CURRENT ENGINEERING PRACTICE OF PAVEMENTS MAINTENANCE IN CHINA

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Abstract: *This paper focused on current construction practice for pavement maintenance of expressway in China. It included identification of typical pavement section distresses, evaluation of pavement condition through surface distress rating, ride quality index(RQI), international roughness index (IRI), pavement condition index(PCI), mechanical performance test and pavement performance tracking. Different treatments are applied based on the distress level. Mix design of some new materials is given. New technologies: Thiopave asphalt, Buton rock asphalt (BRA), hot-in place recycling, foam asphalt cold recycling and rubblization method have been explained and put into engineering practice through some case studies. The application of the different technologies on practical engineering project has given satisfactory results.*

Keywords: *Pavement engineering, Pavement maintenance.*

I. INTRODUCTION

During the last two decades, China's transportation infrastructure is advancing quickly with rapid economic development and urbanization. According to China's 2015 highway statistics issued by the Ministry of communications in May, total length of highways in China have reached 4,577,300 kilometers at the end of 2015 against 4,463,900 km in 2014; an increase of 113,400 km have then be noticed in 2015 compared to the previous year. The highway density is 47.68km/100km2; which is 1.18km/100km2 improvements compared to 2014. The total mileage of classified highway was 4,046,300 km by the end of 2015 against 3,900,800 km at the end of 2014; an increase of 145,500 km in 2015 year compare to previous year. Classified highways occupy 88.4% in the total highway mileage of China. The mileage of the secondary highways class and above was 574,900 km in 2015; an addition of 29,200 km compare to 2014. The secondary highways class and above mileage then occupy 12.6% of the total highways mileage of China, an increase of 0.3% has then been noticed compare to 2014.Roads in China are classified as national highways, provincial highways, county roads, township roads and special purpose roads based on the administrative jurisdiction. National highways mileage is 185,300 km, provincial highways mileage is 329,700km, county roads mileage is 554,300km, township roads mileage is 1,113,200km, special purpose roads based on the administrative jurisdiction mileage is 81,700km. In 2015 there is respectively an increase of 6,100km; 6,900km; 2,300km; 8,100km and 1,400km for national highways, provincial highways, county roads, township roads, special purpose roads over 2014. By the end of 2015, the total mileage of China's expressway was 1,235,000 km against 1,119,000 km in 2014 year. This represents an accretion of 116,000 km compared to the previous year. Among China's expressways, National ones account for 79,600km in 2015, an addition of 6,500 km than 2014. National Rural highways (county roads, township roads, and village roads) mileage was 3,980,600 km at the end of 2015 against 3,881,600km at the end of 2014; an increase of 99,000 km has then been noticed. In 2015 there are 779,200 public highway bridges with a total length of 45,927,700 m, an addition of 22,000 numbers of highway bridges and 3,348,800 meters length is noticed compare to previous year [1]**.** Based on the experience gained by developed countries, a large scale road maintenance era, and road maintenance will be a long term continuous, never ending task when the peak time of road construction is over [2].Looking at the recent 2015 highway statistics issued by the Ministry of communications and comparing to the year 1988 where the first expressway was constructed, it can be noticed that China is currently undergoing development pattern in its road system development. The Highway maintenance has a total mileage of 4,465,600 km which represents 97.6% of China's total highway mileage by the end of 2015.According to the average 5-10 year of major and moderate rehabilitation cycle, by the end of 2020 it is expected to have up to 8000 km per year for total major and moderate rehabilitation mileage, and the maintenance will be maintained over this level, reflecting a huge road maintenance market potential. There is no doubt that the first priority of China's road development is shifting from large scale construction to ever growing maintenance. Many existing highways that were built 10 years ago are wearing out under heavy traffic loads accompanying with China's rapid economic growth. Rehabilitation or maintenance is an urgent need for these highways. The pavement maintenance strategies through engineering construction and under the guidelines of the concept improve the engineering characteristics of the road surface layer from multiple aspects and thus expand the scope of the whole highway transportation service. Although pavement durability is the main objective of highway project and its materials are continuously updating to adjust, but it is still faced with some common disease problem (crack, rutting, and seepage).

This paper aims to investigate the engineering practice of current new technologies in pavement construction maintenance and their benefits for its life cycle

II. CASE STUDIES

Three typical case studies are outlined in this section with respect to pavement material, construction process and quality control.

