

Using Poly Sulphonated Phenol –Formal-Dehyde as Additive of Hot Asphalt Mixes to Reduce a Rutting Depth

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Abstract

The increasing number of vehicles and trucks in combination with the effect of temperatures and moisture lead to accelerated and permanent deformation of the road network in Iraq. In order to decrease the pavement deformation or perfecting the flexible pavement performance was used the polymer as additive from long time. In this study poly sulphonated phenol –formal-dehyde using as additive on the asphalt mix and are used to investigate the potential prospects to enhance asphalt mixture properties. The objectives also include determining optimum polymer content, and Install applicable model for the rutting depth in surface layer.

First determine the optimum asphalt content by using Marshall mix design and found the optimum asphalt content was (5%). six proportions of poly sulphonated phenol –formal-dehyde content were added to asphalt (3, 6,9,12,15,18)% of optimum asphalt content .Three specimens are tested by Marshall apparatus test for each proportion. The 15% of additive can use as optimum content in marshal test.

The wheel tracking device are use to determine the rutting depth. This device not found in the laboratory therefore was decided to make this device by recourse to the specification of standard device. The specimens were prepared by using the optimum asphalt content and optimum additives content 15% of asphalt percent and tested in wheel tracking device using three temperatures (40,50,60) °C. It found the value of rutting depth increase with increasing passes load and temperatures but this increase has the smaller value in asphalt mixtures modified by polymers. To evaluate rutting depth of asphalt surface layer, the Architecture of Neural Network are used to supply an alternate method which shows the least scattering of the results.

Keywords: hot mix asphalt, asphalt additives, wheel tracking device, of poly sulphonated phenol –formal-dehyde, rutting depth.

INTRODUCTION

The increasing number of vehicles and trucks in combination with the effect of temperatures and moisture lead to accelerated and permanent deformation of the road network in Iraq. In order to decrease the pavement deformation or perfecting the

flexible pavement performance should make many improvements on the pavement layers such as improving the design of roadway, using a good materials quality, using effective methods of construction methods, and using sufficient methods for maintenance. To improvement the performance of asphalt pavement was used the polymer as additive from long time.

In Iraq, rutting is the major deformation in the pavement surface especial in stop locations that appear due to increasing of axle load, and increasing of the temperature in summer.

The surface layer is the first layer which contact with axel load, and affected by the variations in temperature and moisture therefore in this study will be using the polymer as additive in order to find the best modification of the pavement surface with high performance.

The principles aims of this study were to:-

1. Determine the effect of using poly sulphonated phenol – formal-dehyde as additive on the asphalt mix.
2. Determine the optimum content of asphalt and additives.
3. Determine the rutting depth at different temperatures for the surface layer with and without additives.
4. using the Architecture of Neural Network to evaluate rutting depth of asphalt surface layer,

MATERIALS AND METHODS

Asphalt Cement:

In this study were used the asphalt cement with grade (40-50) which brought form AL- Basrah refinery. Table (1) shows the physical properties and tests of this asphalt cement.

Aggregate Properties:

In this study was brought the crashed coarse aggregate, the crashed sand, natural sand from AL-Narges hot mix plant in basrah city. The cement was used as filler. Table (2) shows the gradation and physical properties for aggregate and filler.

Polymer:

Six proportions of poly sulphonated phenol –formal-dehyde were used in this study to evaluate the effect of this additive on the performance of asphalt mixture. These proportions are (3, 6, 9, 12, 15, 18)% by weight of optimum asphalt content. The physical properties shown in table (3)

Table 1: The tests of asphalt cement

Test	Unit	ASTM(1)	Test value	SCRB Specification(2)
Penetration @ (25°C,100gm,5sec)	1/10mm	D-5	43	40-50
Softening point	°C	D-36	58	51-62
Specific gravity @25 °C	-----	D-70	1.02	1.01-1.05
Ductility @ (25 °C,5cm/min)	cm	D-113	>100	>100
Flash point	°C	D-92	330	>232

Table 2: Gradation and physical properties for aggregate and filler

Sieve size(mm)	Sample NO.					
	Coarse gravel	Medium gravel	Fine gravel	Crushed sand	River Sand	Cement
19	100	100	100	100	100	100
12.5	29	91	100	100	100	100
9.5	-----	4	99	100	100	100
4.75	-----	1	43	96	98	100
2.36	-----	-----	6	88	74	100
0.3	-----	-----	-----	30	9	100
0.075	-----	-----	-----	3	-----	93
Crash percentage %	97	100	100	100	-----	-----
Bulk Sp.G. (ASTM c127 and c128)	2.54	2.58	2.61	2.63	2.65	3.13
Apparent Sp.G. (ASTM c127 and c128)	2.60	2.64	2.67	2.69	2.71	-----
Percent water absorption (ASTM c127 and c128)	0.7	0.71	0.72	0.71	0.65	-----

