CORRELATION BETWEEN CALIFORNIA BEARING RATIO AND ANGLE OF REPOSE OF GRANULAR SOIL

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Abstract - *The strength of subgrade is a predominant factor in the design of Highways. One of the methods to determine the subgrade strength is the well-known California Bearing Ratio (CBR) test. CBR test is grueling and prolonged, thence a method for correlating CBR value with a soil physical property is proposed. Since the Angle of Repose is one of the physical properties of soil and is relatively easy to determine, it is considered as the correlating factor. The Angle of Repose is determined from the Hollow Cylinder test. In this study, diverse soils samples are collected from various locations within the Eastern Province of Saudi Arabia. Laboratory soaked CBR, Gradation Analysis, and Hollow Cylinder tests were performed on the samples. Thereafter, linear relationship between the Angle of Repose and CBR value of the samples is initiated and scrutinized using simple linear regression analysis (SLRA), and furthermore, predictive equation estimating CBR from Angle of Repose value is developed.*

***Key Words*: Soaked CBR, Angle of Repose, Correlation, Subgrade, Highways**

1. INTRODUCTION

Soil properties are predominant factors that affect all civil engineering projects such as highways, dams, tunnels and other structures. A competent ground layer is crucial for both stability and serviceability of any structure. Subsequently, an appropriate understanding and analysis of soil are required to ensure that the structure remains safe against subsurface failures. The Heterogeneous nature of the soil makes its behavior vary noticeably from site to another. Hence, exhaustive planned investigation for each site is a must for design purpose. Ambala highways system usually comprises of flexible pavement. Different flexible pavement design approaches have existed. The CBR test is an empirical method to design the flexible pavement. The bearing capacity of subgrade soil has a significant role in highway design, especially, in determining the thickness of the pavement. Namely, the lower the subgrade CBR value, the thicker the pavement. CBR values can be obtained directly from a laboratory test in accordance with ASTM-D1883 (Standard Test Method for California Bearing Ratio (CBR) of Laboratory Compacted Soils).

The test to determine the Angle of Repose is much easier than CBR test and can be conducted in laboratory in accordance with spreading of a granular mass on a horizontal plane method, which was improved lately by measuring the angle of repose of granular systems using hollow cylinders method and known as the Hollow Cylinder test. Alternatively, the Angle of Repose can be determined from a laboratory test in accordance with ASTM-C1444, or ASTM-D6393 which is known as Funnel test. The angle of repose of a granular material is the steepest angle of descent or dip relative to the horizontal plane to which a material can be filed without slumping. In other words, it is the angle which accumulated material forms with the horizontal. It is the maximum slope inclination at which the soil is barely stable. It is affected by the morphology of the material, solvents, and other factors. Usually, the Angle of Repose is almost equal to the critical internal friction angle of the material. Geotechnical, the Angle of Repose has many application fields, such as slope stability and the design of retaining structures. Generally, for sand, the angle of repose ranges from 300 to 350

2. LITERATURE REVIEW

Nelson (1955) [1] measured the angle of repose of sulfathiazole materials for a pharmacology application. In this case, the angle of repose was found to be equal to the angle of internal friction of the material only when the grains had a uniform shape and size, and the uncertainty in the measurement was reported as 1.0°

Miura, Maeda and Toki (1997) [2] introduced a funnel-type device to determine the angle of repose in which the pile of soil was formed on a cylindrical pedestal with a depression. They studied the relationship between the angle of repose and the angle of internal friction; examining different factors such as the roughness of the base, density of the soil, mean grain size, grain shape, dilatancy and lifting speed of the funnel. Their results indicate that the angle of repose tends to decrease with an increase in the amount of the material or the size of the conical heap and tends to increase with slower funnel lifting speeds during the experiment.

Rousé (2001) [3] compared six methods for measuring the angle of repose of six types of granular soil. She indicated that the highest value of the angle of repose was obtained from the ASTM International method. The differences between the six methods led to a difference in the factor of safety of approximately 82% for slope stability applications with considerable differences in the soils that require excavation.

E. Lajeunesse, A. Mangeney-Castelnau, and J. P. Vilotte (2004) [4] discussed that the spreading of a granular mass initially enclosed inside a tube and suddenly released on a horizontal surface.

Geldart et al. (2006) [5] studied the angle of repose of powders to investigate their flowability properties. A modified funnel method was used to measure the angle of repose of a slightly cohesive powder; the results being consistent with the Hausner ratio method.

3. METHODOLOGY

10 disturbed soil samples are collected from different locations within the Ambala city. All of these samples are subjected to soaked CBR.

- After performing soaked CBR test, each and every sample goes through Gradation Analysis tests.
- After that, we will perform Angle of Repose tests and try to establish a relation between soaked CBR values and Angle of Repose by comparing various results.
- It must be pointed out that for soaked CBR and Angle of Repose tests, the maximum particle size of the tested material is less than 19 mm.

1. **Collection of Material**: 10 disturbed soil samples are collected from different locations within the Ambala city. All of these samples are subjected to soaked CBR

In order to simulate the smooth and rough surfaces on which granular materials could be deposited, a glass plate is used as the smooth surface, and a porous stone and a wooden table is used as the rough surface. Figure shows these bases with gravel being deposited on their surfaces. Also, the angle of interface friction between the smooth and rough surfaces and the granular materials (sand and gravel) used in the experiments are measured in the laboratory

In these experiments, particles in the form of sand, gravel or a mixture of the two in the form of layers are placed in plexiglass cylinders. One cylinder has an internal diameter equal to 5 cm and a height equal to 17.15 cm, the second cylinder has an internal diameter equal to 12 cm and a height equal to 17.15 cm, and the third cylinder has a diameter equal to 12.5 cm and a height equal to 108.6 cm. The thickness of the cylinders is equal to 5 mm. The cylinders with the granular materials are placed on top of the three different surfaces. After this is accomplished, the cylinders are lifted manually at different velocities. The lifting involved two operators, one lifted the cylinders and the granular material spread over the selected surfaces, the other measured the velocity of lifting using a stopwatch.

