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Research Article

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Comparison of three different design methods of asphalt mixtures

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Abstract Asphalt mixture has become the preferred construction material for road engineering. In order to make full use of the performance of asphalt mixture and prolong the service life of asphalt pavement, this paper introduces the research status of mix design methods of asphalt mixture, such as Marshall method, Superpave method and GTM method, compares their advantages and disadvantages, puts forward improved design methods, and summarizes the future development trend of design methods, which provides a certain reference basis for the development of road industry in the future.

Keywords Asphalt mixture, mix design, design method

1. Introduction

Asphalt pavement has become the main material of highway pavement construction because of its high strength, skid resistance, low noise, comfortable driving and easy construction. The asphalt pavement accounts for more than 95% of the pavement construction projects in the world at present according to relevant statistics [1], which shows that the asphalt pavement has become the main structure type in the highway construction. People's economy capacity and living standards have been significantly improved with the deepening of economic transformation in recent years, and the number of cars continues to grow, which leads to the improvement of the existing road traffic. At the same time, different degrees of damage to the asphalt pavement will be caused by environmental changes and other factors. Common asphalt pavement diseases such as looseness, rutting and oiling will not only severely shorten the service life of the road and cause certain economic losses, but will also threaten the personal safety of passing pedestrians in the long run. In addition to the factors listed above, there are also the influence of asphalt quality, construction technology and other factors, among which the unreasonable mix design of asphalt mixture is the main reason. The rationality of asphalt mixture mix design plays an important role in improving road performance, reducing pavement diseases, prolonging road service life, reducing economic losses and eliminating potential safety hazards.

2. Three different mix design methods of asphalt mixture

The mix design of asphalt mixture is an important part in the construction of asphalt pavement. It is not difficult to find that the mix design mainly consists of three aspects: gradation design, determination of the best asphalt dosage and road performance test from the research results of many scholars. Superpave method and GTM method are also widely used in addition to the most widely used Marshall method. The following will introduce these three different design methods.

2.1. Marshall method

Marshall method was proposed by Marshell of the United States. This design method first determines the combination of different volume proportions of asphalt, aggregate, mineral aggregate and other components in asphalt mixture, then tests the volume parameters of test pieces after asphalt mixture mixing and compaction, and finally determines the proportion of each component.

Wang used Marshall method to design the mix proportion of recycled SBS modified asphalt mixture, prepared asphalt mixture by using different amounts of old materials, and evaluated its road performance [2]. Li improved the traditional Marshall method based on relevant mix proportion research, proposed an improved Marshall design method suitable for mix design of cold patching asphalt mixture, and evaluated its road performance [3]. Han, Jitsangiam and other scholars introduced and compared Marshall asphalt mixture mix design methods [4, 5]. Liu et al adopted sac method for gradation design and Marshall method for determining the best asphalt aggregate ratio [6]. The results show that the asphalt mixture designed by the two methods has excellent road performance. Kumara and Reddyb used Marshall method to design the mix proportion of asphalt mastic macadam mixture with plastic waste [7].

Marshall method is the most commonly used design method in China because of its simple test equipment, simple operation and short test time. However, there are many shortcomings in the gradation design, it needs to rely on rich experience in the design, and the compaction molding method is used in the specimen production. Therefore, the porosity is higher than that of the other two design methods, the content of asphalt is also increased, and the comprehensive performance of road is the worst. There are also shortcomings of long design cycle and low precision.

2.2. Superpave method

Superpave method is proposed by American Research Institute. It selects asphalt grade according to different climate and traffic conditions, and determines the mixing temperature and compactness of asphalt mixture according to the viscosity temperature relationship curve.

