EXPERIMENTAL AND NUMERICAL EVALUATION FOR IMPROVEMENT OF UNDERLYING LAYERS OF ROAD'S PAVEMENT USING JUTE FIBRE SHEETS

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تقييم عملي و نظري لتحسين الطبقات السفليه من التبليط بأستخدام طبقة من الياف الجوت

المستخلص:
ان كلف انشاء وصيانة الطرق تمثل عوامل مهمة في عملية انشاء الطرق. البحث الحالي يحتوي على دراسة لموقع جديد لطبقة من الياف الجوت بين طبقة التربة الطبيعيه و طبقة السبيس (المادة الحصويه) و هو الموقع الذي ندر دراسته سابقاً. البحث يحتوي على مقارنة تأثير استخدام طبقات الياف الجوت في مواقع مختلفة مقارنة بالطرق التقليديه في تثبيت التربه و التي تتضمن استخدام الجوت الفايبر داخل طبقات التربة حصراً. فحص التحمل الكليفورني تم اجراءه على نماذج تحتوي على طبقة الياف الجوت غير المغطاة و كذلك النماذج التي تحتوي على طبقات الياف الجوت المغطاة بالاسفلت و كذلك الياف الجوت الاعتياديه. البحث احتوى ايضا على تحليل عددي بأستخدام طريقة العناصر المحددة و ذلك بأستخدام برنامج ABAQUS لدراسة تاثير استخدام طبقات الجوت في الحد الفاصل بين الطبقات على الاجهادات و الانفعالات العموديه على طبقة التربه الطبيعيه للطريق و التي تكون مسووله عن ظاهرة التخدد في التبليط الاسفلتي. الدراسة العمليه اثبتت ان استخدام طبقة الياف الجوت المغطاة بالاسفلت بين طبقة التربه و طبقة السبيس تزيد مقاومة الاختراق في فحص التحمل الكليفورني بمعدل 190%. كذلك فان استخدام طبقات الياف الجوت المغطاة بالاسفلت تزيد قيمة التحمل الكليفورني بمعدل 125 % مقارنة مع تلك الغير مغطاة بالاسفلت في نفس الموقع. النتائج النظرية بأستخدام طريقة العناصر المحدده اظهرت ان استخدام طبقة الياف الجوت المغطاة بالاسفلت بين طبقة التربه و طبقة السبيس يقلل بشكل كبير الاجهادات العموديه على التربه الطبيعيه و بالتالي يزيد مقاومة التخدد للتبليط الاسفلتي. البحث الحالي يشير الى ان استخدام طبقات الياف الجوت المغطاة بالاسفلت بين طبقة التربة والسبيس يزيد من كفاءة الطبقات وتحملها و بالتالي يقلل كلف انشاء وصيانة الطرق. كما ان عملية اضافة طبقة الياف الجوف بين طبقتي التربة و السبيس يكون اسهل من عملية اضفتها داخل طبقة التربة الطبيعيه.

Abstract

The construction and maintenance costs of pavement are important aspects for road construction. The current research provides a newly technique for the use of jute fibre sheet as an interface layer between the subgrade soil and subbase layer which is limit in previous studies. The work involved comparison different locations for jute fibre sheet with the tradition approach of soil stabilization which imbedded the jute fibre sheet inside the subgrade soil. California Bearing Ratio (CBR) test was conducted on samples with jute fibre sheet, jute fibre sheet coated with bitumen and fibre only. Finite Element Models (FEM) using ABAQUS programme was implemented to show the effect of the new improvement on the vertical compressive strain at the top of subgrade and consequently rutting resistance. The experimental results showed a superior performance for the specimens containing bitumen coated jute fibre sheet placed at the interface between subbase and soil compared with unreinforced specimens (190 % penetration resistance). The bitumen coated jute fibre sheet also showed a significant increase in CBR value compared with traditional improvement of mixing or placing jute fibre within the subgrade soil, and provided higher CBR value (125%) compared with uncoated jute fibre sheet at the same location. The FEM results showed a significant reduction in compressive strain at the top of subgrade and consequently, cause a potential increase in rutting resistance. The research suggested that the use of jute fibre sheet at the interface between subbase and soil layers is efficient and that will lowering the construction cost of highways.

Keyword: Jute fibre sheet, improvement of underlying layers of pavement, CBR, FEM, ABAQUS, Rutting resistance

1. Introduction

The quality and performance of roads pavement rely on the effectiveness of supporting layers (subbase and subgarde). The construction of roads on poor supporting layers leads to an excessive deformation can affect riding quality and design life of the roads. Such layers act as a foundation layer for top road pavement layers to alleviate the deleterious effects of weather and various stresses due to traffic load. For these reasons, the improvement of subgrade and subbase (granular material) layers to get stable foundation is an important aspect of roads design, construction cost and maintenance [1].

The subgrade and subbase layers improvement is generally classified into two main categories: mechanical and chemical processes. The mechanical process involves enhancement the soil or subbase layer properties by mixing the layer with soil or aggregate have better properties or adding reinforcement layer such as fibre or geogrids, etc...[2-4].

The chemical improvement or stabilization involves several techniques for improvement and stabilization of pavement layers system. Some of most popular techniques are the stabilization and improvement of subgrade or subbase layer by lime, cement, fly ash, bitumen, etc.. [5-8].

Many research works have been carried out to study the improvement of subgrade soil with different types of fibre as a mechanical improvement. Jute geotextile has been used for subgrade soil improvement through an experimental investigation [9]. The study involved conducting several tests such as rutting test, dynamic load test, CBR test and durability test. The result of study revealed that the using of Jute geotextile can reduce the pavement thickness and construction cost by improving CBR value of subgrade soil also reducing rutting depth and consequently, reduce the cost of maintenance. However, the durability of Jute geotextile remains a concern issue. In recent investigation, two sections of unpaved rural road were monitored, one with jute-based geotextiles and the other without geotextiles. After eighteen months, no rutting was observed on the section with geotextiles, while 5-35 mm rutting depth was observed on the section which does not have geotextiles [10]. Other research has been carried out to investigated the effect of using natural fibre to improve the properties of subgarde soil [11]. The study showed that using of natural fibre significantly improves Unconfined Compressive Strength (UCS) and CBR values and consequently, reduces the required thickness of pavement. Sonthwal and Sahni [12] investigated the using of different ratios and different fibre length to improve the subgrade soil. Their results showed that the CBR was improved up to 131.81%. Another study has been investigated the effect of using jute fibre, glass fibre and lime to improve the properties of fine grain soil [13]. The results of the study showed that the jute fibre significantly improved the strain hardening and ductility of soil. The mechanical stabilization of subgrade soil of road using geogrid reinforcement was also experimentally investigated [14]. The experimental results revealed that the using of geogrid reinforcement greatly improved CBR value of subgrade soil. This increment in CBR value cause 15% reduction in base course layer thickness for pavement section under consideration. Pavani A., et al. [15] recently investigated using jute geotextile to stabilized the subgrade soil of road pavement. The jute geotextile layers were placed at 1/3, ½, and 2/3 of CBR and UCS mould's height. To protect the jute geotextile against bio-degradation, two types of protection were used bitumen and Polythene (plastic) sheets. The results of study showed that the using of three layers of jute geotextile increases the CBR value. The results also showed that the placing of jute geotextile layers at ½ and 2/3 of soil sample thickness give superior improvement compared with that at 1/3 of soil sample thickness.

