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Decision-making system and verification of pavement diseases treatment scheme for highway reconstruction and extension

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Abstract

Based on the case of a highway reconstruction and extension project in Guangdong Province, a decision-making system for the treatment of the old pavement diseases of semi-rigid base asphalt pavement's reconstruction and extension has been established. The load-carrying capacity of the old pavement structure has been obtained by the Benkleman beam deflectometer; the damage condition of the road surface has been determined by investigation of road surface diseases; the restorability of the pavement diseases has been evaluated by investigation of the pavement maintenance history; the interior damage condition of the pavement has been detected by the three-dimensional ground-penetrating radar; furthermore, the decision-making system of the old pavement damage treatment scheme has been constructed and the treatment scheme of old pavement diseases has been put forward by using the four-hierarchy indexes of 'the load-carrying capacity + the condition of road surface + the maintenance history + the interior damage condition of the pavement'; and the treatment effect of pavement diseases has been verified by bearing capacity test. The results show that the variation level of the deflection representative value of the old pavement has been reduced by about 8.2% ~ 25.1% by adopting different diseases treatment schemes in different sections; 44.2% by adopting the deep grouting of the roadbed scheme, and 61.6% effectively by using the plan of milling all the asphalt layers and the upper base, and then relaying the C20 plain concrete to the top of the upper base and relaying asphalt mixture. The decision-making system for the treatment of the old pavement diseases of the semi-rigid base asphalt pavement's reconstruction and extension can effectively guide the treatment of old pavement disease, notably improve the load-carrying capacity of old pavement structure and the balance of the load-bearing capacity in different sections of the pavement structure.

Keywords: highway, reconstruction and extension, pavement diseases, decision-making system, balance robot[†]Corresponding author.Email address: 551687096@qq.com

1 Introduction

By the end of 2019, China has had a total highway length of 5,012,500 kilometres and an expressway length of 149,600 kilometers [1]. With the improvement of the national highway network system, the proposal of the planning of Greater Bay Area and the steady implementation of the Strategy to Strengthen China through Traffic, the highway reconstruction and extension will become the inevitable choice to improve the service level of the road network [2]. Detection and evaluation of old pavement condition and treatment of diseases are the primary problems to be solved in highway reconstruction and extension projects [3,4].

The highway reconstruction and extension in Guangdong Province has a history of nearly 10 years [5]. In the past projects of the reconstruction and extension of the old highway, due to the limitation of the development of testing equipment and technology, the detection of the condition of the old road surface had been mainly based on the road surface disease, supplemented by the observation result of the lack of drill core in the partial position. The representative of the test results of the old pavement detection thus obtained was not good enough to accurately reflect the real condition of the old pavement and also could not explain the cause and the law of the development of the old pavement disease [6]. With the development of non-destructive testing technology, researchers have begun to try to use technologies such as the three-dimensional ground-penetrating radar and FWD to collect the structural integrity and bearing capacity of pavement to reflect the situation of pavement more realistically [7–9]. Xiong Chunlong used the three-dimensional ground-penetrating radar and FWD to detect the pavement condition in FoShan First Ring from two aspects: visual analysis of three-dimensional diseases inside the road surface and structural mechanical response of the road surface [10]. Luo Chuanxi adopted the three-dimensional ground-penetrating radar to detect the internal structure of the pavement and proposed a three-dimensional radar recognition map of different diseases in the pavement, which promoted the application of the three-dimensional ground-penetrating radar in the detection of the internal structure integrity of the pavement [11]. Wu Pengzhi proposed a set of road hidden disease identification technology and analysis method based on the detection data of bottom detection radar [12]. Wang Hui et al. used the three-dimensional ground-penetrating radar to study the correlation between the internal disease of the pavement in the highway reconstruction and extension and the strength of the pavement structure and proved the reliability of the three-dimensional ground-penetrating radar [13] by the field excavation verification.

