**International Journal of Emerging Engineering Research and Technology**
**Volume 5, Issue 12, 2017, PP 38-44**
**ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)**

# Comparative Assessment of Deformation under Repeated Loading and Wheel Tracking of Reinforced and Asphalt Stabilized Subgrade Soil

**Saad Issa Sarsam[1*], Ahmad Zuhair AL Sandok[2]**

[1, 2] *Department of Civil Engineering, University of Baghdad, Baghdad, Iraq*

***Corresponding Author:** Prof. Saad Issa Sarsam, Head, department of civil engineering, University of Baghdad, Baghdad, Iraq.*

## ABSTRACT

*The subgrade soil layer is considered as the foundation for the roadway structure, the homogeneous stress distribution and the control of deformation in the subgrade are essential to maintain the required serviceability of the roadway. Poor subgrade soil can be improved by implementation of various techniques such as stabilization and soil reinforcement. In this work, the wheel tracking and the pneumatic repeated loading testing techniques have been implemented for comparatively assessing their impact on the deformation of subgrade soil reinforced with geogrid, geotextile and geosynthetics or treated with cutback asphalt. Specimens of 152 mm diameter and 50 mm thickness have been prepared in the laboratory using static compaction to achieve a target density. Specimens were subjected to load repetitions of the wheel tracking under a vertical load, and the accumulated deformation was captured through LVDT. A second group of specimens of 152 mm diameter and 114 mm height have been prepared and compacted to the target density, then subjected to pneumatic repeated loading of 1.0 second and 0.9 second of rest period. The accumulated deformation was detected through LVDT. Data have been analyzed and compared. It was concluded that the deformation under wheel tracking test decreases by (41, 62, and 76) % while the failure potential of the specimens was extended by (10, 235, and 125) % when geogrids, geosynthetic, and geotextile reinforcements have been introduced. The deformation at failure under pneumatic repeated load decreases by (56, 68, and 76) % when geotextile, geogrids, and geosynthetic reinforcements have been introduced. The reduction of deformation for asphalt stabilized soil was (97 and 87) % under wheel tracking and pneumatic repeated loading respectively.*

**Keywords:** *Subgrade, reinforcement, wheel tracking, repeated load, deformation, Cutback*

## INTRODUCTION

The influence of geosynthetics as a reinforcement on the California bearing ratio of the two layers soil with various types of geotextiles has been investigated by [1]. The parameters that tacked into account were the thickness of the soil layer and the different mechanical properties of the geotextiles. The outcome of tested specimens indicated that the field California bearing ratio matched with the values obtained in the laboratory test. The behavior of the sandy soil subgrade reinforced by geogrid was investigated by [2]. The main parameters that were adopted are geogrid type, number of grid layers and grid type. The test results showed that the improvements of strength of sandy soil in presence of geogrid was (20%) in case of one grid, (72%) for two grids and (205%) for three grids. The influences factors on the behavior of the granular based material in case of presence reinforced by geogrid under the effects of repeated loading was studied by [3]. The main parameters adopted are locations of geogrid, geometry, tensile modulus, moisture content and stress concentration. The geogrid selected and used in tests differs by tensile modulus and by form as rectangle, biaxial and two triangles or Triaxial. The results from experimental tests indicated that the geogrid with Triaxial form has high tensile modulus and gave good behavior under repeated loading as compared with the other geogrid performance. Inclusion of geosynthetic ensures a long lasting pavement structure by reducing excessive deformation and cracking as stated by [4]. Addition of geosynthetic in form of geotextile, geogrid reduces pavement thickness significantly. Reinforced pavement by geogrid subjected to cyclic loading (plate load test) was explored by [5]. The method of analysis adopted by the study was AASHTO (MEPDG) Mechanistic-Empirical Pavement Design Guide. Based on the test results, it was concluded that the presence of geogrid increases the resilient modulus of the coarse base in the range (10-90%) and reduced the thickness about (12-49%), also there was enhanced in performance of the coarse base in case used high tensile modulus geogrid. The benefits of geogrid adopted as reinforcement have been discussed by [6], the soil layers exhibit increased stiffness of pavement. The best decision and resolution for selection of the suitable type and specifications of geogrid were based on the behavior and benefits demonstrated for a particular product or set of products in full-scale pavement test geometry. A radical change in performance of the geogrid that reinforced the unbound granular materials was examined by [7], and then after evaluated. The repeated loading was applied on the reinforced and unreinforced unbound granular specimens. The results showed that there was reductions in deformation due to the presence of geogrid reinforcements. Cracks depth of clay linear soil compacted in three layers under cycle of atmosphere in case with and without geotextile cover was analysed by [8]. The existence geotextile cover reduced the cracks in the range of (35 to 79%). The interactions behaviour between soil and geogrid by pull out test was evaluated by [9]. The parameters adopted are types of geogrid, transverse ribs and the quality of sand surrounding the geogrid.

