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Evaluation of limestone crushed dust aggregates in hot mix asphalt

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HIGHLIGHTS

- Laboratory evaluation of HMA mixes with granite and limestone aggregates were investigated.
- Using limestone in fine fractions improved the mechanical behavior in HMA mixes.
- Limestone as filler in HMA mixes can improve permanent deformation resistance.
- The results confirmed the efficiency of limestone as fine fraction and filler in HMA mixes.
- HMA mixtures with granite and limestone aggregates met Brazilian specifications.

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ABSTRACT

The growing demand for aggregates in highway infrastructure makes necessary to search local materials. The objective was to evaluate the inclusion of limestone aggregates in hot mix asphalt mixtures, through laboratory tests. The HMA mixtures were designed by Marshall and Superpave and submitted to indirect tensile-strength, resilient modulus, moisture damage and Flow Number. It was found that HMA mixtures with limestone showed better mechanical behavior, contributed for stiffness and gain of mechanical resistance, mainly to permanent deformation. Relative to moisture damage results, all mixtures were susceptible to water, but even so are technically viable for use in surface courses.

1. Introduction

The road infrastructure is an important part of the transport system that needs adequate materials in the conception. In the constructions of roads, asphalt mixtures composed by combination of aggregates and asphalt binder are common used. The properties of these materials determine the mechanical behavior of asphalt mixtures, influence stiffness, cracking resistance and durability of flexible pavements [1].

The study of these materials is therefore very important and laboratory tests are carried out to select the aggregates and asphalt binder to be used in road construction. There are many types of aggregates that can be used in road construction. In several studies, materials like basalt, granite, gneiss, phonolite, limestone, dolomite, crushed gravel, quartzite, sandstone, schist and siliceous aggregate were investigated for application in asphalt mixtures [2–6].

In Brazil, the granite aggregates are the most used in roads constructions. However, by the increasing of construction industry activities, this type of aggregate has become scarce, which increased transportation costs. Consequently, the demand for using other types of aggregates has significantly increased. An interesting alternative due to its availability is limestone. Quarries are available in Brazilian coast, which can be used in asphalt mixes to minimize transportation costs.

An efficient way to reduce costs and improve the properties of asphalt mixes is the replacement of different portions of the normally used aggregates by other types of aggregates. The join action of these materials can improve the mechanical behavior when

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using appropriate percentage of each material [7]. Therefore, replacements of portions of granite aggregates by limestone in asphalt mixtures becomes a viable option, not only because its meets the growing demand for aggregates, but also because it protects the environment.

2. Literature review

Transportation costs may become a considerable part of road construction because of the need of adequate materials. In most cases, materials with good properties are not always available in nearby mineral deposits. Thus, the road construction should be performed in order to consume local materials to avoid these costs.

Natural aggregates are most materials used in asphalt mixes and consume considerable share of the costs. The granite aggregates have been used in most cases of production of asphalt mixtures because they provide better performance than limestone, sandstone, gravel and other materials [8–10].

In Brazil, HMA mixtures are usually used on construction of surfaces courses. The aggregates properties such as gradation, shape, stiffness and strength influence their resistance and therefore the performance of asphalt mixtures in pavements [11].

To obtain an adequate mixing to resist the traffic loading, the correct combination of aggregates and asphalt binder is essential, in order to obtain proper proportions of them, to meet the technical criteria required by current standards.

With the main objective to reduce transport costs of aggregates to road construction in Brazil, the use of limestone aggregates in production of HMA mixtures may provide lower costs and higher values of resistance, with less consumption of asphalt binder.

HMA mixtures made with limestone aggregates are more resistant to stripping, have less moisture damage potential and good resistance to permanent deformation. In addition, the fine and filler particles sizes of limestone aggregates with basalt in coarse sizes, HMA mixtures showed good results in mechanical characteristics due to the properties of both materials [12–13].

In relation to mixture design, the most common methods are Marshall or Superpave mix designs. HMA mixtures produced by Superpave mix design can carry out better results of fatigue, moisture damage and permanent deformation resistance when compared to similar mixtures produced by Marshall mix design. Asphalt mixes with limestone and basaltic aggregates designed by Superpave can exhibit similar behavior to fatigue resistance and moisture damage [13–17].

