

Rutting Resistance Evaluation of Structural Combinations of Asphalt Pavement Subjected to Heavy Duty

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Abstract. Rut, referred to as a common damage of asphalt pavement, is still a knotty problem to pavement researchers. Many reasons could cause rut, among which heavy duty, improper pavement structural combination design are two principal factors. As a result, three pavement structures and seven types of asphalt mixtures were used to evaluate the rutting resistance performance of different structural combinations. At first, through Marshall design method, the properties of asphalt mixtures were obtained such as gradation, asphalt content and so on. Based on the comparison of gradations and anti-rutting additives, the single layer rut was tested by wheel tracking test. Then, in order to consider the influence of pavement structural design on pavement rut, six types of structure combinations under identical heavy duty condition were designed to perform rutting test. It shows that anti-rutting gradation and anti-rutting additives can improve rutting resistance performance of single layer. Also, a proper structural design could provide a better bearing capacity of wheel load even for heavy duty. It is better to integrate the anti-rutting gradation and anti-rutting additives into structural design. In this paper the results provide some new insight into the relationship between rutting resistance and mixture gradation, anti-rutting additives, heavy duty and structural combination. The consideration of these factors will give a better pavement design.

Introduction

In recent years, as the axis load and tire press increase rapidly in most parts of China, as a consequence, rut becomes a common and difficult damage of asphalt pavement, also makes it hard to determine the index of pavement rehabilitation [1]. When rut depth grows to a certain value, it will be potential risk for drivers even meet a rainy day, because surface irregularities of road cross section easily results in vehicle drift. There are so many factors influence rut such as gradation, asphalt types, asphalt content, aggregate and climate, but even if these factors were known very well, it also has difficulties in finding the effective and economic control methods to reduce and avoid rut, so that many relative researches were in aims at some realm of pavement rut. As we all know that asphalt mixtures exhibit viscoelastic characteristic, whose property is relative with the rutting mechanism [2,3], the mechanism of pavement rut is always deemed that the shear stress in the road is bigger than shear strength of asphalt mixtures, especially in long and steep climbing sections of asphalt pavement [4], other researchers search the mechanism to reduce rut by geotextile [5]. Gradation is significant to asphalt mixtures, because of its direct relationship with various properties of mixtures; in addition, the increase of nominal maximum aggregate size (NMAZ) always results in improvement of rutting resistance [6]. Some kinds of additives can modify qualities of asphalt and the aggregate-asphalt interface then generate a strong mix in order to reduce rut [7]. Numerical analysis and pavement structural design are also used to determine what main reason of pavement rut is [8, 9].

To establish relevant between rut and gradation, anti-rutting additives, heavy duty, structural design, single layer and structure combination track board were applied into wheel tracking test of heavy tire press (1.1MPa), analyzed data of different experimental groups then come to a conclusion.

Marshall design method

This paper employed seven types of asphalt mixtures according to typical ones used in highway: KAC-16, KAC-20, ATB-25, KAC-25, AC-16, AC-20, AC-25, where K is mean anti-rutting gradation, shown in Tab.1. The different NMAZ and gradation were for the sake of considering the gradation's impact on pavement rut. Obviously, anti-rutting gradation's limitation is narrower than a normal one, Fig.1 shows that the aggregates' pass rate of KAC-20 is smaller than AC-20 except 9.5mm sieve, anti-rutting gradation is coarser than the normal one.

Tab.1 Seven types of asphalt mix gradation

Sieve size [mm]	Pass rate [%]												
	31.5	26.5	19	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
ATB-25	100	100	64.8	54.1	46.6	39.8	32	21.1	16	11.4	8.1	6.9	5.9
KAC-25	100	100	82.3	75.2	66.4	57.3	34.7	23.5	16	11.8	7.6	6.7	5.5
KAC-20	-	100	91.7	85.7	73.5	61.4	37.5	23.4	15.6	10.8	7.8	6.8	5.9
KAC-16	-	-	99.7	95.4	82.9	70.5	43.9	27.2	17.2	11.4	8.1	6.9	5.9
AC-25	100	100	88.7	78	69.6	54.2	37.5	28.5	21.4	15.7	11.4	7.2	5.7
AC-20	-	100	93.9	87.4	78.7	59.5	39.9	28.6	21.4	15.7	11.4	7.2	5.7
AC-16	-	-	100	94.1	86.7	67.2	40.9	29.3	22.3	16.4	11.7	9.5	6.8

