EVALUATION OF REINFORCED FLEXIBLE PAVEMENTS BY REPEATED LOAD TESTING

تقييم طبقات الرصف المرنه المسلحه بإستخدام

إختبار الحمل التكرارى

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ملخص :

ثبت فى بحث سابق أن إختبار معامل تحمل كاليفورنيا قد يعطى فكره عامه عن مدى تحسن خواص تربه التأسيس بعد التسليح . و بالرغم من ذلك فأننا بحاجه لتقييم التربه المدعمه بنسيج دعم التربه فى ظروف أقرب ما يمكن للواقع الحقلى . و الغرض من هذا البحث هو دراسه مدى تأثير أنواع مختلفه من نسيج دعم التربه حينما يوضع بين سطح التربه الحامله و طبقه الأساس على إطاله عمر طبقات الرصف مقاسه بالهبوط السطحى نتيجه أحمال تكراريه . و قد تم تصنيع نموذج بحجم مناسب لإجراء الإختبارات على ما يمكن تشبيهه بقطاع إختبارى و إنحصرت عمليه التقييم على نوع واحد من التربه و ثلاثه أنواع من نسيج الدعم أحدهما من النوع الشبكى و تم تكرار الإختبار بإستخدام حمل تكرارى مماثل للحمل القياسى .و قد ثبت أن إجراء هذا التقييم بهذه الطريقه الديناميكيه يعطى فكره أكثر قرباً للظروف الحقليه و كذلك فإن إستخدام نسيج الدعم الشبكى فى تسليح التربه تحت طبقات الرصف أفضل من الأنواع الأخرى .

ABSTRACT

In a previous research, the C.B.R. Test has proved to be useful in evaluating reinforced subgrade soils [1]. When testing specimens after soaking with and without reinforcement one can come up with two values of C.B.R. for comparison. However, the need to evaluate reinforced

subgrade soils in a loading conditions that are as similar as possible to field is warranted .

The purpose of this research is to investigate the life cycle improvements of pavements when they are reinforced by geotextiles and a geonet . Four pavement test groups were constructed to simulate the field conditions as possible . One group was the control sections , and the other three were reinforced with geosynthetics . Simulated traffic repeated loads were applied and the vertical deformation of tested pavement surface was measured at the edge of loading plate . It is concluded that testing relatively larger scale models by repeated loading is more realistic than C.B.R. Also , geonets perform better than geotextiles when employed as reinforcement .

INTRODUCTION

In the design of a flexible pavement , subgrade vertical deformation is considered one of two major failure distresses . Recent design changes have been brought about by heavy wheel loads and higher traffic levels . The effect of environmental conditions during the year on subgrade properties initiates faster propagation of pavement deformation . Chemical stabilization of weak subgrades , thicker pavement thickness or subgrade reinforcement are some alternatives adopted for reducing pavement vertical deformation . Geosynthetics have long been recognized as materials that can improve the performance of highway pavements , particularly those constructed on weak soils . Geotextiles , geonets , geogrids and geocomposits are types of known geosynthetics . . Geotextiles consist of synthetic fibers that are produced either in a woven or a non-woven manner . Geogrids and geonets are manufactured from polypropylenes , high density polyethylene or high tenacity polyester [2] The basic functions of geotextiles in improving pavement's performance are known as separation filtration and , sometimes , reinforcement . Geogrids and geonets are considered mainly as reinforcing members . However , geocomposites are believed to successfully act as separator , reinforcement and filter .

When a pavement system is reinforced , wheel load is distributed over a larger area of subgrade-base interface . The result will be lower vertical stress , strains and deformation of subgrade surface . To achieve a better distribution of wheel load a certain vertical deformation must be reached [3] . This vertical deformation is required together with enough friction between subgrade - geosynthetic - base interfaces to produce the uplift load of reinforcing material . If geosynthetic has enough tensile resistance , the vertical deformation of the subgrade may be controlled . Therefore ; subgrade stabilization by reinforcement is more pronounced for very weak soils (to initiate enough vertical deformation) whilst requires enough pavement thickness (to act as surcharge load for interface friction production) . It is believed that a successful design is that which satisfies the balance between these two constraints . Some researches concluded that the effectiveness of geotextiles is significant when deformation was increased and suggested that the higher the tensile moduli of fabrics as measured by the secant modulus ; i.e. , the tensile force in KN/m divided by corresponding strain ,the larger the amount of subgrade strengthening that was achieved [4] . Others concluded that the benefits of geotextiles is derived from their separation and filtration characteristics [5] .

