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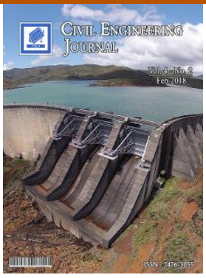

Study the Using of Reed Mats in Asphalt Pavement Layers

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Abstract

During the service life, the asphalt pavement layers subjected to various detrimental types of distresses such as permanent deformation, fatigue, stripping and shoving which lead to the complete failure of the pavement. In Iraq roads the permanent deformation (rutting) is the importance distresses which cause impact on the highway performance and reducing the service life of the pavement. The research aims to utilize locally available materials and environment friendly as reinforcement layer. The program of this research include preparing asphalt mixes represent surface layer by using locally available materials and using the reinforcement layer which made of reed. The permanent deformation test has been done with three temperatures (40˚C, 50˚C and 60˚C) and four locations of the reed mats. The test results of the wheel- Track for the rutting measurement showed that the rut depth decrease in reinforcement layers as compared with unreinforcement layers for all temperature testing. The reed netting embedded bottom and middle of wearing layer has the best amount of improvement (75%, 84% and 85%).

Keywords: Asphalt Pavement; Distresses; Permanent Deformation; Reed; Wheel-Track; Improvement.

1. Introduction

The asphaltic paving mixture during the service life it is normally subjected to various detrimental types of distresses. These distresses are caused by weather, load, construction practices and deceleration of vehicle at checkpoints, and deficient materials. Some of these serious failure includes permanent deformation or rutting, fatigue, stripping and shoving which lead to the complete failure of the pavement. Such types of failures reduce the performance of asphalt pavements, which does not cause bad ride quality to motorists, but also are caused the higher cost at life cycle, some of the mentioned distresses are related to the asphalt cement binder and it can be controlled significantly by modifying the material with chemical additives [1]. Pavement reinforcement recently became an important part of designing and rehabilitating pavement systems which improve pavement performance, increase the service life, and reduce its current premature failures [2]. Base or subbase reinforcement is defined in flexible pavements to support vehicular traffic over the pavement structure, improve the service life and obtain equivalent performance with a reduced structural section [3]. Signs of distresses in the roads due to high traffic loads and the harsh environment. The environmental variations, especially between day and night as well as between summer and winter, are greatly affected the durability of asphaltic pavement. During summer the high pavement temperature that reduces the stiffness of paving mixture that results in pavement deformation[4]. In Iraq, for a little recent year after construction the pavements, permanent deformation distress was appeared at several locations in the highways, because of the increasing of traffic loading, the hot claimant condition during summer days, and poor quality control as shown in Figure 1 [5].

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Figure 1. Shows rutting occurring in pavement (the road located in Iraq)

2. Literature Review

Several literature on geogrid such as steel grid and reed mats reinforcing of flexible pavements, showed that the main aim of the reinforcing. Saad (2003) examined the structural performance of a pavement foundation system with and without the presence of geo-synthetic reinforcement [6]. The resistance to rutting tends to increase with an increase in the maximum compressive strain transmitted to the subgrade and it is mainly dependent on the base depth and the geo-synthetic location. Vacri (2007) [7] collects all the main results obtained from worldwide researchers carried out by universities around the world on pavements reinforced with steel mesh reinforcements, the main results of the researchers are: Cagliari University: the reinforcement increases the pavement life by a factor between 3 and 12. Palermo University: stresses due to shear actions (rutting) are reduced by 50%.

Siriwardane et al. (2010) [8] states the results of an investigation on the effectiveness of geogrid as a reinforcement of asphalt layers in flexible pavements, the vertical displacement have decreased with the inclusion of the geogrid within the asphalt layer with an improvement of approximately 38%. Jassim (2012) [9] are using steel reinforcement grids to study the permanent deformation in wearing course mixes under different temperatures. The results appear that the increase of testing temperature from 30°C to 45°C decreases the number of cycles by 79.6%, 72% and 67.3% for unreinforced, middle and bottom embedded grid samples respectively. Furthermore, increasing the temperature from 45°C to 60°C decreases the number of cycles by 75.1%, 62.4% and 58.7% for unreinforced, middle and bottom embedded grid samples respectively. Meshoah (2012) [10] investigated the benefit of using Reed Mats in reinforcing Flexible Pavement Section. Loading monotonic and loading repeated tests were performed, the analysis of the results showed that an increase in the bearing capability of the pavement due to the presence of the reed mats, where the value of stress at failure was adopted for the normal pavement condition for comparison (bottom layer + base layer + asphalt layer) and equal to 1780 kPa and gave the following results:

Case 1: A layer of the reed mats is spread between the base layer and the asphalt layer Stress at failure = (2311) kPa, the increase rate = (30) %.

Case 2: A layer of reed mats placed in the middle of the asphalt layer Stress at failure = (2950) kPa , the increase rate = 66%.

Case 3: Two layers of the reed mats first between the base layer and the asphalt layer and the second placed in the middle of asphalt layer, stress at failure = (3257) kPa, the increase rate = (93) %.

Sa'adi. et al., (2013) [11] 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. Qassim (2014) [12] using Mesh Steel Reinforcement were prepared and tested in the laboratory, it appears that permanent deformation of asphaltic pavements decreases by (41.1%) and (19.7%) for coarse and fine aggregate gradations respectively. Mohammed, D.I., (2015) [13] prepared a study to improve the pavement performance throughout; experimental and analytical approaches. The results show that criteria to use two modified pavement models to improve the pavement performance against rutting, the surface of pavement permanent deformation decreases for the modified models by (9.3%) and (21.8%) for steel mesh and geogrid model respectively if compared with the raw material model is recorded at 1600 cycle load. pavement permanent deformation is recorded at 1000 cycle decreases for the modified models by (18.3%) and (27.3%) for steel mesh and geogrid model respectively if compared with the raw material model.

Al-Essawi, (2017) [14] Investigated the benefit of Reinforcing Asphalt Concrete Mixtures by Different Geogrid Types. The study illustrates that geogrid is very effective in reducing the deformation; the geogrid reinforcement leads to the highest reduction in the permanent deformation when it is placed at the bottom, between or inside layers of the bituminous concrete layer. The results showed that using the geogrid between and bottom of pavement layer for three types of geogrid (Tensar SS2 Geogrid , Steel grid ,and Netlon CE121 Geogrid), the rutting percent at (40º C) has decreased by (34%,44% and 54%) respectively, the percent at 50º C has decreased by (35%,45% and 55%) respectively and the percent at 60º C decreased by (38%, 48% and 59%) respectively. The main objectives of the research is studying the effect of using reed netting in different modes of layering of flexible pavements in order to improve the resistance of asphalt mixtures against permanent deformation (rutting) and determine the appropriate position for reed netting.

3. Material Properties

The materials used in this study are widely available and currently used in road paving in Iraq except the reed netting that are available in local market in Basra.

3.1. Asphalt Cement

The asphalt cement used in this study is of (40-50) penetration grade, and brought from Al- Basra refinery. Table 1. shows the physical properties of Asphalt Cement.

Table 1. Physical properties of asphalt cement

Test	Test Conditions	ASTM Designation	Units	Penetration Grade 40-50	
				Test Results	SCRB/ R9 Specification 2003
Penetration	100 gm, 25°C, 5 sec., (0.1mm)	D-5	1/10 mm	43	40-50
Ductility	25°C, 5cm/min	D-113	cm	>100	>100
Flash Point	……	D-92	°C	330	>232
Specific Gravity	25°C	D-70	……	1.02	1.01-1.05
Softening Point	(4±1) °C/min.	D-36	°C	58	51-62

3.2. Aggregate

The (crushed) aggregate used in this work is brought from AL-Thariat factory. The physical properties of the aggregate (coarse and fine) are shown in Table 2. One type of mineral filler is used: ordinary Portland cement. It is thoroughly dry and free from lumps or aggregations of fine particles.

