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RESEARCH PROGRESS ON HYDRODYNAMIC PRESSURE OF ASPHALT PAVEMENT

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Анотація
Гідродинамічний тиск є однією з причин пошкодження асфальтного покриття. У цій роботі узагальнено науково-дослідний стан гідродинамічного тиску на асфальтобетонне покриття, проаналізовано причини та фактори впливу гідродинамічного тиску на асфальтове покриття, серед яких швидкість транспортного засобу, навантаження на рух та порожнеча асфальтобетонного покриття мають великий вплив на гідродинамічний тиск на асфальтове покриття. З огляду на проблеми, що існують в поточній науково-дослідній роботі, висуваються деякі заходи, такі як встановлення єдиного методу випробувань і відповідного стандарту оцінки, а також розробка більш науково обґрунтованого випробувального обладнання.
Ключові слова: асфальтобетонне покриття, пошкодження води, гідродинамічний тиск, тиск пори води.

Abstract
Hydrodynamic pressure is one of the causes of asphalt pavement damage. In this paper, the research status of hydrodynamic pressure on asphalt pavement is summarized, and the causes and influencing factors of hydrodynamic pressure on asphalt pavement are analyzed, among which vehicle speed, traffic load and voidage of asphalt pavement have great influence on hydrodynamic pressure on asphalt pavement. In view of the problems existing in the current research work, some measures are put forward, such as establishing unified test method and corresponding evaluation standard, and developing more scientific and reasonable test equipment.
Keywords: asphalt concrete pavement, water damage, hydrodynamic pressure, pore water pressure.

Introduction

Exposed to the natural environment, asphalt pavement is easily affected by water, resulting in raveling, potholes and other diseases. Moreover, under the joint action of water and traffic load, the damage of asphalt pavement will be further aggravated, and continuously spread with the passage of time, which seriously affects the quality and durability of asphalt pavement.[1] A large number of studies have shown that hydrodynamic pressure is an important inducement of water damage to asphalt pavement.

Generation of hydrodynamic pressure

Asphalt pavement has a certain porosity and roughness, and water will accumulate on the pavement when there is poor drainage. Under the action of high-speed traffic load, the retained water is quickly squeezed into the pores of asphalt pavement. If these water cannot be discharged in time, a high pore water pressure will be formed in the pores. When the driving load is quickly removed, the high-pressure water in the pores will also be strongly pumped out, forming negative high pore pressure, and so on. In addition, the retained water also sprays out from both sides of the tire and the tread gap, resulting in a dynamic and instantaneous scouring water pressure when the relatively static water is squeezed. The joint action of pore water pressure and scour water pressure puts forward a severe test to the stability and durability of asphalt pavement.

Research progress on hydrodynamic pressure of asphalt pavement

In recent years, many scientific researchers have systematically studied the hydrodynamic pressure of asphalt pavement, mainly focusing on the influencing factors of hydrodynamic pressure, numerical simulation, test simulation, field measurement, etc., in order to find out the relevant laws of hydrodynamic pressure of asphalt pavement, and put forward reasonable suggestions for improving the durability of asphalt pavement from the perspective of water damage.

Analysis of influencing factors of hydrodynamic pressure

The synergistic effect of road, vehicle and water produces hydrodynamic pressure. From the vehicle point of view, the driving speed, vehicle load and the type of vehicle tire texture are several main factors that affect the hydrodynamic pressure of asphalt pavement.[2-3] Both the scour water pressure and the pore water pressure of the road increased with the increase of the driving speed. The faster the driving speed, the stronger the pressure effect on retained water on road; for asphalt pavement, there will be a large scour water pressure; for the interior of asphalt pavement, the retained water will be quickly pushed into the gap of asphalt pavement, resulting in greater pore water pressure. When the vehicle load increases, its impact force on water will also increase, resulting in a large hydrodynamic pressure.

From the perspective of water, the influence of water film thickness is mainly considered. Dong[4] et al. of Chang'an University believed that when the thickness of the water film is less than the depth of the tread pattern, the hydrodynamic pressure increases slowly with the vehicle speed; when the thickness of the water film is greater than the depth of the tread pattern, the hydrodynamic pressure has an approximately linear relationship with the vehicle speed.

From the perspective of asphalt pavement, the void ratio (permeability), pore radius, roughness, modulus and structure type of asphalt pavement all affect the hydrodynamic pressure. Luo et al. from Tongji University believe that when pore radius is constant, pore water pressure between asphalt pavement layers is proportional to vehicle load; when the vehicle load is constant, pore water pressure is proportional to the square of pore radius; at the same time, the pore water pressure of asphalt pavement surface layer is the largest, the pore water pressure of the lower layer and base layer is smaller.

In general, the hydrodynamic pressure is affected by multiple factors, among which the driving speed, vehicle load, and the porosity (permeability) of the asphalt pavement are the main factors. Relevant research results are relatively fruitful, but there are still disagreements between different scholars in terms of some conclusions.

Numerical simulation of hydrodynamic pressure

In order to study the influence factors, generation process and mechanism of hydrodynamic pressure on asphalt mixture, researchers have constructed many theoretical models and obtained some achievements.