In past research studies and practices which are available in the literature, we observe that the old pavement disease treatment scheme had been generally formulated according to the pavement damage degree, the pavement maintenance history and effects and the subjective experience of the experts in the field. On the one hand, due to the lack of understanding of the causes of the disease, the old pavement disease treatment scheme was judged to be ‘medicine is not right’, and the same kind of diseases still appeared repeatedly after the treatment; on the other hand, due to the lack of understanding of the integrity of the old pavement internal structure and the mechanical condition thereof, it tended to be over-conservative in basing the scheme only on the surface damage condition, and parts of the pavement with only surface damage but with good overall structure will also be milled, resulting in the waste of good highway assets and causing the problem of placement of solid road waste produced [14–16]. The reason is that in the evaluation of the pavement condition of different sections with a single-aspect test index, the result yielded may be inconsistent with the result obtained by using the other test index. How to make a comprehensive evaluation of the road surface condition, the internal condition of the pavement surface and the bearing capacity of the pavement is the premise to accurately evaluate the pavement condition and make the treatment scheme for the disease.

2 Project profile

Reconstruction and extension of the expressway in Guangdong Province was originally a two-way four-lane highway, 16 years since the opening, and consequent to the repeated long-term heavy-load traffic, there have been different degrees of pavement diseases; according to different diseases and levels of damage during the

operation, the pavement maintenance construction has been carried out successively. The settlement deflection value of the old pavement after treatments was 27 (0.01 mm). The types of pavement structures and overlay structures are shown in Table 1.

Table 1 Scheme of old pavement reconstruction

Newly paved pavement	Upper layer	4 cm modified asphalt SMA-13
	Mid-layer	6 cm modified asphalt AC-20C
Old road pavement	Asphalt pavement	4 cm modified asphalt AC-16C Overlay
		4 cm ordinary asphalt AK-13A upper layer
		5 cm ordinary asphalt AC-20I mid-layer
		6 cm ordinary asphalt AC-25I lower layer
	Base	36 cm 5% ~ 6% cement stabilised macadam
	Sub-base	20 cm 3% ~ 4% cement stabilised aggregate
	Cushion	15 cm graded aggregate
Thickness of new pavement	10 cm	
Total thickness	100 cm	

3 Scheme and method of the pavement detection

3.1 Bearing capacity of the pavement structure

The deflection of the road surface is the acceptance index of the asphalt pavement structure design, which has a great relationship with the bearing capacity of the asphalt pavement structure. Taking K3252 + 020 ~ K3258 + 360 section (length of 6.34 km) of a reconstructed and extended expressway in Guangdong province as the testing object, the Benkleman beam deflectometer was used for the detection of the passing lane and carriageway of the old pavement in this section. The detection frequency was 10 m/point/lane. The results of the deflection value are shown in Figure 1.

As can be seen from Figure 1, the average deflection value of the passing lane in this section is 14.6 (0.01 mm), and the representative value is 25.5 (0.01 mm). The average deflection value of the carriageway is 15.7 (0.01 mm), and the representative value is 30.6 (0.01 mm). The deflection values of the passing lane and carriageway are lower than the acceptance deflection value of 27 (0.01 mm) for about 95.3% and 90.7% respectively. There exists a certain proportion of the bearing capacity of pavement structure in partial sections, which does not meet the design requirements, and the proportion of the carriageway is perceptibly higher than that of the passing lane. The difference between the bearing capacity of the old passing lane and the carriageway has a relation with the function orientation of the carriageway of the old pavement mainly as the heavy traffic axle-loaded lane. In addition, the coefficients of variation in the deflection values of the old passing lane and carriageway are 45.4% and 57.5% respectively, and it is not difficult to find that the uniformity of bearing capacity of the old

Fig. 1 Distribution of deflection value in K3139 + 200 ~ K3202 + 500 section.

pavement structure of the passing lane and carriageway along the driving direction is poor.

3.2 Condition of road surface

The damage condition of the road surface is the main index to evaluate the technical condition of the highway pavement in the current ‘*Standard for Evaluation of Highway Technical Condition*’ (JTG/5210). It is also the main basis of the present ‘*Code for Design of Highway Asphalt Pavement Maintenance*’ (JTG/5421) and ‘*Technical Specification for Highway Asphalt Pavement Maintenance*’ (JTG/5142) to formulate the maintenance scheme of asphalt pavement [17–19]. There is no need to consider the road surface functions such as anti-sliding for adopting the project of the design plan for the old pavement overlay, and the damage condition of the road surface is an important index to directly reflect the demand for pavement treatment.