Table 2. Physical properties of aggregates

No.	Laboratory Test	ASTM Designation	Test Results
	Coarse Aggregate		
1	Bulk Specific Gravity	C-127	2.54
2	Apparent Specific Gravity	C-127	2.60
3	Percent Water Absorption	C-127	0.7
	Fine Aggregate		
1	Bulk Specific Gravity	C-128	2.63
2	Apparent Specific Gravity	C-128	2.69
3	Percent Water Absorption	C-128	0.71

3.2.1. Aggregate Gradation

The coarse and fine aggregates sieved and separated to various sizes. Trial and error method has been used to find the aggregates and cement ratios, calculate the limits of the mixing equation as well as the ratios of the mixture equation for the wearing course as shown in Table 3. and Figure 2. which meets the Iraqi specification limits [SCRB 2003/R9].

Table 3. Selected gradations for asphalt concrete mixtures

Sieve size (mm)	Course Aggregate %	Medium Aggregate %	Fine Aggregate %	Crushed Aggregate %	River Sand %	Cement %	The mixture Equation Ratios	The Mixture Equation Limits	Iraqi Specification Limits
19	100	100	100	100	100	100	100	100	100
12.5	38	100	100	100	100	100	94	90-100	90-100
9.5	----	42	100	100	98	100	81	76-87	76-90
4.75	----	----	19	100	95	100	54	46-60	44-74
2.36	-----	----	----	93	85	100	46	42-50	28-58
0.3	----	----	----	18	5	100	11	7-15	5-21
0.075	----	----	----	1	----	95	5	4-7	4-10
The supposed mixture ratios	10	15	25	30	15	5	----	----	----

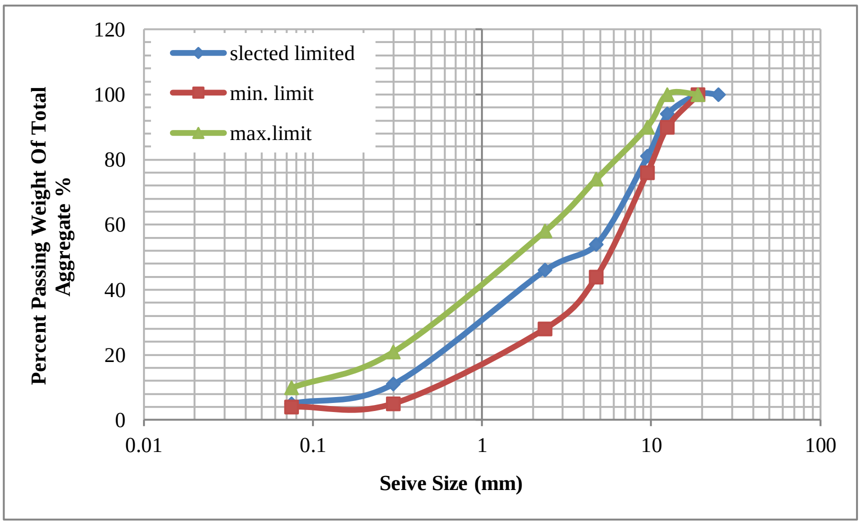


Figure 2. Specification limits and selected mid-point gradation of the mixture equation ratios for wearing course layer

3.3. Reed Netting Reinforcement

Types of geo-synthetics are (Geogrids (GG), Geotextiles (GT)) both types are used widely in the reinforcement of pavement [15]. Geogrids are structured polymeric materials usually made from sheets of high-density polyethylene (HDPE) or polypropylene (HDPP), the improvement in such material depends on many factors such as the type of geo-synthetic, the process of manufacturing, mechanical properties, the location of placement in asphalt concrete, and layering; base course thickness and quality. All the geo-synthetics materials are not available in Iraq and need to import. The type of reed netting which used in this study is (phragmites gragmites), manufactured as a rectangular netting to be used as a reinforcement interlayer material as shown in Figure 3. The advantages of reed mats are obtainable in Iraq, very cheap, environment friendly and don’t need to manufacture. The Properties of reed netting used and tension test for reed sample are illustrated in Table 4 and Figure 4, respectively.

Figure 3. Reed netting

Table 4. Properties of reed netting used

Item	Property	Test method	Unit	Data
1	Dimensions	-	mm*mm	390*290
2	Thickness	-	mm	25
3	Mass per unit area	-	g/m^2	1370
4	color	-	-	Shiny yellow
5	Tension Test(load-deformation)	Tensile Testing Machine	(kN – mm)	33.8 - 21

Figure 4. Tension test for reed samples

3.4. Marshall Mix Design

Marshall Mix design has been used to obtain the optimum binder asphalt content. This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixtures loaded on the lateral surface by means of the Marshall apparatus according to ASTM (D 1559). The optimum asphalt content for wearing layers is found 5%. Marshall Properties of (wearing) mixes were meeting the standard Iraqi specification requirements (SCRB, R/9 2003) as shown in Table 5. This optimum content has been adopted in the method of preparing all the slab specimens of asphalt mixtures to perform the Wheel Tracking Test.

Table 5. Mixtures properties at optimum asphalt contents

Item	Test method	Results	S.C.R.B Specification Requirements
1	Marshall Stability (kN)	9	Min-8
2	Marshall Flow(mm)	2.8	(2-4)
3	Optimum Asphalt Content	5	(4-6)%
4	Bulk Density (gm/cm^3)	2.35	….
5	Air Voids in Total Mix V.T.M%	3	(3-5)%
6	Void in mineral aggregate V.M.A%	15.75	14 min
7	Void filled with bitumen VFB%	81	(70-85)%
8	Asphalt Grade	40-50	

3.5. Calculation of Equivalent Base Thickness for Mold and Moving Plate

Base for mold is made with thickness of 20 mm according to the following calculation for equivalent thickness of steel instead of two layer of asphalt, layer of subbase and layer of subgrade.

Assume E steel $= 3 \times 10^7$ psi

E binder $= 3.5 \times 10^5$ psi and thickness 7 cm

E stabilizer $= 3 \times 10^5$ psi and thickness 10 cm

E subbase $= 5 \times 10^3$ psi and thickness 30 cm

E subgrade $= 1.5 \times 10^3$ psi and thickness 50 cm

$$E\ steel\ d^3 = E\ binder\ d^3 + E\ stabilizer\ d^3 + E\ subbase\ d^3 + E\ subgrade\ d^3$$

$3 \times 10^7 \times d^3$ steel = $3.5 \times 10^5 \times 2.7^3 + 3 \times 10^5 * 3.9^3 + 5 \times 10^3 \times 11.8^3 + 1.5 \times 10^3 \times 19.6^3$

d steel = 1.14 inches = 29 mm

It can be seen that 29 mm the thickness required of steel to be equivalent for the layers of asphalt, subbase and subgrade so that the moving stage is made from plate with thickness 20 mm , the total base will be 50 mm of steel from calculation , Figure 5 shows the equivalent base for mold.

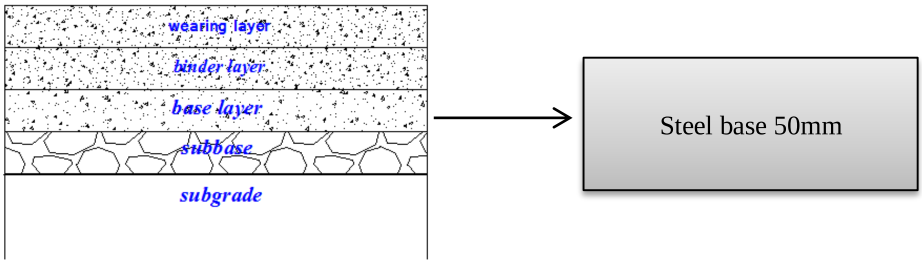


Figure 5. Equivalent steel base of mold

3.6. Specimen Preparation

The hot mixture asphalt HMA slab specimens are prepared depending on the optimum asphalt content 5%, the dimensions of the specimen (400 mm length × 300 mm width × 50 mm height) for wearing layer. Steel rectangular mold with dimensions (400 mm length × 300 mm width × 120 mm height) is used to prepare all specimens. In this research, hand wheel roller has been manufactured in a local workshop, is designed to simulate steel roller which is usually used in the field of compaction to get the same Marshall density of Sample test. The rolling action is taken in x-x direction, and then the same sequence has been repeated in the y-y direction to insure the compaction of the asphaltic slab sides with reinforcement reed netting for rutting testing. It consists of steel skeleton and a rubber cylinder (180mm) in diameter, (200mm) in length and the total weight of this roller is (40 kg). The asphalt mixture is prepared by heating the ready asphalt mixture to (150-160) ˚C. The weight of the asphalt mixture to be introduced into the mold is 13.5 kg to produce asphalt specimen. All steps for preparing the model are described as shown in Figure 6, three readings of permanent deformation for each group of test for specimen and the average results are reported.

