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Effect of Geotextile Reinforcement on Flexible Pavement Roads

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ABSTRACT

A field full scale flexible road is constructed and the effects of geotextile reinforcement in paved road are tested by measuring the occurred rutting. The effect of different numbers and positions of geotextile reinforcement using seven road sections are evaluated and compared with unreinforced pavement section. It is found that a maximum reduction of rut depth is 96% when using three reinforcement layers at three different road layers interfaces, and a minimum reduction is 52% when using one reinforcement layer at interface I (between wearing and binder layers) under the effect of maximum load cycles of 10000. The minimum Traffic Benefit Ratio (TBR= ratio between load cycles on a reinforced section to that of unreinforced section for the same rut depth) is found to be 4 when using one reinforcement layer in the interfaces I , and extremely large values for other reinforcement cases. Once, the above values appear how the service life of the paved road is increased by using geotextile reinforcement.

The cost-benefit analysis is also adopted in this research and found that by using one reinforcement layer the road cost is increased by only 14% resulting in increment value of TBR to 4 (this means that the road life is doubled 4 times if all other circumstances are fixed). This is a minimum case benefit when comparing it with all other cases; it is found that TBR values are exaggerated when different numbers and positions of geotextile reinforcement layers are used.

Keywords: TBR, Geotextile, Road, Reinforcement Position, Rut Depth.

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تأثير التسليح بالمشبكات البوليمرية على الطرق المبلّطة المرنة

الخلاصة

تـم بنـاء طريـق مـرن حقلـي بحجـم كامـل وتـم فحـص اسـتخدام التسـليح بالمشـبكات البوليميريـة (geotextile) فـي الطـرق المعبـدة عن طريـق قيـاس الاخاديـد الحاصـلة (ruts). تـم تقييم تـأثير مختلف اعداد ومواقع التسليح بالمشبكات البوليميريـة باستعمال سبعة مقاطع للطريق ومقارنتها مـع مقطـع طريـق غير مسلح. وجد ان اعلى نسبة لنقصان عمق الاخدود هو 96% عند استخدام ثلاثـة طبقـات تسليح بثلاثـة مناطق فاصـلة بـين طبقـات الطريـق, واقل نسـبة نقصـان هـي 52% عنـد اسـتخدام طبقـة تسـليح واحـدة فـي المنطقة الفاصـلة I (بين الطبقتين السطحية والرابطة) تحت تأثير اقصى عدد دورات للحمل هو 10000 . وجد ان اقل نسبة للاستفادة المرورية (TBR = النسبة بـين عـدد دورات الثقل للمقـاطع المسـلحة الـى تلـك الغير مسلحة لنفس عمق الاخدود) كانت 4 عند استعمال طبقة تسليح واحدة في الموقـع I , وبقيـة القيم عاليـة جدا فـي حـالات التسـليح الاخـرى. ان القيم اعـلاه تظهـر كيفيـة زيـادة العمـر الخـدمي للطريـق المعبـد عنـد استخدام مشبكات التسليح البوليميرية.

كذلك تم اعتماد تحليل الكلفة والفوائد في هذا البحث ووجد ان استخدام طبقـة تسليح واحدة, فـان كلفـة الطريق تزداد بنسبة 14% وهذا يؤدي الـى زيـادة قيمـة (TBR) الـى 4 (وهذا يعنـي ان عمـر الطريـق قـد تضاعف 4 مرات اذا كانت جميع الظروف الاخرى ثابتة). ان هذه الفائدة هي الحد الادنى عند مقارنتها مع بقيـة الحـالات حيث وجد ان هنالك تعـاظم فـي قيم (TBR) عنـد استخدام أعداد ومواقع مختلفـة لطبقـات التسليح البوليميرية.

INTRODUCTION

The application of vehicular load to a flexible pavement results in dynamic stresses within various pavement components [1]. As vehicular loads are repeatedly applied, permanent strain is induced in all layers of flexible pavements and accumulates as traffic passes grow, which leads to rutting of the pavement surface. The rutting appears at the surface of flexible pavement can be caused by shear deformation within bituminous mixtures and/or by plastic deformation in the underlying unbound layers (foundation, subsoil ….etc.) [2].

Bertuliene et al. (2011) [3] indicated that Ruts otherwise called a wheel path, are one of the most frequent defects of asphalt pavement which related to shear strains are difficult to be calculated and modeled due to the following difficult obstructs; material characteristics relation is too complex, dependent, and non-linear, permanent changes of material properties under the effect of dynamic loads and temperature. Many others (Perkins and Islamic (1997) [4], Al Saadi (1997) [5], Benjamine et al. (2009) [6], Moayedi et al. (2007) [7], and Holtz et al. (1998) [8]) used geosynthetic reinforcement into unpaved and paved flexible roads. They concluded that in most cases, reinforcement improves the performance of transportation support due to improving the effective bonding between asphaltic concrete and geosynthetic, prevention of local shearing of sub base and subgrade, and also improving load distribution through the base coarse, reduction or reorientation of shear stresses of the subgrade and tension membrane effect, increase bearing capacity of the subgrade, stiffens the base layer by reducing normal stresses. Giroud et al. (1984) [9] Stated geosynthetic restricts lateral movement of the base course material and subgrade and can provide tensioned membrane support where deep rutting occurs.

Benjamin et al. (2009) [6] and Christopher (2010) [10] investigated the improvement of flexible roads when geosynthetic reinforcement placed at the interface between sub base and subgrade layers. Whereas, many others (Zomberge and Gupta (2010) [1], Christopher (2010) [10] and Perkins et al. (2009) [11]) studied the behavior of flexible paved road under the effect of the reinforcement placed at the bottom of the base layer. Other researchers (Moayedi et al.(2007) [7], IGS (2006) [12], Laurinavicius and Oginkas (2006) [13] and Grawbowski and Pozarycki (2008) [14]) investigated the properties changes of flexible pavement when the reinforcement is placed within asphaltic concrete layer or between the interface of any two consecutive layers or between asphaltic and granular aggregate layers.

Since Al saadi (1997) [5] there are a few serious laboratorial modeled studies and no full scale in-ground field test is achieved in Iraq. To simulate a true effect of truck load cycles and to investigate the flexible paved road response, a full scale field road constructed by using several cases of geosynthetic reinforcement (seven cases in current study) with available construction materials. The development in this study, one or more reinforcement sheets are ubiquitously used and the resulting asphaltic pavement response is observed.

