Comparison of Prefabricated Assembled Tunnel Schemes Based on Overhead Electrified Highways

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Abstract. In order to address the ecological challenges posed by overhead electrified highways, including the reduction of driving lanes, the exacerbation of extreme weather events, and the incompatibility with inner-city environments where overhead resources are scarce, three prefabricated and assembled new bridge-tunnel structures have been designed. The Guangfu Road in Kunming City, Yunnan Province, has been selected as a case study. The spatial finite-element modeling and numerical simulation calculations have been carried out using the MIDAS GTS NX and MIDAS CIVIL software for the three structures. A comprehensive comparison is made between the three options in terms of force characteristics, economy. This is achieved through the use of numerical simulation calculations. The findings of the study indicate that: 1) Scheme 1 is less economical, the construction difficulty is general, the force characteristics of the components are better but the side wall corners are worse; 2) Scheme 2 saves materials, the economy is better, the construction difficulty is simple, and the force at the corners of the side walls and at the center of the roof slab span is worse; 3) Scheme 3 has the best economy, the construction difficulty is more difficult compared to the other two schemes, and the attention to the maintenance of the later works is needed. In summary, the three schemes have their own respective advantages and disadvantages. However, they can also serve as a reference scheme for the practical application of overhead electrified highways.

Keywords: Overhead electrified highway; numerical simulation; force characteristics; scheme comparison

1 Introduction

With the current technological development, the conversion of traditional fuel heavy duty trucks to electrified new energy trucks is a must. The electrified highway technology mainly involves three technical solutions: overhead, rail and wireless. [1-3] Among them, the overhead electrified highway is considered to be the most suitable technology for long-distance driving of heavy trucks. This technical solution mainly installs charging pillars on both sides of the road, and sets up high-voltage pick-up wires over the road to connect with the charging pillars, so that when the vehicle is running low on

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electricity, it can drive into the charging lane and raise the pantograph to connect with the high-voltage wires, thus achieving charging while walking. However, the design characteristics of the overhead technology solution of installing charging columns and high voltage wires along the road will bring about the problem of reducing the number of original lanes, ecological problems such as extreme weather hazards, and the inability to be applied in the inner-city where high altitude resources are in short supply.

To address the environmental and energy impacts of electrified highways, the Institute of Transportation Studies at Iowa State University in Ames, Iowa, USA, proposed a methodology for evaluating the environmental and energy impacts of electrified highways, and found that electrified highway applications will reduce chemical fuel use by more than 25%. [4, 5] Domestic studies have also provided constructive comments on the adoption of electrified highways. Huang Shaoxiong [6] made a corresponding feasibility analysis on the technical progress of electrified highway and whether electrified highway can be applied in China; Zheng Zedong [7] et al. explored the technical scheme of electrified highway transportation system; He Jijiang [8] made a detailed explanation on the inspiration of European electrified highway construction on China's transportation carbon neutrality.

Comprehensively, the electrified highway research in China is only carried out in the implementation of the proposal and other aspects, targeted research programs and how to solve the overhead electrified highway caused by all kinds of traffic safety problems of the research results are very few. In view of the significance of overhead electrified highways for the implementation of new energy heavy trucks in the future, the exploration of the practical application of overhead electrified highways is of great practical significance.

2 Engineering Overview

Located in Kunming, Yunnan Province, Guangfu Road is densely populated with shopping malls and residential buildings, with a high volume of daily traffic. It is the main logistics and transportation channel in Kunming, Yunnan Province. In this study, the geological conditions of Guangfu Road in Kunming City, Yunnan Province are taken as an example to establish a model for numerical simulation calculation. The main geologic parameters are shown in Table 1.

Table 1. Table of main geological parameters

Ground Level	Densities /kN.m⁻3	Cohesion /kPa	Internal friction angle/ (°)	Modulus of elasticity/MPa	Poisson's ratio
miscellaneous fill	18.0	15	10	4	0.35
plastic clay	18.0	28	16	5	0.33
siltstone	19.7	12.3	30	8.5	0.33
sand	19.5	12.2	30.8	7	0.36
peaty soil	15.0	15	5	3	0.34

3 Methods

3.1 Option 1

This scheme adopts the method of prefabrication of the top slab, cast-in-situ casting of the side walls and bottom slab, and solid connection of the beams and piers for structural design. The ground load is transferred to the piers by the top plate, and then transferred to the foundation by the piers. Side wall mainly bear side soil pressure, ground load mainly by the abutment to undertake transfer. The thickness of the top plate is 0.8m, the thickness of the side wall is 0.8m, and the thickness of the bottom plate is 0.9m. The abutment adopts the rectangular abutment of 0.8×0.8m. Program 1 structural design drawings shown in Figure 1, 2.

