APPLICABILITY OF MARBLE QUARRY WASTE IN PAVEMENT LAYERS

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ABSTRACT: The applicability of Marble quarry waste, an industrial by-products resulting from ornamental stone extracting, was studied through a series of procedures. The physical characterisation tests preceded the application of the waste material in the granular layers of experimental pavements. Its performance was assessed with the falling weight deflectometer (FWD), and the results show that, according to the Portuguese Road Administration requirements, the by-product tested can be used as granular material in both the road base and sub-base of a road pavement.

1 INTRODUCTION

The study and application of by-products is a subject with relevance nowadays because its applicability reduces the storage quantities, therefore decreasing the economic costs involved with storage while preventing possible environmental negatives impacts. Also, the use of industrial by-products allows to preserve natural materials, such as the aggregates usually used in construction, which are more important in those countries having scarce resources of these materials.

In the Alentejo region of Portugal there is a very large number of quarries that extract marble has an ornamental stone. Those quarries produce a considerable volume of marble that cannot be used for environmental purposes. At present this marble waste is stored is large piles surrounding the quarries, resulting in a very negative visual impact. Since in that same region there is scarcity of the aggregates with the characteristics usually required for use in road pavements, it was decided to study the viability of using the quarry waste as total or partial substitute for those aggregates.

2 CHARACTERISATION OF THE BY-PRODUCT

2.1 *Chemical characterisation*

Chemical characterisation of industrial by-products t is important in order to determine the concentration of major, minor and some trace elements that may have relevance to the intended application. Leaching tests are also interesting to find the chemical composition expected for the leachates. However, in the present study, the chemical analysis and leaching tests were not done because it is thought that the results would reflect the usual composition of a marble rock, since the waste did not experience chemical, thermal or any other kind of industrial transformation.

2.2 *Physical characterisation*

Besides determining the physical characteristics of the quarry waste, it was also considered interesting to study the behaviour of mixtures of the waste with natural aggregates, which should allow to evaluate the possibility of using the quarry waste as a partial replacement of the aggregates. Therefore, besides the marble quarry waste, it was also characterised a mixture of 80 % of marble quarry waste with 20 % of dolomite limestone (mixture 80/20). This material was also used in experimental pavement layers. The decision of mixing marble quarry waste (MQW) and dolomite limestone (DL) was taken with the objective to improve the marble quarry characteristics. The proportion of 80 % in weight of marble quarry waste was adopted based in AASHTO standards for grading of road base materials.

The physical characterisation of each material followed the requirements of the Portuguese Road Administration according to its possible use in the different layers of a road pavement.

Several laboratory tests were conducted, such as: i) gradation; ii) relative density and absorption; iii) sand equivalent; iv) titration with the methylene blue; v) Los Angeles abrasion; vi) consistency limits. The results obtained are presented in Table 1.

Table 1 Physical characteristics of MQW

Properties	MQW	MIXTURE 80/20
Relative density (kN/m^3)	26.6	26.5
Absorption (%)	0.8	1.1
Los Angeles abrasion (%)	35 – 45	38 - 39
Liquid limit[1]	ID	ID
Plasticity index[1]	NP	NP
Maximum dry density (kN/m3)	22.9	2.32 - 2.38
Optimum moisture content (%)	5.5	4.1 – 5.6
Sand equivalent (%)	59	50 - 52
Titration with the methylene blue (mg/l for 100 g fine material)	0.3	---

[1] ID – indeterminable; NP – Not plastic

After the physical characterisation a comparison was made between the materials characteristics and the requirements of Portuguese Road Administration for materials to be used in the different layers of a road pavement. The results are shown in Table 2.

Table 2 Possible applicability of all materials in road pavements

Application	MQW
Bituminous wearing course	+
Bituminous layers, except wearing courses	+
Unbound road base	++
Unbound sub-base	+++

+++ Complies with almost all requirements
++ Could comply with all requirements if some minor treatments are done
+ Does not comply with requirements, even if treatments are done

Although the comparison between the results of the laboratory tests and the requirements are generally favourable, it is important to keep in mind that the construction requirements are for traditional materials. Therefore, it was considered that only the monitoring of experimental pavements should allow to conclude if the marble quarry waste are or not suitable to be placed in road layers.

3 EXPERIMENTAL PAVEMENTS

The aim of building experimental pavements was to assess the performance of marble quarry wastes and mixtures of this b-product with traditional aggregates when applied in the different layers of a pavement. The marble quarry waste was used in the granular layers of two experimental pavements at motorway A6 section Estremoz-Borba in the South of Portugal.

