The design of Superpave compared with Marshall design method

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Abstract：In order to compare and analyze Superpave and Marshall design method for asphalt mixture. Through the analysis about gradation selection, predicition asphalt content, the determination method of theoretical maximum density, the compaction methods of specimens, the determination method of optimum asphalt content and the test method of mixture performance of these two design methods. The following conclusions have been come to：Superpave design method is better than Marshall design method for asphalt mixture.

Keyword：Superpave；Marshall design method；gradatiom；compaction methods；optimum asphalt

1 FOREWORD

At present, the common asphalt mixture design method is Marshall (Marshell) method and the Superpave method. Marshall method first by Bruce Marshall (Brue Marshall) is put forward, in 1948 the U.S. army corps of engineers of this method is improved, and add some test performance test, standard development into the mix proportion design of asphalt mixture; Superpave method is 1987 ~ 1992, the United States SHRP plan of asphalt project research results, this system puts forward a new set of design based on performance related to traffic and climate on the basis of material selection and mixture design method.

The Marshall developed on the basis of experience and have some certain limitation at the field of method of sample shaping and test indexes. And the Superpave is not popularized in china because of the stiff price. There have some different between the grading choose, the method of sample shaping and OAC design. So most technician care for that whether have some point and relationship between two methods.

2 COMPARE WITH THE METHODS

(1) the grading choose

Marshall method is fit of the design of asphalt of continuity dense grading. In the past the grading choose usually use the mid-value that recommend by norm. The present norm was required to confirm the "engineering design gradation scope" by engineering practice, and according to the highway classification, climate and traffic condition to choose the coarse type (C) or thin type (F). Usually the gradation curve must continuousness, smooth and has large compactness. It is need to analyze whether form the skeleton structure .

Superpave gradation selection is through (area) to implement the control points and limits, locus of control is the requirement that aggregate gradation shall not exceed that of the specified range, respectively in nominal maximum size screen, medium sieve (2.36 mm) and minimum screen (0.75 mm). Its purpose is that to limit the amount of sand and provide enough VMA. Restricted area is located in the biggest density level wiring between the medium sieve and 0.3 mm sieve. There have same question of compaction if the asphalt beyond the restricted and lack of ability to resist permanent deformation during using [3] . And then, it is cause VMA too small to affect the asphalt usage when the gradation beyond the restricted by Superpave. Therefore, Superpave should make design gradation in between control points and avoid the limits when choose the gradating, and this grading are usually formed the skeleton structure.

(2) estimate the content of cementing agent

Marshall use this formula to estimate the asphalt usage:

$$p_a = \frac{p_{a1} \times \gamma_{sb1}}{\gamma_{sb}} \qquad （1）$$

among：p_a is the estimate asphalt-aggregate ratio,%; p_{a1} is normal proportion of asphalt in the same constructed project,%; γ_{sb} is the bulk

volume relative density of aggregate; γ_{sb1} is the bulk volume relative density of aggregate of same constructed project.

This way can quickly to count the resolute. But there have some reasons to cannot confirm the estimate proportion of asphalt was very access the really one. The reasons are that there have much error because the data that from the constructed project is not fully reliable[4].

The formula about estimate the asphalt usage in the Superpave is :

$$p_{bi} = \frac{G_b \times (V_{be} + V_{ba})}{\left[G_b \times (V_{be} + V_{ba}) \right] + W_s} \quad (2)$$

among： p_{bi} is the percent of cementing agent; W is the quality of aggregate, g; V_{be} is the volume of the cementing agent; V_{ba} is the volume of cementing agent of absorbent; G_b is density ratio of cementing agent;

$$V_{be} = 0.081 - 0.02931 \times [\ln(S_n)] \quad (3)$$

among： S_n is nominal maximum mesh size of grading of aggregate（inch）。

$$V_{ba} = \frac{p_s \times (1 - V_a)}{\left(\frac{p_b}{G_b} + \frac{p_s}{G_{se}} \right)} \times \left(\frac{1}{G_{sb}} - \frac{1}{G_{se}} \right) \quad (4)$$

among： P_s is the content of aggregate; P_b is the content of cementing agent; V_a is the volume of void; G_{sb} is density ratio of aggregate; G_{se} is the valid density of ratio of aggregate.

$$G_{se} = G_{sb} + C(G_{sa} - G_{sb}) \quad (5)$$

among： G_{sb} is the bulk volume density ratio of aggregate; G_{sa} is the surface density of aggregate ; C is the coefficient of hydroscopicity of aggregate.