PCI threshold value required by the large and mid-sized maintenance of the asphalt pavement is 80, and the corresponding damage rate of the asphalt pavement is 2.01%. On the base that the width of each lane is 3.75 m, there are about evaluated 75.4 m² of various damages appearing on the road surface of the unit section of the length of 1000 m. When the damage area is converted into the lane width and the concentration length of damage diseases, it can be known that the concentration length of damage diseases is about 20 m. When the length of the unit evaluation section is more than 20 m, and even if there is a part of the unit evaluation section of 20 m which needs large or mid-sized maintenance, still because the road surface condition of the other length range in the section is excellent, it will lead to overestimating the overall road surface condition of the unit evaluation section to reduce the demand level of the pavement maintenance and form an unreasonable decision of the maintenance scheme. To improve the veracity of the evaluation result of the road surface damage, the artificial pedestrian survey was adopted in the K3252 + 020 ~ K3258 + 360 section of the expressway with reconstruction and extension in Guangdong Province, and taking 20 m as the evaluation unit section length, the valuable PCI calculation formula is proposed to calculate the road surface condition index. The result is shown in Figure 2.

Fig. 2 Index distribution of the condition of road surface damage in K3139 + 200 ~ K3202 + 500 section.

As can be seen from Figure 2, the mean value of the road surface condition index of the passing lane is 91, the coefficient of variation is about 10.7% and the good rate is about 85.9%, and the average value of the road

surface condition index of the carriageway is 92, the coefficient of variation is about 8.2% and the good rate is about 97.2%. In a different position of this section, there are differences in the road surface condition index of the carriageway and the passing lane. The road surface condition index of the passing lane in K3252 + 070 ~ K3253 + 780 section is slightly lower than that of the carriageway, while the road surface condition index of the passing lane in K3256 + 080 ~ K3257 + 380 section is slightly lower than that of the carriageway. The good rate of the road surface condition index of different lanes is more than 85%, and the road surface condition of this section is still in good condition, but the good rate of the road surface condition index of the passing lane is perceptibly lower than that of the carriageway, which has some relation with the attention and maintenance history of different lanes; if the frequency of the road surface disease and the attention and maintenance is higher, the road surface condition index is relatively higher.

3.3 Historical investigation of pavement maintenance

Through the investigation of attention and maintenance history, it is an important basis of the decision-making to the large and mid-sized maintenance to ascertain the identity of those pavement sections which are prone to repeated diseases and reappearing diseases after conclusion of maintenance activity. The investigation results of the history of pavement attention and maintenance in K3252 + 020 ~ K3258 + 360 section of the expressway with reconstruction and extension in Guangdong Province are shown in Table 2.

As can be seen from Table 2, the attention and maintenance of the pavement have been carried out in different sections since the section was opened to traffic, and it has been mainly concerned with the milling and relaying of the overlay. The pavement maintenance plan of K3252 + 070 ~ K3253 + 880 section has been mainly concentrated on the carriageway, while the pavement maintenance plan of K3255 + 307 ~ K3258 + 360 section has been mainly concentrated on the passing lane, and it is not difficult to find out that there is a good correlation between the implementation section and location of the pavement attention and maintenance plan and the road surface condition index, and the road section and lane where the milling and relaying has been carried out, the road surface condition index is at a better level.

3.4 Detection of hidden diseases inside the pavement

The traditional pavement maintenance practice lacks comprehensive testing and evaluation of the internal condition of the pavement, and the causes of damage cannot be accurately described; thus, the treatment of diseases is often unreasonable, resulting in poor treatment effects or wastes of resources for excessive maintenance. Three-dimensional ground-penetrating radar has been used to detect the internal structure damage of old pavement, which is an important assistant of making the pavement maintenance scheme. The three-dimensional ground-penetrating radar was used to detect the interior damage of K3252 + 020 ~ K3258 + 360 section of the expressway with reconstruction and extension in Guangdong Province. The results are shown in Table 3.

As what can be seen from Table 3, the main type of internal diseases of pavement with different structural layers is crack, and the crack density of the asphalt surface, the base and the sub-base is about 136.2, 143.6 and 33.6 m/km, respectively, and the defects of crack are mainly concentrated on the asphalt surface and the base.

To describe the severity of hidden diseases inside different sections and different lanes, the maximum quantity of the crack disease was selected to establish the index of crack rate, as shown in Eq. (1).

$$\gamma = \frac{l_c}{Area} \times 100 \quad (1)$$

In the above-mentioned equation, γ for the crack rate, unit m/100 m²; l_c for the statistical length of cracks in the inner surface of a paragraph, the inner structure of a base, unit m; $Area$ for the area of a paragraph, unit m².

