A Review of Soil Stabilization Using Resilient Modulus

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Abstract. In civil engineering the pavement design is equally important as the construction or design of any building. The pavements are subjected to continuous traffic load so it needs to be constructed or designed as much stiff as they can bear the required traffic load. As the pavement is constructed with different layers and they have their own bearing capacities, but the pavements are still situated on heterogeneous soil. The value of resilient modulus is going to be changed when there is variation in moisture content during the construction of the base, sub-base and subgrade soils. In this paper we will discuss about how much stabilization of soil is depend upon on resilient modulus.

Keywords: CBR · Materials · Resilient modulus · Soil · Stabilization

1 Introduction

In civil engineering it is very important to analyze the different aspects while the construction or design of any building like how it is equally important while the construction of pavement design. As the pavement is constructed with different layers of the soil which makes it challengeable or becomes an important factor to analysis the bearing capacity of each layer present in the soil and equally important to analyzed the structure of the soil which tends us to tell about resistible of the soil or the failure of the soil of the specific layer which is designed for certain vehicle load. To find out the significance behavior of layer of the road like subgrade, base and base soil has a great impact on the working efficiency of the flexible pavement. In road construction the design of pavement is only depend upon the on-site performance which only requires the material that has assumable properties which is same as the in-situ unconstrained layer. There are many field tests or methods which couldn't be able to find the in-situ performance of unconstrained layer which is highly depend upon traffic load. California bearing ratio test which is known as CBR test is widely performed test around the world and is used to calculate or performed to study about unbound layer. There are many drawbacks of using California bearing ratio test which are like slow performance test, couldn't be able to find out the

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whole stresses observed by unbound layer (Moazami et.al. 2013). We cannot maintain the on-site field conditions; in that case the resilient modulus test is the only worldwide trusted experiment performed highly in the deferent part of the countries which is highly recommended and performed, to determine the unbound layer under the dynamic traffic loads.

2 What is Resilient Modulus (MR)

Resilient modulus is the fundamental property which is same as the modulus of elasticity, thus we can say resilient modulus is a stress-strain relationship. Resilient modulus is a slightly different what's why it is defined from the repeated load, triaxle-compression test (unconfined compression) based only on the resilient modulus or recoverable portion of the strain. Resilient modulus is defined as

$$\text{Resilient modulus} = \frac{\text{Strees amplitude}}{\text{Strain amplitude}}$$

where,
Stress amplitude = load/area of the specimen
Strain amplitude = recoverable deformation/original height

Under the dynamic load there is increase in stress exactly like increase in strain and vice-versa, however, all strains cannot be recovered when the total stress is eliminated. Therefore, the total strain is consisting of some parameters like permanent which is known as plastic component and a recoverable which is known as the elastic component are to be considered. We cannot include permanent which is known as plastic in resilient modulus. MR test is a kind of an experiment which is basically designed to analyze the behavior of soil and soil granular materials of pavement which are under traffic load (Elliott and Thornton 1988; Mulungye et al. 2007). Therefore, all the process like sample preparation and testing were performed in accordance of field conditions.

3 Factors Affecting Resilient Modulus

3.1 Confining Stress Effect

As we all know, the resilient modulus is made up of elastic, stress-strain relationship. The resistance of roadbed materials to deformation caused by stress comes from the friction between particles, so the stiffness mainly depends on the effective limiting stress between the particles located at this position and the applied deviatoric stress. On non-cohesive granular soils, but not on fine-grained clayey soils, the effect of restraint stress is more obvious. The friction between particles caused by effective restraint stress is produced by granular soil, and cohesive force and cohesive stress both produce resistance, the level at which the limiting stress affects the resilient modulus mainly depends on the properties of the given soil material. With the increase in confining pressure, the resilient modulus of fine-grained cohesive soil will also increase. The increase in confining pressure will affect the dynamic response of aggregates based on granular materials.

3.2 Deviatoric Stresses Effect

The resilient modulus of fine-grained cohesive soil are generally decreases with increase of the deviatoric stresses, with increase in deviatoric stress there is suddenly decrease in resilient modulus.

3.3 Moisture Effects on Resilient Modulus

The resilient modulus is composed of main three stress variables. Axial stress, matrix suction and net confining pressure. If changes in the moisture content of fine-grained soil tend to change the effective stress, it will cause changes in soil suction ("negative pour pressure"), and therefore will change the moisture content of unsaturated soils. According to previous studies the saturation of granular non-cohesive soil mainly depends on the content of fine particles present in the soil, due to lack of small voids clean gravel and sand are not sensitive to moisture content which are subjected to form suction between soil particles, so there is an increase in moisture content that will reduce the resilient modulus of the soil.

