SAMPLE PREPARATION FOR LABORATORY TESTING THE INFLUENCE OF VOID RATIO ON GRANULAR LAYERS OF ROAD PAVEMENTS

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ABSTRACT

To evaluate whether the framework of European standards, regarding the grading requirements, is adjusted to be used in the compaction control of unbound limestone materials for base and sub-base layers of road pavements a laboratory test program was envisaged. According to the Portuguese practice, two distinct approaches are used. An approach takes into account the nature of the compacted materials and its potential density. The other one requires that a target value for the density of the compacted material is reached, but it does not take into account if the grading of the material allows reaching that target density. Practice has shown that materials meeting the grading requirements of the specifications do not reach the target void index. To evaluate the void ratio variations five grading representative of an all-in aggregate, of category G_A and size 0/20 mm, included in the range defined by the standard EN 13285 were prepared. The steps and constrains required to obtain the five different gradings is presented. The all-in aggregate was collected at a quarry and processed in order to separate the different particle size. The procedure used to rebuild the five grading using the individual particle sizes previously separated is explained and illustrated.

Keywords: Aggregate, Void ratio, Compaction, Road pavements

INTRODUCTION

Granular materials have a wide applicability on road pavements. Often used in unbound granular layers, sub-base and base, have as main function the structural support of the overlying layers and traffic loads.

According to the most representative Portuguese road specifications, namely EP - Estradas de Portugal, SA [1] and BRISA - Auto-Estradas de Portugal, SA [2], can be used in the implementation of sub-base layers, selected soils, crushed aggregates all-in aggregates and recycled aggregates. In the base layer, representing the most important structural layer of the pavements crushed all-in aggregates or recycled aggregates must be used. Crushed all-in aggregates (AIA) are among the materials more often chosen by designers for the implementation of granular layers as they are the materials presenting the best structural behavior and for which it is easier to guarantee the supply capacity and regularity of features. By definition, an AIA is a natural aggregate produced by crushing, comprising a mixture of coarse and fine aggregates, which can be produced both without separation of the coarse and fine fractions or by mixing fine and coarse aggregates.

The quality requirements set by the Portuguese specifications for the granular layers of unbound road pavements are focused on two sets of characteristics: 1) the characteristics of the material to be used and; 2) the material characteristics after application. In the first set are the geometrical, physical and mechanical characteristics of the aggregate. The geometrical characteristics are the ones that most affect the behavior of granular layers, particularly those related to particle size.

The harmonization of the Portuguese road specifications with the European standards under the Construction Products Directive was partially done in 2009 by Estradas de Portugal, and was later revised in 2011. For granular materials, this review wanted to meet the requirements of EN 13242:2002 + A1:2007 "Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction" [3] and EN 13285:2010 "Unbound mixtures. Specifications" [4].

As regards the grading characteristics of the granular materials for use in sub-base and base layers, EP and BRISA adopted two different approaches. EP establishes a set of grain size requirements: i) designation of the mixture; ii) content of fines; iii) oversize material; iv) particle size distribution; v) tolerances specified by the manufacturer; and vi) differences in values of the material passed through the sieves. On the other hand, BRISA sets as only requirement that the particle size distribution must be limited by an upper and lower grading for the material.

With regard to the characteristics of the granular material used in the layers, the two institutions adopted two different approaches, namely:

• EP requires that the control of the compaction be done by comparing the in situ values with the reference values of the modified Proctor test, requiring that the dry density of the aggregate after compaction reach 98% of the maximum dry density.

• BRISA requires that the control of the compaction is done by comparison with the density of the aggregate particles, requiring a void ratio of the material after compaction to be lower than a defined limit value, which is usually 0.15, establishing a stricter limit value of 0.13 for limestone aggregate.

These two approaches are quite different. While the first matters the particle size distribution of the compacted material and its potential density increase, the second, by requiring an absolute value for the density of the compacted material does not take into account if the particle size distribution of the material allows achieving the target density. Practice has proved the existence of difficulties in meeting some requirements established for the control of compaction. According to some authors [5,6], there is the possibility of finding materials whose grading, physical and mechanical characteristics fit the requirements of the mentioned specifications but are not capable to achieve the target void ratio.