Figure 6. Slabs preparation compacted manually by hand wheel roller

4. Testing Methods

The experimental program conducted in this work was designed through laboratory tests to investigate and evaluate the effects of reinforcing asphalt mixtures with reed netting against the main expected distresses in flexible pavement. Specifically the following test method was considered in the program of this work:

4.1. Permanent Deformation Test

Permanent deformation is considered the major distress in flexible pavements in Iraq and has a major impact on pavement performance. The accumulation of plastic deformations in asphalt layers is now recognized to be one of the major components of rutting in flexible pavements due to the increasing of axle loads and climate conditions. The basic types of rutting are: rutting occurs in HMA and subbase or subgrade rutting when the pavement surface exhibits wheel path depressions as a result of compaction and inadequate mix design, the permanent deformation of asphalt mixture occurs. Also, granular material/subgrade rutting occurs when the layers exhibit wheel path depressions caused by excessive loading. To study the permanent deformation phenomena for both reinforced and unreinforced asphalt samples, the wheel tracking device was used, so the asphaltic slab samples were prepared for this test.

4.2. Wheel-Tracking Testing

The Wheel tracking machine in the highway laboratory in the college of engineering in Basra university use for the rutting depth test of asphalt slab sample reinforced with reed netting in different layers. It is necessary to simulate conditions that occurring in the field as close as possible. So wheel tracking machine has been used because it has ability to applied repeated loads in order to simulate the permanent deformation occurring under a load of traffic. The apparatus consists of the following parts (device frame, motor and gearbox installation, heating system, control unit, moving plate, wheel frame rubber, Shaft encoder, Loads, steel mold. Other electrical components have been added to the wheel tracking machine to add an automation touch to the machine such as PLC, HMI, VFD, and laser distance sensor. This device was shown in the Figure 7. The information about the rate of the rutting from a moving and concentrated load are provides by the test. It uses a laser distance sensor to measure the deformation in the middle of specimen after each specific numbers of passes. The loaded wheel applies about 700 ± 10 N of load, passes repetitively over the sample for up to 10,000 cycles at contact points of sample. Test results are compiled in a programmable logic controllers (PLC) database application which provides several means of reporting results.

Wheel-tracking machine is fabricated to enable the test specimen to be moved backwards and forwards under the loaded wheel in a fixed horizontal plane. The center-line of the tire track is (5 mm) from the theoretical center of the. The contact area center of the tyre describes a simple harmonic motion with respect to the center of the top surface of the test specimen with a total distance of travel of (230±10) mm and a constant loading frequency of (41) cycles per minutes for the test device in approximately 10,000 load repetitions. The experimental design for the permanent deformation test is a factorial with one asphalt content, three testing temperatures, and four different locations of reinforcement in the testing samples, resulting in a nominal total of 15 slab tests. After complete prepare the specimens in the mold, then placed in on the carriage table of WTD for testing, entering the required test information into the PLC Controller. The testing device automatically stops the test when the device applies the number of desired cycles. Finally at the end of the test the arm of the wheel is lifted off while the display will show the results of the test which can be saved in the archives and/or transmitted to an external computer.

Figure 7. Wheel tracking device

5. Results and Discussion

The experimental design for the permanent deformation test with using reed netting at different layers is a factorial with one asphalt content, three testing temperatures, and four different locations of reinforcement in the testing samples, resulting in a nominal total of 15 slab tests.

5.1. Effect of Reinforcement Reed Netting Location on Permanent Deformation (Rutting) for Asphalt Concrete

Table 6 explains Improvement Ratio (IR) for the reinforced samples as compared with the unreinforced samples for the permanent deformation test. Figures 8 to 10. show that the improvement ratio for reinforced specimens at optimum asphalts content 5% for different temperatures. These figures compare Improvement Ratio at 10000 load repetition of each reinforcement location in a histogram form. At (40°C) it is clearly showed that the higher improvement ratio can be noticed in two cases of reinforcement embedded above base layer and embedded at the bottom and between wearing layer (double reinforcement) (75%), while the lowest improvement ratio can be observed in reinforcement embedded above subgrade layer (52%), at (50°C) the higher improvement ratio can be noticed in double reinforcement for wearing layer (84%), while the lowest improvement ratio can be observed in reinforcement embedded above subgrade layer (59%) and at (60°C) the higher improvement ratio can be noticed also in double reinforcement for wearing layer (85%), while the lowest improvement ratio can be observed in reinforcement embedded above subgrade layer (65%). These figures show that an improvement was observed in rutting behavior at different location of reinforcement for different testing temperatures.

Table 6. Improved ratio for the reinforced samples compared to control samples

Reinforcement Location	Temperature (°C)	Cycle (N)	Improvement Ratio (IR) (%)
Embedded Above Subgrade layer	40	10000	52
	50		59
	60		65
Embedded Above Base layer	40		75
	50		83
	60		84
Embedded Above Binder layer	40		68
	50		77
	60		77
Embedded at the bottom and between wearing layer (double reinforcement sample)	40		75
	50		84
	60		85

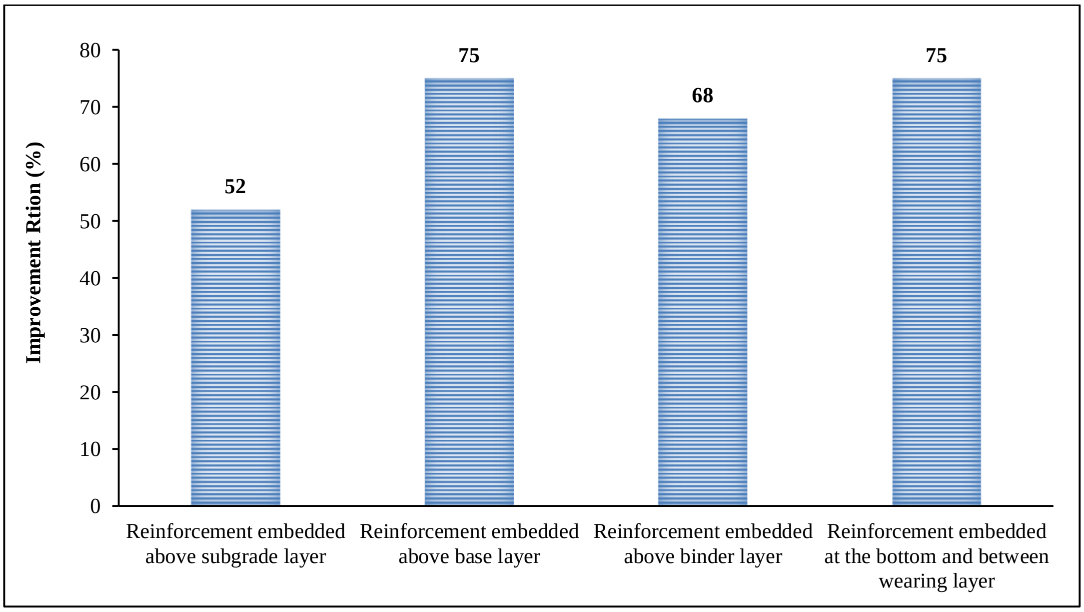


Figure 8. Effect of reinforcement (reed netting) location on improvement ratio (IR) at optimum asphalt for 40 °C