All previous mentioned studies investigated the use of jute fibre or jut fibre sheet with the subgrade soil layer to enhance their characteristics, reduce the total thickness of pavement layers; consequently, cut-down the construction and maintenance costs. Although that they gave a good results, the placing of jute fibre sheet at the interface between the subgrade soil and subbase layer has not been investigated. The position can be considered easier and lower cost compared with other location of placing jute fibre sheet.

The current research examined the use of jute fibre sheet between the subgrade soil and subbase layer as a new technique for soil improvement, which could improve the engineering properties of pavement system. Also, it facilities the application of jute sheet at the top of subgrade instead of placing it within the subgrade soil. The jute fibre sheet was used as uncoated and coated with bitumen. A numerical analysis (Finite Element Model -FEM) using Abaqus programmes was also carried out to model the experimental work and show the effect of using jute fibre sheet on the compressive strain and displacement at the top of subgrade soil and consequently rutting resistance.

2. Experimental work

2.1. Materials

2.1.1. Soil

The soil samples were collected from local site in Al-Diwaniya city. The properties of soil and particles size distribution curve were determined experimentally as shown in Table 1 and Figure 1, respectively.

Table 1: Soil prosperities

Property	Value	Reference
Colour	Brown	vision
Liquid limit (LL), %	40	Measured - ASTM D 4318
Plastic Limit, (PL), %	15	Measured - ASTM D 4318
Optimum Water Content (OWC), %	17	Measured - ASTM D 1577
Max. Dry Density (MDD), (gm/cm3)	1.732	Measured - ASTM D 1577
California Bearing ratio (CBR), %	3.5	Measured - ASTM D 1883
Type	Silty clay	

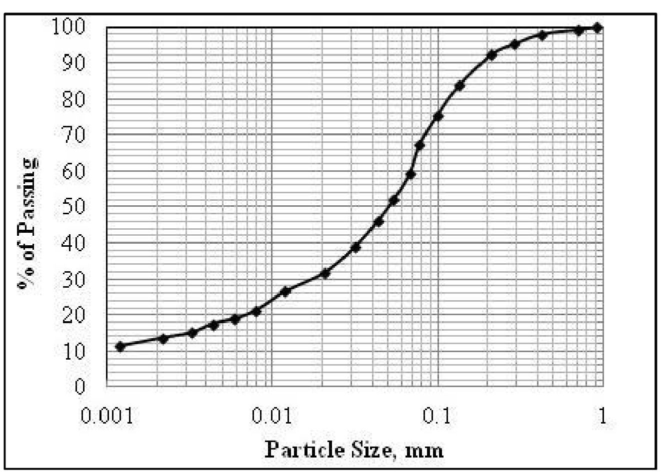

Figure 1. Soil's particles size distribution curve

2.1.2. Granular material (Subbase)

The subbase material was brought from al-Najaf site and sieved to be satisfying class C according to SORB/R6. Their properties and gradation are illustrated in Table 2 and Figure 2, respectively. Table 2 involved the measured properties of granular material.

Table 2: Granular material (Subbase) properties

Property	Value	Reference
Colour	Red	vision
LL %	20	Measured - ASTM D 4318
PL %	NP	Measured - ASTM D 4318
OWC %	7.5	Measured - ASTM D 1577
MDD (gm/cm3)	2.209	Measured - ASTM D 1577
CBR %	31.2	Measured - ASTM D 1883
Type	Granular material	

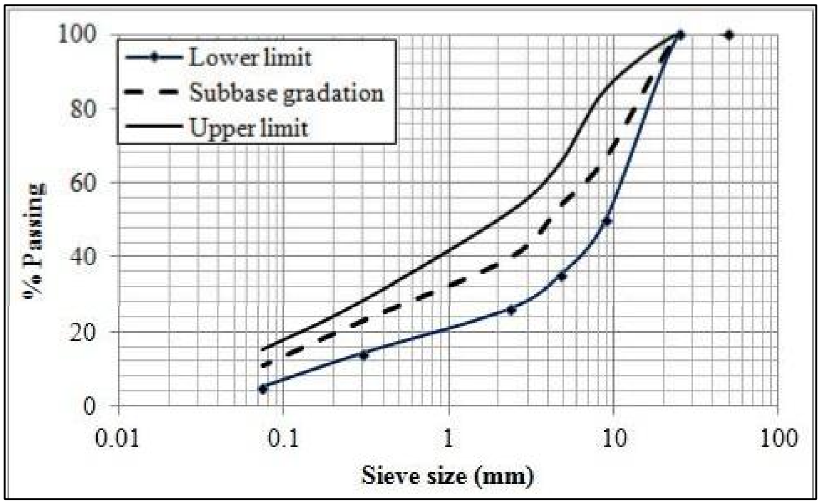

Figure 2. Granular material (Subbase) gradation

2.1.3. Jute fibre sheets

The jute fibre sheets were obtained from the jute bags available in local markets. The properties of jute fibre sheet were determined according to authors' measurement as shown in Table 3.

Table 3: Jute fibre sheets prosperities

Property	Value	Reference
Colour	Brown	vision
Fibre length, mm	50-100	measured
Fibre diameter, mm	0.15-0.2	measured
Water absorption, %	30	measured
Mesh size, mm*mm	5*5	measured
Thickness, mm	2	measured

2.1.4. Bitumen (Asphalt binder)

The bitumen of penetration Grade 85-100 was used for coating the jute fibre sheet. Even the bitumen used as coating material its properties were determine in laboratory as listed in Table 4.

Table 4: Properties of bitumen

Property	Value
Grade	85-100
Softening Point	44 ^{o}C
Flash Point	250 ^{o}C
Fire Point	260 ^{o}C
Specific gravity	1.01

2.2.Experimental tests (CBR tests)

Standard CBR test described in ASTM D1883-07 [16] consist of compacting five layers of soil by 56 blows per layer using 4.5 kg hammer. The current research modified the standard procedure by adopting pavement structure consist of three layers of soil and two layers of subbase material (five in total). This modification was adopted to investigate the effect of using jute fibre sheet at the interface between soil and subbase layers. All other steps of test according to standard method illustrated in ASTM D1883-07 were followed such as compaction, socking for 96 hours with surcharge weight and finally testing the specimen. Five cases were investigated in addition to standard tests of CBR for soil and granular material (mentioned before) as listed below:

- Mould contains three layers of soil and two layers of subbase without jute fibre sheet (unreinforced specimen).
- Mould contains three layers of soil and two layers of subbase with jute fibre sheet at the interface between the soil and subbase.
- Mould contains three layers of soil and two layers of subbase with jute fibre sheet coated with bitumen at the interface between the soil and subbase.
- Mould contains three layers of soil and two layers of subbase with jute fibre sheet at top of second layer of soil.
- Mould contains three layers of soil and two layers of subbase with jute fibre (not sheet) mixed thoroughly with third layer of soil.

