment was planned. To be able to analyse the influence of this parameter, it has been decided to carry out tests with different moisture contents, for this purpose, the same test was carried out with fifteen different moisture levels. Some of them below the optimum soil moisture and others above, from a humidity of 1.29 % to 19.56 %.

Furthermore, soil characteristics are also thought to vary according to its compaction. To verify this, CBR cyclic tests (Ševelová, Florian, Hrůza, 2020) have been carried out on the top and bottom of the mortar, that is, on the part where the soil is less compacted (CBR MIN) and on the part where it is more compacted (CBR MAX). This compaction is done in 3 layers. The 3 layers must have a similar amount of soil, and each layer must be compacted with 56 blows. Furthermore, these blows have to be made in the same order. The compaction energies are as follows:

- CBR MAX = 0,582886 MJ/m3
- CBR MIN = 0,194295 MJ/m3

Results

The laboratory analysis consisted of two different geotechnical tests- the classification of subgrade soil materials and determination of the resilience modulus using the cyclical CBR test.

To classify the subsoil according to Unified Soil Clasification System (USCS). Three different tests have been done: Humidity , Granulometry with aerometry and Atterberg limits (ČSN EN ISO 14689-1, 2004). The soil used was classified as F6-CI, with an optimum humidity of 15.3 % and a maximum dry density of 1785 kg/m^3 (ČSN EN ISO 13286-2, 2015)

As already mentioened, samples were prepared for the experiment from a humidity of 1.29 % to 19.56 %, with a dry density varying from 1550 kg/m^3 to almost 1800 kg/m^3.

A total of 60 cyclic CBR tests were carried out, 30 tests of 2.5 mm constant penetration ($M_{R,2}$) and 30 tests of 210 kPa constant stress ($M_{R,3}$). Of these tests, 15 were carried out on the upper part of the mortar, i.e., with the minimum compaction level (MIN), and another 15 on the lower part, with the maximum compaction level (MAX).

Once the tests had been carried out, the results obtained were analysed. Tab. **1** shows some of the parameters obtained in the $M_{R,2}$ tests with the two compaction levels. As can be seen, the stresses obtained are higher in the tests performed at the maximum compaction levels. Furthermore, the Resilience Modulus obtained have been analysed, in most cases the modulus obtained with the maximum compaction are higher than those obtained with the minimum compaction, reaching a difference of 60 %.

Tab. 1: MR,2 results

Test	Cycle range	Stress range (kPa)	$M_{R,2}$ range (MPa)
MR,2 MAX	10-22	41.23-2200.53	7.45-116.61
MR,2 MIN	10-37	26.68-1880.77	4.66-119.11

Tab. 2 presents some of the results obtained in $M_{R,3}$ tests. In this case the compaction also influences the modulus value in direct proportion. The highest results have been obtained when the compaction is maximum.

Tab. 2: MR,3 results

Test	Cycle range	Deformation range (mm)	$M_{R,3}$ range (MPa)
MR,3 MAX	4-71	0.074-17.59	11.1-300
MR,3 MIN	4-34	0.863-8.081	7.66-190

As for the deformations during the $M_{R,3}$ test, in most cases the largest deformation occurs on the less compacted surface, and the average difference with respect to the most compacted surface is 54 % (Fig. 1). This occurs until the optimum humidity is reached, after that, larger deformations occur on the more compacted surfaces.