Converting the cracks in the testing range into the transverse cracks through a lane of 3.75 m width by length, and getting an analysis of the number of cracks and converting into transverse spacing, as shown in Eq. (2).

$$L = \frac{100}{\gamma} \quad (2)$$

Table 2 History of the attention and maintenance of K3252 + 020 ~ K3258 + 360 section of the expressway with a reconstruction and extension in Guangdong Province

Initial stake number	Terminal stake number	Treatment lane	In 2003	In 2008	In 2010	In 2014	In 2015	In 2016	In 2017	In 2018
3252 + 020	3252 + 250		Open to traffic	4cmAC13C						
3252 + 250	3252 + 524	Carriageway	Open to traffic	4cmAC13C				Milling and relaying		
3252 + 524	3252 + 580		Open to traffic	4cmAC13C						
3252 + 580	3252 + 680	Carriageway	Open to traffic	4 cm AC13C					Milling and relaying	
3252 + 680	3252 + 810		Open to traffic	4 cm AC13C						
3252 + 810	3253 + 330	Carriageway	Open to traffic	4 cm AC13C					Milling and relaying	
3253 + 308	3253 + 500	Carriageway	Open to traffic	4 cm AC13C						Milling and relaying
3253 + 500	3253 + 680		Open to traffic	4 cm AC13C						
3253 + 680	3253 + 888	Carriageway	Open to traffic	4 cm AC13C						Milling and relaying
3253 + 888	3255 + 307		Open to traffic	4 cm AC13C						
3255 + 307	3256 + 800	Passing lane	Open to traffic	4 cm AC13C		Milling and relaying				
3256 + 800	3257 + 435	Passing lane	Open to traffic	4 cm AC13C		Milling and relaying				Milling and relaying
3257 + 435	3257 + 504	Passing lane	Open to traffic	4 cm AC13C		Milling and relaying				
3257 + 504	3258 + 050	Passing lane	Open to traffic	4 cm AC13C		Milling and relaying				Milling and relaying
3258 + 050	3258 + 545	Passing lane	Open to traffic	4 cm AC13C		Milling and relaying				
3258 + 545	3258 + 848	Passing lane	Open to traffic	4 cm AC13C		Milling and relaying		Milling and relaying		
3258 + 848	3258 + 360	Passing lane	Open to traffic	4 cm AC13C	4 cm AC16C		Milling and relaying			

In the above-mentioned equation, L for the crack spacing, unit m/bar.

The distribution of the pavement surface and base crack rate of passing lane and carriageway along the driving direction in K3252 + 020 ~ K3258 + 360 section of the expressway with reconstruction and extension in Guangdong Province, as shown in Figure 3.

As can be seen from Figure 3, the mean crack rate of the surface of the passing lane is about 3.3 m/100 m²

Table 3 Summary of Diseases Statistics in K3252 + 020 ~ K3258 + 360 Section

Types of disease	Crack			Looseness		Cavity beneath slab		Subsidence		Water-rich	
Structural layer	Quantit y/place	Leng th/m	Density/ (m/km)	Quantit y/place	Acrea ge/m ²	Quantit y/place	Acrea ge/m ²	Quantit y/place	Acrea ge/m ²	Quantit y/place	Acrea ge/m ²
Acreage	265	1239	136.2	0	0	0	0	0	0	0	0
Base	198	1306.8	143.6	12	236	6	16.6	5	98.5	0	0
Sub-base	47	306	33.6	3	60	0	0	1	127.5	0	0
Soil foundation	0	0	0	0	0	0	0	1	90	3	1500

(a) Passing Lane

(b) Carriageway

Fig. 3 Distribution of index of road surface damage condition in K3252 + 020 ~ K3258 + 360 section.

(the crack spacing is about 30.3 m/bar), and the crack rate of the base is about 3.4 m/100 m² (the crack spacing is about 29.4 m/bar); the crack rate of the surface in the carriageway is about 1.8 m/100 m² (the crack spacing is about 55.5 m/bar) and the crack rate of the base is about 5.7 m/100 m² (the crack spacing is about 17.5 m/bar), and the level of the crack rate of the surface and the base is low of different sections and different lanes.

