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## Comparative analysis of BP neural network model prediction of asphalt aging index of hot in-place local recycling asphalt pavement

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# Comparative analysis of BP neural network model prediction of asphalt aging index of hot in-place local recycling asphalt pavement

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**Abstract.** In order to use in the regeneration of asphalt pavement regeneration scientific monitoring of the asphalt pavement decay index and the next period of regeneration of aging asphalt. Based on Shenyang to Dalian and Tieling to Fuxin expressway, this paper uses the BP neural network time series model and support vector machine model as two typical forecasting methods to predict and analyze the decay of asphalt aging index in geothermal regeneration asphalt pavement, and solve it with the help of MATLAB software. The prediction results show that the support vector machine model has the higher prediction accuracy in the case of limited data. On the basis of this, Summed up the optimal maintenance time combined with the local regeneration maintenance standard in Liaoning.

## 1. Introduction

The core work of road pavement maintenance and management is to make asphalt pavement regeneration maintenance planning and scientific and judicious timing of maintenance. Asphalt index is the main factor to determine the performance of asphalt pavement. Therefore, the scientific prediction of the asphalt indicator aging of asphalt pavement is particularly important.

A large number of studies have been carried out by scholars at home and abroad on the prediction of asphalt pavement performance decay. Foreign scholars have put forward mechanical analysis and empirical prediction methods, and road surface skid resistance, rutting and other prediction problems<sup>[1]</sup>, use of theoretical analysis, test or field survey data to establish a predictive model of asphalt pavement<sup>[2]</sup>; In this regard, a general model for pavement failure assessment and pavement performance prediction are proposed in China. Combined with Ultraviolet rays film aging, pavement performance evaluation and other methods. According to different pavement structure, indoor fatigue test, pavement performance evaluation analysis and prediction method are put forward<sup>[3]</sup>. The gradation of asphalt mixture in different layers, the index of asphalt used and the road environment are different, which lead to the great difference in the rate of failure transmission. The existence of this difference has an important influence on the prediction accuracy.

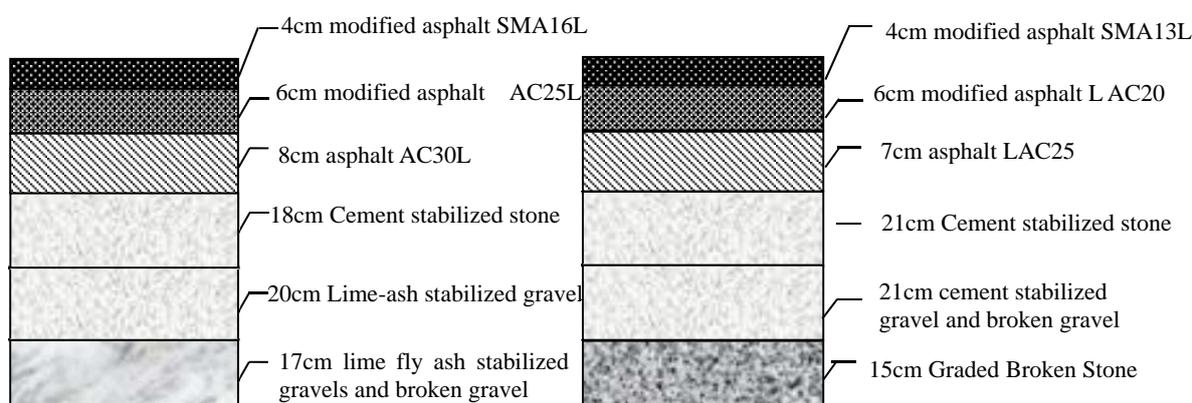
## 2. Source of research

This paper takes Liaoning Shenda expressway and Tiefu expressway as samples. These two types of road maintenance types are hot in-place recycling. At the same time, it is also the research object and data source of this paper.



The decline in asphalt pavement performance is directly due to the aging of the asphalt index in the asphalt mixture and affects the road regeneration mode directly. It is also an important factor in judging the optimal timing of road maintenance<sup>[4]</sup>. In this paper, the stratification of expressway surface layer is used as the way to study asphalt aging. Two classical prediction methods, BP neural network time series model and the support vector machine model are used to predict the aging law of asphalt and compare and analyze judge the best maintenance opportunity.