TESTING PROGRAM

The testing program was conducted at the highway materials laboratory in the Faculty of Engineering , Mansoura University, Egypt .The program was divided into two phases . Phase one included routine testing of materials , i.e. , subgrade , base and geosynthetics . Characteristics of materials such as , gradation ,maximum density and optimum moisture content , specific gravities , C.B.R. values , physical and tensile properties of geosynthetic were evaluated . In addition , the C.B.R. values of compacted subgrade soil before and after soaking while reinforced with different types of geosynthetics were determined. Phase two comprised testing the subgrade soil as a part of a pavement section inside a model simulating the field condition before and after reinforcement .

Four different pavement sections were constructed in a specially manufactured steel mold . One test section was unreinforced , control section , two test sections were reinforced with geotextiles and the fourth was reinforced with a geonet . Following the construction of each section the pavement surface was repeatedly loaded by way of a rigid plate whilst the surface rutting was measured using mechanical sensitive dial gauges . The components and the methods of constructing the test sections are summarized below .

Testing Equipment

Routine testing equipment and methods were according to standard specifications . A rigid steel mold bad a 300 x 300 mm crossection and

500mm height was employed for pavement section inclusion . The mold was provided with a side hinged door to allow soil removal . The door had two locks for tightening in place during compaction and testing . Mold joints were carefully sealed to prevent any leakage of water . The subgrade material was compacted manually using the modified proctor hammer in seven 40mm layers . Before compaction soil was mixed thoroughly with water at a predetermined moisture content . Compaction was then continued till a known batch weight was filling a predetermined volume to achieve the required maximum wet density . The same approach was followed in base layer compaction overlaying the subgrade but in 50 mm lifts . The system was prepared to allow measuring base surface deflection using sensitive mechanical dial gauges A steel frame provided with a dropping steel hammer was employed to apply the repeated load . Weight of dropping hammer and height of drop were adjusted to apply a surface stress representing dual tire loading of an 80 kn (18000 lb) axle . The dropping load was repeated using an electric motor and a speed controller system similar to that of the mechanical proctor compactor . The loading calibration revealed that a drop weight of 34 N , a drop height of 40mm and a loading base of 40 mm diameter were needed for applying a surface stress of 0.5MN/m2 (70psi) . The loading frequency was about 1.3 Hz .

Testing Materials

The control test sections consisted of a compacted silty sand subgrade and a well graded sandy gravel base course . For the three reinforced sections a geotextile or a geonet was placed at the subgrade-base interface . Characteristics of testing materials are presented in the following sections .

Subgrade Soil :

The subgrade soil was a fine poorly graded silty sand classified as A-3 according to AASHTO obtained from the north coast near Port-Saied . Non plastic fines content were 82 % , the specific gravity of particles was 2.737 and the maximum dry density was 1.762 t/m3 at an O.M.C. of 12.3 % . The C.B.R. values at different moisture contents of subgrade soil are given in table (1)

Table (1) : Effect of Moisture Content on Subgrade CBR Value

% moisture content	5.5	7.0	12.3	14.6	18.0
% C. B. R.	15	25	31	20	3

Base course:

Sandy gravel was used as a base course in the testing model . The gradation of the base course aggregate met the specifications of grade D soil aggregate mixture of AASHTO . The modified proctor maximum dry density was 2.36 t/m3 at an optimum moisture content of 6.5 %.

