Research on bearing jacking method of steel-concrete composite beam bridge

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Abstract. There are plenty of advantages of steel-concrete composite beam bridges. However, transverse cracks in composite girder bridges usually appear because of the tensile stresses in the concrete deck induced by the negative bending moment at the intermediate supports of continuous composite girder bridges. There are many measures to reduce the tensile stress in the negative bending moment zone of steel-concrete composite beams. At present, bearing jacking method is used more and more in engineering. Taking a composite beam in Shaanxi province as an example, this paper studies the influence of jacking amount and span number on the improvement effect of bearing jacking method. The improvement of stress level of concrete deck in negative moment zone of steel-concrete composite beam bridge is studied and analysed which puts forward relevant engineering solution.

1. Introduction
The steel plate composite beam gives full play to the material properties of steel and concrete. But transverse cracks in composite girder bridges usually appear because of the tensile stresses in the concrete deck induced by the negative bending moment at the intermediate supports of continuous composite girder bridges. There are many measures to reduce the tensile stress in the negative bending moment zone of steel-concrete composite beams. The common way is prestress. The prestress includes bearing jacking, prestressing tendons and adding weight. However, in the practical engineering of prestressing tendons, most of the pre-stressed stress is applied to the steel beam. Moreover, the application conditions of the adding weight method are limited. Therefore, it is of great significance to study improvement effect of bearing jacking method. This paper mainly studies the influence of jacking amount and span number on the improvement effect of bearing jacking method. Finally, through scientific research and summary, reasonable scientific engineering suggestions are given for related fields.

2. Finite element model
The background is a proposed bridge project in Shaanxi Province. The supporting engineering bridge is a steel-concrete composite continuous beam bridge, the steel beam adopts the double girder, and the section is a typical π section. The upper part of the composite section is a concrete bridge deck,
and the precast concrete bridge deck adopts a full-width prefabricated form. The concrete mark of the precast deck is C50, and C55 concrete is used in the wet joints. The lower part of the section is a typical double steel girder, which is Q345DNH (weather resistant steel). In this paper, span combination of engineering examples is 2×35m, 3×35m, 4×35m. Specific information of the composite section is shown in figures 1 and 2.

![Figure 1. Section at Fulcrum (mm).](image1)

![Figure 2. Mid-span Section (mm).](image2)

Finite element software ABAQUUS CAE (Fig. 3) is used to complete the simulation of steel-concrete composite continuous beam bridge. The bridge deck adopts solid element (C3D8R) and steel beam adopts shell element (S4R).

![Figure 3. Finite element model.](image3)

3. Bearing jacking construction scheme design

In order to highlight the mechanical properties of concrete bridge deck in the negative moment area improved by bearing jacking method, the controlling variable method is used to analysis the steel-concrete continuous beam bridge. The principle of bearing jacking method to reduce the stress of the concrete bridge deck in the negative moment zone is that after the steel beam construction is completed and before the bridge deck construction, the steel beam is jacked up, which causes certain bending deformation of steel beam jacking. After the bridge deck construction is completed and the concrete bridge deck reaches a certain strength, the jacking of steel beam is released, so as to generate the pre-stressing force caused by the bending deformation in the early stage and to effectively reduce the stress level of the concrete bridge deck in the negative moment area of the structure.

The jacking design scheme is to jack up the middle bearing. The construction conditions are designed as: steel beam construction → steel beam jacking → bridge deck construction → fall back → full consideration of time effects.

3.1. jacking scheme for two-span

The two-span beam jacking diagram is shown in Figure 4. The jacking amount is shown in the Table 1.