A series of actions of loading and unloading continued up to ultimate applied loading and the shear strain distribution was obtained. The result of tests indicated that the soil showed dilative behavior occurred at peak resistance. [10] Investigated the influence of reciprocal action between soil and reinforcement strips and considered there was a frictional force at the interface. The pull out test was adopted to test the specimens under cured conditions and the presence of MC-30 cutback asphalt for stabilization. The laboratory test included the specimen that represented reinforced embankment model box. The reinforcements selected in study are plastic material and aluminium as strip form that reinforced the compacted layers inside the box. The strips were subjected to a pull out test to explore the frictional forces that developed between the interface of soil and strips. The test results showed that the shear stress increased as the period of curing increased and the use of cutback asphalt as stabilizer material gave a high pull out stress as compared with the soil without stabilizer. The influence of the emulsion and cutback asphalt on shear strength of Gypseous soil was studied by [11]. The parameter adopted in investigation was the percentages of the stabilizers material. Two testing techniques have been implemented, direct shear and one dimensional confined compression. Test results indicated that the presence of liquid asphalt enhanced cohesion strength of the layer and worked as water proof.

## Materials and Methods

### The Soil

The sub-grade soil is brought from site located near the Tigris River (Al-Tajy city), north of Baghdad, the soil was excavated from a depth of (1 to 2.5 m) after removal of the top soil. This Soil is the typical fill materials commonly used for embankment construction as a subgrade layer in pavement structure at Baghdad urban area. Grain Size distribution of this Soil was found by Sieve analysis. The results are shown in "Figure.1". Soil is classified as (SP) by Unified Soil Classification System (USCS) according to ASTM D 2487, [12]. Using American Association of State Highway and Transportation Officials AASHTO, [13], the subgrade soil was classified as (A-3). Table 1 shows the chemical composition of the soil, while Table 2 presents the physical and geotechnical properties of the soil.

**Table1.** *Chemical composition of the soil*

| Chemical Composition | Test Result % |
|---|---|
| Total ($SO_3$) | 0.712% |
| Carbonate content (Ca $Co_3$). | 1.069% |
| Calcium sulfate (Ca SO4) | 1.111% |
| Total soluble Salts (T.S.S.). | 1.31% |
| PH value | 10.03 |

**Table2.** *Physical and geotechnical properties of the soil.*

| Property | Test results |
|---|---|
| Percent passing 0.075 mm sieve | 18.7 |
| AASHTO Classification, [13] | A-3 |
| Unified soil classification | SP |
| Specific gravity | 2.64 |
| Liquid limit % | 23 |
| Plasticity index % | Non plastic |
| Maximum dry density (gm/cm$^3$) (Modified compaction) | 1.76 |
| Optimum water content % | 16 |
| Cohesion kPa (Direct shear box) | 41 |
| Angle of internal friction | 29.2 |
| Undrained shear strength kPa (Unconfined compression test) | 50 |
| Unconsolidated undrained shear strength kPa (Triaxial test) | 54 |

