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Research progress in the mechanism and treatment of asphalt pavement cracking

Yinyan Li[1,a,*], Yifei Chen[1,b], Yuwei Song[1,c]

[1]Jinhua Highway and Transportation Management Center, Jinhua, Zhejiang, China
[a]398251891@qq.com, [b]36262534@qq.com @qq.com, [c]1335247246 @qq.com
[*]Correspoding author

Abstract: *Cracking defect is one of the diseases of asphalt pavement to be solved urgently, in recent years, with the continuous improvement of pavement custody requirements, maintenance of new materials, new technology, new technology constantly emerging, based on the asphalt pavement engineering of the typical Top-Down cracking and reflection cracking, both at home and abroad were reviewed on the analysis of its mechanism and treatment measures, It can provide a reference for pavement engineering maintenance researchers and technicians.*

Keywords: *Top-down cracking, Reflection cracking, Generation mechanism, The disposal measures*

1. Introduction

Under the background of the double carbon strategy, the transport industry has entered a new stage of accelerating the construction of transport power and promoting high-quality development of transport. According to the 2021 Statistical Bulletin on the development of the transport industry, by the end of 2021, the total length of roads in China was 5.280,700 kilometers, and the length of road maintenance was 5.251,600 kilometers. Accounting for 99.4% of the total highway mileage, the road network has gradually formed, and the development of highway transportation has shifted from construction to paying more attention to the coordinated development of construction, management, maintenance, and transportation. Pavement maintenance and disease treatment play an increasingly important role in prolonging the service life and service quality of the pavement. Crack damage will directly affect the service function and service life of the flexible pavement. Moreover, the infiltration of water through cracks may lead to the reduction of the function of the base and/or subgrade. Cracks are also the inducement of many other diseases of asphalt pavement, which can cause other secondary hazards such as pavement spalling, loosening, pit groove,s and subgrade bearing capacity reduction, and seriously affect the service performance and life of pavement[1]. This review starts with the typical crack diseases of semi-rigid base pavement in China and analyzes the research status of Top-Down crack and reflection crack mechanism and disposal methods at home and abroad. With the continuous development of new materials, new technology, and new technology, the disposal methods of pavement crack diseases are more diversified and more effective. This review can provide a reference for pavement engineering maintenance researchers and technicians.

2. Mechanism of asphalt pavement crack disease

Under the comprehensive action of traffic load and environment, the asphalt pavement will appear inevitable crack disease during its service period. Since the 1960s, people have been studying the crack mechanism of flexible pavement. The main failure mechanisms of flexible pavement crack include fatigue crack, reflection crack, low-temperaturee crack and TOP-down crack, among which the fracture mechanics method is considered to be the most suitable method to simulate the crack mechanism of pavement. However, fracture mechanics is based on continuous homogeneous material, and asphalt mixture is a three-phase heterogeneous material.

2.1 The the TOP – down cracking

Different asphalt pavement structures have typically different failure characteristics. For asphalt pavement with a thick surface layer, Top-Down cracks generated by the pavement surface and

