

Influencing factors and improving methods of fatigue properties of cement stabilized macadam

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Abstract: In order to make full use of the performance of cement stabilized macadam and prolong the service life of pavement structure, this paper summarizes the influencing factors and improvement methods of cement stabilized macadam fatigue performance according to the relevant research on the fatigue performance of cement stabilized macadam, which provides a certain reference basis for the relevant design of semi-rigid base structure pavement in the future.

Keywords: Cement stabilized macadam, Fatigue properties, Influencing factors, improving methods

I. INTRODUCTION

Semi-rigid structure will be mostly used in the selection of pavement structure of high-grade highway in China because the traffic volume of highway is relatively heavy, and cement stabilized macadam is the most widely used. Cement stabilized macadam is a composite material composed of 3% - 8% cement, graded macadam and optimal water consumption. Since cement can be hydrated and hardened, which can significantly increase the stiffness and strength of loose aggregate [1-3]. However, it is not difficult to see that the traffic load has increased significantly in the last few years, and the environmental factors are becoming more and more complex, resulting in the fatigue cracking of cement stabilized macadam. The fatigue resistance of pavement materials is adopted by most countries as the basis for determining the design method and design standard of semi-rigid asphalt pavement to ensure the good durability of asphalt pavement [4-6]. Zhou and Sha considered the influence of material composition factors on the fatigue characteristics of semi-rigid base materials, applied fractal theory to study the gradation of semi-rigid materials, and analyzed the influence of material composition on fatigue characteristics by using grey relational theory [7]. Lv et al proposed an equation that can fully represent the fatigue performance of cement stabilized macadam, realized the unified characterization of fatigue performance, and eliminated the influence of test methods and conditions on fatigue performance [8]. The analysis of fatigue properties of cement stabilized macadam is mainly realized through bending fatigue and splitting fatigue tests at present. However, even for the same type of fatigue test method and the same material, the conclusions of different research institutions are quite different. This difference is caused by the great variability of cement stabilized macadam. In order to further study and determine the fatigue performance of cement stabilized macadam and provide theoretical reference for the reasonable selection of cement stabilized macadam in the actual design work, this paper summarizes the relevant research on the fatigue performance of cement stabilized macadam, and puts forward the factors affecting the fatigue performance of cement stabilized macadam, and puts forward the methods to improve the fatigue performance of cement stabilized macadam.

II. INFLUENCING FACTORS

The fatigue performance of cement stabilized macadam will be affected by various factors such as cement dosage, gradation and molding method. The related research on the influencing factors of fatigue performance by many scholars will be introduced below.

1. CEMENT DOSAGE

As one of the important factors affecting the performance of cement stabilized macadam, too little cement content will affect the decline of bonding capacity between cement and aggregate, and finally affect the fatigue performance and mechanical properties of cement stabilized macadam. Too much cement content will also be unfavorable to the performance of cement stabilized macadam. Therefore, a reasonable cement content must be determined.

Yang and Tie found that the cement dose has a significant impact on the fatigue performance of cement stabilized macadam, and found that the high cement dose cement stabilized macadam has a better fatigue life than the low cement dose cement stabilized macadam, which is enough to show that increasing cement dose can correspondingly improve the fatigue performance of cement stabilized macadam in a certain range [9]. Wang et al conducted strength and indirect tensile fatigue tests to study the effect of different cement content on the performance of cement stabilized macadam [10]. The results show that the anti-overload and anti-overrun properties of cement stabilized macadam gradually become better with the increase of cement content. Xie et al found that the cement content has a great influence on the fatigue performance of cement stabilized macadam through the fatigue test of cement stabilized macadam with different cement content [11].

2. GRADATION

Gradation is also an important factor affecting the fatigue performance of cement stabilized macadam. Unreasonable gradation design will affect the aggregate skeleton structure and finally affect the relevant performance of cement stabilized macadam.

Gan et al found that the fatigue characteristics of cement stabilized macadam are greatly affected by gradation, and the fatigue resistance of cement stabilized macadam with skeleton dense structure is better than that of suspension dense structure [12]. Sun and Wang studied and compared the fatigue performance of cement stabilized macadam prepared by coarse, medium and fine grades. It was found that the gradation change had an obvious change on the fatigue performance of cement stabilized macadam, and their fatigue performance was greatly different when different gradations were used, and the fatigue performance of coarse graded cement stabilized macadam is weaker than that of fine graded cement stabilized macadam [13].

3. MOLDING METHOD

Molding method is also another important factor affecting the fatigue performance of cement stabilized macadam. Different molding methods have different effects on the fatigue performance of cement stabilized macadam.

Jiang and others found that the cement stabilized macadam formed by vertical vibration has better fatigue cracking resistance than the cement stabilized macadam formed by heavy compaction and static pressure [14]. Liu found that under the same other conditions, the fatigue resistance of cement stabilized macadam formed by vibration forming is better than that by static pressing [15]. Zhao and Wei also found that the fatigue resistance of cement stabilized macadam formed by vibration is better than that formed by static pressure [16].

4. OTHER FACTHORS

There are also factors such as load, loading mode, vehicle speed and so on in addition to the above-mentioned factors affecting the fatigue performance of cement stabilized macadam.

Lv et al found that different loading modes also have different effects on the fatigue resistance of cement stabilized macadam, and established a fatigue equation based on relevant stress ratio that can represent the fatigue performance of cement stabilized macadam under different loading modes [17]. Wang et al studied the effects of load and vehicle speed on the fatigue performance of cement stabilized macadam. The results show that the fatigue life is less affected by the vehicle speed when the vehicle speed is 10-40km/h. The fatigue life is affected by the vehicle speed when the vehicle speed is greater than 40km/h and the vehicle speed increases. The fatigue life decreases continuously with the increase of load, and the relative change rate curve of fatigue life of cement stabilized macadam basically changes linearly with the increase of load [18].

