Research on Calculation on Overturning Resistance of Highway Bridge and Design Scheme for Reinforcement and Reconstruction

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Abstract

Recently, the buildings of bridges were made in concentrated traffic areas of cities with the acceleration of urbanization process and increase in the traffic, in order to relieve the traffic stream in related region. However, the researches on highway bridges are still in their infancies due to the unavailability of competent department's rules for the overturning resistance of highway and bridge, an effective reinforcement measures for highway bridges, causing occasional occurrence of overturning urban highway bridges, adding certain potential safety hazards to highway and bridge projects and seriously threatening the safety of related persons. For this reason, overturning resistance design for urban design for highway bridges and evaluation standards for construction safety are firstly analyzed in this paper, then the overturning resistance load of urban highway bridges are subject to the calculation and selection, and then the reinforcement scheme for highway bridges are given with the aim of raising theoretical reference for highway and bridge projects.

Keywords: Urban Highway Bridges, Overturning Resistance, Checking Calculation, Design Scheme.

1. RESEARCH BACKGROUND

1.1 Literature review

In current stage, as overturning resistant collapse accidents of highway bridges occurred frequently, gradually causing researches of many scholars on check calculation on related parameters of highway bridges, but uniform standard is available to regulate the calculation process, related calculation load and the criterion for overturning resistance lack of effective standards (Liu et al., 2015). Furthermore, the highway bridges are at risks of disequilibrium with the increase in the load of heavy vehicle, the stability of the overpass for some highway is subject to a series of studies with relevant research method, targeted corresponding reinforcement measures are taken according to the results of studies, and reference and basis for the construction of related highway bridges (Cui and Ma, 2017). Chinese administration lacks of related regulations to the stability of the highway and bridges, to the domestic research is still in its infancy, the bridge is more a lack of a set of reinforcement measures. Through the analysis on causes for failure of highway bridges, and to put forward some Bridges capsized checking project, and a feasible reinforcement scheme may be raised according to calculation results (Wu, 2010). And, the reason and strategy for the overturning of highway bridges are subject to systematic analysis, the reasons for overturning of highway and bridges are evaluated by combining with the status quo of development of urban highway bridges, and reinforcement effects of highway bridges are designed to make its safety performance in line with the state standards, facilitate the design of highway bridges and the progress of related projects, improve the efficiency of construction projects, ensure the safety of highway bridges (Xie, 2017). By combining the examples for the design of highway bridges, several feasible bridge reinforcement schemes are raised on the basis of the research on the reasons for overturning, a series of comparison analysis, and optimal reinforcement scheme may be secured (Xu and Yang, 2017).

1.2 Research purposes

Common highway works are featured with large quantity, high cost, unpredictability and difficult technology. By combining actual situation of related work, various engineering protection solutions may be raised, and optimal reinforcement design scheme may be compared and selected by reference to the construction site, engineering cost and other factors to make it coincide with related practice effect of works (Li, 2012). In order to conduct thorough review on the reasons for overturning of highway bridges, provide theoretical references and basis for subsequent projects, and take checking calculation on the vehicle weight born by the bridge, the load model of
highway bridge vehicle may be concluded by combining with the results of related areas, and then the safety of highway bridges are subject to the checking calculation under different vehicle loads by the comparison and analysis on examples (Zhao et al., 2017). In recent years, highway bridges are widely used in the sites of highways where there is substantial ramps, the overload of the vehicle is frequently found above the bridge, thereby gradually reducing the safety of highway bridges and frequent occurrence of collapse accidents above bridges, and seriously threatening safety of people and works (Wang et al., 2014). Related data is subject to the checking calculation through comparative analysis on reasons for the overturning of highway bridges, then targeted reinforcement design scheme is proposed according to the results of checking calculation, delivering certain economic and social effect on the improvement of stability of highway bridges, and theoretical references may be set for the framework of highway bridges in the future (Shi and Chen, 2015). Presently, the overturning events of bridges in China frequently occur, it is necessary to conduct detailed research on the reinforcement performance of bridges and to present checking calculation method and stability evaluation criterion on the bridge to further guarantee the safety of the bridge operation, delivering important application value for bridge designs later (Guan, 2017). Therefore, the checking calculation on the overturning resistance of urban highway bridge and design scheme of reinforcement and reconstruction casts vital significance.