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propagating to the interior are the main fracture failure form. This kind of crack first appears as a longitudinal crack, and then gradually appears transverse crack. Finally, the transverse and longitudinal joints form network cracks, and it is easy to form loose spalling at the crack edge under the comprehensive action of rain and vehicles. According to the cause of the crack, there are mainly load crack and nonload crack, the load crack is mainly due to traffic load especially heavy load traffic caused by shear type crack, nonload type crack mainly has temperature stress, temperature crack is mainly reflected in the open type transverse crack, in addition, materials, design, construction technology, The maintenance mode will also affect the generation and development of asphalt pavement cracks. Road workers at home and abroad have conducted in-depth research on the generation and development of Top-Down. Current studies on the mechanism of Top-Down mainly believe that the main cause of Top-Down cracks is that (1) the tensile stress exceeds the tensile strength (2) the shear stress exceeds the shear strength (3) the stress intensity factor exceeds the fracture strength (4) Li Feng used finite element analysis to analyze the longitudinal cracking of Top-Down cracks. According to Li Feng, shear stress is the main cause of Top-Down cracking[2]. Xu Ouming believes that the expansion of micro-cracks inside asphalt is mainly due to tensile stress[3]. Zhao et al. believe that the repeated tensile strain at the bottom of the asphalt layer under traffic load is the main reason for the bottom-up cracks. For the semi-rigid pavement treated with cement at the base, the top-down cracks are the main type of fatigue cracking, and the bottom-up cracks are unlikely to occur due to the strong support of the base. For granular base pavement, bottom-up cracking is more likely to occur at moderatelyte low temperatures, and it is more likel to start cracking from the top at high temperatures. With the increase in temperature and thickness of the asphalt layer, the possibility of top-down cracking increases[4]. The theory of multilayer elasticity is also widely used to determine the tensile strain used to predict bottom-up cracking behavior[5] Kim et al. believe that the maximum tensile strain predicted by the traditional multi-layer elastic analysis of pavement occurs at the bottom of the asphalt layer, so it cannot lead to the critical state of the pavement[6]. Meanwhile, the finite element (FE) method was used to analyze the longitudinal and transverse stress of the tire tread for the researchers, and it was found that there were tensile stresses or strains on the pavement surface, which could lead to top-down cracks occurring[7]. Roque evaluated the effects of aging and healing on the cracking performance of Top-Down cracks, and the test results showed that aging and potential repair effects were relatedthe to cracking performance of Top-Down cracks in asphalt pavem ent.When the pavement undergoes mild to moderate aging, it may maintain a relatively high level of healing, which helps to effectively recove the damage caused by HVS loading. A pavement that has been aged for a long tim may have completely lost its ability to heal, which makes it more prone to cracking[8].According to the study of Svasdisant et al., Top-Down cracks are mainly caused by two reasons: (1) lateral tensile stress caused by tier-road contact and modulus gradient changes caused by construction, temperature, and aging;(2) Asphalt aging reduces the tensile strength and tensile strain of asphalt mixture[9] .Through the above research, it can be found that Top-Down mainly occurs at the wheel track, and its causes and influencing factors mainly include the temperature of the road surface, load, pavement conditi,on and aging degree, as well as construction and maintenance[1 0].Uhlmeyer believes that the thickness of the pavement structure has a great influence on the Top-Down cracks[11]. Nunn studied that the horizontal tensile stress in the returned asphalt surface layer was the main cause of Top-Down cracks[12] .Wang et al. believe that Top-Down cracks are related to the morphology characteristics of aggregate particles and the distribution state of voids, and the probability of Top-Down cracks is small at low temperatures [13].According to Zhang Xiangyu's research, the influencing factors of cracks in the development stage are successively horizontal load, vertical l,oad and temperature load. The crinkthe of road surface is mainly caused by the maximum shear stress and tensile stress generated under the comprehensive action of horizontal load and vertical load than the shear strength and tensile strength[14].

2.2 Reflective cracking

Semi-rigid base layer is widely used in China due to its high strength and compact structure. However, the asphalt surface layer often has poor elastic modulus and low tiffness, which makes it easy to have reflection cracks[15,16].Th e survey found that Chinese roads will appear crack disease after 2-3 years of use, and ccrackswill further expand with the increase in service life[17], mainly due to the first crack in the base and then under the comprehensive action of load, climate, and other upward development of reflection cracks, according to the causes can be divided into temperature type of reflection cracks and load type of reflection cracks, the main formation reasons are dry shrinkage cracking, temperature shrinkage cracking, asphalt surface layer is thin, etc[18,19] .According to fracture mechanics theory, crack propagation mainly consists of three forms: opening, shearing, and tearing, as shown in Fig1.

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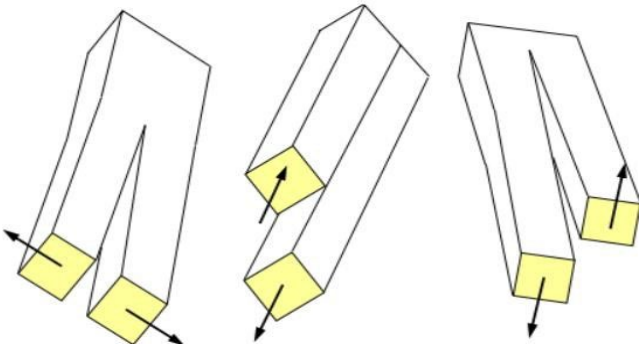

Figure 1: Crack propagation type[20]

