Selection of pavement foundation geomaterials for the construction of a new runway

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Abstract. The selection of foundation geomaterials including base/subbase unbound granular aggregate is critical for the design of flexible airfield pavements in the United States. These materials must meet the Federal Aviation Administration (FAA) selection criteria for airport pavement construction. A comprehensive testing study was conducted to select granular materials for the construction of a proposed runway North Carolina, United States. The objective was to evaluate granular materials and subgrade soils within the Greensboro area, to establish their pertinent engineering properties including strength and deformation parameters. This paper focused on three granular materials selected for the runway construction. The test results including grading, CBR, shear strength and resilient modulus indicated that all the three samples met the FAA selection criteria as base/subbase materials for the construction of the runway.

Keywords. Resilient modulus, Shear strength, CBR, runway, granular materials

Introduction

Road and airfield pavement materials found at selected sites and within the locality are often evaluated and considered for use as construction materials. The in-place materials may be removed and replaced with a higher quality material, or they may be modified in some manner to provide qualities that meet construction specifications.

A comprehensive laboratory testing study was recently conducted at the University of Illinois at Urbana-Champaign to support an expansion project of an international airport in North Carolina. The project involved the construction of a hub facility and a new runway capable of accommodating large aircrafts. As part of the study, three granular materials were selected for evaluation. Generally, granular base/subbase materials and subgrade soils i.e., geomaterials, constitute the pavement foundation materials. The granular base layers serve a variety of purposes including reducing the stress applied to the subgrade layer and providing drainage for the pavement. This paper presents the engineering properties of three granular materials for a runway.

The properties include, CBR, shear strength and resilient modulus. These properties are used by United States Federal Aviation Administration (FAA) to characterize granular materials for airport pavement thickness design [1, 2].

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1. Granular Materials and Properties

Granular materials (crushed aggregates) from three quarries in North Carolina were selected for this study. Representative samples were obtained from Jamestown, North and Pomona quarries in the Greensboro area. The samples were tested to determine the CBR, compaction density and optimum water content and gradation. Additional tests for shear strength and resilient modulus were performed on the sample from the Pomona quarry. A detailed description of sample preparation, testing equipment and test procedures used for this study are provided by [3]. All test specimens were prepared in accordance with ASTM and AASHTO testing procedures that have been recommended by the FAA for airport pavement designs.

2. Laboratory Testing Program

2.1. Sieve Analysis Test

Sieve analysis tests were conducted to determine grading of the crushed aggregates at the three stone quarries. The tests were performed in accordance with America Society of Testing Materials (ASTM) test method [4]. Grading of granular materials is an indicator of aggregate performance and it is one of the criteria used by the FAA for selecting crushed aggregate as a base material for an airport pavement. The FAA specification requires the maximum fines content of 8% for base materials [5].

Figure 1 compares the grading results of the three samples studied. The FAA minimum and maximum requirement of base course materials is compared in the figure. The fines content were approximately 5.5% for the Jamestown sample, 8.0% for the Pomona sample, and 8.7% for the North sample. It can be seen that the North sample did not meet the FAA criteria of 8% fines although it barely failed to meet this criteria. All the three samples have nearly the same grading characteristics. The materials may therefore, have similar strength and engineering properties.

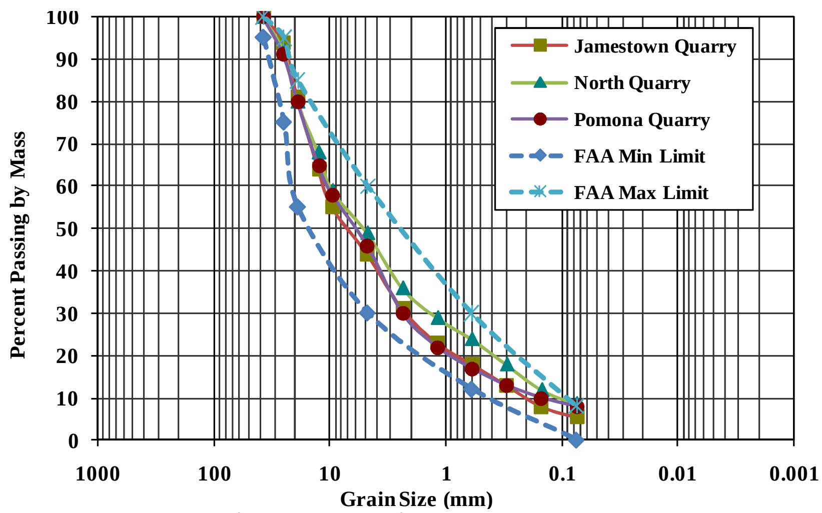

Figure 1. Grading of granular materials from Jamestown, North and Pomona quarries.