Goals

In the middle and south Iraqi roads, a permanent deformation is the major problem encountered in flexible pavement roads which may be attributed for one or more reasons such; high summer temperature, truck heavy axle load; method of design, pavement constructed materials, construction priorities, compaction, and testing technology. The following main goals are undertaken in this research.

1- The effect of geotextile reinforcement on light paved roads is aimed to be investigated.
2- Cost-benefit study is developed to evaluate the use of geotextile reinforcement in flexible paved roads.

METHODOLOGY OF THE WORK

A temporary roadway is designed and constructed in the field to allow some rutting to be occurred over a visible life of flexible road to save time and labor. Several steps are followed in this research; they are:-

1- Field geotextile reinforcement with Iraqi construction materials are used to construct the field model show in Figure (1).

2- Seven reinforcement cases is suggested for better understanding of flexible pavement road behavior for the expected dynamic axle loads are positioned in interfaces I,II&III as shown in Figure (2).

MODEL CONSTRUCTION AND TESTING

A full scale field flexible pavement road of 28m long and 4.6m wide is carefully constructed and trafficked to compare the relative performance of each individual section B, C, D, E, F, G, H, and I as shown in Figure (1) against the applied dynamic axle loads. Each section of the pavement road is suggested to be reinforced with geosynthetic Reinforcement. For instance, for zone-B of Figure (1), reinforcement layer is placed in the interface between the wearing and binder layer namely (I). To facilitate reinforcement methodology of each section of Figure (1), Table (1) shows the details of how each section has been reinforced.

The road section of field model shown in Figure (1) is connected with 1m paved and 5m unpaved straight road sections to facilitate vehicle entrance and exit and to avoid the unfavorable effects of impact, wheels torque due to turning, and vehicular acceleration and/or deceleration. The end limps of straight road of Figure (1) is completed with two unpaved circular roads of 22m outer diameters and provided with supper elevation to aid in vehicular rotation without deceleration and/or acceleration.

The distance of each truck travel (load cycle) is about 90m.This offer cycle time about 13sec. (equivalent to 275 truck pass/hr) when average truck speed rate is 25km/hr.

10^4 truck cycles were done in two weeks during June, 2012. This trafficking time is chosen for highest temperature rates in Iraq (average temperatures of $43C^0$) to investigate the effect of worst case of road pavement rutting [15].

Preliminary preparation are undertaken for the field site such as cleaning, land leveling and grading by using lightweight grader, unrolling and fitting of the geotextile rolls according to the design section of the model of Figures (1&2) before any testing. Textile rolls are spread and overlapped (400mm) manually (geosynthetic overlap in between (300-450mm) when CBR of subgrade soil is $\geq$ 3% [12]).

The meshes of the geotextile rolls Figure (3c) are fixed to be in contact pavement layer surfaces by anchored pins (for soil surfaces) or hilted screws (for paved surfaces) at a rate of $2/m^2$.

Tack coat at interface I and prime coat at interface II are spread according to Iraqi specification [16]. After the geotextile mesh has been placed, tack and prime coats are added to improve bonding of contacting surfaces. Back dump of base materials and spread it to the design thickness and compact it. Asphaltic binder and wearing materials are provided and spread using spreader machine. The required properties for the whole model construction are compared with Iraqi specifications [16].

LOADS ANALYSIS

The analysis of loading is conducted by vehicle of tandem axles having a dual tires rear axle and a single tire front axle. The truck is overloaded with 98kN rear axle and

49kN front axle which lead to load of 24.5kN for each wheel. According to tire size, it is found the pressure of each is 830kPa (120psi).

RUT MEASUREMENTS

Traverse measurements of uplift and down-lift ruts across road sections are taken during trafficking for every 1000cycles by installing 100mm mechanical dial gauge of

0.1mm sensitivity. This gauge is provided by additional 76mm extension part to be used for reading of rutting in control section.

To obtain higher accurate dial indicator readings in the period of the test, a rigid iron beam Figure (3d of 4.6m) is provided with a uniform stable support for the dial indicator and can be easily positioned and locked for each 100mm on the beam. Each side of the beam has two legs which set at constant, limited, and previously leveled points at each end of cross section. The dial readings for each section are 45, one in the road centerline and 22 for right and left sides.

FULL SCALE ROAD CONSTRUCTION & STRATIFICATION

Very light traffic flexile roadway plan and section Figures (1&2) and photos Figures (3a, b) is designed to facilitate testing process. The model cross-sectional profile is consisted of the following layers:-

- 50mm of asphaltic wearing layer with nominal aggregate size of 12.5mm.
- 70mm of asphaltic binder layer with nominal aggregate size of 19mm.
- 180mm of gravel and sand mix base layer of nominal aggregate size of 37.5mm.
- Infinity depth of ordinary in-situ weak subgrade soil.

Some testing properties of the above layers materials are listed in Tables (2, 3).

The reinforcement used in this study is the geotextile of aperture size 34mm in vehicle direction and 24mm across vehicle direction. Some properties of geotextile are listed in Table (4).

The laboratory CBR test for the base layer is conducted according to ASTM (1987) [17] using 24hr saturation time, it is found to be 25%, Whereas the field CBR of the subgrade soil according to SOIL TEST (1967) [18] is found to be 3% , it is also found that the moisture content, Liquid Limit, and Plasticity Index of 18%, 48%, and 22% respectively. The filler (1.5% of total aggregate weight) is also used with Ordinary Portland Cement.

RESULTS AND DISCUSSION

Figures (4-11) present the field rutting measurement of the reinforced and unreinforced pavement road sections. The rutting values reflect the effect of geotextile reinforcement with seven different positions by comparing with control pavement section (section with no reinforcement or Nile). These figures are show the difference in rut area, shape changes, and sections (deformation) behavior under the effect of load cycle variation. The values of up-lift, down-lift and total ruts are summarized in Table (5) and represented graphically in Figures (12 and 13). Table (5) reveals how these ruts are exaggerated under the effects of number load cycle repetitions (N). Figure (12) presents the relation of rut depth versus different numbers and positions of geotextile reinforcement. To illustrate this, consider for instance the load cycle 10000. The curve shows a high reduction in rut depth in case of one or more reinforcement layer is used,

this from one hand. It is also found the position of reinforcement layer has also a major effect on reduction of rutting values and increasing the economical road life.