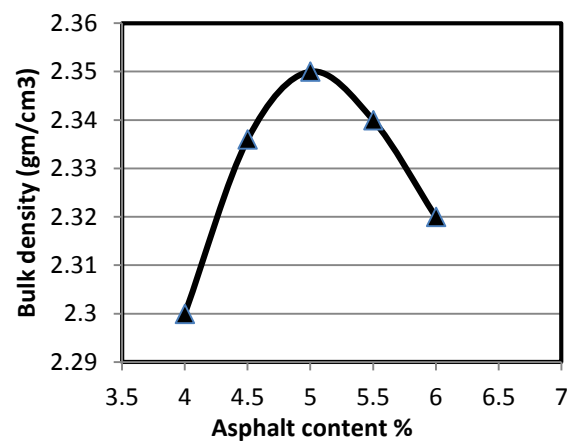
Table 3: Physical properties of poly sulphonated phenol –formal-dehyde

Consistency	Liquid
color	Brown
Solid content %	35-40
SO4%	15-17
PH	7-9
Density gm/cm ³	1.103

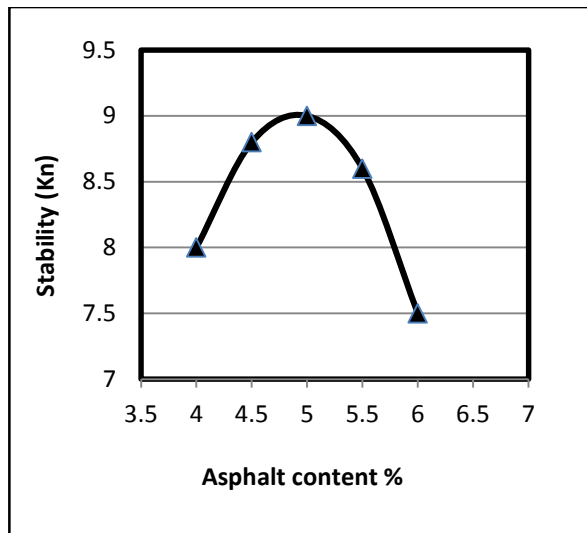
MIX DESIGN

The mix design is consist of four steps:

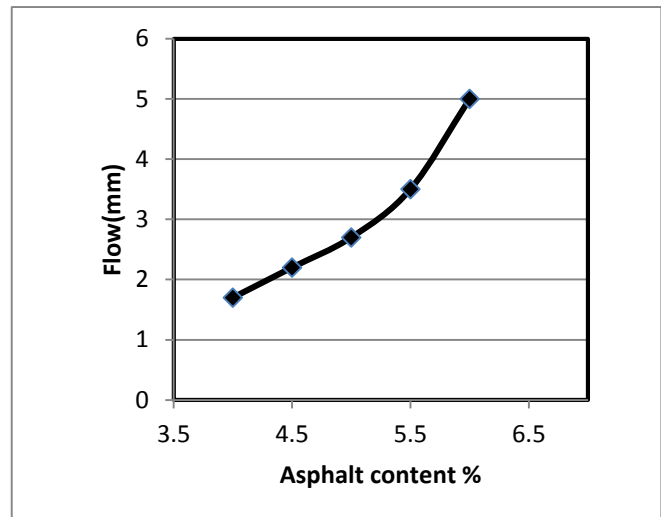
1. The first step is determination the correct gradation for the aggregate to achieve the specification (SCBR,) which could be worked by try and error.
2. The second step , 15 specimens of 1200 gram in weight were prepared according to gradation output in first step with asphalt content (4,4.5,5,5.5,6)% .three specimens to each proportion and compacted with 75 blow in top and bottom in accordance with the standard Marshall design method for designing hot asphalt concrete mixtures, designated as (ASTM Designation: D 1559).
3. The third step, determine the optimum asphalt content that would make asphalt concrete mixtures with stability and durability properties. In order to achieve this, the specimens are tested by Marshall Apparatus test according to ASTM (D1559. The Marshall Mix design curves show the optimum asphalt contents equal to 5% (see figure (1))
4. The fourth step, in order to determine the optimum additive content six proportions of poly sulphonated phenol – formal-dehyde content were added to asphalt (3, 6,9,12,15,18)% of optimum asphalt content .Three specimens are tested by Marshall apparatus test for each proportion.