Case study 1: Nanchong - Wusheng expressway.

The original pavement test section of Nanchong-wusheng expressway was as follows:

- 4 cm modified asphalt SMA-13
- 6 cm conventional asphalt AC-20 C
- 6 cm conventional asphalt AC-20 C
- 20 cm cement stabilized gravel base
- 30 cm cement stabilized macadam subbase.

After many years of operation, many distress such as cracking (transverse, longitudinal) and rutting occurs in some of the pavement sections: K4+140-+280, K4+040-+140, K3+940-K4+040, K4+280-+420, K4+420-+790, K4+790-+894.In order to give to the road users a comfort and safety while driving, a new structure has been implemented in the deteriorated sections areas. The six concerned pavement sections with different length have almost the same pavement structure used: SBS modifier asphalt in surface layer and in the middle and lower layer,70 grade petroleum with level A.Pavement sections K4+420-+790 and K4+790-+894 have their subbase layer improve at 2% of cement. High performance asphalt pavement SUP19 is used to improve the performance and elevate the level of original pavement. The subgrade showed good bearing capacity. It is the first time that Emei Basalt has been used in SMA-10. Aggregate-asphalt ratio was respectively 6.3%, 4.5% and 4.1%for SMA-10, high performance asphalt pavement SUP19 and asphalt treated base (ATB-25) and pebble stone has been used as aggregate in both SUP 19 and ATB-25. The new pavement structure performs well to traffic load after many years and no obvious distresses have been shown. The composition and structure of the new pavement structure of Nanchong -Wusheng direction is shown in table 1 of the appendix.

Case study 2: Chengdu-Chongqing expressway

Cement concrete pavement uses cement concrete as surface material .This type of structure has many benefits of high stiffness, good rigidity, durability and a small routine maintenance work load,etc.The Chinese Design Standard prescribes a 30 - years life for cement concrete pavement. However many investigations on the usage have found that few cement concrete pavements can achieve a 15 to 30 year life cycle, and even some serious problem occur after being opened to traffic for 3 to 5 years.

The case study is located in Chengdu-Chongqing expressway and the pavement sections have been opened to traffic flow in 1995 .The original pavement comprises of different sections presented below:

A. K7+000-K10+000 section:

The original pavement section is consists of:

- 24cm concrete slab
- 20-30cm lime ash stabilized gravel

B. K10+000-K22+700section:

The original pavement section is consists of:

- 24cm concrete slab
- 20-30cm lime stabilized gravel

In these two sections above of the expressway, the original pavement condition is evaluated and results are summarized.

1. Original pavement condition evaluation

Prior to any maintenance or rehabilitation, researches have been conducted to evaluate the pavement condition index (PCI),the joint transfer capacity, the percent of voids beneath the concrete slab, pavement ride quality index (RQI) and mechanical performance test in both directions of the concern expressway. All these data have been found every kilometer of road. Results of all these indexes or data evaluated are shown in Appendix respectively through tables 2 to 6.

2. Results and Discussion

From table 2 (in Appendix), it can be concluded that most of sections are in very poor condition; most of sections in passing lane for both directions are either in good condition or sometimes fair condition. For both directions, either main lane or passing lane, the percent of broken slab is high and is either in very poor or poor condition. Table 3 shows the load transfer in the pavement concrete joint. The load transfer along joint in concrete slabs is excellent in both directions for some part and poor or very poor condition in other parts. The voids beneath the concrete slab are higher in main lane for both directions compare to the passing lane. Its results are shown in table 4.Table 5 showed the ride quality index and in table 6, the mechanical performance test results. From table 5, it is shown that the quality of pavement related to riding is range from fair to good. Two different test were performed (splitting tensile strength and compressive tensile strength) to analyze the mechanical performance of the pavement cores. From the table 6, it can show that compressive strength value is higher than splitting tensile strength one.

3. Old pavement structure regulation

Three problems are mainly emphasized to be solved in terms of application of asphalt surface course in old cement concrete structure: (1) prevention of reflection crack[3-5], (2) bonding between surface course and cement concrete slabs[6-7], (3) water infiltration of pavement surface[8-13]. Researches results showed that international technical exchange with America and Europe and China's engineering experience show that the stress absorbing layer technology has obvious advantages technologically and economically[14-15]. After inspecting original pavement structure condition, and reporting deficiencies, the next step has consisted of treatment .In the Chengdu - Chongqing expressway case, the treatment is done per section of road. The overlay structure for different sections is shown below.

