Combined Loadings and Universal Panel Tester

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Abstract: This study presents an inelastic non-linear element with combined bending, shear and axial force interaction for analysis of reinforced concrete (RC) structures. This concrete model uses an orthotropic constitutive relation in which the directions of orthotropy are the principal directions of total strain. These directions will change during the load displacement response, following the Soften Membrane Model. The model was developed based on softening (reduction of concrete compressive strength with respect to lateral tensile strain) which was derived with the help of Universal Panel Tester in University of Houston.

1. Introduction

The analytical modeling of the behavior of structures under combined loadings has received considerable attention in recent years. One of the main applications is the modeling of bridge columns, beams and several other onshore and offshore RC structures, which are prone to fail in brittle manner under bending, shear and axial interaction. Concrete constitutive relations are important for analyzing these types of structures and these relations are derived from the Universal Panel Tester (Fig. 1) in University of Houston. This facility is the only one of its type in the United States, and is currently one of the two available in the world. It is also capable of performing strain-control tests and applying any prescribed types of cyclic loading beyond the yield point [1].

Fig.1 Universal Panel Tester

2. Fiber Beam Element Formulation

The RC member is modeled with an assembly of interconnected beam elements that resembles the non linear behavior of steel and concrete at fiber level. The beam element is formulated with the help of classical stiffness method or displacement based method and flexibility method or force based methods which are explained in below sections.

3. Concrete Biaxial Constitutive Relations

The concrete constitutive models in principal directions 1-2 is evaluated based on the Universal Panel Tester experiments. The equation for compressive strength reduction factor proposed by Hsu and Zhu (2002) is:

$$\zeta = \left(\frac{5.8}{\sqrt{f_c^{'}(MPa)}} \leq 0.9 \right) \left(\frac{1}{\sqrt{1+400\bar{\varepsilon}_1}} \right) \left(1 - \frac{|\beta|}{24^\circ} \right) \tag{1}$$

Where ζ is the softening coefficient, $f_c^{'}$ is the uniaxial concrete compressive strength, $\bar{\varepsilon}_1$ is the equivalent uniaxial tensile strain and β is the deviation angle.

4. Results

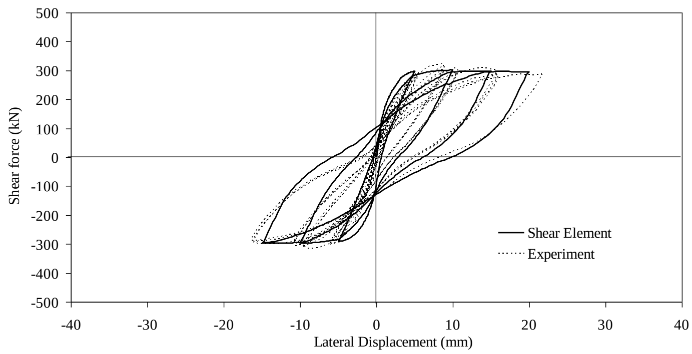

Fig. 2 Cyclic load - displacement comparison with experiment and a shear element

The proposed element was validated by modeling a high strength reinforced concrete squat column (Column HC4-8L 16-T6-0.2P) tested by Xiao and Martirossyan (1998). An axial load of 1068 kN was applied constantly to the column. Rotations were fixed at the column bottom and top so that the column deforms anti-symmetrically with respect to the mid height under combined axial and lateral loading. Shear element showed a very good correlation with the experimental results (Fig. 2). This column failed with a shear cracks following the degradation of the transverse shear reinforcement.

5. Acknowledgements

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6. References

1. Hsu, T.T.C., Belarbi, A., and Pang, X. (1995). "A Universal Panel Tester, Testing and Evaluation" *Journal, American Society for Testing and Materials*, Vol 23, No 1, pp. 41-49.
2. Hsu, T. T. C. and Zhu, R. R. H. (2002), "Softened Membrane Model for Reinforced Concrete Elements in Shear," *ACI Structural Journal*, Vol. 99, No. 4, pp. 460-469.
3. Xiao, Y., and Martirossyan, A., 1998, "Seismic Performance of High-Strength Concrete Columns," *Journal of Structural Engineering*, ASCE, V. 124, No. 3, pp. 241-251.