Study on Scheme Optimization of bridge reinforcement increasing ratio

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Abstract: The bridge reinforcement methods each method has its advantages and disadvantages. The load-bearing capacity of bridge members is controlled by the ultimate strain of concrete in the compression zone or the ultimate strain of reinforcement in the tension zone, so the selection of the bridge reinforcement method is affected by the section reinforcement ratio. When the reinforcement ratio of the section is between the minimum reinforcement ratio and the critical reinforcement ratio, we should choose the beam bottom reinforcement plan; when the section reinforcement ratio is between the critical reinforcement ratio and the maximum reinforcement ratio, it should be adopted Reinforcement method of bridge deck reinforcement layer.

1. Introduction
Most of the existing bridges have low design load standards, insufficient carrying capacity and traffic capacity, and long-term use, man-made and natural factors cause structural damage, making many bridges gradually unable to adapt to modern traffic requirements. According to statistics from the Ministry of Communications in 2007, there are about 570,000 bridges of various types in my country's highway network, with about 2,319 linear meters, of which more than 98,600 dangerous bridges, accounting for about 17%.

It can be seen that the issue of strengthening and repairing old and dangerous bridges and how to improve their bearing capacity is very urgent. Reinforcing the cost of the bridge is about 10% to 20% of the new bridge costs. Research on old bridge reinforcement or renovation technology can better serve modern traffic.

2. Existing bridge reinforcement methods
Bridge reinforcement methods can be summarized as: Bridge deck reinforcement layer, increasing cross section and rebar, pasting the steel plate, pasting carbon fiber cloth, external prestress, changing the structure of the force system, increasing the main beam, anchor shotcrete. Each method has its advantages and disadvantages and scope of application. By comparison, bridge deck reinforcing layer having a high reliability and the reinforcing long cycle life characteristics.

The bridge slab reinforcement method refers to adding reinforced concrete to the bridge deck to increase the effective height of the main girder and improve the lateral load distribution capacity of the bridge, thereby increasing the single girder bearing capacity or the overall bearing capacity of the bridge structure. According to the "Specifications for strengthening design of highway bridges" (JGB/T J22—2008), the thickness of the newly added concrete should be no less than 100mm, and the strength
should be at least one grade higher than the original design concrete. The main advantage of this method is simple construction, which can greatly improve the bending resistance of the front section of the structure. However, the reinforcement ratio of the component section can achieve better results within a certain range of reinforcement. This paper is based on the smaller value of the ultimate stress of the compressed concrete and the tensile steel bar to convert the critical section reinforcement ratio. Reinforcement ratio as the basis for selection of the structural reinforcement plan.

3. Critical reinforcement ratio
Engineering, in order to prevent the damage of over-reinforced beams and less-reinforced beams, the code stipulates the minimum reinforcement ratio and the maximum reinforcement ratio, denoted by $\rho_{\text{min}}$ and $\rho_{\text{max}}$ respectively. However, considering the latter part of the bridge reinforcement and repair simple and feasible method requires the use of deck reinforcement layer reinforcement method. During the design of the original beam, the need to consider a critical ratio of reinforcement, namely $\rho_c$.

3.1. Judgment of controlled factors after original beam reinforcement
In the reinforcement calculation, it should be judged whether the load-bearing capacity of the beam section is controlled by the original beam’s compressive concrete limit $\varepsilon_{cu}$ or the tensile zone’s limit strain $\varepsilon_{su}$. According to related specification, concrete for C50 or less, the limit strain $\varepsilon_{cu} = 0.0033mm$, steel ultimate strain of $\varepsilon_{su} = 0.01mm$. When the cross-section under load moment, there are two cases, one first tension steel strain reaches its limit, the carrying capacity at this time by the tensile reinforcement section control, corresponding to the critical compression zone height $\xi_s h_{01}$. Second, the concrete compressive strain to the limit, the carrying capacity at this time is controlled by the cross section of the concrete compression zone. Corresponding to the height limit compression zone $\xi_b h_{01}$. Deck reinforcing layer for reinforcing method, only the height $x_2$ compression zone $\xi_s h_{01} \leq x_2 \leq \xi_b h_{01}$ satisfies the reinforcement, this reinforcement method can achieve good reinforcing effect. The cross-section reinforcement ratio calculated by $\xi_s h_{01}$ and $\xi_b h_{01}$ is the critical cross-section reinforcement ratio $\rho_c$ and the maximum reinforcement ratio $\rho_{\text{max}}$ respectively. $\xi_b$ can be calculated by looking up the table, and $\xi_s$ is calculated by formula (1).

$$\xi_s = \frac{\beta \varepsilon_{su}}{\varepsilon_{su} + \varepsilon_{cu}}$$  \hspace{1cm} (1)

In the formula: $\varepsilon_{su}$ — steel ultimate strain, take 0.01mm; $\varepsilon_{cu}$ — the ultimate strain of concrete in the compression zone is 0.0033mm for concrete below C50; $\beta$ — the ratio of the height of the rectangular pressure diagram to the height of the neutral axis assumed by the flat section, 0.8 for concrete below C50.