K7～K9+100 section (Chongqing to Chengdu direction)

After the treatment of original pavement disease (without grouting), overlay has been applied and consist of

- 2.5cm stress absorption strata layer
- 8cm medium granular modified asphalt concrete AC-20
- 4cm asphalt mastic macadam SMA-13.

The overlay structure has been constructed on July 2006 and after 10 years of operation, only few transverse cracks have been obvious.

- **K7-K9+100 section (Chengdu to Chongqing direction)**

After treatment of concrete panels, vertical and horizontal width of 50 cm cracks have been filled with adhesive SBS membrane and 14cm thickness of overlay has been applied and the overlay structure is presented as follows:

- 5cm medium grained modified asphalt concrete leveling layer AC-20C
- 5cm medium grained modified asphalt concrete middle layer AC-20C
- 4cm modified stone mastic asphalt SMA-13.

The overlay structure has been also constructed on July 2006 and after 10 years of operation, only few transverse cracks have been obvious. The above two sections of white and black exhibits better performance, thus the original pavement has better performance after treatment which was the target.

- **K9+100-K18+750 section (both directions)**

After crushing the original pavement with hammer, a certain thickness has been implemented as overlay and the pavement structure is shown below:

- 20 cm cement stabilized crushed stone subbase
- 20cm cement stabilized macadam base
- 6cm medium grained conventional asphalt concrete AC-20
- 6cm medium grained modified asphalt concrete AC-20
- 4cm modified stone mastic asphalt SMA-13.

The original pavement condition and construction process are shown respectively in figures 1and 2.