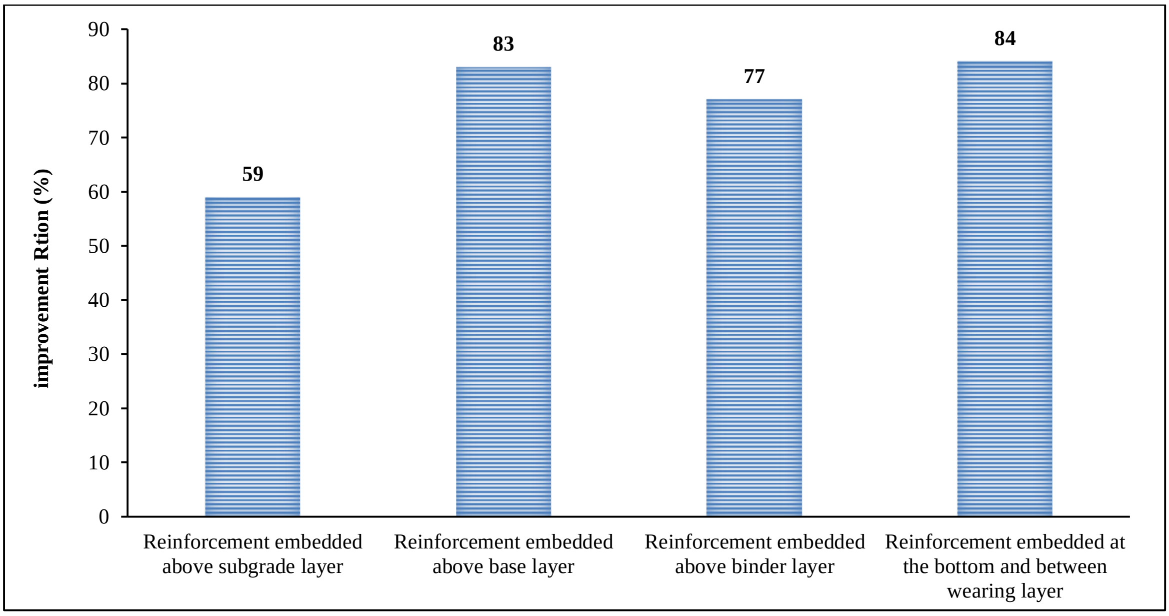


Figure 9. Effect of reinforcement (reed netting) location on improvement ratio (IR) at optimum asphalt content for 50 °C

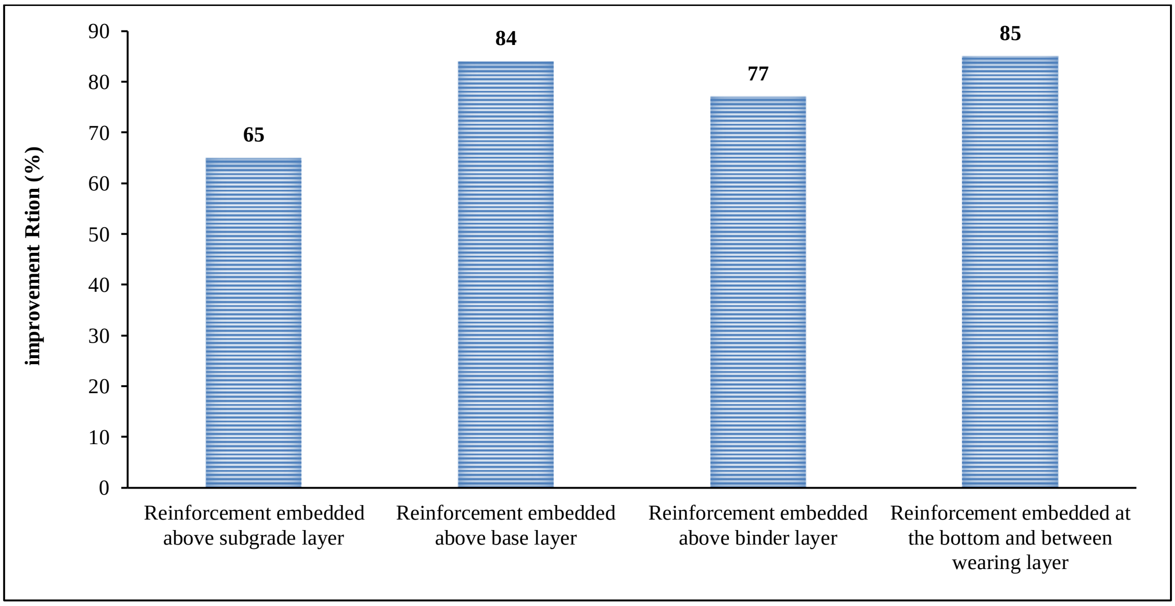


Figure 10. Effect of reinforcement (reed netting) location on improvement ratio (IR) at optimum asphalt content for 60 °C

Figures 11 to 13 show the variation of rut depth with number of load application due to the change in reinforced location for the reinforced and unreinforced samples at different testing temperatures. It has been seen that the rut depth for the pavement layers increases with the increase of the load application (cycling loading). Moreover, the highest value of the permanent deformation can be seen in unreinforced sample and then gradually decreases to achieve the lowest rutting depth at case of reinforcement embedded at the bottom and between wearing layer. The failure of the unreinforced slabs was manifested as shear distress with the asphalt forced out beneath the machine wheel and slabs edge to such an extent. At (40°C) the rutting value of unreinforced sample after 10000 load repetitions is found to be (15.5 mm) and decreases gradually according to the location of reinforcement to (7.5 mm, 4.9 mm, 3.9 5 mm and 3.85 mm) at reinforcement embedded (above subgrade, above binder, above base and at the bottom and between wearing) layers respectively, at (50°C) the rutting value of unreinforced sample is found to be (30 mm) and decreases gradually to (12.3 mm, 6.8 mm, 5.2 mm and 4.9 mm) respectively, and at (60°C) the rutting value of unreinforced sample is found to be (39 mm) and decreases gradually to (13.6 mm, 9.5 mm, 6.3 mm and 5.85 mm) respectively.

From the above-mentioned figures, it is clear that the role of reinforcement reed netting in redistribution of the load repetition over a greater area and in enforcing the development of rut depth at the same number of load application for reinforced and unreinforced samples, where the improvement provided by reed netting reinforcement is manifested primarily at intermediate and high temperatures rather than low temperatures.

