THE INFLUENCE OF MOISTURE ON THE SOILS DEFORMATION PROPERTIES IMPROVED OR NATURAL FOR LOW VOLUME ROADS UNDER CONDITIONS OF CLIMATIC CHANGES

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The design and service life of structures depend on various factors, including material properties, calculation model accuracy, and the methodology used. In Low Volume Road pavement design, it is essential to consider subsoil behavior and factors influencing its mechanical properties, particularly moisture, which significantly affects soil deformation when improved or no improved materials. This issue becomes more relevant under climate change conditions. The resilient modulus, derived from the cyclic California Bearing Ratio test, is a key parameter for assessing soil resistance to repeated loads. Furthermore, road design should consider the recreational potential of the area and ensure proper maintenance for sustainable use. Intensive use can accelerate road degradation, leading to environmental damage and reduced recreational enjoyment. Therefore, solutions based on best practices and experiences from the Czech Republic and other countries are being explored. Finally, poorly maintained, damaged, or excessively deformed road surfaces not only reduce functionality but also increase fuel consumption and the costs associated with non-renewable resources. Ensuring proper design and maintenance can help mitigate these negative impacts while promoting sustainable infrastructure. The paper will present the results of tests investigating the effect of moisture on both the Resilent Modulus and permanent and elastic deformation of the subgrade.

Key words: resilient modulus, cyclic test, soil geotechnic analysis, environment for recreation

Introduction

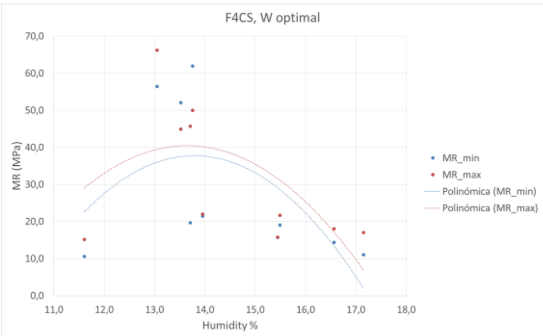
Dedicated roads, forest roads, and dirt roads that provide access to managed natural areas are classified as Low Volume Roads (LVRs) according to the AASHTO 2008 Comprehensive Highway Design Methodology. These roads often traverse areas with high recreational potential and must meet several criteria, ranging from full functionality for guest services to reliability, functionality, and aesthetics for leisure and recreational use. At the same time, given current climate changes and the need to retain water on the roadway, it is essential to incorporate these factors into the road design, as they directly affect its reliability and durability. The design and durability of structures depend on several factors, including the properties of construction materials, the accuracy of the calculation model, the methodology for determining material properties, and the technological application. During these processes, uncertainties and even human errors can arise (Ortiz, Ševelová, 2015), both in material selection and testing. When designing pavements for rural roads, it is crucial to consider subgrade behavior and the factors that influence its mechanical properties. In particular, moisture significantly affects the deformation of unimproved soils or those enhanced with secondary raw materials, especially under climate change conditions (Arias, Ševelová, 2020). The goal is to minimize the use of nonrenewable resources, whose natural characteristics, along with water demand and retention in the landscape, complicate the determination of their deformation and strength properties. To address this, an analysis was conducted on the deformation behavior of two fine-grained alluvial soils typical of South Moravia in the Czech Republic.

Material and methods

The fine-grained alluvial soil of South Moravia is characterized by its low bearing capacity and high sensitivity to moisture, making it prone to deformation. On low volume roads (LVR), its resilience, deformation, and elasticity modulus are analyzed, and improvements with secondary materials are considered to increase its strength. To evaluate the properties of the material used, various soil classification and characterization tests were performed in accordance with European and Czech standards. Moisture content was determined using the water content test according to ČSN EN ISO 17892-1. The particle size distribution was obtained using sieve and aerometric analyses, following ČSN EN ISO 17892-4. Additionally, the Atterberg limits (liquid limit, plastic limit, and plasticity index) were determined in accordance with ČSN EN ISO 17892-12, allowing soil plasticity to be assessed. These tests enabled classification of the soil both by granulometric composition and plasticity characteristics. The overall subgrade classification was carried out based on the Unified Soil