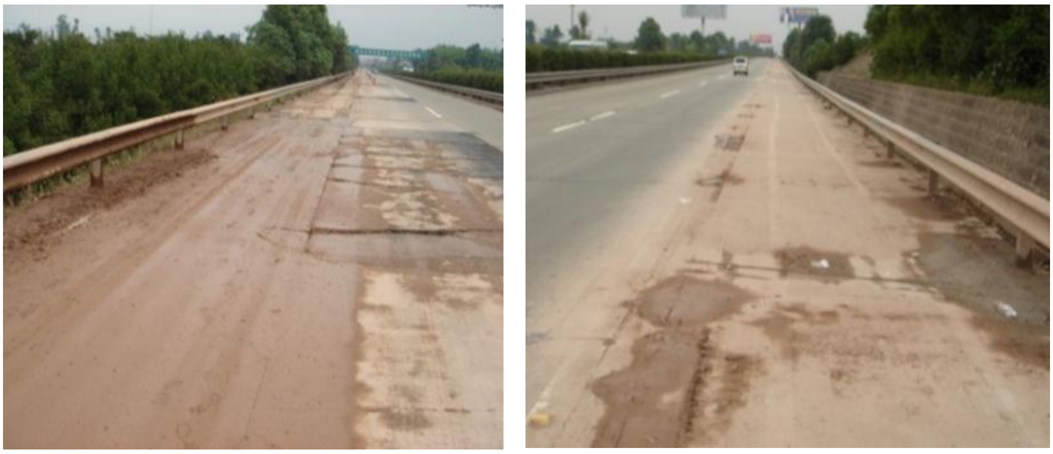

Fig 1. *Original pavement condition*

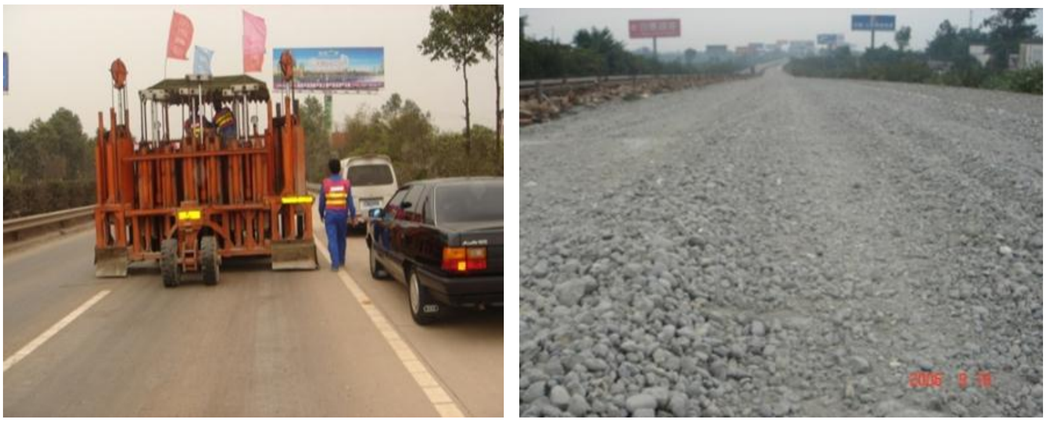

Fig 2. *Construction process*

4. Pavement performance tracking.

In order to check the effect of different method of treatment on the concrete pavement performance, numerous tests have been done. In December 2013 the general condition of pavement distress has been evaluated by pavement vehicle data acquisition and in April 2014 a walking survey has been done. Tables 7 and 8(in Appendix) show the evaluation of pavement distresses for both directions. No obvious raveling, settlement, flushing distresses are noticed in the pavement surface. In 2008, 2010, 2013 the pavement deflection has been detected and it is shown in tables 9 and 10 for both directions. There is no deflection and the pavement is in excellent condition. In 2008, 2010, 2012 and 2013, the section K7+000-K18+750 have been checked by laser profiler track for testing rutting. The results of rutting over years are shown in tables 11 and 12 for both directions. It can be concluded that there is not obvious rutting and pavement condition is either good or excellent. From 2007 to 2013 every year, laser instrument has been used to detect the flatness of pavement cross section and results from this investigation for both directions of travel are shown in tables 13 and 14.It can be seen that pavement has good riding quality. Section K7-K18+750 after being treated have good pavement condition, good riding quality and there is no obvious rutting and deflection.

C. K157-161 section: Chongqing to Chengdu direction, Yinshan section

In order to verify the construction operability and practical effect, 4km Thiopave asphalt mixture was paved on the large longitudinal slope uphill section of highway from Chongqing to Chengdu;4cm AC-13C (Thiopave asphalt mixture) surface layer was overlaid on the original pavement on May 2009.Composite gradation of mineral aggregate is shown in table 15. Asphalt-aggregate ratio determined by target proportion was 5.3%, optimal asphalt content was 5.5%. According to the principle of equal volume conversion, the final asphalt content (asphalt: mineral aggregate) = 4.37%, Thiopave percent (Thiopave: mineral aggregate) = 2.05%. The test results of Thiopave asphalt mixture performance shown in table 16. After many years of operation on the large longitudinal slope uphill section of highway from Chongqing to Chengdu(K157＋000～K161＋000), the road performance is better, there is no obvious early disease . Table 17 summarize the test results of pavement road test of 2010 and 2013.

D. K223-K225 section

Buton rock modified asphalt overlay was constructed on November 2008. It was overlaid over an original modified asphalt mix AC-13 for a given section. Indonesian buton rock asphalt (BRA) is a production from the Indonesian buton Island submarine rock asphalt. It is broken by mining into fine powder particles which have a light brown color. Trichloroethylene as solvent and automatic extraction Infratest 20-1120 instrument detection were used to extract asphalt content from the rock and final mineral aggregates has resulted. Table 18 shows the BRA extraction test results (in Appendix) and its screening results before and after extraction is shown in table 19.In table 18 it is shown that BRA asphalt content is 21.7% and the mineral aggregate percentage accounts for 78.9. Before extraction buton rock asphalt screening are too coarser with maximum particle size of mineral aggregate control below 1.18mm.More than 70% of mineral particles diameter are less than 0.15 mm after extraction. Fine, mineral particles mainly composed of limestone (reacted with hydrochloric acid to bubble), have strong adsorption of asphalt and used as powder. Fine mineral particles of buton rock asphalt mix before and after extraction and its reaction with hydrochloric acid are shown in figure 3.

a) Before extraction *b) After extraction* *c) Reaction with hydrochloric acid*

Fig 3. *Fine mineral particles of buton rock asphalt mix:*
a) before extraction; b) after extraction; c) reaction with hydrochloric

In order to see the effect of buton rock asphalt overlay after few years, the overlaid structure has been evaluated in term of occurrence of distresses: pavement damage condition evaluation, roughness and rutting. Test results are shown through tables 20 to 22. It can be concluded that the buton rock asphalt overlay pavement is in good condition.