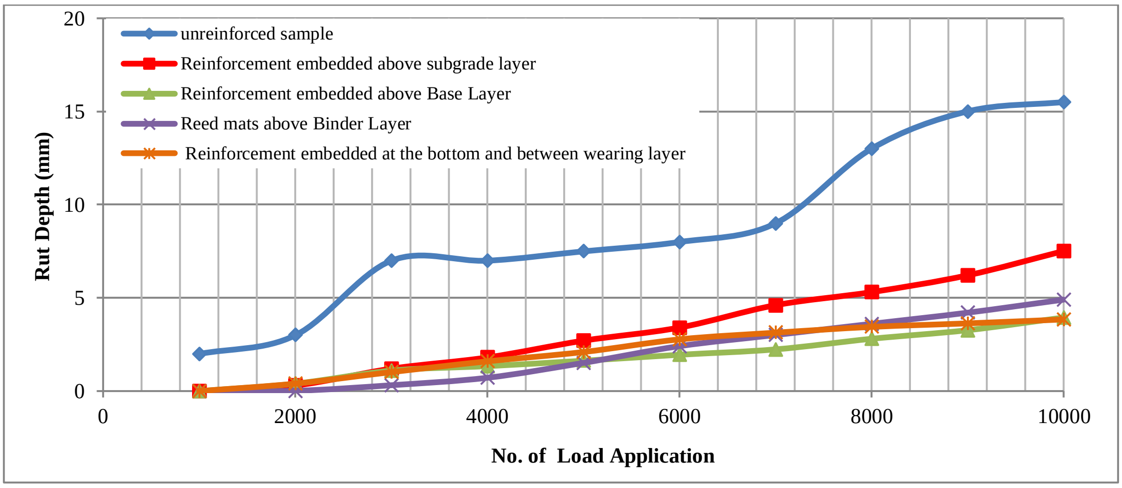


Figure 11. Variation of rut depth with number of load application at 40°C

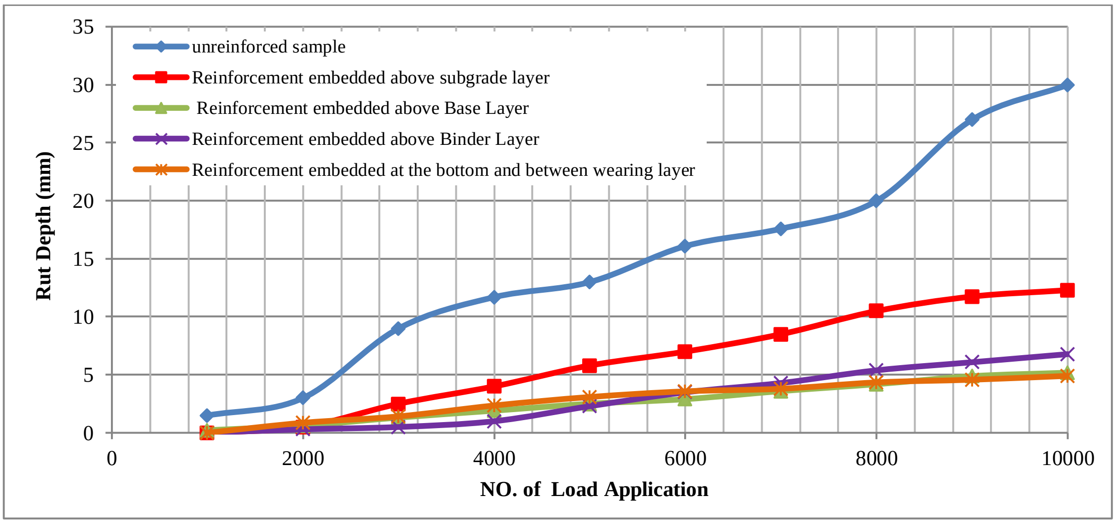


Figure 12. Variation of rut depth with number of load application at 50°C

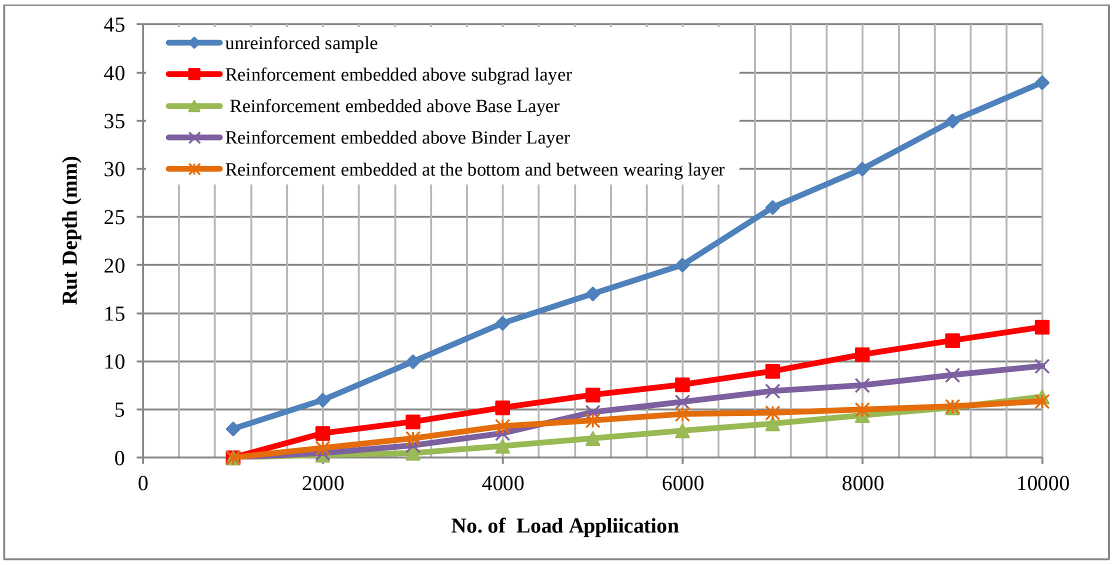


Figure 13. Variation of rut depth with number of load application at 60°C

5.2. Effect of Testing Temperature and Location of Reinforcement on Permanent Deformation

The temperature effect on the rut depth has been proved by choosing three test temperature; 40 °C, 50 °C and 60 °C, with applied 10000 cycle load. Table 7 shows the variation of rut depth due to the change in testing temperatures for the reinforced and unreinforced samples at optimum asphalt content (5%).

Table 7. Increasing percentage in rut depth for reinforced and unreinforced specimens with the temperature changed

Reinforcement Location	Wearing layer AC 5%	
	40° C to 50° C	40° C to 60° C
Unreinforced Sample	93.55	151.6
Embedded above Subgrade Layer	64	81.33
Embedded above Base Layer	31.65	59.49
Embedded above Binder Layer	38.78	93.88
Embedded at the Bottom and Between Wearing Layer (Double Reinforcement Sample)	27.27	50.63

Figures 14 and 15 show the relation between rut depth and number of load application for unreinforced samples. The test results were 15.5 mm, 30 mm and 39 mm for the temperature of the test 40 °C, 50 °C and 60 °C respectively. These results give indication that the increase of the rut depth of asphalts Pavement due to the increase of temperature. Also Figure 16 presents in a histogram form the relation between rut depth and number of load application for different temperature test. It can be seen when temperature decreased from 50 °C to 40 °C the permanent deformation will decrease 48 % while the increasing rutting 30 % when temperature increased from 50 to 60 °C.

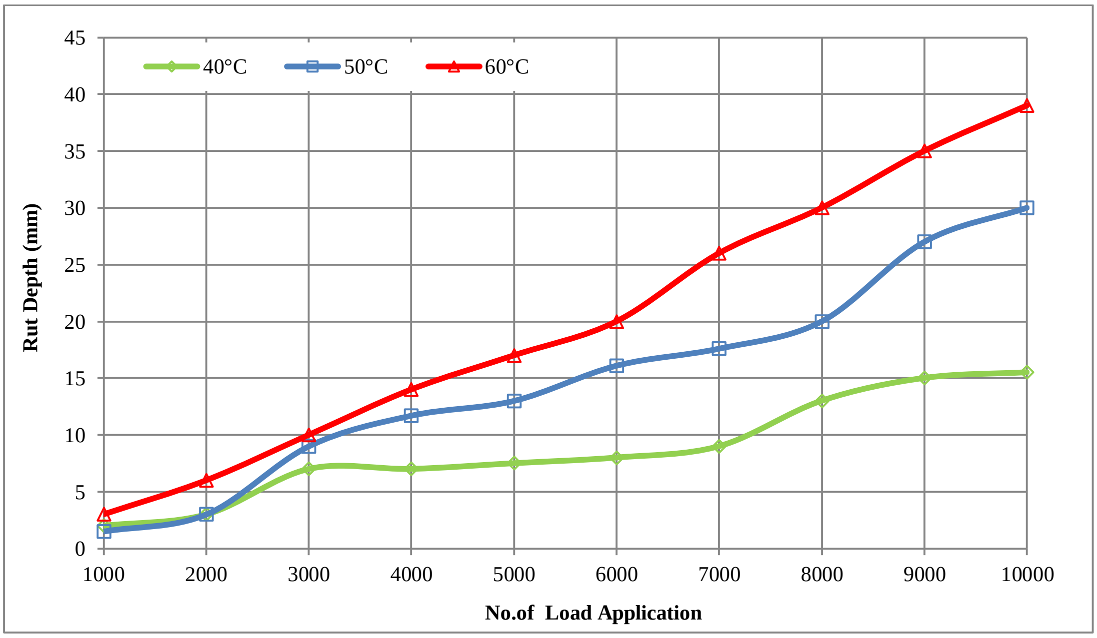


Figure 14. Effect of testing temperatures on rutting depth (mm) for unreinforced sample