Figure 3 shows a graphical representation for the location of jute fibre sheet between subbase and soil layers, while the Figure 4 shows photos for preparation of experimental specimens.

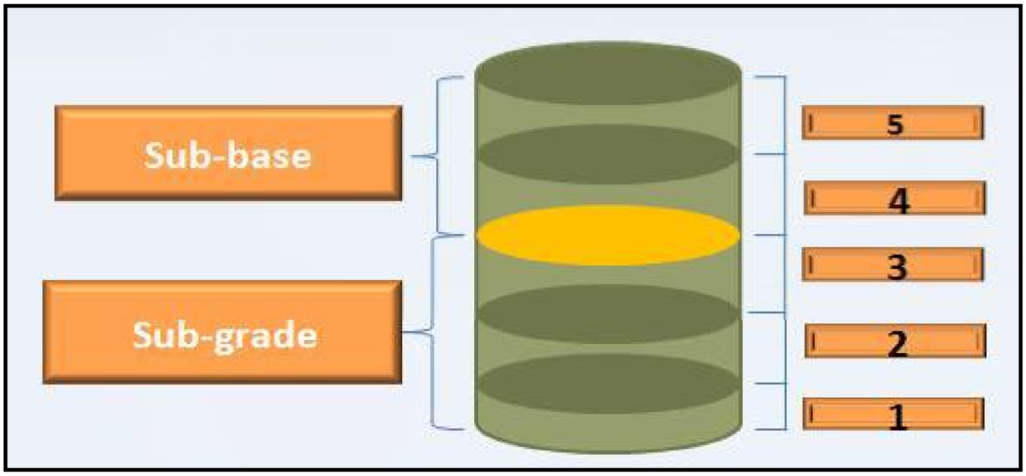

Figure 3. A graphical representation for the location of jute fibre sheet at subbase-soil interface.

Figure 4 . Photos for preparation of experimental specimens.

2.3.Experimental results

The CBR tests were conducted for all specimens under consideration according to modified procedure described in previous section. Three samples were taken for each test and the average value was adopted. The results of tests are shown in Figure 5. These results clearly illustrated the differences between tested specimens. The placing of jute fibre sheet (uncoated and coated with bitumen) between the subgrade soil and subbase layers is a new technique and has not been investigated before. To shown the advantages of placing jute fibre sheet at this position, jute fibre sheet and jute fibre placed in the last layer of soil (optimal location according to studies mentioned in literature) were examined for the comparison purpose. Also, unreinforced specimen was tested as a control (reference) specimen.

The results showed a significant increase in load magnitude required to create the desired penetration (12.5 mm) for specimens containing jute fibre sheet at the interface between subbase and soil layers comparing with all other specimens. This finding is attributed to that the jute fibre sheet act as membrane layer with high stiffness to reduce and redistributed the stresses transmitted to subgrade soil. The jute fibre sheet coated with bitumen need about 190%, 146%, 138%, and 117% load to create same penetration at the end of test compared with unreinforced specimens, reinforced with jute fibre sheet above the second layer of soil, reinforced with jute fibre mixed with last layer of soil, and uncoated jute fibre sheet placed at the interface between subbase and soil respectively. This interesting performance for bitumen coated jute fibre may attributed to that in addition to benefit of using jute fibre sheet, the presence of bitumen increases the stiffness and durability of jute sheet, binding the particles of granular material (subbase), hardening the bottom of subbase layer, plug the capillary voids on granular materials and reduce the migration of moisture during socking of specimens and provided more bond between subbase and subgrade soil. Some previous studies [15] investigated the using of bitumen coated jute fibre within the soil layers, however, in this case the bitumen acts only as a protection against bio-degradable for jute fibre sheets. The results also showed that the jute fibre mixed with last layer of soil gives a good strength at lower load but the penetration resistance decreases with the increase of load magnitude. This behaviour may be related to the that fibre reinforcement strengthening the subgrade soil under low stresses but these reinforcement may not be able to resist higher load as jute sheet due to distortion of soil particles under such loads. In addition to that, the using of jute fibre for subgrade soil improvement needs more efforts and cost compared with jute fibre sheets. Figure 6 shows the calculated CBR values for all specimens under consideration with composite section (three layers of soil and two layers of subbase) proposed in the current study. Since these values were calculated from the load-penetration relation, it gives similar trend for the results explained before.