Reinforcing materials:

Two types of geotextiles were evaluated . The first (type 2) has a woven structure of 3.0 mm by 2.0mm size openings . It has a nominal thickness of 0.44 mm and an average weight of 63.5 gm/m2 . The second (type 3) had also woven structure with 0.02 mm by 2.0 mm openings . Its nominal thickness was 0.20 mm and its weight was 70.0 gm/ m2 . One geonet (type 1) was also selected for comparison . It had 11.0 mm by 11.0mm openings , 3.10 mm thickness and an average weight of 728.0 gm/m2 . All geosynthetics thicknesses were measured unloaded ; i.e., at zero over

-burden pressure. Also the three reinforcing materials were stored and tested at room temperature, 25±2 °C. Other routine testing of geosynthetics such as degradiation with time, puncture resistance, resistance to chemicals and resistance to temperature change were out of the scope of this research. A specially designed 152.4 mm ring was manufactured to fix the reinforcing material in a C.B.R. mold for testing. Load - penetration relation for types 1, 2 and 3 are shown in figure (1) using the same testing plunger and loading rate of standard C.B.R. test. The wide - width tensile strength of different reinforcing materials has been computed, employing the Italian (ENEL) standard equation at different strain levels and are given in table (2) [2].

REPEATED LOAD TESTING PROCESS

Repeated load testing was run on four different groups of pavement sections employing the same subgrade and base materials. One group was prepared without reinforcement and each of the other three groups contained a layer of reinforcement known as type 1, type 2 or type 3 between the subgrade-base interface. In the control subgroup (unreinforced), base thickness and subgrade moisture content were varied at three levels. In other words, sections of subgrade moisture content at 12.3%, 16% and 18% were prepared for each case of base course thickness of 50mm, 100mm and 150mm then tested. For reinforced sections the subgrade moisture content was set at two levels only; i.e., at optimum moisture content (12.3%) and at soaking condition (18%). After preparing a test section, the loading system and the deflection measuring system were installed. The repeated loading was applied on the surface of base whilst the displacements at the pavement surface near the edge of the loading plate were recorded after

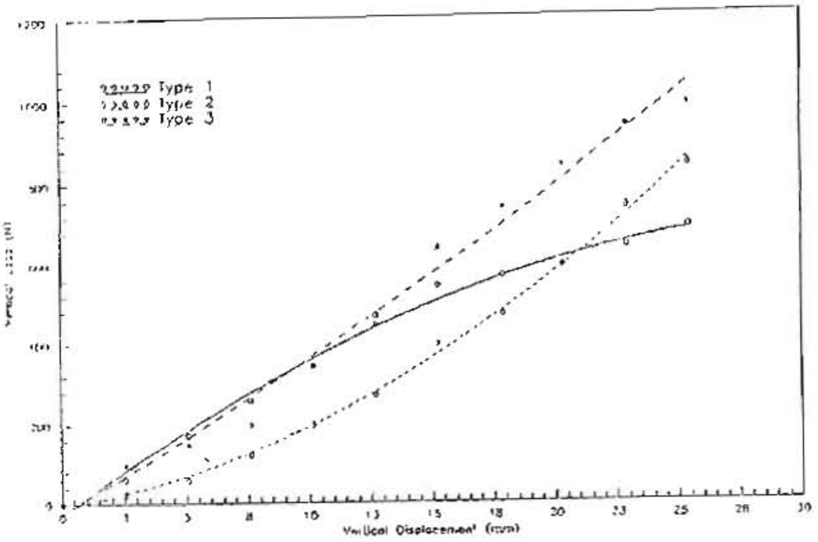

Figure (1) Load - Displacement curves for the Three Types of Geosynthetics in a CBR Test

Table (2) : Computed Wide-Width Tensile Strength of Reinforcement

Type of reinforcement	1% strain (N / cm)	2% strain (N / cm)	5% strain (N / cm)	Ultimate (N / cm)
Geonet (type 1)	11.3	12.6	11.0	12.5
Geotextile (type 2)	5.4	7.0	9.0	13.0
Geotextile (type 3)	8.6	11.5	14.4	14.7

40 , 80 , 320 , 640 , 960 , 1200 , 2000 cycles of load . After finishing one test , the testing mold was carefully excavated . The pavement was cut along the centerline and the materials were excavated from the front door of the mold . The condition of the final base and subgrade were visually impacted .

RESULTS AND ANALYSIS

The C.B.R. values of subgrade without reinforcement as well as with reinforcement employing the three types of geosynthetics are given in table (3).

Table (3) : CBR Values for Different Cases .