Classification System (USCS), using ČSN EN ISO 14688-2 for soil and ČSN EN ISO 14689-1 for rock components, where applicable. To assess the soil's bearing capacity California Bearing Ratio (CBR) test was performed in accordance with ČSN EN ISO 13286-47.
To assess the soil's fatigue and elastic bearing capacity repeated California Bearing Ratio (cyclic CBR) test were performed for response to transport loads in modify CBR machine in Mendel University in Brno acording PV 304642. In this test, a cyclic load with a maximum stress of 210 kPa was applied to simulate real-life traffic conditions. The results were then used to analyze the mechanical and deformation behavior of the soil and to calibrate numerical models used for pavement design (Ševelová, Kozumplíková, 2010). The procedures and interpretations followed national and international recommendations, particularly those established in TP 170 – Design of Pavement Structures and the Methodical Guide to the Design and Implementation of Pavement of Low Volume Roads (23327/2015-MZE-16222/M108), ensuring that the evaluation meets Czech transportation infrastructure criteria.
Cyclic CBR is a variant of the California Bearing Ratio (CBR) test that evaluates the strength and deformability of soils and granular materials under repetitive loading. Unlike conventional CBR, which applies a static load, this method subjects the material to loading and unloading cycles with a specified maximum stress, in this case, 210 kPa (PV 304642), reproducing the real-life conditions of vehicular traffic on pavements and stabilized soil structures. This test analyzes key parameters such as resistance to permanent deformation, elastic recovery after each cycle, accumulated deformation, and the modulus of resilience, which measures the material's ability to recover its shape.

Results
The classification results indicate that the materials that have been used are medium plasticity clay - F6CI (materiál M3) and sandy clay F4CS (material M6).
Cyclic tests for determination of Resilient Modulus MR (MPa) and deformations - elastic, palstic and total, were prepared for optimum moisture W_opt (%) and maximum bulk density parameters determined from Proctor standard test. Samples for cyclic CBR test are prepared by densifying Proctor standard energii. In the graphs, can be seen two different results, one called min, and the other max. This means that the min part is the least compacted, specifically 56 strokes. On the other hand, the max part is the most compacted, 56 times three.
In the Fig. 1a, resp. 1b, it is possible to observe the dependence of Resilient Modulus (MR_max, MR_min) values on moisture (Fig. 1a), resp. compaction (Fig. 1b), of sandy clay F4CS.



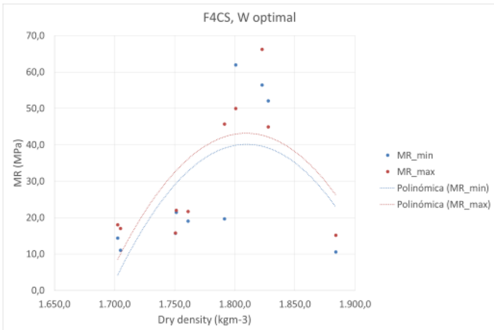
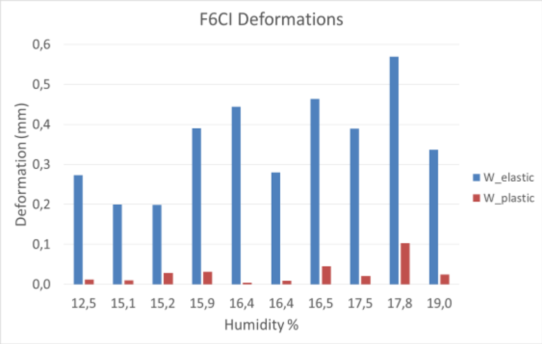


Fig. 1a: The dependence of Resilient Modulus on moisture
Fig. 1b:The dependence of Resilient Modulus on compaction

As humidity increases, the Resilient Modulus decreases, especially after 14% idicating that the material loses elastic recovery capacity under more humid conditions (Fig. 1a). The maximum Resilient Modulus (MR_max, MR_min) exhibits a parabolic relationship with moisture, reaching its highest value near 14 %, indicating optimal moisture content for maximum soil strength.
The Resilient Modulus reaches its maximum value near a dry density of 1810 kg/m³, suggesting that there is an optimal density where the soil exhibits its best mechanical behavior (Fig. 1b). In both cases, there is a noticeable significant effect of the compaction level on the MR magnitude.
For the two analyzed soils, Fig. 2a F6CI and Fig. 2b F4CS, the deformations from the last loading cycle show a similar character. The plastic deformations are negligible and the elastic for MR calculation ones increase with increasing moisture content. This suggests that moisture increases the deformability of the soil, which compromises its resistance under cyclic loading.



