

# Survey on the Formation Top-down Crack

Jianfeng ZHENG

Institute of Civil Engineering and Construction, Chongqing Jiaotong University, Chongqing, 400074, CHINA

**Abstract:** This paper mainly from the flexible asphalt pavement how to generate top-down cracking (self-oriented development of cracks and damage of pavement cracks in this the problem started, combined with domestic and foreign experts on top-down cracking produced the mechanism study of contrast, by of asphalt mixture and asphalt pavement forming mechanics analysis, based on asphalt mixture of top-down crack of asphalt pavement were analyzed, the main consideration of aggregate ratio, asphalt pavement aging degree, grade three main factors, by using orthogonal experiments respectively on three main factors make produce top-down crack this problem analysis. The stress intensity factor  $K$  is used to analyze the mechanical stress of the asphalt pavement which is produced by the combination of the first type of fracture and the second type crack or the two crack. At last, this paper tries to give prevention and improvement suggestions for the analysis of asphalt mixture and asphalt pavement.

**Keywords:** Top-Down crack; Asphalt mixture; Fracture mechanics; Aging of asphalt pavement

## 1. Introduction

Shanghai Jiading Expressway opened to traffic, marks China officially entered the era of high speed, at the end of the first half of 2016, China's highway mileage has reached 12 million km of ranked first in the world. Asphalt pavement is national highway the main type of pavement. Foreign use of flexible base in expressway construction, flexible pavement surface layer is thick and our country current < asphalt pavement design specification > has asphalt layer thicker of flexible base asphalt pavement as a main types are recommended. Asphalt pavement structure different, the main disease of asphalt pavement are also different. Top down cracking (top-down) became the main form of pavement diseases. This paper from the leach Comprehensive analysis of the two aspects of the mixture and asphalt pavement Top-Down crack generation mechanism, and gives suggestion for improvement.

## 2. Top-down Crack at Home and Abroad Research Status

### 2.1. Top-down crack research reasons

Top-down cracking is different from the previous reflective cracking and reflective cracking is due to the semi rigid base can't resist layer at the bottom of the flexural tensile stress caused by roadbed fracture, and the traffic load under produce stress concentration caused by the cracks in the pavement, reflection cracking is bottom-up generated. And top-down cracking is mainly top-down development, to produce longitudinal cracks after transverse cracks and eventually become a net cracks, severe loss of the pavement bearing capacity and reduce the PSI (using performance evaluation index) [1]. Because our

country take the current < asphalt pavement design specification > to flexible base asphalt pavement as to Design road surface. The future road Top-Down crack will be produced in large quantities.

At present at home and abroad that top-down cracking due mainly to the following five kinds: (1) the stress exceeds the tensile strength, (2) shear stress exceeds the shear strength; (3) should be stress intensity factor exceeds the fracture toughness (4) dissipated creep strain to energy ratio exceeds a critical value. (5) other reasons.

### 2.2. Current status of Top-Down research in China

Our country highway pavement cracks due to past the "strong foundation and thin surface" theory so the reflection crack mostly, abroad for study of top-down cracks to some night.

Chang'an University Xu Ouming, Professor Hao Peiwen [2] first of top-down crack generation mechanism are analyzed, the fracture mechanics and finite element model is then used, on a pavement crack crack propagation mechanism and crack growth stage were studied. Sun Yao, Qiu Jun, Wang Chunlin [3] the cracks are divided into two: (1) "by" type transverse cracks, temperature and shrinkage cracks, caused by temperature; (2) "and" type longitudinal crack, surface crack. Huang Zhitao [4] that top-down cracking crack generation and propagation mode is open type crack, namely tensile stress damage model.

### 2.3. Research status of Top-Down in foreign countries

Svasdisant said, the top-down cracking mainly is caused by two reasons: (1) the wheel load induced surface radial tensile stress and the construction, temperature and aging caused by the strength difference degree; (2) because the

asphalt binding material aging, tensile strength and tensile strain of the mixture decreased Birgisson [J] that the pavement structure itself because of the material, the reasons for the design and construction are micro cracks. The larger tensile stress caused by the contact of tire road surface promotes the expansion of micro cracks, the aging of the surface asphalt binder decreases the tensile strength and tensile strain of the mixture.

### 3. Asphalt Mixture to Explain the Mechanism of Top-Down

Combination of top-down made by domestic and foreign scholars research analysis shows that, the rutting test measured dynamic stability, splitting the experimentally measured flow value and stability. Draw the crack mechanism. Affecting the rutting of the main factors for mineral aggregate gradation, asphalt aggregate ratio void age, thickness, temperature, effect of splitting tensile strength of the main factors for gradation and aging, voids, asphalt aggregate ratio; main influencing factors of asphalt pavement top-down oil stone ratio, kinds of asphalt, asphalt aging, gradation, temperature. Common factors that affect the: asphalt content, gradation and aging. So the main changes of these three factors to study t The influence of op-Down crack.

