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THE EFFECT OF LATERAL FORCE ON STABILITY MARGIN OF FLEXIBLE FRAME SYSTEMS

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ABSTRACT

Investigation on the stability margin of typical structures subjected to gravity loads is usually based on Eigen analysis for the first buckling mode of the system using stiffness characteristics of the structure (including its geometrical stiffness) (Bazant & Cedolin, 2010; Timoshenko & Gere, 1985). However, introducing lateral force on a structural system makes its stability assessment difficult. In the presence of lateral loads in a structural system, material nonlinearity (in the form of plastic hinges in structural members) and geometrical nonlinearity (due to $P-\Delta$ effect) are the main concerns in determination of stability margin for the system (Bernal, 1992, 1998). In these cases, Eigen analysis cannot be directly used to address stability problems of the structural system. On the other hand, in tall structures and braced frame systems subjected to lateral loads there is another source of nonlinearity in the system that makes identification of the first bucking mode of the structure difficult. The fact is, introduction of lateral force on a structural system makes the axial force distribution in the structure dependent on the magnitude of lateral force. This in turn modifies the geometrical stiffness of the system and results in changing the first buckling mode of the system and its stability margin. Such tendency in shifting the stability margin of structural systems is considered important in the design procedure of tall flexible frame systems (Ziyaeifar, 2002).

METHODOLOGY

In this work, the role of axial force distribution in changing the first buckling mode of two-dimensional moment resisting frames and braced frame systems has been investigated. In this approach geometrical stiffness matrix of the structural system continually updates at each step of lateral load increment on the system. Consequently, the change in stiffness matrix of the structure at each step of its lateral deformation is taken into consideration for Eigen analysis of the system. The result of such analyses represents the change in buckling modes and stability margins of the system in terms of increase in lateral load on the structural system. In this study, it is assumed that the change in first buckling mode of the system initiates before development of material and geometrical nonlinearity in the structural system (formation of plastic hinges or $P-\Delta$ effect).

RESULT AND CONCLUSION

In short and wide moment resisting frames, the change in axial load pattern on the structure by introducing lateral loads on the system in elastic range of behavior is usually very small as shown in Figure 1. According to this figure, in the range of 1% lateral drift in the system there is no practical changes in the first buckling mode and its stability index (λ) of the structure. However, as shown Figure 2, in a braced frame system there is a fundamental change in stability index of the structure in the same level of lateral deformation for the system.

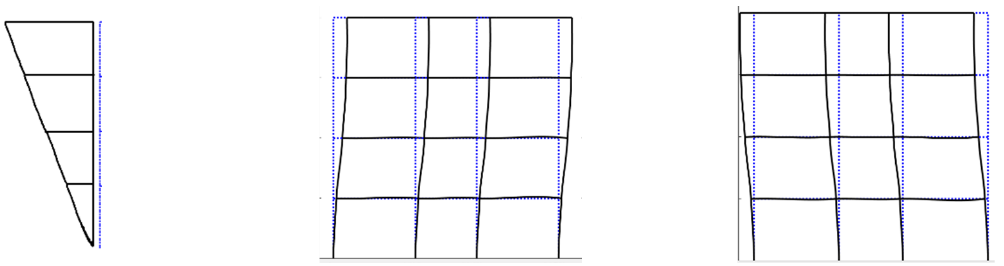

Figure 1. First buckling mode of a moment resisting frame in lateral drifts of 0.0 and 1%.

Such kind of analyses is required for slender structural systems to understand the potential of change in the first bucking mode of the system from a typical sway mode to a localized buckling mode with much smaller stability margin.

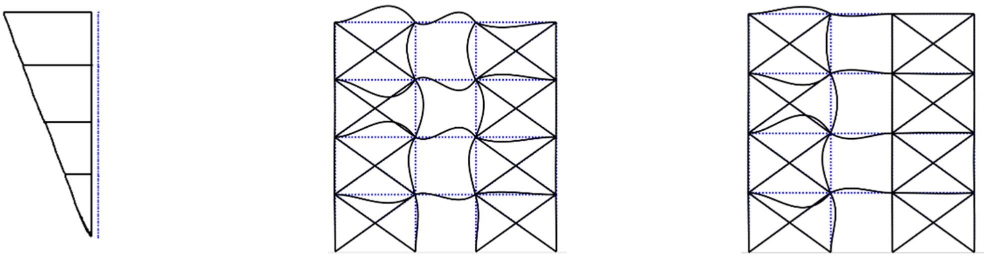

Figure 2. First buckling mode of a braced frame in lateral drifts of 0.0 and 1%.

For flexible tall moment resisting frames in high damped structural systems the change in axial load pattern of the system by lateral loads is high. This is due to large base moment in the structure that may add tremendously to the axial forces in columns of the system. In such case the change in first buckling mode of the structure and its stability margin is quite important in design process of such systems (Ziyaeifar, 2002; Ziyaeifar et al., 2012).

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