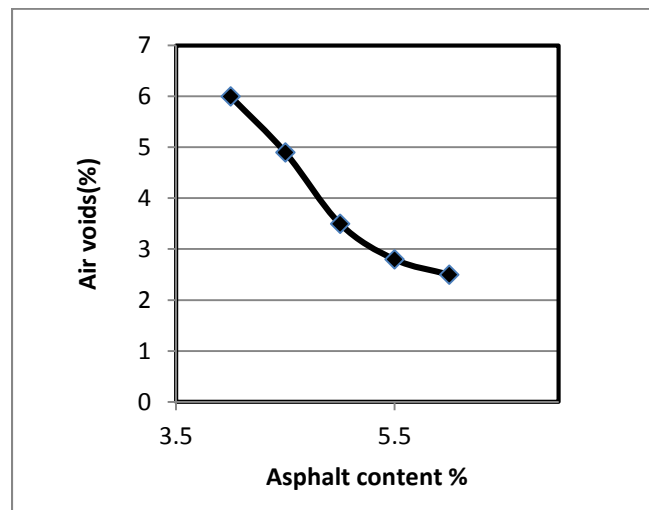
(a)



(b)



(c)



(d)

Figure 1: Marshal Mix design curve

RESULT OF MODIFIED ASPHALT MIXES

a- Bulk density

The bulk density is increased with increase the poly sulphonated phenol -formal-dehyde content until the 9% of additives after that the bulk density decreases with increase the additive until reaches the same bulk density with normal asphalt mixes at 18% of additives. See figure (2)

b- Stability

Figure (3) show the stability increase when using the poly sulphonated phenol -formal-dehyde as additive .the optimum stability occurs at additive equal to 15% after that the stability decreases with increase the additive.

c- Air voids

Figure (4) show the air voids interchange between increasing and decreasing when using the poly sulphonated phenol -formal-dehyde as additive but this value still with the SCBR specification.

d- Flow

The flow is not affected by using the poly sulphonated phenol -formal-dehyde as additive until 6% of additive, after that the flow is increasing by 0.5 mm for all proportions. See figure (5)

According to the result of stability, bulk density, air void, and flow the 15% of additive can used as optimum content in marshal test.

