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DYNAMIC INERTIAL EFFECTS DURING STRUCTURAL PROGRESSIVE COLLAPSE IN RC STRUCTURES

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ABSTRACT

Throughout recent history, famous records of building failures may be found, unfortunately accompanied by great human loss and major economic consequences. One of the mechanisms of failure is referred to as ‘progressive collapse’: one or several structural members suddenly fail, whatever the cause (accident or attack). The building then collapses progressively, every load redistribution causing the failure of other structural elements, until the complete failure of the building or of a major part of it. This phenomenon is generally regarded as a dynamic phenomenon, and therefore ideally simulated by dynamic computations. When compared to quasi-static computations under similar loads, a dynamic computation will show stress redistribution over larger portions of the structure, as well as larger deflections and plastic hinge rotations [1]. The differences are such that they should not be overlooked, and the different progressive collapse mitigation procedures indeed take them into account. For instance, the U.S. General Services Administration and Department of Defense recommendations [2, 3] either impose that a dynamic computation should be performed, or specify a load factor of 2 to be applied on both dead and live loads when a quasi-static procedure (with or without material or geometrical non-linear effects) is carried out.

Although dynamic computations are perfectly feasible, they usually require a deeper computational expertise than quasi-static ones, and are more time consuming. As a result, practitioners in the industry often do not have the tools that would allow them to perform dynamic computations. An interest therefore arises for procedures designed to take dynamic inertial effects during progressive collapse into account through quasi-static computations, and several such procedures may now be found in the literature. Some of these [2-5] are based on dynamic amplification factors to be applied to the loads during the design process. Others approaches [5-6] propose procedures based on energetic evaluations for the internal and external forces. Assuming that the structure reaches a vanishing kinetic energy state, and that this situation represents the design configuration for the structure, this state should be such that the works of the internal and external forces are equal at that very instant. Although only a dynamic computation can provide the exact displacements, a quasi-static computation, associated with a

carefully chosen loading sequence, may provide a good assessment of the dynamic displacements, and by extension, the works of the internal and external forces.

The aim of the present paper is to present a discussion relative to these different procedures, and to propose some variations for some of them, as well as and assess their level of accuracy, based on real dynamic analyses. Note that only dynamic effects of inertial nature (as opposed to viscous) are considered here.

A numerical model consisting in the association of linear elastic beams at large displacements with plastic hinge elements is used to perform the various computations. The different approaches will be compared based on computations of a realistically designed RC structure.

Conclusions will be drawn with respects to the ability of energetically equivalent quasi-static procedures in the sense defined above to account for inertial dynamic effects, with a focus on the accuracy of the assessed ductility (plastic rotations) demands on the structure during the dynamic progressive collapse.

REFERENCES

[1] Kaewkulchai, G., and Williamson, E. (2004). "Beam element formulation and solution procedure for dynamic progressive collapse analysis." *Computers and Structures,* 82, 639-651.

[2] United States General Services Administration (GSA). (2003). *Progressive Collapse Analysis and Design Guidelines for New Federal Office Buildings and Major Modernization Project,* Washington DC.

[3] Department of Defense (DoD). (2005). *Unified Facilities Criteria (UFC): Design of Structures to Resist Progressive Collapse,* Washington, D.C.

[4] Ruth, P., Marchand K., and Williamson E. (2006). "Static equivalency in progressive collapse alternate path analysis: reducing conservatism while retaining structural integrity." Journal of *Performance of Constructed Facilities,* November 2006, 349-364.

[5] Powell G. (2004). "Progressive collapse: case studies using nonlinear analysis." *SEAOC Annual Convention Proceedings*, Monterey, August 2004.

[6] Izzuddin B. A., Vlassis A. G., Elghazouli A. Y., Nethercot D. A. (2007). "Progressive collapse of mutly-story buildings due to sudden column loss – Part 1: simplified assessment framework." *Engineering Structures*, July 2007.