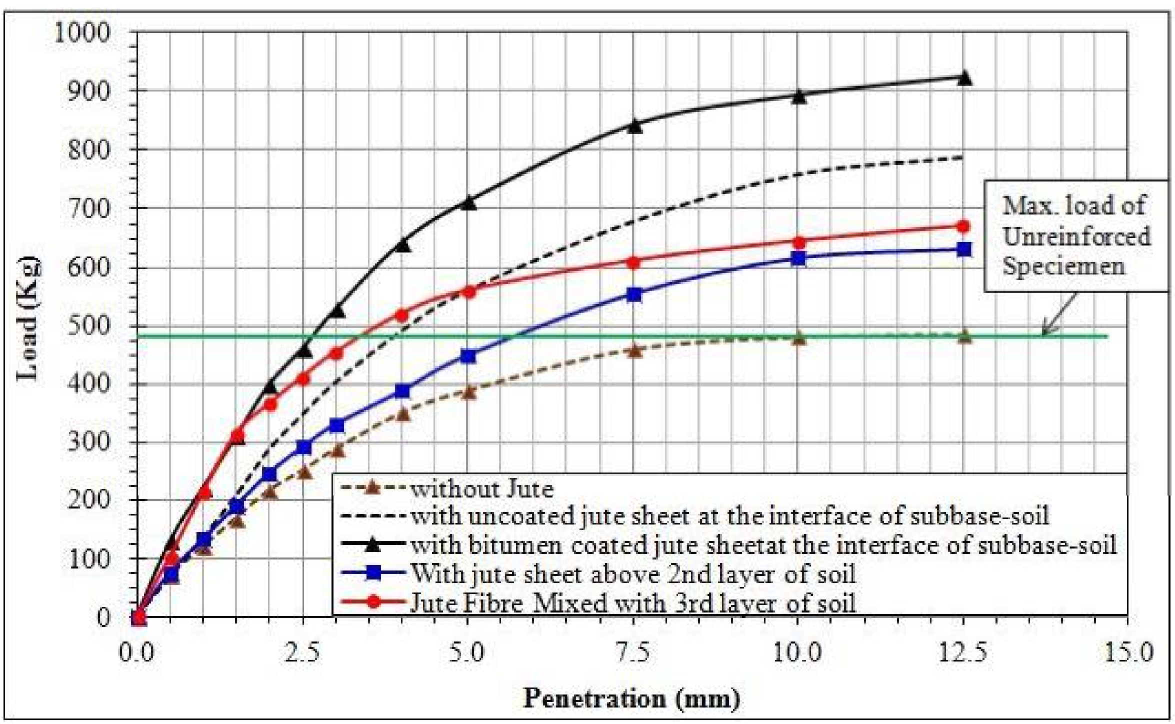

Figure 5. Experimental results of CBR tests for the considering specimens

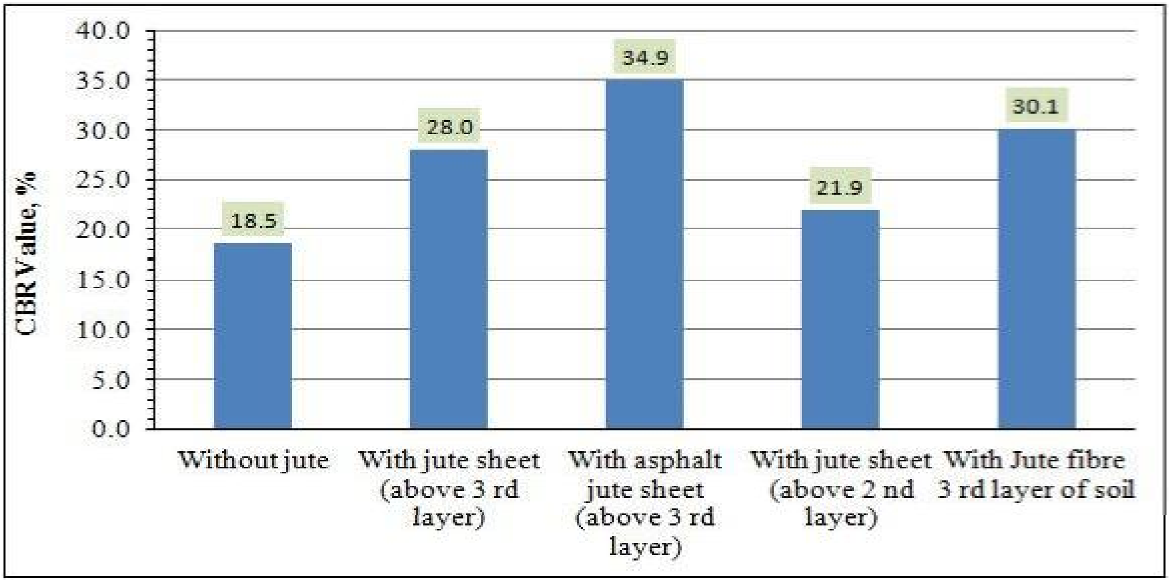

Figure 6. CBR values for the considering specimens

3. Numerical (Finite element) model (FEM)

ABAQUS programme was used for numerical simulation for the current experimental investigation. ABAQUS is versatile numerical simulation software able to model different problems with linear, nonlinear or visco-elastic behaviour. The model consisted of three layers of soil and two layers of subbase the diameter of each layer is 150 mm (equal to interior diameter of CBR mould) and the height of each layer was 25 mm. One jute fibre sheet with same diameter and thickness of 2 mm was inserted between the layers according to its location in experimental tests.

Three dimensions solid continuum element with 8 nodes (reduced integration) C3D8R was used to model all components of the model. This element capable to represent different linear and non-linear problems also, can overcome the convergence problems in the presence of contact formulation [17]. The interaction between jute sheet and subbase, jute and soil was modelled using surface to surface contact. The mechanical behaviour for soil and subbase material was represented by defining the elastic parameters for each material for elastic part, and the Mohr coulomb plasticity for inelastic part. These parameters are listed in Table 5 as obtained from experimental and literature, due to lack of laboratory resources [18]. Dilation angle was calculated from Equation (1) for non-clay soil [19]. Since the socking of materials (soil and subbase) causes a reduction in the stiffness of materials, a sensitive analysis was carried out to estimate the reduction in Young modulus of these materials. A various percentages of reduction in Young modulus (E) were investigated starting from 0.3 E to 1.0 E and validated with socked and un-socked samples. The validation showed that 0.8 E gives a good agreement with experimental results. The mechanical behaviour of jute fibre sheet was modelled by orthotropic elasticity model described in ABAQUS user manual volume 3 [17]. The stiffness matrix of orthotropic elasticity of jute was defined according to Jute fibre sheet properties mentioned in Table 6 [20]. Even some of these parameters were obtained from previous studies and may not be exactly the same for our material, the using of these parameter for all cases of numerical simulation eliminate any small errors due to that and make the comparison between different models gives accurate results.

$$\varphi = \emptyset - 30 \qquad (1)$$

Table 5: Friction ($\emptyset$)and dilation (φ) angles for subbase and subgrade soil.

Material type	Friction angle $\emptyset$ [18]	Dilation Angle φ	E [21]	µ [21]
Subbase	45	15	73500	26700

Subgrade soil	34	4	0.35	0.4

Table 6: Jute fibre sheet properties [20].

Material (Mpa)	E1	E2	E3	μ12	μ13	μ23	G12	G13	G23
Jute	39618	5500	5500	0.11	0.11	0.35	7124.1	7124.1	2037

Where; E: Young modulus
μ: Poisson's ratio
G: Shear modulus
1, 2, and 3: X, Y, and Z directions for the specimen in the model

3.1.Validation of model with the experimental results.

The numerical simulation was adopted to show the internal stresses and strains of materials which cannot be captured from the experiment. However, these values cannot be considered without validation the model with a real state (experimental results). Since the penetration value and corresponding load the only values can be taken from the experiment, these values were verified with experimental results as shown in Table 7 and Figures 7, 8, and 9. The numerical results showed a favourable agreement with experimental results, consequently, the model can be used to predict the internal stresses and strains. Three experimental specimens were modelled: unreinforced specimen, specimen with uncoated jute fibre sheet at the interface between subbase and soil, and specimen with jute fibre sheet above the second layer of soil. These three cases can clearly show the effect of improvement type on stresses and strains at the top of subgrade. For the comparison purposes, same load was used for all numerical simulation runs (486 kg). This load represents the maximum load for the unreinforced specimen. This load was converted to Newton unit and applied as pressure on circular area has a radius equal to radius of piston (25 mm). The surcharge load of 5kg (in CBR test) was also converted to pressure on the remaining area around the piston at the top surface of specimen.