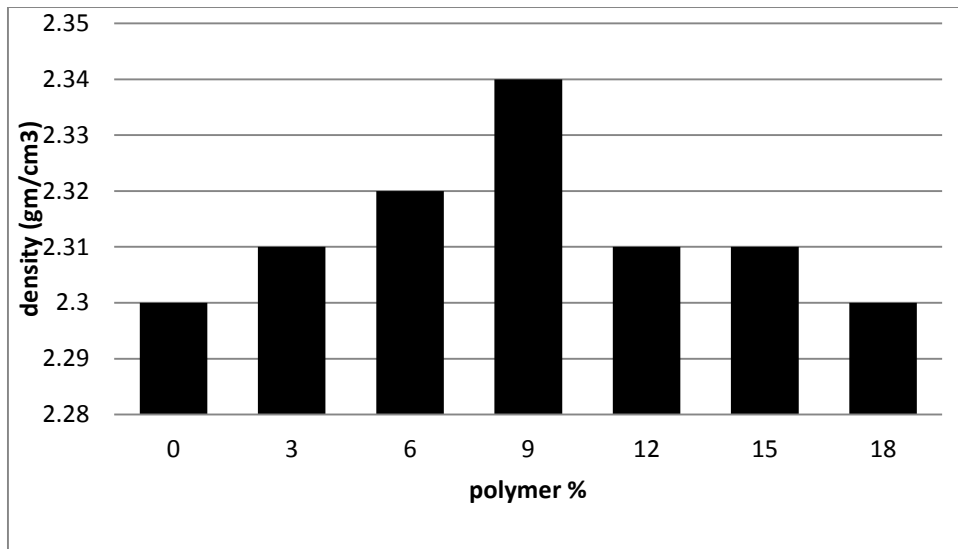


Figure 2: The relationship between polymer content and bulk density

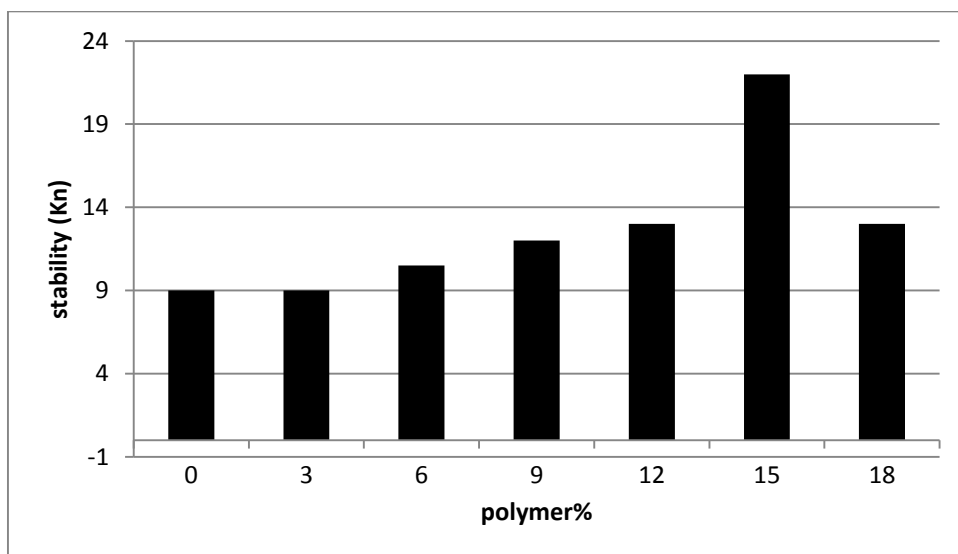


Figure 3: The relationship between polymer content and stability

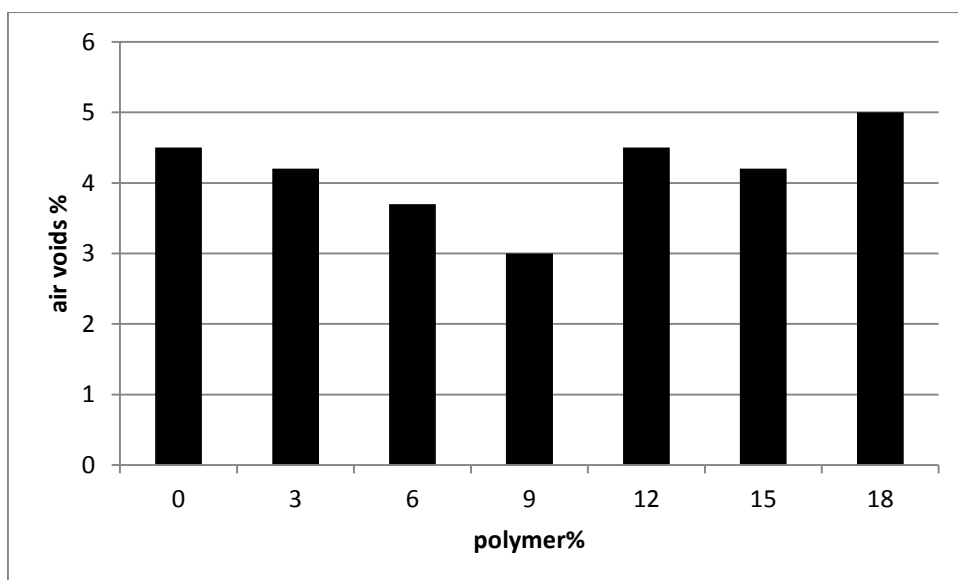


Figure 4: The relationship between polymer content and air void

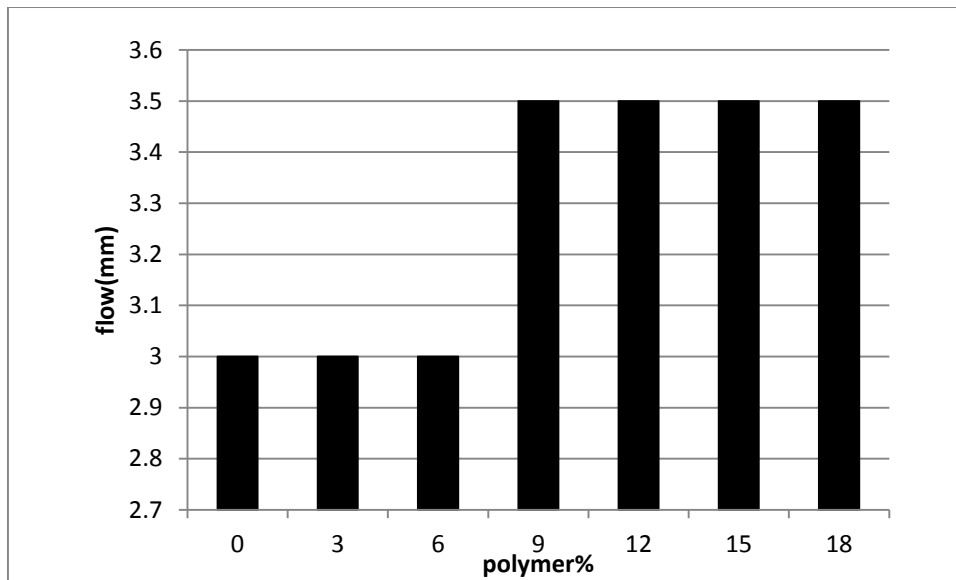


Figure 5: The relationship between polymer content and flow

WHEEL TRACKING TEST AND DEVICE

The wheel tracking device is used to determine the rutting depth that occurs at number of cycles (passes) of loading to samples failure. This device not found in the laboratory therefore was

decided to make this device by recourse to the specification of standard device.