The analytical solutions of the stress field in the tip region of the open and shear cracks are shown in equations (1) and (2)[21]:

$$\begin{cases} \sigma_x = \frac{K_I}{\sqrt{2\pi r}}\cos\frac{\theta}{2}\left(1-\sin\frac{\theta}{2}\sin\frac{3\theta}{2}\right)+\cdots \\ \sigma_y = \frac{K_I}{\sqrt{2\pi r}}\cos\frac{\theta}{2}\left(1+\sin\frac{\theta}{2}\sin\frac{3\theta}{2}\right)+\cdots \\ \tau_{yx} = \frac{K_I}{\sqrt{2\pi r}}\cos\frac{\theta}{2}\sin\frac{\theta}{2}\cos\frac{3\theta}{2}+\cdots \end{cases} \quad (1)$$

$$\begin{cases} \sigma_x = -\frac{K_{II}}{\sqrt{2\pi r}}\sin\frac{\theta}{2}\left(2+\cos\frac{\theta}{2}\cos\frac{3\theta}{2}\right)+\cdots \\ \sigma_y = \frac{K_{II}}{\sqrt{2\pi r}}\cos\frac{\theta}{2}\sin\frac{\theta}{2}\cos\frac{3\theta}{2}+\cdots \\ \tau_{yx} = \frac{K_{II}}{\sqrt{2\pi r}}\cos\frac{\theta}{2}\left(1-\sin\frac{\theta}{2}\sin\frac{3\theta}{2}\right)+\cdots \end{cases} \quad (2)$$

Where, Ky and KII are stress intensity factors of open and shear fractures, respectively. Among them, the open mode and shear mode are the main forms of reflective fractures[22], Li Sheng on rigid base asphalt pavement structure, using the theory of damage mechanics and numerical simulation method, combining with the actual engineering to study the damage behavior and mechanism of asphalt road surface, cloud computing results are shown in figure 2, it can be seen that under the action of load, the load side of the base asphalt fatigue damage,cracking after injury, will be under the influence of load and temperature, Cracks expand, and reflection cracks are finally formed[23].

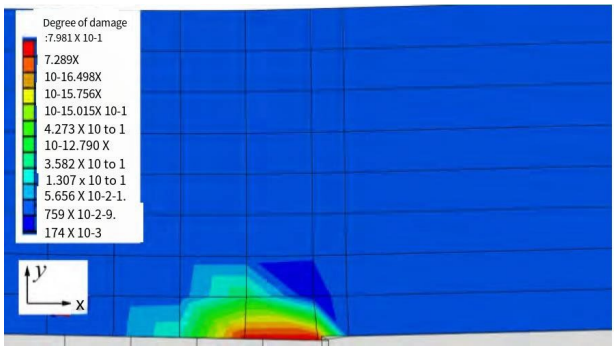

Figure 2: Load fatigue damage cloud diagram of asphalt layer at joint[23]

Researchers at home and abroad have conducted an in-depth analysis of various cracks and drawn many conclusions. However, there are many reasons for the cracks, and the cracking mechanism is relatively complex and not unified. This is mainly due to the incomprehensive factors considered in the analysis of the mechanism, which will cause the difference in judgment standards and conclusions. Moreover, many domestic studies on crack mechanism focus on the finite element method, and the model prediction and laboratory tests are not enough.

3. Crack disposal measures for asphalt pavement

Crack treatment measures generally from the material and structure, generally according to the cause of crack disease, crack development degree, combined with climate, load, and other factors to develop

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crack prevention and repair measures, according to the construction process mainly have the following:

3.1 Direct irrigation seam

This technology is a traditional crack repair method, simple operation, cheap, and widely used, usually using hot asphalt materials such as ordinary asphalt, SBS asphalt, and SBR asphalt as filling filler[24]After the crack is cleaned, the repair material is directly inserted into the crack to repair and seal the crack. This method has a poor repairing effect and is prone to a lack of filling. Moreover, the hot asphalt grouting material is easy to age and is easy to be damaged again after construction, and the maintenance time is short.

3.2 Slotted irrigation joint

This kind of slotting technology is a more traditional slotting technology. It needs to use professional slotting equipment to groove asphalt pavement, with a layout width of no less than 1cm and a depth of 1-3cm. At the same time, it ensures that the surface of the pavement is not less than 5cm in width and no less than 1-2cm in thickness. Slot, cao seam in dust in the air blower to clean, through the use of glue gun after heated to a suitable temperature, the repairing adhesive mainly modified asphalt or emulsified asphalt prepared artificial pumping trough, the implementation of effective repair cracks of asphalt pavement, after filling and sewing, fine sand, with similar spray repair color scrape to evenness heater repair materials for processing. Generally, traffic can be opened about 10min after irrigation. Slotted irrigation is generally suitable for fatigue cracks caused by vehicle load, which are usually irregular in direction and small in width.