Figures (12 & 13) indicate that when one reinforcement layer is positioned at interface II, there are some improvements of road performance but less than that if it is positioned in the interface

III. Rutting has been induced and accumulated the lateral strain permanently in the base aggregates as traffic load cycles are proceeded.

In case of reinforcement position in the interface I, the effect of the reinforcement on rutting reduction is too little comparing it with the positions of reinforcement in the interfaces II and III. This is attributed to that the reinforcement of interface I provide Lateral traverse resistance due to frictional and interlocking forces between geotextile sheet and bottom of

Wearing layer. This position of reinforcement reduces the physical activity of the geotextile sheet. Fortunately, this position increases membrane support of wheel loads and the bearing capacity of failure zones within the considered pavement layers to enhance the shear strength of the interface I [10].

Figures(12, and 13) Also indicate that in case of using two reinforcement layers (in three different positions I+II, I+III, and II+III) or three reinforcement layers, the interpretation to this is that the pavement behavior under the effect of simultaneous employment of the three positions of geotextile reinforcement is too complex to be understood. This is attributed that there is an accumulative improvement that occurred ubiquitously due to the placement of the three reinforcement layer in the considered interfaces.

By using Traffic Benefit Ratio TBR (TBR = N_R/N_u Where N_R = No. of load cycles on a reinforced section, N_u = No. of load cycles on unreinforced section for the same rut [19]) for rut depth= 45mm, as in Figure (12), it is found that TBR= 4, 6.3 for one layer in the interfaces I, and II respectively, and extremely large values for other reinforcement cases. Once, the above values reveals on how the service life of the paved road is increased by using geotextile reinforcement.

By using, Table (6) and Figure (14), to analyze the cost-benefit of using geotextile reinforcement in paved road, it is found that (for rut depth=45mm) by Using one reinforcement layer leads to increase the road cost by only 14% but it is found that the corresponding increment in TBR is 4. This is the minimum benefit in this case by comparing it with all other cases including different numbers and positions of reinforced layers. This means that an exaggerated TBR values is obtained for few increment of reinforced road cost.

CONCLUSIONS

The followings may be concluded in this research:-

1- Multi-geotextile reinforcements of paved road offer less rutting than single geotextile reinforcements.

2- Triple reinforcement layers, namely (I+II+III) reduces the amount of rutting depth by 96%.

3- Interface III reinforcement is best case to reduce Rutting if a single reinforcement layer is used. The cost increasing of 14% results in rutting reduction of 85%.

4- If two layers of reinforcement is used, II+III reinforcement interfaces is the best case since it offers rutting of 93% whereas, the increasing in cost is 28% by comparing it with the control section (Nile).

5- If three layers of reinforcement is used, I+ II+III reinforcement interfaces offers rutting of 96% whereas, the increasing in cost is 42% by comparing it with the control section (Nile).

6- For 45mm rut depth, a significant increase in TBR is occurred of 4, 6.3 for one layer of interfaces reinforcement I and II respectively. This can be attributed that road service life doubled 4 and 6.3 times in case I and II interfaces respectively when other circumstances are fixed.

REFERENCES

[1]. Zomberge, J. G. and Gupta, R., “9th International Conference on Geosynthetic” Brasil., (2010).

[2].Asphaltic, Acadamy, “Technical Guideline:Asphalt Reinforcement for Road Construction, TG#, 1st ed. (2008).

[3]. Bertuliene, L., Oginskas, R. and Bulevicius, M., “Research of Rut Depth in Asphalt Pavement Reinforced with Geosynthetic Materials”, the 8th International Conference of Environmental Eng., (2011).

[4].Perkins, S. W. and Islamic M., “ A synthesis and Evaluation of Geosynthic-Reinforced Base Coarse Layer in Flexible Pavements” Part I, Experimental Work, Geosynthetic International, Vol.4, No.6, pp 549-604, (1997).

[5]. Al Saadi, A.H.M., IMPROVEMENT OF EARTH SLOPES BY REINFORCEMENT, Phd. Thesis, Eng. College, Baghdad Unv., Iraq., (1997).

[6]. Benjamine, C. U., Bueno, B. and Zomberge, J. G., “Design of Soil-Fabric-Aggregate System”, T.R.R. 671, PP 64-75, (2007).

[7]. Moayedi, H., Kazemian, S., Prasad, A. and Huat, B.K., “Effect of Geogrid Reinforcement, Location in Paved Road Improvement” EIGE, Vol.14, Bund.P., (2009).

[8]. Holtz, R. D., Christopher, B.R. and Berge, R.R., “Geosynthetic Design and Construction Guidelines”, U.S. Department of Transportation, Fedral Highway Administration, Washington, DC, FHWA-HI-98-038, P.460., (1998).

[9]. Giroud, J.B., Ah-Line C., and Bonapate ,"Design of Unpaved Road and Trafficed Area with Geogrids", Polymer Grid Reinforcement, A Conference Sponserd by SERC and Netlon, Ltd., Thomas Telford, (1984).

[10]. Christopher, B. R., "GEOGRIDE IN ROADWAY PAVEMENT SYSTEM", Ph.D., P.E., Nave GmbH&Co.KG and Global Synthetics Pty. Ltd., (2010).

[11]. Perkins, S.W., Christopher B.R., Cuelho E.L., Eiksund G.R., Schwartz C.S. and Savano G., “A Mechanistic-Empirical Model for Base-Reinforced Flexible Pavements”, International Journal of Pavement Engineering, Vol.10, No.2, PP 101-114, (2009).

[12]. IGS, IN-GROUND TEST FOR GEOSYNTHETIC REINFORCED FLEXIBLE PAVED ROADS, Guide to the specification of Geosynthetic, South California 29642, USA, (2006).

[13]. Laurinavicius, A., and Oginkas R., “ Experimental Research on the Development of Rutting in Asphalt Concrete Pavements Reinforced with Geosynthetic Materials”, Journal of Civil Eng. Management, Vol. XII, No.4, PP. 311-317., (2006).

