IITK – bmtpc Earthquake Tip 27

Learning Earthquake Design and Construction

How can Non-structural Elements be protected against Earthquakes?

Non-Structural Elements

Structural Elements (SEs) in a building have a primary role of resisting the effects of earthquakes ground shaking, and of protecting life and property of building occupants. But, buildings contain many other items, such as *contents*, *appendages* and *services & utilities*, which are attached to and/or supported by SEs, and affected by earthquake ground shaking; these items are called *Non-Structural Elements* (NSEs).

NSEs can be classified into three groups, namely:

(a) *Contents of buildings*: Items required for functionally enabling the use of spaces, such as (i) furniture and other items, *e.g.,* storage shelves, (ii) facilities and equipment, *e.g.,* refrigerators, multi-level material stacks, false ceilings, and (iii) door and window panels and frames, or ply board or aluminum partitions;

(b) *Appendages to buildings*: Items projecting out from buildings, either horizontally or vertically, such as chimneys, exterior glass or stone cladding (*pasted* on the building surface as façades), parapets, small water tanks rested on top of buildings, sunshades, advertisement hoardings and communication antennas atop buildings;

(c) *Services and utilities*: Items required for facilitating essential activities in the buildings, such as water mains, electricity cables, air-conditioning ducts, rainwater drain pipes, and elevators.

Earthquake Effects on NSEs

During strong earthquake shaking, NSEs can (a) *slide* or *topple*, or (b) *move* or *swing*, if they are not secured well to SEs of the building. These actions can cause loss to functionality of NSEs and potential secondary disasters, *e.g.,* spill of chemicals leading to laboratory fires (Figure 1a). Loss of functionality of an NSE can be small or substantive depending on its importance, the function it serves, and its cost. For instance, if book shelves of a library are not properly secured, they can distort (Figure 1b) or topple; the former may only dislodge books, but the latter can cause threat to life. If gas pipelines are pulled apart or electric control panels are toppled (Figure 1c), then both direct and indirect losses can be significant. With increasing sophistication in building systems, seismic performance of NSEs is becoming more important. In many earthquakes, economic losses due to damages in NSEs have been very substantial.

Protecting Non-Structural Elements

NSEs can demonstrate either *acceleration-sensitive* or *displacement-sensitive* behaviour during earthquakes.

(a) *Acceleration-sensitive* NSEs may topple or slide, if *not anchored adequately to SEs* (*e.g.,* a diesel generator unit on a floor, and expensive contents of museums). Thus, the SEs and the anchors by which NSEs are secured to SEs should be designed to resist the induced forces corresponding to the accelerations developed in these NSEs.

(b) *Displacement-sensitive* NSEs may bend, compress or stretch by large amounts during earthquake shaking (*e.g.,* glass facades, water and gas pipes running between floors of a building, and electric lines running from a street pole to a building). Also, NSEs are significantly affected by the flexibility of SEs and their deformations. The connection of NSEs with SEs should be designed to accommodate *relative displacements* generated between support points on SEs with adequate slack.

Some NSEs are both *displacement* and *acceleration-sensitive*, and they have to be designed for both *forces* and *relative displacements*. For example, false ceilings suspended from floor slabs above, may not only pull out vertically from slabs, but also swing laterally and knock on walls.

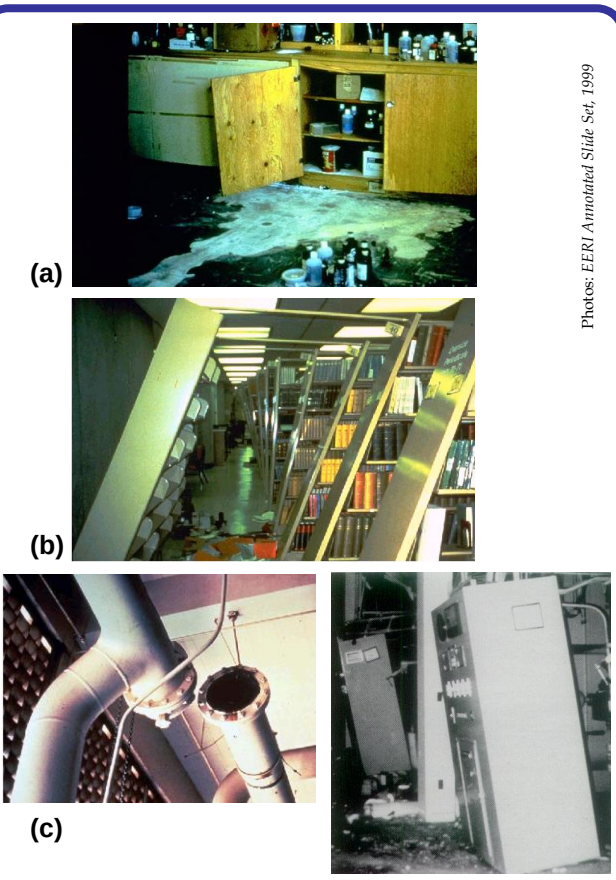

Figure 1: Earthquake performance of non-structural elements – *(a) chemical spill in a laboratory, (b) library book shelves, and (c) water pipelines and electrical control panels.*

How can Non-structural Elements be protected against Earthquakes?