E. K42-K47 section (Chengdu-Chongqing Expressway) overlay

Hot in place recycling technology is used as overlay in Chengdu - Chongqing Expressway K42-K47 section as pavement test section. On the top of the original pavement surface, 3 to 5cm of hot - in place regeneration is applied followed by 4cm of conventional asphalt mixture. A total of 170 Km of road test has been implemented based on experience and a tracking observation has been investigated as shown in figure 4.

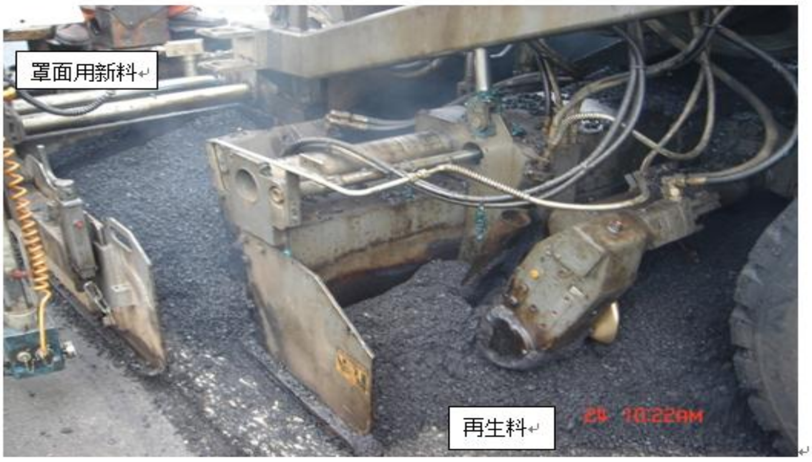

Fig 4. *Tracking observation after hot-in place regeneration*

After application of hot-in place recycling overlay in Chongqing Chengdu expressway; deflection, pavement distresses, rutting and pavement roughness were evaluated to see the effect of its application as overlay. Tables 23 to 26 respectively give details of each pavement component measured. From table 23 it can be noticed that in 2005 and 2007, deflection data has been detected in both lanes. In 2006, 2008, and 2010: only the main lane has been put into accoumpt for deflection detection. From 2005 to 2010 the deflection of the pavement decreases considerably. In 2009, Comprehensive test vehicles have been used to detect the road surface damage condition. According to the results obtained of the original road in table 24, there are no obvious types of distresses. The track of the test section was detected by laser beam profiler in 2008 and 2009, and the results of the detection of the hot in place recycling rutting test are in table 25. From table 25, it can be concluded that by 2009 most of pavement sections are either in good or fair condition. Only two pavement sections are in poor condition. Table 26 showed that pavement smoothness is also in good condition.

Case study 3: Zigong to Yibin expressway

Based on the experience of test section of Chengdu -Chongqing expressway in foamed bitumen cold recycling asphalt, an implementation of 13 kilometers of foamed bitumen cold recycling site has been extended in Zigong to Yibin expressway. The original pavement structure is shown bellows:

- 5cmAK-16B anti-sliding surface layer
- 7cm coarse grained -asphalt concrete AC-25I
- 20cm lime fly ash stabilized base
- 39cm lime stabilized mudstone subbase.

After few years of operation the pavement surface was not in good condition and thus the main and overtaking road surface has been improved and the new structure is as follows:

- 4cm fine grained modified asphalt concrete AC-13C

- 6cm medium grain type conventional asphalt concrete AC-20C
- 0.6cm slurry seal
- 14cm foam asphalt cold regeneration,

The pavement test section was treated by slurry before application of the cold regeneration asphalt layer. 14cm of foam asphalt cold regeneration refers to 12-13 cm of original milling asphalt added by 1-2cm top of base layer. According to the original road site grading requirement and amount of new material added, the asphalt foam recycling layer actual thickness is about 17cm. The pavement section has been constructed on May 2010 and after 5 years the road performance tracking is in good condition (table 27).