The possibility of using this by-product is very interesting, since traditional aggregates are scarce in the motorway A6 area. The materials used were a mixture of 80 % marble quarry waste and 20 % of dolomite limestone (mixture 80/20) with nominal size 0/37.5 and dolomite limestone (DL) with the same nominal size. The subgrade soil was classified as A-1-a or A-1-b in AASHTO System. The structure of the experimental pavement is shown in Figure 1.

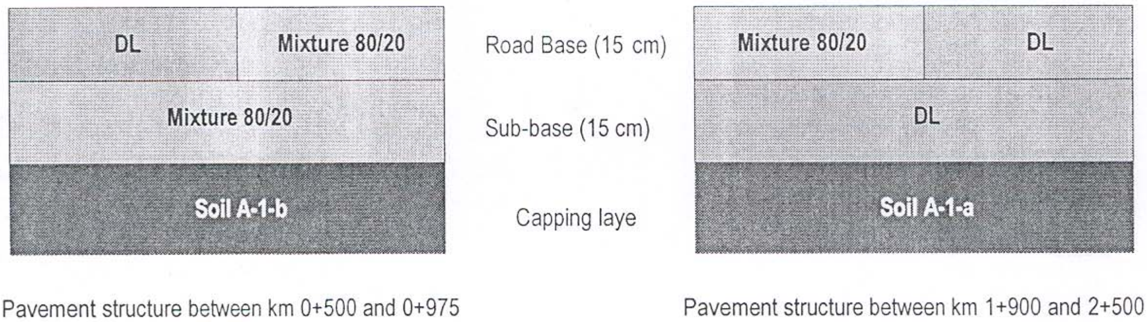

Figure 1 Structure of experimental pavement with marble quarry waste [LNEC, 1999]

In order to evaluate the pavement performance, several falling weight deflectometer (FWD) tests were performed at the top of each layer. The tests were done along three alignments located near each shoulder and in the road axis. The distance between tests was 25 meters. The diameter of the loading plate was 0.45 m and the deflections were measured at surface, with seven geofones located at 0, 30, 45, 60, 90, 150 and 250 cm from the centre of the plate.

The test results were interpreted with ELSYM5 for a 20 kN impact force. The modulus computed for the two experimental pavements are shown in Figure 2.

For the pavement between km 0+500 and km 0+975 the capping layer modulus ranged between 150 and 350 MPa. However, it is possible to distinguish a zone where the modulus is higher (250 to 350 MPa); for the sub-base constructed with mixture 80/20 the modulus obtained ranged from 350 to 650 MPa; for road base the modulus variation was from 350 to 650 MPa, but the section constructed with dolomite limestone had lower modulus (350 to 450 MPa) than the section constructed with mixture 80/20 (450 to 650 MPa).

As for the pavement between km 1+900 to km 2+500, the capping layer has modulus between 50 and 350 MPa; the sub-base generally presented modulus from 250 to 550 MPa; and for the road base it is possible to observe modulus varying between 350 e 500 MPa for the layer constructed with mixture 80/20 and from 250 to 500 MPa for the part constructed with dolomite limestone.

Table 3 shows the arithmetic mean and the most frequent values (1st and 3rd quartiles) for each layer, and each material. The statistical analysis was done with 21 data points. Clearly, the analysis show that the mixture 80/20 of the marble quarry waste with the natural aggregates have modulus generally within the same range as the modulus of the natural aggregates, when applied in the road base or in the sub-base. This is a clear indication that the use of the marble quarry waste mixed with natural aggregates may be a viable alternative to the use of natural aggregates alone.

