Effect on the Stresses and Strains within Pavements Due to Uneven Settlements of Subgrade

Qinwen Du, Xiangkai Zhang, Yongliang Li, Yaofu Liu and Liujun Zhang

ABSTRACT

Aiming at the situation that the failure mechanism of pavement structure is difficult to be analyzed under the condition of uneven settlement of soft soil foundation, the finite element model of the mechanical response of asphalt concrete pavement is established by introducing the method of numerical analysis. Based on the analysis of four kinds of uneven settlement forms that is uniform settlement, one end settlement, both ends of settlement, and center settlement, the effects of uneven settlement of soft soil foundation on stress and strain of pavement structure under different settlement modes were studied. This provides the basis for the further study of the coordinated deformation of foundation-subgrade-pavement in soft soil area.

INTRODUCTION

The uneven deformation of the subgrade in soft soil foundation is a common problem in highway engineering. The deformation will have a large additional stress[1] on the pavement structure. This additional stress may even exceed the stresses caused by the traffic load, resulting in early damage to the pavement.

Qinwen Du, Xiangkai Zhang, Liujun Zhang, School of Highway, Chang’an University, Shanxi Xi’an 710064, China.
Yongliang Li, Yaofu Liu, Shanhai Civil Engineering Co., LTD of CREC, Anhui Hefei 200436, China.
Liujun Zhang, CCCC First Highway Consultants CO.LTD, Shanxi Xi’an 710075, China.
structure[2]. The existing norms in the design of the road mainly consider the impact of traffic load, the subgrade uneven settlement to the pavement structure layer to bring additional stress to consider less[3]. And the numerical method is used to simulate the damage effect of subgrade and pavement structure under uneven settlement conditions [4]. The conclusion can be valuable for studying the uneven settlement of soft soil foundation and guiding the filling of subgrade.

MODEL ESTABLISHMENT

In this paper, the finite element model of the finite element analysis software ABAQUS software is used to analyze the stress and deformation of the pavement structure. In the analysis, the model is studied by plane strain problem [5].

Model Geometry

The finite element model is used to analyze the whole section. The width of the road surface is 15m, the thickness of the surface layer is 20cm, the thickness of the base layer is 25cm, the thickness of the cushion is 25cm, the height of the roadbed is 9m, the slope of the subgrade is 1:1, and the thickness of the foundation is 40m.

Boundary Conditions And Different Conditions

According to the actual situation of the project, the boundary condition chosen in this paper is: The bottom of the foundation limits the displacement and rotation in all directions. The horizontal and horizontal boundaries of the foundation part of the foundation are set to allow the vertical displacement, and the top and left and right sides of the road are free. Considering the additional stress of the pavement structure caused by the uneven deformation of the foundation, the displacement method is simulated by using the displacement loading method. Different displacement modes are used to simulate several conditions of uneven settlement of foundation. Set the maximum displacement at the top of the foundation to 3cm.

Material Parameters

The material parameters of each layer of the road are shown in Table 1.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Density (kg/m³)</th>
<th>Modulus (MPa)</th>
<th>Poisson's ratio</th>
<th>Cohesion (kPa)</th>
<th>Angle of internal friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>surface course</td>
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<td>1200</td>
<td>0.3</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>base course</td>
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<td>1100</td>
<td>0.25</td>
<td>500</td>
<td>35</td>
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<tr>
<td>cushion layer</td>
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<td>500</td>
<td>0.25</td>
<td>450</td>
<td>30</td>
</tr>
<tr>
<td>subgrade fill</td>
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<td>45</td>
<td>0.35</td>
<td>14</td>
<td>22</td>
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<tr>
<td>foundation</td>
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<td>300</td>
<td>0.32</td>
<td>12</td>
<td>20</td>
</tr>
</tbody>
</table>

TABLE I. MATERIAL PARAMETER VALUES.
ANALYSIS OF NUMERICAL SIMULATION RESULTS

Analysis of Stress Effect on Surface Layer of Uneven Settlement of Foundation Under Different Settlement Modes

Under the effect of uneven settlement of the foundation, the horizontal tensile stress of the asphalt pavement will appear. The distribution of horizontal normal stress in each layer is different.

Figure 1. Horizontal stress of bottom layer under different settlement modes.

Figure 2. The settlement of roadsurface under different settlement modes.

Figure 1 shows the variation of the horizontal stress of the bottom of the road surface along the width of the road surface in the four displacement modes. It can be seen from the figure that the absolute value of the stress increases gradually from the curb to the center of the road. Different bending modes, the bending stress also changes in different laws: In the four displacement modes, the bending stress at the bottom of the roadbed is compressive stress. From the curb to the center of the road, the stress gradually increased, the magnitude of the variation varies with the displacement pattern and the maximum compressive stress occurs at the center of the embankment. In the center subsidence mode, the bottom of the road surface is mainly subjected to compressive stress, and the maximum tensile stress position in the center of the road. The maximum tensile stress position appears at the center of the pavement. So the uneven settlement of the foundation is likely to cause the pavement structure to crack at the center of the road surface.

Analysis of Effect of Different Settlement Patterns on Road Surface Settlement

Because of the direct contact between the foundation, the embankment and the road surface, the uneven settlement of the foundation will affect the deflection of the
pavement structure. The effect of uneven settlement of foundation on deflection of road surface is analyzed by finite element simulation of different modes of uneven settlement.

Figure 2 shows the distribution of the vertical displacement of the surface layer and the top of the subgrade with the width of the road. It can be seen from the figure that the uneven settlement of the foundation is reflected in the pavement structure, and the displacement law at the top of the pavement in different settlement modes is very different. In the uniform settlement mode, the settlement of the surface layer from the curb to the pavement gradually decreases, and the maximum settlement occurs at the curb position. In one end settlement mode, the top displacement of the top layer gradually increases from left to right, but the rate of change from slow to fast, the maximum displacement appears in the right of shoulder position. In both ends of the settlement mode, the road center position within 8m within the positive displacement, that is, within the scope of the road uplift. In the central settlement mode, the settlement of the surface layer gradually increases from the curb to the center of the pavement, and the maximum settlement value occurs at the center of the pavement. From the above analysis we can see that the uneven settlement of the foundation has a great impact on the pavement structure. However, due to the structural factors of the roadbed and pavement itself, the uneven settlement of the foundation is not a complete reaction on the road.

CONCLUSION

In this paper, the uneven settlement of highway foundation in soft soil area is studied and the effect of uneven settlement on the pavement structure under different settlement modes is analyzed by numerical analysis.

1. In different settlement modes, the limit stress value in both ends of settlement is obviously higher than that of other modes.
2. The displacement law of the top of the pavement varies obviously with the uneven settlement of the foundation. Consistent in the same settlement mode of road surface at the top of the vertical displacement distribution and the top surface of the foundation uneven settlement form, but because of the modulus of subgrade and pavement structure and thickness and other factors, the uneven settlement of foundation is not fully reflected in the road.

REFERENCES