[14]. Grawbowski, W. and Pozarycki A., “Energy Absorption in Large Dimension Asphalt Pavemet Samples Reinforced with Geosynthetics” Foundation of Civil Environmental Eng., No.11, (2008).

[15].Al Gebury, H.M., APPLICATION OF CREEP TEST FOR PREDICTION RUTTING IN LOAD ASPHALT MIXTURE, M.Sc. Thesis, College of Eng., Univ. of Babylon, Iraq, (2006).

[16].NCCL, MATERIALS SPECIFICATION AND CONSTRUCTION WORKS, Baghdad, Iraq, (2001).

[17]. ASTM, ANNUAL BOOK OF ASTM STANDARD, USA. , 1987.

[18]. SOIL TEST, SOIL TEST Inc. General Catalog, USA. ,(1967).

[19]. Berg R.R., Christopher B.R. and Perkins, S.W., “Geosynthetic Reinforcement of the Aggregate Base/Subbase Courses of Pavement Structures GMA White Paper II, Geosynthetic Materials Association, Roseville, MN, P.176, (2000).

Table (1) Definition of the Model Sections Reinforcement.

Section	Naming of reinf. position	Details & Description
A	-	Entrance and Exit Zone
B	I	Reinforcement in the interface between the wearing and binder layers
C	II	Reinforcement in the interface between the binder and the Base Coarse layers
D	III	Reinforcement in the interface between the Base Coarse and Subgrade
E	I+II	Reinforcement of interfaces I and II are used ubiquitously
F	I+III	Reinforcement in interfaces I and III is used ubiquitously
G	II+III	Reinforcement in sections II and III is used ubiquitously
H	I+II+III	Reinforcement in sections I, II, and III is used ubiquitously
I	without Reinforcement	Control Section(Without Reinforcement)
J	-	Entrance and Exit Zone

Table (2) Physical Properties of Asphalt Cement (Al-Nasyria Refinery).

Test	ASTM Definition	Test Result	Iraqi SORB Specification
Specific Gravity	D-70	1.057	-
Ductility	D-113	118cm	>100
Kinematic Viscosity	D-2170	415Cts	-
Penetration	D-5	52	40-50 south of Iraq 50-60 middle of Iraq 60-70 North of Iraq

SORB one part of the National Center for Construction Laboratory (NCCL, 2001)

Table (3) Gradation of Aggregates Results.

Sieve Size	Grading of Road Materials					
mm	Wearing Layer		Binder Layer		Base Layer	
	Result, %	Specification Limits, %	Result, %	Specification Limits, %	Result, %	Specification Limits, %
37.5					100	100
25			100	100	81	75-95
19			85	80-100	-	-
12.5	100	100	69	60-84	-	-
9.5	88	80-100	59	49-74	56	40-75
4.75	60	46-76	40	32-58	43	30-60
2.36	41	28-58	31	23-45	31	21-47
.30	17	8-24	12	8-20	19	14-28
.075	9	4-12	5	3-8	8	5-15

Table (4) Properties of Geotextile Reinforcement*.

Property	Unit	Vehicle Direction	Cross Vehicle Direction
Unit Weight	$gm./m^2$	330	330
Aperture Size	mm	34	24
Peak Tensile Strength	KN/m	17	25
Tensile Strength at 2% Strain	KN/m	5	8
Yield Point Strain	%	9	8

*According to Sinan Factory Properties, Izmir, Turkey

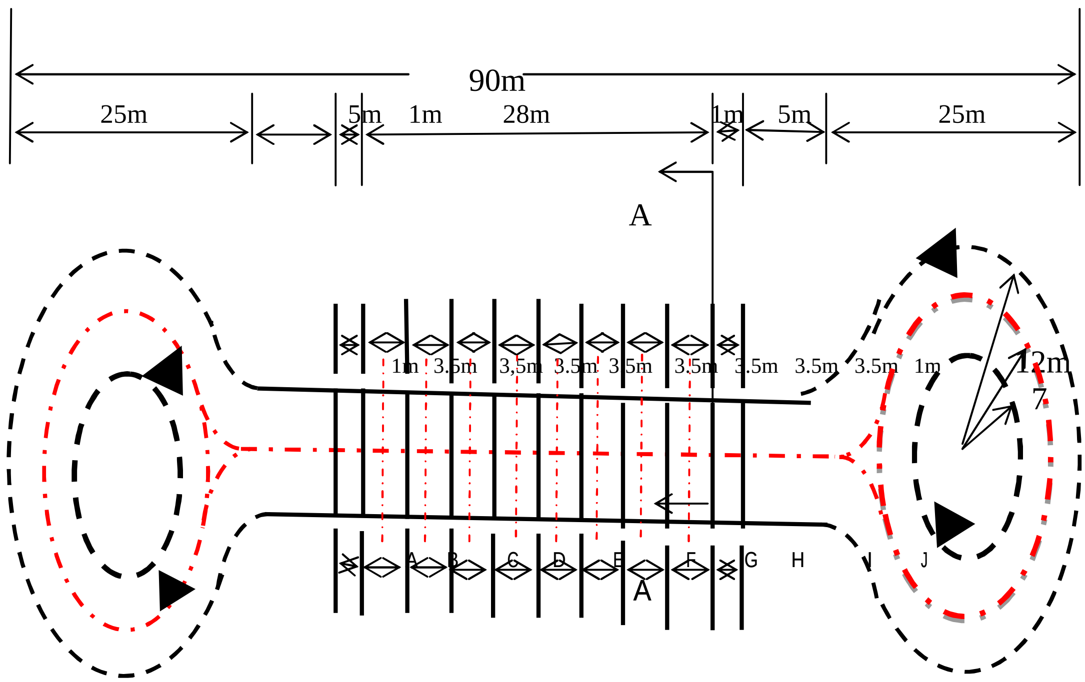

Figure (1) Plan View of Full Scale Flexible Road Model.