Tests are as follows:

(1) Asphalt content (OAC)

The asphalt aggregate ratio: 3.8%, 4.3%, 4.8%, 5.3%, 5.8%

Parallel specimens: 3 groups

(2) Gradation: AC-13 upper limit, AC-13 limit, lower limit of AC-13;

Parallel specimens: 3 groups

(3) Aging and aging of the two kinds;

Parallel specimens: 3 groups

AH-70 paving asphalt was selected. In accordance with the provisions of the < highway engineering asphalt and asphalt mixture test procedures >method determination of the penetration, softening point, ductility, flash point and density measurement [5]. The experimental results show that the: asphalt softening point, penetration index and extension degree can meet the requirements of design and < highway asphalt pavement construction technical specification > JTGF40-2004.

#### 3.1. To determine the optimum asphalt content (OAC)

In the cooperation than the design by Marshall test method to determine the optimum asphalt aggregate ratio, in order to estimate the aggregate ratio for median at certain intervals of dense gradation asphalt mixture material from 0.5%) moulding specimens according to. Through experimental determination of different asphalt aggregate ratio related to the mixture of the Marshall test index.

Analysis of the above data can be carried out in Figure 1 and Table 1.

Table 1. Experimental results of AC-13 of asphalt

Asphalt aggregate ratio (%)	Bulk density (g/cm <sup>3</sup> )	Asphalt saturation (%)	Stability (KN)	Flow values (mm)
3.8	2.312	47.9	9.16	2.9
4.3	2.334	57.7	10.52	3.2
4.8	2.345	71.5	11.62	3.9
5.3	2.342	75	11.36	4.4
5.8	2.341	79.7	10.46	4.9

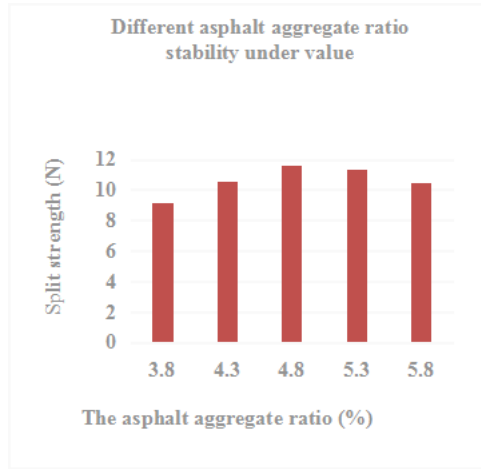


Figure 1. AC-13 Marshall test results of asphalt mixture

Through the above experimental data available in the Marshall stone ratio of 4.8% maximum stability.

#### 3.2. Effect of different grading or aging on Top-Down crack

The aging of asphalt pavement and aging asphalt pavement were analyzed, using the thin film oven aging test (TFOT) or rotating thin film oven aging test (PAV) on the pavement aging treatment, look at the splitting strength of two cases [6]. The thin film oven aging test (TFOT) is shown as Figure 2. The experimental data can be sorted out in Table 2.



Figure 2. The thin film oven aging test (TFOT)

Table 2. Effect of asphalt on Top-down crack under different gradation and aging

The asphalt aggregate ratio (%)		4.30%	4.80%	5.30%	
Split strength (N)	C13 upper limit	Not aging	1340	1450	1620
		aging	960	1190	1310
	AC13 limit	Not aging	1260	1300	1350

	AC13 lower limit		960	1040	1150
--	------------------------	--	-----	------	------

Table 2 can be aging and non aging case splitting strength, and that coincides with the situation above, specific see Figure 3.

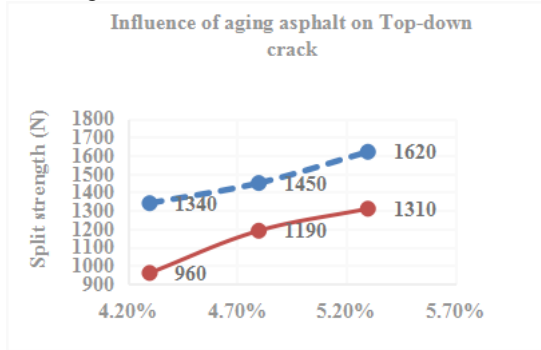


Figure 3. Analysis on Top-down crack of aged asphalt under the same gradation

At the same time, the splitting strength of different grades is also different. The upper limit of the splitting strength is greater than the lower bound of the splitting strength, and the conclusion is consistent with the above assumptions. Analysis on Top-down crack of asphalt mixture under different gradation is shown as Figure 4.