The source of the research data is from the year of regeneration, the test results of the core sample are drilled on the roadway each year. SBS modified pitch is used for both the surface layer and the middle layer of cementing materials. The lower surface course uses Liaohu 90 base asphalt. The structure of the main line surface is shown in Figure 1-1 and Figure 1-2. The basic information of core samples drilled by Shenda Line in 2011-2016 and the Tiefu Line in 2012-2015 are shown in Table 1.



**Fig.1-1** Pavement structure of Shenda line **Fig.1-2** Pavement structure of Tiefu line structure

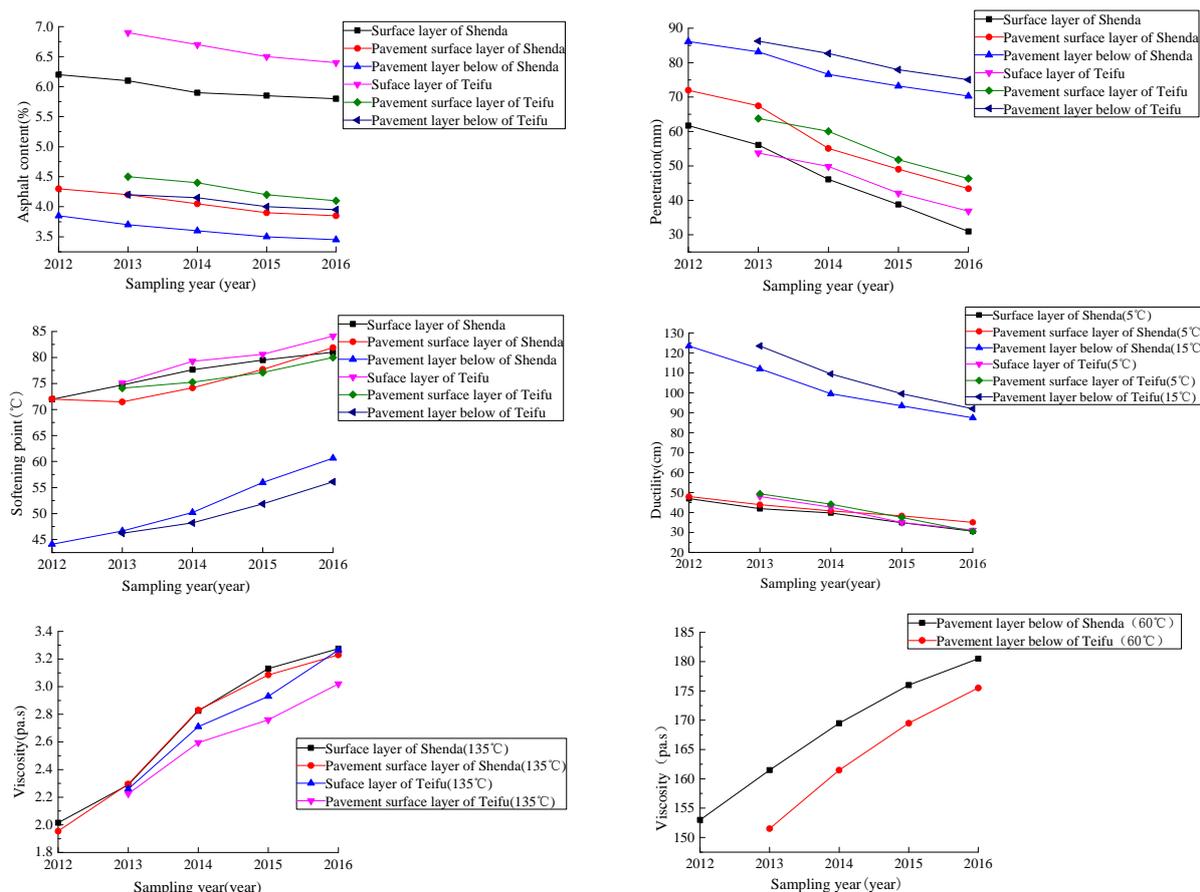
**Tab.1** Pavement core information

Line	Construction Year (year)	Sampling Year (year)	Sampling Station number	Sampling location	thickness (cm)	Design thickness (cm)
Shenyang-Dalian line	2011	2012	K21+600	carriageway	18.4	18.0
			K21+700	carriageway	18.6	18.0
		2013	K21+900	carriageway	18.5	18.0
			K30+000	carriageway	18.6	18.0
		2014	K30+200	carriageway	18.4	18.0
			K30+300	carriageway	18.9	18.0
		2015	K140+280	carriageway	18.2	18.0
			K140+380	carriageway	18.3	18.0
		2016	K210+200	carriageway	18.9	18.0
			K210+240	carriageway	18.6	18.0
Tieling-Fuxin line	2012	2013	K294+980	carriageway	17.4	17.0
			K295+080	carriageway	17.6	17.0
		2014	K295+250	carriageway	17.5	17.0
			K293+060	carriageway	17.6	17.0
		2015	K48+000	carriageway	17.4	17.0
			K48+200	carriageway	17.9	17.0
		2016	K110+050	carriageway	17.5	17.0
			K110+120	carriageway	17.8	17.0

### 3. Analysis of decay of pavement asphalt index

As the road is open to traffic, asphalt aging directly leads to the decay of the performance of the mixture, and affects the use of asphalt pavement. So it is particularly important to monitor and predict the asphalt aging index<sup>[5]</sup>.

The author selects different sections of the road for sampling in the field. Then, according to the specification<sup>[6]</sup> to extract the asphalt, determine the asphalt content and three major indicators, viscosity, the average of the core sample measurement results, draw a line chart of the data, indicators and trends are shown in Figure2, 2010-2016 Shenda line and Teifu shovel line The annual average daily traffic volume is shown in Table 2.



**Fig.2** Aging trend of old asphalt index of revived asphalt pavement surface layer

**Tab.2** Annual average daily traffic with 2011-2016 Shenyang-Dalian line and Tieling-Fuxin line

	2011	2012	2013	2014	2015	2016