Table 7: Comparison of Experimental and FEM values of penetration at load of 486 Kg

Type of specimens according to location of jute fibre sheet	Penetration value (mm)	
	Experiment	FEM
unreinforced specimen	12.5	12.79
specimen with uncoated jute fibre sheet at the interface between subbase and soil	3.95	4.45
specimen with jute fibre sheet above the second layer of soil	5.85	6.48

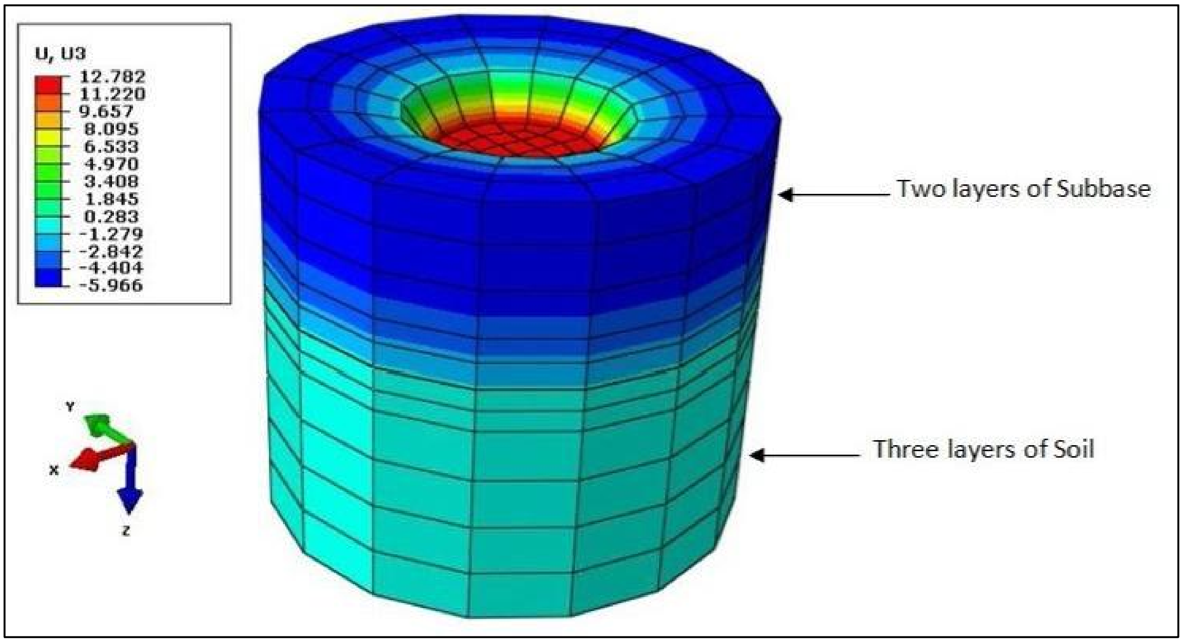

Figure 7. FEM model for unreinforced specimen

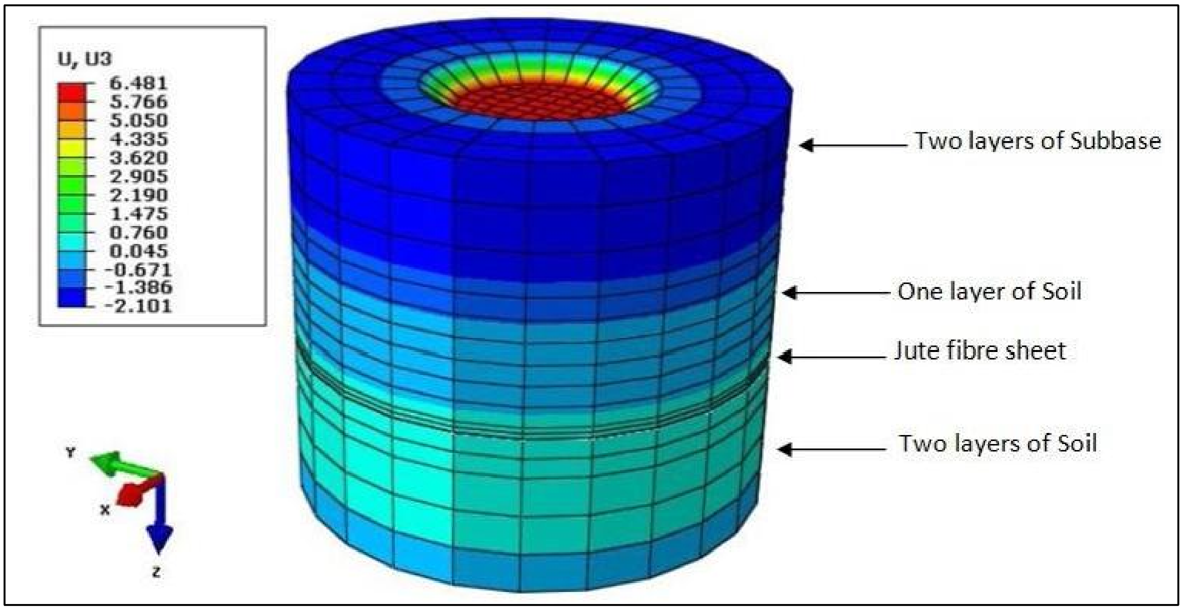

Figure 8. FEM model for specimen with jute fibre sheet above the second layer of soil

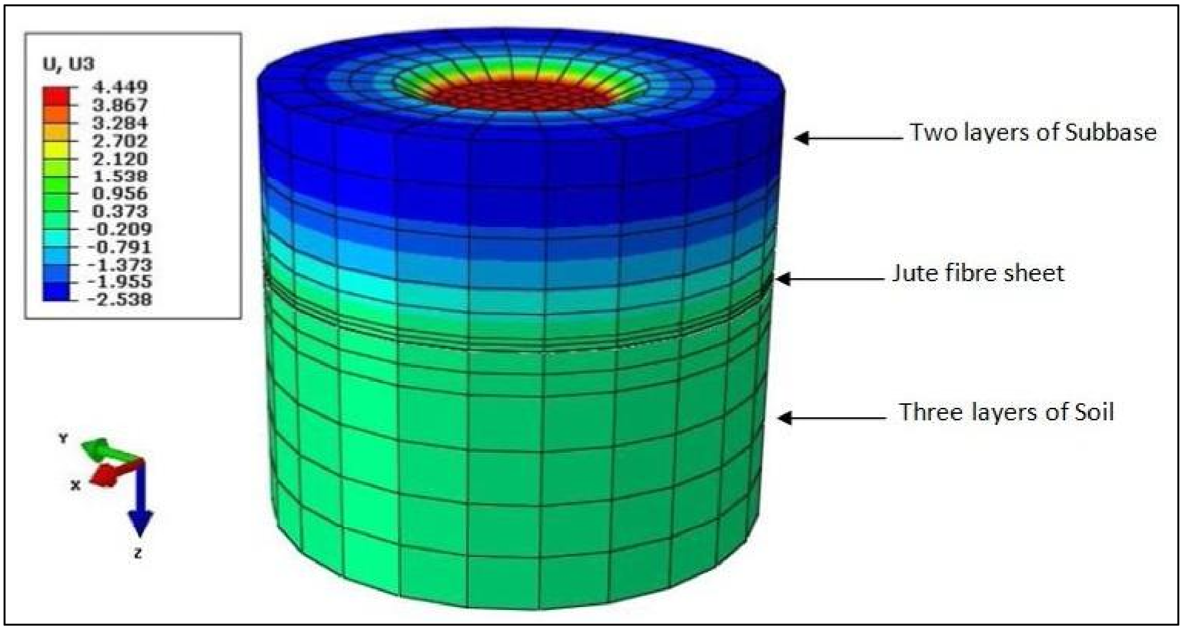

Figure 9. FEM model specimen with uncoated jute fibre sheet at the interface between subbase and subgrade soil