OBJECTIVES

The main goal was to evaluate if in the framework of European standards, particularly with regard to its particle size requirements, it was justifiable to maintain the two different compaction control approaches. Therefore, it was decided to evaluate:

• The impact of AIA particle size variations on the void ratio and compaction grade achieved using the modified Proctor compaction test; and

• The influence of the density of the compacted AIA on its mechanical performance, using the immediate bearing index test (IBI) [7].

To perform the tests previously indicated, whose results are not addressed in the present paper, five different grading mixtures of limestone AIA were prepared, encompassing the particle size requirements of the reference European standards.

The selection of the limestone aggregate was based on two main reasons: limestone is one of the main raw materials used in aggregate production in Portugal, and; the amount of work involved in preparing the five grading mixtures, from previously sieved fractions, required a huge amount of work, turning impracticable the inclusion of other rock types in the study. The material for this study was produced in the quarry Penedos Altos nº4 in Alvaiázere, Portugal.

WORK METHODOLOGY

The work program was divided in four phases [8]: 1) Selection of the materials to be studied; 2) Collection of the limestone AIA sample on the quarry; 3) Laboratory characterization of the aggregate sample and separation of individual particle sizes; 4) Selection and preparation of the five grading mixtures that would later be used in the accomplishment of the Proctor compaction tests and the IBI.

At the quarry an AIA 0/31.5 mm (Fig. 1) was collected. At the laboratory the following particle sizes were separated: 31.5 mm, 20 mm, 16 mm, 10 mm, 8 mm, 4 mm, 2 mm, 1 mm, 0.5 mm, 0.250 mm, 0.125 mm, 0.063 mm. In the first phase of separation, dry sieving was used in order not to introduce any factor that could alter the properties of the particles, especially the fines. This procedure proved disadvantageous in the separation of the finer fractions due to frequent clogging of the mesh of the sieves, turning very slow to achieve the required quantities. It was then decided to continue the separation by washing the material, taking into account that the water could affect the finest particles, endangering the objectives set for the study. The separation of the fines fraction was the phase that took longer.

Fig. 1 - All-in aggregate 0/31.5 mm.

The preparation process of the various size fractions followed the procedure:

• Washing of the AIA using the washing sieve (0.063 mm), and collecting the passing material (Fig. 2a).

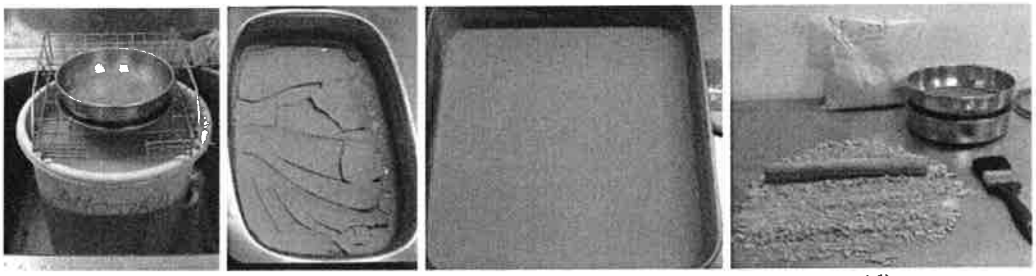
• The washed coarse material was oven dried while the passing material was decanted during several hours, until the fines completely settle, allowing to remove the water.

• The washed and dried coarser fractions were sieved using the sieve sizes referred previously.

• The sediment fines were transferred to trays and oven dried. It was observed that oven drying at 100° C caused excessive rigidity (Fig. 2b) in the material, hindering its separation. As a result, the material was subsequently dried at ± 50° C (Fig. 2c).

• The disintegration of the dried fines was carried out with a brush or with the passage of a wooden roll, and sieved on the 0.063 mm sieve (Fig. 2d).

• As the aggregate was separated, the quantities of each fraction were placed in plastic bags. Before the preparation of the samples, the material of each fraction was homogenized.



(a) (b) (c) (d)

Fig. 2 - a) Washing of fines; b) Fines oven dried at 100° C; Fines oven dried at 50° C; d) Disintegration of dried fines.

