Standardized Design and Performance Analysis of Prefabricated Construction Temporary Road

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Abstract. To promote the standardization and assembly of temporary roads for construction, according to the investigation and research, combined with the requirements of the code, from the perspective of bearing capacity and economy, a standardized construction temporary road scheme was proposed. The load and temperature stresses of assembled panels of different sizes were analyzed using the elastic ground plate theory. The load stress is significantly affected by the axle load of vehicle, and the temperature stress is significantly affected by the plate length. Plate length should not exceed 4m. The numerical analysis method was adopted and the joints were optimized. The tenon could effectively transfer the load. While the length of the tenon is 4cm, the load transfer effect is the best.

1. Introduction

Construction temporary roads are important temporary facilities on the construction site and are one of the prerequisites for the start of the project. They are responsible for the transportation of personnel and materials, but because they are temporary facilities, they have not received the attention of all parties to the project, and there is no uniform standard and no special design, the construction quality is uneven, resulting in serious temporary road damage during construction, and the quality of use is not high. After the construction, the temporary road treatment measures are directly buried, destroyed or used as the base of permanent roads, resulting in waste of resources. Therefore, research on temporary road construction will help improve its use quality and achieve the goals of resource and cost savings[1][2].

Prefabricated concrete pavement can be produced in a factory, not affected by the weather, and the quality of the concrete can be easily guaranteed; the construction progress is fast, and it can be opened to traffic after being paved; and it can be easily replaced for repair after damage. At present, it is mainly used in the rapid repair of cement concrete pavement[3]-[10]. If precast concrete pavement is used in temporary road construction, it can not only give full play to the advantages of cement concrete pavement, but also shorten the construction period, reuse, save resources and reduce costs.

In view of the current research on construction temporary roads, this research starts from the construction requirements of construction temporary roads and combines the characteristics of fabricated roads. The research can provide a reference for the application of prefabricated pavement to temporary road construction.

2. Temporary road scheme and load stress analysis

2.1. Temporary road scheme
Temporary roads for construction are characterized by short service life, large axle load, but low number of actions, and low requirements for driving speed and comfort. The parties to the project are reluctant to invest more. According to the characteristics of construction temporary roads, combined with "Code for Design of Highway Cement Concrete Pavement" (JTG D40-2011) and related research, the following suggestions are put forward: (1) When the temporary road route is determined, it should be comprehensively determined in accordance with the geological conditions and drainage requirements along the route; (2) The subgrade of temporary roads should be rolled to ensure the strength and stiffness of the subgrade, and the rebound modulus of the top surface of the subgrade should not be less than 40MPa; (3) The base layer should choose materials with good water stability and reusability, and graded crushed stones can be used; (4) The subgrade and base layer should be wider than 30cm wider than the two sides of the surface layer to ensure that the bottom of the board is not empty and meet the construction requirements of the surface layer; (5) The assembled concrete pavement is adopted, and the plate thickness and plane size are determined in combination with the temporary road width, load and lifting situation; (6) The indirect joints of plates should have a certain load-transmitting capacity; (7) Temporary road drainage should be done well, and measures such as diversion, drainage, and interception should be adopted to make the water flow as much as possible on the subgrade to avoid water accumulation; (8) The size of a plate should not exceed 25m², and the aspect ratio of the plate should not exceed 1.35. According to the characteristics of the temporary road and the requirements of the economical type, the proposed temporary road structure combination is shown in Figure 1.