3.2.Effect of using Jute fibre sheet on rutting resistance

In case of adequate materials and construction of hot mix asphalt the only factor effect the permanent deformation (rutting) occurrence in flexible pavement is the compressive strain at the top of subgrade [22]. The Asphalt Institute [23] proposed a relation between permanent deformation of flexible pavement (rutting failure) and compressive strain at the top of subgrade soil of pavement as shown in Equation (2).

$$Nr = 1.365 * 10^{-9} (1/\varepsilon_c)^{4.477} \quad \ldots\ldots (2)$$

Nr: Number of applications of traffic load to limit rutting.
ε_c: compressive strain at the top surface of subgrade soil.

From the previous equation, it can be observed that rutting criterion is directly proportion to compressive strain at the top of subgrade. FEM results in Figure 10 showed that the placing of jute fibre sheet at the interface between subbase and subgrade soil significantly reduces the compressive strain at the top of subgrade compared with unreinforced specimens, consequently, significantly increases rutting resistance. These values of strain may not represent the actual values in real pavement because the dimensions of specimen (especially thickness) differ than the typical section of pavement; however, it gives a clear view for the different cases. The specimen with jute fibre sheet at the interface between subbase and subgrade soil shows approximately linear elastic behaviour until the maximum load, while inelastic response of unreinforced specimen started at about 30 % of same applied load. Figure 11 presented the displacement (settlement) at the top of subgrade. Similar response was observed to what was noticed in compressive strain results. The placing of jute fibre at the interface between subbase and subgrade soil reduces the settlement up to 20% of unreinforced specimen. Figures 12, 13, and 14 presented the graphical views for the displacement at the top of subgrade for unreinforced specimens, specimen with jute fibre sheet between subbase and soil, and specimen with jute fibre sheet above second layer of soil respectively.

Figure 10 .Compressive strains at the top of Subgrade soil

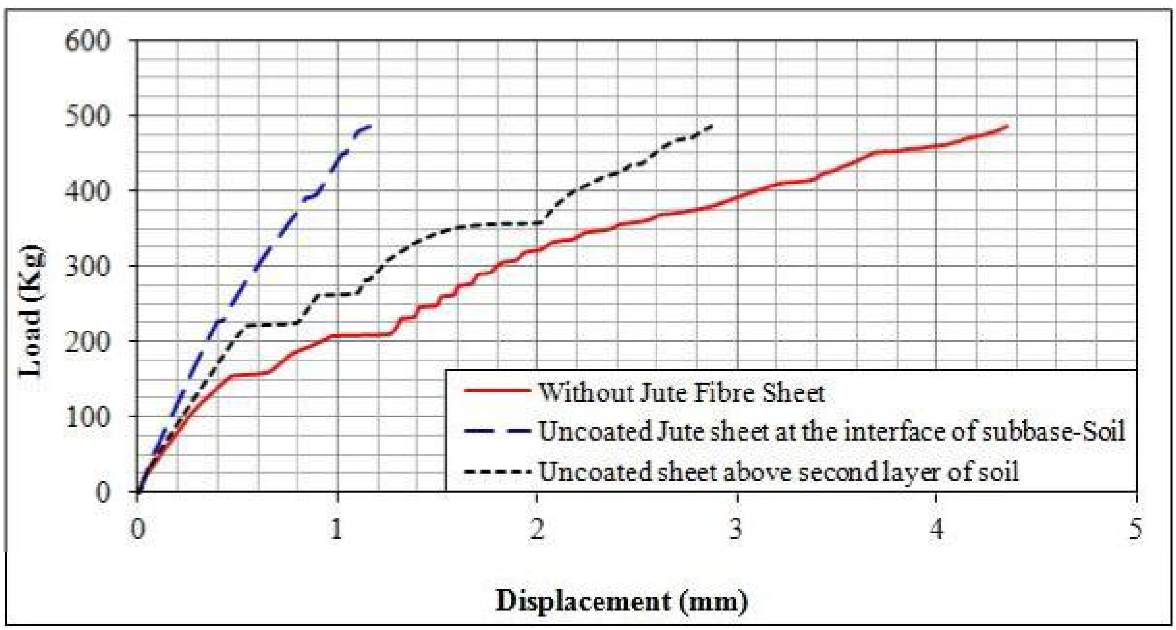

Figure 11. Displacement (Settlement) of subgrade soil

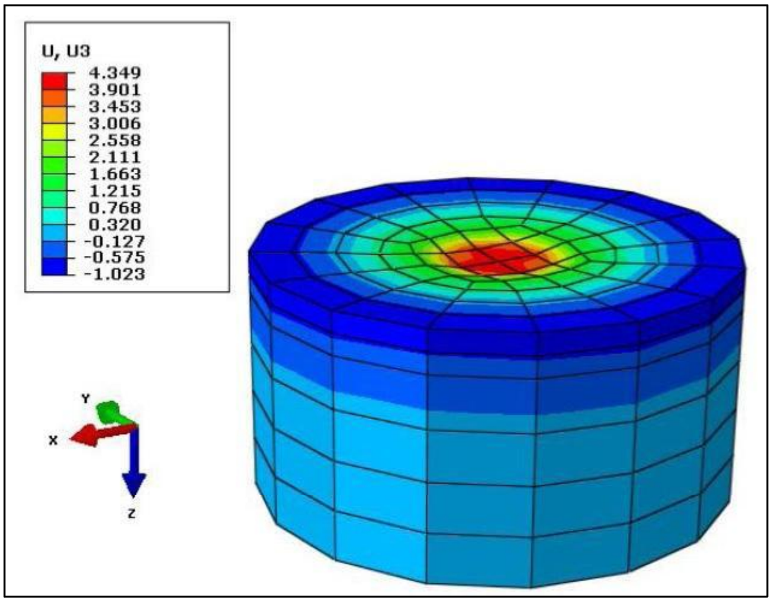

Figure 12. Displacement at the top of subgrade for unreinforced specimen.