The crack rate of the base in different lanes is greater than that of the surface, and the crack rate of the base in carriageway is higher than that of the surface. The crack spacing of the base is about 1.7 m/bar ~ 2 m/bar, and the crack spacing of the surface is more than 50 m/bar, and the crack density of the base is about 25 times that of the surface. In the passing lane, about 26% of the crack rate of the surface in the passing lane section is perceptibly larger than that of the base, and the crack spacing of the surface is about 3 m/bar ~ 5 m/bar, and the crack spacing of the base is about 10 m/bar ~ 20 m/bar. With the distribution of cracks in different

depths detected by the three-dimensional ground-penetrating radar, it can be seen that the cracks in the surface of the carriageway are appropriately corresponding to those in the base, and most of the cracks in the surface are reflected cracks in the semi-rigid base. Cracks in the surface in most areas of passing lane are also reflected cracks mainly, and about 26% of these sections are top-down cracks, which may be related to the influence of water (center separation with w-beam guardrail) and temperature on the surface structure of the passing lane.

To verify the reliability of the detection results of the interior diseases of the pavement from the three-dimensional ground-penetrating radar, according to the results of the three-dimensional ground-penetrating radar, the stack number and position of the diseases were determined at random, and the surface structure of K3252 + 020 ~ K3258 + 360 section of the expressway with reconstruction and extension in Guangdong Province was excavated and verified by means of milling and artificial chiseling. The results are shown in Figure 4. After excavation, it was found that the top surface of the base has had serious mesh cracking, which is highly consistent with the result of radar detection.

(a) Diseases results of the three-dimensional ground penetrating radar detection

(b) Diseases status of corresponding structural layer after excavation

Fig. 4 Field excavation verification.

4 Decision-making system and verification of the old pavement diseases treatment scheme

The evaluation system of disease ‘the road surface condition + the core sampling + the maintenance history’ has often been used in the evaluation of the pavement condition and the making of maintenance scheme of traditional attention and maintenance of old pavement. This evaluation system has limitations to the excavation of pavement, and the causes of damage cannot be described, the old pavement treatment scheme is not complete sometimes, resulting in repeated reappearing of diseases after the treatment of pavement; or the treatment scheme is too conservative, resulting in the waste of resources. To evaluate the condition of the old pavement in a more comprehensive way, the road surface and internal condition will be fully considered, and from the aspects of pavement integrity and pavement mechanical condition, the decision-making system for the treatment of the old road surface diseases is established, according to the idea of sub-section and sub-quality treatment and based on the four factors of the pavement structure bearing capacity, the road surface condition, the pavement maintenance history and the road surface internal loss. The treatment scheme of pavement diseases is determined according to ‘Technical Specification for Highway Asphalt Pavement Maintenance’ (JTG/5142) and other instructive codes.

(1) The section whose deflection value is ≤ 27 (0.01 mm) is only treated for surface treatments of cracks, potholes and other diseases, and the kinds of treatment mainly are surface cracks filling, cracks sticking, rut filling, potholes repairing for bad patching and so on.

(2) When the deflection value is > 27 (0.01 mm) and the road surface condition index is < 80 , the plan is to fill back the top surface of C20 concrete and relay the asphalt mixture to the top surface, after milling the asphalt surface + the upper base.

(3) The section where the deflection value is > 27 (0.01 mm) and the road surface condition index is ≥ 80 , is determined for whether there is a history of repeated maintenance of the old pavement first, if so, a plan is adopted to fill the base of C20 plain concrete to the top + relay the surface of asphalt mixture to the top after milling the asphalt surface + the top of the base; if not, the rate of cracks in the base of the section is determined then. If it is > 20 m/100 m², a plan is adopted to fill the base of C20 plain concrete to the top + relay the surface of asphalt mixture to the top after milling the asphalt surface + the top of the base. If it is < 20 m/100 m², the scheme of grouting + surface treatment scheme is adopted.

The detecting frequency of the deflection value is 10 m/point/lane, and the deflection value is expressed as the representative value of deflection in the section of the unit; and the index statistics of the road surface condition, the maintenance history and the internal crack rate are made on the detection data in the section of the unit.

According to the decision-making system and testing results of the old pavement diseases treatment, the plan decision is made with 20 m as a unit section, and the distribution map of the pavement diseases treatment plan of K3252 + 020 ~ K3258 + 360 section of the expressway with reconstruction and extension in Guangdong Province is obtained, as shown in Figure 5.

