PAPER REF: 4064

DESIGN FOR ROBUSTNESS OF MULTI-STOREY REINFORCED CONCRETE FRAME STRUCTURES UNDER EXTREME LOADS

Ioan Petran(*), Mihai Senila

Department of Structures, Tehnical University of Cluj-Napoca, Romania
(*)*Email:* ioan.petran@dst.utcluj.ro

ABSTRACT

Reinforced concrete (RC) frame structures present some advantages over steel frame structures for direct effects of explosions and high velocity impacts. When properly designed, they can also survive the loss of a key member, i.e. a column. In order to take full advantage of these properties, careful detailing needs also to be considered. Seismic design for continuity and tying can be used as reference but this needs to be extended to provide adequate level of protection.

The paper investigates the potential for progressive collapse of seismic resistant RC frames in case of loss of a column. The benefits of seismic design philosophy on the integrity of the multi-storey structures will be identified.

Keywords: reinforced concrete frame, robustness, extreme load, progressive collapse.

INTRODUCTION

There are numerous hazards that could trigger the progressive collapse, each with different probability of occurrence: intentional or accidental (bomb detonation, gas explosion) or natural hazard (earthquakes, extreme wind). Progressive collapse of multi-storey buildings under such load events is an important issue and needs to be considered, at least for important buildings. According to EN 1990, a structure shall be designed and executed in such a way that it will not be damaged by extreme events, such as gas explosion or impact, to an extent disproportionate to the original cause.

Reinforced concrete (RC) frame structures present some advantages over steel frame structures for direct effects of explosions and high velocity impacts. When properly designed, they can also survive the loss of a key member, i.e. a column. In order to take full advantage of these properties, careful detailing needs also to be considered. FEMA 277 report (1996) concluded that, in case of the Oklahoma City bombing, in 1995, the Murah Building would have been designed to seismic action, the progressive collapse would have been precluded. Seismic design for continuity and tying can be used as reference but this needs to be extended to provide adequate level of protection.

The paper investigates the potential for progressive collapse of seismic resistant RC frames in case of loss of a column. The benefits of seismic design philosophy on the integrity of the multi-storey structures will be identified.

PRELIMINARY RESULTS

The preliminary results have shown that the progressive collapse resistance largely depends on the plastic deformation capacity of the RC beams adjacent to the missing column. When

the interaction between concrete floors and concrete slab is taken into account, the ductility demand is much reduced. Fig. 1 shows the snapshots of the structure for one column loss scenario.

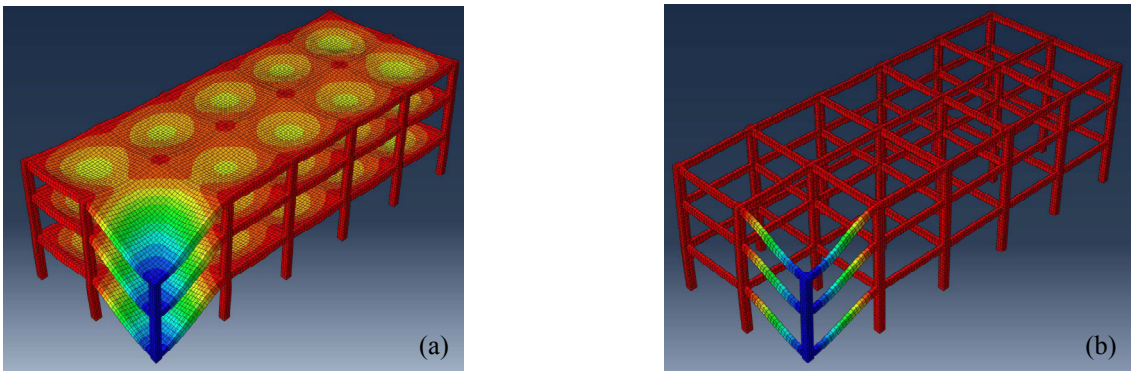

Fig. 1 - Behavior of multi-storey RC building in case of column loss: (a) structure without concrete floor; (b) concrete floor considered

Progressive collapse behavior for a reinforced concrete frame structure with disabilities and a slab floor type structure has also been studied. Impaired (disabled) structure is defined as an existing structure built prior to the occurrence of more severe stipulations for seismic resistance and structural integrity. Such a structure with disabilities, involves insufficient lower longitudinal reinforcement, inadequate shear force reinforcement and insufficient anchorage length of longitudinal reinforcement. Based on comparison results for nonlinear static analysis procedure and nonlinear dynamic analysis procedure, dynamic amplification factor values lower than recommended by GSA Guide, between 1.52 and 1.72 were also obtained. However, same as with the study structure, the author recommends using the 2.0 factor specified in this design guide for progressive collapse, as for the deficient structure, only dynamic effects resulting from static application of gravity load were considered. However, additional dynamic effects can occur from the collapse of higher levels, more than that, the damages considered in the deficient structure case, could be higher than initially assumed.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by the Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI), Romania, under grant PN II PCCA 55/2012.

REFERENCES

[1]-FEMA 277 (1996): The Oklahoma City Bombing: Improving building performance through multi-hazard mitigation, ASCE.

[2]-EN 1990: Eurocode 0 - Basis of structural design, 2002.

[3]-GSA 2003, Progressive Collapse Analysis and Design Guidelines for New Federal Office Buildings and Major Modernization Projects, U.S. General Service Administration, 2003.

[4]-U. S. Department of Defense (DoD 2005), Design of building to resist progressive collapse, Unified Facility Criteria, UFC 4-023-03, Washington, DC, 2005.

[5]-Huynh, C.T., Park, J., Kim, J., Progressive collapse resisting capacity of reinforced concrete beam-column sub-structures, 2009.