![Figure 1. Temporary road structure](image)

**2.2. Stress analysis of temporary roads during construction**

According to the thickness of the surface layer of the temporary road currently under construction and the economic requirements, the thickness of the assembled surface layer is 20cm, the thickness of the graded aggregate base course is 20cm, and the subgrade rebound modulus is 40MPa. Due to the small number of vehicle loads on temporary roads during construction, the fatigue analysis does not consider fatigue effects, excluding joint load reduction \( k_r = 1 \), comprehensive impact coefficient \( k_c = 1 \), and adopts a single-layer plate mechanical model for elastic foundations. The calculation parameters are shown in Table 1. In the stress analysis, the axial load takes into account the effect of the standard axial load. In view of the current situation of overloaded vehicles, especially on temporary roads during construction, several overload conditions (relative to standard axle loads) of 20%, 50%, and 100% are analyzed. The length of prefabricated plates is 3m, 4m, 5m, and 6m. The results of stress analysis are shown in Table 2.

| Maximum temperature gradient (°C/m) | Coefficient of linear expansion of concrete (°C⁻¹) | Resilient modulus of graded aggregate base (MPa) | Elastic modulus of concrete (MPa) | Poisson's ratio of concrete |
|-------------------------------------|-----------------------------------------------|-----------------------------------------------|--------------------------------|--------------------------|
| 89                                  | \(1 \times 10^{-6}\)                          | 300                                           | 30000                          | 0.15                     |

![Table 1. Calculation parameters of stress analysis of fabricated plate](image)
Table 2. Results of stress analysis

| Axle load (kN) | Slab length (m) | Load stress (MPa) | Temperature stress (MPa) | Comprehensive stress (MPa) |
|----------------|-----------------|-------------------|-------------------------|---------------------------|
| 100            | 3               | 2.214             | 0.605                   | 2.819                     |
|                | 4               | 2.214             | 1.407                   | 3.621                     |
|                | 5               | 2.214             | 1.897                   | 4.111                     |
|                | 6               | 2.214             | 2.093                   | 4.307                     |
| 120            | 3               | 2.214             | 0.605                   | 3.233                     |
|                | 4               | 2.628             | 1.407                   | 4.035                     |
|                | 5               | 2.628             | 1.897                   | 4.525                     |
|                | 6               | 2.628             | 2.093                   | 4.721                     |
| 150            | 3               | 3.241             | 0.605                   | 3.846                     |
|                | 4               | 3.241             | 1.407                   | 4.648                     |
|                | 5               | 3.241             | 1.897                   | 5.138                     |
|                | 6               | 3.241             | 2.093                   | 5.334                     |
| 200            | 3               | 4.247             | 0.605                   | 4.852                     |
|                | 4               | 4.247             | 1.407                   | 5.654                     |
|                | 5               | 4.247             | 1.897                   | 6.144                     |
|                | 6               | 4.247             | 2.093                   | 6.340                     |

It can be seen from the results that when the plate size is increased from 3m to 4m, the temperature stress increases by 132.6%. When it is increased to 5m, the temperature stress is increased by 213.6%, and when it is increased to 6m, the temperature stress is increased by 246.0%. With the increase of the plate size, the trend of temperature stress is gradually gentle. When the overload is 20%, the load stress increases by 18.7%, when the overload is 50%, the load stress increases by 46.4%, and when the overload is 100%, the load stress increases by 91.8% The relationship between stress and axial load is linear. According to the combined effect of temperature stress and load stress, when the flexural tensile strength of the concrete panel is 4 MPa, the standard plate load should not exceed 4 m, and when the overload is 20%, the plate length should not exceed 3 m, and the overload is 50% When the plate length is not more than 3m, when the overload reaches 100%, the plate length should be smaller. Therefore, the length of temporary road plates during construction should not exceed 4m, and overloading should be controlled.

3. Design and research of prefabricated pavement joints

3.1 Analysis model

Joints are an important link affecting the application of fabricated pavement. The joints of fabricated pavement include tongue and groove type, cemented interlock type, force transmission type and prestressed type. Through reasonable joint design, the load can be transmitted between the plates, thereby improving the force of the assembled plate. According to the construction characteristics of the temporary road construction, it is recommended to use a joint seam that is convenient for assembly and disassembly.