Case study 4: Chengdu to Mianyang Expressway

Chengdu-Mianyang Expressway plays an important role and represents the main squeleton road network in Sichuan province. According to statistics, Chengdu-Mianyang highway average daily traffic volume data over years before reconstruction is shown in table 28 and table 29 shows Chengdu-Mianyang expressway observation data after Mojia town toll station after reconstruction. From table 29, it can be noticed that after open to traffic, Chengdu-Chongqing expressway traffic flow slightly decreases for some case and still high for others in 2010.The original pavement structure consists of 23cm thick cement concrete slab +25cm thick cement stabilized gravel base (or 23cm thick cement concrete plate+ 20cm thick cement stabilized gravel base). Due to the large traffic volume with high proportion of trucks, the original pavement experienced some early damage in its structure. Therefore in Luojiang County K79-K81 section along Chengdu-Mianyang expressway, 5 sections of rubblization test have been conducted including drop hammer methods or resonant beam rubblizing. Rubblizing is the process of fracturing pavement of Portland Cement Concrete into angular pieces for direct overlay. It is an effective means of rehabilitating deteriorated Portland Cement Concrete (PCC) pavement. The concrete is broken into pieces, and then it is overlaid with Hot Mix Asphalt (HMA). In our case ,after breaking the original concrete pavement structure into pieces, an overlay structure has been applied and it is presented as follow:6cm of conventional asphalt AC-20C+4cm conventional asphalt AC-13C+6cm conventional asphalt AC-20C+4cm modified asphalt SMA-13. The overlay section has been constructed on March 2007 and the mixture design for both SMA-13 and AC-20C are as follows:

- SMA-13 mixture design bitumen aggregate ratio OAC: 6.2%.

Corresponding parameters:

=2.581,=2.475,VV(%)=4.1,VMA(%)=17.2,VFA(%)=76.2

- AC-20C mixture design bitumen aggregate ratio OAC: 4.9 %.

Corresponding parameters:

=2.581,=2.475, VV(%)=4.2, VMA(%)=14, VFA(%)=76.2,

(%) =4.44, (%) =10.89, (%) =84.91, FB=1.19, DA () =9.66.

The results of pavement condition survey after application of rubblization method are shown in tables 30 and 31 in appendix. From table 31, it can be see that the pavement condition index (PCI) values are above 90, which means that all pavement sections are in very excellent condition. The same effect is shown in table 31 for roughness index test results.

III. CONCLUSION

In this paper, we evaluate the diseases characteristics and poor condition of existing road for different expressways; use different current technologies for pavement maintenance. Results from these technologies application are summarized as following:

♦ The elevation of the road process of Nanchong-Wusheng expressway is greatly increase by setting a thick layer of high performance asphalt mix SUP 19. It was the first time that SMA10 which aggregate source is Emei basalt was used.

♦ After survey its diseases characteristics in section K7-K9+100 along Chongqing – Chengdu direction, a 2.5 cm thickness of stress absorption strata layer technique is introduced to solve reflection cracks in pavement. After few years of operation only very few transverse cracks were noticed. In the same time for the same section of expressway but in opposite direction, vertical and horizontal cracks on the concrete panels were filled with an adhesive SBS membrane; the section of white (concrete) and black (asphalt) together exhibits good performance.

♦ Pavement performance tracking test has been conducted few years later in the new pavement structure in K9+100-K18+750 after the original one has been crushed by hammer, it is conclude that there is no obvious raveling, settlement and flushing disease in the new built pavement.

♦ In K157-K161 (Chongqing to Chengdu direction, Yinshan section), Thiopave asphalt mixture was used to overlay the existing pavement. After many years of operation the road is still in good condition.

♦ Buton rock asphalt (BRA) mix was used to overlay a given section (K223-K225) in Chengdu-Chongqing expressway. Few years later after evaluation of pavement distresses, roughness and rutting. Buton rock asphalt overlay pavement is in good condition.

♦ Hot-in place recycling asphalt technology has been used to treat the top surface of existing pavement along Chengdu-Chongqing expressway for a K42-K47 section. Few years later the survey has been conducted on the pavement and found that the pavement is in good condition.

♦ Foam asphalt cold recycling has been implemented for use in Zigong-Yibin expressway to replace the existing poor pavement structure after being treated by slurry. After 5 years, road performance tracking test was conducted and pavement condition is in good state.

♦ Rubblization test has been applied in Chengdu-Chongqing expressway (Luojian county K79-K81 section) using both drop hammer methods and resonant beam rubblizing in the cement concrete pavement, the results of pavement condition survey after rubblization test are good. The values of pavement condition index (PCI) are above 90.

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