2.2. Moisture-Density Test

A laboratory moisture-density test was performed on the three samples using [6]. This test was performed to determine the water content needed to achieve the maximum dry unit weight of the granular materials. These values would be used to control field compaction during the construction of the runway. Compactions of aggregate materials generally increase density, shear strength, and stiffness, and decreases permeability. Thom and Brown [7] reported that resistance to rutting in granular materials under repetitive loading improves when the density is increased. It is well know that unbound granular materials resilient modulus decreases as the moisture content increases.

Figure 2 shows the compaction properties results of the three samples studied. The optimum water content of the North, Jamestown and Pomona samples were 5.5%, 6.2% and 6.5%, respectively and the corresponding maximum dry densities were 23.6 kN/m^3, 23.2 kN/m^3, and 23.1kN/m^3. The results indicate that the compaction properties of all three samples are close, although the same from the North quarry has slightly better compaction properties than the samples from Jamestown and Pomona quarries.

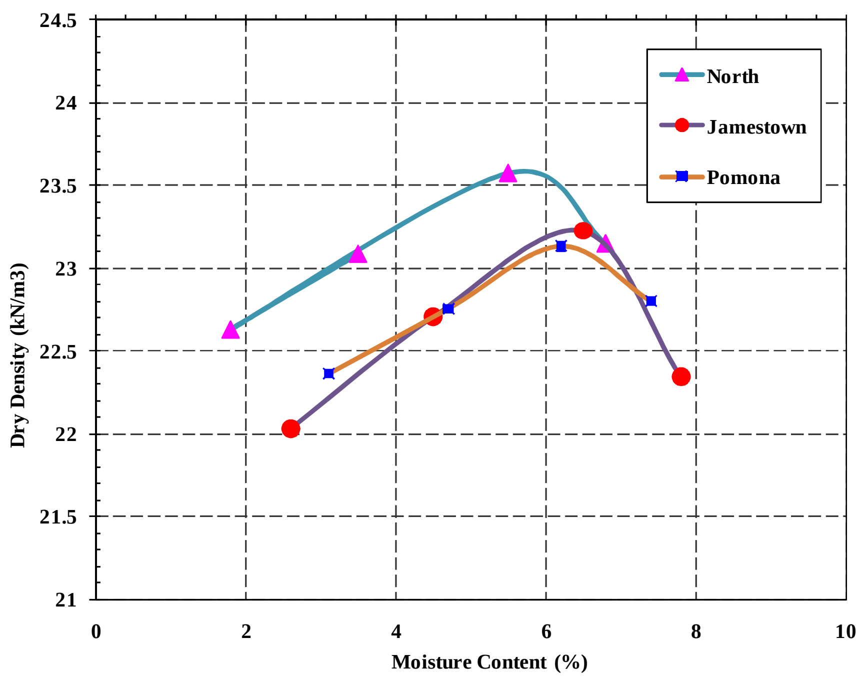

Figure 2. Moisture-density relationship of Jamestown, North and Pomona granular materials.

2.3. California Bearing Ratio (CBR) Test

California Bearing Ratio (CBR) value is a strength parameter used by the FAA for airport pavements design. The FAA AC 150/5320-6D specifies that the minimum CBR value of 80 is required for a crushed stone to be used as a base material for airport pavements. The CBR test was conducted on the granular materials samples using the ASTM D 1883 [8]. Soaked CBR tests were performed on the three quarry materials.

Figure 3 shows the CBR test results of the three samples. The results indicate that all the three granular materials had CBR values greater than 100. Accordingly, all the three granular materials met the FAA specifications. A comparison of the CBR values and the maximum densities of all the three quarries were made. The North sample with the highest maximum dry density had the highest CBR value of 230 when compared with Jamestown sample (CBR = 200) and North sample (CBR = 180). It follows that compaction characteristics had an effect on the strength of the materials.