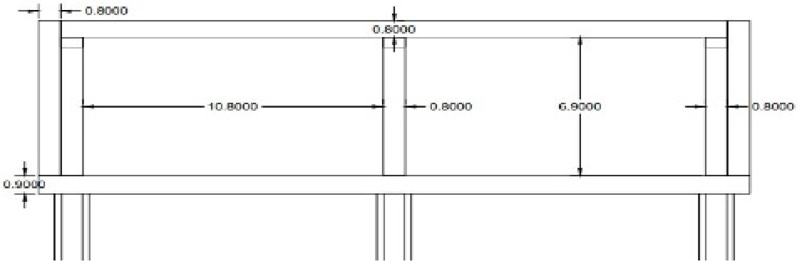

Fig. 1. Cross-section of Option 1 structure

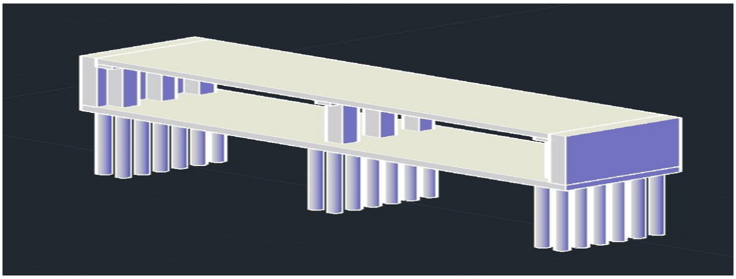

Fig. 2. Option 1 structural elevation

3.2 Option 2

Program two top plate with prefabricated box girder, side walls and base plate cast-in-place, pier cap and piers using elastic connection between the side walls mainly bear side soil pressure, ground load is mainly carried by the piers to transfer. Among them, the thickness of the side wall is 0.8m, the thickness of the floor plate is 0.9m, and the piers are rectangular piers of 0.8×0.8m. Program two structural design diagram shown in Figure 3,4.

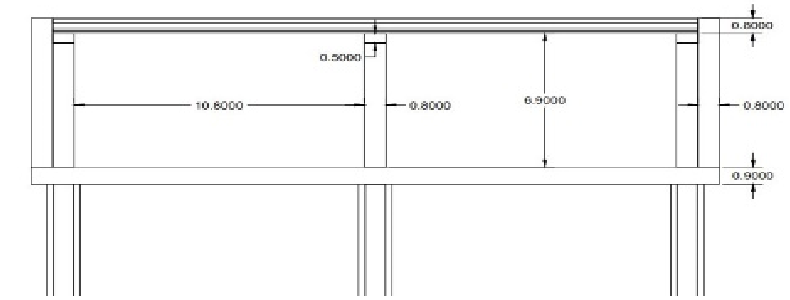

Fig. 3. Option 2 structural cross-section

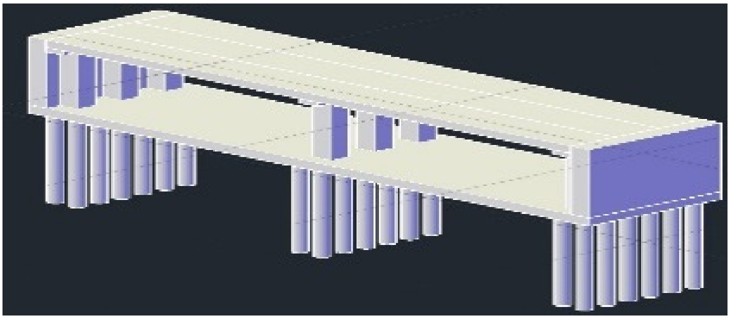

Fig. 4. Option 2 structural elevation

3.3 Option 3

Program three top plate using prefabricated T-beam, side walls and base plate cast-in-place, pier cap and piers using elastic connection between the side walls mainly bear side soil pressure, ground load is mainly carried by the piers to transfer. Among them, the thickness of the side wall is 0.8m, the thickness of the base plate is 0.9m, and the piers are rectangular piers of 0.8×0.8m. Program three structural design diagram shown in Figure 5, 6.