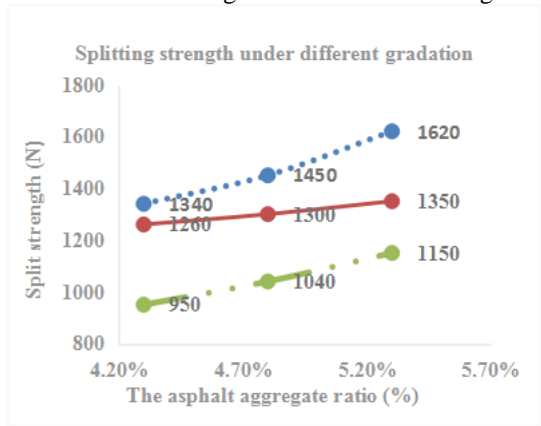


Figure 4. Analysis on Top-down crack of asphalt mixture under different gradation

Based on the above experimental data analysis shows that in the perspective of asphalt mixture top-down cracking, is of different asphalt aggregate ratio of asphalt pavement, split tensile strength values from low temperature to high peak and then decreased. Therefore, before mixing asphalt mixture first by Marshall test determine optimum asphalt aggregate ratio, not only saving asphalt to reduce the cost and ensure the asphalt pavement enough bearing capacity and reduce the occurrence of top-down crack.

And gradation is also a need to consider the important elements and different gradation, asphalt pavement splitting tensile strength is not the same. Aging is also an important factor, the asphalt pavement well maintenance can also reduce the cracks in existence. Others, such as water, temperature and humidity, difference construction, compaction degree, different landform is also possible an important cause of top-down cracking. Because of the limited space not in this one are discussed in detail.

#### 4. Fracture Mechanics to Explain the Mechanism of Top-Down

##### 4.1. Fracture mechanics and fracture analysis hypothesis

Fracture mechanics is the study of crack in a material or structure strength and crack propagation law of a discipline. It uses principles of continuum mechanics, to study with defects of the homogeneous continuous material made of engineering structure strength and fracture condition, to ensure its safe service[7].

##### 4.2. Three types of fracture

For the pavement structure, even in the same environment, due to the different of the external load, pavement cracks will exhibit different forms of cracks. In fracture mechanics, according to crack under the load cracks and the external form, the crack is divided into three types, respectively, for I type crack, type II cracks and type III cracks.

##### 4.3. Crack judgment criterion

Should stress intensity factor K and the critical stress intensity factor KC is two different concepts. Stress intensity factor K is caused by external loads, the reflect crack tip field of mechanical effects of the parameters, the critical stress intensity factor KC is to reflect the material performance parameter

$$KI > [KIC] \tag{5}$$

When the opening fracture occurs, the same way we can know when to meet the conditions

$$KII > [KIIC] \tag{6}$$

Shear type failure occurs.

From the point of view of fracture mechanics and top-down cracking is from the road itself and force characteristics of the watch, the crack is of course there will be the solution is to limit the crack expansion. When appears inclined to cracks, cracks can be divided into horizontal and vertical cracks, horizontal fracture due to the gravity of the pressure and will not be easily extended, and vertical fracture need fiber adhesion, so crack propagation must pull off or the fiber is separated from the concrete pavement, here has greatly increased the pavement anti cracking ability. In addition, you can also through to the newly built road just a overload, the as-

phalt road surface plasticity zone expansion Big, so it is not easy to produce cracks.

## 5. Conclusions

To analyze the top-down cracking from the viewpoint of asphalt mixture, we can know for anti-aging and maintenance of asphalt mixture by Marshall test to find optimum asphalt content (oilstone ratio) and select the gradation limit selection quality aggregate should not be for the convenience of all materials, as well as on the asphalt road surface, in mixture construction should be strictly in accordance with the norms of construction as far as possible to reduce the difference of construction.

From the aspect of the whole point of view of fracture mechanics and pavement to analyze pavement stress can by reduced stress intensity factor  $K$  to prevent cracks and expand, add fiber concrete pavement reinforcement, on the road was only a overweight load makes new asphalt road surface plasticity region expanded is for preventing top-down cracking on the asphalt.

## References

- [1] Wu Jianmin. Pavement maintenance management[M]. System.Beijing: China Communications Press, 2015, pp.40-41.
- [2] Xu Ouming, Hao Hao. "Top-Down crack analysis of thick asphalt pavement and Its Revelation to pavement design" [J]. Chinese and foreign highway, 2006.
- [3] Sun Lu yao Qiu Jun, Wang Chun lin,. "Analysis of the causes of asphalt pavement "from top to bottom" type crack" [J]. highway engineering and transportation, 2008.
- [4] Huang Zhitao. "Evaluation of Top-Down cracking of asphalt pavement" [J]. highway engineering, 2008
- [5] Pan Xue-zheng, Dong Hai-bo, Zhang Hong-liang. "Study on the influence factors of Top-down cracking of asphalt mixture" [J]. construction technology
- [6] JTJ052-2000."Highway engineering asphalt and asphalt mixture test procedures" [S]. Beijing: People's Communications Press, 2000
- [7] Li Peng Hui. "Numerical and experimental study on crack growth of asphalt pavement"[D]. Huazhong University of Science and Technology, 2007:pp.8-15.