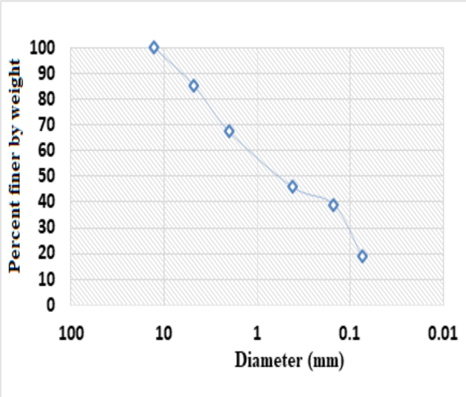


**Figure1.** *Grain size distribution of the soil*

## Soil Reinforcements

### *Polypropylene Geogrid*

This physical and mechanical properties of geogrid are summarized in Table 3. The test results are as supplied by the manufacturer. The mechanical properties were determined and checked as per ASTM D6637, [12] requirements

**Table3.** *The Physical and Mechanical Properties of Polypropylene Geogrid.*

| **Property** | **Unit** | **Requirement or Value** |
|---|---|---|
| Aperture size (SD×LD) | mm | 6×8 |
| Mass per unit area | g/m² | 744 |
| Rib thickness | mm | 1.65×1.50 |
| Junction thickness | mm | 2.80 |
| Roll width | m | 4 |
| Roll length | m | 50 |
| Standard color | ---- | Black |
| Polymer type | ---- | PP |
| Peak tensile resistance | kN/m | 6.4 |
| Upper yield strength | MPa | 5 |
| Tensile strength | MPa | 9 |
| Upper yield strength | MPa | 5 |
| Lower yield strength | MPa | 5 |
| Non-proportional extension strength | MPa | 6 |
| Total extension strength | MPa | 5 |
| Elastic modules | MPa | 0.39 |
| Fracture percentage elongation | % | -99 |
| Percentage elongation at maximum load | % | 6 |
| Total percentage elongation | % | 11 |

### *Geosynthetics (Glass Fibre Mesh)*

This mesh is an alkali-resistant glass fabric. The properties as supplied by the manufacturer are presented in Table 4.

**Table4.** *Reinforcing Geosynthetics Mesh properties*

| Property | Value |
|---|---|
| Weight/unit area | 160 g/m2 |
| Mesh size | 4 x 4 mm |
| Initial tear strength | 2200 N/5 cm |
| Thickness | 0.5 mm |
| Length | 50 m |
| Color | blue |
| Ceiling area | 4-5 minutes/m2 |

### *Geotextile*

Geotextile are permeable non-woven fabrics which, when used in association with soil, have the ability to separate, filter, reinforced, protect or drained. The three type of soil reinforcement are shown in “Figure.2”.


**Figure2.** *Soil reinforcement implemented*

### *Cutback Asphalt*

The type of Asphalt used in this study was Medium curing Cutback Asphalt (MC-30) that had been produced according to (ASTM D 2027), (AASHTO - M 82 - 75), [12 and 13] by Al - Dora Refinery using one step, it is composed of 91.2 % asphalt cement of grade 40-50, and 8.8% Kerosene. The Properties of Cutback Asphalt (MC-30) as supplied by the refinery are illustrated in Table 5. The reason of using this type of liquid asphalt (Low grade) as a Stabilizer in this study because it gives higher dry density than other grades of Cutback Asphalt due to less Viscosity of (MC-30) and has more solvent content which causes better mixing and coating of Soil's Particles and better compaction.

**Table5.** *The properties of Cutback Asphalt (MC - 30)*

| Property | Results |
|---|---|
| Flash Point (C.O.C) °C (min.). | 38 |
| Viscosity (Cst.) @ 60 °C. | 30 – 60 |
| Water % V (max.). | 0.2 |
| Distillation Test to 360 °C, Distillate % V of Total Distilled<br>To 225 °C (max.).<br>To 260 °C (max.).<br>To 315 °C (max.). | <br><br>25<br>40 – 70<br>75 – 93 |
| Residue from distillation to 360 °C % V (min). | 50 |
| Tests on Residue from Distillation<br>Penetration @ 25 °C (100 g, 5 sec, 0.1 mm).<br>Ductility @ 25 °C (cm) (min).<br>Solubility in Tri-chloro Ethylene % wt. (min). | <br>120 – 250<br>100<br>99 |

