

PAPER • OPEN ACCESS

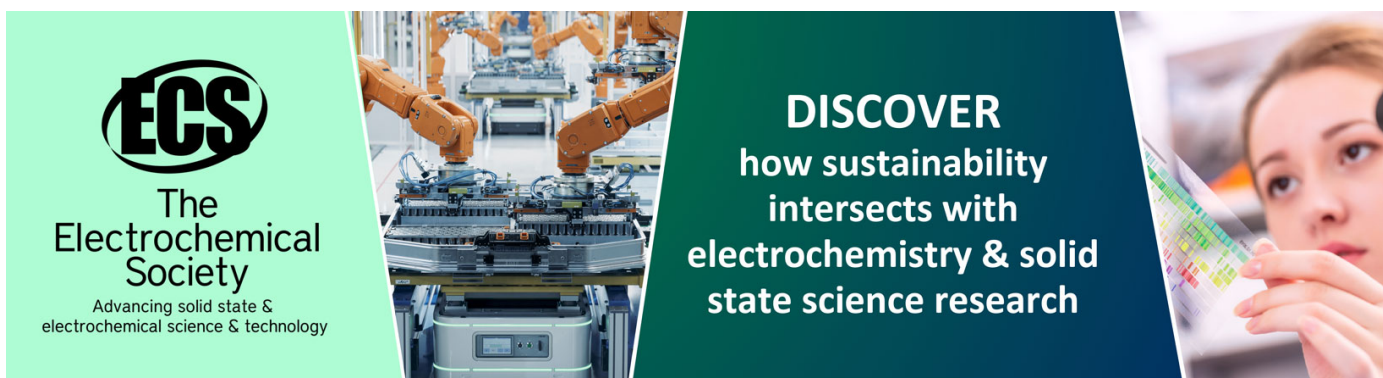
Cause Analysis on the Void under Slabs of Cement Concrete Pavement

To cite this article: Li Wen *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **205** 012011

View the [article online](#) for updates and enhancements.

You may also like

- [Standardized Design and Performance Analysis of Prefabricated Construction Temporary Road](#)
Yin Jin-ming, Jiang yi and dong xiao-jin
- [The Mechanical Analysis of Cement Concrete Surface Layer With Load - transfer Bar for Joints Based on Computer](#)
Xiaoxi Bi, Yang Yv, Zhijun Zhang et al.
- [Groove Depth Detection Method Base on the Line Laser Vision Measurement on Cement Concrete Pavement](#)
Hong Ying, Shunxing Chen, Yana Jiang et al.



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Cause Analysis on the Void under Slabs of Cement Concrete Pavement

Li Wen, Guo Xin Zhu and Baozhu

Communication and Transportation School of Changsha University of Science and Technology, China
617303487@qq.com

Abstract. This paper made a systematic analysis on the influence of the construction, environment, water and loads on the void beneath road slabs, and also introduced the formation process of structural void and pumping void, and summarizes the deep reasons for the bottom of the cement concrete pavement. Based on the analysis above, this paper has found out the evolution law of the void under slabs which claimed that the void usually appeared in the slab corners and then the cross joint, resulting void in the four sides with the void area under the front slab larger than the rear one.

1. Introduction

With the rapid development of the traffic construction in china, there is also a rapid increase in the mileage in highway open to traffic, along with a heavier maintenance task.

The pavement built in the early days were concrete pavement mainly. Affected by the repeat vehicle loads and environmental factors, there was an objective existence of void between some certain parts of the concrete slabs and the interlayers. The void under slabs has been one of the most significant problems for the concrete pavements. Once a broken slab, a kind of structure damage appeared, the maintenance would be quite difficult, not only including a high cost, but also large time consumption. Therefore, the discovery of the cause and evolution laws of void is of great practical and theoretical significance for the treatment of the broken slabs in rigid pavement.