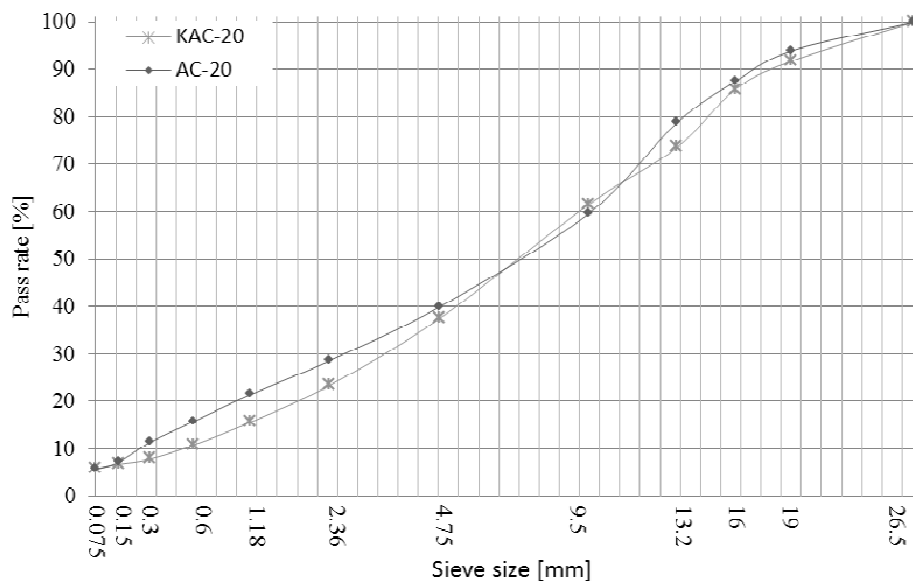


Fig.1 KAC-20 and AC-20 gradation curves

After gradations were determined, Marshall design method was applied to calculate the optimum asphalt content of seven mixtures, then obtained some volume indexes shown in Tab 2. All the data met requirements of *Enforceable Handbook of Technical Specifications for Construction of Highway Asphalt Pavements*.

Tab.2 Data of Marshall design method

Types	OAC [%]	γ_b [g/cm ³]	VV [%]	VFA[%]	MS [KN]	FL [mm]
ATB-25	3.8	2.537	4.0	60	11.3	2.32
KAC-25	4.1	2.400	4.5	62.9	10.5	2.90
KAC-20	4.9	2.500	4.8	67.0	12.1	3.70
KAC-16	5.1	2.467	3.6	73.8	11.8	2.90
AC-25	4.2	2.500	4.5	68.3	8.9	2.93
AC-20	4.7	2.495	4.4	69.0	15.5	3.70
AC-16	5.4	2.459	4.5	71.2	10.6	3.94

Single layer wheel tracking test

Based on data of the first section, gradation and asphalt content were applied into single layer wheel tracking test to estimate and check the property of anti-rutting resistance. According to *Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering*, wheel rolling equipment was used to shape experimental boards (300mm×300mm×50mm), wheel track testing was in 60°C and remained 60 minutes at least until the curve reached stable. At last, the *DS* (Dynamical Stability) could be worked out by formula 1

$$DS = \frac{(t_2 - t_1) \times N}{d_2 - d_1} \times C_1 \times C_2 \quad (1)$$

Where t_1 and t_2 are the 45 minute and 60 minute from test began, d_1 and d_2 are corresponding deformation of t_1 and t_2 , C_1 is correction factor of wheel tracking test equipment, in this test it is 1.5, C_2 is specimen coefficient depending on the size of tracking boards, it is 1.0 in this test, N is velocity of wheel tracking tire moving there and back, it is 42 round per minute.

In this section, took gradation and anti-rutting additives into consideration subjected to single layer test, but used normal tire press (0.7MPa). Aimed at finding how do these two factors effect rut, the results of these differently compared groups shown as follow.