Case	Without Rnft		With Rnft After Soaking		
	at O.M.C.	after soaking	type 1	type 2	type 3
% C.B.R.	31	3	20	9	8

When subgrade soil is tested at optimum moisture content , it can be considered as excellent subgrade , since the C.B.R. is 31 . However when soil is soaked , reflecting the case of high ground water table and bad surface and subsurface drainage , the C.B.R. is reduced to 3 . None of the three types of geosyntheticss employed in this research have succeeded in upgrading the C.B.R. of subgrade to its maximum value ; i.e , C.B.R. at optimum moisture content . In other words reinforcing soaked subgrade has raised its C.B.R. value from 3 to 20 , 9 and 8 for type 1 , type 2 and type 3 respectively . As stated before type 1 reinforcement is a geonet of 11mm x 11mm opening and 3.1 mm thickness . It is believed that the larger width of opening and the greater reinforcement thickness mobilized enough friction interlock between the base ,the geonet and the subgrade soil to produce an upward resistance to balance acting vertical load resulting in a higher C.B.R. value ; 20 versus 3 . The other two geotextiles had not enough friction fixation to produce high upward reaction .

Repeated Load Evaluation

Performance of testing section was evaluated to study the effect of repeated loading on pavement displacement for the following conditions :

1 - Unreinforced pavements on subgrade soil prepared at three different moisture contents ; 12.3% , 16.0% , and 18.0% .

2 - Reinforced pavements on subgrade soil at its weakest and at its best condition ; i.e., soaking moisture content (18.0%) and optimum moisture content (12.3%).

3 - For the above two conditions , pavement thickness was variated .

Effect Of Subgrade Moisture :

A typical relationship between surface rutting and number of load repetitions for unreinforced sections are presented in figures (2 , 3 , 4). In all figures the surface rutting (displacement) increased with increasing the number of load repetitions . However , The rate of displacement decreased . A large percentage of the total surface rutting after 2000 load repetitions occured shortly after test begining . The thicker the pavement the larger the number of load repetitions needed to produce 50% of the final displacement . The thicker the pavement the smaller the subgrade settlement and the larger the pavement displacement

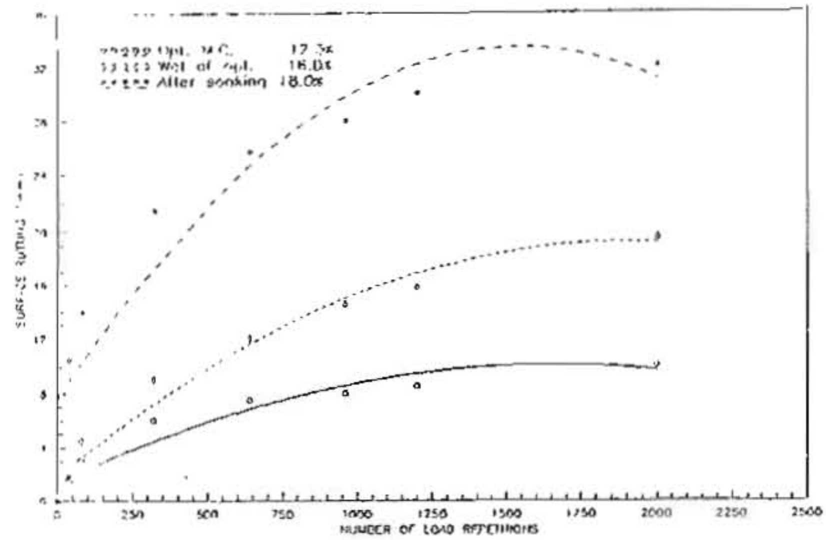

Figure (2) Effect of Subgrade Moisture Content on Progressive Surface Rutting , Witout Reinforcement (Base Course = 50 Mm)