3.4 Temperature Effects

The influence of temperature may have a great influence on the resilient modulus of the pavement system. Generally, the significant effects of the system that can be divided into three different categories: frozen, unfrozen or recently unfrozen. There is increase in resilient modulus as there is increase in freezing of fine-grained and coarse-grained soils. If there is increase in the deviatoric stress level and temperature, the resilient modulus will change slightly.

3.5 End Conditions Effect

Earlier, before the resilient modulus AASTHO recommends to perform 500–1000 conditioning cycle of the soil to maintain the gap between the top and bottom plates of the soil sample. The purpose of adjusting is to minimize the gap or uneven contact between the soil sample. In order to measure the real value of resilient modulus one must measure the axial deformation of the soil sample.

3.6 Size and Preparation

From the beginning to the present, the sample size and preparation method are designed through AASHTO resilient modulus test. The sample size ranges from 2.8 in. (71.1 mm) to 7.5 mm. The diameter of fine-grained soil is 4.0 in (101.6 mm), and the diameter of 101.6 mm is 4.0 in (101.6 mm). The maximum diameter of coarse-grained soil is (152.4 mm).

4 Effect of Additives on Increase MR

In the world of stabilization cement is that material which is proudly used to enhance the performance of roadbeds present in pavement structure. In the stabilization process some common used stabilizing agents are like (lime, fly ash, and cement), where the cement used as stabilizing agent is the only one which improve strength and rigidity of the soil. The degree of effectiveness varies with a stabilizer. There are many studies across the world which have been conducted which states to evaluate the performance of stabilized soil and aggregates in the pavement construction (Solanki and Zaman 2011; Tastan et al. 2011; Rout et al. 2012). According to the new MEPDG (2004) which determined the input required for the stabilizing of the soil. While designing a new pavement, some of the parameters like resilient modulus (MR) and unconfined compressive strength (UCS) and some additives discussed below.

4.1 Lime

Lime is often used to stabilize clay because it has some desired properties and can be used to change the plasticity of the soil. Solanki et al. (2009) conducted a study prepare samples by the addition of 3%, 6% and 9% lime to the original soil classified as CL-ML. The additives are mixed manually and make them to mix properly in the entire mix. After the mixing process, addition of required amount of water to obtain the optimum moisture content (OMC) Then add mixture in the mold then compact it thoroughly in mold which have dimensions like diameter of 101.6 mm (4.0 in.) and a height of 203.2 mm (8.0 in.) to obtain a maximum dry density (MDD) which is about 95% to 100%. The extruded sample was cured in a controlled room at a temperature of 23.0 ± 1.7 °C, which is about 96%, and duration of 28 days. Use AASHTO T 307–99 to carry out MR Test, and carry out UCS test according to ASTM D1633 test method. Their research concluded that due to the composition more in cement compounds, there is increase in the value of resilient modulus while increase in the percentage of lime. For the raw soil, 153 MPa is the MR value. For the samples containing 3%, 6% and 9% lime, the MR value is 5.6 times, 7.1 times and 7.3 times respectively. The value of UCS test of the original soil is 227 kPa. As compared with the control sample, addition of 3%, 6% and 9% of lime can increase the value of UCS test by 1.7, 1.7 and 2 times, respectively.

Rout et al. (2012) studied about resilient modulus which is of three subgrade soils (according to AASHTO T-307). According to the unified classification, the tested soil is CH with various plasticity. Use lime cement to stabilize the soil to evaluate the efficiency of enhancing elasticity. In addition, the influence of ultimate stress and deviator stress is also studied. In their research, the laboratory samples were compacted so that the height of the sample was twice its diameter (for example, a height of 142 mm and a diameter of 71 mm). After the soil is air-dried, then addition of 6% lime with 3% cement. A soil sample containing 3% water content was prepared first. After initially mixing of the soil with lime and cement, before compacting keep mixture of the soil in the room temperature near about 3 days or 72 h. The control sample and the treated sample were cured in a humidity cabinet for at least 2 to 7 days, respectively. The value of resilient modulus of untreated soil is lie between 30 and 50 MPa Resilient moduli can be increased by up to three times for the same treated soil sample, especially for the soil with the highest plasticity. It can also have obtained in the untreated subgrade soil, for all the three test have confining pressures about (13.8, 27.6, 41.4 kPa), with the increase in deviator stress the resilient modulus is going to be decrease.