Gradation. From Fig.2, it shows that anti-rutting gradation has a positive influence on improving the capacity to resist vehicle loads. The *DS* of KAC-20 increases by 17.4% comparing to AC-20, and the result of KAC-16 increases by 28.5% comparing to AC-16, while to KAC-25, it decreases by 3.4%, because when NMAZ reaches 26.5mm, the anti-rutting gradation seems similar with normal one when keeping a qualified VV. If just only increase the difference between two types of gradation, the anti-rutting one will be difficult to meet the regulation requirement such as a proper VV. But KAC-20 and KAC-16 do not have these problems, a wider selection in gradation than KAC-25. The maximum *DS* is exhibited in 19.5mm NMAZ either anti-rutting or normal gradation.

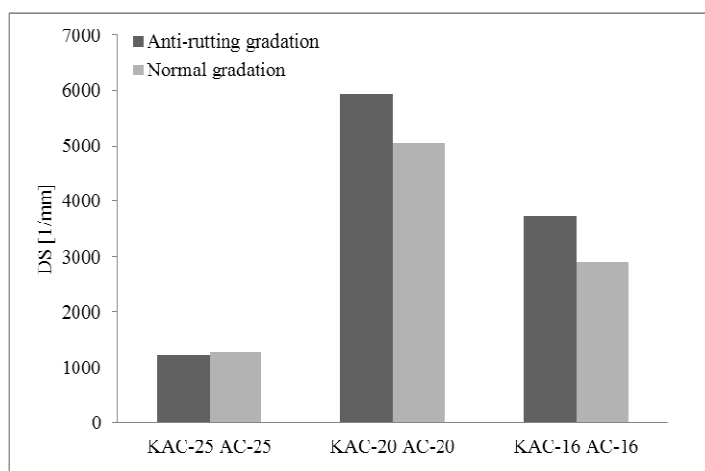


Fig.2 DS of different gradations

Anti-rutting additives. As a kind of modifiers, anti-rutting additive is playing a important role in modifying asphalt, it can improve cohesiveness of asphalt and aggregate, also strengthen interface peeling resistance between asphalt and aggregate. So this additive not only enhances anti-rutting capacity also improves low temperature cracking resistance. In this section, KTL additive was chosen because of its wide use in China and it has a good effectness, known as a kind of product of Beijing Tian Cheng KenTeiLai Technology Co., Ltd. Following recommend, dosage of admixture is 0.3%, and all gradations were chosen as anti-rutting gradation type, wheel tracking test results are illustrated in Fig.3, where + is added KTL anti-rutting additives into gradation.

It is obvious that KTL additive improves rut resistance. Comparing to KAC-16 and KAC-20, the KTL gradations' *DS* increase by 88.4% and 78.6%, which are significantly effectiver than anti-rutting gradation. Then after combination of KTL additive and anti-gradation, it strengthened cappacity of rutting resistance, in addition, KTL additive is more cheaper than others.

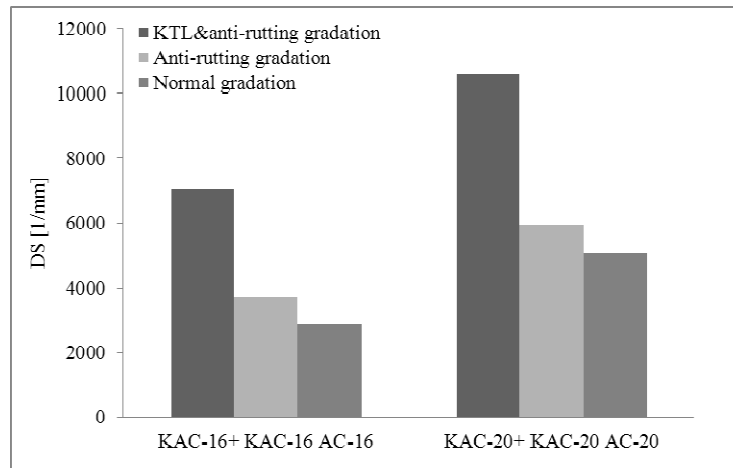


Fig.3 DS of different gradations and KTL additive

Combined structure boards wheel tracking test

Besides gradations and anti-rutting additives, pavement rut is always sensitive to pavement structural design, it could be proved that single layer wheel tracking test does not confirm real high temperature performance of highways. In this section, two layer combined structure boards chosen among three pavement structures of real projects were applied to simulate the real pavement structures, the boards and pavement structures are shown in Fig.4 and Tab.3.