This device consist of device frame, wheel frame and rubber, motor and gear box installation, heating and control units, and moving plate(3). Plate (1) show this device.



Plate 1: Wheel Tracking Machine

Mold of asphalt specimen made from steel plate thicknesses 15mm with dimensions 30 wide and 40 cm long with the height of 8cm, and using moving plate thicknesses 30 mm.(4)

The specimens were prepared by using the optimum asphalt content and optimum additives content 15% of asphalt percent. Then the specimens compacted by compression testing machine by applied a 200 KN static at speed 0.01 KN/sec at four times and then removed slowly. Then this sample tested in wheel tracking device using three temperatures (40,50,60) °C.

RESULT OF WHEEL TRACKING ADVICE (RUT TEST)

A-Effect of poly sulphonated phenol -formal-dehyde on the Rutting Depth

The rutting depth for surface layer is evaluated by using wheel track test. The results of this test for asphalt mixes with and without polymer is represented with the value of rutting depth increase with increasing passes load but this increase has the smaller value in asphalt mixtures which modified by polymers. See figures (6-8)

B-Effect of Temperature on the Rutting Depth for the Asphalt Mixtures Modified by poly sulphonated phenol -formal-dehyde

The temperatures have significant effect on the rutting depth with the increasing of the load passes. This increase has large value which reaches to twice when increase temperature from 40 °C to 50 °C and three times when increase temperature from 40 °C to 60 °C in normal asphalt mixes. In asphalt mixtures which modified by polymers the temperature has a little effect on the rutting depth. See figures(6-8)

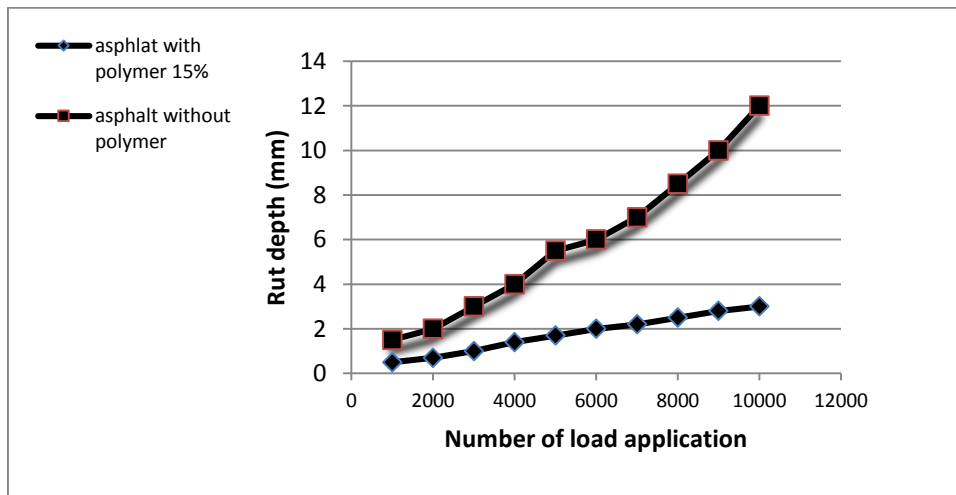


Figure 6: wheel tracking result for asphalt mix with and without additives at 40 °C

