23rd Australasian Conference on the Mechanics of Structures and Materials

2014

Seismic design of buildings: looking towards the future

R P. Dhakal
University of Canterbury

Publication details

Dhakal, RP 2014, 'Seismic design of buildings: looking towards the future', in ST Smith (ed.), *23rd Australasian Conference on the Mechanics of Structures and Materials (ACMSM23)*, vol. I, Byron Bay, NSW, 9-12 December, Southern Cross University, Lismore, NSW, pp. 13-14. ISBN: 9780994152008.

SEISMIC DESIGN OF BUILDINGS: LOOKING TOWARDS THE FUTURE

R.P. Dhakal*
Department of Civil and Natural Resources Engineering, University of Canterbury
Christchurch 8140, New Zealand. rajesh.dhakal@canterbury.ac.nz (Corresponding Author)

ABSTRACT

In the last century, seismic design has undergone significant advancements. Starting from the initial concept of designing structures to perform elastically during an earthquake, the modern seismic design philosophy allows structures to respond to ground excitations in an inelastic manner, thereby allowing damage in earthquakes that are significantly less intense than the largest possible ground motion at the site of the structure. Current performance-based multi-objective seismic design methods aim to ensure life-safety in large and rare earthquakes, and to limit structural damage in frequent and moderate earthquakes. As a result, not many recently built buildings have collapsed and very few people have been killed in 21st century buildings even in large earthquakes. Nevertheless, the financial losses to the community arising from damage and downtime in these earthquakes have been unacceptably high (for example; reported to be in excess of 40 billion dollars in the recent Canterbury earthquakes). In the aftermath of the huge financial losses incurred in recent earthquakes, public has unabashedly shown their dissatisfaction over the seismic performance of the built infrastructure.

As the current capacity design based seismic design approach relies on inelastic response (i.e. ductility) in pre-identified plastic hinges, it encourages structures to damage (and inadvertently to incur loss in the form of repair and downtime). It has now been widely accepted that while designing ductile structural systems according to the modern seismic design concept can largely ensure life-safety during earthquakes, this also causes buildings to undergo substantial damage (and significant financial loss) in moderate earthquakes. In a quest to match the seismic design objectives with public expectations, researchers are exploring how financial loss can be brought into the decision making process of seismic design. This has facilitated conceptual development of loss optimisation seismic design (LOSD), which involves estimating likely financial losses in design level earthquakes and comparing against acceptable levels of loss to make design decisions (Dhakal 2010a). Adoption of loss based approach in seismic design standards will be a big paradigm shift in earthquake engineering, but it is still a long term dream as the quantification of the interrelationships between earthquake intensity, engineering demand parameters, damage measures, and different forms of losses for different types of buildings (and more importantly the simplification of the interrelationship into design friendly forms) will require a long time.

Dissecting the cost of modern buildings suggests that the structural components constitute only a minor portion of the total building cost (Taghavi and Miranda 2003). Moreover, recent research on seismic loss assessment has shown that the damage to non-structural elements and building contents contribute dominantly to the total building loss (Bradley et. al. 2009). In an earthquake, buildings can incur losses of three different forms (damage, downtime, and death/injury commonly referred as 3Ds); but all three forms of seismic loss can be expressed in terms of dollars. It is also obvious that the latter two loss forms (i.e. downtime and death/injury) are related to the extent of damage; which, in a building, will not just be constrained to the load bearing (i.e. structural) elements. As observed in recent earthquakes, even the secondary building components (such as ceilings, partitions, facades, windows parapets, chimneys, canopies) and contents can undergo substantial damage, which can lead to all three forms of loss (Dhakal 2010b). Hence, if financial losses are to be minimised during earthquakes, not only the structural systems, but also the non-structural elements (such as partitions,

ceilings, glazing, windows etc.) should be designed for earthquake resistance, and valuable contents should be protected against damage during earthquakes.

Several innovative building technologies have been (and are being) developed to reduce building damage during earthquakes (Buchanan et. al. 2011). Most of these developments are aimed at reducing damage to the buildings' structural systems without due attention to their effects on non-structural systems and building contents. For example, the PRESSS system or Damage Avoidance Design concept aims to enable a building's structural system to meet the required displacement demand by rocking without the structural elements having to deform inelastically; thereby avoiding damage to these elements. However, as this concept does not necessarily reduce the interstory drift or floor acceleration demands, the damage to non-structural elements and contents can still be high. Similarly, the concept of externally bracing/damping building frames reduces the drift demand (and consequently reduces the structural damage and drift sensitive non-structural damage). Nevertheless, the acceleration sensitive non-structural elements and contents will still be very vulnerable to damage as the floor accelerations are not reduced (arguably increased). Therefore, these concepts may not be able to substantially reduce the total financial losses in all types of buildings.

Among the emerging building technologies, base isolation looks very promising as it seems to reduce both inter-storey drifts and floor accelerations, thereby reducing the damage to the structural/non-structural components of a building and its contents. Undoubtedly, a base isolated building will incur substantially reduced loss of all three forms (dollars, downtime, death/injury), even during severe earthquakes. However, base isolating a building or applying any other beneficial technology may incur additional initial costs. In order to provide incentives for builders/owners to adopt these loss-minimising technologies, real-estate and insurance industries will have to acknowledge the reduced risk posed by (and enhanced resilience of) such buildings in setting their rental/sale prices and insurance premiums.

KEYWORDS

Seismic design, structural system, non-structural elements, building contents, damage, downtime, financial loss.

REFERENCES

Bradley, B.A., Dhakal, R.P., Cubrinovski, M. and MacRae, G.A. (2009) "Seismic loss estimation for efficient decision making", *Bulletin of the New Zealand Society of Earthquake Engineering*, Vol. 42, No. 2, pp. 96-110.

Buchanan, A.H., Bull, D., Dhakal, R.P., MacRae, G.A., Palermo, A. and Pampanin, S. (2011) *Base Isolation and Damage Resistant Technologies for Improved Seismic Performance of Buildings*. Report for the Royal Commission of Inquiry into Building Failure Caused by the Canterbury Earthquakes, Christchurch, 99 pages.

Dhakal, R.P. (2010a) "First step towards loss optimization seismic design (LOSD)", *Asian Conference on Earthquake Engineering (ACEE)*, Bangkok, 1-3 December 2010, 8 pages.

Dhakal, R.P. (2010b) "Damage to Non-Structural Components and Contents in 2010 Darfield Earthquake", *Bulletin of the New Zealand Society of Earthquake Engineering*, Vol. 43, No. 4, pp. 404-411.

Taghavi, S. and Miranda, E. (2003) *Response Assessment of Non-Structural Building Elements*. Report No. 2003/05. Pacific Earthquake Engineering Research Center, Richmond, CA.