Influence of Unilateral Widening by Gravel Soil on Expressway Road

Huang Pengyu  
Guangxi Xianglu Construction Co., Ltd.  
Nanning, China  
1390736262@qq.com

Wang Xu  
Road&Bridge International Communication Technology Co., Ltd.  
Beijing, China  
wx_28688@126.com

Yang Yifan  
School of Civil Engineering, Chongqing Jiaotong University  
Chongqing, China,  
972889695@qq.com

Yang Rong  
China Gezhouba Group Investigation & Design Co., Ltd.  
Yichang, China  
2438160580@qq.com

ABSTRACT
Gravel soil is a kind of filling material with excellent mechanical properties, which can be widely used in roadbed filling. In this paper, the calculation by finite element analysis shows that the maximum tensile stress of the surface layer is reduced from 1.34MPa to 1.05MPa and that of the base layer is reduced from 0.54MPa to 0.42MPa after the new subgrade is completely filled with crushed stone soil. The maximum settlement value of unilateral widening is reduced from 11.43 cm to 8.7 cm. The use of gravel soil to fill new roadbed cannot only reduce subgrade settlement, but also reduce pavement deflection.

KEYWORDS: gravel soil; subgrade settlement; pavement deflection

1 INTRODUCTION
In some reconstruction and expansion of fill subgrade widening projects, when the fill of widened subgrade is high, the compactness of filled subgrade is insufficient, the occlusive state of the stone-filled subgrade is not good, or the roadbed filler is clay with a long consolidation time, if it is an old subgrade of which the settlement has basically completed under the action of self-weight load and driving load, thus, there will be no subsequent settlement, or the subsequent settlement is very small, which can be neglected; however, after widening, if it is a new subgrade, it still has a large settlement under the action of self-weight and traffic load after opening to traffic. In the case that the geological conditions are not very bad, the settlement of the new roadbed accounts for a large proportion of the total settlement, and results in large uneven settlement of the new and used roadbed, which affects the service performance of the pavement. When it reaches a certain level, it will lead to the destruction of some road surface in the widening project[1-3]. At present, there have been many studies on light embankments. Light fillers are often used to reduce the self-weight of subgrade, and reduce the stress of newly added foundation, further reducing the consolidation settlement of new foundation, and light embankments itself can reduce compression...
settlement also. Light embankment using light fillers such as EPS, fly ash, etc, has good effect on reducing the uneven settlement of new and used subgrade in widening project. However, the price of light embankment is often higher than that of ordinary subgrade filling. The adoption of such treatment measures will increase the project cost or make the transportation cost higher because of the long distance.

Crushed soil refers to soil with particle size greater than 2mm and particle content exceeding 50% of the total mass, from small to large, including round gravel (breccia), pebble (gravel), and boulder (block stones). Corresponding artificial gravel soil refers to natural soil mixed with breccia, crushed stone or round gravel, block stone or pebble and boulder, so that the content of particles with a particle size greater than 2 mm is not less than 50%. Gravel soil particles can be widely used in roadbed filling due to their large gradation difference, good compaction performance and good mechanical properties.After compaction, the settlement of gravel soil is smaller than that of ordinary roadbed filling, and the settlement speed is faster[4-5]. During the construction stage, the gravel soil subgrade has already settled by a considerable part, so the settlement of the new embankment after construction is reduced, and the uneven settlement of the used and new subgrade after construction is reduced. The newly widened subgrade structure is paved after the filling of the new subgrade is completed, so the influence of subgrade settlement on the new pavement structure in the construction stage is not considered, and the settlement of the subgrade after construction is reduced, thus achieving the effect of controlling the uneven settlement of the new and old subgrade after construction and reducing the negative influence on the pavement structure.