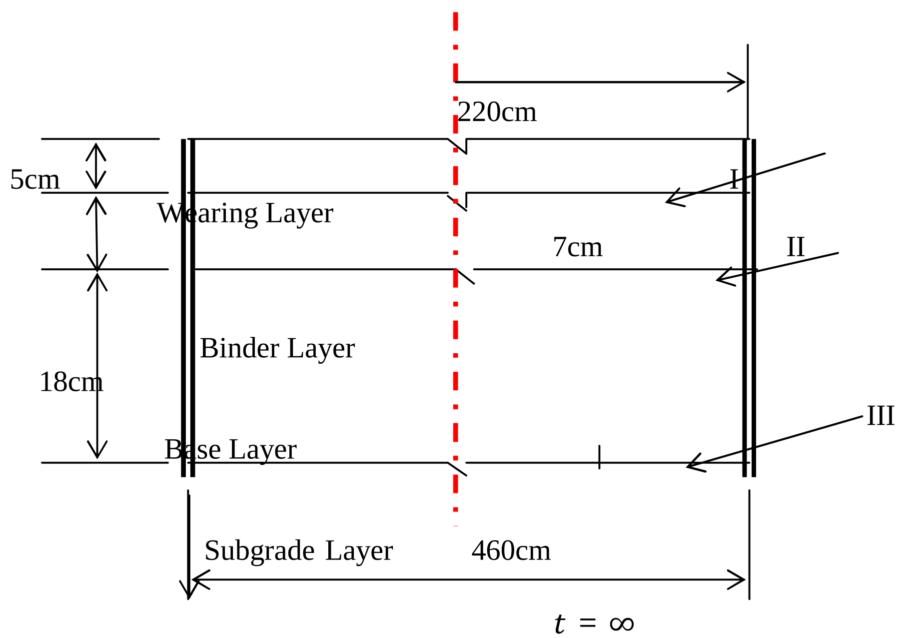

Figure (2) Cross Section A-A (as shown in Figure (10).

a) High Plasticity Subgrade

b) Wearig Layer Layout

c) Geotextile Reinforcement Roll

d) Rigid Iron Beam

Figure (3) Some Site photos.

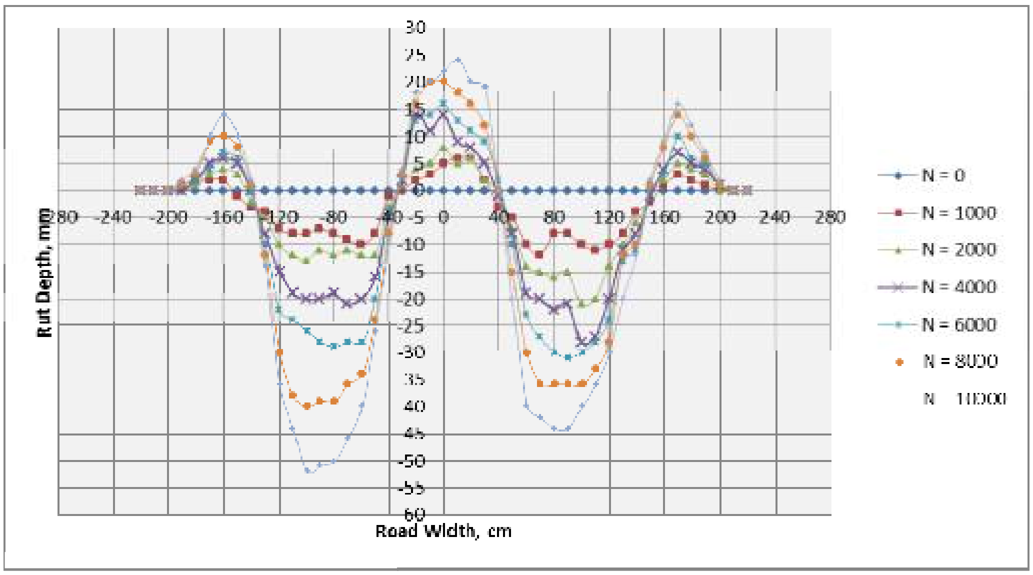

Figure (4) Rut Depth for Interface I

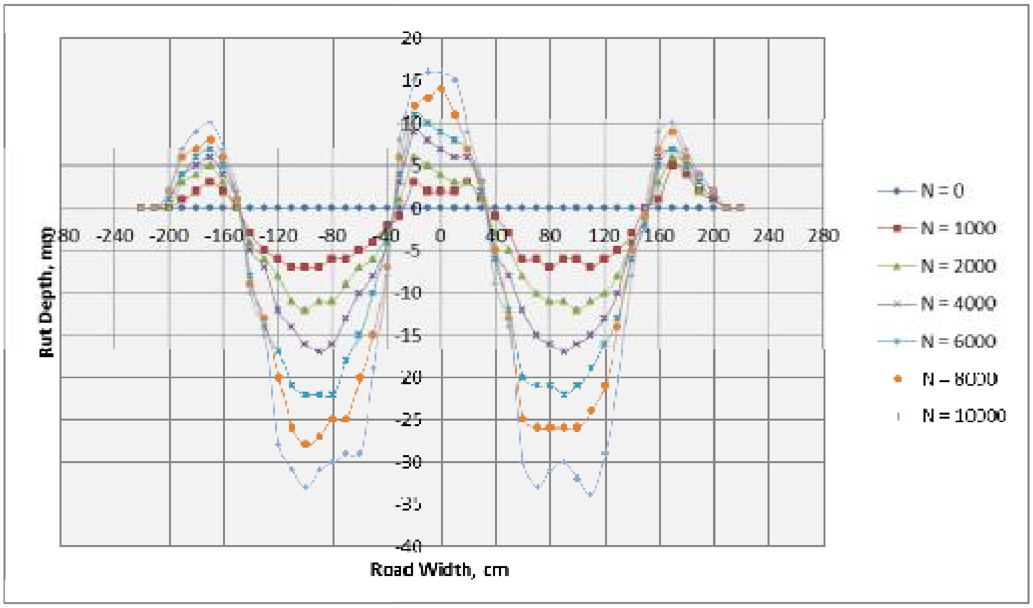

Figure (5) Rut Depth for Interface II.