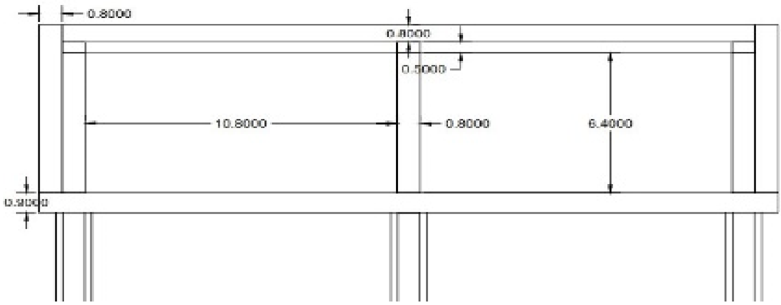

Fig. 5. Option 3 structural cross-section

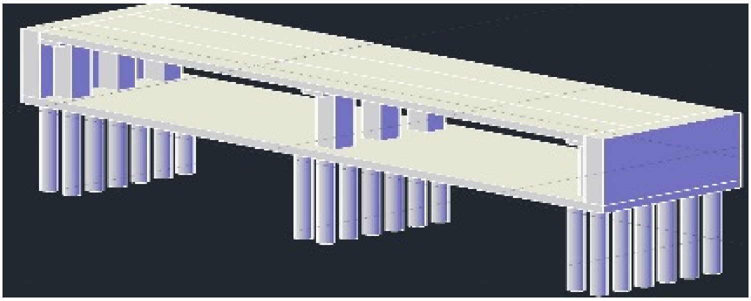

Fig. 6. Option 3 structural elevation

4 Results and Discussion

4.1 Force Characteristics

MIDAS GTS NX and MIDAS CIVIL are used to establish the spatial finite element model of each scheme and carry out the corresponding computational simulation analysis. As shown in Fig. 7, the top plate of scheme 1 has better stress, but the stress at the corner of the side wall is poor, and the maximum moment is 659 KN.m. The structural moment diagram of the upper box girder of scheme 2 is shown in Fig. 9, and the maximum moment is located in the middle of the span, which is 103.55 KN.m. The structural moment diagram of the upper T-beam of scheme 3 is shown in Fig. 11, and the maximum moment is located in the middle of the span, with the value of 196.18 KN.m. The substructure of schemes 2 and 3 is the same, the specific structural moment diagram is shown in Fig. 13, the overall sidewalls of schemes 2 and 3 are the same. The lower structure of Option 2 and Option 3 are the same, and the specific structural moment diagram is shown in Fig. 13, the overall side wall and bottom plate are better stressed, but the side wall corner has the largest moment, and the maximum moment value is 385KN.m. The maximum moment value is 385KN.m. The maximum moment value is 385KN.m.

According to the deformation simulation results in Fig. 8, Fig. 10, Fig. 12 and Fig. 14, it can be seen that the deformation of the bottom plate of Scheme II and Scheme III is the same, and the deformation of the bottom plate of Scheme I is the smallest. Among them, the maximum deformation of Scheme I is located in the middle section of the top slab between the abutment and the side wall. The maximum deformation of the upper box girder structure of Scheme II is located in the middle of the top plate between the abutment and the side wall. The maximum deformation of the upper T-beam structure of Scheme III is larger compared to the upper structure of Scheme II, but it is also located in the middle of the top slab between the abutment and the side wall.