SELECTION AND PREPARATION OF THE FIVE GRADING

In the selection of the five grading to be included in the study, the following guiding principles were followed [8]:

1) Any particle sizes used should meet the requirements of the EN 13285 standard;

2) The grading should be compatible with the constraints imposed by the modified Proctor compaction test and the IBI test, so it was opted for a single dimension, 0/20 mm, corresponding to the size considered as the one that guarantees better performance levels;

3) As there were no possibility to test all categories defined in EN 13285, the most demanding category was adopted, so it was opted a G_A as it is the one whose grading range, both by the specification and by the manufacturer, admit the smaller amplitude;

4) The hole of the grading should be representative of the expected range in particle size of the chosen category, selected for this purpose: - An average grading that is equidistant from the boundaries defined by the standard or declared by the manufacturer; - Two grading representing the upper and lower boundaries of the standard; - Two grading considering the limit conditions imposed by the standard EN 13285 for the differences between passed in successive sieves (Table 1);

5) With respect to the content of fines and the oversize particles it was tried to obtain the extreme and the intermediate positions, having as reference the fines content category specified in the preamble of the French version of the EN 13285 standard, respectively UF_9 and LF_4.

It is important to highlight that rejecting the fraction coarser than 22.4 mm of an aggregate 0/31.5 we get an aggregate 0/20. Fig. 3 present the grading of a 0/20 mixture of category G_A and a mixture 0/31.5 of category G_B to which the fractions coarser than 22.4 mm were removed. As can be observed the two curves are very similar.

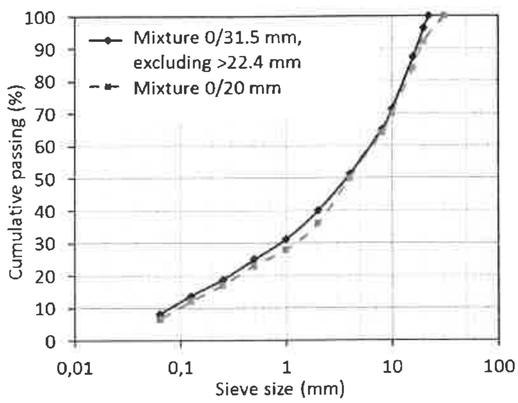


Fig. 3 - Comparison of the grading 0/20 mm with an aggregate 0/31.5 mm with rejection of the material coarser than 22.4 mm

The procedure for the construction of the five mixtures took into account the following steps [8]:

Step 1 - Draw the grading limits of the standards and the grading limits declared by the manufacturer (Fig. 4), in accordance with the NP EN 13285.

Step 2 - Draw the wanted grading inside the grading limits declared by the manufacturer. The example in Fig. 5 refers to the construction of the curve identified as "more fines".

Step 3 - Apply the tolerances of the grading declared by the manufacturer, as defined in NP EN 13285, to the grading identified as "more fines". The final curve was drawn within the tolerance limits, looking forward to an approach of the fines to the maximum tolerance and on the coarse side to the minimum tolerance. Thus, it can be seen that the grading presented is situated at the extremes of the specification limits (Fig. 6).

Step 4 – Check if the final grading meets the differences set out in the standard NP EN 13285, relative to the passing values (Table 1).

Following the above criteria, the five gradings were prepared (Fig. 7, 8 and Table 2) and can be described as follows:

• Lower limit mixture – corresponds to the lower grading limit of the standard and is

Table 1 - Differences in passing material of the grading "more fines"

Sieves (mm)	Cumulative passing of the grading "more fines" (%)	Passing differences (%)
31.5	100	
20	85	
10	63	63 – 53 = **10**
4	53	53 – 43 = **10**
2	43	43 – 36 = **7**
1	36	36 – 32 = **4**
0.5	32	
0.063	9	

characterized by a small amount of fines and abundant coarser material;

• Less fines mixture - with less fines and less coarse material, being more uniform;

• Average mixture - regarded as the most balanced mixture, passing along the middle of the grading limits;

• More fines mixture - has more fines and more coarse material, with some shortage of particles with intermediate sizes;

• Upper limit mixture - corresponds to the upper grading limit of the standard, and is characterized by abundant fines and a small amount of coarse material.