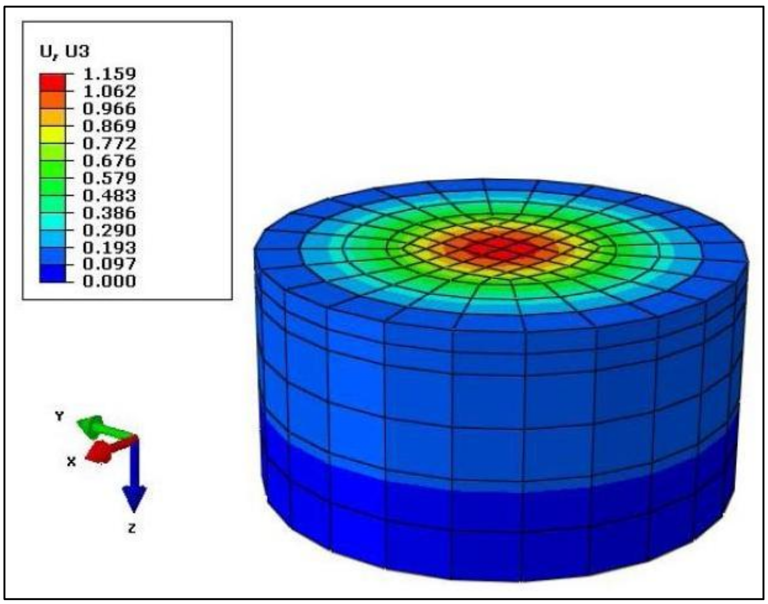

Figure 13. Displacement at the top of subgrade for specimen with jute fibre sheet between subbase and soil.

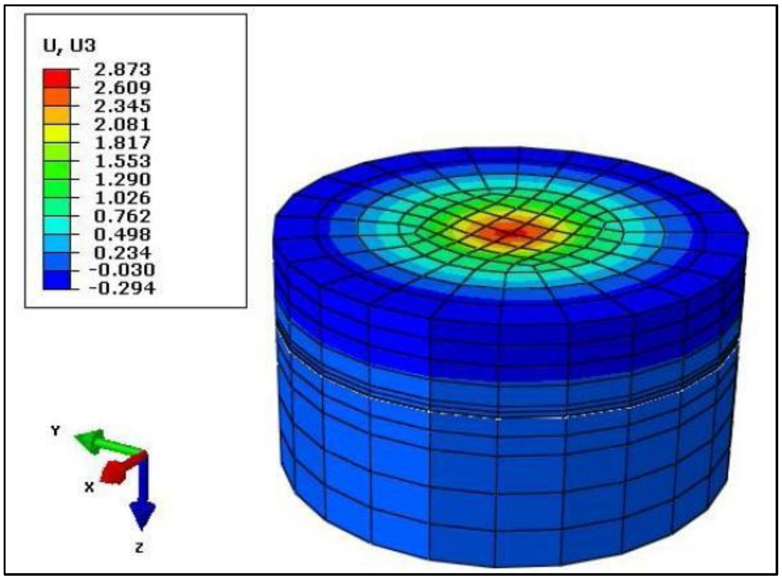

Figure 14. Displacement at the top of subgrade for specimen with jute fibre sheet above second layer of soil

3.3. Effect of using Jut fibre sheet on full depth layers

In order to show the usefulness of using jute fibre sheet in real pavement, a pavement structure was modelled with real thickness of pavement layers. This structure consisted of two layers, subbase and soil with thickness of 250 mm for each layer. The top layer is the subbase layer and the lower one is the subgrade soil layer which supported on Winkler foundation with modulus of subgrade reaction of 54 MN/m^3. The selected load (P) was 20 kN as one tire of dual wheel single axle load with tire pressure (q) of 550 kPa. The contact area was represented by circular area with radius (r) calculate according to Equation (3) [24].

$$r = \sqrt{\frac{P}{q\pi}} \quad \text{...}(3)$$

Two cases from this model were considered for the purpose of the comparison: first case with uncoated jute fibre sheet at the interface between subbase and subgrade soil and second case without jute fibre sheet. Figure 15 illustrated the total displacement under load for the two cases, in which the case of uncoated jute fibre sheet at the interface between subbase and subgrade soil has a reduction in surface displacement of 30 %. This reduction should be greater for bitumen coated jute fibre sheet as was observed in experimental tests. However, this case was not modelled due there is no clear description for the mechanical behaviour (or material properties) of jute fibre sheet with bitumen, to be represented in ABAQUS programme.

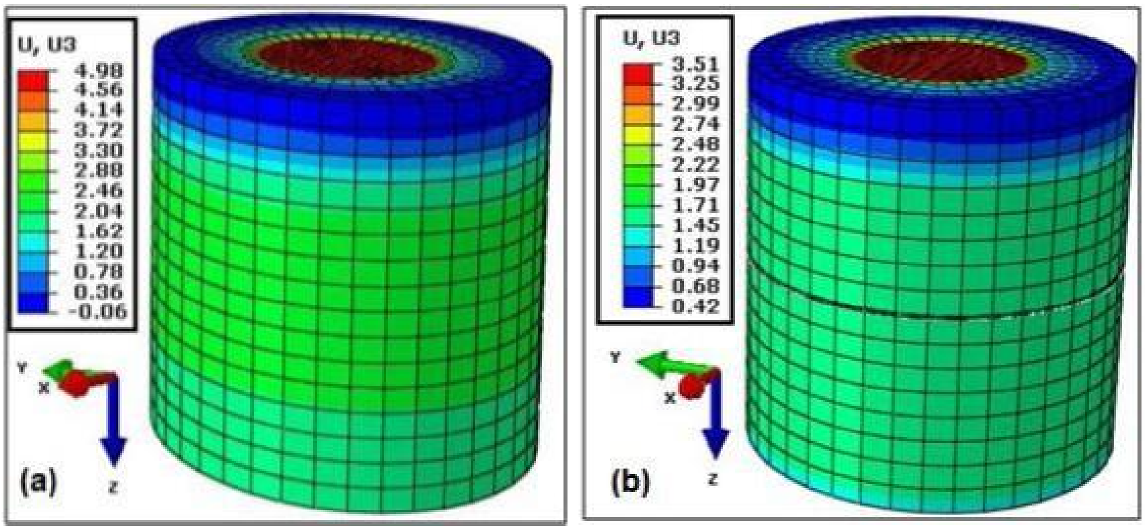

Figure 15. Full-depth model for pavement layers : (a) Without Jute fibre sheet, (b) With jute fibre sheet at the interface between subbase and soil.

3.4. Saving of subbase material and construction cost

To clarify the economical advantage of using jute fibre sheet in road pavement, several FEM runs were carried out. The output results of FEM showed that the vertical compressive strain and displacement (see Figures 16 and 17 respectively) for specimen with uncoated jute fibre sheet are equivalent for unreinforced specimen with subbase layer has a thickness of 345 mm. This means the use of jute fibre sheet at the interface reduces the subbase material by 38 %.

