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Effect of Moisture Content, Bitumen, Gravel Grain Shape and Density on Shear Strength Parameters of Well-Graded Gravel Materials in Contact with Asphalt Concrete Core

A. Nabizadeh[1*], S. Mohammadijou[2], S. Bahrami[2]

[1]Shahid Rajaee Teacher Training University, Department of Civil Engineering, Lavizan, Tehran, Iran
[2]Islamic Azad University, Central Tehran Branch, Faculty of Technology and Engineering, Tehran, Iran

ABSTRACT: In recent years, the use of embankment dams with asphalt concrete cores has become more popular in comparison with clay core dams owing to its implementation restrictions. Because in this type of dam, asphalt materials form the core of the dam and granular materials are used as a filter around the asphalt core. Therefore, investigation of behavior at the contact surface between these materials is of great importance. In this research, using large-scale direct shear experiments and applying vertical stresses of 1, 3 and 5 kg/cm2 in both dry and saturated states, the mechanical behavior at the contact surface of asphalt materials and gravel filters has been investigated. The effect of parameters such as material density, gravel grain shape and bitumen type has been investigated. The results showed that the shear strength at the contact surface of the materials decreases with increasing moisture content. Changing the shape of the filter material grains to the angular increased the shear strength of the contact surface and the ratio of maximum stress to residual stress at the contact surface for dry and saturated states with different relative densities showed that this ratio increased very little at low densities.

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1- Introduction

For a long time, embankment dams have been built for regulating and storage of water. An embankment dam is a dam type that is widely used in the world [1]. Embankment dams are comprised of two fundamental components, the first is an impermeable core and the other is a support shell that maintains dam stability [2]. Clay is often used as the core material due to its low permeability, but its application is associated with some limitations. In some projects, the borrow materials are not close to the project site and the transport of clayey material to the site is too costly. In some projects, while the borrow materials are accessible but due to the presence of rainfall and high humidity of clay, the construction of clayey core is faced with some problems [3]. The application of asphalt concrete could be an appropriate solution in these areas. The asphalt concrete core was first used 50 years ago in Germany. From 1987 on, by introducing the machine compaction equipment, great advancements were attained in the execution and compaction of cores with the surrounding filters. The asphalt concrete core is practically impermeable; it is resistant against erosion and is flexible. The core and filter materials are compacted and executed at 20 and 25-cm layers. The asphalt concrete core provides an impermeable layer that is protected by the transition zone [4].

2- Materials and test method

Angular and rounded shape gravel materials have been used for this research. The size of the largest used grain is 25 mm. for better investigating the physical properties of the materials used in grain size analysis, the minimum and maximum densities were calculated together with the specific gravity of the solid particles. The physical properties of used materials are given in Table 1.

The selected bitumen for making asphalt concrete is grade 60/70 which belongs to the hard bitumen class and is appropriate for the asphalt mix design needed for this research.

Table 1. Properties of graded grains for test

Type of materials	Angular gravel	Rounded gravel
Maximum Aggregate Size (mm)	25	25
Cc	28.70	23.75
C	2.41	2.30
γdmax	2.03	2.11
γdmin	1.57	1.66
Soil classification	GW	GW

*Corresponding author's email: ali.nabizadeh@sru.ac.ir

Fig. 1. Preparation of the asphalt mix at the lower half of the direct shear box

Fig. 2. Preparation of the filter materials at the lower half of the direct shear box

In order to select the proper grain size distribution for asphalt concrete mix, use the Fuller curve method to making the asphalt concrete mix Finally an asphalt concrete specimen was prepared for Marshall Test according to Standard ASTM D 6927-06 with 6% bitumen.In order to perform the test, use has been made of the direct shear test apparatus with 15x30x30cm dimensions. The direct shear test was performed according to ASTM D 3080-90 method. The test was performed under four general states:

1-Gravel materials in the dry state

2-Gravel materials in the saturated state

3-Interface of the gravel materials and asphalt in the dry state

4- Interface of the gravel materials and asphalt in the saturated state

For performing the test, the specimens were placed within the shear box at relative compaction values of 40%, 60% and 80% and under surcharge loads of 1, 3 and 5 kg/cm^{2}Rapid tests (Cu) were performed on the specimen and they underwent shear at 1 mm/minute speed. The implemented method for states no. 3 and 4 was similar to the previous ones but with this difference that immediately after mixing, the hot asphalt mix was placed at the lower half of the shear box, then preparation of gravel materials with the above-mentioned relative compaction values was done at the upper half of the box. Figures 1 and 2 show a view of the preparation stages for placing the specimen in the shear box.

3- Results and Discussion

In the saturated state the shear strength and dilation behavior are reduced with respect to the dry state and the reason could be attributed to the lubricating role of water within the gravel materials.By compacting the gravel materials one could enhance the interlocking of grains in the asphalt materials and consequently improve the shear strength. The angular gravel materials in contact with asphalt concrete provide better interlocking, which results in increased shear stress and internal friction angle between the materials.

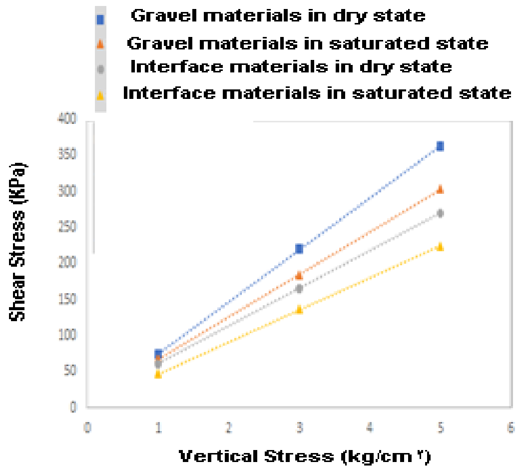

Fig. 3. Changes in residual shear stress versus vertical stress at 60% relative density

The gravel materials specimen and the gravel–asphalt interface specimen in the saturated state fail at lower shear stress and by the increase in the initial vertical stress; the difference between failure envelops corresponding to the dry and saturated states increases. This means that the internal friction angle of the gravel materials is larger in the dry state with respect to that in the saturated state.

The residual shear strength of non-plastic soils is generally obtained from the correlation between the residual shear strength in laboratory tests or from back analysis of the post-failure geometry under static or seismic loadings. Figure 3 shows the linear residual failure envelope, and previous studies confirm this. Also, it is observed that by the increase in the surcharge load, the difference between residual shear stress values increases in different states. By increase in the relative density percentage, the shear stress to residual stress ratio also increases, but per 40% relative density the ratio approaches unity and the difference between dry and saturated states becomes negligible.

4- Conclusion

By increase in the relative density of both the gravel filter and along the interface between gravel and asphalt (dry and saturated states), the internal friction angle also increased.

By changing the shape of the grains from rounded to angular, in both dry and saturated states, the amount of maximum shear stress at a low compaction increases by about 18-26%, but at intermediate compaction, it increases by 12-22% and at high compaction, it increases by 11-16%.

Investigating the maximum stress to residual stress ratio along the interface of specimens in dry and saturated states with different relative density values, revealed that this ratio has negligible increase at lower compaction percentages, but at intermediate and large compaction percentages, the increase is about 8-10%., the comparison made at similar density percentages but in dry and saturated states showed that this ratio does not show a significant change.

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