2. Causes and Formation Mechanism of void Under Slabs

2.1. Causes of Void under Slabs

During the operation period of the cement concrete pavement, plastic deformation appeared on the basic level under the repeat influence of the traffic loads due to a rigidity of the base materials under the slabs weaker than the panel materials especially for the pavement with a the gravel as its base materials. When the wheel load acts on the road surface, the surface plate will be bent and deformed. As the deflection of the plate will cause a certain amount of plastic deformation, and the roadbed will remain part of the plastic deformation can not be restored. And with the accumulation of the plastic deformation, the void under the concrete slabs appeared. Meanwhile,, due to the uneven distribution of the temperature in the cement cement concrete pavement, it causes the buckling of the slab up or down, which accelerates the separation between the plate and the foundation. The void under slabs provided space for the intrusion of water. Cement concrete pavement has seams (and sometimes cracks) and free edges. During the rainy season, the rainwater infiltration from the gaps of the pavement formed ponding in the void area. Under the repeat squeezing action of the traffic load, the ponding together



with the fine particles in the base materials formed the mud which then caused pumping when splashed from the joints and cracks of the pavement. The production of pumping enlarged the void area under the slabs and then caused the breakage of the slabs with the interaction of overload vehicles. In conclusion, there are four main factors causing the void which are presented below:

2.1.1. Construction Factor

With the increase of service life, the increase of traffic volume, cement concrete substrate material will be a certain plastic deformation, the load away, this part of the plastic deformation can not be fully restored, will remain in the grassroots and soil for a long time, the formation of local Support conditions weakened or empty; the same time, because the material and construction of non-uniformity, the assessment of plastic deformation is more unpredictable. Due to the difference of the engineering geological conditions in the highway alignment areas, the longitudinal part usually adopted the design of secant lines. Most of them were fill subgrade (10m in height) and excavation subgrade (10m in depth), with some semi-filling and semi-excavating, no filling and shallow excavation subgrades, which made the construction control of the subgrade uniformity quite difficult. If the bright culvert and bridges were constructed in advance, the rolling equipment would not be able to get close to the culvert wall and the abutment back. As a result, the differential settlement of the filling area increased after the construction and also the void under the butt straps.

2.1.2. Influence of the Natural Factors

Changes in temperature and humidity will cause the pavement to warp, the force at this time is very unfavorable, under the action of the load is more prone to cracks. In order to avoid excessive temperature stress leaving the plate arch or broken, set up a variety of joints, but with the panel shrinkage, expansion, cracks are open, closed, these weak locations for the water immersion to create the conditions. This factor can not be avoided, but as long as dealing with other reasons, natural factors will not become the main reason for the void. Due to the infiltration of cement paste in the concrete during the process of cast-in-place, an integral material with a certain shear capacity formed between the slab and the subgrade. However, affected by the temperature, there would be an expansion of the slab which resulted in the decrease of the horizontal shear capacity. At the same time, there was a nonlinear temperature distribution in the slabs, which resulted in the upward or downward bend of the slab, accelerating the separation between the slab and subgrade. As a result, part of the cement concrete slabs lost the continuous touch with the slab thus causing the partially void under the slabs.

2.1.3. Scour of the Surface Water

The water inside the cement concrete pavement joints or cracks into the pavement, arrived at the site and at the base of weakening the void, under the effect of vehicle load, the basic materials of scour, deterioration of bottom supporting conditions, increasing the void area. Sometimes the subgrade was infiltrated due to the rainfall and other factors. When affected by the load effect, a high pressure flow would appear between the slab and the infiltrated subgrade, which would erode the subgrade surface. The whole process was the so-called scouring action. Once such action happened, part of the slab would lose the bearing of the subgrade thus causing the breakage and dislocation. At the same time, due to the dynamic load effect of the wheel, moisture will be carried out from the bottom of the joints and column points with the base material, which further aggravate the bottom of the slab.

2.1.4. Multiple Influence of the Vehicle Loads

Most of the transport vehicles seriously overloaded, overrun the road so that the actual number of standard load is much larger than the design value. Under the action of these vehicles, the pressure of the plate at the bottom of the pressure can be a few orders of magnitude larger than the standard car, which damage the road and its serious. When the vehicle load acted on the pavement, flexure and deformation would appear on the slab, causing certain deformation on the subgrade. The slab reverted after the vehicles left, however, there were some plastic deformation unable to be reverted in the subgrade. Although the amount of the rudimental plastic deformation each time was minimum, the accumulated amount after millions of times vehicle load actions were quite large. Therefore, a certain extent of void phenomena appeared in most carriageways after an operation of 3 to 5 years. Longitudinal and transverse joints were destroyed resulting in the penetrating cracks, which intensified the scour of surface water.

2.2. Formation Mechanism of the Void under Slabs

Cement concrete road surface layer and the grass-roots bonding as a whole of this state is impossible to maintain it, due to the concrete surface of the concrete layer of solidification, in the temperature and volume shrinkage, the surface layer and the grass between the The overall bonding state will soon change, resulting in the separation of the surface layer and the base layer to form a broken layer, and then in the role of rain and load, prone to empty.