Shenda line	44560	47095	45858	47385	40878	45304
Teifu line	11105	8508	9386	9589	8879	9091

According to the Table 2, traffic volume data of Shenda line and Tiefu line all fluctuated, and the overall difference is not big. The trend of various indicators of old asphalt shows that the change of traffic volume is aging of asphalt index has little effect in Figure 3.

In Figure 2, the slope of the surface layer of the Shenda line and the shovel line is relatively larger than that of the middle and lower layers, indicating that the aging rate of the surface layer asphalt is faster, and the pavement layer below is the slowest. Due to the geographical environment of Shenda Line and Tiefu Line, there are differences in the aging rate of asphalt on the surface layer, and there is

little difference between the middle and lower layers. The surface layer of the Shenda line and the Teifu line is 2 to 3 years after regeneration, and the middle layer is gradually approaching the specification technical requirements after 3-4 years after regeneration .

In the technical specifications for local asphalt pavement regeneration in Liaoning Province, it is proposed that when the old asphalt pavement has an penetration of less than 20, the old material cannot be used in the hot reclaimed road and can only be used in cold regeneration. It is the best time node for maintenance. The penetration of SBS modified asphalt on the surface layer of Shenda Line and TieFu Line was 3 years after regeneration, and the ductility was 2 years after regeneration. The index has deteriorated to the technical requirements, which means that the road surface cracking began to increase. Water damage during the subsequent use of the pavement will exacerbate the aging of the asphalt index.

#### 4. Algorithm discussion and data processing

##### 4.1 BP neural network time series model

The BP neural network time series model is established by using time series model analysis to determine the correlation between the observed random items and their previous single values.

The stochastic component simulation of the surface data of Shenda line is used to identify the model and determine the order. Normal P - P diagram is used to test normality. Normal P-P diagram is shown in Figure 4. It can be clearly seen from the diagram that the distribution of observation values basically falls on the diagonal line, which leads to the conclusion that  $Z_t$  obeys normal distribution.