2. OVER TURNING RESISTANCE DESIGN FOR URBAN HIGHWAY BRIDGES AND SAFETY ASSESSMENT ON CONSTRUCTION

2.1 Overturning resistance design for urban highway bridges

Strict criterion is imposed on urban overturning design for urban highway and bridges, the managements and safety checks at different levels are required, in practical construction of urban roads, the bridge of the road is an extremely practical form in the design and the construction of urban roads, therefore such roads and bridges are widely used in practical applications, and detailed investigation is required on the overturning resistance of urban roads. In the process of inspection, firstly it is required to actively conduct inspections on all factors of the bridge design, sort out the construction data according to design requirements, further compare and analyze related overturning resistance parameters, and further acquire the overturning resistance factors impairing the safety of urban road. The overturning resistance parameters of urban highway bridges including overall design of the bridge structure, design time of bridge and bridge quality indicate proper curve design of bearing standards of the bridge. Timely grasp of the information relating to the highway bridge may facilitate thorough understanding on the safety of the highway bridges in order to further test the operation of urban high bridges.

Meanwhile, in order to facilitate the understanding the overturning resistance of urban highway bridge, guarantee the safety operation of the urban roads. It may be concluded from previous experience in overturning resistance of urban highway bridge building, the application cycle and weight bearing of central pier of urban highway bridge focuses on piers on both sides of the roads and bridges, and the construction diagram for urban highway bridge is provided as shown in Figure 1. It is further pointed out that the overturning resistance of central tier is required to be strengthened and greater than that of piers on both sides when urban bridge design is made.

![Figure 1. Construction Diagram for Overturning Resistance of Urban Highway Bridge](image)

2.2 Safety evaluation on overturning resistance construction of urban highway bridge

Main bearing force of urban highway bridges also concentrates on the central piers of the bridge, the deck width and the distance between piers city during te construction of highway bridge will be influenced by overturning resistance factors, and the overturning resistance of the bridge itself must be less than that of highways between bridges when the applications of urban bridge buildings are compared and analyzed, the safety of urban highway
bridge is to be timely checked, and the overturning resistance of urban highway bridge is to be subject to the maintenance and improvement according to actual situation.

Meanwhile, in order to conduct further studies on the safety factors of overturning resistance of urban highway bridge, related management department of urban highway bridge conducted the analysis and research on the safety factors of overturning resistance of the bridge, and only the safety factors of urban highway bridges are inconformity with relevant standards in the course of the study can safe operation of the highway bridge be secured. When the research object of overturning resistance of urban highway is made, it is required to select appropriate way to conduct the research and evaluation on overturning resistance of urban highway bridges. The studies on the support and connection of pier are mainly involved in the process of research on safety factors of urban road bridges. If the bearing capacity of the pier for urban highway bridge is greater than preset factors, the situation of vacant urban highway bridge will appear, thereby affecting the quality of urban highway bridge.

Therefore, the overturning resistance design of central pier for the bridge during the design and construction of urban high bridge, firstly it is required to accurately define the distance during the construction phase to further secure the safety of the construction of the bridge pier the next phase, and it is required to guarantee independent support state of the pier and the accuracy of measured data of overturning resistance of urban highway bridge. Additionally, if the overturning property of urban highway bridge is closely related to the supporting effect of bearing support, and the bridge structure starts to overturn when the bridge bearing fails or escapes. Therefore, it is required to conduct the checking calculation on the fall-off details of pier supports for urban highway bridge with standard combination between the makeup load of vehicle and dead load of structure and to further determine the overturning resistance of the bridge. Although the bridge support drop-off technique is conservative to determine the overturning capacity of the bridge, this technique is favorable for checking such computations result.

