Distribution of Inelastic Demand in Slender R/C Shear Walls Subjected to Eastern North America Ground Motions

Structures located in Eastern North America are subjected to earthquakes that are rich in high frequency motions and promote significant higher mode responses. The inertia forces considering higher mode effects could amplify shears and moments in storey levels above the base which could lead to plasticity in the upper part of the wall in addition to the plastic hinge at the base. This could compromise the capacity design principles with the base shear being larger than the shear capacity associated with the formation of the base plastic hinge. The potential formation of plastic hinge in the upper part of shear walls is not currently recognized in design (or seismic rehabilitation) guidelines. However, the capacity design approach and higher mode effects have been considered in Canadian codes after 1990. Other National codes (i.e. New-Zealand) provide dynamic amplification factors for shear and moment above the base plastic hinge excluding the possible plastic behavior in the upper part of the walls. If a plastic hinge forms above the base, the proposed code dynamic amplification factors are inadequate.

To better understand these aspects, this paper presents classical response spectra (R-T-μ) and non-linear time history analyses of a prototype slender multi-story RC shear wall from a typical building located in Montreal, Canada. The wall was designed according to the National Building Code of Canada (NBCC) 2005 and is modeled using three different constitutive models: 2D plane stress RC finite elements (VecTor2 software), fiber elements (Perform3D software) and lumped plasticity beam-column elements (Ruamoko software). The base shear and moment distributions obtained from response spectra and nonlinear analyses are compared to the load distributions obtained for the same building floor plan from different version of NBCC ranging from 1977 to 2010. The ratio of base shear, V, to seismic weight, W, (V/W) decreased as ductile R/C detailing requirements were implemented. Some variations in internal shear forces and bending moments are noted as empirical formulas to estimate the fundamental period of vibration and the flexural stiffness (lately accounting for axial loads) have been implemented. These comparative results are essentials in the context of developing guidelines for rehabilitation of existing buildings built many years ago. Using the current code (NBCC 2005) it is found that the base shears obtained from nonlinear analyses is approximately 40% more than the shear capacity prescribed by the concrete code (CSA-A23.3-04). In addition nonlinear behavior expressed in curvature ductility demand above unity was observed for both the base and in the upper part of the wall.

Finally, a large scale shake table test to validate the numerical predictions is described. The test is scheduled to take place at the Structural Laboratory of Montreal Polytechnic Institute. Its objectives are to investigate the presence of inelastic behavior in the upper part of the wall, the influence of damping, shear and flexural stiffness degradation of a 9m high shear wall specimen scaled down by a factor of 2.33 from the prototype.