Appliance of Orthogonal Experiment in Bridges Seismic Engineering

Yongjun ZHOU
Lecturer
Chang'an university
Xi'an, China
zyj@gl.chd.edu.cn

Shuanhai HE
Professor
Chang'an university
Xi'an, China
Keji-1@chd.edu.cn

Gang ZHANG
EngD
Chang'an university
Xi'an, China
Zhangg_2004@126.com

Wei QUAN
EngD
Dalian university of technology
Dalian, China
bridgeqw@sohu.com

Yu ZHAO
Associate professor
Chang'an university
Xi'an, China
zy@gl.chd.edu.cn

Summary

Continuous rigid frame bridges are widely applied in China. There are many influence parameters of seismic response for the long-span continuous rigid frame bridges with high piers. Using orthogonal experimental design, orthogonal experimental table is laid out to arrange different factors, and based on finite element method, numerical models are built to figure out the seismic response sensitive factors for the rigid frame bridges, the parameters of which include the height of pier, the boundary simulation mode for the substructure, the number of spans, the wave-travelling effect and the type of earthquake wave. The results indicate that the pier's height and the substructure boundary simulation mode are the sensitive parameters for the structural seismic response. The study shows that the calculation amount can be greatly reduced with the help of orthogonal experimental table, so it is an effective method to analyze sensitive parameters.

Keywords: bridge engineering; continuous rigid frame bridge; orthogonal experimental design; seismic response; parameter analysis.

1. Introduction

At the bridge's primary design stage, there are so many factors which will influence the seismic response of the structure, the computation will extremely huge if every factor is analyzed respectively. As it can reduce the numbers of experiment, the orthogonal experiment has been widely used in machine design, mix design and so on, but it is seldom used in the civil engineering, especially in the aspect of bridge seismic design. The finite element analysis is used in the paper for the continuous rigid frame bridge, regarding the model parameters as variables, and taking a numerical analysis as an experiment. Using the orthogonal experiment design and the statistical analysis method, the sensitivity of seismic response is studied when several design parameters act on the structure, then the primary parameters and the secondary parameters are analyzed.

2. Orthogonal experiment design

The orthogonal experiment is an effective method to arrange the multi-factors experiment and to solve the multi-factor experiment problem. The statistical analysis of orthogonal experiment design includes extreme value analysis and variance analysis. The extreme value analysis is to distinguish the primary and secondary order of various factors' effects on the examination index, variance analysis is to divide the undulation of examination index into two parts.

3. Parameter sensitivity analysis

A long-span continuous rigid frame bridges with high pier is presented for the experiment, the prototype span of which is 110+200+200+110 meters, and single-box ,single-cell is used for the superstructure. This bridge sites on Ⅱ type foundation, the earthquake acceleration motion peak of the location is 0.20g.

In order to analyze the seismic parameters effects on the structure seismic response, $L_{18}(6^1 \times 3^4)$ orthogonal is adopted to arrange the experiment(Table 1).

https://doi.org/10.2749/222137908796294072
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Table 1: Numerical Parameters Analysis of Seismic Responses

Factors	A Pier Height(m)	B Model of Substructure	C Wave Travelling Velocity(m.s^{-1})	D Span Numbers	E Earthquake Wave Type
Level 1	60	Confined at pier bottom	400	3span	El Centro
Level 2	70	SSI	1000	4span	Taft
Level 3	80	Confined at pile bottom	∞	5span	Tianjin
Level 4	90	—	—	—	—
Level 5	100	—	—	—	—
Level 6	110	—	—	—	—

Using the traditional method, 486 experiments are needed to accomplish the overlapping experiments, but using the orthogonal testing method, only 18 experiments are needed.

From the extreme value analysis and variance analysis, it shows that:

(1)To the moment of the beam root, the obvious influence factor is A, namely changing the bridge pier height may greatly affects the seismic response of the superstructure's negative moment. Next is the factor B, namely the computation model of substructure. Spans of bridge have the smallest influence. At the same time by the extreme value analysis, as the pier' height increase, the superstructure negative moment reduces gradually, the superstructure negative moment increased when considering SSI effects.

(2)To the moment of pier top, the influence of factor is A and B. The type of earthquake wave has the least sensitivity to the moment. With the increasing of pier' height, the pier top moment reduces gradually, when the travelling wave effect, the span numbers of bridge and earthquake wave type are considered, the pier top moments change slowly, and when SSI effects is considered, the pier top moment is reduced.

(3)To the moment of pier bottom, the influence of factor A and B is also fundamental, travelling wave has the smallest effects, with the increasing of pier' height, the pier bottom moment reduces gradually, whereas, the response begins to rise at certain height. When the wave-travelling effect and the span numbers of bridge are considered, the pier bottom moments change slowly, when SSI effects is considered, the pier bottom moment is reduced.

(4) To the shear and the axial force of the pier bottom, the analysis results are similar to the moment of the pier bottom.

(5)To the maximum displacement, the factor A and B still occupy the first position, next are span numbers and the wave-travelling effect, finally is the earthquake wave type. But generally speaking, the involved factors bring equal effects to the average displacement.

4. Conclusion

In the numeral simulation of seismic response analysis, the model parameters selection is quite important to the results. This paper regards the model parameter as influence factors, using the orthogonal experiment design to analyze the sensitivity of the parameters of the model, and distinguishes primary parameters and the second parameters. In the paper, through the parameter sensitive analysis, the primary factors of affecting structural internal force and displacement are the pier' height and the substructure computation model; If the maximum peak of earthquake wave is the same, in most cases, the structural response has no relationship with the type of earthquake wave, the wave-travelling effect's influence is also not clear in the paper, namely it is the secondary factor.