Proposal of nonlinear dynamic analytical method taking account of effects of local buckling damage

Toshitaka Yamao
Professor
Kumamoto University
Kumamoto, Japan
tyamao@kumamoto-u. ac .jp

Akito Morimitsu
Civil Engineer
ARC Information Systems
Tokyo, Japan

Atavit Sujaritpong
Lecturer
Ramkhamhaeng University
Bangkok, Thailand

Faizal Chandra
Master Course Student
Kumamoto University
Kumamoto, Japan

Summary

The nonlinear dynamic analytical method taking account of effects of local buckling damage was developed. The stress-strain hysteresis model based on obtained average stress versus average strain relationship was introduced into the elasto-plastic dynamic analysis program with a fiber beam element. The seismic response analysis of several bridge piers and frame structure models were performed by this proposed analytical method. The validity and effectively of the present method was shown by comparing the numerical results and the experimental results.

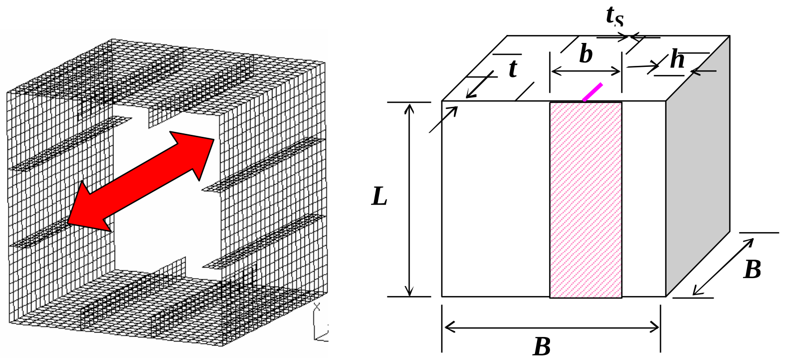
Keywords: Nonlinear dynamic analysis; local buckling damage; fiber beam element; seismic response; stress-strain; hysteresis model

1. Nonlinear dynamic response analysis using a fiber beam element

Let us consider a member element with the box cross section as shown in Fig. 1.The Equation of motion is witten as follows;

$$M\ddot{u} + C\dot{u} + Ku = F \qquad (1)$$

where M represents the mass matrix, C is the damping matrix, K is the stiffness matrix and F is an external force, respectively. The stress-strain hysteresis model based on obtained average stress versus average strain relationship was developed in order to introduce into the elasto-plastic dynamic analysis program with a fiber beam element. The local buckling behavior of a unit length member with a stiffened or un-stiffened box cross-sections subjected to cyclic loads of axial compression and tension was analyzed by FEM program MARC [1] by changing width-to-thickness ratio parameters and slenderness ratio parameters for stiffener member of the stiffened box section. Based on the analytical results, stress-strain hysteretic curves and envelope one obtained from numerical analysis are shown in



(a) FEM analytical model (b)Sstiffened cross section

Fig.1 FEM analytical model with stiffened cross section r

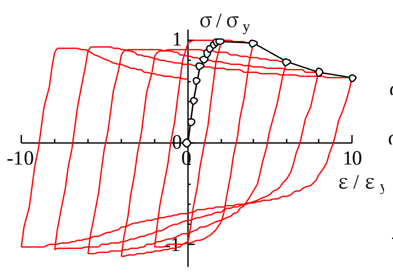


Fig.2 Hysteretic curves and envelope curve

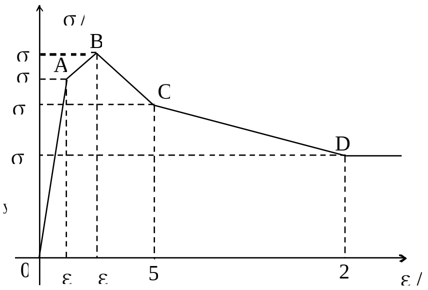


Fig.3 Approximated skeleton curve

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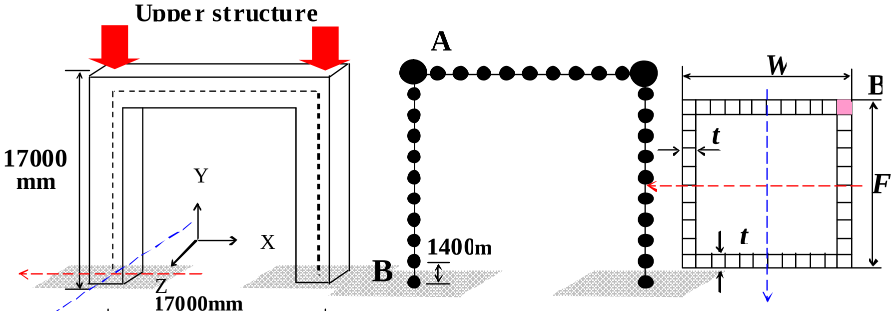
Fig.2. An approximated skeleton curve and approximated hysteretic ones is shown in Fig. 4.