Ran found that the Superpave design method is the best for airport asphalt pavement due to the special load requirements of the airport, and the optimal asphalt content for the epoxy asphalt mixture for airport construction is determined to be 5.12% through the gradation design of the two aggregates[8]. Yao et al used Superpave method to design the mix proportion of rubber asphalt mixture [9], and the results show that the high temperature rutting resistance of rubber asphalt mixture can be significantly improved by Superpave method. Liu et al used Superpave method to design the mix proportion of Buton rock asphalt modified asphalt mixture [10]. The results show that the high temperature stability and water stability of Buton rock asphalt modified asphalt mixture are obviously improved designed by Superpave method. Ghuzlan, Hasan and other researchers use Superpave method to design asphalt mixture, and the results show that the asphalt mixture has better anti rutting ability designed by this method [11,12]. Jitsangiam et al used the Superpave method and Marshall method to design the mix ratio after taking into account the load and environmental conditions. They compared the performance of the asphalt mixtures obtained by using the two mix ratio designs after obtaining the results. The results show that the performance of the asphalt mixture designed by the Superpave method is better than that obtained by the Marshall method [4].

Superpave method increases the selection of gradation under the condition of considering the properties of aggregate, instead of only taking the median gradation in the past, so as to ensure that the most reasonable gradation can be selected, and the asphalt content of the asphalt mixture is lower designed by Superpave method, and it has better road performance than Marshall method, but it also has the disadvantages of expensive test equipment, complicated design process and long design cycle.

2.3. GTM method

GTM design method is also a mix design method proposed by the United States. The design method adopts rotary compaction shear testing machine, which can simulate the actual situation of the action of tires on the pavement when the vehicle is driving on the highway to the greatest extent, mainly aiming at the strain capacity of asphalt materials.

Han et al introduced GTM method in detail [5], and found that the asphalt mixture designed by GTM method has low volume parameters such as asphalt aggregate ratio, and has good high temperature stability and water stability. Chai and Li used GTM method to design the mix proportion of asphalt mixture and evaluate its performance. The results show that GTM design method is better than Marshall method in improving the pavement performance of mixture, and the volume parameters such as void ratio are decreased [13]. Lv et al found that the asphalt mixture designed by GTM method is more suitable for humid, high temperature and heavy traffic environment than Marshall method [14].

GTM method adopts the compaction method that is closer to the actual construction in the production of specimens, which can effectively simulate the compaction of the actual vehicle load on the pavement and the interaction between the vehicle tire and the pavement during the vehicle operation. Therefore, the asphalt mixture designed by this design method has smaller porosity, less asphalt consumption, and low design cost, but it also has some disadvantages, such as expensive test equipment, high equipment maintenance cost, complex operation technology.

The most widely used asphalt mixture mix design methods in the world are Marshall method, GTM method and Superpave method. These three methods have their own advantages and disadvantages. Combined with the comparative analysis of these three commonly used design methods by Han, Zhou and other scholars [5,15], the comparison results are showed in Table 1-3.

Table 1: Comparison of specimen forming

Design method	Molding mode	Test equipment
Marshall	Compaction	Marshall compaction instrument
Superpave	Rotary compactor	SGC rotary compactor
GTM	Rotary compactor	GTM rotary compactor

Table 2: Comparison of results of different mix design methods

Design method	Marshall	Superpave	GTM
Mineral aggregate gradation selection	Gradation close to the median of gradation.	Three different gradations meeting the requirements of corresponding control points and restricted areas.	Gradation close to the median of gradation.
Determination index of optimum asphalt dosage	Gross bulk density, VV, VMA, VFA, stability and flow values.	VV, VMA, VFA, Powder binder ratio and voids at initial compaction times.	Density when the specimen is compacted to equilibrium, GSI and GSF.
Road performance	The comprehensive performance of asphalt mixture is the worst compared with the other two mix design methods.	The comprehensive performance of asphalt mixture is between the other two mix design methods.	The comprehensive performance of asphalt mixture is the best compared with the other two mix design methods.