![Figure 4. Schematic diagram of two-span beam bridge jacking scheme.](image4)
Table 1. Bearing jacking amount (two-span).

| Scheme | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|--------|---|---|---|---|---|---|---|
| Jacking Amount (cm) | 0 | 11 | 13 | 14 | 15 | 16 | 17 |

3.2. jacking scheme for three-span

The three-span beam jacking diagram is shown in Figure 5. The jacking amount is shown in the Table 2.

| Scheme | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--------|---|---|---|---|---|---|---|---|
| Jacking Amount (cm) | 0 | 8 | 9 | 12 | 13 | 15 | 16 | 17 |

3.3. jacking scheme for four-span

The construction conditions in this scheme are designed as: steel beam construction → steel beam jacking (②, ③, ④) → bridge deck construction → fall back (②, ④), partial fall back (③) → bridge deck construction→ fall back(③) → full consideration of time effects. The four-span beam jacking diagram is shown in Figure 6. The jacking amount is shown in the Table 3.

| Scheme | 1 | 2 | 3 | 4 | 5 |
|--------|---|---|---|---|---|
| Jacking Amount (cm) | 9 | 14 | 15 | 16 | 17 |

4. Results analysis of finite element model

4.1. results analysis for two-span

For a two-span steel-concrete composite continuous beam bridge, the stress levels of the steel-concrete composite continuous beam bridge under different jacking amounts are shown in Figure 7 ~ Figure 8.
Figure 7. Maximum stress of steel beam. Figure 8. Maximum stress of concrete deck.

According to the data analysis in Figure 7~8, the effect of bearing jacking on reducing the stress level in negative bending moment area is significant, and its effect is closely related to the jacking amounts. When the jacking amount is 17cm, the tensile stress of bridge deck is less than 1.89MPa specified in the code. When the jacking amount is greater than 17cm, the stress of the steel beam is too large in the construction process. When the stress level is large, a series of problems will occur, which may have adverse effects on the structure. Therefore, it is not suitable to further increase the jacking amount of steel beam.

4.2. results analysis for three-span

For a three-span steel-concrete composite continuous beam bridge, the stress levels of the steel-concrete composite continuous beam bridge under different jacking amounts are shown in Figure 9 ~ Figure 10.

Figure 9. Maximum stress of steel beam. Figure 10. Maximum stress of concrete deck.

From the analysis in Figure 9 ~ Figure 10, it can be known that in the construction scheme designed by this group, the stress level of the steel beam is always at a relatively low level during the construction of the bridge deck, while the tensile stress level of the concrete bridge deck is relatively large. Therefore, in this case, the choice and optimization of the scheme are determined by the tensile stress level of the bridge deck. With the increase of jacking amount, compressive stress appears in the upper part of the concrete bridge deck after jacking is lifted, and the amplitude increases synchronously. After 10 years of construction completed, when the time effect is fully considered, the tension stress on the top of the concrete bridge panel is reduced correspondingly. The stress level of the concrete bridge deck is gradually optimized. When the jacking amount reaches 16cm, the ultimate tensile stress level of the concrete bridge deck is in a reasonable state. When the jacking amount is further increased to 17cm, its stress level is further optimized. However, considering the
convenience of construction and the full use of materials, the jacking amount up to 16.5cm can meet the engineering requirements.

4.3. results analysis for four-span
For a four-span steel-concrete composite continuous beam bridge, the stress levels of the steel-concrete composite continuous beam bridge under different jacking amounts are shown in Figure 11 ~ Figure 12.

![Figure 11. Maximum stress of steel beam.](image1)
![Figure 12. Maximum stress of concrete deck.](image2)

From the analysis in Figure 11 ~ Figure 12, when the jacking amount reaches 16cm and partial fall back (③) is 9.5cm, the concrete stress level is lower than the design limit value. This method is feasible and effective.

5. Conclusions
The stress of the concrete deck in the negative moment area of the steel-concrete composite continuous beam bridge is more complicated, the concrete deck cracks are more serious. This paper mainly carried out a large number of simulation calculations on the influence of bearing jacking method on the stress level of concrete bridge deck in negative moment zone of steel plate-concrete composite continuous beam bridge. Based on the analysis and summary, the following conclusions and engineering suggestions are drawn:

The jacking method is effective to improve the stress level of concrete in negative moment zone. The implementation process is controllable and the effect is obvious. However, there are also some disadvantages in construction, as follows: ① Need to reinforce the steel beam at the jacking position; ② Need large tonnage jacking device; ③ Construction risks.

The improvement is more obvious with fewer span numbers than with more span numbers. Compared with the original design scheme, the stress of concrete deck in bending moment area of two span composite beam is optimized by 67%, while 54% for three-spans and 44% for four-spans. As the number of spans increases, bearing jacking may need to be combined with other measures to reduce tensile stress.

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