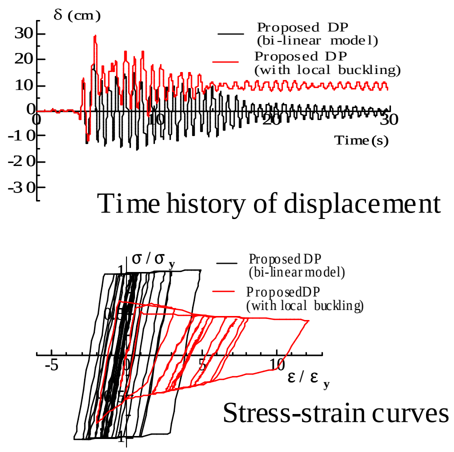
2. Results and discussions

A steel frame bridge pier with box cross-section subjected to the ground motion is analyzed under constant upper structure dead loads as shown in Fig. 4. The numerical results of the proposed DP [2] with bi-linear model are compared with the numerical results of TDAPIII [3] with bi-linear model for the frame bridge pier. Fig. 5 shows the time-history displacement response at the top of the pier (point A) and stress-strain curves at the point B. The effects of the local buckling on the response of frame bridge pier with width-to-thickness ratio parameter R_R=1.13 are shown in Fig. 5. Lager response of the displacement at the top of the pier and lower yield stress at the bottom of the pier are recognized.



(a)Experimental model (b) Analytical model (c) Cross-section of model

Fig. 4 Experimental model and analytical one

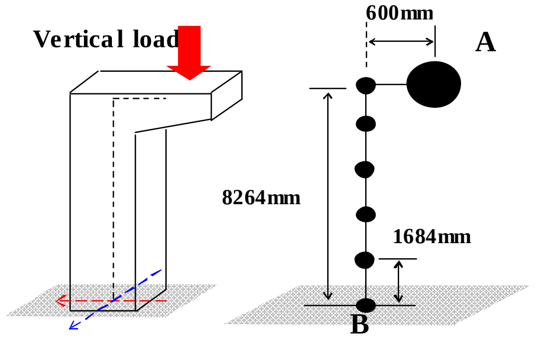


Time history of displacement

Stress-strain curves

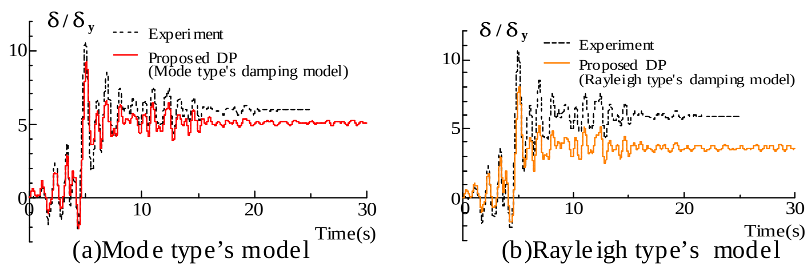
Fig. 5 Effects of the local buckling on the response of frame bridge pier (R_R=1.13)

An inverted L-shaped steel bridge pier with box cross-section subjected to the ground motion is analyzed under a constant upper structure dead load as shown in Fig. 6. Fig. 6(b) shows the analytical model with fiber elements. Material properties of the models are assumed to be SM490YA steel with yield stress σ_y = 405 MPa, Young's modulus E = 206 GPa and Poisson's ratio = 0.3. The comparisons between the experimental results and analytical results by the proposed DP with the Rayleigh type's and mode one's damping model shown in Fig. 7. In these figures, dotted lines indicate the experimental results. From numerical results, it can be recognized that the time history and stress-strain curves of the mode type damping model are correspondence to those of the experiment. This was caused by the difference of the calculation method of the damping matrix. That is, it is found that this analytical program for the non-linear dynamic behavior of steel frames fail by local buckling damage was able to develop.



(a)Experimental model (b)Analytical model

Fig. 6 Experimental model and analytical one



(a)Mode type's model (b)Rayleigh type's model

Fig. 7Comparison of experimental results and proposed DP's ones

3. References

[1] NIPPON MARC, *MARC K7 User's Manual* ; A-E, 1997.

[2] SAKIMOTO T., WATANABE H., NAKASIMA K. "Hysteretic models of steel box members with local buckling damage", *Journal of JSCE*, No.647/I-51, 2000, pp.343-355. (In Japanese)

[3] NIPPON TDAP III, Ver. 2.00, *User's Manual* , 1998.