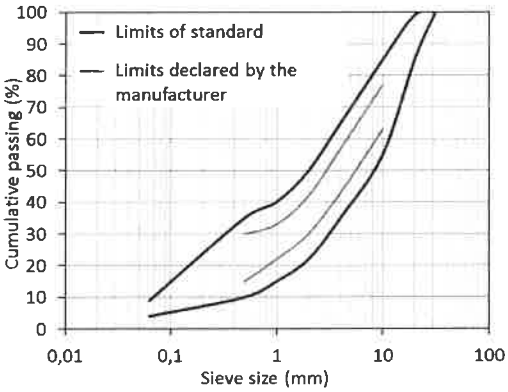


Fig. 4 - First step in the construction of the grading.

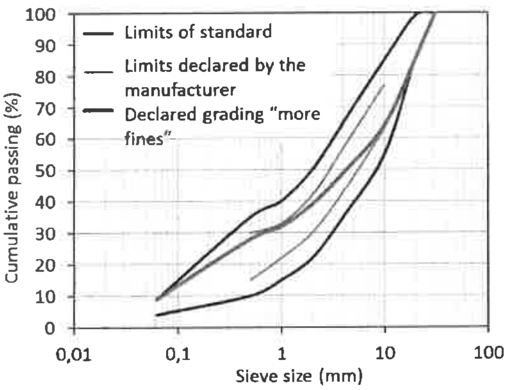


Fig. 5 - Second step in the construction of the grading.

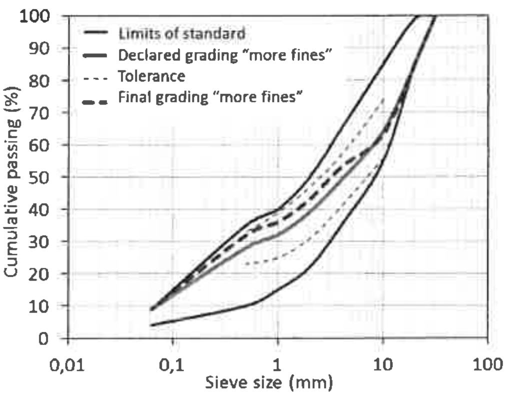


Fig. 6 - Third step in the construction of the grading.

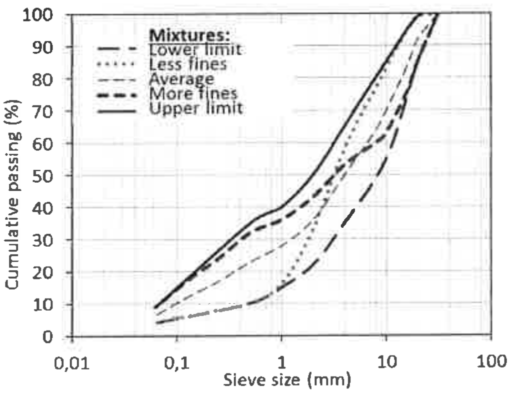
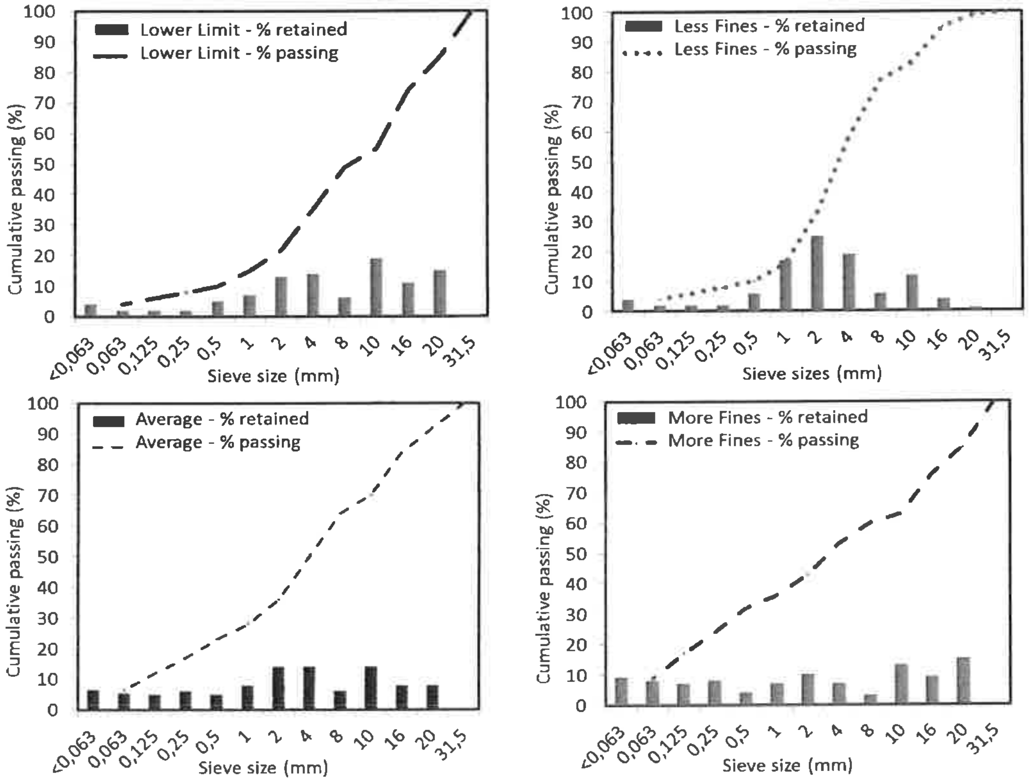