Through the formula it is can be found that the superpave about the method of asphalt usage is conclude the volume based on the mixture. The Pb need a initial value is from the experience. And the coefficient C choose by hydroscopicity of aggregate. The more small the value, the more big the hydroscopicity, and common the rage is 0.5~0.8.

There have to setting parameter is Pb and C if measure the density of aggregate and cementing agent because the void ratio Va is 4%

in the Superpave. The void ratio of Superpave is 4%, but marshall is a rage. Marshall will confirm a aim void ratio when count the asphalt-aggregate ratio, and the aim void ratio is confirm by experience.

(3) confirm the max theory density ratio

The Marshall using the vacuum test method for determining the biggest theory relative density for the modification of ordinary asphalt mixture, and for the modified asphalt and SMA mixture calculated using the following formula:

$$\gamma_{ti} = \frac{100 + p_{ai}}{\frac{100}{\gamma_{se}} + \frac{p_{ai}}{\gamma_b}} \text{ 或 } \gamma_{ti} = \frac{100}{\frac{p_{si}}{\gamma_{se}} + \frac{p_{bi}}{\gamma_b}} \quad (6)$$

among： γ_{ti} is the max theory density of asphalt mixture relative to count the Pbi, dimensionless; p_{ai} is the asphalt-aggregate ratio of the asphalt mixture,%; P_{bi} is the asphalt usage, Pbi=Pai/(1+Pai)，%; P_{si} is the content of ore charge, Psi=100-Pbi,%; γ_{se} is the valid density ratio of ore charge, dimensionless; γ_b is the density ratio of asphalt, dimensionless.

among， the formula of valid density ratio of aggregate is：

$$\gamma_{se} = C \times \gamma_{sa} + (1 - C) \times \gamma_{sb} \quad (7)$$

This formula is same with the Superpave about valid density ratio of ore charge, and the different is coefficient C. the C of Superpave is the rage of 0.5～0.8, and conclude the hydroscopicity of aggregate, the Marshall is confirm by this formula.

$$C = 0.033w_x^2 - 0.2936w_x + 0.9339 \quad (8)$$

among ： w_x is the hydroscopicity of mineral aggregate,% ;

$$w_x = \left(\frac{1}{\gamma_{sb}} - \frac{1}{\gamma_{sa}} \right) \times 100$$

compare with the Superpave, in the current specification, the C that asphalt absorptive of ore charge was regard as a constant. It is rational reflect the ability of adsorb asphalt of mineral aggregate and the adsorb condition of the open mouth of aggregate. The resolute is too access the really theory max density ratio.

Superpave completely adopt the vacuum field measurement method（AASHTO T209）. Form now on, this method was accepted by even more. But in the course of vacuumize the asphalt

film may be destroyed and lead to the water into the void of aggregate. For the polymer modified asphalt, because of the biggest viscosity of asphalt, it is difficult to disperse the mixture and especially the fine aggregate was require disperse under the 6.4mm. It will make the measured value have much error. Therefore, it will use Marshall to count the mixture max theory density ratio of modified asphalt.

(4) the way of moding

Marshall compaction instrument is pure compaction which the hammer weight is usually constant and only increasing number of compaction work to increasing the compation. Although the price is cheap and simple structure, it can't accurately discriminate different traffic volume of asphalt mixture with the requirements of technical indicators. It is not suitable for large size asphalt mixture. The main reason is this way cannot simulate the situation that the road roller press the road. One thing is the compaction instrument of some particles will break easily thereby to change the grading of mixture. The other ting is this way cannot stimulate the press that road roller and load of car to the road.

Superpave shear compaction methods using rotational rubbing molding, it is sat the parameter of compaction through the traffic parameter. It is best stimulate the forming process of asphalt mixture, and the design process also consider the shote period aged of asphalt mixture. All of them make the Superpave to be more suitable, so Superpave design method mainly exist the following advantages:

①Because of Marshall stability have nothing to do with the correlate and asphalt mixture of road performance, it is have useless to improve the compactness of asphalt for increase the time to compaction. Rotating compaction method is not only close to actual pavement compaction process, but also the compaction effect is more close than the Marshall compaction method. Rotating compaction is super one way that have value to popularize.

②When it design the asphalt mixture with Superpave method, it is considering the aging of asphalt mixture, the design results are more in conformity with the actual.