A **B** **C**

Figure 15. Unreinforcement samples at different temperatures (A) 40 °C; (B) 50 °C; (C) 60 °C

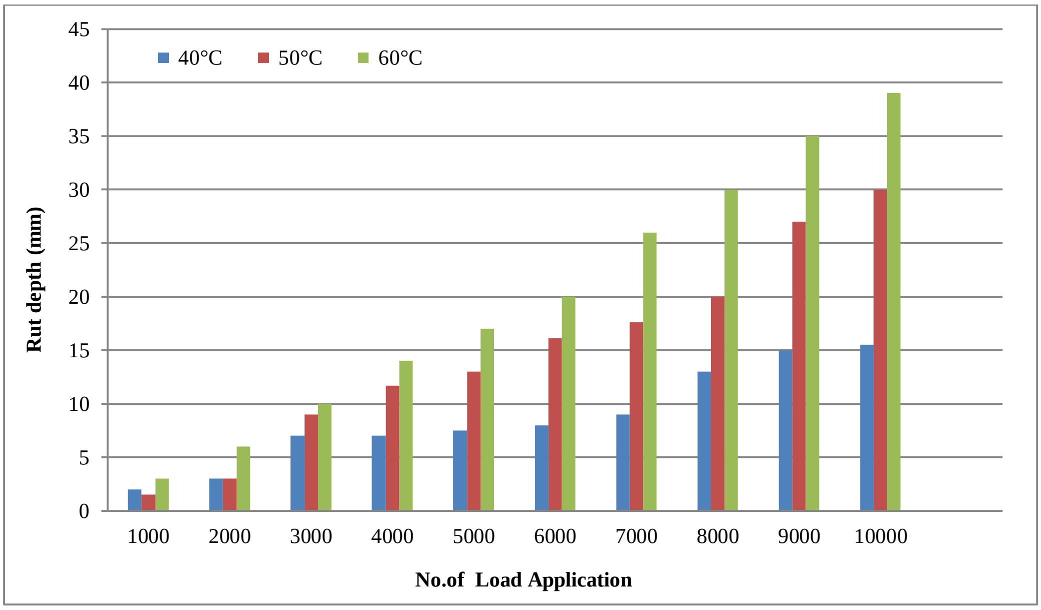


Figure 16. The relation between rut depth and number of load application for unreinforced samples at different temperatures

Figures 17 and 18 show the relation between rut depth and number of load application for reinforcement embedded above subgrade layer. The test results were 7.5, 12.3 and 13.6 mm for the temperature of the test 40°C, 50 °C and 60 °C respectively. These results give indication that the increase of the rut depth of asphalts Pavement due to the increase of temperature. Also Figure 19. presents in a histogram form the relation between rut depth and number of load application for different temperature test. It can be seen when temperature decreased from 50 °C to 40 °C the permanent deformation will decrease 39 % while the increasing rutting 10.6 % when temperature increased from 50 to 60 °C.

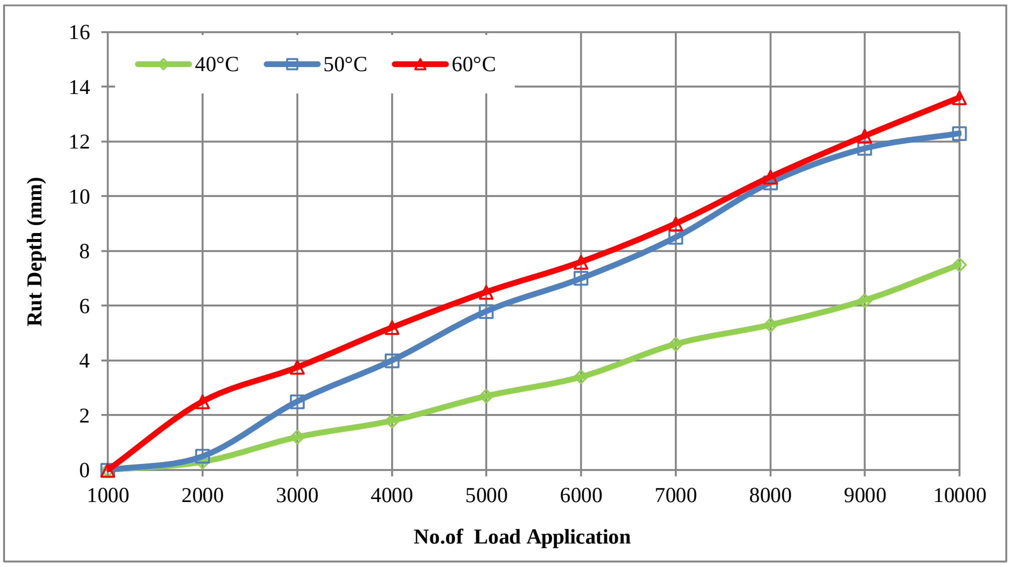
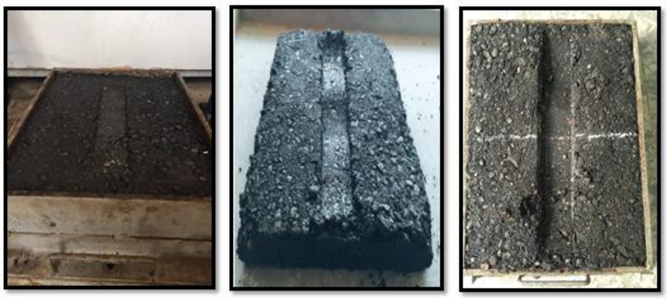


Figure 17. Effect of testing temperatures on rutting depth (mm) for reinforcement embedded at above subgrade layer



A **B** **C**

Figure 18. Reinforcement embedded at above subgrade layer at different temperatures (A) 40 °C; (B) 50 °C; (C) 60 °C

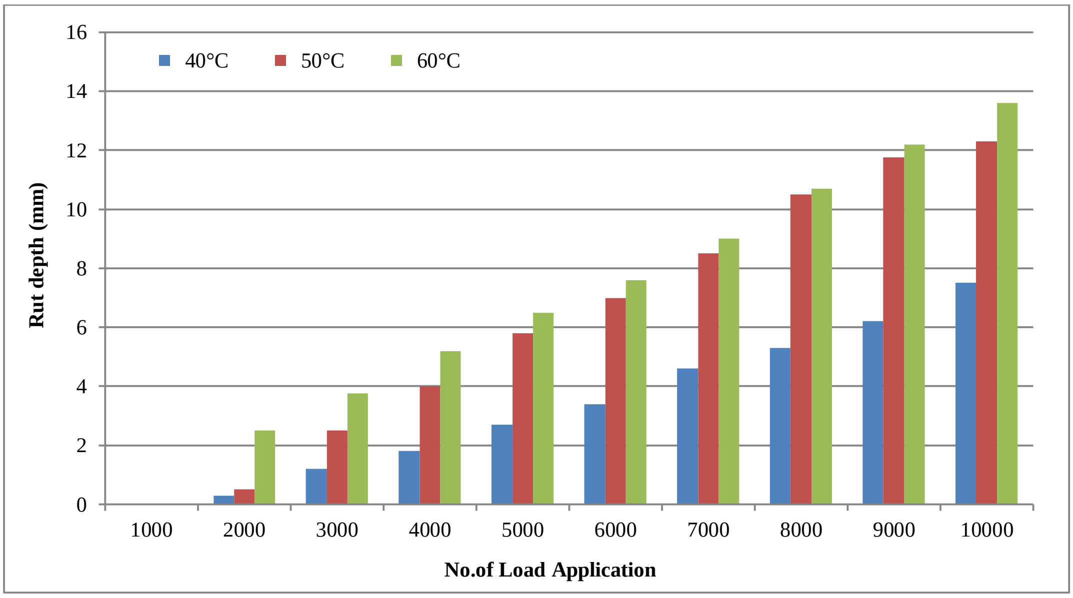


Figure 19. The relation between rut depth and number of load application for reinforcement embedded above subgrade layer at different temperatures

Figures 20 and 21 show the relation between rut depth and number of load application for reinforcement embedded above base layer. The test results were 3.95, 5.2 and 6.3 mm for the temperature of the test 40 °C, 50 °C and 60 °C respectively. These results give indication that the increase of the rut depth of asphalts Pavement due to the increase of temperature. Also Figure 22 presents in a histogram form the relation between rut depth and number of load application for different temperature test. It can be seen when temperature decreased from 50 °C to 40 °C the permanent deformation will decrease 24 % while the increasing rutting 21 % when temperature increased from 50 to 60 °C.