Fig. 5 Distribution map of the pavement diseases treatment plan of K3252 + 020 ~ K3258 + 360 section of the expressway with a reconstruction and extension in Guangdong Province.

As what can be seen from Figure 5, the overall condition of the pavement of this section is good, and the passing lane only adopts the surface treatment; most sections of the carriageway adopt the surface treatment scheme; the deflection representative value of K3256 + 160 ~ K3256 + 280 section is 43 (0.01 mm), and the road surface condition index is 86, the crack rate of the surface is 4 m/100 m², the crack rate of the base is 2.4 m/100 m², and this section adopts the scheme of deep grouting of the roadbed + surface treatment; the deflection

representative value of K3252 + 020 ~ K3252 + 080 section is 70 (0.01 mm), the road surface condition index is 93, the crack rate of the surface is 0 m/100 m², and the crack rate of the base is 48.9 m/100 m²; the deflection representative value of K3254 + 300 ~ K3254 + 480 section is 63 (0.01 mm), the road surface condition index is 100, the crack rate of the surface is 0 m/100 m², and the crack rate of the base is 54 m/100 m². The two sections adopt the plan of filling the base of C20 plain concrete to top + relaying the surface of asphalt mixture to the top, after milling 19 cm of the asphalt surface + 18 cm of the upper base.

To verify the effectiveness of the decision-making system of the above-mentioned old pavement diseases treatment scheme, after the treatment of the old pavement disease is completed, the deflection of the treated section was re-measured by using the Benkleman beam deflectometer, before and after the disease treatment; the detection point setting and detection frequency were consistent. The results are shown in Figure 6.

Fig. 6 Distribution of deflection value of the Benkleman Beam Deflectometer before and after the old pavement disease treatment.

The calculation was made about the statistics of the deflection value before and after the treatment of the old pavement diseases, and the change results of the deflection representative value and the deflection variation level before and after the treatment are obtained, as shown in Table 4.

As what can be seen from Figure 6 and Table 4, after the treatment of the old pavement diseases, the deflection value of the pavement structure has been reduced obviously, and the variation level of the deflection value has been improved obviously. In the scheme of deep grouting of the roadbed + surface treatment, the representative value of the deflection of the old pavement decreased by 44.2% compared with that of the old pavement before the treatment of the disease; and in the scheme of filling the base of C20 plain concrete to top + relaying the surface of asphalt mixture to the top, after milling 19 cm of the asphalt surface + 18 cm of the upper base, the representative value of the deflection of the old pavement decreased by about 61.6% compared with that of the old pavement before the treatment of the disease. Different treatment schemes can improve the deflection representative value of the old pavement, and the variation level of the deflection value of the old pavement can be reduced by about 8.2% ~ 25.1% after the treatment.

5 Conclusion

The following conclusions are drawn from the study: (1) The coefficient of variation of the deflection representative value of the old pavement can be reduced by about 8.2% ~ 25.1% when different treatment schemes are adopted in different sections. By adopting the deep grouting of the roadbed scheme, the deflection representative value of the pavement structure can be reduced about 44.2%. The deflection representative value of the pavement structure can be reduced by about 61.6% by means of filling the base of C20 plain concrete

Table 4 Comparison of the Deflection Value before and after the Treatment of the Old Pavement Diseases

Stack number	Treatment scheme	Before the treatment		After the treatment		Variation range before and after the treatment (%)	
		Deflection representative value (0.01 mm)	Coefficient of variation (%)	Deflection representative value (0.01 mm)	Coefficient of variation (%)	Deflection value	Coefficient of variation
K3252 + 020 ~ K3252 + 080	After milling 19 cm of the asphalt surface + 18 cm of the upper base, filling the base of	70	25.5	26	19.1	62.9	25.1
K3254 + 300 ~ K3254 + 480	C20 plain concrete to top + relaying the surface of asphalt mixture to the top	63	28.1	25	24.6	60.3	12.5
K3256 + 160 ~ K3256 + 280	Deep grouting of the roadbed + surface treatment	43	18.3	24	16.8	44.2	8.2

to top + relaying the surface of asphalt mixture to the top, after milling 19 cm of the asphalt surface + 18 cm of the upper base. The decision-making system of the pavement disease treatment scheme of semi-rigid base asphalt pavement's reconstruction and extension can effectively guide the treatment of the old pavement disease, improving the bearing capacity of the old pavement structure and balancing the bearing capacity of different sections of the pavement structure.