Swedish scholar P Kettil[5] et al. used porous media theory, fluid mechanics theory and finite element method to analyze and conclude that under dynamic load, stagnant asphalt pavement is subject to alternating action of positive and negative pore water pressure, which is easy to cause the stripping of asphalt and aggregate.

American scholars M Emin Kutay and Ahmet H Aydilek[6-7] used the Boltzmann (LB) method to study the pore water pressure and its changes in the asphalt pavement, and verified the feasibility of the method through laboratory experiments. The results showed that the pore water pressure changes irregularly with the increase of the depth from the top of the asphalt pavement, presenting a pressure gradient, which produces shear action on the asphalt pavement. They established a three-dimensional fluid flow model to calculate the pore water pressure of asphalt mixture under load. It was calculated that, influenced by the shape and tortuous change of asphalt pavement voids, pore water pressure changed with the depth of asphalt mixture specimen, and the pore water pressure was higher at 10~40mm away from the surface[8-9].

Korean scholars C.-W.Oh et al.[10] used finite element, finite difference method and asymptotic method to study the lifting effect of retained water on asphalt pavement on vehicle tires, and also concluded that the scouring speed of road surface water increases with the increase of vehicle speed and water depth.

QiangXue et al.[11] established a hydraulic coupling model to study the effect of permeability, modulus and thickness of asphalt pavement on pore water pressure, and found that asphalt pavement with low modulus is more likely to produce higher pore water pressure; the larger the pavement permeability is, the smaller the pore water pressure is; the thicker the asphalt pavement surface, the greater the pore water pressure, the maximum pore water pressure appears in the middle of the surface.

Laboratory test simulation of hydrodynamic pressure

In order to systematically study the influence of hydrodynamic pressure on asphalt pavement, Tan Yiqiu et al.[12] from Harbin Institute of Technology independently developed an indoor hydrodynamic scour test device for asphalt mixture. In this device, water in the device repeatedly scour Marshall specimen through the up-down reciprocating movement of MTS indenter, after scour, the specimen is taken out to measure its related technical indexes. The test results show that the performance of asphalt mixture decreases significantly after dynamic water scour.

Xu et al.[13-14] used X-ray CT to study the water distribution in asphalt mixture under the action of moving water, and the test results showed that driving speed and load promoted the migration of water on the road surface, so high speed and heavy load conditions seriously affected the water stability of asphalt mixture.

Zhang[15] from South China University of Technology independently designed a hydrodynamic test device excited by air pressure. The test process is to immerse the asphalt mixture sample into the water in the test vessel, seal it, start to apply 0.7MPa air pressure to the vessel, then relieve the pressure, and then apply 0.095MPa negative pressure. In this way, the dynamic water pump of asphalt pavement is simulated by alternating circulation.

Yang[16] studied the pore water pressure of asphalt mixture by dynamic triaxial test. The results show that the pore water pressure increases with the increase of deviation stress and the peak value of pore water pressure increases with the increase of loading frequency.

Actual measurement of hydrodynamic pressure

Li et al.[2] of Tongji University embedded electromagnetic fluid pressure sensor in pavement interior to test hydrodynamic pressure. The test results show that under the condition that the pavement surface structure depth is 0.6 mm and the water film thickness is 3 mm, the hydrodynamic pressure on the road surface corresponding to 80 km/h driving speed is about 25 kPa after fitting, and the square is proportional.

Gao et al.[17] also designed an optical fiber hydraulic sensor to measure the pore water pressure of asphalt pavement. The test shows that the pore water pressure increases with the increase of vehicle driving speed. However, with the increase of driving speed, the action time of pore water pressure on a certain point of the road surface will also decrease.

Ou et al.[18] of Shandong University developed a high-temperature hydrodynamic pressure and dynamic stress sensor which was embedded in the pavement during paving. The test results show that under the action of fast-moving vehicle load, positive and negative pore water pressure alternately occur, and the maximum hydrodynamic pressure/pressure decreases continuously with the increase of pavement depth [19-22]. The maximum hydrodynamic pressure in the upper middle layer corresponding to 80 kmh speed is close to 500 kPa.

In conclusion, the test results of different scholars vary considerably. This should be due to the different sensors used, the different road surfaces and vehicle types tested, and the different environmental factors. In general, vehicle speed has great influence on hydrodynamic pressure of asphalt mixture.

Conclusion

At present, in the field of asphalt pavement hydrodynamic pressure research, scholars carry out hydrodynamic pressure numerical simulation research much more than field measurement or test simulation, so it is necessary to strengthen the implementation of the latter.

The influence of surface dynamic water scouring on asphalt mixture is less than that of high pore water pressure. The pore water pressure is greatly affected by driving speed, followed by vehicle load. When the void ratio is between 8% and 15%, the pore water pressure of asphalt pavement is high and its peak value is generally lower than 0.5mpa, which can be used as a reference in laboratory test simulation of hydrodynamic pressure.

In view of the existing problems, it is still necessary to carry out systematic and in-depth research on the quantitative relationship between the hydrodynamic pressure of asphalt pavement and the main influencing factors, the standardization of research methods, the development of field measured sensors, laboratory test devices and theoretical modeling, etc.

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