The separation of the surface layer from the base layer will produce a small interlayer gap. Due to the brittle nature of the cement concrete pavement, the bearing capacity of the pavement will be reduced. The reason is that the separation as a form of destruction, which in the vicinity of the separation interface is accompanied by the destruction of the material, in the rain erosion, continuous vehicle load, etc. under the constant action of the separation of materials near the interface will be severely damaged, A crushing layer is formed between the topsheet and the base layer. The non-uniform expansion of the crust layer will aggravate the non-uniform voiding of the pavement in the transition layer between the surface layer and the base layer. In addition, under the constant impact of the vehicle load, the erosion of the crushing layer will be caused, damage.

AASHTO road test observations show that: in the cement concrete pavement and the location of the plate angle, there is a large number of cement mud due to the cement concrete slab under the foundation of the phenomenon. Based on large amount of survey data on the void phenomenon, the void under slabs in cement concrete pavement can be classified into two kinds. One is the structural void and the other is the pumping void.

2.2.1. Structural Void

Under the multiple factors of environmental factors (temperature change and humidity change) and vehicle load, the deflection of cement concrete panel will produce a certain amount of plastic deformation, the plate after the load away from the original state, and the roadbed remains this part of the plastic Deformation, the plate after the load away from the original state, although the load after each role of the roadbed residual plastic deformation is very small, but millions or even tens of millions of times after the cumulative amount is not small, the load on the road On different parts, the amount of deflection generated by the different corner of the corner, the edge of the board followed by the bottom of the plate under the smallest. In this way, the bottom of the plate and the edge of the board at the edge of the formation of the bottom of the roadbed between the top of the empty. Environmental factors caused by the accumulation of voids and plastic deformation are called structural voids.

2.2.2. Pumping Void

The rainwater infiltrated into the lower space of the slabs through the joins and the margin of the slabs, which formed pressured water under the multiple influence of the vehicle loads flowing in high speed along the joints and margins of the slabs. When the front wheel of the vehicle passes, the edge or corner of the rear panel is bent downwards, squeezing the water in the hollow area, and then the wheel is pushed to the rear. Driving speed is fast, the stagnant water is squeezed by the flow velocity is very high before and after the roadbed material in the high-speed water flow is easy to be washed, and stagnant water has become a fine mud containing mud. With the continuous loss of the fine particles, void formed under the slabs. This kind of void caused by pumping is called the pumping void.

3. The Evolution Law of the Void under Slabs

Under the condition of the positive temperature gradient, which means the temperature in the top surface is higher than the temperature in the bottom of the slabs, the void usually appeared in the middle lower space of the slab. While in the condition of negative temperature gradient when the temperature in the top surface was lower than the temperature in the bottom of the slabs, the void appears in the corners and margins of the slabs. Under the effect of vehicle load, the pressure on the corners and margins was larger due to a larger deflection in those areas. Plastic deformation appeared when the pressure was larger than the yield limit of those materials. The more times the vehicle passed the pavement, the larger the structural void space under the slabs was. When the loading acted on different parts of the slabs, the amount of deflection was also different, with the deflection amount in the corners larger than in the margins, and the middle parts of the slabs enduring the least deflection

amount. Because the deflection amount differs in different parts of the slab, the accumulated amount of plastic deformation was also different, with the amount in the corners larger than in the margins and the middle parts of the slabs having the minimum amount. Therefore, void between the slab bottoms and the subgrade surface appeared in the corners and margins of the slabs. The void means the slab has lost partial support which caused an evident increase of the flexural-tensile stress in the slabs inevitably. The research showed that the structural void under the slabs caused by Temperature warping and/or the accumulation of subgrade plastic deformation was relatively less both in degree and magnitude. Thus it had small effect on the increase of stress deflection and also a little influence on the enlargement of the void areas under the slabs. However, if the rainwater infiltrated into the structural void areas and the subgrade materials were easy to be washed away, thus, under the multiple influence of the vehicle loads, bumping was produced with fine particle being brought out continuously. The original void area would become larger and the stress deflection of the slabs increased at the same time, which resulted in the breakage of the slabs. Meanwhile, when the vehicle moves forward, the mud with fine particles jets in high speed to the void area of the rear slabs, leaving some fine clay deposited in the void area, thus elevating the rear slab and forming the vertical dispersion between the two joint unbroken slabs. This kind of problem is called dislocation which intensified the unevenness of the pavement. The structural void under the slabs was the cause of the pumping void, while the pumping void develops the structural void. The alternative or the combined action of the two kinds void promoted the evolution of the void under slabs. Based on the field observation and measurement, when the vehicle passed a joint areas, the front and rear parts of the slab on the pavement were of great difference in the void scale, with the scour in the front and deposition in the rear, which means when the vehicle passed the corner of the first slab(the rear slab), due to the structural void area, part of the saturated water and sub-saturated water under the slabs expelled from the pumping channels under the effects of a relatively low pressure difference. When the vehicle passed through the front slab corners, the rear slab sprang back and a negative pressure produced under the slab. Under the effect of transient compression, the water under the front slab scoured the subgrade materials in the opposite direction at a high speed due to the mutual effects of a relatively high pressure difference and the pumping effects of the rear slab, bringing fine particles back to the void area under the rear slab. A part of the fine particles deposited in the rear slab while others jetted out through the pumping channels (breathing joints and other cracks with poor tightness or the aged ones), resulting in a slow expansion of the void under the rear slabs due to the fine particles deposition and a continuous enlargement in the void area under the front slabs due to the water scour. Figure 1 is the general schema of the void under slabs.