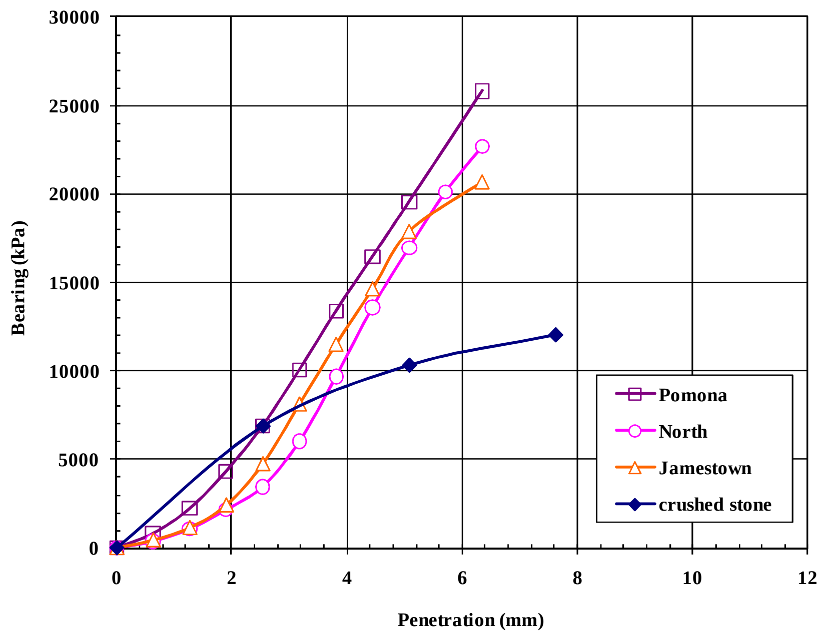

Figure 3. Comparisons of load-penetration curves of the three granular materials with standard crushed-rock.

3. Stiffness and Shear Strength Tests

Resilient modulus and shear strength tests were performed on the Pomona sample to evaluate the stiffness and strength properties. Only Pomona sample was enough to prepare samples for these tests. A 150 mm diameter by 300 mm high cylindrical specimens of the granular base materials were prepared for conducting both the shear and resilient modulus tests. The specimens were prepared at the optimum water and maximum dry density, and compacted using a pneumatic vibratory compactor.

3.1. Resilient Modulus Testing on Pomona Sample

Repeated load triaxial tests were conducted on the Pomona sample to determine its resilient modulus properties following the standard test procedure [9]. The data recorded in this test were bulk stress θ, resilient modulus M_R and the deviator stress σ_d

at 15 stress states. The test specimen was compacted at the optimum water content of 6.5%, and the maximum dry density of 23.1 kN/m^3. Figure 4 shows the resilient modulus results for the Pomona sample. It can be seen that resilient modulus increased with bulk stress, which is typical of granular materials.

The phenomenological K-θ model presented in Equation 1 was used to estimate the modulus value of the sample. The resilient modulus test data were analyzed used to develop the parameters (*n*, *k*) for the model.

$$M_R = k\theta^n \tag{1}$$

where M_R = resilient modulus; *k* and *n* are material constants obtained from regression analysis. The M_R model was expressed in logarithmic relationships to transform the power functions into linear expressions having two separate terms. A generalized resilient modulus model obtained for the Pomona is represented by Equation 2.

$$M_R = 64.255 \times \theta^{0.2202} \tag{2}$$

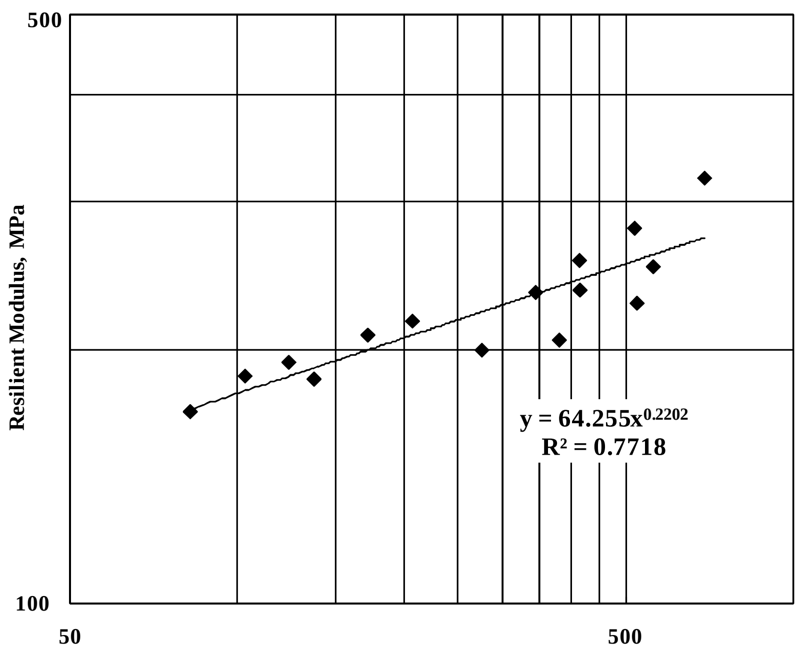

Figure 4. Resilient modulus-bulk stress relation for Pomona granular material.

