The Seismic Ductility Capability Influence Factors Analysis of Integral Station-Bridge Frame Structure

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Abstract: When performance-based structure design is adopted, the structure has a clear structural performance objective under the specified setting criteria, and the performance target is specifically reflected in the damage degree of the structure. The components of the “bridge-building” structure are mainly concentrated on the pier column of the station hall. Therefore, the degree of damage of the pier column of the station hall layer reflects the degree of damage of the structure to a certain extent. This paper describes the earthquake-resistant ductility of the combined bridge structure. The performance indexes were quantitatively analyzed. Then, through the elasto-plastic analysis of the structure, the influence of various factors on the seismic ductility of the structure was obtained. The ductility of the piers under the earthquake was discussed, which provided a reference for structural design.

1. Basic concept of ductile earthquake resistance
The seismic design method based on ductility[1] is the main method of structural design at this stage. The dynamic behavior of the structure exhibiting nonlinear changes is the research basis of the method. Its main idea is to improve the setting of structural plastic hinge and improve the limit of structural members. Deformation ability and hysteresis ability[2]. It is the basic idea of ductility design to use the local deformation of the member to consume energy to ensure the proper ductility and strength of the structure as a whole[3].

2. Quantification of ductility indicators
The curvature ductility ratio is widely used to quantify the ductility index of the structure, which is also commonly referred to as curvature ductility[4].

The inelastic deformation ability[5, 6] of steel malleable members is mostly from the rotation of the section of the plastic hinge. The rotation ability can be reflected by the curvature ratio of the section. The wallpaper of the post-yield curvature and the yield curvature is defined as the curvature ductility ratio. The design is concerned with the maximum curvature ductility ratio \( \varphi_p \), which is defined as:

\[
\varphi_p = \frac{\varphi_y}{\varphi_p}
\]

In the formula, \( \varphi_y \) with \( \varphi_p \). The yield curvature and the ultimate curvature of the section of the plastic hinge region are respectively indicated.

3. Model establishment
Guzhenkou South Station is a two-story island station on the road side. The structural form adopts a four-column frame structure of a combined bridge structure system, and the section bridge is overlapped
with the station through the ox leg. The total length of the station is 126m, including 85m for the main body of the station and 41m for the auxiliary equipment. The main body of the station is two floors above ground, from the bottom to the top, the exhibition hall floor and the platform floor.

4. Analysis of ductility performance of pier columns

When the moment curvature analysis of the component is carried out\cite{8, 9}, kl1 is selected as the analysis object, and the change rules of the delay characteristics of the other pier columns are the same as those of kl1, and no further analysis is performed. When the whole structure is subjected to linear analysis. Under some factors, the analysis results of other piers are also compared.

4.1 Influence of axial compression ratio

The axial compression ratio is the ratio of the design value of the axial pressure of the pier column to the product of the total cross-sectional area of the column and the design value of the compressive strength of the concrete,

$$ u = \frac{N}{Af_c} $$

Where: $u$ is the axial compression ratio, $A$ is the total cross-sectional area of the column, and $N$ is the design value of the column axis pressure. $f_c$ Design values for concrete compressive strength.

In order to avoid the high axial pressure ratio, the axial compression ratio limit selected in this paper is 0.3.

In order to analyze the influence of axial compression ratio on the ductility of the pier column, the pier column kl1 is analyzed in detail, and the response law of the other pier columns is similar to that of kl1. Finally, the ductility of the four piers is compared with the axial pressure.

Figure 2 Variations of yield and ultimate moments

Figure 3 shows the change in yield curvature and ultimate curvature as a function of axial compression ratio. As the axial compression ratio increases, the limit curvature of the section decreases, and the yield curvature increases, but the change is not obvious. Therefore, the maximum curvature ductility coefficient of the section is basically controlled only by the section limit curvature.
As shown in Fig. 4, as the axial compression ratio increases, the curvature ductility coefficient decreases. As the axial compression ratio increases, the ultimate curvature decreases and the yield curvature increases, resulting in a decrease in the curvature ductility coefficient, which adversely affects the ductility of the pier. When the axial pressure ratio is increased to 0.25, the value of the curvature ductility coefficient remains substantially unchanged. In order to ensure the ductility of the pier, it is not suitable to use a large axial pressure ratio.

Figure 5 shows the variation of the curvature ductility coefficient of four types of pier columns with axial force. It can be seen from the figure that the curvature ductility coefficients of different types of pier columns are different under the same axial compression ratio, but the values are not much different, indicating that the ductility of various types of piers is the same at the same axial compression ratio. almost the same.

4.2 Influence of longitudinal reinforcement strength
Taking KL1 as the research object, the model with the standard tensile strength of steel bars of 300MPa, 335MPa was established for price analysis.
By comparing the calculated data of three strength longitudinal steel bars, it can be seen that increasing the strength of the longitudinal reinforcement reduces the ductility performance by 39%. The response to the maximum curvature is reduced by 31%. Therefore, in order to ensure the ductility of the structure, it is best not to use high-strength steel bars. However, high-strength steel bars can reduce the corner angle of the section, so the design should be considered comprehensively.

4.3 Effect of longitudinal reinforcement ratio

K11 is selected as the analysis object, and the influence of the reinforcement ratio on the ductility is studied by changing its reinforcement ratio. In the structural design, if the reinforcement ratio is changed, it is often changed with the same type of pier. In this paper, when changing the reinforcement ratio, not only the one column is changed, but the same type, and the remaining pillar reinforcement ratio remains unchanged.