Table 3: Advantages, disadvantages and applicability of different mix design methods

Design method	Marshall	Superpave	GTM
Advantages	The equipment is simple and cheap, the test operation is simple, and the practical experience is rich.	The diversity of mineral aggregate gradation selection is increased, and the designed asphalt mixture has small void ratio and less asphalt dosage.	The design cost is low, the void ratio of asphalt mixture is small, the amount of asphalt is small, and the high-temperature rutting resistance is excellent.
Disadvantages	The design cycle is long, the designed	The test equipment is expensive, the design	The test equipment is expensive, the

	asphalt mixture has large voidage and large asphalt content, and the design method has no good correlation with road performance.	process is complex, the test data is greatly affected by the inclination of the rotary compactor, and the design cycle is long. Many results are still in the test stage and need to be improved.	equipment maintenance cost is high, and the operation technology is complex.
Applicability	The grading design is applicable to low-grade highways under medium and light traffic conditions.	Highway with large traffic volume and high rutting resistance requirements.	Highway with heavy traffic and high rutting resistance requirements.

3. The improvement method of asphalt mixture proportion

Although the traditional mix design method is widely used at present, various problems often occur in practical engineering application, and there is a disadvantage of long design process cycle. Therefore, it is particularly important to explore improved design methods, and computer technology is becoming more and more mature with the development of science and technology, some scholars have applied the algorithm model to the mix design and achieved research results. The following will introduce the improvement research of scholars on the design method based on the long design cycle.

Moghaddam and Baaj proposed a new method to optimize the mix design of asphalt concrete by using compressible packaging model, which optimizes the mix design of asphalt mixture by optimizing the bulk density of asphalt mixture [16]. The optimum asphalt content (OAC) of hot mix asphalt (HMA) is determined by six values obtained from mix design. However, the curves of these six values may have deviations due to the influence of various factors, so it needs to be corrected by regression trend line, but the ordinary correction process is too cumbersome, therefore Du and Kuo proposed a grey relational regression analysis algorithm for HMA, which can determine and analyze OAC in HMA mix design [17]. Sebaaly et al developed an auxiliary program to optimize asphalt mixture mix design by using artificial neural network and genetic algorithm to overcome the long-term and repeated test process of traditional asphalt mixture mix design [18]. The program can save a lot of time, and the calculated gradation and asphalt dosage are in good agreement with the measured values in the laboratory, which can be widely used in mixture mix design. Wang has developed a mix design system which can improve the efficiency and accuracy of mix design [19]. The relevant design process of mix design can be carried out through the system, which not only saves the design time, but also improves the accuracy of design.

Many variables need to be designed in the process of asphalt mixture mix design. The traditional design method will not only consume a lot of manpower and time, but also sometimes lead to design errors. Therefore, improving the traditional asphalt mixture design method is a problem that researchers have been exploring.It can be found that it is feasible to combine computer technology and asphalt mixture mix design combining the relevant research of the above-mentioned scholars. And there is no obvious difference in the design results of the mix design using the algorithm model compared with the design results of the traditional mix design method, and the effect is even better, it can save a lot of time for relevant personnel at the same time.

4. Development trend

It can be found that the traditional mix design method is more and more difficult to meet the growing requirements of road construction, which leads to various problems in the actual road construction process according to the research of many scholars in the world. More and more scholars focus on improving the traditional design methods based on the actual situation, and more scholars will devote themselves to the research in this field in the future to meet the higher and higher requirements of engineering construction. Scholars gradually have a deeper understanding of algorithms, models and programming with the continuous development of modern information technology. Some scholars who are at the forefront of this field have applied algorithms, models and programming to mix design, and found that applying algorithm models or mix

design programs can save a lot of time compared with traditional design methods. Moreover, scholars will gradually focus on the combination of computer technology application and mix design, such as algorithm model and program design to meet the time-saving needs of designers and make research points innovative.

5. Conclusion

(1) This paper introduces and compares three different asphalt mixture mix design methods. The results show that the asphalt mixture designed by different mix design methods has great differences in volume parameters and road performance, and the asphalt mixture designed by GTM design method shows better volume parameters and road performance, the asphalt mixture designed by Marshall method is relatively poor.

(2) It is found that the combination of mix design method and algorithm model is an improved mix design method to effectively improve the design efficiency by aiming at the disadvantage of long design time in common mix design methods and combined with relevant research.

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