3.2. Shear Strength Results for Pomona Sample

The shear strength tests were performed at confining pressures of 35 kPa, 69 kPa and 103 kPa to determine the friction angle (ϕ) and cohesion (c) used to define the Mohr-Coulomb failure envelope. Using the University of Illinois in-house shear test procedure, the deviator stress was applied axially at a constant displacement rate of 38mm/second (strain rate of 12½ percent per second). The linear relation between the shear stress and the normal stress was used to determine the friction angle and cohesion of the granular material. The relation is expressed as:

$$\tau = c + \sigma \tan\phi \tag{3}$$

where τ is the shear stress and σ is the normal stress.

Figure 5 shows the test results represented by Mohr circles at failure for the three confining stress states of the Pomona sample. High c value is associated with high resistance of the granular material to shearing stresses, and high ϕ value implies ability of the Pomona sample to develop strength and resist rutting under aircraft loading on the runway. Shear strength parameters were obtained by drawing a straight line that is tangent to the circles. The results obtained (ϕ = 58 deg, c = 96.6 kPa) can be used to determine the maximum shear strength of the granular material. These strength parameters are put in the relation, $\tau = c + \sigma \tan\phi$ to model the granular material.

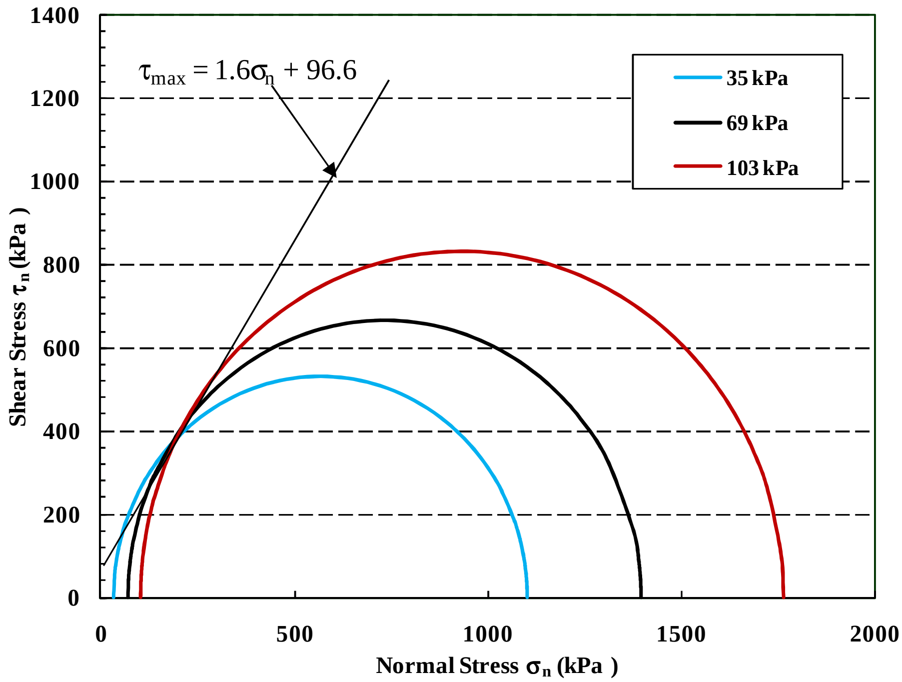

Figure 5. Shear strength properties of Pomona granular material.

4. Summary and Conclusion

This paper presented laboratory evaluation results of three granular materials selected for consideration as base/subbase material for the construction of a new runway in the United States. Specimen preparations and testing procedures conform to ASTM and AASHTO standard procedures. All tests were conducted to meet Federal Aviation Administration (FAA) specifications and requirements of granular materials used as base/subbase for the design and construction of airport pavements. Based on the FAA specifications, it was evident that all the three granular materials evaluated meet the FAA selection criteria of base/subbase course materials for the airport runway and associated taxiways and aprons. The study has shown that granular materials from the selected quarries could be used for future design and construction of pavements in North Carolina.

Acknowledgments/Disclaimer

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