Three strategies are adopted for design of NSEs in a building and their connections with SEs, namely:

(i) *Non-Engineered Strategy*: generic NSEs (*e.g.*, glass bottles on shelves, and crockery) cannot be individually secured, but can be protected with simple strategies (*e.g.*, hold-back strings) (Figure 2);

(ii) *Prescriptive Strategy:* factory-made, reasonably large NSEs (*e.g.*, cupboards, refrigerators, laboratory equipment and large panel glass windows) often have manufacturer prescribed protection or anchorage details provided at the time of purchase (Figure 3), and

(iii) *Engineered Design Strategy:* large, specialised, massive NSEs (*e.g.*, cooling plant of central air-conditioning systems, billboards) and those whose failure can be critical (*e.g.*, fire hydrant pipes running along building height) require formal design calculations for protecting them (Figure 4).

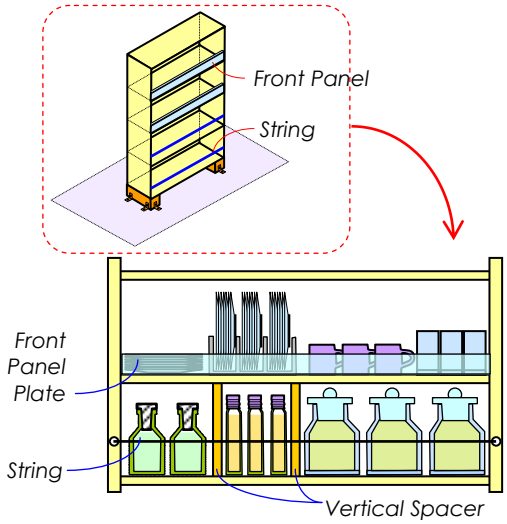

Figure 2: Non-Engineered approach for earthquake protection of NSEs: *small NSEs that cannot be anchored individually*

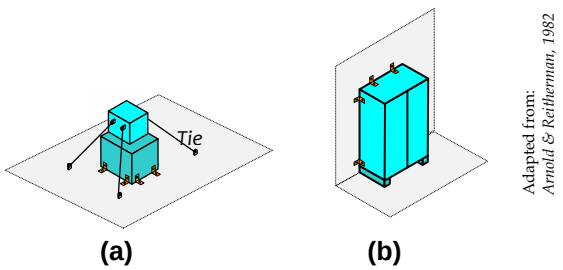

Figure 3: Prescriptive (engineered) approach for earthquake protection of NSEs – *(a) Tie it to SE, (b) Bolt it to SE.*

NSEs located in upper levels of buildings and their connections to SEs must be designed for shaking expected at those floor levels (Figure 5); this floor shaking can be different and even of higher intensity than the shaking at the ground level. Hence, NSEs that project vertically or horizontally from buildings at the upper elevations needs special attention. Some countries (*e.g.*, USA) have provisions for *engineered design* of NSEs and their connections with SEs.

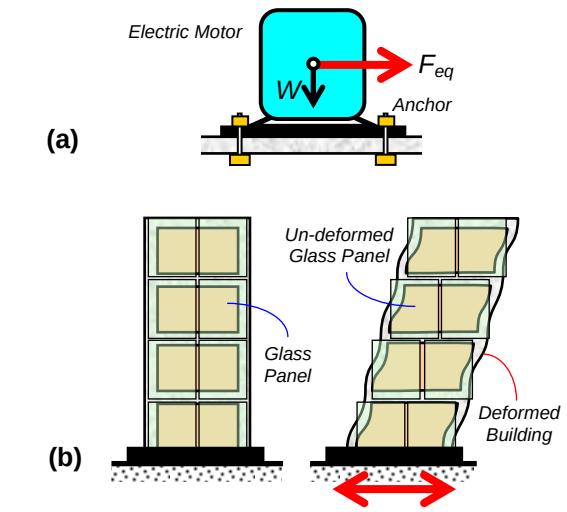

Figure 4: Engineered approach for earthquake protection of NSEs *(a) force design for stiff & massive NSEs, and (b) relative displacement design for flexible & slender NSEs.*

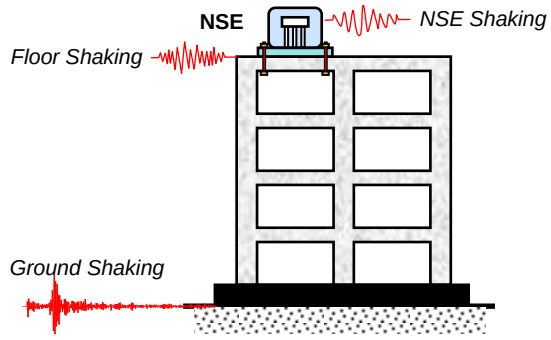

Figure 5: NSE shaking different from ground shaking – *shaking at NSE can be more severe and different in characteristics*

Related IITK - BMTPC Earthquake Tip

Tip 23: Why are buildings with shear walls preferred in seismic regions?

Resource Material

FEMA E-74, (2011), *Reducing the Risks of Non-structural Earthquake Damage – A Practical Guide*, Applied Technology Council, USA

Mondal,G., and Jain,S.K., (2005), "Design of Non-Structural Elements for Buildings: A review of codal provisions," August 2005; and "Proposed Draft for IS:1893 on Design of Non-Structural Elements," October 2005, *The Indian Concrete Journal*, ACC Limited, Thane, India

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