③Superpave method have the clear purpose because the rotation of the compaction number apply with traffic.

④ Superpave method provision the compatibility with the different staged compaction by initial N, design N and max N. It is can adequate disclosure the character of compaction.

According to research, the speed of bulk volume density increased with rotating compaction times was slowly. And regardless of the times of rotating compaction, the bulk volume density by rotating compaction is higher than by Marshall at the same asphalt aggregate ratio. That means rotary compaction compaction can greatly improved than Marshall work[4].

(5) confirm the best asphalt-aggregate ratio

Marshall method using the compaction molding specimens, compaction number for 75 times, in order to forecast or experience of asphalt content is of value, molding specimens, 0.5% interval change test specimen density, calculate void fraction. It is calculate VMA and VFA, at the same time to test the Marshall stability and flow values of the specimens. And then draw the diagram of asphalt dosage and the indicators. To confirm the best asphalt-aggregate ratio by the range of the amount of asphalt which meet the various indexes. In the process of the optimum asphalt content, it is can't fully control the voidage at the range of reasonable after the pavement compaction because the voidage is not confirm. In addition, Marshall stability and not clear the relationship between road performance[6], therefore. In this sense, when it design the asphalt mixture , it is difficult to ensure optimum asphalt content accurately determined.

Superpave using rotation compaction to molding the mixture, and the rotation time is confirmed by the design traffic level. And then requires mixture should aged before the moding for the situation is more close the reality. It is demand to estimate the compaction of mixture, and separate provision the initial compaction times and the max compaction under the max compaction times. This aspect was dominance than Marshall because it is avoid produce the instability mixture and ensure the ability to resist the track.

The final dosage of asphalt of superpave is ensured by the 4% voidage when the rotating compaction. At the same time the VMA and VFA and rubber powder were fill the bill when the voidage was 4%. The initial and the final compaction degree meet the requirements.

Because of SGC compaction method and the compaction work more close to the site construction, no matter the way and the force of compaction is is quite different from the scene. It will lead to the Marshall method design of mixture ratio was to large and bulk volume to small. In field construction control, the degree of compaction often appear compaction of the overpressure phenomenon, to move forward a single step that the Marshall compaction merits is small and not close with the actual construction situation.

(6)the performance testing of mixture

The Marshall need to testing the performance on the base of the mix design according to the

standard for the highway and first-class highway. If the mixture is not satisfactory, it must reopen the design. Other grades highway asphalt mixture can be reference to perform. It is use the wheel tracking test to evaluation the high temperature stability of mixture (nominal maximum size is equal to or less than the mixture of 19 mm), and use the immersing Marshall test and freeze-thaw splitting test to evaluate the water stability of asphalt mixture, and use low-temperature bending test to evaluate asphalt mixture (nominal maximum size is equal to or less than the mixture of 19 mm) of the low temperature crack resistance.

Superpave have hear tester (SST) and indirect tensile test and instrument (IDT) to test and prediction the mixture performance. These two instruments were improve the forecast methods for performance test. But it was too expensive and the research are rarely. Superpave about water sensitivity of the test mixture, is not based on performance test, and there are two purposes: first, determine whether the combination of asphalt cement and aggregate is sensitive to water; Second, the effect of measuring antistripping agent. Superpave mixture water sensitivity of the test method is similar to the current specification of freeze-thaw splitting test[3].

Due to the shear test and indirect tensile test method and standard is perfecting, when the domestic scientific research units in the Superpave mixture design, they usually to test method to performance verification of the mixture by Marshall. Although it is not fully reflect the Superpave mixture excellent road performance, it yet be regarded as a kind of auxiliary Superpave mixture design method.

3 CONCLUSION

（1）when gradation selection, Superpave used the concept about restricted area and restricted, and the design of the grading was better than Marshall generally with skeleton structure.

（2）Superpave is more reasonable than experience of the Marshall method because it is based on the volume of the mixture properties for Forecast for cement content

（3）To determination the theoretical maximum density of mixture, the Marshall method use the vacuum test for ordinary asphalt mixture, and for modified asphalt mixture was used by calculation method. But Superpave are all made of the measurement method. It is due to the many shortcomings of measurement method for modified asphalt mixture, that use the Marshall to test the max theoretical density .

（4） Superpave conclude the traffic parameter for moding. At the same time to conclude the situation of pavement.Ttherefore the design of mixture density than the Marshall method design.

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