(2) To accurately determine the level of the road maintenance demand, the unit evaluation length of the section for the road surface damage condition index should not be longer than 20 m, because the road surface condition is also related to the road maintenance history; thus, it may be inferred that the investigation of the road maintenance history can effectively help to determine the road maintenance condition.

(3) The testing results of the three-dimensional ground-penetrating radar are consistent with those of the site excavation verification, which is a rapid and non-destructive method for effectively detecting road surface diseases.

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References

- [1] Ministry of Transport of the People's Republic of China. "Transport Industry Development Statistics Bulletin" 2019 [N]. China Transport News, 2020-05-12(002).

- [2] Hou Fujin, Yang Yaohui, Wei Jincheng, & Zhang Xiaomeng. “Renovation and Expansion and Centennial Safety Quality Project” [J]. *China Highway*, 2020(17): 46-53.
- [3] Zhang Jing, Xie Songlin, Xiao Kaifeng, Wang Bo, & Qing Song. “Research on detection index and evaluation method of old asphalt pavement for highway renovation and expansion” [J]. *Highway*, 2020, 65(03): 19-22.
- [4] Song Liang. “Detection and evaluation of old road surface based on grey theory” [J]. *Highway*, 2017, 62(07): 88-93.
- [5] “Measures of the Ministry of Transport of Guangdong Province on the Administration of Highway Modification and Expansion” [J]. *Bulletin of the Guangdong Provincial People’s Government*, 2018(32): 52-54.
- [6] Meng Huajun, & Wang Gangyi. “Probe into the treatment scheme of the large and medium section asphalt pavement in the antecedent section of the high-speed renovation in Foshan” [J]. *Highway*, 2017, 62(11): 52-57.
- [7] Yazhe Hu, Tomonari Furukawa. Automatic Detection and Evaluation of 3D Pavement Defects Using 2D and 3D Information at the High Speed [J]. *International Journal of Automotive Engineering*, 2018, 9(4).
- [8] J Su, W Zhang, H Xiang, X Guo. Application and Analysis of Ground Penetrating Radar in Non-destructive Testing and Evaluation of Civil Airport Runway [J]. *IOP Conference Series: Earth and Environmental Science*, 2018, 153(3).
- [9] Shuai Li, Chenxi Yuan, Donghai Liu, Hubo Cai. Integrated Processing of Image and GPR Data for Automated Pothole Detection [J]. *Journal of Computing in Civil Engineering*, 2016.
- [10] Xiong Chunlong. “Research on structural health evaluation method of asphalt pavement based on non-destructive testing technology” [D]. *South China University of Technology*, 2017.
- [11] Luo Chuanxi. “Application of Road Nondestructive Detection Technology Based on 3-D Ground Penetrating Radar” [D]. *South China University of Technology*, 2018.
- [12] Wu Pengzhi. Research and application of ground penetrating radar based identification and diagnosis technology for hidden diseases of pavement structure [D]. *Beijing Jianzhu University*, 2019.
- [13] Wang Hui, & Nie Wen. “Analysis and evaluation of the correlation between pavement diseases and structural strength in highway reconstruction” [J]. *Guangdong Highway Communications*, 2020, 46(04): 7-12.
- [14] Shi Yan, Ling Tianqing, Cui Lilong, Ge Hao, & Chen Qiaoqiao. “Study on Evaluation Criteria and Decision Optimization of Preventive Maintenance of Asphalt Pavement” [J]. *Journal of Highway and Transportation Research and Development*, 2020, 37(10): 25-34+56.
- [15] Feng Li, Jinyan Feng, Youxin Li, Siqi Zhou. *Preventive Maintenance Technology for Asphalt Pavement* [M]. Springer, Singapore: 2020-07-29.
- [16] Bin Yu, Xingyu Gu, Fujian Ni, Rui Guo. Multi-objective optimization for asphalt pavement maintenance plans at project level: Integrating performance, cost and environment [J]. *Transportation Research Part D*, 2015, 41.
- [17] JTG 5210-2018, Standard for Evaluation of Highway Technical Conditions [S].
- [18] JTG 5421-2018, Code for Design of Highway Asphalt Pavement Maintenance [S].
- [19] JTG 5142-2019, Technical Specification for Highway Asphalt Pavement Maintenance [S].