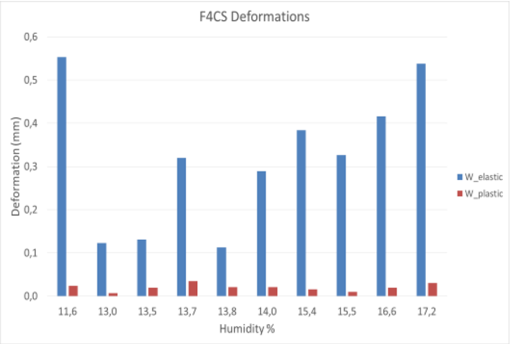


Fig. 2a: The dependence of deformation on moisture on F6CI
Fig. 2b: The dependence of deformation on moisture on F4CS

At the same time higher compaction of soil sample reduces these deformations and the material has higher resistance capacity Fig. 3.

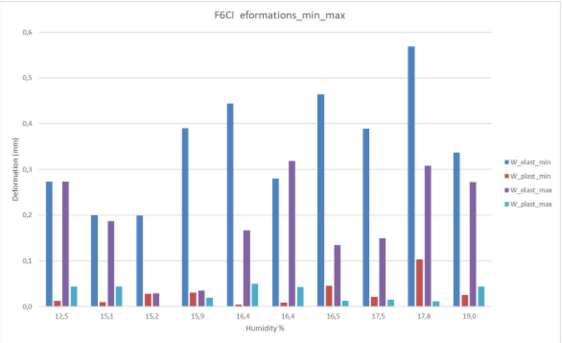


Fig. 3: The dependence of deformation on moisture for min and max compactation

Discussion

Comparison of test results for the determination of Resilien Modulus MR and deformation min and max, which take into account the level of compaction, it was verified that good subgrade compaction leads to greater durability and stiffness. Although the elasticity increases with moisture, by comparing min and max, the elastic deformation can be reduced by good compaction.

Conclusion

The findings confirm the importance of controlling the amount of subgrade moisture for proper design of pavement structures not only for forest roads. Their use is essential in the evaluation of road foundations and subgrades, analysis of stabilized soils and verification of recycled materials in road infrastructure. It can be said that the cyclic CBR test offers a more realistic view of the behaviour of materials under repeated loading, allowing designs to be optimised, drainage and compaction construction technology to be closely monitored and thus improving the durability of roads with the emerging trend of global change and the tendency of the need for rational water retention in the landscape.

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Souhrn

Kvalita a životnost konstrukcí závisí na různých faktorech, včetně vlastností materiálu, přesnosti výpočtového modelu a použité metodiky a technologií. Při návrhu vozovek účelových komunikací, kam patří lesní a polní cesty, je nezbytné zohlednit chování podloží a faktory ovlivňující jeho mechanické vlastnosti, zejména vlhkost, která významně ovlivňuje deformaci zeminy. Tato problematika nabývá na významu v podmínkách klimatických změn s měnícími se hodnotami vlhkosti. Modul pružnosti, odvozený z cyklické zkoušky kalifornského poměru únosnosti, je klíčovým parametrem pro posouzení odolnosti zeminy vůči opakovanému zatížení se zahrnutím vlivu měnící se vlhkosti a míry zhutnění. Kromě toho by se při navrhování silnic měl zohlednit rekreační potenciál oblasti a zajistit řádná údržba pro udržitelné využívání. Intenzivní a nevhodné používání může urychlit degradaci silnice, což vede k poškození životního prostředí a snížení rekreačního využití. Proto se hledají řešení založená na osvědčených postupech a zkušenostech nejen z České republiky, ale i dalších zemí, a současně se ověřují inovativní postupy stanovení reálných parametru a charakteristik podložních zemin. Lze říci, že patentovaný postup a software cyklického CBR, vyvinutého na MENDELU, nabízí realističtější pohled na chování materiálů při opakovaném zatížení, což umožňuje optimalizovat návrhy a zlepšit trvanlivost vozovek při nastupujícím trendu globálních změn a potřebám zadržování vody v krajině. Z porovnání výsledků zkoušek pro stanovení modulu pružnosti MR a deformací min a max, které zohledňují úroveň zhutnění, bylo ověřeno, že dobré zhutnění podloží vede k větší trvanlivosti a tuhosti. Ačkoli se pružnost zvyšuje s vlhkostí, porovnáním min a max lze pružnou deformaci dobrým zhutněním snížit. V neposlední řadě špatně udržované, poškozené nebo nadměrně deformované povrchy silnic nejen snižují funkčnost, ale také zvyšují spotřebu pohonných hmot a náklady spojené s neobnovitelnými zdroji. Zajištění správného návrhu a údržby může pomoci zmírnit tyto negativní dopady a zároveň podpořit udržitelnou infrastrukturu.

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