2 ANALYSIS ON THE INFLUENCE OF NEW SUBGRADE FILLED WITH GRAVEL SOIL ON PAVEMENT

2.1 Basic Assumptions

The influencing factors of the highway widening problem are relatively complex. In order to simplify the calculation when using finite element method for analysis, the following assumptions are made:

(1) The embankment is long enough to be considered to be a plane strain problem for a two-dimensional finite element analysis;

(2) The constitutive relation of subgrade fill and foundation soil adopts Drucker-Prager ideal elasto-plastic model;

(3) The interface between the original subgrade and the widened subgrade does not undergo relative slip and detachment during the settlement and deformation process;

(4) The consolidation of the old subgrade and foundation is considered to have been completed under long-term self-weight loads and vehicle loads;

(5) The self-weight of road surface and vehicle load are considered by the equivalent uniform load of 20KPa.[3]

2.2 Size and Parameters of the Calculation Model

Taking the two-way four-lane widening as the two-way eight-lane as the research background, the original roadbed height is 6m, the width is 26m, the unilateral widening width is 16m, the width of the roadbed after widening is 42m, and the slope gradient of the new and used subgrade is taken as 1 : 1.5, and other specific dimensions of the model are shown in Figure 1. Considering that the original highway foundation has been basically consolidated and settled stably, while the foundations on both sides are roughly the original foundation. The calculated width is 200 m (greater than 3 times the width of embankment bottom), and the calculated depth of the foundation is 20 m.

A simulation by finite element software was used to study the influence of replacement of gravel soil in different layers of the new subgrade on the settlement of roadbed, road structural stress and road deflection.

Referring to the relevant specifications and related literature[6-9], the calculation parameters of the model are shown in table 1 below. Figure 1 is a schematic diagram of the new subgrade partially replaced with gravel soil.
### Table 1 Model Parameter Values

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Height (m)</th>
<th>Modulus (Es/MPa)</th>
<th>Poisson ratio (υ)</th>
<th>Cohesive force (c/KPa)</th>
<th>Internal friction angle (ψ/°)</th>
<th>Capacity γ (KN/m³)</th>
<th>Osmotic coefficient (m/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old subgrade soil</td>
<td>6</td>
<td>10</td>
<td>0.3</td>
<td>34</td>
<td>19</td>
<td>19</td>
<td>0.01</td>
</tr>
<tr>
<td>Gravel soil</td>
<td>/</td>
<td>33</td>
<td>0.18</td>
<td>26</td>
<td>31</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>Silty clay</td>
<td>10</td>
<td>8</td>
<td>0.3</td>
<td>28</td>
<td>18</td>
<td>18.5</td>
<td>0.005</td>
</tr>
<tr>
<td>Clay</td>
<td>10</td>
<td>6</td>
<td>0.35</td>
<td>36</td>
<td>16</td>
<td>17.5</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

Figure 1 Schematic Diagram of Local Replacement of Gravel Soil for New Subgrade

Taking the unilateral widening of the 6m embankment as an example, the embankment is divided into 6 layers from low to high, and each layer is 1m thick.

Figure 2 The Replacement Nephogram of 1st and 2nd Layers Replacing with Gravel Soil

#### 3.1 ANALYSIS OF EFFECT OF UNILATERAL FILLING ON DEFORMATION OF GRAVEL SOIL

##### 3.1 Influences on Subgrade Settlement

It can be seen from Figure 3 that the maximum settlement value is 11.43 cm when the new subgrade is not filled with gravel soil; the maximum settlement value is reduced to 10.34 cm after the first and second layers of the new subgrade are filled with gravel soil; After the third and fourth layers of the new subgrade are filled with gravel soil, the maximum settlement value is reduced to 10.45 cm; after the fifth and sixth layers of the new roadbed are filled with gravel soil, the maximum settlement value is reduced to 10.51 cm; after the new roadbed is completely filled with gravel soil, the maximum settlement value is reduced to 8.75 cm.

It can be seen that the effect of replacing the gravel soil on the bottom of the new embankment to reduce the settlement is better than that of replacement of the gravel soil at the high-level. The effect of replacing the gravel soil at the middle level of the new embankment to reduce the settlement is better than that of replacement of gravel soil at the higher level, but the difference is not so obvious and the effect is not significant. In some widening projects, the uneven settlement is relatively small, but when
it is necessary to treat, the measures of replacing the gravel soil in a certain range at the bottom of the new subgrade can be taken to achieve the purpose of controlling uneven settlement.