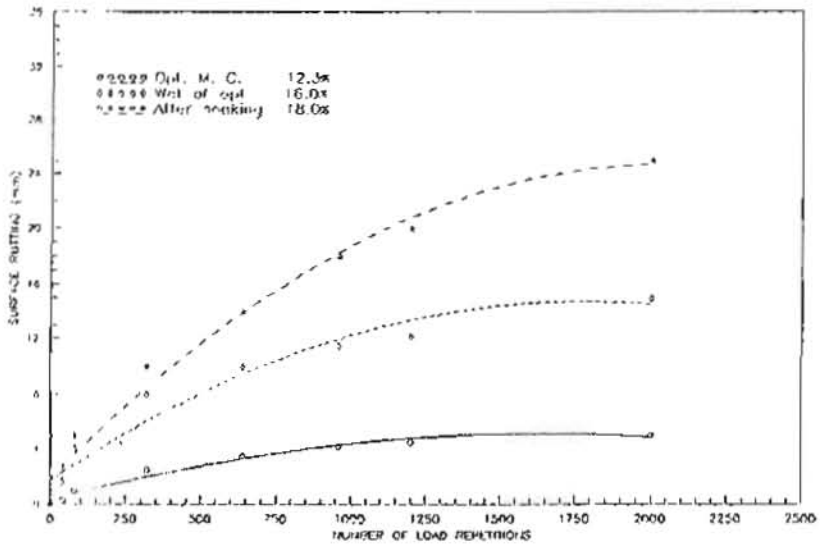

Figure (3) Effect of Subgrade Moisture content on Progressive Surface rutting , Without Reinforcement (Base course = 100 mm)

As shown in figures the wetter the subgrade moisture content from optimum the larger the surface rutting . The total surface rutting for subgrade after soaking was about 3.0 , 5.0 , and 5.5 times that at O.M.C. for 50 mm , 100 mm and 150 mm base thickness respectively . These numbers clarifies the moisture sensitivity of that type of subgrade soil (silty sand) to moisture saturation . Also , for three cases of subgrade moisture the thicker the pavement thickness the lower the value of surface rutting (displacement) . For example , after 2000 load repetitions ,surface rutting of pavement on subgrade after soaking was 32mm , 25mm and 11mm for base thickness of 50mm , 100mm and 150mm respectively .

Effect Of Subgrade Reinforcement :

Same observations , as for control section, related to large values of initial displacement and the decrease in rate of displacement by time are experienced when testing reinforced subgrade . In general , a relatively slight improvement in surface rutting is achieved when a layer of reinforcement is introduced between subgrade at optimum moisture content and pavement layer . When subgrade was at optimum moisture content , the improvement is less than that at soaking condition , comparing figure (5) to figure (6) .

When subgrade was at weaker condition; i.e., after soaking , the effect of reinforcement was more pronounced as shown in figure (6) , specially when the larger number of load repetitions increased. In this figure and for a pavement thickness of 50mm , surface rutting after 2000 load repetitions when employing a geonet (type 1) was 24mm compared to 32mm when unreinforced . The other two geotextiles reduced surface

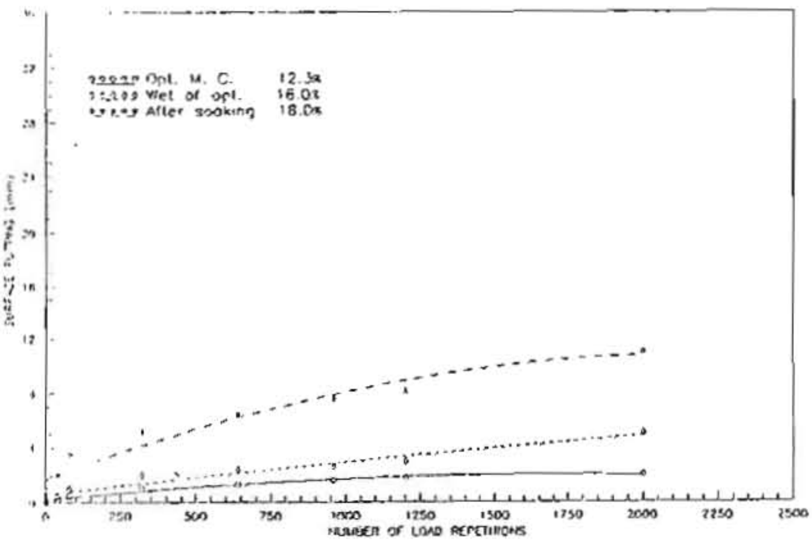

Figure (4) Effect of Subgrade Moisture Content on Progressive Surface Rutting, Without Reinforcement (Base course = 150 mm)

