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Pavement Deterioration Caused by Hydrodynamic Scouring and Associated Fatigue Loading

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Abstract

Pavement made of Portland cement concrete (PCC) is subjected to a variety of environmental factors, including temperature fluctuations and chloride salt erosion, in addition to fatigue loading. As a result, PCC's durability and mechanical properties gradually decline. Crack initiation and propagation are caused by repeated wheel loading; It is thought to be the primary factor in PCC damage. PCCs' inner structure, durability, and mechanical properties under fatigue loading have all been the subject of research. Yang and others discovered that numerous cracks developed within PCC after it was loaded; The cracks got bigger until the concrete split. Yang and co. separated this procedure into three phases: initial compaction, stable and unstable crack expansion, respectively. Likewise, Zhao et al. investigated the PCC failure following a load and divided the process into three stages: dispersion of microcracks, selection of macrocracks, and expansion of the main crack.

Keywords: Cement concrete • Microcracks • Hydrodynamic

Introduction

When subjected to a load, the performance of concrete typically deteriorates slowly at first, but then quickly in later stages. Zhou and co. developed nonlinear mathematical equations for the relationships between mechanical properties and fatigue life and investigated the residual flexural strength of PCC under coupled fatigue loading and low-temperature conditions. Guan and co. During fatigue loading, the transport properties of chloride ions within PCC were investigated. They calculated the coefficient in terms of the initial density of microcracks and the cumulative damage caused by fatigue and looked into the diffusion coefficient of chloride ions in fatigue-damaged concrete. Guo and others Ten, Eleven, and Yang et al. Discovered the mechanisms by which fatigue loading and environmental factors combined to deteriorate PCC's pores and interface transition zone. Zhao et al. used regression analysis to as well as Shen et al. Found that the aperture had the strongest correlation with flexural strength when they looked at the relationship between PCC microstructure and strength [1].

However, prior research primarily focused on PCC damage caused by four-bending loading under static fatigue, which is inconsistent with pavement concrete's actual stress. During service, PCC pavements are subjected to rolling dynamic wheel loads for which there are no experimental laboratory studies. Additionally, PCC shrinkage caused by fatigue loading may cause PCC cracks to expand or initiate new crack formation. PCC pavement's cracks allow moisture to enter its interior through channels. Scholars have thoroughly examined how moisture damage manifests itself in the form of deformation as a result of water retention at the surface layer. Zhu looked at how PCC pavements with unbonded concrete overlays performed in Ohio and found that water damage to the structure severely affected its serviceability. Additionally, as vehicle tires squeeze the pavement surface, water causes a brief hydrodynamic pressure to be applied, resulting in the removal of water [2].

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Literature Review

Wang and others demonstrated the three processes into which hydrodynamic scouring of the pavement surface can be broken down. The first stage of damage is caused by hydrodynamic scouring damage caused by rolling wheel leakage runoff. Hydrodynamic scouring damage, which is caused by further compression of water stored in cracks, is the second stage of damage. After that, a certain amount of vacuum pumps stored water from the pavement's inner cracks when the wheel's tread leaves the surface, degrading the pavement and causing future structural damage. As a result, rolling loads and hydrodynamic pressure exerted by rolling wheels on PCC pavements merit greater consideration [3,4].

Hydrodynamic pressure research currently focuses primarily on two aspects. One is the establishment of analytical models for the numerical simulation of dynamic pressure. The measurement of hydrodynamic pressure in the field is the other. However, numerical simulations do not replicate the real-world material properties or loading mode. In addition, a number of experiments aimed at better simulating the actual pavement environment have been used to simulate hydrodynamic scouring. A device with a water pump and regulator that Wang designed had a range of available water pressure from 0 to 100 kPa. Yang et al. used a triaxial cell as a dynamic water condition chamber simulated the pavement's pore water pressure when loaded with traffic. Wang et al. developed devices similar to these, who achieved hydrodynamic scouring action by alternating positive and negative pressures using hydraulic equipment assembled with a vacuum pump [5].

Discussion

Jiang et al.'s research on measuring hydrodynamic pressure in the field created a piezoelectric sensor that measured the hydrodynamic pressure produced by a 90 km/h car. Similar to that, Gao et al. found that the pressure between the car tiers and the pavement surface was 0.234 MPa for cars traveling at 80 km/h. Wang proposed a functional relationship between vehicle speed and maximum pressure at various pavement layers by embedding pressure sensors in various layers. This allowed for a comparison of the dynamic pressure at the surface and inside of the pavement [6].

The results of the majority of these studies, which focused on asphalt concrete pavements, demonstrated that the dynamic water pressure had a significant impact on pavement. However, it is unknown whether PCC pavements are impacted by hydrodynamic pressure and whether this pressure is more detrimental to PCC when combined with vehicle loading. The majority of field measurement studies in the literature focus on measuring hydrodynamic pressure at various driving speeds, and cars are frequently used as the test vehicle. The influence of vehicle loading on hydrodynamic pressure has only been the subject of a few field measurement studies. In addition, despite the fact that some studies utilized devices to simulate hydrodynamic pressure, very few of them matched the hydrodynamic pressure generated by repeatedly rolling wheels. Although fatigue damage and hydrodynamic scouring are mutually influential processes, pavement damage caused by coupled fatigue loading and hydrodynamic scouring has received relatively little research attention [7,8].

This study aims to identify the mechanism and process by which fatigue loading, coupled fatigue loading, and hydrodynamic scouring damage pavement. In order to accomplish this, the hydrodynamic pressure that is caused by rolling wheels on a PCC pavement surface was measured in the field, and a device was designed to simulate the fatigue loading and hydrodynamic pressure that are caused by wheel loading repeatedly. In addition, the pavement's flexural strength, dynamic elastic modulus, chloride diffusion coefficient, and BPN were examined at various damage stages and under various conditions [9,10].

Conclusion

A device with a rolling wheel and high-pressure pumps was designed to simulate coupled fatigue loading and hydrodynamic scouring. The frame, dynamic water test chamber, motor, and wheels made up the majority of this coupled test machine. The sample box was used to store the test specimens, and the jack's two wheels provided fatigue loading. The track was 100 mm, the wheel diameter was 200 mm, and the wheel width was 65 mm. Beam brackets made of stainless steel formed the specimens' bottoms with a width of 300 millimeters and the capacity to carry out a fatigue loading test with four points. A regulating valve set the hydrodynamic pressure supplied by a water pump. In order to stop water from deteriorating the samples, a pumping unit was added to the sample box's bottom.

Acknowledgement

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Conflict of Interest

None.

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