## Preparation of Specimens

### *Reinforced Soil Specimens*

Two groups of mixtures have been prepared in the laboratory, the first group consist of cutback asphalt stabilized soil. The dry soil was mixed with optimum water content for two minutes to become homogenous then it was mixed with the required percentage of cutback asphalt for three minutes so that the soil particles are covered with thin film of asphalt. The mixture was left for aeration at room temperature of 25°C for two hours as recommended by [14 and 15]. “Figure.3” shows mixture under aeration.


**Figure3.** *Aeration of asphalt stabilized mixture*

The procedure of obtaining the optimum percent of cutback asphalt is published elsewhere, [16]. The mixture was then inserted into the mold and subjected to static compaction to a target density of 1.760 gm/ cm$^3$. Specimens were prepared with optimum fluid content (water +cutback asphalt) of 16%. Additional specimens were prepared using 0.5 % fluid content above and below the optimum. Specimens were left for curing at room temperature of 25°C for one week as recommended by [10 and 11] before testing. The second group of mixtures prepared in the laboratory consist of pure soil mixed with optimum water content of 16% and compacted to the target density under static load. The soil water mixtures were divided into two portions, the first portion was inserted and spread inside the mold, the soil reinforcing element was then inserted and leveled inside the mold, and finally the second portion was added to the mold and leveled. The mold was then subjected to static compaction for a target density of 1.760 gm/ cm$^3$. For each type of the above mentioned mixtures (asphalt stabilized mix and pure soil water mix), two groups of Specimens have been prepared. For the first group, a specimen of 152 mm diameter and 50 mm thickness have been prepared in the laboratory using static compaction to achieve a target density. This group of specimens will be subjected to load repetitions of the wheel tracking under a vertical load, and the accumulated deformation. “Figure. 4” shows part of the specimens left for curing. Specimens were prepared and tested in duplicate and the average value was considered.

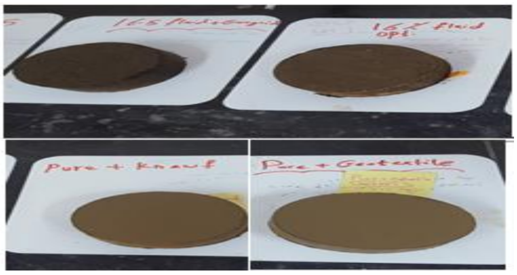

**Figure4.** *Part of Specimens of wheel tracking test under curing*

The second group of specimens of 152 mm diameter and 114 mm height have been prepared and compacted to the target density inside the CBR molds. This group of specimens will be subjected to pneumatic repeated loading of 1.0 second and 0.9 second of rest period. Specimens were prepared and tested in duplicate and the average value was considered.

## Testing of the Specimens under PRLS

This test on the specimens of 152 mm in diameter and 114 mm in height was conducted according to AASHTO 201, [13]. The pneumatic repeated load System (PRLS) shown in “Figure. 5” was used for the test. A constant Stress equal to 56 kN/m$^2$ was implemented with a loading duration of 0.1 second and a rest period of 0.9 second. Specimens of reinforced or stabilized soil have been tested in the PRLS system, the accumulated vertical deformation was recorded after each load repetition with the aid of LVDT.

"Figure.6" shows the test setup. The test was conducted at 25±2 °C.

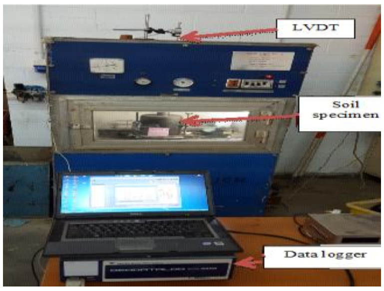


**Figure5.** *PRLS Testing*

## Testing of Specimens under Wheel Tracking

The Apparatus used in this test is shown in "Figure.7". This test was used to find the depth of Rutting of pure, reinforced (with geogrid, geosynthetic and geotextile) and asphalt stabilized soil (with optimum, and ± 0.5% of optimum fluid content) by exposing the specimens to repeated load for 1000 Cycle.

