Characterization of Road Pavements' Granular Layers by the use of Cyclic Tri-axial Tests

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Summary

The crushed materials of extended grading are highly applicable in the unbounded granular layers of road pavements, namely in granular subbase and base. The behaviour of those materials in layers of pavements, in spite of some studies already developed on that matter, is not yet characterized enough, especially for reasons of heterogeneity of the rock masses from which they come. In the attempt to contribute to a better knowledge of that behaviour a work is being developed, which main objective is the mechanical characterization and the elaboration of typical models of behaviour for crushed materials of several lithologies, susceptible of being used on that kind of layers. This communication describes the results obtained until now, for one of those materials, the limestone. Essentially, the paper gives the geotechnical characterization of the material and makes it possible to evaluate which is the range of variation of the resilient modulus obtained in cyclic tri-axial tests.

Introduction

In this paper we analyse the behaviour of a crushed limestone of extended grading, used as unbound granular subbase of road pavements in Portugal.

We make the geotechnical characterization through tests such as the blue methylene or the micro-Deval as well as the characterization of the mechanical behaviour, using cyclic tri-axial tests, performed according to the standard AASHTO TP 46 [1]. The aim is, in the ambit of a PhD thesis, to contribute to the modelling of the behaviour of that type of material.

Tested Materials

In this work we used five samples of crushed limestone, with characteristics of subbase according to Portuguese technical specifications. Four of them were collected in a construction undertaking in the beginning of the works, in the motorway A23, fragment of Castelo Branco Sul - Fratel, center of Portugal and the fifth one was collected directly at the stone-quarry that supplied the construction.

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Geothecnical Characterization

On the collected samples a set of laboratory tests was performed in view to the evaluation of their geothecnical characteristics. For that [2] were performed the following tests: Los Angeles [3], micro-Deval [4], sand equivalent [5], methylene blue [6] and california bearing ratio (CBR) [7].

Due to the grading characteristics of the material, the compaction was done by vibration, according to the BS 1377: part 4 standard [8], compacting specimens with the thickness varying between 127 mm and 133 mm in 3 layers for 60 seconds each.

The average values of the results of the tests are presented in tables 1 and 2.

Table 1- Results of the grading analysis [9]

Sieve		Passed
nº	Opening	(%)
2”	50.80	100
1” 1/2	38.10	99.8
1”	25.40	96.6
3/4”	19.10	90.4
1/2”	12.70	78.8
3/8”	9.520	69.9
4	4.760	49.8
10	2.000	28.5
20	0.840	16.1
40	0.420	10.5
80	0.177	6.9
200	0.074	5.0

Mechanical Behaviour Characterization

To characterize the mechanical behaviour of the specimens, cyclic tri-axial tests were executed according to the AASHTO TP 46 - 94 standard [1].

In this standard, the material in study, having the maximum dimension of 37.5 mm, is classified as type I. So, the tests are done on specimens of 150 mm of diameter and height of 300 mm. The specimens are compacted by vibration as said, in 6 layers with the approximate thickness of 50 mm, in a split mould, and the compaction has the duration needed to obtain that thickness to be able to attain the intended dry density. The equipment used in the compaction should have the following characteristics: Frequency of percussion: 1800-3000 impacts by minute; Absorbed power: 750-1200 W; Diameter of compactor head: not inferior to 146 mm.

Table 2- Results of the characterization tests

Parameter	Unit	Average value
Optimum moisture content	%	3.6
Maximum dry density	g/cm^3	2.29
CBR	%	99
Swell	%	0
Los Angeles	%	33
Micro-Deval		14
Equivalent of sand	%	70
Blue methylene (0/0,075 mm)	g/100g	0.88
Blue methylene (0/38,1 mm)	g/100g	0.05

The conditions of moisture content and dry density to be used in each specimen can be the values obtained in the compaction in the lab, 95% of the maximum dry density and optimum moisture content, or the values obtained in the “in situ” control. These values should be used every time if they are known.

The test consists on the application of 16 sequences of charge on the specimen, in which both the confining pressure and the deviator stress vary. The number of applied cycles is 1000 for the first sequence, which corresponds to the conditioning of the specimen, and of 100 in the 15 others.

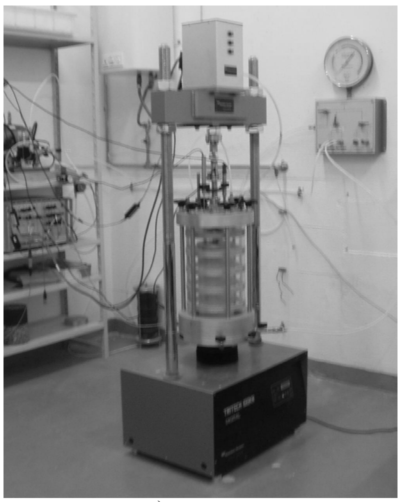
Each cycle has a frequency of 10 Hz, the phase of load corresponds to 0.1 seg and the phase of rest to 0.9 seg.