3.3 Seam stacking technology

Foreign asphalt concrete professionals have studied a series of pavement crack adhesives, the first use of the main petroleum asphalt, emulsified asphalt, etc., in recent years, there is a wide variety of sealants on the market, mainly polyurethane, polyurethane, epoxy resin composite, acrylic, polyurethane, ATPU (polyethylene glycol (peg), ethylenediamine, toluene diisocyanate synthesis), oligomer polyurethane polymer repair materials, such as, but different repair materials formula, quality is uneven, enacted in 2015, domestic stick glue industry standards, The properties of the adhesive tape were evaluated by cone penetration, flow test, elasticity test, elongation test and tensile test[25]. With seam is similar to the asphalt surface "band-aid", at the time of construction of the crack surface need only for simple cleaning can, need not for pavement slot processing, simple construction, high efficiency, is not easy to produce secondary hazards, has the very broad application prospects, but at the same time also should see, stick a seam there are easy to fall off easy trip.

3.4 Processing of reflective cracking

In the treatment of semi-rigid base pavement reflection crack, domestic and foreign scholars conducted a lot of research, through stages such as pavement design, construction, maintenance, and general at the design stage are reasonable and gradation, increase the degree of asphalt surface's thickness, placing the stress absorbing layer, etc., set the reinforced layer, the stress absorbing layer, cracking pavement interlining, etc[26]Ling Xu proposed the design method of stress absorption layer for geotextiles, whose main function is isolation and anti-seepage.In USA, non-woven poly (propyl rare earth) geotextiles are used to reduce the effect of reflective cracks. Long-term observation shows that the geotextiles have a good effect in preventing cracks[27], glass fiber grille and SAMI stress absorption layer can effectively prevent the occurrence of reflective cracks, and low temperature and de-icing salt have important effects on the crack resistance of asphalt[28]. Also, some scholars put forward the pavement crack pressure grouting process, through the pressure grouting machine, injection of crack repair materials, internal pore filling cracks, crack repair, snow to polymer grouting repair technology is put forward, such as by injecting polymer material into the pavement structure, the rapid expansion of injection materials to fill the pore structure of asphalt layer cracks around the micropore, fast curing, Thus, the overall strength of the pavement structure can be improved[29].

Xie Zhuoran et al. predicted the spacing and location of cracks by calculation and eliminated shrinkage and temperature stress by presetting expansion joints, which played a good role in slowing down the occurrence and expansion of cracks[30].The phyletic and various crack repair technology and materials, repair material is uneven, the material in the deepening of research and development, and

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technology constantly optimized, but there are also emerging classes of organic polymer repair materials prices tend to be high, and the intensity of asphalt kind of mending material itself and bond strength can not meet the requirements, therefore, for a particular type of fracture, It is necessary to further optimize the construction process and develop green, economic, environmental protection, and efficient crack repair materials.

4. Conclusion

To sum up, because the asphalt material itself belongs to viscoelastic-plastic material, asphalt pavement is easy to produce various types of crack diseases due to the comprehensiveThe action of load and temperature during the service period, which is difficult to avoid completely.In highway construction in the process of custody and how to reduce crack defects caused by The secondary disease is the top priority, the need to further study the theory of the cracks of asphalt pavement, from the mechanism, combined with the environment, and load conditions, targeted for maintenance and prevention plan, to further enhance the level of road service and extend the service life, reduce the cost of custody late.