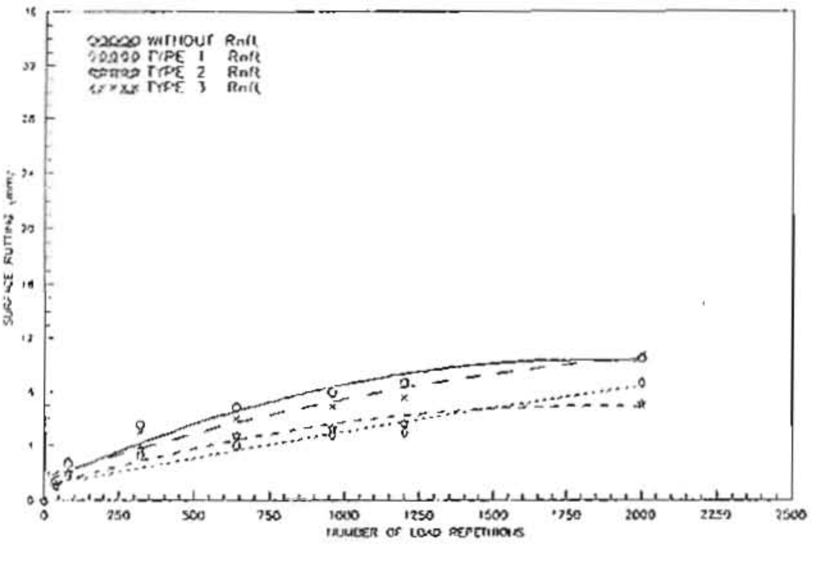

Figure (5) Effect of type of reinforcement on progressive surface Rutting for Subgrade at OMC (Base course = 50 mm) rutting to 26mm for type 2 and 28mm for type 3 after 2000 load repetitions .

When pavement thickness was increased to 100mm a better improvement in surface rutting was gained . Although the three types of reinforcements acted almost equally a greater reduction in surface deformation is achieved . As shown in figure (7) ; base course = 100 mm , the effect of reinforcement was more pronounced after larger number of load repetitions . At 2000 load repetitions the surface displacement for unreinforced pavement was 24 mm compared to 8 to 10 mm for a reinforced pavement .

Generally and as many researches concluded , a geosenthetic layer between subgrade and base facilitated better distribution of surface load resulting in lower displacement of subgrade (3) . In figure (6) for a base of 50mm thickness , when surface rutting for control section was 24mm after about 675 load repetitions , employing any of the three types geosynthetics reduced surface rutting to 70 to 80% of control section value . After 2000 load repetitions the reduction was 75 to 90% . Moreover , when base thickness was 100mm surface rutting was reduced to about 40% of control section value after 2000 load repetitions , this may be because of the better friction between reinforcing material and subgrade achieved from bigger surcharge load of thicker pavement .

Comparing figures (3,6) , one can observe that surface rutting of unreinforced 100mm base is lower than that of reinforced 50mm base pavement up to 2000 load repetitions . May be if test had been extended after that number of load repetitions a geonet reinforcement would have provided better performance . The same observations apply when comparing unreinforced 150mm base to reinforced 100mm base, as in figures (4,7) . After 2000 load repetitions surface rutting of unreinforced