### 3. OVERTURNING CHECKING LOAD AND CRITERION OF URBAN HIGHWAY BRIDGE

#### 3.1 Checking load

According to analysis of urban highway bridge accidents and combining above safety evaluation of design and construction of urban highway bridge, this paper found that there is urban highway bridge overturning caused by heavy overload in China now, so anti-overturning checking and reinforcement design of bridge shall be made. Meanwhile, according to the *Regulations on Motor Vehicle Loading in Anti-overturning Checking of Bridge Superstructure* and survey results of actual operation of urban highway bridges in China, this paper carried out anti-overturning checking of urban highway bridge under four load conditions below respectively: Condition 1, highway (Grade I lane load)

Condition 2, 1.3 times highway (Grade I lane load)

Condition 3, dense 55-ton vehicle load

Condition 4, dense 1.3 times normative 55-ton vehicle load

#### 3.2 Checking criterion

This paper carried out anti-overturning checking of urban highway bridge pier according to relevant provisions of checking criterion in final draft of *Code Highway Reinforced Concrete and Prestressed Concrete Bridges Culverts* (JTG D62-2012). And it is clearly pointed out that during verification process, when all bridge piers are located inside the bridge, the bridge overturning line is the line between bridge outside and bridge bearing; when all bridge piers are located outside the bridge, the bridge overturning line is the line between outside bridge bearing and pier. Overturning stability coefficient of bridge must meet \( k_{af} = \frac{\sum R_{Gi}x_i}{(1+\mu)(q_sG+P_kE)} > 2.5 \), where, \( k_{af} \) represents anti-overturning coefficient, \( R_{Gi} \) represents the counter-force of each bearing at the time of normal bridge operation, \( x_i \) is the distance between bearings, \( \mu \) is impact force at the time of normal bridge operation, \( q_s \) is uniform load force of bridge lane load, \( p_k \) is centralized ground load of lane load, \( G \) is the area of bridge overturning axis and bridge lane, and \( e \) is vertical distance between bridge lane and overturning line. Further verify selected bridge checking load according to above bridge anti-overturning criterion and obtain the results shown in Table 1.
Table 1 Anti-overturning Stability Results of Urban Highway Bridge

<table>
<thead>
<tr>
<th>Load</th>
<th>Anti-overturning coefficient of urban highway bridge</th>
<th>Standard anti-overturning coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition 1</td>
<td>3.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Condition 2</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Condition 3</td>
<td>2.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Condition 4</td>
<td>1.6</td>
<td>2.5</td>
</tr>
</tbody>
</table>

We can see from Table 1 that urban highway traffic meets the bridge overturning requirements only under Condition 1 and 2, so urban highway bridge should be reinforced and reconstructed necessarily to ensure actually normal use of bridge.

4. URBAN HIGHWAY BRIDGE REINFORCEMENT SCHEME

4.1 New pier column to increase bridge anti-overturning

To ensure normal use of urban highway bridge, improve bridge anti-overturning and conduct convenient construction, this paper adopted the scheme of increasing cross section of original independent column pier of bridge. Specifically, build new concreting columns on two sides of original pier column of bridge transversely to disperse the stress of original pier column to prolong service life. Meanwhile, new concreting columns connect with original column of bridge with rebar. Building new concreting columns is to change original single-point support of bridge to two-point support to increase bridge anti-overturning. In addition, current urban highway bridge mainly uses three-span structure and bridge pier has encroached on sidewalk, extending original pier is not suitable. Building new concreting columns can further reduce the occupation of sidewalk and blocking of driver’s vision.

4.2 Separated interchange for bridge reinforcement

Anti-overturning of urban highway separated bridge in China also hardly meets relevant standard now, so this paper mainly built new reinforced beam and tension-compression bearing outside the web and under the flange of main bridge at bridge abutment support to increase the bridge overturning through design and calculation. Specifically, when build new reinforced beam, remove the baffle outside main bridge and weld new reinforced beam and main bridge as a whole with chemical anchor. Build the tension-compression bearing under new beam to increase supporting points on two sides of bridge, improve bridge anti-overturning under unbalance load, and further enhance integral bridge anti-overturning ability.

5. CONCLUSION

To sum up, through analysis of safety standards for anti-overturning design and construction of urban highway bridge and checking of related load, this paper proposed urban highway bridge reinforcement design scheme, making it have great application value in highway field, and effectively solving overturning problem of highway bridge, greatly improving the safety of highway bridge, and this reinforcement design method also has broad development prospect accordingly. We believe that this design scheme must be widely applied in relevant fields and can effectively improve the highway bridge construction efficiency.

REFERENCES

Xie J.X. (2017). Study on the anti-overturning design and construction strategy of highway and urban road bridge. Building materials and decoration, 10 (36), 86-86.