2. **Measurement of Angle of Repose**: Analogous to the definition of the angle of repose, the method of measurement should be selected based on predefined objectives and for a specific material and application. Although there are different methods and guidelines available in the literature, the methods are neither standardized nor consistent. The existing methods measure both the static and dynamic Angle of Repose, as will be discussed later in this section. However, for each method, instruments of different size and scale are used.
3. **Hollow Cylinder Test:** The hollow cylinder method is employed to determine the static angle of repose of a cohesionless material. The test material is placed into a hollow cylinder of a certain diameter and height atop a selected base with known roughness properties. The cylinder is then carefully pulled off of the base, like in a concrete slump test, at a particular velocity to allow the material to flowand forma conical shape. The Angle of Repose is then measured by the (arctan) rule.

4. **CBR Test:** The California bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers.CBR value of soil sample is used to find out the thickness of pavement layers. CBR value is inversely proportional to thickness of the pavement layer. If the sub-grade is stronger, higher the CBR value, lesser thickness is required and vice-versa. California bearing ratio test conducts in laboratory as well as on field also.

4. ANALYSIS OF SOIL SAMPLE

As per standard, Higher CBR value from penetration 2.5 mm and 5 mm is considered. For Result accuracy total 10 soil sample is collected from different location of stretch.

The following table gives the standard loads adopted for different penetrations for the standard material with a C.B.R. value of 100%

Table-1: Standard loads adopted for different penetrations

Penetration of Plunger (mm) Standard Load (Kg)	Penetration of Plunger (mm) Standard Load (Kg)
2.5	1370
5	2055
7.5	2630
10	3180
12	3600

The test may be performed on undisturbed specimens and on remolded specimens which may be compacted either statically or dynamically. This test is done to determine the California bearing ratio by conducting a load penetration test in the laboratory. The California bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

Below given table summarizes the results of soaked CBR, soil classification, and Angle of Repose tests from performed in the laboratory on the 10 non-plastic soil samples. CBR tests are performed at the optimum moisture content. As can be seen from the table, the soaked CBR values range between 13.4 -34.9 %, and the Angle of Repose values lie within 23.70 - 34.70°.

5. EXPERIMENTAL PROGRAM RESULTS

The results of the experimental program are incorporated into SPSS software program, and simple linear regression analysis (SLRA) with the stepwise method is used to establish a regression model for estimating the value of soaked CBR from the Angle of Repose. Figure illustrates linear trend line between soaked CBR and Angle of Repose values. The value of soaked CBR is considered as a dependent variable, while Angle of Repose value is selected to be the independent variable. Subsequently, a correlation between soaked CBR and Angle of Repose values is developed.

6. CONCLUSION

Based on the linear regression analysis and experimental works conducted in this study, there is a high positive correlation between soaked CBR and Angle of Repose values. An empirical relation between the soaked CBR and Angle of Repose is derived from regression analysis equation. The relationship shows reasonably fitting between the predicted and experimental soaked CBR values. In general, as Angle of Repose increases CBR value increases.

1. The relationship shows reasonably fitting between the predicted and experimental soaked CBR values. In general, as Angle of Repose increases CBR value increases.

2. The Angle of Repose of the granular systems is influenced by the degree of roughness of the base on which the grains come to rest. It is determined that the rougher the base is, the higher is the angle of repose.

3. The mode of failure of the conical pile of grains is different depending if the base is rough or smooth. For the case of a rough base, the initial lifting of the cylinders caused the granular material to form first a pile of conical shape. As the lifting of the cylinders continued, more material is released from the cylinders. This additional material moved on the face of initially formed conical shape. The conical shape increased in height maintaining, however, its initial conical shape. For the case of a smooth base, the lifting of the cylinders caused the granular material to form first a pile of conical shape. As the lifting of the cylinders continued, more material is released from the cylinders. This additional material caused the original conical shape to spread and fail over the smooth base. During the spreading, the conical pile of granular material maintained its shape.

4. The lifting velocities of the cylinders are varied between a slow velocity (2 to 3 cm/sec) and a high velocity (7 to 8 cm/sec). The angle of repose is found to be smaller when the high velocity of cylinder lifting is used regardless of the degree of roughness of the bases. The lifting velocities of the cylinders represent the velocity of failure of a granular material from the top section of a slope of a composite shape (steep top section, semi-flat lower section). Failure of the steep section of a slope by physical degradation is always slow. Failure of the steep section of a slope resulting from seismic loading is always fast.

5. The angle of repose is also found to decrease in value as the amount of material contained in the cylinders increased in value. This result reflected field findings that indicated that the angle of repose of material at the toe of a composite in shape failed slope decreased in value as the amount (volume) involved in the failure increased in value.

6. The results of the tests helped to explain the angle of repose found in rock slopes made of a steep face and a lower section made of granular material that accumulated after the failure of the steep section of the slope.

7. FUTURE SCOPE

The test to determine the Angle of Repose is much easier than CBR test and can be conducted in laboratory by the Hollow Cylinder test. Alternatively, the Angle of Repose can be determined from a laboratory test by the Funnel test. Since, this study shows that soaked CBR values are somehow correlated with the Angle of Repose thus provides an easy alternative to the CBR test. In general, the angle of repose of a granular material is the steepest angle of descent or dip relative to the horizontal plane to which a material can be filed without slumping.

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