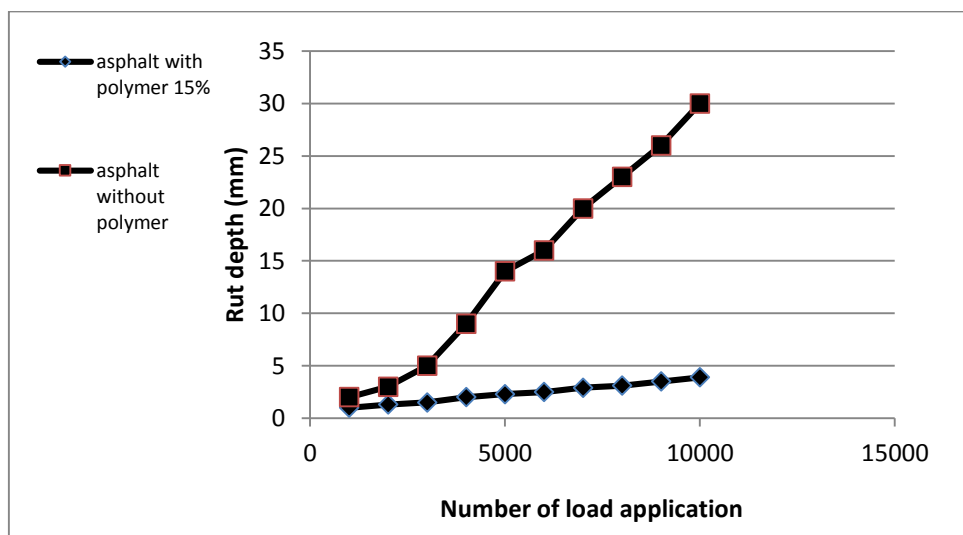


Figure 7: Wheel tracking result for asphalt mix with and without additives at 50 °C

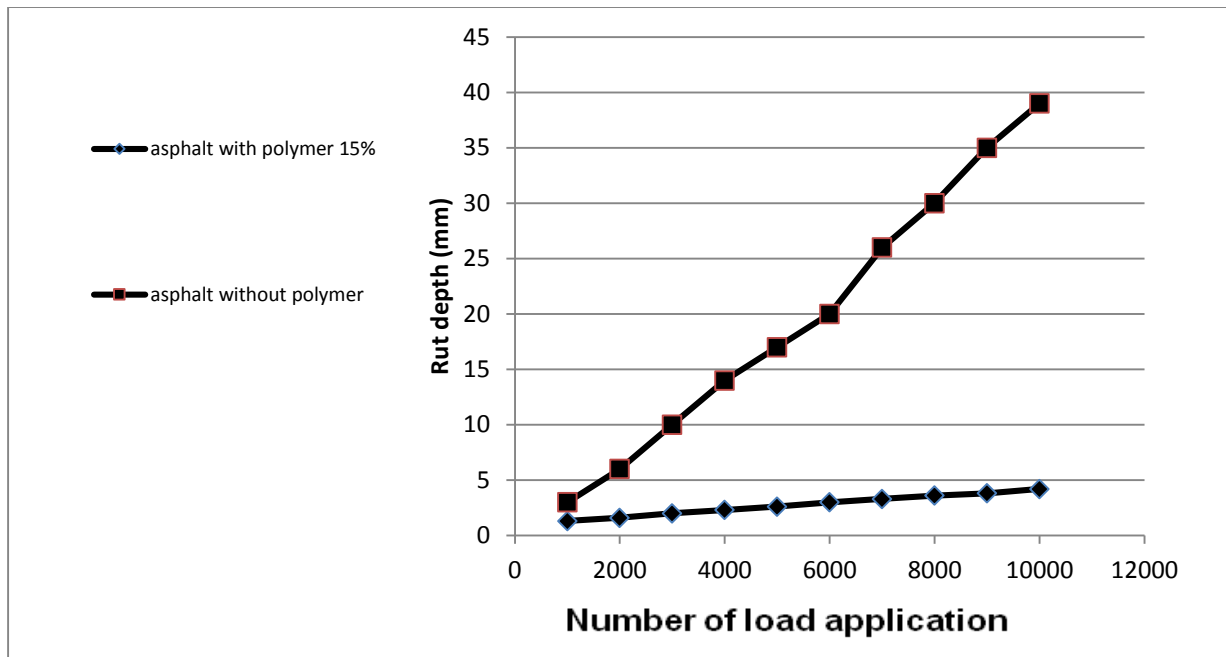


Figure 8: Wheel tracking result for asphalt mix with and without additives at 60 °C

NEURAL NETWORK DESIGN and TRAINING

To evaluate rutting depth of asphalt surface layer the Architecture of Neural Network(ANN) are used to supply an alternate method. To coach the ANN models, at first, the exclusive coaching data file is randomly divided into training, validation and testing data sets. The ultimate verification test for the ANN models is a true forecast for these circumstances. These tests have to be applied for (input and output) answer within the domain of coaching. Preparation of data by span was carried out to betterment the coaching of the neural network. The input and output data were scaled between the interval 0.1 and 0.9 in order to abate the slow rate of knowing near the end points especially of the output range due to the property of the sigmoid function model.(5)

The ANN was elaborate by using the popular MATLAB software package [MATLAB R2014b]. To coach the ANN models, first the totally experimental data file was randomly divided into training, validation, and testing data sets. The forty two patterns were used to coaching the different network architectures. The remaining eighteen patterns were used for testing to verify the forecast ability of each coached ANN model. The model has two input parameters and one output parameter. The models have one hidden layers with four nodes each, an Figure (9) presents typical layer feed-forward neural

networks. The rapprochement of the models in coaching is built on minimizing the error of tolerance for mean squared (MSE) error during the coaching cycles and monitoring the overall the performance of the coached networks by comparing the outputs.