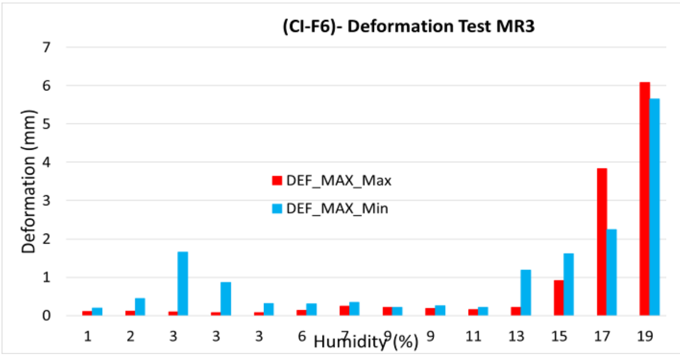

Fig. 1: Deformation $M_{R,3}$

Comparing the results of $M_{R,2}$ and $M_{R,3}$ tests it can be said that the $M_{R,3}$ test is more reliable with respect to the compaction conditions (Fig. **2**) and does not break the analysed material during the test. This test is able to better describe the elasticity of the material, and therefore the resilient modulus.

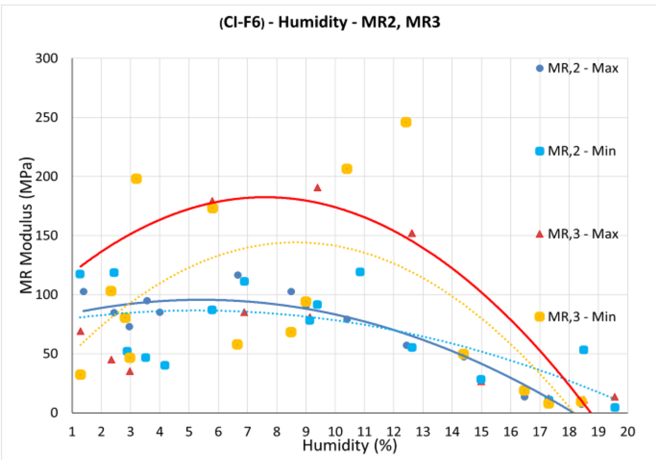

Fig. 2: Results of M_R

Discussion

Comparing the results of the $M_{R,2}$ and $M_{R,3}$ tests it can be said that the $M_{R,3}$ test is more reliable with respect to the compaction conditions and does not break the analysed material during the test. This test is able to describe better the elasticity of the material, and therefore the modulus of resilience. As for the deformations during the $M_{R,3}$ test, in most cases the biggest deformation occurs on the less compacted surface, and the average difference with respect to the more compacted surface is 54 %

(Fig. **1**). This occurs until the optimum moisture content is reached, after which larger deformations occur on the more compacted surfaces.

Conclusion

The level of compaction influences many soil parameters. A very important relationship was found between the more compacted layers, where the deformations were minimised and the modulus reached higher values in most cases.

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Souhn

Stávající metodiky pro návrh konstrukce vozovek považují modul pružnosti za základní vlastnost pro charakterizaci materiálů nízkoobjemových vozovek. K získání tohoto modulu byl použit cyklický CBR test, ale předtím byl použitý materiál klasifikován na základě USCS (Unified Soil Classification System) jako (CI).

Byly provedeny dvě různé varianty cyklických zkoušek CBR, první s opakovaným konstantním 2,5 mm průnikem, dokud pružná deformace nedosáhne konstantní hodnoty (MR,2), a druhá s konstantním napětím 210 kPa (MR,3). Bylo provedeno celkem 60 testů, zkoušený materiál byl testován na patnáct různých obsahů vlhkosti a pro každý obsah vlhkosti byly uvažovány dvě různé úrovně zhutnění.

Po ukončení zkoušek byl analyzován vliv zhutnění a vlhkosti. Při zkouškách MR,2 jsou napětí získána vyšší při zkouškách prováděných při maximálních úrovních zhutnění. Dále byly analyzovány získané moduly pružnosti, ve většině případů jsou moduly získané s maximálním zhutněním vyšší než moduly získané s minimálním zhutněním a dosahují rozdílu 60 %. To se také děje v testech MR,3.

Pokud jde o deformace při zkoušce MR,3, ve většině případů dochází k největší deformaci na méně zhutněném povrchu a průměrný rozdíl vzhledem k nejvíce zhutněnému povrchu je 54 %.

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