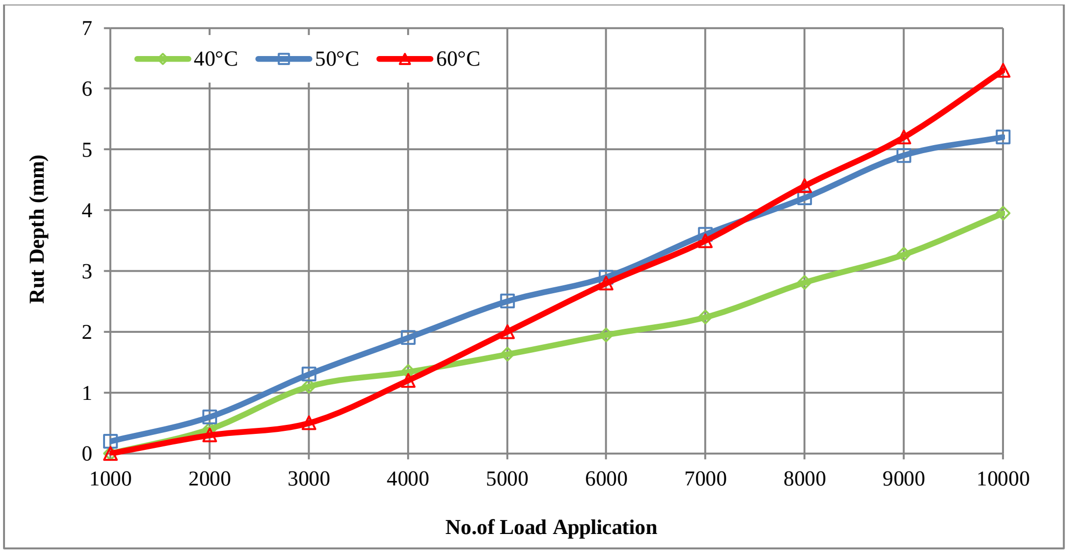


Figure 20. Effect of testing temperatures on rutting depth (mm) for reinforcement embedded at above base layer

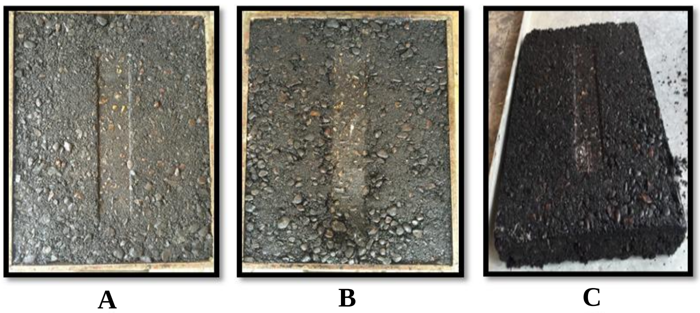


Figure 21. Reinforcement embedded at above base layer at different temperatures (A) 40 °C; (B) 50 °C; (C) 60 °C

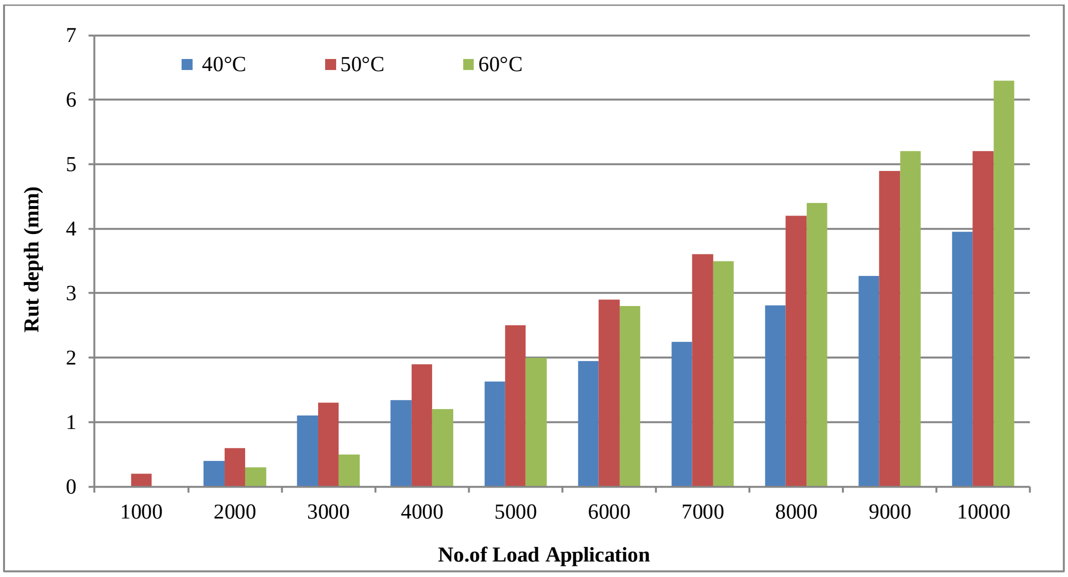


Figure 22. The relation between rut depth and number of load application for reinforcement embedded above base layer at different temperatures

Figure 23 and 24 show the relation between rut depth and number of load application for reinforcement embedded above binder layer. The test results were 4.9 mm, 6.8 mm and 9.5 mm for the temperature of the test 40, 50 and 60 °C respectively. These results give indication that the increase of the rut depth of asphalts Pavement due to the increase of temperature. Also Figure 25 presents in a histogram form the relation between rut depth and number of load application for different temperature test. It can be seen when temperature decreased from 50 to 40°C the permanent deformation will decrease 28 % while the increasing rutting 39.7 % when temperature increased from 50 to 60 °C.

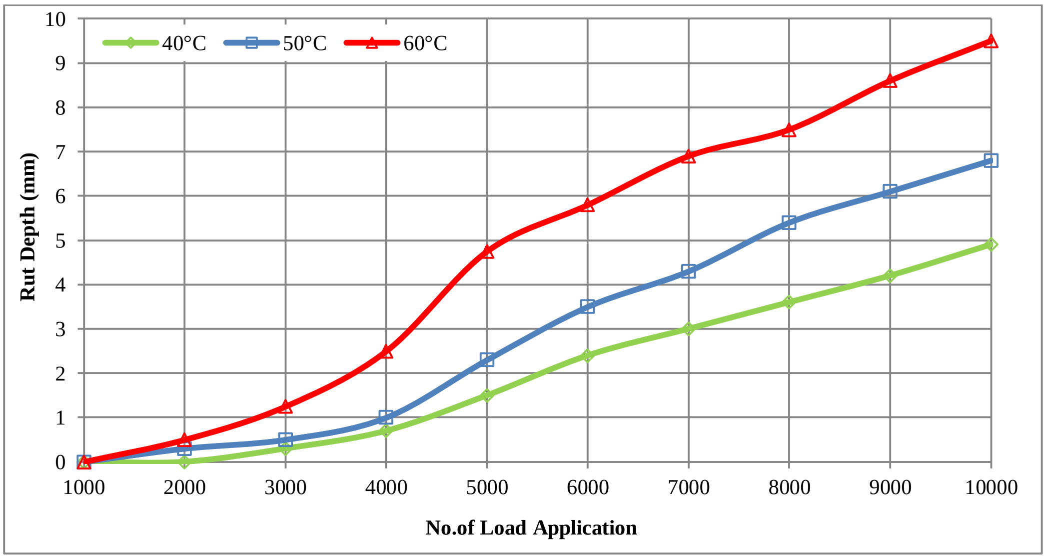


Figure 23. Effect of testing temperatures on rutting depth (mm) for reinforcement embedded at above binder layer