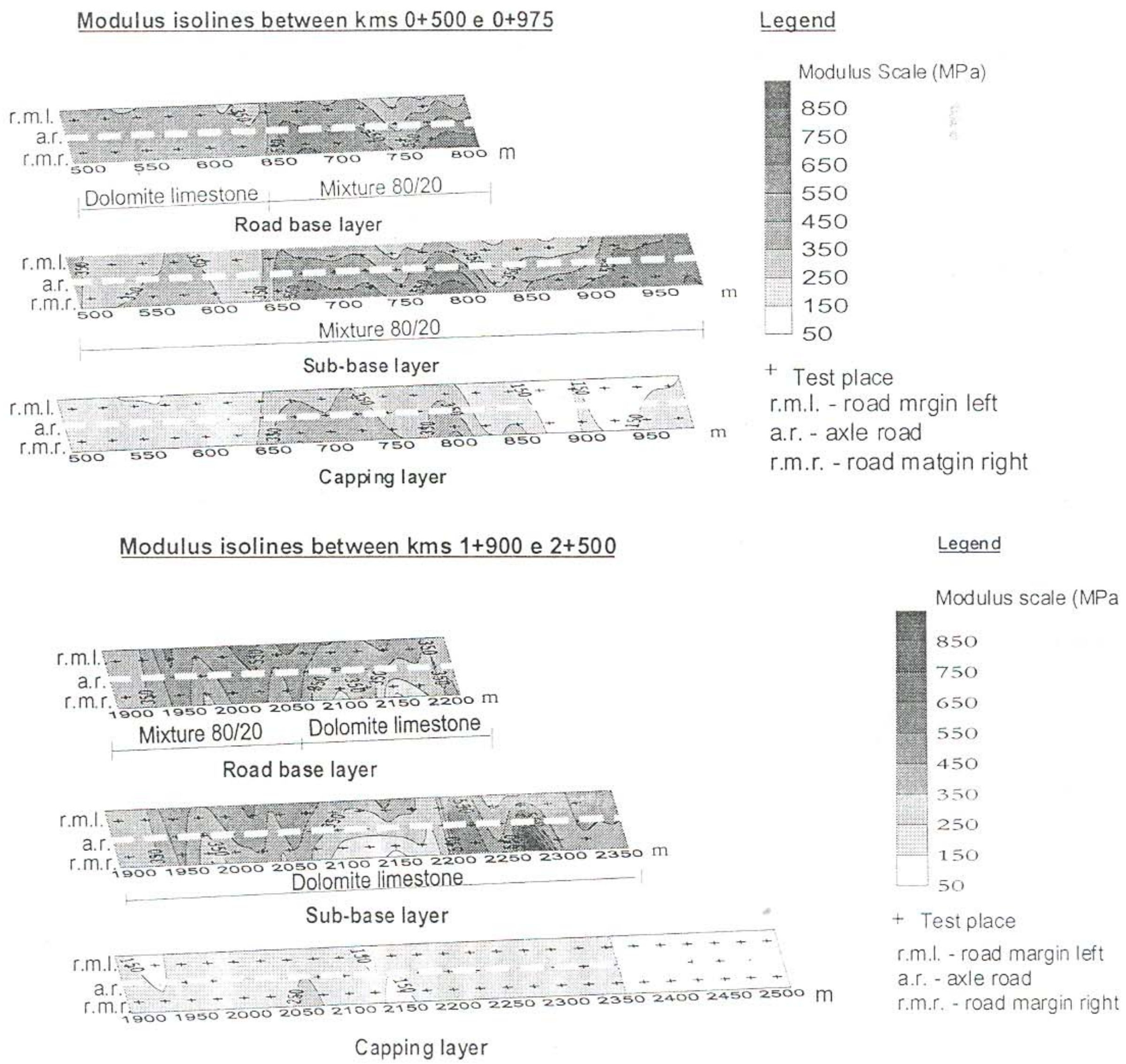

Figure 2 Modulus variation along the two experimental pavements [LNEC, 1999]

Table 3 Mean and most frequent modulus values obtained by FWD for the experimental pavements constructed with marble quarry waste [LNEC, 1999]

Km	Road base layer				Sub-base layer				Capping layer	
	Dolomite limestone		Mixture 80/20		Dolomite limestone		Mixture 80/20			
	Most frequent values	Mean	Most frequent values	Mean	Most frequent values	Mean	Most frequent values	Mean	Most frequent values	Mean
0+500 – 0+650	350-420	380					300-370	340	160-200	190
0+650 – 0+800			480-650	560			440-620	530	310-400	360
0+825 – 0+975							290-550	440	140-175	160
1+900 – 2+050			330-500	420	300-450	380			150-240	200
2+050 – 2+200	245-520	370			210-485	330			160-225	200
2+200 - 2+350					370-520	460			195-220	210
2+350 - 2+500									130-150	140

4 CONCLUSIONS

In this paper it was presented a study concerning the applicability of an industrial by-product, marble quarry waste, in road pavements layers. The material and especially mixture of the waste with traditional aggregates show potentialities for being used as aggregates in the granular layers of a road pavement. The marble quarry waste resulting from marble rock without ornamental characteristics shows good characteristics to be used as aggregates in sub-base and road base layers, particularly if mixed with a traditional aggregate in an 80/20 proportion in weight. Traditional aggregates for use in pavement layers are scarce in Alentejo (Central – SW Portugal), but the number of quarries extracting marble and limestone for ornamental purposes is considerable in that region. Therefore the use of marble quarry waste may be of local importance, both in replacing the traditional aggregates and decreasing the environmental impact linked with the multiples places where the waste is piled.

REFERENCES

LNEC, 1999, Estudo da aplicação de materiais de escombreira de mármore em camada granulares do pavimento da auto-estrada A6 sub-lanço Estremoz-Borba, Repport 118/99 – NPR, Laboratório Nacional de Engenharia Civil, Portugal.

Lima H et al, 2000, Applicability of industrial by-products in pavement layers – some research studies in LNEC, Proceedings of UNBAR 5, Nottingham, United Kingdom, 21-23 June.