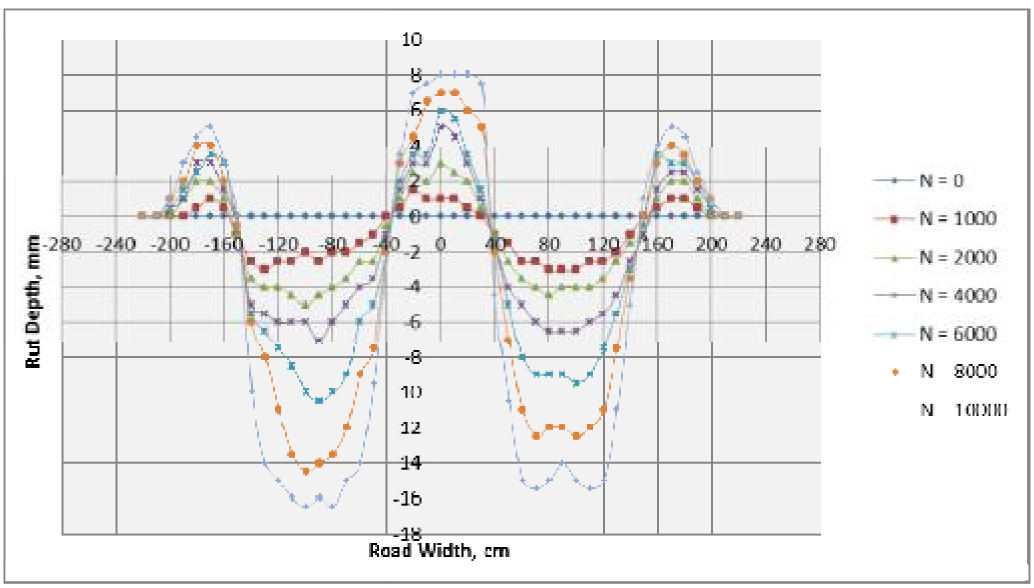

Figure (6) Rut Depth for Interface III.

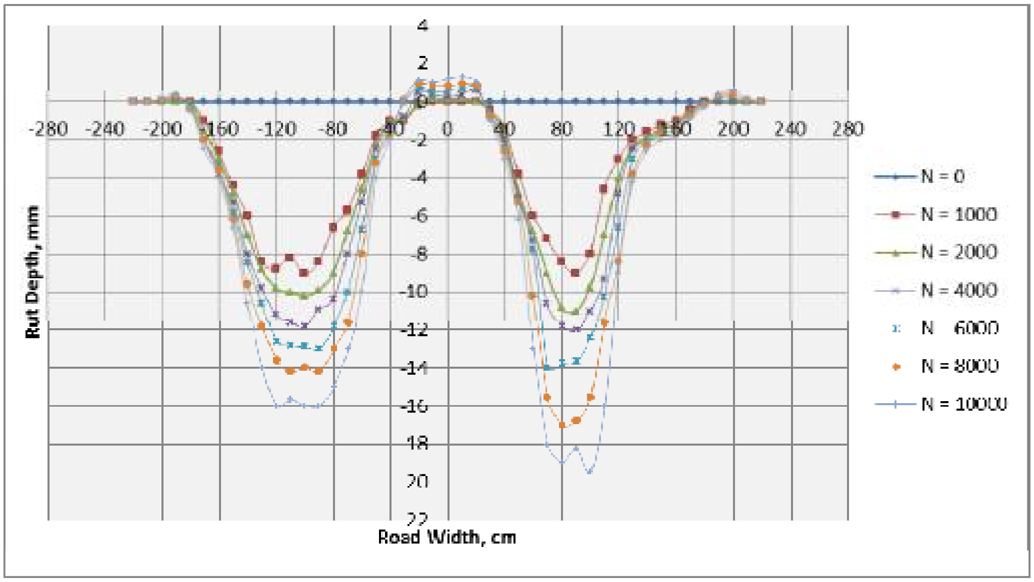

Figure (7) Rut Depth for Interfaces I+II.

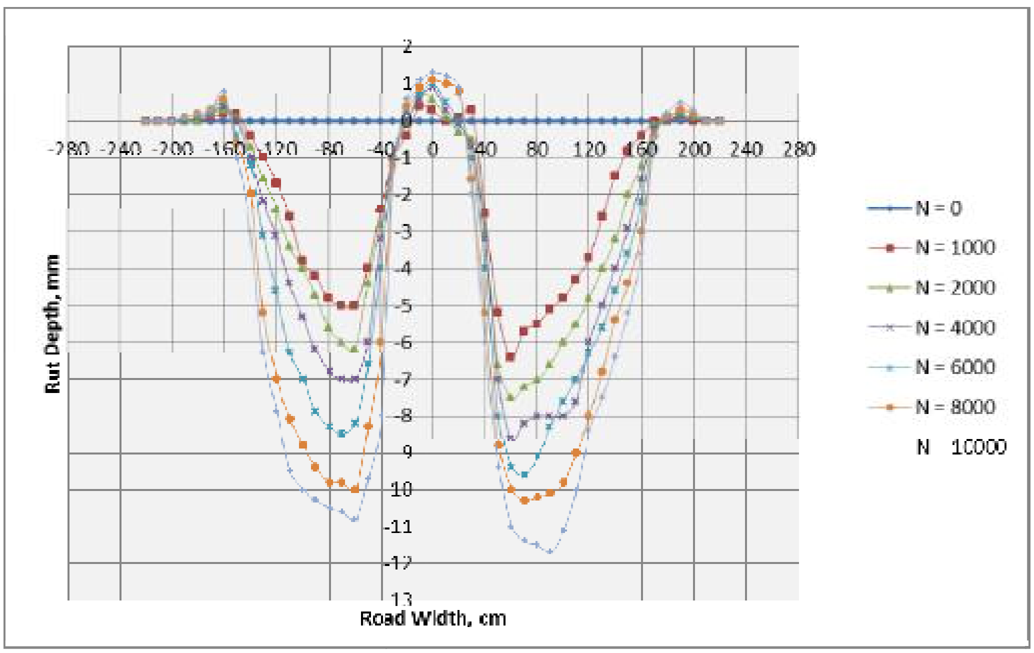

Figure (8) Rut Depth for Interfaces I+III.