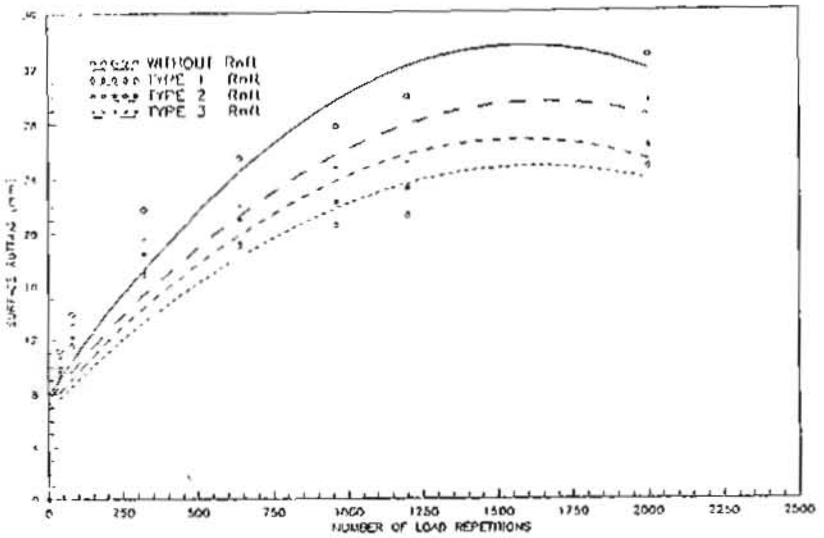

Figure (6) Effect of Type of Reinforcement on Progressive Surface Rutting for Subgrade at Soaking Condition (Base course = 50 mm)

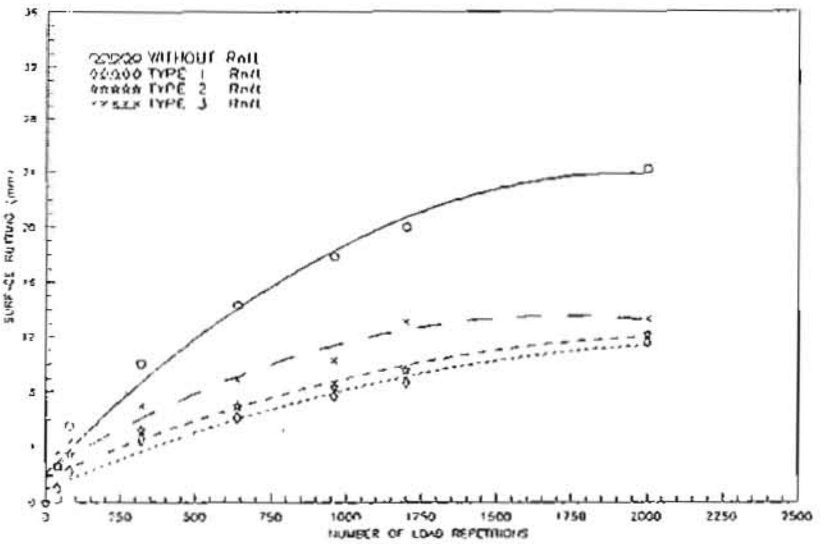

Figure (7) Effect of Type of Reinforcement on Progressive Surface Rutting for Subgrade at Soaking Condition (Base course = 100 mm)

150mm base is 11mm while it is 11mm , 12mm and 13mm for 100mm base with type 1 , type 2 and type 3 reinforcement , respectively .

CONCLUSIONS

Based on the materials used , testing methods followed and data available , the following conclusions can be drawn :

1- Evaluating reinforcing geosenthetic materials in highway applications employing static types of testing ; i.e. C.B.R. test , can be misleading . The performance of these materials under repeated loading (simulating actual condition) is more realistic; however , both tests are recommended .

2- A geonet is better than a geotextile as a reinforcing material. A geotextile may act mainly as a separation layer in a pavement system .

3- Improving the draining quality of a subgrade soil provides better improvement in reducing surface rutting than employing an additional layer of reinforcement . Cost comparison must be considered in a decision making .

REFERENCES

1 - Sakr , H. And G. Hady " Evaluation of Non-Woven Geotextiles Reinforced Clayey Sub-grade using the C.B.R. test , " 1st international conference , Transportation Dept. , Alexanderia , Egypt , April 1992 .

2 - Koerner , R. , " Designing with Geosenthietics , second edition " Prentice Hall , Englewood Cliffs , N.J. 1990 .

3 - Giroud , J. P. , and I . , Noiray " Geotextiles - Reinforced Unpaved Road Design " , Journal of the Geotechnical Engineering Division , ASCE , Sept. 1981 , pp. 1233 - 1254 .

4 - De Gardiell , R. , and E. Javor , " Mechanical Reinforcement of Low Volume Roads by Geotextiles " proc. 3rd International Conference on Geotextiles , Vienna , Austria , 1986 .

5 - Resl , S. and G . Wener " The Influnce of Non-Woven Needle Punched geotextiles on the Ultimate Bearing Capacity of The Subgrade " , proc, 3rd International conference on geotextiles , Vienna , Austria , 1986 .