The Finite Element Analysis of Loading Stress in Cement Concrete Pavement Slab with Void Underneath

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Abstract: Due to the repeated action of vehicle load and water seepage, the base course becomes wet and soft, and the strength is gradually reduced in the actual use process of cement concrete pavement. A certain amount of plastic deformation and pumping mud will be produced under the base course of cement concrete pavement. And it will lead that concrete slab no longer keeps continuous contact with the base course in the local scope. So the pavement slab with void underneath will be produced under the slab corners, which leads to slab corner crack in the end. The paper analyzes loading stresses under various sizes of void underneath by Ansys. The paper is hoped to provide reference for the study of theory and lay the foundation of cement concrete constriction control.

Keywords: Cement concrete pavement; Finite element; Void; Loading stresses

1. Introduction

As a form of high grade road pavement structure, cement concrete pavement have many advantages, such as long service life, small day-to-day maintenance, less energy consumption, convenient construction, strong adaptability to traffic levels and environment. And it was widely applied. The loading stress research on the viod of cement concrete pavement dates back to 20 or 30s of the last century. During that time American scientists Goldbeck and C.Old supposed that the pavement is cantilever beam and put concentrated load on the slab corners in accordance with the observed result of breaked slab corners[1].And the designformula of cement concrete pavement was worked out. In 1939 Kelley put forward the stress calculation formula of slab corners and edges in the case of local void under base course. In 1946 Pickett put forward the maximum stress experience formula in consideration of corner load transferring and warping effect. It began in 1965 that the finite element method is used to the stress analysis of rigid pavement. In the year Zhang Youqi and Zienklewicz, D.C put forward the body of thought that the analysis of finite element was applied to concrete plate on elastic foundation. Since then the structural analysis of cement concrete pavement goes into a new stage[2].

Cement concrete pavement has strong compressive strength and less rupture tensile strength. Before the bottom of pavement does not appear viod, owing to the support of base course the pavement has less rupture and tensile stress under vehicle load. And it does not affect use of pavement. In the process of actual use the flexure deformation of pavement will be produced and some plastic deformation will be produced in base course[3].The mud will overflow from joint or crack under vehicle load and viod will be produce. The part of pavement slab viod is equivalent to a cantilever beam. Under the action of overload and dynamic load the tensile stress of pavement will greatly increase and the fissure and fracture will appear. The flexure in the part of viod will be greatly improved. The area and depth of viod will also greatly increase. The rain seeps into base course, which causes continued increase in area and depth of viod and leads to destruction of the pavement in the end[4].So this will seriously affect the use condition and fatigue life of pavement. The paper analyzes loading stresses under various sizes of void underneath by Ansys. And the paper is hoped to provide reference for the study of theory.

2. The Calculation Model and Parameters

Because the bearing force of cement concrete pavement is very complicated and the shape of viod has various forms, This paper sets the shape of viod as triangles. The wheel load acts on the corner of pavement slab and the shape of load is setted as rectangular shape. Calculation parameters of the model are as follows:5m times 4m is the size of concrete surface course, thickness is 50cm,elasticitymodulus is E=31Gpa,poisson'sratio is μ=0.15,the planviewsize of base course is 10m times 8m(the ultra wide effect of base course and the effective range of surface stress being introduced into base course is considered).The double base material is selected. The material of upper base course is ce-

ment stabilized macadam, and the material of the subbaseis graded crushed rock. The thickness of upperbase 20cm,elasticitymodulus is E=1500Gpa,and poisson'sratio is μ=0.2. The thickness of subbase is 15cm,elasticitymodulus is E=300Gpa,and poisson'sratio is μ=0.3.The elasticitymodulus of earth base is E=50Gpa and poisson'sratio is μ=0.35.The parameters of the pavement structure layer is listed as Table 1.

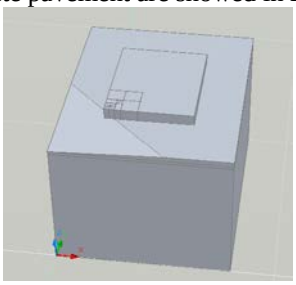
Table 1. The parameters of the pavement structure layer

Structure layer	Surface course	Upper base course	Subbase	Earth base
Thickness (cm)	25	20	15	—
Elasticity modulus (Mpa)	31000	1500	300	50
Poisson's ratio	0.15	0.2	0.3	0.35

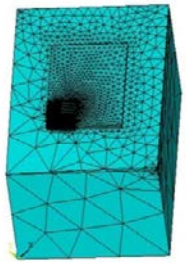
Table 2. Stress along the direction of the center line on the corner of slab under different sizes of viod

Distance(m) / Viod sizes(m)	0.25	0.5	0.75	1	1.25	1.5
0.5	0.009	0.408	0.787	0.773	0.723	0.67
0.75	0.01	0.384	0.85	0.876	0.834	0.775
1	0.01	0.431	0.88	0.953	0.954	0.891
1.5	0.013	0.434	0.88	0.971	1.036	1.053

The stress of cement concrete pavement under vehicle load stress can be solved by the theory of elastic thin plate. The calculation of pavement stress is based on the calculation model of elastic half-space foundation. And the surface course, upper base course, subbase and earth base are simulated by the element of Solid65.Becausethe surfacebase and subbase in the model is made up of different materials which have different characteristics, the contact problems among every layers should be considered. The interaction of structural layers is simulated by the surface contact in the contact analysis. When the meshing of the model is considered, portion of the grid in viod should be refined and the rest parts are meshed by free meshing because the stress of voids is calculated emphatically[5]. The surfaces under and around the earth base are applied fixed constraint. The structure model of Cement concrete pavement are showed in Figure1.