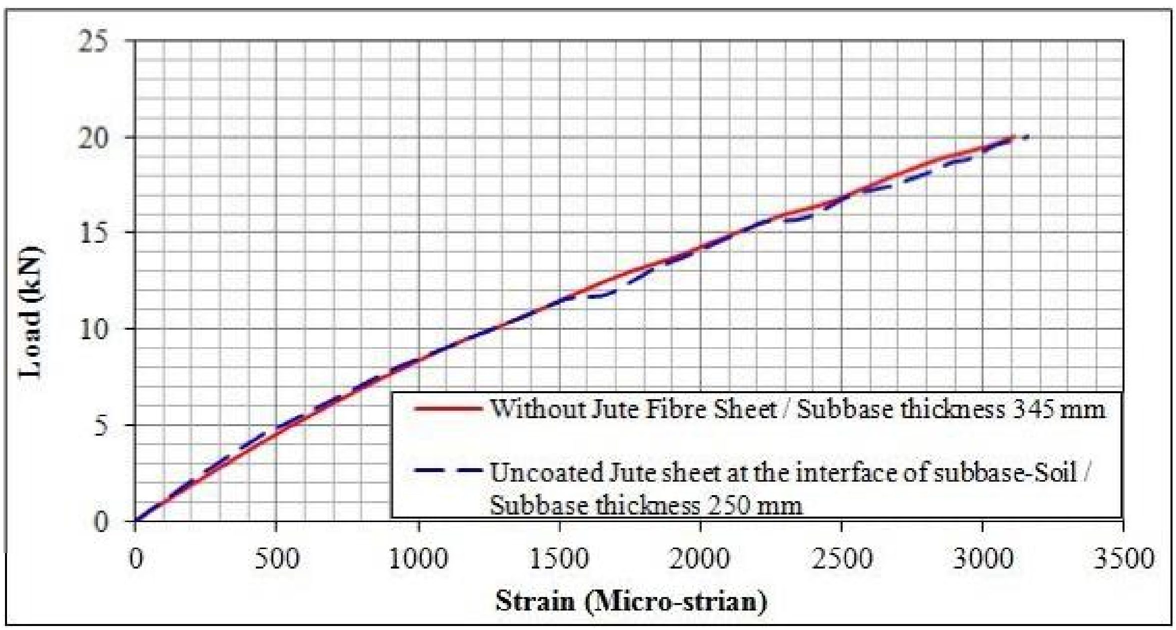

Figure 16. Comparison of compressive strain at the top of subgrade for reinforced and unreinforced specimens with different thickness.

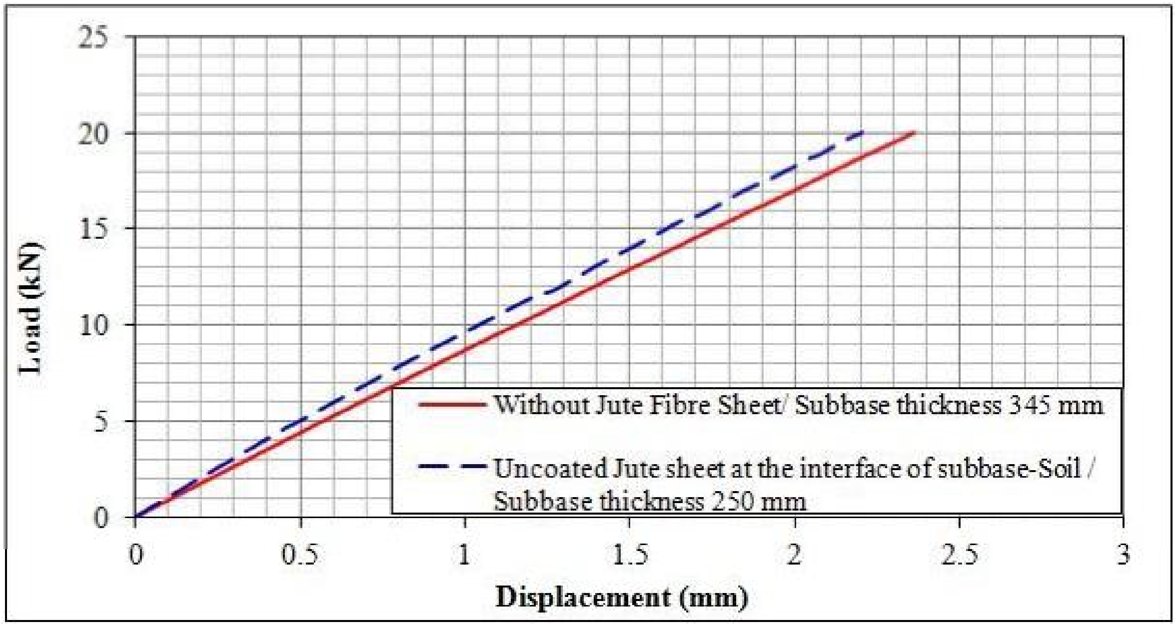

Figure 17. Comparison of displacement at the top of subgrade for reinforced and unreinforced specimens with different thickness.

Small economical feasibility study showed that the using of uncoated jute fibre sheet can save 1.9 $ from the cost of each square meter of pavement (the prices are obtained from local markets).

The cost of 1 m^2 (0.25 m thick) of subbase = 8000 ID / 1200 $ = 6.67 $
The cost of 1 m^2 of uncoated jute fibre sheet = 750 ID / 1200 $ = 0.63 $
The saving cost for each 1 m^2 = 6.67 * 0.38 – 0.63 = 1.9 $

4. Summary and conclusions

The current article presented an experimental investigation and numerical simulation using ABAQUS programme to examine different locations of placing of jute fibre sheet and jute fibre in flexible pavement layers. The jute fibre sheet was used as uncoated and coated with bitumen. The following conclusions can be drawn from this study:

1- The placing of jute fibre sheet at the interface between subbase and subgrade soil layer (which is a new technique has not investigated before) give a significant improvement for the stiffness of underlying layers of pavement.

2- The placing of bitumen coated jute fibre sheet at the interface of subbase and subgrade soil layer reduces the penetration up to 50 %. Also, the FEM showed this position of jute fibre sheet reduce the compressive strain and settlement at the top of subgrade soil up to 10 % and 20 % respectively compared with unreinforced specimen.

3- The using of jute fibre sheet at the interface between subbase and subgrade soil layer can be considered easier and lower cost compared with the other improvement techniques that include mixing the jute fibre with subgrade soil or cut the upper layer to place the jute fibre sheet.

4- The coating of jute fibre sheet not only protects the jute sheet against biodegradable effect as when it is used within the subgrade soil, where, it strengthening the subbase layer by binding there particles in case it is used at the interface..

5- The significant improvement of underlying layers of pavement due to placing bitumen coated jute fibre sheet at the interface between subbase and soil leads to significant decreases of pavement construction and maintenance costs.

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