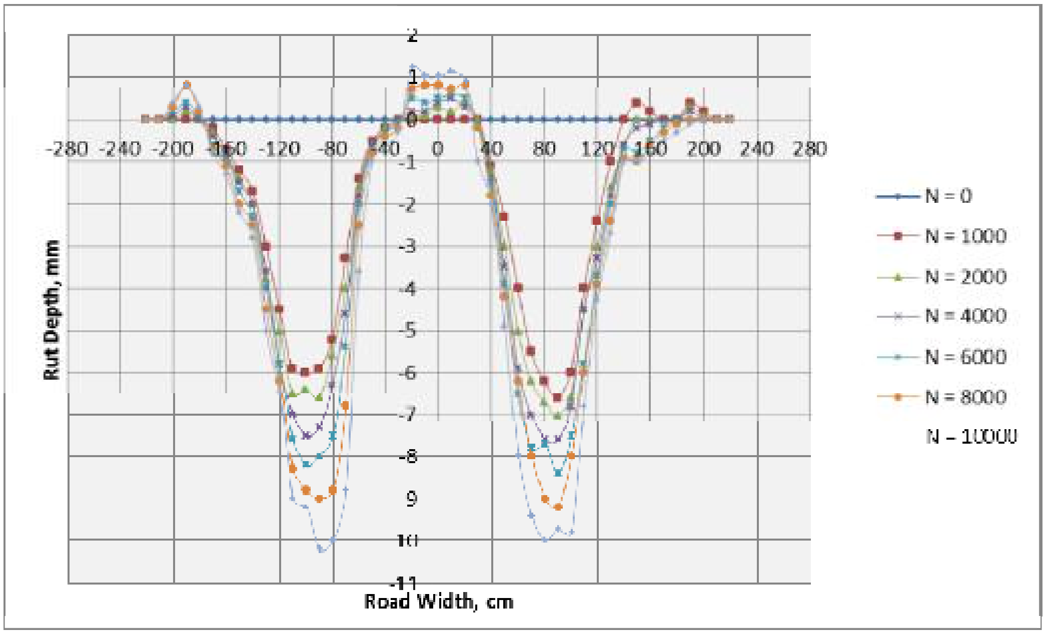

Figure (9) Rut Depth for Interfaces II+III.

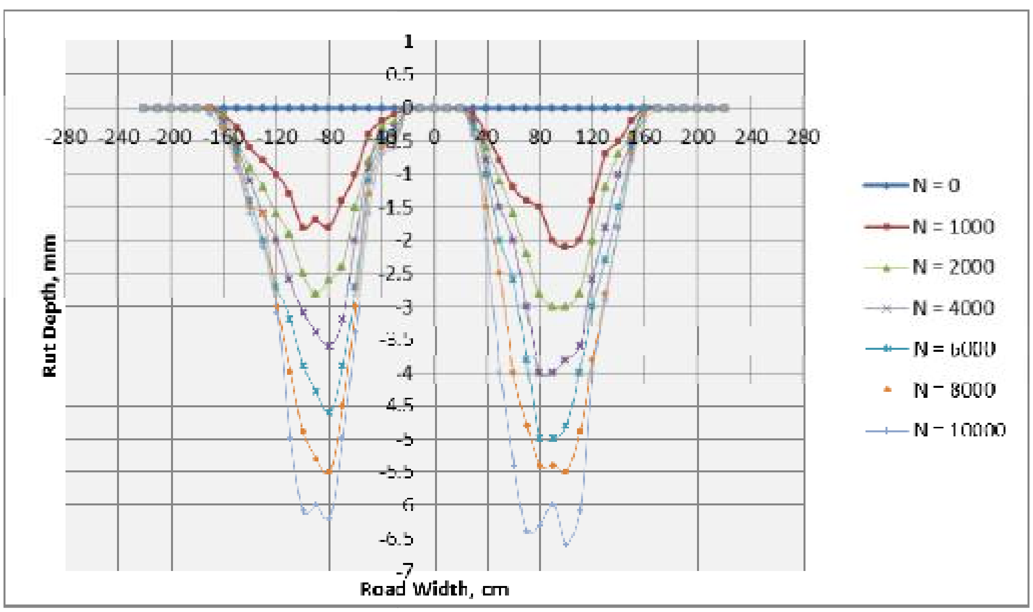

Figure (10) Rut for Interfaces I+II+III.

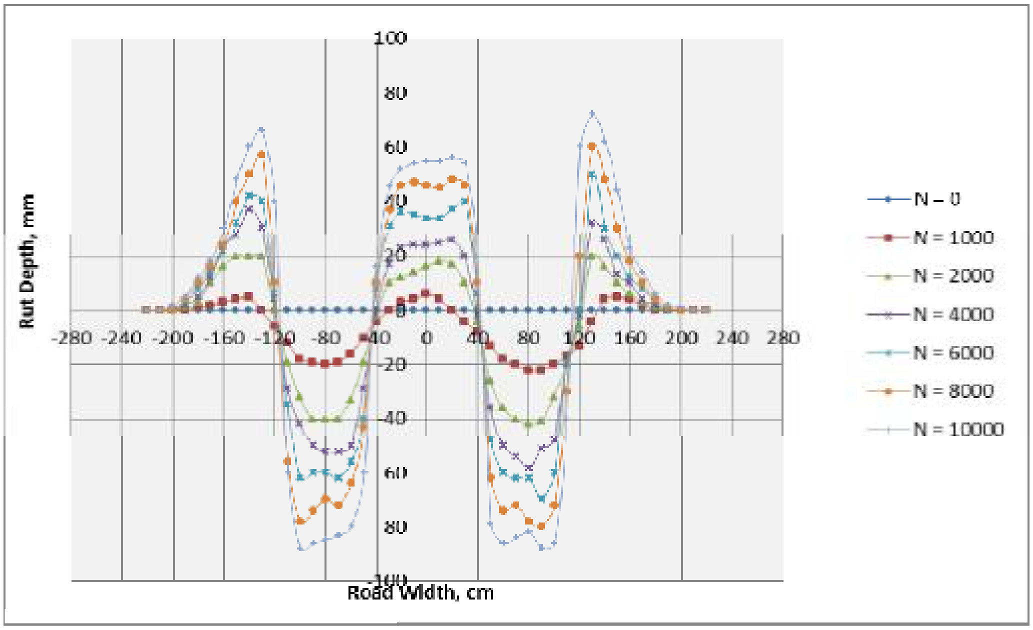

Figure (11) Rut for Control Section.