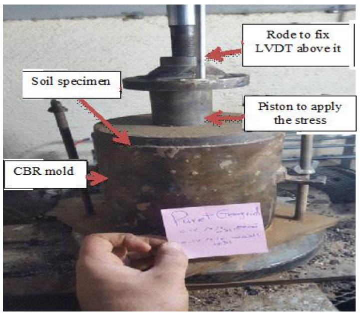


**Figure6.** *Test setup*

Each cycle equals to two passes under the Wheel Tracking apparatus. In this test the deformation was recorded continuously for each load pass with the aid of LVDT. "Figure. 8" shows a close up view of the test.

**Figure7.** *Wheel tracking apparatus*

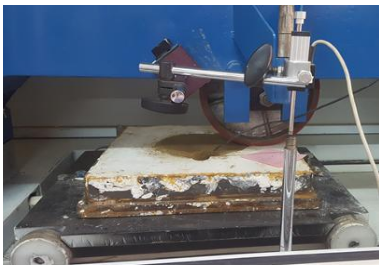

**Figure8.** *Close up view*

# RESULTS AND DISCUSSIONS

## Behavior of Reinforced Soil

"Figure.9" exhibit the accumulation of vertical deformation for reinforced soil under the wheel tracking action. The improvement in the resistance to deformation of the soil when the reinforcements are implemented can be observed. After 200 load repetitions, the deformation decreases by (41, 62, and 76) % when geogrids, geosynthetic, and geotextile reinforcements have been introduced as compared to the soil without reinforcements. On the other hand, the failure potential of the specimens was extended by (10, 235, and 125) % when geogrids, geosynthetic, and geotextile reinforcements were used as compared to the pure soil. Such findings agrees well with the work reported by [17].

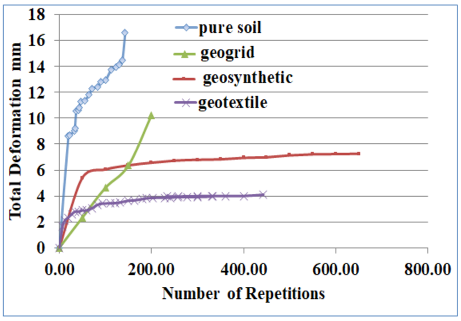


**Figure9.** *Total deformation under wheel tracking test*

"Figure.10" shows the accumulation of permanent deformation of the soil tested under pneumatic repeated load, it can be observed that implementation of reinforcement's causes a reduction in the permanent deformation. The deformation at failure decreases by (56, 68, and 76) % when geotextile, geogrids, and geosynthetic reinforcements have been introduced as compared to pure soil. The total deformation under this testing technique is lower than that measured under wheel tracking test, this may be attributed to the confined nature of the soil inside the CBR mold, while the soil under the wheel tracking test has more freedom to move laterally to the sides of the wheel in the form of shear failure.

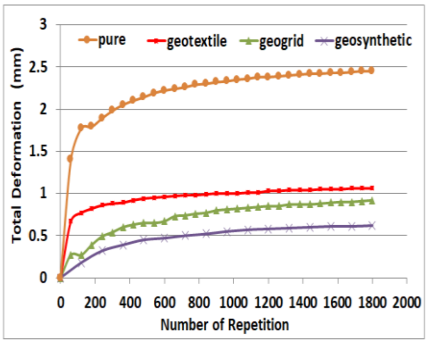


**Figure10.** *Total Deformation under Repeated loading in the PRLS*

### Behavior of Asphalt Stabilized Soil

"Figure.11" exhibit the accumulated deformation of asphalt stabilized soil under load repetitions of wheel tracking test. It can be observed that the addition of cutback asphalt has significantly increases the resistance of the soil to deformation. The reduction in the deformation was in the range of 97%, while the impact of asphalt content was not significant. Asphalt stabilization exhibit better performance as compared to soil reinforcements from the deformation point of view. On the other hand, the failure potential of the asphalt stabilized mixture was extended by nine folds as compared to pure soil.