Fig. 7 - Representation of the five grading defined for the experimental study.

The described procedure was also applied in defining the mixture "less fines", although in this case it has been leaning against the grading to the minimum tolerance relating the fines and to the maximum tolerance relating to the coarser material. Thus, each mixture is characterized by the particle size distribution presented in Table 2 and Fig. 7 and 8. In Fig. 8 the lines represent the cumulative percentage of passing material and the bars represent the percentage of material retained on each sieve. Table 2 also shows up the curvature coefficient (CC) and uniformity coefficient (Cu) of each mixture.

Table 2 - Grading of the five prepared mixtures

Sieve sizes (mm)	Lower limit	Less fines	Average	More fines	Upper limit
	Passing (%)				
31.5	100	100	100	100	100
20	85	99	92	85	99
16	74	95	84	76	95
10	55	83	70	63	85
8	49	77	64	60	80
4	35	58	50	53	65
2	22	33	36	43	50
1	15	16	28	36	40
0.500	10	10	23	32	35
0.250	8	8	17	24	27
0.125	6	6	12	17	18
0.063	4.0	4.0	6.5	9.0	9.0
C_u	30.0	10.5	70.0	133.3	51.7
C_c	1.9	2.1	2.8	0.4	0.5



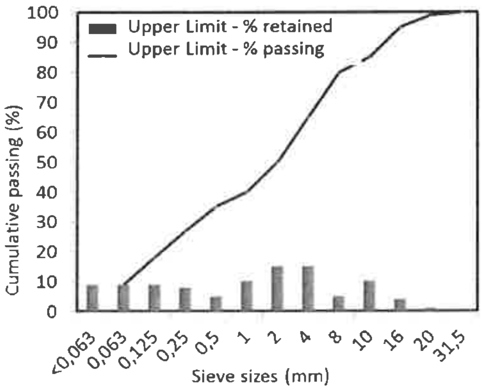


Fig. 8 - Graphic representation of the five handmade grading mixtures.

In order to have an effective control of the particle size mixtures, the laboratory test specimens were prepared by adding the precise amounts of each fraction to obtain the above mentioned grading.

FINAL REMARKS

The work described has, as main goal to guarantee that the sample preparation for laboratory testing the influence of void ratio on granular layers of road pavements, is suitable to allow rigorous test results. In order to prepare well defined grading, a detailed laboratory procedure was developed in order to assure that the grading tested is meaningful to evaluate the AIA characteristics. Only rigorous particle size distribution will permit the understanding of the influence of grading in the void ratio variation.

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