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Louisiana Transportation Research Center

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Effect of Drainage in Unbound Aggregate Bases on Flexible Pavement Performance

Introduction

The presence of free water within the pavement layers can cause detrimental effects on pavement performance, which is directly linked to many premature failures observed for constructed pavements. It has been well recognized that the inclusion of a subsurface drainage system within the pavement structure offers the best approach to mitigate this problem. A complete subsurface drainage system is comprised of a permeable aggregate base layer, longitudinal drains, and transverse outlet systems. Typical permeable base materials include asphalt/cement-treated, open-graded aggregates, and unbound aggregates. Although asphalt/cement-treated, open-graded permeable bases perform well based on the past engineering practice, they are expensive solutions and less desirable for some roadways when compared to unbound aggregates, especially for low- to medium-volume roadways. To ensure proper performance, a permeable unbound aggregate should have adequate permeability while remaining structurally stable during the construction and service life of pavement. However, there is a trade-off between permeability and structural stability of unbound aggregates (i.e., the increase of permeability is often at the cost of structural stability or vice verse.). The purpose of this study is to determine a proper/optimum gradation of unbound Mexican limestone aggregates that meet both permeability and structural stability criteria.

Objective

The main objective of this study is to optimize the gradation of Mexican limestone aggregate for use as an unbound drainable base material that has adequate permeability while staying structurally stable during the construction time and the pavement's service life.

Scope

A series of laboratory tests were conducted to optimize the gradation of Mexican limestone aggregate material for use as a drainable base to satisfy both permeability and structural stability criteria. Basic and specific properties of the Mexican limestone with various gradations were determined. Five different gradations (Louisiana class II-coarse, Louisiana class II-fine, New Jersey-medium gradation, optimum-coarse gradation, and optimum-fine gradation) were examined in terms of their permeability and structural stability. The laboratory tests included constant-head hydraulic conductivity tests, tube suction tests, California bearing ratio (CBR) tests, dynamic cone penetrometer (DCP) tests, monotonic load triaxial tests, and repeated load triaxial (RLT) tests. Based on the results of laboratory tests, a range of optimum aggregate gradation was recommended.

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Research Approach

To identify an optimum gradation for the Mexican limestone aggregate having sufficient permeability while staying structurally stable for use as a drainable base, extensive laboratory tests were performed to determine the basic physical properties, permeability, and structural stability of five different gradations. These gradations include Louisiana class II-coarse, Louisiana class II-fine, New Jersey medium gradation, optimum coarse gradation, and optimum fine gradation. The permeability of unbound

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aggregate is quantified by its saturated hydraulic conductivity while its structural stability is characterized by various laboratory tests on the strength, stiffness, and permanent deformation of the material. Constant-head hydraulic conductivity tests were conducted to quantify permeability of unbound aggregates. Structural stability of unbound aggregates was evaluated through laboratory shear strength and stiffness tests. The laboratory tests included standard geomaterial tests, constant head hydraulic conductivity tests, tube section tests, CBR tests, DCP tests, Monotonic load triaxial tests, and RLT tests. The criteria for selecting an optimum gradation are: (1) an adequate permeability to drain the infiltrated-water from the pavement as quickly as possible, and (2) a sufficient structural stability to support the traffic loading. The process of achieving such an optimum gradation, however, is trial-and-error in nature because both permeability and structural stability depend on multiple factors.

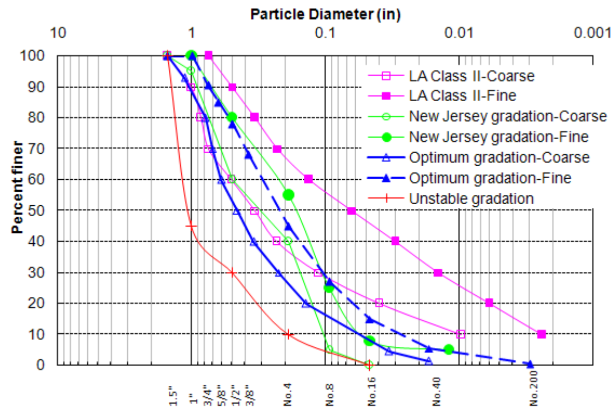

Figure 1
Particle size gradations of tested specimens

Conclusions and Recommendations

Based on the results of this research study, the following conclusions can be drawn:

- All gradations except Louisiana II-fine achieved the permeability criterion recommended by Federal Highway Administration (FHWA), which is 0.35 cm/sec. (1,000 ft/day).
- Louisiana II-coarse and optimum-coarse gradations achieved higher shear strength and resilient modulus values compared to other gradations.
- Mexican limestone base material has gained strength when compacted at optimum moisture contents and maximum dry density. However, it experiences strain-softening behavior, post-peak shear strength, in which the shear stress decreases with the strain increase until reaching the residual shear strength.
- The results of tube section tests showed that the Louisiana II-fine gradation of Mexican limestone has a relatively high dielectric value and can be considered a poor base in terms of water susceptibility. The rest of the gradations are considered in general marginal bases with respect to water susceptibility.
- There is a strong correlation between the optimum moisture content determined from the Standard Proctor test and the maximum dielectric values [$DV = 11.4 \ln(w_{opt}) - 8.7$] with a coefficient of determination $R^2 = 0.87$.
- The results of RLT tests showed that coarser gradations (optimum-coarse, Louisiana II-coarse, and New Jersey-medium) had much smaller permanent deformation and strain rate compared to finer gradations (optimum-fine and Louisiana II-fine).
- Different performance rankings were obtained for the different gradations based on the results of different structural stability tests and the permeability requirement. Accordingly, the optimum-course gradation was ranked A (the best performance), and Louisiana II-fine gradation was ranked E (the worst performance).
- There are good correlations between the dynamic cone penetrometer index DCPI and resilient modulus as well as between the unsoaked CBR and permanent strain.
- There is a narrow range between the optimum-coarse and optimum-fine aggregate gradations that can provide a stable and drainable pavement base layer. To meet the narrow acceptable drainable range in the field would require an extra estimated cost of $18.50 per cubic yard.

It is recommended that LADOTD consider modifying the specification of gradation by moving toward the coarse side to achieve a better long-term performance.