Reasonable gap design needs to meet the requirements of load transfer between plates. This topic uses numerical analysis to study and optimize the gap parameters. The numerical analysis software uses FLAC3D. A typical notched seam is shown in Figure 2. The left side of the seam is a convex plate and the right side of the seam is a concave plate. The tongue and groove tenon width b and the tenon slope 1: n are optimized parameters. The tongue width b is 2cm, and the tongue slope 1: n is 1: 2, 1: 3, 1: 4, 1: 5, 1: 6. When analyzing the influence of the tongue width, the tongue slope is 1: 4. The tongue width b is 1cm, 2cm, 3cm, 4cm, 5cm, respectively. See Table 3 for the numbering table of each
The numerical analysis models are shown in Figures 3 and 4. The parameters of each structural layer are shown in Table 4. The interface models between the road surface blocks and between the road surface blocks and the roadbed are simulated by the contact surface model. The contact surface model is shown in Figure 5. The parameters of the contact surface are determined according to the software recommendation using the following formula: 

\[ kn = ks = 10 \max \left( \frac{K + 4G/3}{\Delta z_{\text{min}}} \right) \]

where \( kn \) and \( ks \) are the normal stiffness and tangential stiffness of the contact surface, \( K \) and \( G \) are the bulk modulus and the shear modulus of the contact material, and \( \Delta z_{\text{min}} \) is the size of the smallest element.

The load was applied in the form of an equivalent circle, the diameter of the equivalent circle was 30 cm, and the pressure was 0.7 MPa, which was applied to the edges of the plate joints.

| Numerical model | Slope of tenon | Length of tenon \( b \) (cm) |
|-----------------|----------------|-----------------------------|
| I               | 1:2            | 2                           |
| II              | 1:3            | 2                           |
| III             | 1:4            | 1                           |
| IV              | 1:4            | 2                           |
| V               | 1:4            | 3                           |
| VI              | 1:4            | 4                           |
| VII             | 1:4            | 5                           |
| VIII            | 1:5            | 2                           |
| IX              | 1:6            | 2                           |

| Pavement structure | Material       | Length *width *thickness (m) | Material parameters |
|--------------------|----------------|------------------------------|---------------------|
|                    |                |                              | Modulus of elasticity \( E \) (MPa) | Poisson's ratio \( \mu \) |
| pavement           | concrete       | 1*1*0.2                      | 30000               | 0.15                |
| pavement base      | graded aggregate | 4*3*0.3                     | 300                 | 0.2                 |
| subgrade           | soil           | 4*3*0.1                      | 50                  | 0.3                 |
3.2 Numerical analysis results

There are two types of joint load capacity indicators. One is calculated based on the stress results, that is, the load transfer coefficient $K = \sigma_2 / \sigma_1$, where $\sigma_1$ is loading side plate tensile stress, $\sigma_2$ is non-loading side plate tensile stress; the other is calculated based on the deflection results, that is, the load transfer coefficient $K = \omega_2 / \omega_1$, where $\omega_1$ is loading side plate deflection value, $\omega_2$ is non-loading side plate deflection value. The results of the influence of different tenon slopes on the joint load capacity are shown in Table 5, Table 6 and Figure 6, the results of the influence of different tenon widths on the load transfer capacity are shown in Table 7, Table 8 and Figure 7.

| Loading method | Concave plate side loading | Convex plate side loading |
|----------------|---------------------------|--------------------------|
| Tenon slope    | $\sigma_1$ (MPa) | $\sigma_2$ (MPa) | $K$ (%) | $\sigma_2$ (MPa) | $\sigma_1$ (MPa) | $K$ (%) |
| 1:2            | 1.175 | 0.845 | 71.87 | 0.807 | 1.167 | 69.14 |
| 1:3            | 1.187 | 0.838 | 70.64 | 0.810 | 1.166 | 69.51 |
| 1:4            | 1.191 | 0.836 | 70.21 | 0.809 | 1.166 | 69.44 |
| 1:5            | 1.195 | 0.835 | 69.89 | 0.808 | 1.167 | 69.27 |
| 1:6            | 1.198 | 0.833 | 69.56 | 0.807 | 1.167 | 69.19 |