![Figure 3 Settlement Curve of Replacing Gravel Soil in Different Vertical Ranges](image)

**Figure 3 Settlement Curve of Replacing Gravel Soil in Different Vertical Ranges**

### 3.2 Influences on Pavement Deflection

Previous studies have shown that \[^{10-11}\]: the pavement deflection gradually decreases with the increase of subgrade modulus, as shown in Figure 4 below.

The use of gravel soil to fill a new subgrade can effectively reduce the deflection on the road surface and help to extend the service life of the pavement structure.

![Figure 4 Influence of subgrade Modulus on Pavement Deflection](image)

**Figure 4 Influence of subgrade Modulus on Pavement Deflection**

### 4 EFFECT OF NEW SUBGRADE FILLED WITH GRAVEL SOIL ON PAVEMENT STRUCTURAL STRESS AND DEFLECTION

In order to research the influence of new subgrade filled with gravel soil on pavement structure, pavement structure parameters were taken as shown in table 2\[^{12}\], whose structure met the following assumptions.

1. the contact between the subgrade, the pavement and the structural layers of the pavement is completely continuous.
2. in the pavement structure, the surface layer, the base layer and the subbase layer are uniform, continuous and isotropic materials with linear elasticity.

**Table 2 Pavement material parameters**

<table>
<thead>
<tr>
<th>Materials</th>
<th>Thickness (cm)</th>
<th>Compression rebound modulus (Es/MPa)</th>
<th>Poisson ratio (υ)</th>
<th>Split Strength (σ/MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Concrete</td>
<td>18</td>
<td>1600</td>
<td>0.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>
when the new subgrade is not filled with gravel soil, the maximum tensile stress value of the surface layer is 1.34 MPa, the maximum tensile stress of the base layer is 0.54 MPa; After the first and second layers of the new subgrade are filled with gravel soil, the maximum tensile stress value of the surface layer is 1.17 MPa, and the maximum stress of the base layer is 0.47 MPa; After the third and fourth layers of the new roadbed are filled with gravel soil, the maximum tensile stress value of the surface layer is 1.21 MPa, and the maximum stress of the base layer is 0.49 MPa. After the fifth and sixth layers of the new subgrade are filled with gravel soil, the maximum tensile stress value of the surface layer is 1.22 MPa, and the maximum stress of the base layer is 0.49 MPa. After the new subgrade is completely filled with gravel soil, the maximum tensile stress value of the surface layer is 1.05 MPa, and the maximum stress of the base layer is 0.42 MPa.

By increasing the modulus of new subgrade, the uneven settlement of new and old subgrade can be controlled, and the maximum stress of pavement structure can be reduced. However, it is also necessary to combine other measures to jointly treat uneven settlement of new and old subgrade.

![Figure 5 Tensile Stress of Pavement Surface](image1.png) ![Figure 6 Tensile Stress of Pavement Base](image2.png)

5 **CONCLUSIONS**

(1) Through the calculation by finite element analysis, the study shows that the maximum settlement value is 11.43 cm when the new subgrade is not filled with gravel soil. After the first and second layers of the new subgrade are filled with gravel soil, the maximum settlement value is reduced to 10.34 cm; After the third and fourth layers of new subgrade are filled with gravel soil, the maximum settlement value is reduced to 10.45 cm; After the fifth and sixth layers of new subgrade are filled with gravel soil, the maximum settlement value is reduced to 10.51 cm; After the new subgrade is completely filled with gravel soil, the maximum settlement value is reduced to 8.75 cm. In the case of replacing the same filling layer, the effect of using gravel soil to fill the bottom layer of new subgrade to reduce the settlement is better than that of filing the higher layer. After the new subgrade is completely filled with gravel soil, the effect of reducing settlement is obvious.

(2) After the new subgrade is completely filled with gravel soil, the maximum tensile stress of the surface layer is reduced from 1.34 MPa to 1.05 MPa. The maximum tensile stress of the base layer decreased from 0.54 MPa to 0.42 MPa. The use of gravel soil to fill new subgrade cannot only reduce the settlement of the new subgrade but also reduce deflection on road surface.
REFERENCE