By comparing the calculated data of three strength longitudinal steel bars, it can be seen that increasing the strength of the longitudinal reinforcement reduces the ductility performance by 39%. The response to the maximum curvature is reduced by 31%. Therefore, in order to ensure the ductility of the structure, it is best not to use high-strength steel bars. However, high-strength steel bars can reduce the corner angle of the section, so the design should be considered comprehensively.

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Fig.7 Effect of reinforcement ratio on longitudinal ductility

It can be seen from Fig.7 that increasing the longitudinal reinforcement ratio does not improve the ductility of the pier, but it will reduce it. The maximum curvature and the top displacement will decrease rapidly when the reinforcement ratio is less than 1.5%. There is little change between ~2.8%. Considering the recommendation, the longitudinal reinforcement ratio is about 1.5%.
4.4 Influence of concrete strength
Taking kl1 as the analysis object, in order to compare and analyze the influence of concrete strength on the ductility of the pier, this section selects seven kinds of labeled concrete between c20 and c50 for analysis.

| Concrete strength | Yield curvature | Equivalent yield curvature | Limit curvature | Curvature ductility coefficient | Yield bending moment | Ultimate bending moment |
|-------------------|-----------------|----------------------------|-----------------|-------------------------------|----------------------|-------------------------|
| C20               | 2.8681202       | 3.95628932                 | 7.8502254       | 2.737062902                   | 5482.6223            | 6367.7797               |
| C25               | 2.9117172       | 3.883104395                | 8.0954409       | 2.780297772                   | 5517.3255            | 6718.9558               |
| C30               | 2.9705201       | 3.818720264                | 8.3988578       | 2.827403154                   | 5686.1681            | 7024.9388               |
| C35               | 3.047452        | 3.77408452                 | 8.834437        | 2.915039721                   | 5730.1733            | 7280.8953               |
| C40               | 3.1511692       | 3.744051198                | 9.5434138       | 3.028531032                   | 5730.7133            | 7691.3142               |
| C45               | 3.2940245       | 3.721169599                | 10.10602        | 3.069073247                   | 5730.1733            | 7691.3142               |
| C50               | 3.4701105       | 3.696502065                | 10.671084       | 3.075142488                   | 5777.4579            | 7843.8554               |

It can be seen from Table 2 that when other influencing factors remain unchanged, only the concrete strength grade is increased, and the yield curvature, ultimate curvature, yield bending moment and ultimate bending moment of the pier column increase with the increase of concrete strength. Therefore, under the same conditions, the strength of the concrete can be improved, and the ductility of the pier can be improved. However, when the higher concrete grade is used, the improvement of the ductility of the pier is not obvious, so it is not suitable to use high-grade concrete to improve the pier ductility.

4.5 Influence of section size
KL1 was used as the analysis object to study the influence of the change of section size on the ductility of the pier column. The change is the KL1 type of pier. The section size varies from 1000mm to 1500mm.

| section | Yield curvature | Equivalent yield curvature | Limit curvature | Curvature ductility coefficient | Yield bending moment | Ultimate bending moment | Response maximum curvature | Pier top displacement |
|---------|-----------------|----------------------------|-----------------|-------------------------------|----------------------|-------------------------|---------------------------|----------------------|
| 1000    | 3.634864        | 4.50886878                 | 11.6887        | 3.216                         | 3548.814             | 4616.94                 | 6.531                     | 4.908                |
| 1100    | 3.256540        | 4.04453999                 | 10.5860        | 3.251                         | 4737.302             | 6190.52                 | 4.294                     | 4.044                |
| 1200    | 3.9117171       | 3.721169595                | 10.10602       | 3.472                         | 5730.1733            | 7691.31                 | 5.711                     | 4.448                |
| 1300    | 2.67048         | 3.34972806                 | 9.56186        | 3.581                         | 7395.217             | 9780.03                 | 3.79                      | 3.797                |
| 1400    | 2.37244         | 2.9950817                  | 8.98849        | 3.789                         | 9281.67              | 11847.32                | 2.955                     | 3.36                 |
| 1500    | 2.17320         | 2.8696752                  | 8.57958        | 3.954                         | 10785.45             | 14335.1                 | 2.964                     | 3.447                |

It can be seen from Table 4 that, under the condition that other influencing factors are unchanged, only the size of the pillar column is changed. The curvature ductility coefficient, the yield bending moment and the ultimate bending moment increase with the increase of the section size, and the section size increases. The axial compression ratio is reduced, and the reduction of the axial pressure can increase the ductility of the pier. Therefore, increasing the size of the pier column has a significant effect on improving the ductility of the pier column.

5. Conclusion
Based on the basic concept of ductile seismic resistance, this paper analyzes some factors affecting the ductility of piers and columns, and obtains the influence of various factors on the ductility of piers.

(1) When the parameters of other influencing factors are constant, as the axial compression ratio increases, the ductility of the pier column decreases, but when the axial compression ratio increases to a certain extent, the axial compression ratio increases to the ductility of the pier column. The impact will be weakened.
(2) As the strength of the longitudinal reinforcement increases, the ductility of the pier column decreases, but at the same time, the curvature of the section is reduced, and the design should be considered comprehensively.

(3) With the increase of the longitudinal reinforcement ratio, the ductility of the pier column is reduced, and the displacement of the pier top and the response curvature are not obvious when the reinforcement ratio is between 1.5% and 2.8%. Therefore, the longitudinal reinforcement ratio is recommended. At around 1.5%.

(4) Under the same conditions, improving the strength grade of concrete can improve the ductility of the pier column, but when the concrete grade is higher, the effect is not obvious;

(5) The increase in section size is advantageous for the ductility of the pier.

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