References

[1] Lin Tingting, A review on the application technology of preventive maintenance of asphalt pavement,Fujian Construction Science and Technology, 2022, (02): 89 ~ 92
[2] Li Feng, Sun Lijun, Finite element analysis of Top-Down cracking in asphalt pavement, Journal of Highway Transportation Science and Technology, 2006, (06): 1 ~ 4
[3] Xu Ouming, Hao Peiwen, Analysis of Top-Down Cracks in Thick Asphalt Pavement and Its Implications for Pavement Design, Chinese and Foreign Highways, 2006,26 (5): 5
[4] Zhao Y, Alae M, Fu G, Investigation of Mechanisms of Top-Down Fatigue Cracking of Asphalt Pavement, ROAD MATER PAVEMENT, 2018,19 (6) : 1436 ~ 1447.
[5] Jablonski B, Regehr J, Rempel G, Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures, Final Report Part Design Analysis, 2001,
[6] Kim J, Roque R, Byron T, Viscoelastic Analysis of Flexible Pavements and its Effects on Top-DownCracking, J MATER CIVIL ENG, 2009, 21 (7): 324 ~ 332
[7] Wang H, Ozer H, Al-Qadi I L, et Al., Analysis of Near-Surface Cracking under Critical Loading Conditions Using Uncracked and Cracked Pavement Models, et al., J TRANSP ENG, 2013,139 (10): 992 ~ 1000
[8] Rogue R , Zou J , Kim Y R , et al. NCHRP Web-Only Document 162: Top-Down Cracking of Hot-Mix Asphalt Layers: Models for Initiation and Propagation. 2010.
[9] Sangpetngam B, Birgisson B, Roque R, Multilayer margin-element Method for Evaluating Top-Down Cracking in Hot-Mix Asphalt Pavements, Journal of Transportation Research Record of the Transportation Research Board, 2004, 1896:129 ~ 137
[10] Liang Yue, Zou Xiaoling. Review on the causes of Top-Down cracks in asphalt pavement [J]. Chinese and Foreign Highway, 201,41(03):58-65,
[11] Uhlmeyer J, Willoughby K, Pierce L, et al., Top-Down Cracking in Washington State Asphalt Concrete Wearing Courses, (SCI) Journal of Transportation Research Record, 2000,1730 (1) : 110 ~ 116.
[12] Nesnas K, Nunn M, A Model for Top-Down Reflection Cracking in Composite Pavements, Materials & Structures, 2004, 91 (2): 207 ~ 213
[13] Wang L, Myers L, Mohammad L et al., Micromechanics Study on Top-Down Cracking, Transportation Research Record Journal of the Transportation Research Board, 2007, 1853: 121 ~ 133
[14] Zhang Xiangyu, Study on the surface cracking of asphalt pavement under traffic load and temperature, Master's Degree, Hunan University, 2007
[15] Chen Qinglan, New technology of Reflection Crack treatment in semi-rigid asphalt pavement, Transportation World, 2020, (16): 52 ~ 53
[16] Liu Lanbo, Huo Guangbusong, CAI Wencai, et al., Analysis of the new technology of Reflection Crack treatment in semi-rigid base asphalt pavement: A Case study of Anhui Heliuye Expressway , Heilongjiang Transportation Science and Technology, 2019,42 (11) : 27 ~ 28
[17] Zhi S, Gun W W, Hui L X et al., Evaluation of Fatigue Crack Behavior in Asphalt Concrete Pavements with Different Polymer Modifiers, Construction & Building Materials, 2012,27 (1) : 117 ~ 125
[18] Zhou Huaien, Research on crack treatment technology of semi-rigid asphalt pavement, Urban Road Bridge and Flood Control, 2021, (8): 291-295

ISSN 2706-655X Vol.4, Issue 9: 25-30, DOI: 10.25236/IJFET.2022.040905

[19] Yuan Yuan, Research on Causes and Prevention measures of reflection cracks in semi-rigid asphalt pavement, Transportation World, 2019, (16) : 32 ~ 33
[20] Al-Qadi I L , Elseifi M , Leonard D . Development of an overlay design model for reflective cracking with and without steel reinforcing nettings[J]. Journal of the Association of Asphalt Paving Technologists, 2003, 72:388-423..
[21] Chao Shan, Chuanfeng Zheng, Xue Yang, et al., Experimental study on the formation and expansion mechanism of reflective cracks in semi-rigid asphalt pavement, Subgrade Engineering, 2021, (06) : 69 ~ 74
[22] Huang Xiaoming, Zhang Yuhong, Li Chang, et al., Finite element Analysis of Stress intensity factors in cement concrete pavement, Journal of Highway Transportation Science and Technology, 2006,023 (002) : 52 ~ 55
[23] Li Sheng, Chen Shangwu, Liu Zhaohui, et al., Failure behavior and mechanism of asphalt layer in rigid base asphalt pavement, Journal of Central South University (Science and Technology), 2016,47 (03) : 1065 ~ 1070
[24] Sun Ke, Study on grout diffusion and grouting technology in cold irrigation joints of asphalt pavement cracks, Master's Degree, Shandong University, 2016
[25] Editorial Department of China Journal of Highway and Transportation, Review of Academic Research on Pavement Engineering in China ·2020, China Journal of Highway and Transportation, 2020, 33 (10) : 1 ~ 66
[26] Wang Y X. Research on the application of epoxy modified polyurethane in the repair of existing cracks in semi-rigid base asphalt pavement [D]. Changsha University of Science and Technology,2015.
[27] Mcdonald E B . Reduction of reflective cracking by use of impervious membrane. Impacts. [J]. Impacts, 1974.
[28] Gao Zhanhua, Study on crack resistance of asphalt mixture under freezing rain and ice snow extre me climate, Master's Degree, Changsha University of Science and Technology, 2010
[29] Bai Xue, Jia Qinlong, Analysis and Treatment of highway asphalt pavement Disease, Road Construction Machinery and Construction Mechanization, 2016,33 (09): 76 ~ 79
[30] Xie Zhuoran, Research on Prevention and Control of asphalt Concrete Pavement Crack Disease in Alpine Region, Inner Mongolia Highway and Transportation, 2006, (3): 3.