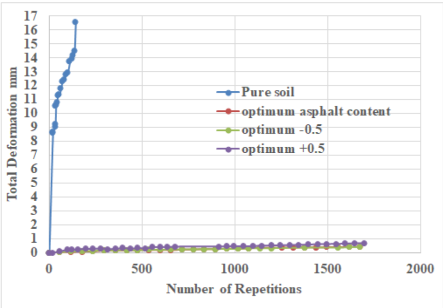


**Figure11.** *Deformation of asphalt stabilized soil under Repeated loading in wheel tracking*

"Figure.12" shows the total deformation of asphalt stabilized soil subjected to pneumatic repeated loading, it can be noted that there is significant increase in the resistance of soil to deformation after stabilization. The reduction in the deformation was in the range of 87%, while the impact of asphalt content was not significant. Asphalt stabilization exhibit better performance as compared to soil reinforcements from the deformation point of view. Such findings are in agreement with the work reported by [18 and 19].

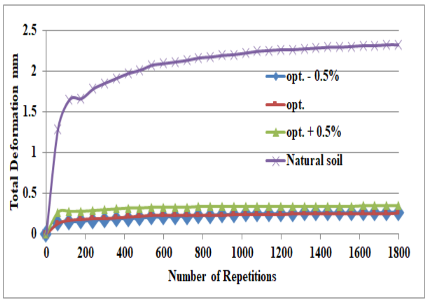


**Figure12.** *Deformation of asphalt stabilized soil under Repeated loading in PRLS*

### Conclusions

Based on the testing program, the following conclusions may be drawn

1. The deformation under wheel tracking test decreases by (41, 62, and 76) % while the failure potential of the specimens was extended by (10, 235, and 125) % when geogrids, geosynthetic, and geotextile reinforcements have been introduced as compared to the soil without reinforcements.
2. The deformation at failure under pneumatic repeated load decreases by (56, 68, and 76) % when geotextile, geogrids, and geosynthetic reinforcements have been introduced as compared to pure soil.
3. The reduction in the deformation under wheel tracking test for asphalt stabilized soil was in the range of 97%, while the impact of asphalt content was not significant. The failure potential of the asphalt stabilized mixture was extended by nine folds as compared to pure soil.
4. The reduction in the deformation under pneumatic repeated load for asphalt stabilized soil was in the range of 87%, while the impact of asphalt content was not significant.

### References

[1] P. Ullagaddi, and Nagaraj, T. "Investigation on geosynthetic reinforced two layered soil system". Proceedings, 7th international conference on case histories in geotechnical engineering, Missouri University of Science and Technology. 2013, April 29- May 4.

[2] S. Sarsam, and Al-Saidi, A. "Impact of Plastic Grid Reinforcement on Behavior of Composite Soil Embankment Model". Open Journal of Functional Material Research, 2015, OJFMR, 2 (2).

[3] M. Abu-Farsakh, Souci, G., Voyiadjis, G. Z., and Chen, Q. "Evaluation of factors affecting the performance of geogrid-reinforced granular base material using repeated load Triaxial tests". Journal of Materials in Civil Engineering, 2011, 24(1), 72-83.

[4] J. Anitha. "Effect of geosynthetic on soft subgrade –literature review", International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 01 | Jan -2017. Pp.1446-1448.

[5] Q. Chen, and Farsakh, M. A. "Structural contribution of geogrid reinforcement in pavement". In Geo Congress 2012: State of the Art and Practice in Geotechnical engineering (pp. 1468-1475).

[6] S. Archer, and Wayne, M. H. "Relevancy of Material Properties in Predicting the Performance of Geogrid-Stabilized Roadways". In Geo Congress 2012: State of the Art and Practice in Geotechnical Engineering (pp. 1320-1329).