The respective values are substituted into the formula (1), can be obtained $A = 0.1985$.

3.2. Calculation of critical reinforcement ratio
This paper mainly uses T beams to analyze the critical reinforcement ratio, and mainly considers the flexural reinforcement of the mid-span normal section. The calculation diagram of the T-shaped member by adding concrete to the nip to increase the flexural bearing capacity of its front section is shown in Figure 1.
Through calculation, after obtaining the concrete compression zone height \( x_2 \), the relationship between \( x_2 \) and \( \varepsilon_{mu}h_0 \) needs to be used to determine whether the reinforced section bearing capacity is controlled by the ultimate strain of the compression concrete or the ultimate strain of the tensile steel. When \( x_2 \leq \varepsilon_{mu}h_0 \), for the section after reinforced concrete, the bearing capacity of the normal section is controlled by the ultimate strain \( \varepsilon_{su} \) of the steel bar in the tension zone, and as the strength of the reinforced concrete in the compression zone increases, the height of the compression zone gradually decreases. Therefore, adding value of concrete strength in the compression zone of the component cannot improve its bearing capacity.

The above analysis shows that if you want to add reinforced concrete in the compression zone of the component to improve the bearing capacity of the component, the required condition is \( x_2 \geq \varepsilon_{mu}h_0 \). The height of the critical compression zone is:

\[
x_2 = \varepsilon_{mu}h_0
\]

(2)

Through formula (2), further calculate the ratio of tensile steel bars.

\[
A_c = \frac{f_{cd2}b h_j^2}{f_{cd1}b h_j^2 + f_{cd1}(x_2-h_{j2})}
\]

\[
\rho_c = \frac{A_c}{bh_{01}}
\]

(3)

(4)

In the formula: \( f_{cd2} \) — design value of Post-pouring concrete strength; \( f_{cd1} \) — design value of original concrete strength; \( h_{j2} \) — post-pouring concrete thickness. \( x_2 \) — height of section compression zone after reinforcement; \( f_{cd} \) — value of steel bar strength; \( b_j \) — effective width of section.

Through a large number of statistical analysis, it is concluded that \( a_s = 110 \text{mm} \) of a standard span reinforced concrete T-beam bridge. In this paper, \( a_s = 110 \text{mm} \), and the reinforcement thickness is \( h_{j2} = 100 \text{mm} \), the analysis shows that the critical reinforcement ratio of reinforced concrete simply supported T-beam bridges with different spans varies with the strength of the design value of original concrete strength and different types of steel bars as shown in Figure 2—Figure 5.

![Fig.1 Schematic diagram of calculation of flexural bearing capacity of front section of concrete members in nip](image1)

Fig.1 Schematic diagram of calculation of flexural bearing capacity of front section of concrete members in nip
In this paper, a 10m-span simply supported T-beam bridge is further analyzed. Calculate the minimum reinforcement ratio and the maximum reinforcement ratio according to relevant specifications, and calculate the critical reinforcement ratio (reinforcement thickness $h=100\text{mm}$) according to the scheme of calculating the critical reinforcement ratio of steel bars in this paper. The three reinforcement schemes of bridge deck reinforcement method, steel plate reinforcement method and carbon fiber cloth reinforcement method are compared and optimized. Based on the above data, the optimal plans for reinforcement schemes with different original concrete strength configurations with different types of steel bars are drawn.

It can be seen from the figure above that the minimum reinforcement ratio, maximum reinforcement ratio and critical reinforcement ratio divide the reinforcement plan into zone A and zone B. The compressive concrete in zone A first reaches the ultimate strain, and the bearing capacity of the section is determined by Concrete control in the compression zone, the reinforcement ratio of the original...
section meets $\rho_\ell \leq \rho \leq \rho_{\text{max}}$. Considering the reliability after reinforcement, the service life of the components after reinforcement, and the convenience of construction, the bridge deck reinforcement layer reinforcement method should be selected for reinforcement; The tensile steel bar in zone B reaches its ultimate strain first, the bearing capacity of the section is controlled by the tensile steel bar, and the reinforcement ratio of the beam section satisfies $\rho_{\text{min}} \leq \rho \leq \rho_\ell$. The bridge deck reinforcement method should not be selected, but should be pasted at the bottom of the beam. Steel plate reinforcement method or fiber cloth reinforcement method and other reinforcement methods at the bottom of the beam.

5. conclusion
Through the above analysis, the following conclusions can be drawn:

(1) If the reinforcement ratio of the original section meets $\rho_{\text{min}} \leq \rho \leq \rho_\ell$, the bridge deck reinforcement method should not be selected, but the steel plate reinforcement method or fiber cloth reinforcement method at the bottom of the beam should be selected.

(2) If the reinforcement ratio of the original section satisfies $\rho_\ell \leq \rho \leq \rho_{\text{max}}$, considering the reliability after reinforcement, the service life of members after reinforcement, and the convenience of construction, the bridge deck reinforcement layer reinforcement method should be selected for reinforcement.

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