The forecast of the ANN model as compared to the experimental values are shown in Fig (10) for training, testing, and validation data set of asphalt mixes without polymer. The coefficient of correlation (R) was equaled to 0.99984, 0.99717 , and 0.9979 for training, testing and validation data set, respectively. The coefficients of correlation (R) were equaled to 0.99865 for the ANN model. figure(11) show The forecast of the ANN model as compared to the experimental values for training, testing, and validation data set of asphalt mixes with polymer. The coefficient of correlation (R) was equaled . to 0.99832, 0.98857 , and 0.99571 for training, testing and validation data set, respectively. The coefficients of correlation (R) were equaled to 0.99635 for the ANN model

The accuracy of the predicted ANN values of the rutting depth is shown in Figure (10) and (11). This model, predict the training sets and testing sets quite well. From these results, it can be seen that the neural network model predict the rutting depth successfully. On the other hand, the ANN model shows least scattering of the results.

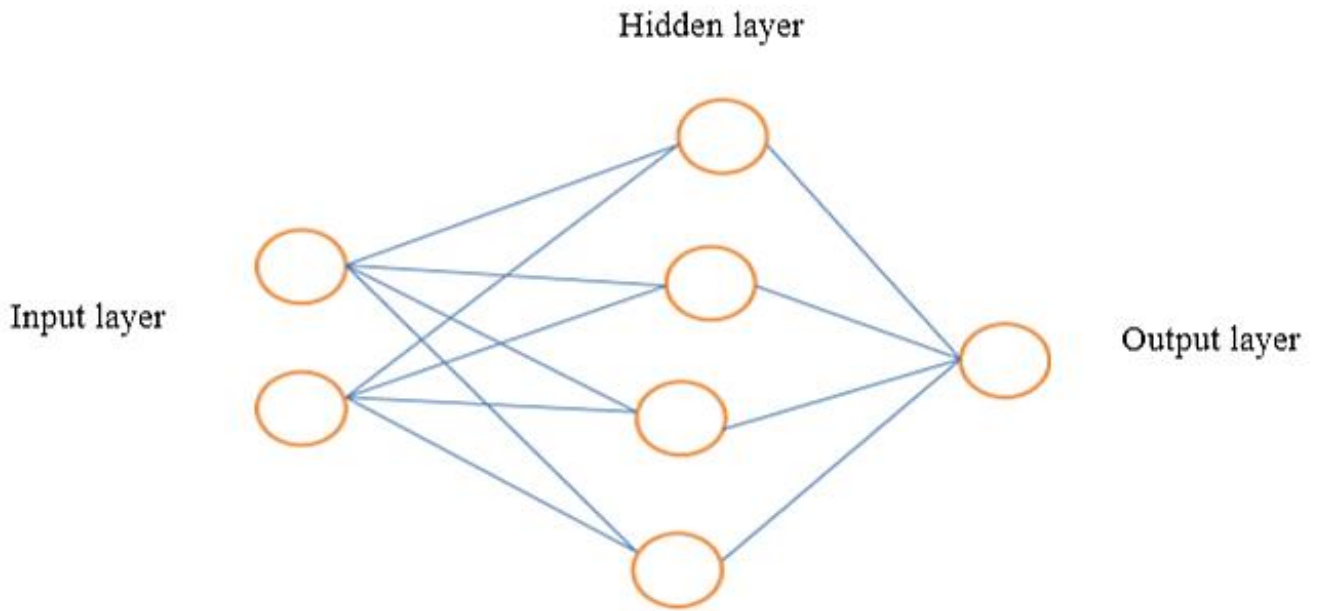


Figure 9: Typical neural network model

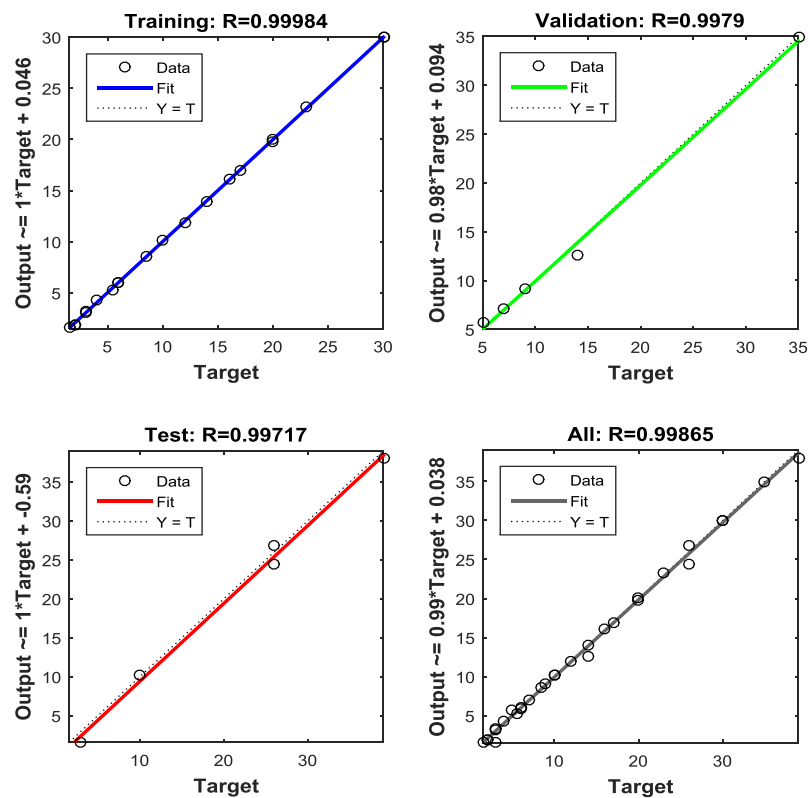


Figure 10: Comparison of experimental and predicted rutting depth of asphalt mixes without polymer

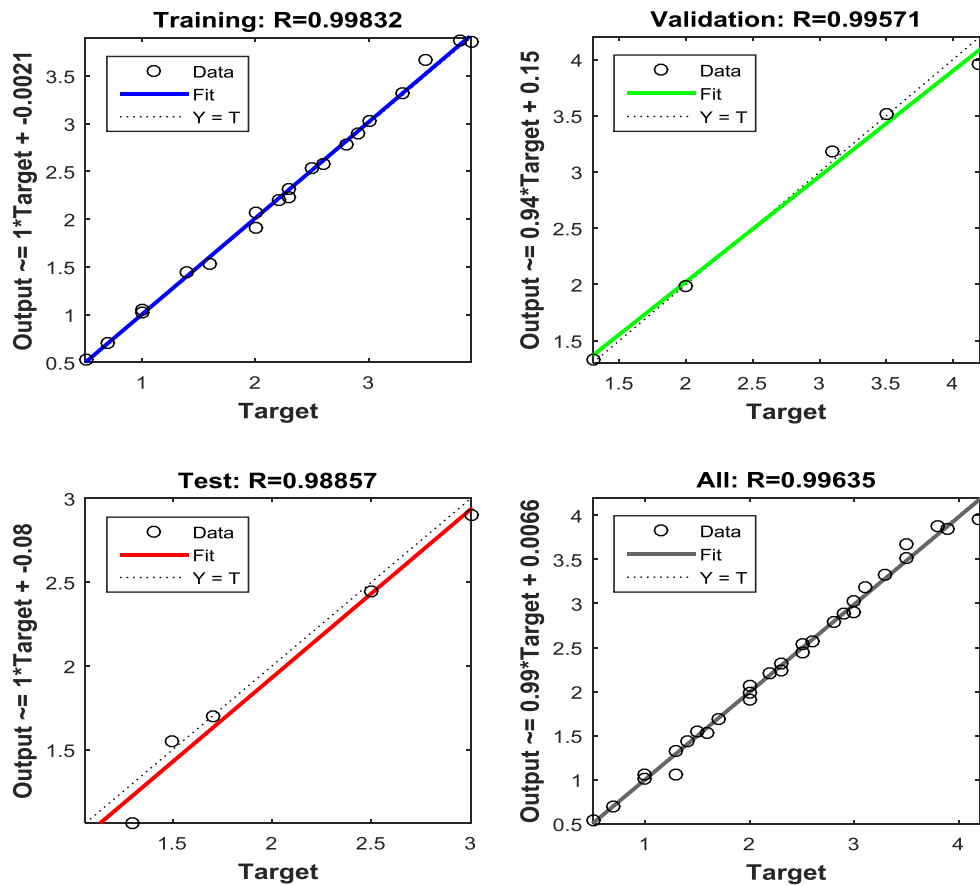


Figure 11: Comparison of experimental and predicted rutting depth of asphalt mixes with polymer

CONCLUSIONS

1. The 15% of poly sulphonated phenol –formal-dehyde can be used as optimum content of additive.
2. The value of rutting depth increases with increasing passes, load, and temperatures, but this increase has a smaller value in asphalt mixtures which are modified by polymers.
3. The ANN model shows the least scattering of the results.

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