The above studies of many scholars in the world show that factors such as cement dosage, gradation and forming method have a great impact on the fatigue performance of cement stabilized macadam. Some scholars have studied the significance of the above factors on the fatigue performance of cement stabilized macadam. The specific impact and significance of each factor on the fatigue performance of cement stabilized macadam are summarized in Table 1.

Table 1 Main influencing factors and significance of fatigue performance of cement stabilized macadam

Main Influencing Factors	Cement Dosage	Gradation	Molding Method
Specific Impact	The fatigue performance of cement stabilized macadam also improves with the increase of cement dosage in a certain range.	Generally speaking, the cement stabilized macadam with skeleton dense structure has better fatigue life than that with suspension dense structure, and the fatigue performance of cement stabilized macadam with fine grading is better than that with coarse grading.	The fatigue stability of cement stabilized macadam formed by vibration is better than that of other cement stabilized macadam forming methods.
Cause Of Influence	The cementation performance of cement stone also improves with the increase of cement dosage in a certain range, which enhances the bonding performance between cement stone and between cement stone and aggregate surface, and improves the strength and deformation resistance of cement stabilized macadam.	The aggregate particles of suspended dense cement stabilized macadam are suspended in the cement stone structure and cannot be effectively embedded to form a skeleton structure. Therefore, there are many voids in the structure and the fatigue performance of the material is poor. The aggregate particles of the skeleton dense cement stabilized macadam are embedded with each other to form a skeleton, which has a large internal friction angle and stronger ability to resist deformation. The cement stone after cement hydration is filled in the pores of the skeleton at the same time, so there are fewer voids in the structure and the fatigue performance of the material is better. The fine graded cement stabilized macadam has relatively fewer micro cracks and holes in the specimen compared with the coarse graded cement stabilized macadam, so the fine graded cement stabilized macadam has better fatigue performance.	The cement stabilized macadam is affected by the external high-frequency vibration under the condition of vibration forming, the internal particles move with each other, the intercalation between the material and aggregate structure is stronger, and the fine aggregate fully fills the gap, making the whole more dense.
Degree Of Significance	Forming Method > Cement Dosage > Grading		

III. IMPROVING METHODS

The fatigue performance is one of the important properties of cement stabilized macadam, and its quality determines the service life of pavement structure. Relevant scholars in the world have made relevant research on improving the fatigue performance of cement stabilized macadam, and the research focus is mainly on adding solid waste, bio-oil, fiber and other materials.

1. BIO-OIL

Yang and Yang studied the effect of bio-oil on the properties of cement stabilized macadam. The results show that the fatigue cracking resistance of cement stabilized macadam without bio-oil is worse than that of cement stabilized macadam with bio-oil [19]. Li et al also studied the effect of the addition of gutter oil on the performance of cement stabilized macadam [20, 21]. The results show that the fatigue resistance of the mixture added with gutter oil was better than that of ordinary mixture. The research of these scholars shows that the addition of some bio-oil can improve the fatigue performance of cement stabilized macadam.

2. SOLID WASTE

He found that the fatigue life of cement stabilized slag macadam is lower than that of cement stabilized macadam, and the fatigue performance of cement stabilized slag macadam gradually decreases with the increase of slag content, which shows that the addition of slag has no obvious effect on the fatigue performance of cement stabilized macadam [22]. Wang, Dong and other scholars studied the effect of the addition of waste rubber powder on the properties of cement stabilized macadam. They found that the addition of rubber powder improved the fatigue life and durability of cement stabilized macadam [23,24]. Sun found that the fatigue resistance of 4% and 10% fly ash cement stabilized macadam is better than that of cement stabilized macadam without fly ash under the same fatigue action times [25]. The research of these scholars shows that the addition of solid wastes such as fly ash and rubber powder can improve the fatigue performance of cement stabilized macadam materials, while the addition of slag can't improve the fatigue performance of cement stabilized macadam. The impact of other solid wastes on the fatigue performance of cement stabilized macadam needs further research and exploration.

3. FIBER

Tong found that the fatigue life of cement stabilized macadam with PVA fiber is 2.06 times that of cement stabilized macadam without fiber [26]. Ma et al studied the effect of low fiber content polypropylene fiber (CAPFF) on the fatigue characteristics of cement stabilized macadam and established the bending fatigue equation [27]. The results show that the fatigue life of CAPFF is increased by 1.0-4.2 times compared with ordinary cement stabilized macadam under the same stress level, which further verifies that the addition of CAPFF can significantly improve the fatigue performance of cement stabilized macadam. Dong found that the fatigue life of cement stabilized macadam has been significantly improved after adding polypropylene fiber [28]. Wu, Zheng and other scholars found that the cracking resistance and fatigue resistance of cement stabilized macadam after adding basalt fiber were significantly improved [29, 30]. The research of these scholars shows that the addition of fiber can significantly improve the fatigue performance of cement stabilized macadam, which is one of the effective measures to improve its fatigue performance.

IV. CONCLUSION

- (1) This paper summarizes the research on the influencing factors of the fatigue performance of cement stabilized macadam by relevant scholars. The results show that among the various factors affecting the fatigue performance of cement stabilized macadam, cement dosage, gradation and molding method have the greatest impact on the fatigue performance, among which the molding method has the most significant impact, cement dosage takes the second place, and the gradation has the last impact.
- (2) Adding some solid waste, fiber and bio-oil can significantly improve the fatigue performance of cement stabilized macadam, but the research on improvement methods is not comprehensive. In the future, we should continue to study the impact of adding other substances or adopting new materials on the fatigue performance of cement stabilized macadam.

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