In the production of HMA mixtures, both methods can be used. Marshall can design the optimum asphalt content (OAC), after that the mechanical properties of HMA mixtures, as indirect tensile-strength, fatigue, resilient modulus, permanent deformation and the moisture damage susceptibility can be designed by Superpave. Good results were obtained to asphalt mixtures with limestone fine and filler, and basalt coarse [7,18].

The limestone aggregate is also effective to minimize the moisture damage and improve the resistance of permanent deformation, one of the most distresses of HMA mixtures. The moisture damage occurs due to a loss of adhesion between aggregates and asphalt cement, resulting in stripping and raveling in pavements. The moisture susceptibility of HMA mixtures are evaluated upon determining the Tensile Strength Ratio (*TSR*) of compacted specimens. A minimum of 0.8 in *TSR* is required in order to prevent HMA mixes failure by moisture damage [14,19,20]. The Flow Number was introduced as a test to evaluate the deformation resistance of asphalt mixes with limestone aggregate [14,13,15,21,22].

In this way, due to these good properties, limestone aggregate has potential applications in road construction. This study was undertaken to evaluate the use of limestone aggregate in the composition of HMA mixtures. Tests have been carried out which are Marshall Stability, indirect tensile-strength (ITS), resilient modulus, flow number and moisture damage tests were carried out to perform the mechanical behavior of asphaltic mixtures with limestone and granite aggregates. In this study the main objectives were: (*i*) To study the effects of adding fine and filler limestone to HMA mixtures with granite coarse aggregates; (*ii*) Compare the results of HMA mixtures with combinations of limestone and granite aggregates to a conventional mixture; (*iii*) Determine an optimal mix, with adequate quantities of each aggregate to obtain an effective HMA mixture with good resistance to majority distresses of bituminous pavements.

3. Materials and method

3.1. Materials

In order to assess the mechanical behavior of HMA mixtures, an experimental program was conducted including collection and characterization of granitic aggregate, limestone aggregate and asphalt binder. The granitic aggregates and asphalt binder were collected from asphalt plant and limestone aggregate was collected from a mineral deposit. The limestone aggregates were crushed in laboratory to produce aggregates in similar sizes to granite.

HMA mixtures were produced and the optimum asphalt contents were selected to produce air voids, voids with asphalt (VFA) and Marshall Stability within the Brazilian standard limits of DNIT ES-031/2006 for flexible pavements. At the obtained OAC's, mixes were compacted using Marshall compactor and Superpave gyratory compactor for mechanical behavior investigation to select the optimal mix.

3.2. Experimental procedure

3.2.1. Materials characterization

First, both aggregates were characterized by standard tests from National Department of Transport Infrastructure (DNIT). The tests were performed to obtain physical and chemical properties of the aggregates. Concerning asphalt binder, tests methods according ASTM standards were performed to characterize his properties.

3.2.2. Mix design

The asphalt mixtures were produced by Marshall mix design to determine the OAC's, where the cylindrical specimens were compacted with 75 blows on each side, according to Brazilian standard DNER ME-043/95. For evaluating the mechanical performance of the mixtures, Marshall and Superpave mix designs were utilized. The air voids was the volumetric parameter utilized to compare the mechanical properties of asphalt mixes by two methods. The Indirect Tensile-Strength, Resilient Modulus, Moisture Susceptibility and Flow Number tests were carried out to perform the mechanical behavior.

For the production of HMA mixtures, the aggregates were heated between 140 and 150 °C for 24 h and were mixed with the asphalt binder at 155 °C. These temperatures ranges were determined by application of Brookfield viscosity test in the asphalt binder.

The number of gyrations was determined to produce specimen's air voids up three to 5%, with OAC's determined in the Marshall mix design. The parameters utilized to determine the number of gyrations were air temperature and Equivalent Single-Axle Loads (ESALs) traffic. The specimens were made with 96 gyrations, based on an average air temperature under 39 °C and ESALs traffic under 10 million.