(a) Finite element structural model



(b) Ansys grid model

Figure 1. Finite element structural model& Ansys grid model

3. Calculation Analysis

According to actual situation of pavement voids, the shape of viod is setted as rectangular pyramid. The plan view sizes of viod respectively are 0.5m times 0.5m, 0.75m times 0.75m, 1m times 1m and 1.5m times 1.5m.The axle load 200KN of Single-shaft dual wheel is applied on the model and the contact pressure which is applied to the rectangular area of void is a rectangular area is 0.85Mpa.The results of contrastiveanalysison different viod sizes are listed in Table 2 below.

The nephograms of load stress under different sizes of viod are below Figure 2 to Figure 5.

As you can see from the Figure 2-5 and Table 3 above, first main stress increases with the increase of viod size after viod appears. The stress scope of pavement continues to expand with increase of viod scope, and increment of stress and increment of viod scope are directly proportional. When viod scope is up to 1.5m times 1.5m, the value of stress increases to the value between 4Mpa and 5Mpa.If the thickness of pavement slab is small, concrete pavement will be damaged already. So increase of slab thickness can improve stress effectively after viod appears[6]. And the range of viod is larger, the effect of improving is more obvious.

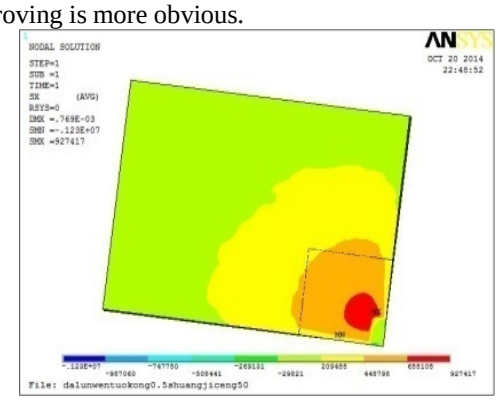


Figure 2. Sizes of viod 0.5m times 0.5m

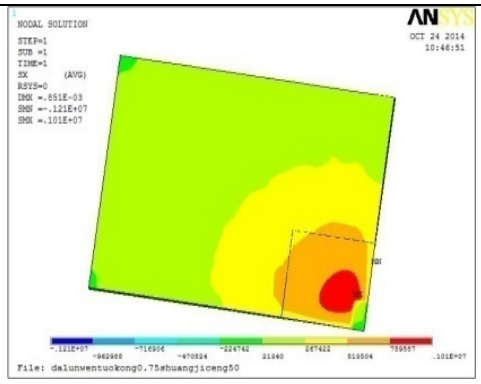


Figure 3. Sizes of viod 0.75m times 0.75m

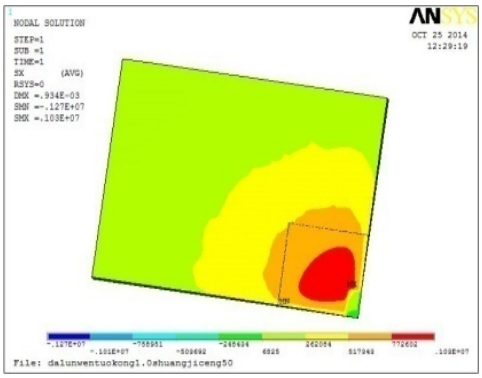


Figure 4. Sizes of viod 1.0m times 1.0m

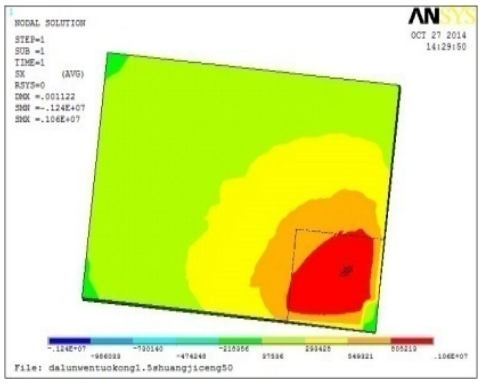


Figure 5. Sizes of viod 1.5m times 1.5m

Table 3. The maximum of first main stressunder in accordance with different sizes of viod

Sizes of viod(m)	0.5	0.75	1	1.5
First main stress(Mpa)	0.654	0.671	0.677	0.679

4. Conclusion

1.The stress of pavement slab increases rapidly after viod appears in the corner of pavement, and with the increase of viod area, the stress of pavement slab continues to increase. When the thickness of slab is small, viod develops to a certain extent and the value of strees is several times of pavement which has not viod.

2.The increase in thickness can effectively improve the pavement stress after void appears in the corner of pavement. The effect of improving is more obvious with the range of void increasing. When the thickness of surface course is up to 50cm or more, increment of pavement stress is very small with increasing of void range.

3.After the base course is void completely in a certain area of slab corner, stress of the pavement is increasing and the increase of stress is more obvious with the increase of viod range. According to the calculation results it can be deduced that the rate of stress increase is more and more small with increase of slab thickness.

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