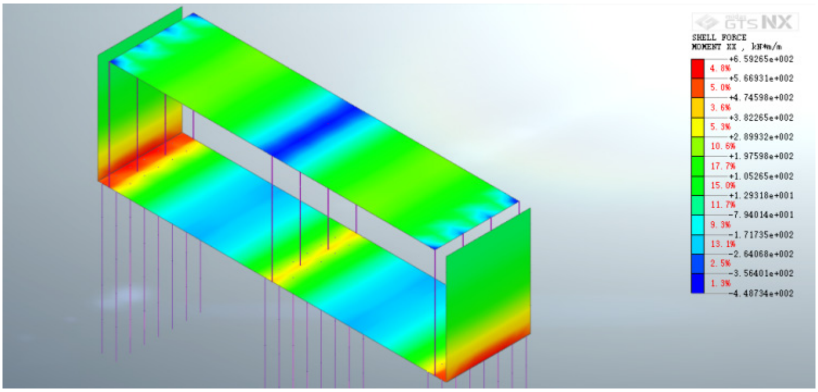

Fig. 7. Scenario1 bending moment diagram

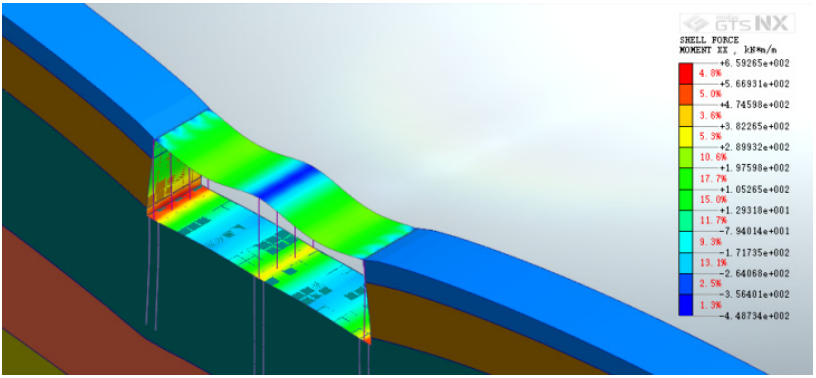

Fig. 8. Option 1 deformation diagram

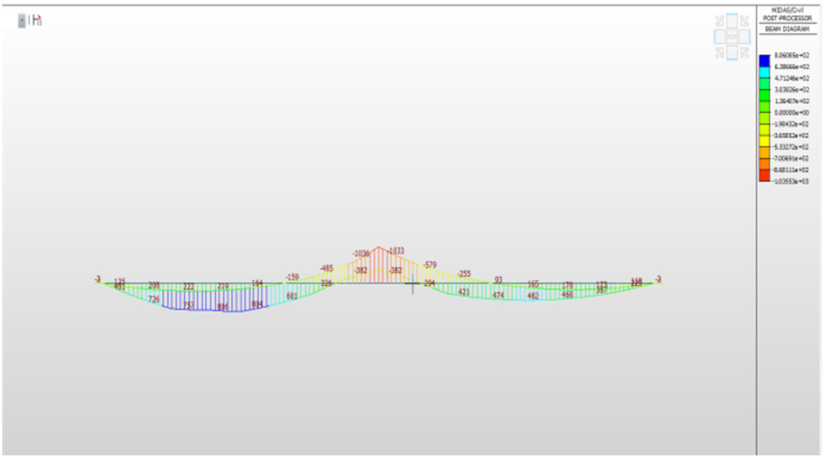

Fig. 9. Scenario2 bending moment diagram

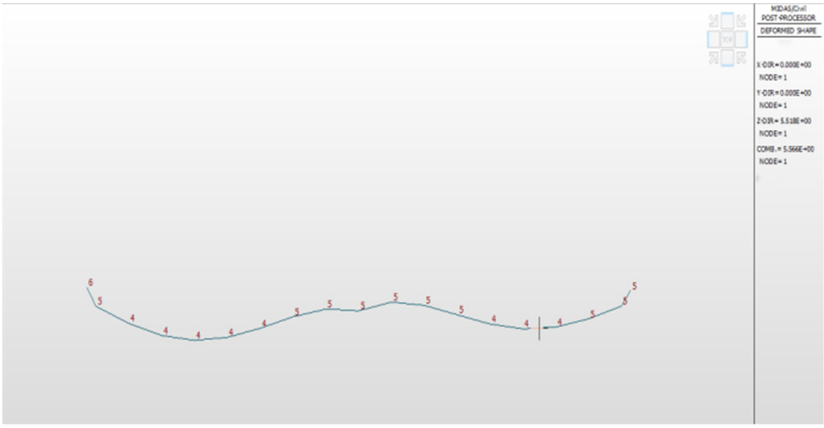

Fig. 10. Option 2 deformation diagram

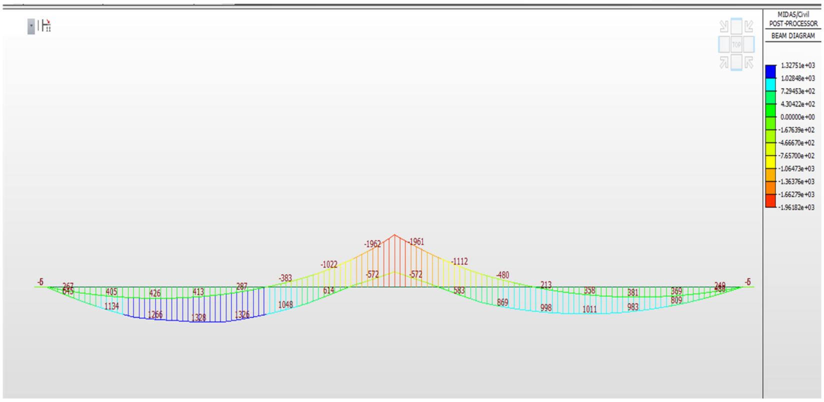

Fig. 11. Scenario3 bending moment diagram

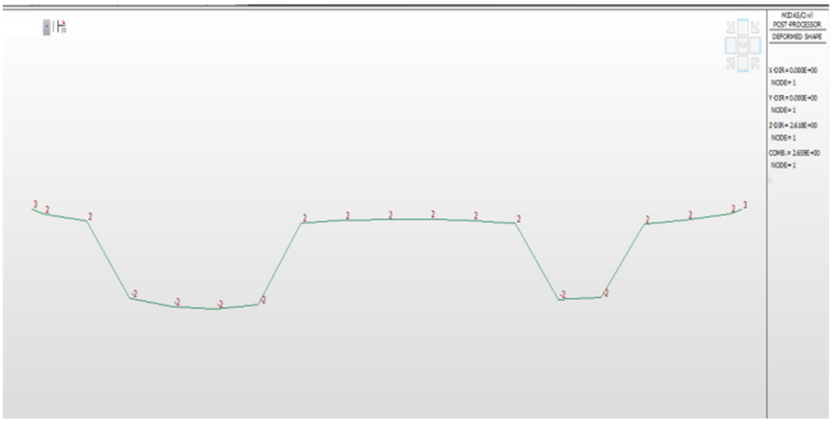

Fig. 12. Option 3 deformation diagram

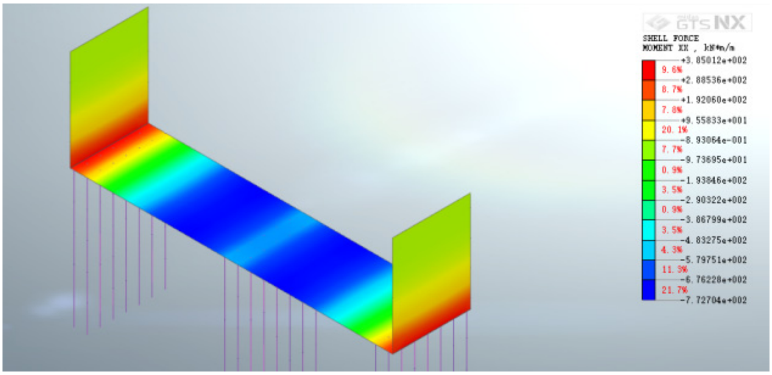

Fig. 13. Scenario2,3 bending moment diagram

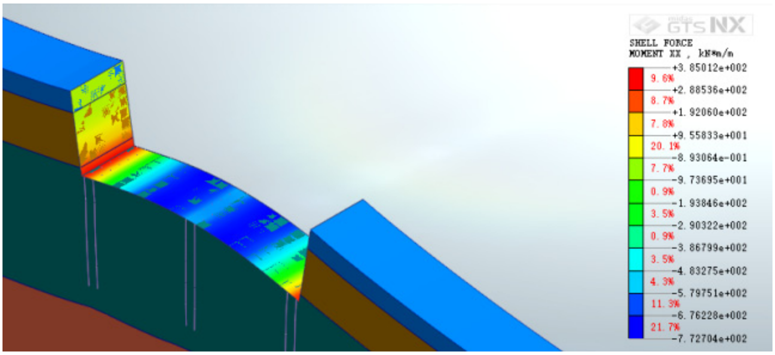

Fig. 14. Option 2,3 deformation diagram

4.2 Economy

(1) Overall cost: the top plate of Scheme I is prefabricated with a whole rectangular plate, compared with the prefabricated box girder of Scheme II and the prefabricated T-beam of Scheme III, which uses the most materials. Scheme III and Scheme II substructure is the same, but the T-beam uses less material than the box girder. So from the cost point of view, the economy of each scheme is: Scheme III > Scheme II > Scheme I.

(2) Engineering excavation volume: the engineering excavation volume of the three programs is basically the same. The reason is that the substructure of the three schemes basically belongs to the mode of casting the whole side wall and base plate, so the excavation volume of each scheme is too similar.

(3) The total amount of main structure: Program 1 adopts the whole rectangular top plate prefabrication, pier cap and pier fixed structural design, compared with Program 2 and Program 3, the total amount of main structure is the least. Program two and program three are used pier cap and pier elastic connection, considering the later maintenance works and support works, the final conclusion of the program two and program three main structure of the total amount of work is the largest.

5 Conclusions

The specific characteristics of the three programs are as follows:

(1) Program 1 overall structural stress is better, but the prefabrication of the whole rectangular plate makes the economy worse. Construction is relatively simple. However, the actual project location of the objective factors are not large and the budget is sufficient to consider the case of program one.

(2) Program 2 is the best force, good economy, construction is simple. Can be applied to most of the actual project conditions. But need to pay attention to the later maintenance of the project.

(3) Option 3 is worse than option 2, but the economy is better, the construction is relatively simple. Applicable to the budget is not high, the actual project is located in the objective conditions of the project is not high.

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