A Numerical Comparison Between Static Methods For Redundancy of Steel Truss Through Bridges

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Summary

This paper investigates redundancy analysis methods and compares the result of linear redundancy analysis method with the result of nonlinear redundancy analysis method. The results showed that the nonlinear approach judged a higher redundant level than the linear one did.

Keywords: Redundancy, steel truss bridges, damages, linear analysis, nonlinear analysis.

1. Introduction

The bridge redundancy is the capacity of the bridge superstructure to continue to carry loads after the damage to or the failure of one of its members. Such redundancy analysis methods by URS [1], E. Yamaguchi [2] and H. Nagatani [3] are about a linear analysis method. The nonlinear method that is well known for high accuracy is not study much in term of redundancy analysis. Hence, this paper investigated a completed nonlinear method of redundancy analysis. The result of the nonlinear approach was compared to result of the linear approach.

2. Static redundancy analysis

2.1 Linear redundancy

The linear redundancy method was presented in studies of URS [1] and H. Nagatani [3]. The robustness of bridges was assessed by strength checking of every single member of the bridges. Because of different behavior between tensile members and compressive members, those members are treated separately in equation (1) which is for tensile members and in equation (2) which is for compressive members. If any member gives $R \geq 1$, that member violates its safety. That failed member leads to collapse of the whole bridge.

$$\mathrm{R} = \frac{\mathrm{N}}{N_p} + \left(\frac{\mathrm{M}}{M_p}\right)_{\text{out-plane}} + \left(\frac{\mathrm{M}}{M_p}\right)_{\text{in-plane}} \tag{1}$$

$$\mathrm{R} = \frac{\mathrm{N}}{N_u} + \left(\frac{1}{1-\dfrac{N}{N_E}}\right)\left(\frac{\mathrm{M_{eq}}}{M_p}\right)_{\text{out-plane}} + \left(\frac{1}{1-\dfrac{N}{N_E}}\right)\left(\frac{\mathrm{M_{eq}}}{M_p}\right)_{\text{in-plane}} \tag{2}$$

2.2 Nonlinear redundancy

The second- order analysis with distributed plasticity was employed in conjuntion with phased analysis option. The steel material strength was model by a trilinear model with the last horizontal range accounts the softening effect. The softening range starts at strain of $\alpha\varepsilon_y$ where the peak point of loading set in material test is reached. Reinforced concrete was assumed a perfected plastic with yield stress equals compressive strength f'_{ck} of concrete. The initial imperfection of truss members was accounted. The final collapse of the structure was defined by either buckling of a compressive member or defined break of a tensile member. The defined break forms when the strain reaches an ultimate strain of 5%. The buckling appears when the response-loading curve passes the peak.

3. Numerical comparisons

3.1 Analysed bridge and finite element model

A typical steel truss-type bridge in Niigata, Japan is used to illustrate the research findings. The bridge is modeled in a 3D model with the virtual break on 4 candidates of Fracture Critical Members (FCM), D1, D2, D4 and U1 as shown in Fig. 1. Each candidate was assumed breaking at a time of analysis.

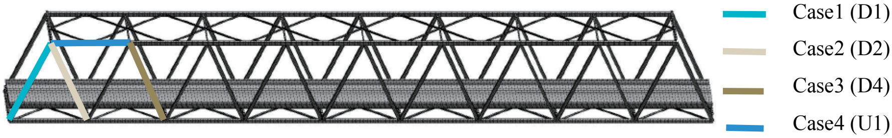

Fig. 1 FEM model and cases of study

3.2 Comparison and discussions

Table 1: Comparison between linear and nonlinear redundancy

	α=1,00 (No dynamic effect)		α=1,854 (with dynamic effect)	
	Linear	Nonlinear	Linear	Nonlinear
FCMs	D1,D2,U1	None	D1,D2,D4,U1	None
Redundant	Not redundant	Redundant	Not redundant	Redundant

Table 1 showed that nonlinear redundancy concluded that the bridge is redundant in all cases while linear approach found the bridge is not redundant. In addition, all of the four candidates are identified as FCMs by linear redundancy while none of them is FCM in nonlinear redundancy. The investigation of sectional forces proved that the nonlinear redundancy enlarged the member strength. This indicated a higher redundancy level was found in nonlinear approach. The virtual break is commonly considered a temporary deterioration, has to be addressed immediately after it is discovered. Hence, it is a waste the strength of structure if a linear elastic method is employed to assess the bridge redundancy. Nonlinear method has even though more risk than linear elastic does, this method seems to be reasonable solution for redundancy evaluation.

4. Conclusions

Two static methods of redundancy analysis were investigated. The nonlinear method assessed a higher redundancy level than linear method did. The linear approach may give a high safety level for redundancy assessment, but it wastes the strength of structures for a temporary damage. Hence, it is reasonable to use a nonlinear redundancy for bridge redundancy analysis.

References

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