| Loading method | Concave plate side loading | Convex plate side loading |
|----------------|---------------------------|--------------------------|
| Tenon slope    | $\omega_1$ (mm) | $\omega_2$ (mm) | $K$ (%) | $\omega_2$ (mm) | $\omega_1$ (mm) | $K$ (%) |
| 1:2            | -0.300 | -0.218 | 72.67 | -0.204 | -0.287 | 71.08 |
| 1:3            | -0.310 | -0.217 | 70.90 | -0.203 | -0.286 | 70.98 |
| 1:4            | -0.301 | -0.217 | 72.09 | -0.203 | -0.285 | 71.23 |
| 1:5            | -0.301 | -0.202 | 67.11 | -0.202 | -0.286 | 70.63 |
| 1:6            | -0.301 | -0.216 | 71.76 | -0.202 | -0.286 | 70.63 |

| Loading method | Concave plate side loading | Convex plate side loading |
|----------------|---------------------------|--------------------------|
| Tenon width    | $\sigma_1$ (MPa) | $\sigma_2$ (MPa) | $K$ (%) | $\sigma_2$ (MPa) | $\sigma_1$ (MPa) | $K$ (%) |
| 1cm            | 1.194 | 0.717 | 60.01 | 0.729 | 1.195 | 61.02 |
| 2cm            | 1.191 | 0.836 | 70.21 | 0.810 | 1.166 | 69.44 |
| 3cm            | 1.157 | 0.885 | 76.53 | 0.848 | 1.141 | 74.36 |
| 4cm            | 1.095 | 0.858 | 78.38 | 0.870 | 1.123 | 77.53 |
| 5cm            | 1.060 | 0.831 | 78.40 | 0.845 | 1.131 | 74.70 |

| Loading method | Concave plate side loading | Convex plate side loading |
|----------------|---------------------------|--------------------------|
| Tenon width    | Displacement ($\omega_1$) | Displacement ($\omega_2$) | Load transfer coefficient $K$ (%) | Displacement ($\omega_2$) | Displacement ($\omega_1$) | Load transfer coefficient $K$ (%) |
| 1cm            | -0.294 | -0.186 | 63.27 | -0.203 | -0.295 | 68.81 |
From the results, it can be seen that the setting of the seam gap has a certain load transfer capacity, which can reach 80%. In general, the load transfer coefficient decreases as the tenon slope becomes slower (n increases), but the influence of the slope is not significant, and the curve is flat; The load transfer coefficient is significantly affected by the width of the tenon. As the width of the tenon increases, the load transfer coefficient increases and there is an extreme phenomenon. When the width of the tenon reaches 4 cm, the load transfer coefficient reaches the maximum value. The load transfer coefficient obtained from the stress result and the displacement coefficient obtained from the displacement result are basically consistent with the influence of the tenon slope and the tenon width. In general, the load transfer coefficient calculated from the displacement is greater than the load calculated from the stress coefficient.

4. Conclusion

(1) Prefabricated cement concrete pavement can be used as a feasible solution for the construction of economical temporary roads. The thickness of prefabricated surface course should be 20cm, and the base course should be reusable graded crushed stone with a thickness of 20cm. The modulus should not be less than 40MPa. Drainage design should be done for temporary roads.

(2) The load stress of fabricated cement concrete panels is significantly affected by the axle load of the car, and the two have a linear relationship; the temperature stress is significantly affected by the length of the panel; according to the combined effect of the two, the length of the assembled panel should not exceed 4m. Controlling vehicle overload conditions.

(3) Assembled pavement blocks used in the construction of temporary roads can be assembled with gap joints. The load transfer coefficient of the notch decreases as the slope of the tenon decreases, but the impact is small; the load transfer coefficient is greatly affected by the width of the tenon. When the width of the tenon reaches 4 cm, the load transfer coefficient reaches the maximum; through reasonable design, the load transfer coefficient of the gap can reach more than 80%.

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