From the test is obtained the resilient modulus, Equation 1, corresponding to each one of the 16 sequences, being that value the average of the resilient modulus found for the 5 last cycles.

$$M_r = \frac{S_{cyclic}}{\varepsilon_r} \quad \text{MPa} \qquad (1)$$

where S_{cyclic} = resilient stress and ε_r = resilient axial strain.

The tri-axial equipment, that exists in the Lab of Road Pavement Mechanics of the Department of Civil Engineering of the University of Coimbra, is a Wykheam Farrance tri-axial load frame of 100 kN of capacity, with a tri-axial cell for 160 mm x 300 mm specimens, 8 channels for control and data acquisition, a 25 kN load cell and compressor (Figure 1).


a)

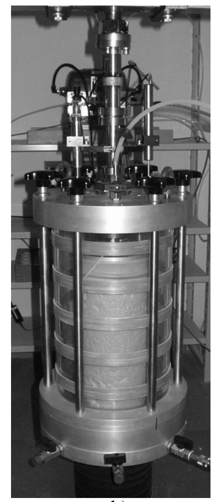

b)

Figure 1- a) Tri-axial equipment of Lab of Road Pavement Mechanics of the Department of Civil Engineering of the University of Coimbra; b) Location of the LVDT's

The results of the tests performed until now, with density and moisture content obtained in the lab conditions, that is, 95% of the maximum dry density (2.18 g/cm^3) and optimum moisture content (3.6 %), are presented in Table 3 as well as the load conditions referred in AASHTO TP 46 - 94 standard [1].

In what concerns the permanent deformation, in all the tests executed, we obtained values going from 0.1% to 0.2%, much under the 5% referred to in AASHTO TP 46 standard [1]. That is why we performed the shear test until the limits of capacity of the equipment, having obtained maximum values of permanent deformation of 4.9%.

Conclusions

Analysing the results of the tests performed until now on the limestone material, we may conclude that it is not plastic and, according to the Technical Guide for the Construction of Embankments and Subgrade Pavement [10] we may even consider that the fines are not sensible to the water, given the values of adsorption of the blue methylen obtained. We conclude, on the other hand, that it is a material with good capacity of resistance, average CBR values of 100%, as well as a good resistance to deterioration by abrasion and impact, taking into account the results of the Los Angeles and of micro-Deval tests.

Table 3- Average values for the Resilient Modulus

Sequence	Base/Subbase Materials				nº cycles	Resiliente Modulus (MPa)
	σ_3 (kPa)	σ_{max} (kPa)	σ_{cyclic} (kPa)	$\sigma_{contact}$ (kPa)		
0	103.4	103.4	93.1	10.3	1000	394
1	20.7	20.7	18.6	2.1	100	163
2	20.7	41.4	37.3	4.1	100	201
3	20.7	62.1	55.9	6.2	100	214
4	34.5	34.5	31.0	3.5	100	207
5	34.5	68.9	62.0	6.9	100	240
6	34.5	103.4	93.1	10.3	100	259
7	68.9	68.9	62.0	6.9	100	293
8	68.9	137.9	124.1	13.8	100	331
9	68.9	206.8	186.1	20.7	100	352
10	103.4	68.9	62.0	6.9	100	318
11	103.4	103.4	93.1	10.3	100	341
12	103.4	206.8	186.1	20.7	100	392
13	137.9	103.4	93.1	10.3	100	376
14	137.9	137.9	124.1	13.8	100	394
15	137.9	275.8	248.2	27.6	100	453

σ_3 - Confining pressure; σ_{max} - Maximum axial stress; σ_{cyclic} - Cyclic axial stress (resilient stress); $\sigma_{contact}$ - Contact stress

In what concerns the mechanical behaviour we verify, for values of optimum moisture content and 95% of maximum dry density, values of the resilient modulus variable between, approximately, 160 MPa and 450 MPa, function of the load conditions.

We verify, on the other hand, that in what concerns the permanent deformation, it is not significant for the test conditions, in general.

We are going to proceed the characterization of another type of material, a granite, which being of a different geological nature, will present, certainly, some differences in its characteristics, namely, in what concerns the weathering and the resistance.

Having in hands the mechanical characterization of both materials, namely the resilient modulus and the evolution of the permanent deformation, we will try to proceed to the modelling of their mechanical behaviour in granular layers of road pavements, using the interpretation of the variation of its state of stress obtained in the cyclic tri-axial tests. For that we are thinking to resort to current models of interpretation [11], [12] to be able to try to explain de values defining the behaviour in non destructive tests performed using the falling weight deflectometer (FWD).

Reference

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