[7] Q. Chen, Abu-Farsakh, M., Voyiadjis, G. Z., & Souci, G. “Shakedown analysis of geogrid-reinforced granular base material”. Journal of Materials in Civil Engineering, 2012, 25(3), 337-346.

[8] M. Ghazizade, and Safari, E. “Analysis of Desiccation Crack Depth in Three Compacted Clay Liners Exposed to Annual Cycle of Atmospheric Conditions with and without a Geotextile Cover”. Journal of Geotechnical and Geo environmental Engineering, 2016, 143(3), 06016024.

[9] N. Giang, Kuwano, J., Izawa, J., & Tachibana, S. “Influence of unloading–reloading processes on the pullout resistance of geogrid”. Geosynthetics International, 2010, 17(4), 242-249.

[10] S. Sarsam, Al-Saeidy, A., & Falih, M. “Assessing Pullout Resistance of Earth Reinforced Embankment Model”. Journal of Engineering Geology and Hydrogeology, 2014, (JEGH), 2(1), 9-14.

[11] S. Sarsam, and Ibrahim, S. “Contribution of liquid Asphalt in shear strength and rebound consolidation behavior of Gypseous soil”. Engineering and Technology, 2008, 26(4).

[12] American Society for Testing and Materials, ASTM- 2009. “Road and Paving Material, Vehicle-Pavement System”, Annual Book of ASTM Standards, Vol.04.03.

[13] AASHTO, “Standard Specification for Transportation Materials and Methods of Sampling and Testing”, American Association of State Highway and Transportation Officials, 14th Edition, 2013, Part II, Washington, D.C.

[14] S. Sarsam, Alsaidi, A. A., and Alzobaie, O. M. “Impact of Asphalt Stabilization on Deformation Behavior of Reinforced Soil Embankment Model under Cyclic Loading”. Journal of Engineering Geology and Hydrogeology 2014, JEGH, 2(4), 46-53.

[15] S. Sarsam, and Barakhas, S. “Assessing the Structural Properties of Asphalt Stabilized Subgrade Soil”. International Journal of Scientific Research in Knowledge, 2015, (IJSRK), 3(9), 0227-240p.

[16] A. Al Sandok A. “Verification of layered theory for stabilized and reinforced subgrade model”. MSc. Thesis, 2017, Department of Civil Engineering, University of Baghdad, Iraq.

[17] S. Mirzapour, Karim, M. R., Khodaii, A., and Almasi, M. H. “Improving rutting resistance of pavement structures using geosynthetics: an overview”. The Scientific World Journal, 2014.

[18] Y. Chen, Dai, W. T., & Wang, L. “Test study on road performance of soils stabilized by liquid stabilizer in seasonally frozen regions”. In ICCTP 2010: Integrated Transportation Systems: Green, Intelligent, Reliable (pp. 3245-3252).

[19] A. Olutaiwo, Adedimila, A. S., and Sidiq, U., "An Examination of the Use of Liquid Asphalt Binders in Road Works in Nigeria" Journal of Engineering and Applied Sciences, 2008, Vol. 3, No. 1 (p 134-142).


## AUTHOR’S BIOGRAPHY

**Prof. Saad Issa Sarsam** was born in Baghdad (1955), got his BSc. In Civil Engineering (1977), Post graduate diploma and MSc. in Transportation Engineering (1978) and 1980 respectively. Worked as senior material Engineer for NCCL (1982-1992); He joined the academic staff at University of Mosul (1992-2005), then at University of Baghdad (2005 until now) and got the Professor degree at (2007). He is the Head of Civil Engineering department at university of Baghdad, since (2016).

**Ahmad Zuhair AL Sandok** was born in Baghdad, 1994, got her BSc. In Civil Engineering (2015), and MSc. In Geotechniquics Engineering (2017).

**Citation:** *I. Saad and A. Ahmad Zuhair, "Comparative Assessment of Deformation under Repeated Loading and Wheel Tracking of Reinforced and Asphalt Stabilized Subgrade Soil", International Journal of Emerging Engineering Research and Technology, vol. 5, no. 12, pp. 38-44, 2017.*