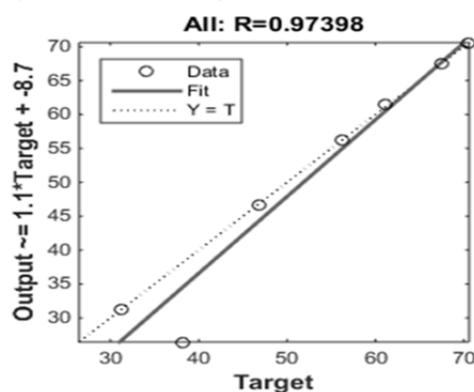


Fig.3  $Z_t$  sequence's P-P chart

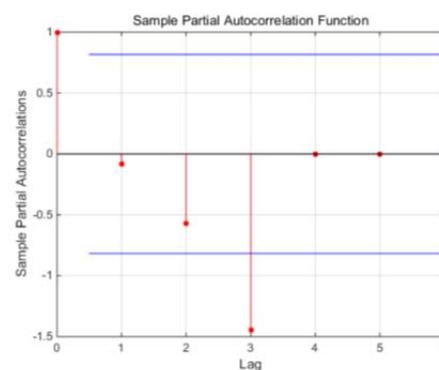


Fig.4 Partial autocorrelation of  $Z_t$  sequence

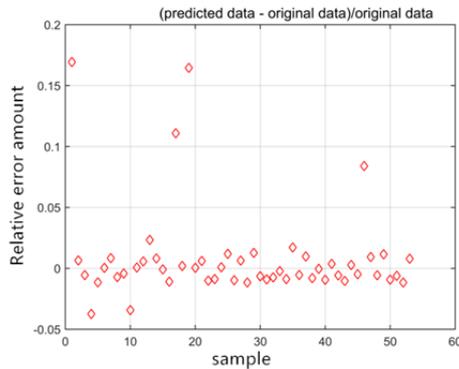
Get the autocorrelation coefficient of the autocorrelation coefficient of  $Z_t$ , and partial autocorrelation map is drawn, as showed in Figure 5. It is evident from the partial autocorrelation diagram that most data satisfy the 95% admissible limit. The autocorrelation analysis is used to get the autocorrelation coefficient of the  $\varepsilon_t$  sequence of the residual term. It is found that the autocorrelation coefficient of the  $\varepsilon_t$  sequence is within the critical level of the significant level  $\alpha = 0.05$ , and it is obviously an independent residual process.

##### 4.2 Support vector machine model

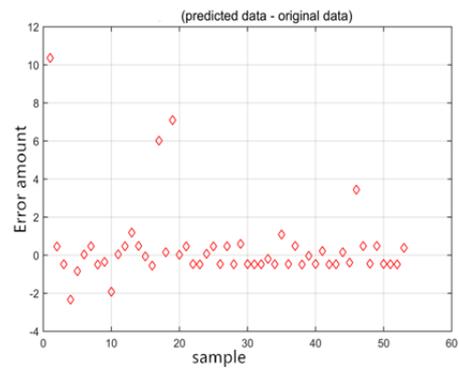
The support vector machine regression algorithm is the basic vein to learn the limited sample data, and then the relationship between the independent variable and the dependent variable is established. Finally, the regression estimation function is constructed to predict the result.

In this paper, the support vector machine model is applied, and the three-layer index of the surface layer, the middle layer and the lower layer, including the asphalt content, the softening point, the ductility and the viscosity, are included in the regenerative use years of the Shenda line and the Teifu

line. Error analysis, the vast majority of relative errors are within 5%, as showed in Figure 5, the error is within 2, as showed in Figure 6.



**Fig.5** Relative error chart



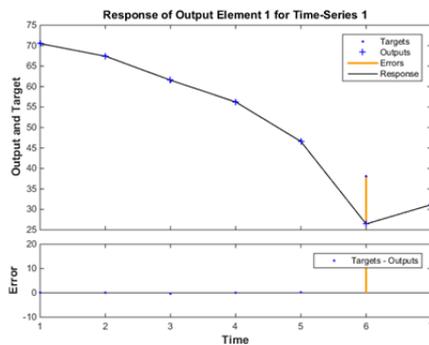
**Fig.6** Error amount chart

Figure 5 and Figure 6 show that the vast majority of the errors are in the ideal range, and the prediction of the penetration of each layer is made with high accuracy.