4.2 Cement

In the study of Solanki et al. (2009), they used the same lime stabilization method with the addition of 5, 10 and 15%of cement kiln dust (CKD) with the CL-ML raw soil. According to their results, the MR value of the original soil was 153 MPa, while the MR value of stabilized specimens at 5, 10 and 15% of CKD increased by 4.8, 15.7 and 16.7 times, respectively The value of UCS test of untreated soil was observed to be 227 kPa, and for 5, 10, and 15% of CKD, the UCS test value is going to be increased by 1.3, 4.8, and 6 times, respectively.

Mohammad and Saadeh (2008) used the lime stabilization method, by adding ratio of 8% cement to stabilized the clay. They concluded from the study that there is increase in resilient modulus by 10% to 15% relative with addition of cement mix to the controlled sample having resilient modulus of about 35 MPa. The result is shown about influence of cement stabilizer on improving the performance of soil engineering properties.

4.3 Fly Ash

Fly ash is an amorphous pozzolana and cementitious material. It is a kind of solid waste that is harmful to the environment, and mainly extracted by the process of burning of coal in thermal power plants. According to Solanki et al. (2009), they use the lime and cement as a stabilizing agent, and specimens were prepared with the addition of 5, 10, and 15% of Class C fly ash (CFA) with CL-ML soil. They state from there theory that the value of Mr. observed to be 153 MPa before the stabilization process, an increase of 1.7 to 4.2 times, respectively on using of 5, 10 and 15% CFA stabilizers. The main reasons for increase in value of MR is co-related to be the highest pozzolana content in CFA, this can be the reason for the formation of gelled products. The value of UCS test of the control sample is observed to be 227 kPa. They observed that while adding of 5, 10, and 15% CFA which can increase the value of UCS test by 1.3%, 2.4%, and 4%, respectively.

In the study of Lin et al. (2009) they concluded from there theory that the efficiency of fly ash to enhance the properties like unconfined compressive strength and stiffness of subgrade soil in the laboratory as well as on-site were based on dry weight, which is about to be 12% grade of C fly ash which is going to be mixed with the roadbed soil. The MR test (AASHTO T292 1991) is carried out to be with the optimal moisture content immediately after compaction of the sample, and sealed in plastic packaging after 14 days of curing and then kept in a room having humidity is about to be 100%, and then the MR test is performed. This theory is based on ASTM D 5102 which conclude that the compact soil-lime mixture having the strain rate about to be 0.21% per minute for the UCS test, after 7 days of solidification on site, the strength and stiffness of the stabilized soil were analyzed with a soil hardness meter (SSG) and dynamic cone permeability meter (DCP), and its weight was measured.

Deflection meter (FWD). The results show that the initial value of MR for the roadbed is lie between 34 to 42 MPa on an average value of 38 MPa, while the MR value of the laboratory mixed fly ash stabilized soil is between 115 and 167 MPa (average value = 139 MPa). The MR value of the fly ash stabilized soil mixed on site is 60 to 129 MPa (average value = 82 MPa). Their research concluded that the adding of 12% of fly ash into the original soil can increase the MR value by 3.7 times and 2.2 times in the laboratory as well as on-site, respectively.

5 Conclusion

In civil engineering a stable pavement is the main component of the sidewalk structure., which have engineering performance such that strength and resilient modulus of the road pavements are the main parameters that affect the total efficiency of the pavement structure, because in many cases, road fatigue or rutting damage is caused by insufficient stiffness modulus of the soil layer. Due to its importance, the new "Mechanical Pavement Design Guide" designed by (AASHTO 2002) incorporates the engineering characteristics of subgrade soil (unbounded or stable) in the design process. It is not always easy to provide sufficient stiffness for the roadbed. Therefore, it is inevitable to strengthen the pavement layer, and it is highly necessary to improve or maintain the existing project by using various stabilizers discussed as above.

- In treated soil, the increase in deviator stress which tends to increase in the value of resilient modulus, because the treated soil exhibits non-plastic behavior and its modulus will depend up on the confinement stress exerted by the granular material
- For specimens stabilized by lime and fly ash, the MR value has been improved. In addition, MR decreases as the stress ratio increases.
- The MR value increases as there is increase in the ratio of lime. This case happens with the only soil which are having high plasticity.

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