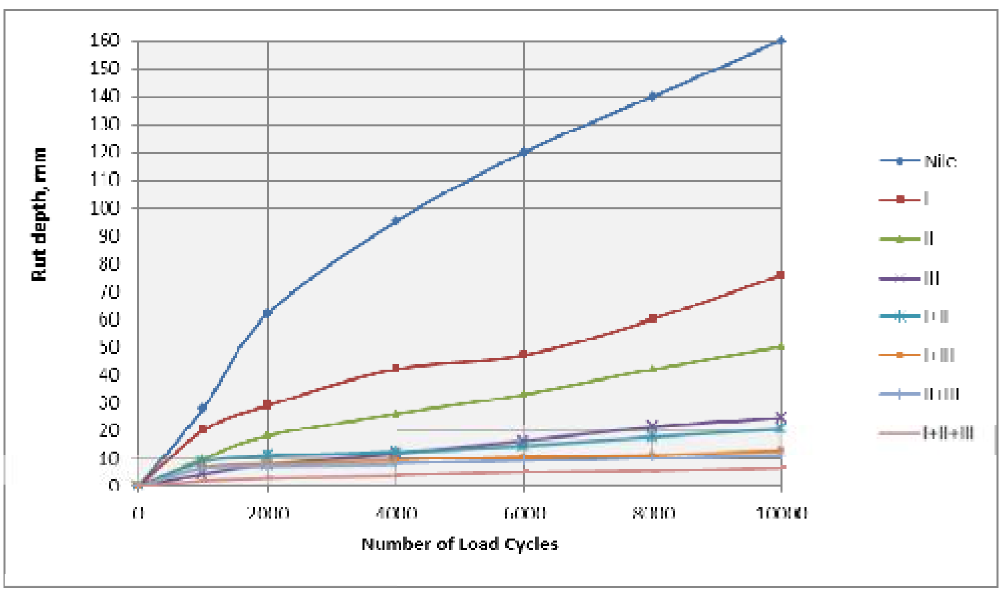

Figure (12) Rut Depth for Different Load Cycles and Interfaces.

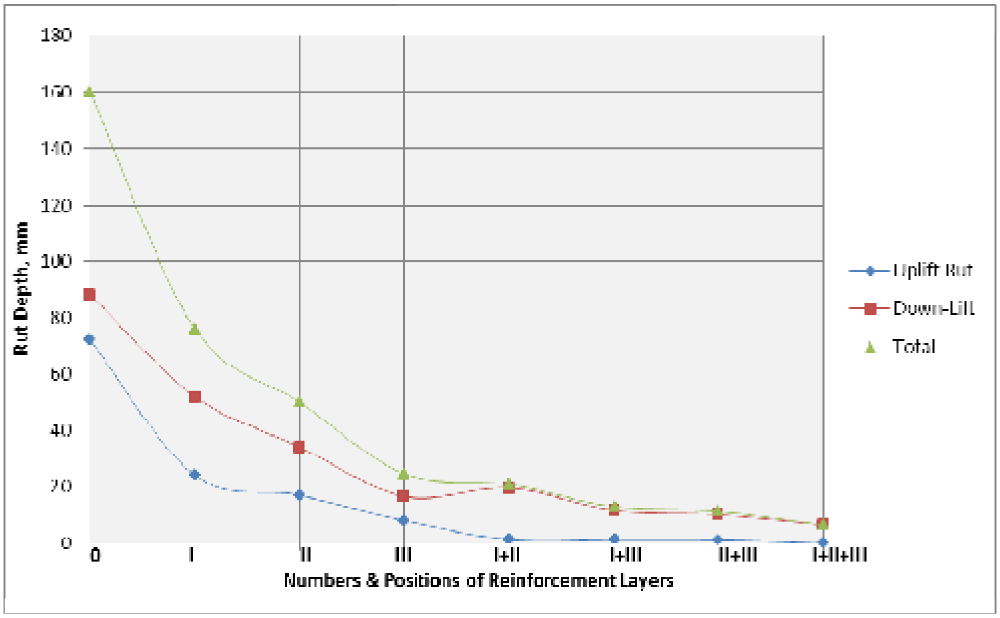

Figure (13) Rut Depth versus Numbers & Positions of Reinforcement Lawyers for Load Cycles=10000.

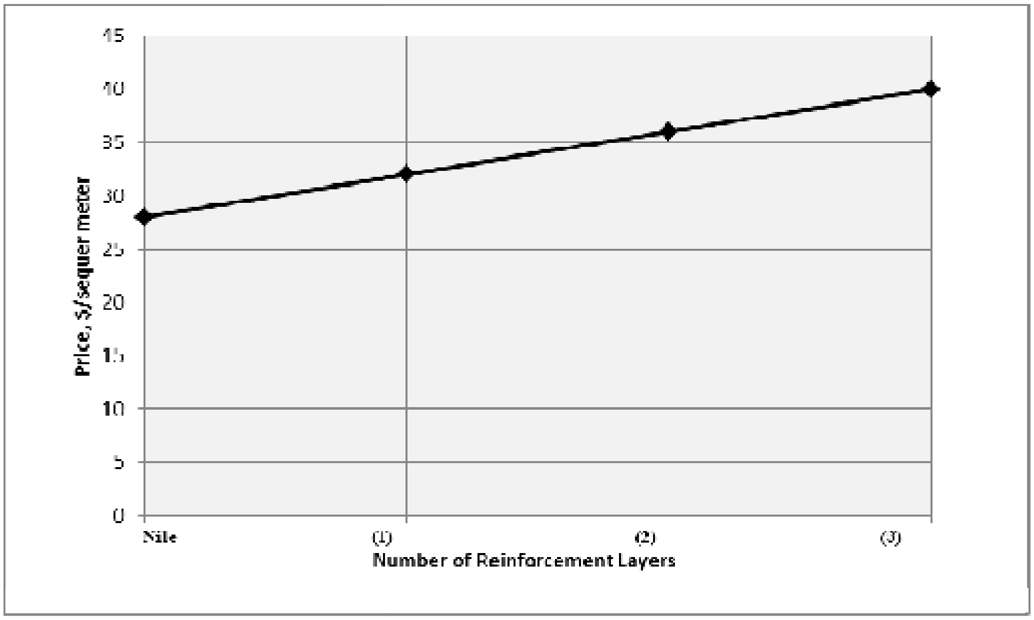

Figure (14) Cost Analysis of Reinforced and Unreinforced Road Sections.