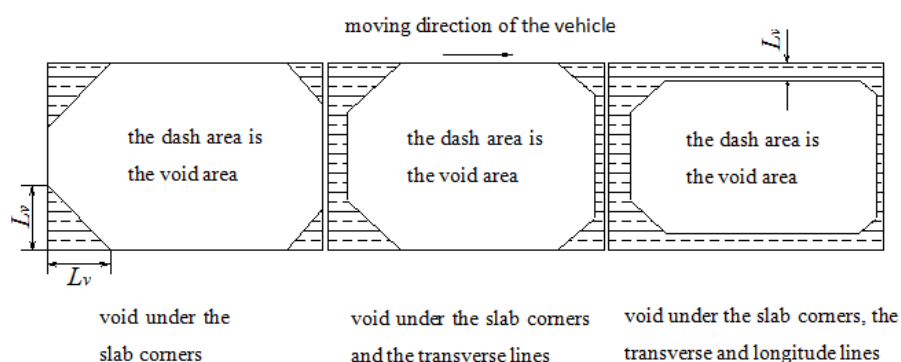


Figure 1. general schema of the void under a single slab

The evolution law of the void under the slabs usually starts from the corners and then to the transverse joint, forming a four sides void in the end. The void area under the front slab is larger than that in the rear slab based on the direction of vehicle movement.

4. Conclusion

(1) The void under the butt strap caused by the differential settlement during the construction, the nonlinear environmental temperature distribution, scour of the surface water and the repeat influence of the vehicle loads were the main reasons of the formation of the void under slabs of cement concrete pavements.

(2) The evolution law of the void under the slabs usually started from the corners and then to the transverse joint, forming a four sides void in the end. The void area under the front slab was larger than that in the rear slab based on the direction of vehicle movement.

5. References

- [1] Liu Hai. Research on the Technology of Adopting Modified Emulsified Asphalt Cement Based Composite Material to Treat Void under Slabs of Cement Concrete Pavement [D].Changan University, 2013.
- [2] Gao Shunping. Analysis on the Operation Conditions of Cement Concrete Pavement with Void under Slabs and Research on the Evaluation Technology of Void[D].Kunming University of Science and Technology,2014
- [3] Zhang Yinchao. Research on Taking Rubber Powder Cement Mortar as the Grouting Agent for Void under Slabs of Cement Concrete Pavement [D].Hebei University of Technology, 2014.
- [4] Zhang Jizhou. Cause Analysis on the Typical Diseases of JRCP Pavement of Lianyi Highway and Research on the Maintenance Strategies [D].Changsha University of Science and Technology, 2013.
- [5] Wei Guojie, Feng Minglin. Cause Analysis and Treatment of the Void under Slabs of Cement Concrete Pavement [J].Science and Technology Information, 2013, (35):227.
- [6] Tang Shanlin. Research on Typical Types of Diseases and Cause Mechanism of Cement Concrete Pavement in Cold Regions [D].Chongqing Jiaotong University, 2014
- [7] Zhang Guoxiong. Research on the Void Mechanism and Fatigue Damage of Concrete Pavement Affected by the Dynamic Water pressure under the slab [D].Changsha University of Science and Technology, 2012.
- [8] Zhang Xiaoran. Response Analysis on the void under the slab of cement concrete pavement affected by dynamic loads [D].Hebei University of Technology, 2015.