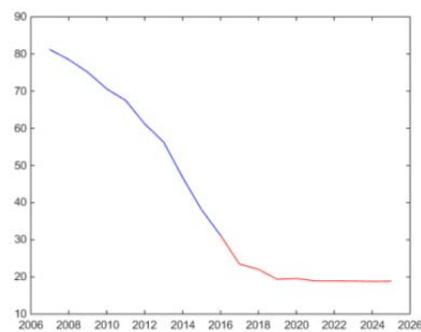
**4.3 Forecast results and comparative analysis**

BP neural network time series model, the model requires a large amount of data to dig a higher regularity, so as to predict a more accurate prediction value. The principle is still based on the time series model. If the limited data of the longitudinal time nodes collected in this paper is more accurate, it needs to run the program many times.

Taking surface data of the Shenda line as an example, the error analysis chart of the data is shown in Fig.7, and the penetration degree prediction chart is shown in Fig.8.



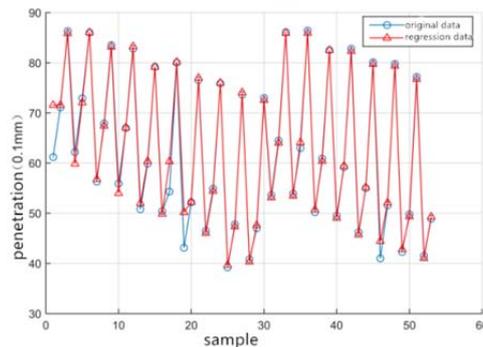
**Fig.7** Error analysis chart



**Fig.8** Penetration prediction chart

As showed in Figure 7 and Figure 8, According to the local regulations of Liaoning Province [6], when the penetration degree decays to 20, it is not suitable for thermal regeneration. The forecast data show that when 2019-2020 (that is, after 8-9 years of post-regeneration road use), the penetration of the surface layer decays to below 20.

In this paper, the lateral data of all asphalts in the surface layer, the middle layer and the lower layer of the two roads are used to predict the penetration degree, and then compare with the actual penetration measurement value.. Obviously seen from the comparison chart, the predicted value of the red line is highly consistent with the raw data of the blue line.



**Fig.9** Comparison chart of the original data and regression data

Verified by this article, under the condition of limited longitudinal data, compared with the BP neural network time series model, the support vector machine regression model algorithm makes full use of the horizontal data constraint, and the obtained prediction value is more accurate and scientific.

## 5. conclusion

(1) According to the forecast data, after the reclaimed road surface is used for 8-9 years, surface penetration is reduced to below 20, provided by the local recycling standards of Liaoning Province, the old materials recovered from the 10th year after the regeneration are not in a regeneration mode suitable for thermal regeneration;

(2) According to the aging data and trend of asphalt pavement, it has little relationship with the growth of traffic volume.

(3) Verified by this article, under conditions of limited longitudinal data, compared with the BP neural network time series model, the support vector machine regression model algorithm makes full use of the horizontal data constraint, and the obtained prediction value is more accurate and scientific. If high-precision prediction is achieved before the data volume is limited, it is recommended to use the support vector machine model for prediction;

(4) When re-cultivation, the prediction method of the support vector machine model can be used to accurately predict the aging degree of the old asphalt index of the asphalt pavement. When the penetration value decays to 20, it is the best maintenance time for hot recycling, otherwise the old material will only be used in Cold Recycling.

## References

- [1] WANG H, WANG Z. Evaluation of pavement surface friction subject to various pavement preservation treatments [J]. *Construction and Building Materials*, 2013, 48: 194-202.
- [2] DONE Z J, GONG X B, XIAO G Q, et al. Rutting resistance evaluation of structural combinations of asphalt pavement subjected to heavy duty [J]. *Advanced Engineering Forum* 2012, 5: 316-321.
- [3] MENSCHING D J, MCCARTHY L M, MEHTA Y, et al. Modeling flexible pavement overlay performance for use with quality-related specifications [J]. *Construction and Building Materials*, 2013, 48: 1072-1080.
- [4] EVDORIDES H, BURROW M, SULAIMAN S. A methodology to model the variability in pavement performance [J]. *Proceedings of the Institution of Civil Engineers Transport*, 2013, 166 (4): 233-240.
- [5] PROZZI J A, MADANAT S M. Development of pavement performance models by combining experimental and field data [J]. *Journal of Infrastructure Systems*, 2004, 10 (1): 9-22.
- [6] FENG H, PROZZI J A. Estimation of pavement performance deterioration using Bayesian approach [J]. *Journal of Infrastructure Systems*, 2006, 12(2): 77-86.