Fig.4 Two layer combined structure boards

Tab.3 Three pavement structures

Layer	Structure 1	Structure 2	Structure 3
Upper layer	5cm SBS AC-16	5cm SBS+KTL KAC-16	5cm SBS+KTL KAC-16
Middle layer	6cm SBS AC-20	6cm SBS+KTL KAC-20	6cm SBS+KTL KAC-20
Bottom layer	7cm AC-25	7cm KAC-25	7cm ATB-25

Heavy duty. Based on heavy duty investigation, the tire press of wheel track is 1.1MPa.

Combined structure design. Classification of combined structure is distinguished by different layer and structure combination, so that experimental groups' serial number is defined as H-K, when H is 1, which means that boards is combined by upper and middle layer, H is 2 means that middle and bottom layer, K is 1 means that structure 1, the rest can be done in the same manner. Then the wheel tracking test of heavy duty and combined structure were conducted, the results are shown in Fig.5.

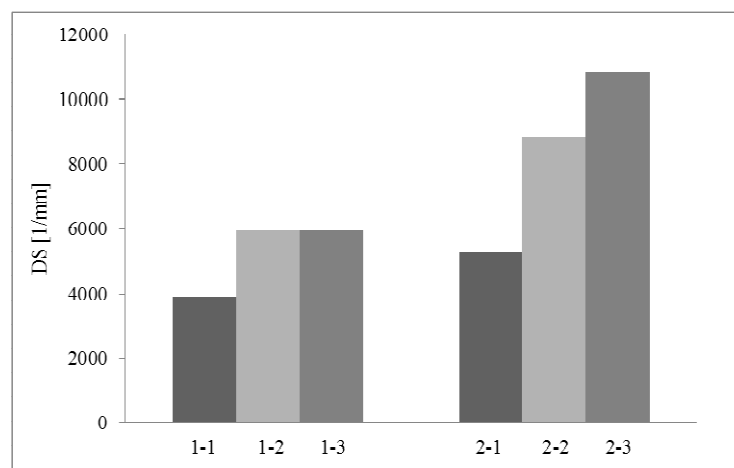


Fig.5 DS of different groups

Analyzed data of groups, comparing to single layer test results, combined structure boards could be more balanced, because the combination integrates the difference between two kinds of single layers, such as 1-1, *DS* of AC-16 and AC-20 is 2907 and 5054, while the combined one is 3917, this phenomenon is same to other groups, which shows that combined structure boards are similar to real pavement structures. For group 1 and group 2, the KTL additive and anti-rutting gradation are important to improve structural rutting resistance, a substantial increase shows in figure. What more, the combination of middle and bottom layers exhibits a better anti-rutting capacity than one of upper and middle layers, as a result, these two layers play a significant role in bearing heavy duty. For group 2, the difference of 2-2 and 2-3 is diverse bottom layer, 2-2 is KAC-25 and 2-3 is ATB-25, the result of 2-3 increases by 22.7%, it is remarkable that a flexible layer such as ATB-25 can provide a more reasonable structure combination for rutting resistance, because flexible layer can dissipate more vehicles moving energy.

Summary and conclusion

The major objective of the study presented in this paper is to find the relationship between rut and gradation, anti-rutting additives, structural design. The effort has provided different groups and experimental boards to evaluate the rut resistance of them, then got some conclusions as follow.

1. Anti-rutting gradation and anti-rutting additives can improve the capacity to avoid rut, however a coarse gradation has some limitation, and it is a kind of physical method. What more, additive has a advantage in enhancing properties of asphalt mixtures, its effectiveness is better than anti-rutting gradation.

2. Test results of single layer board based on diverse mixture are extremely various, combined structure boards are similar to real pavement structures and *DS* of combined structure boards seem to be more balanced.

3. Combination of middle and bottom layer shows a stronger resistance than upper and middle layer combination, these two layers play a significant role in bearing heavy duty. What more, on the basis of comparison between 2-2 and 2-3 experimental groups, the result of 2-3 increases by 22.7%. A flexible layer such as ATB-25 might provide a proper structure combination for rutting resistance, because flexible layer can dissipate more vehicles moving energy.

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