A **B** **C**

Figure 24. Reinforcement embedded at above binder layer at different temperatures (A) 40 °C; (B) 50 °C; (C) 60 °C

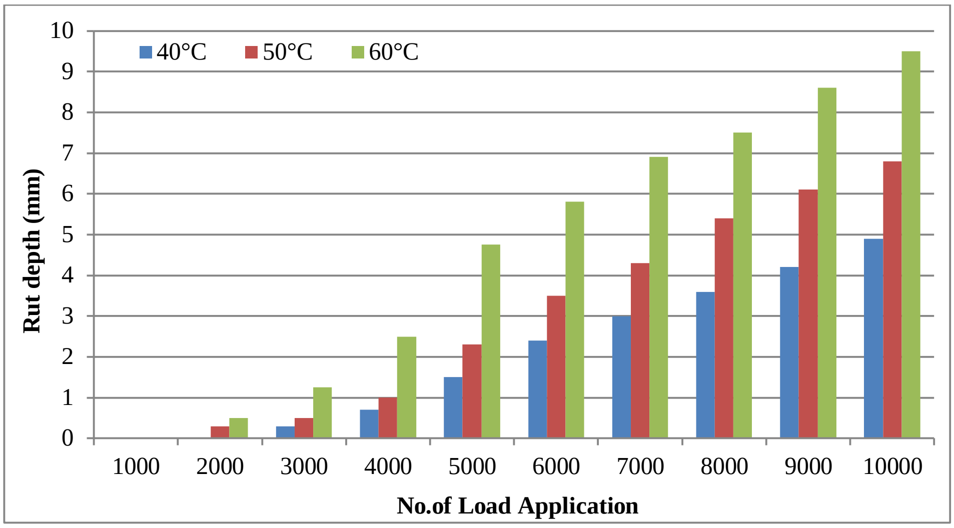


Figure 25. The Relation between Rut Depth and Number of Load Application for Reinforcement Embedded Above Binder Layer at Different Temperatures

Figures 26 and 27 show the relation between rut depth and number of load application for reinforcement embedded at bottom and other is embedded at middle of wearing layer. The test results were 3.85, 4.9 and 5.85 mm for the temperature of the test 40 °C, 50 °C and 60 °C respectively. These results give indication that the increase of the rut depth of asphalts Pavement due to the increase of temperature. Also Figure 28 presents in a histogram form the relation between rut depth and number of load application for different temperature test. It can be seen when temperature decreased from 50 °C to 40 °C the permanent deformation will decrease 21 % while the increasing rutting 19 % when temperature increased from 50 to 60 °C. According to these figures, the reducing in the viscosity of the binder causing increase in the permanent deformation due to the temperature increasing. The use of reed netting modified the performance of HMA. Generally, the permanent deformation at higher temperatures occurs due to pavement consolidation.

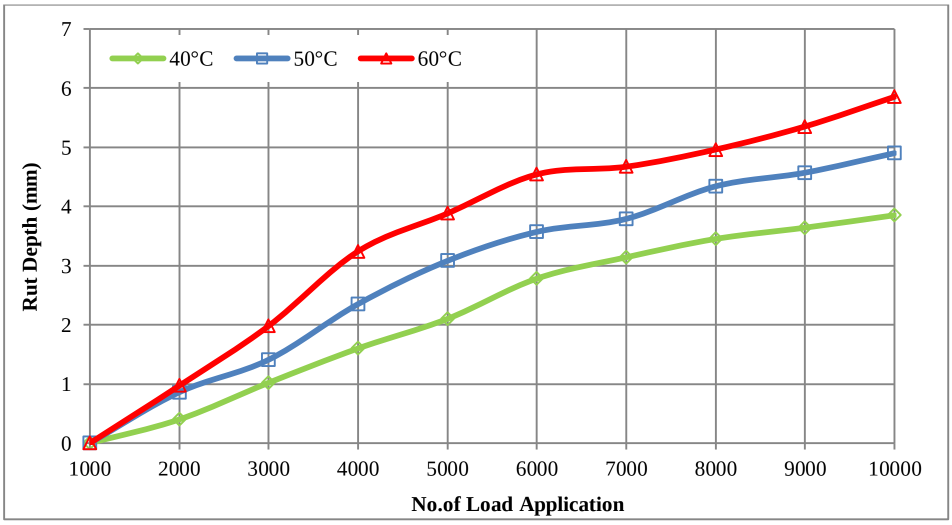


Figure 26. Effect of testing temperatures on rutting depth (mm) for reinforcement embedded at bottom and other is embedded at middle of wearing layer

A **B** **C**

Figure 27. Reinforcement embedded at bottom and other is embedded at middle of wearing layer at different temperatures (A) 40 °C; (B) 50 °C; (C) 60 °C

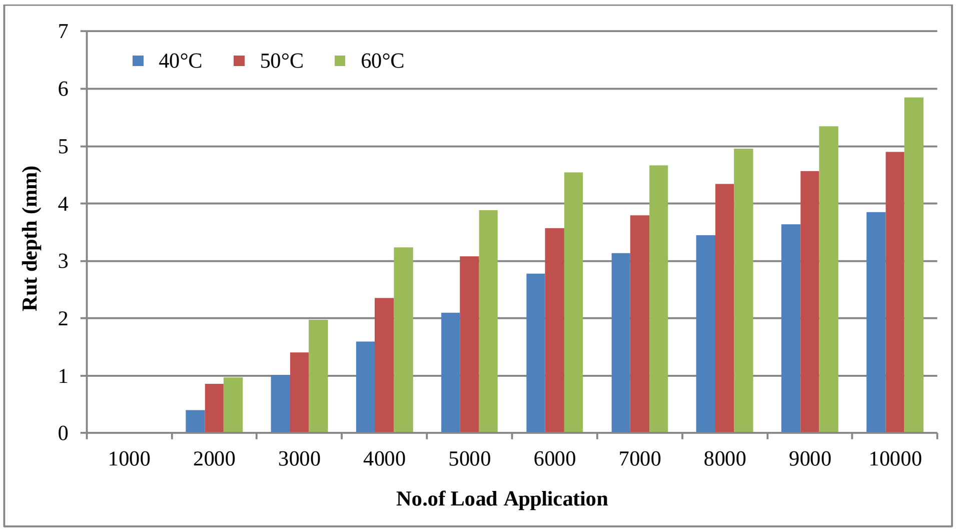


Figure 28. The relation between rut depth and number of load application for reinforcement embedded at bottom and other is embedded at middle of wearing layer at different temperatures

6. Conclusion

From the results of the present study, the important conclusions are as follows:

- In general, it is concluded that, the reinforcement reed netting improve the structural performance of flexible pavement against the main distresses (permanent deformation).
- The value of improvement ratio increase when the temperature testing increased.
- The best position of the reed netting in all investigated flexible pavement sections at reinforcement embedded at the bottom and between wearing layer (double reinforcement sample), where the best improvement ratio in reed netting at 60 ºC was (85%), then the reinforcement embedded above binder layer was (77%).
- The study shows that reed netting is very effective in reducing the rut depth, when the reed netting reinforcement embedded bottom and middle of wearing layer; it leads to the highest reduction in the permanent deformation. The test results of the wheel- Track for the rutting measurement were showed that, when placing the reed netting above the subgrade layer the amount of improvement in the layer (52%, 59% and 65%) respectively, for different temperatures. When placing the reed netting above the base layer the amount of improvement in the layer (75%, 83% and 84%) respectively, for different temperatures. When placing the reed netting above the binder layer the amount of improvement in the layer (68%, 77% and 77%) respectively, for different temperatures and the reed netting embedded bottom and middle of wearing layer the amount of improvement (75%, 84% and 85%).

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