Seismic design

Seismic design of secondary parts and components

Background

The National Code of Construction (NCC) 2022 Volume One B1D3 Determination of individual actions subclause (c) clarifies that AS 1170.4 Earthquake actions in Australia (2007) is applicable as appropriate.

Seismic design in Victoria has been identified by the Australian Institute of Building Surveyors (AIBS) as an area of practice that is being applied inconsistently. As a result, there is an urgent need to confirm the current design and compliance verification roles of practitioners.

Seismic design applies to the primary structural elements of Classes 2-9 buildings and their secondary parts and components. These secondary elements include architectural, mechanical, electrical and life safety parts and components, such as partition walls, suspended ceilings, HVAC ducts, cable trays, firefighting piping and so forth.

Evidence from post-disaster investigations, such as the Christchurch earthquake of 2011, has revealed failures leading to injury and worse on many occasions, arising from poorly restrained or incompatible secondary elements of buildings.

Failures of parts and components have either caused the collapse of other elements or compromised the primary structural elements of buildings, leading to the loss of building use and deeming buildings unsafe. This loss of use delays recovery and produces the greatest costs to owners and the economy.

Design responsibilities

Design documentation, considering seismic loading, and certificates of compliance must be presented by architects, designers, endorsed building (design) engineers and parts and components (seismic)engineers for their respective design works to the relevant building surveyor (RBS) for review and acceptance.

Architects and endorsed building (design) engineers collaboratively develop the detailed design and its documentation, ensuring compliance with the NCC Volume One (2022). For building services, endorsed building engineers generally develop schematic designs based on design briefs and client requirements, along with architectural and structural documentation. In many cases, schematic designs of services are detailed by parts and components engineers, who either work directly with the builder’s installer or the supplier/manufacturer. They detail and develop the schematic design into specific products, which are accordingly either supplied or specifically manufactured.

For instance, in the design of an office Class 5 building, an endorsed building mechanical engineer schematically designs a heating, ventilation, and air conditioning (HVAC) system comprising of outdoor and indoor units, ducting, outlets and control modules. The parts and components engineer identifies specific HVAC supplies, and details ducting and installations, including fixing ducting to slab soffit and structural walls. These design works must demonstrate compliance with the NCC and its listed specifications, including AS 1170.0, 1170.1, 1170.2 and 1170.4. It’s important to note that secondary elements are specifically controlled by Section 8 of the AS 1170.4, which is the prime focus of this article. For building projects, a parts and components engineer is, or is working under the supervision of, an endorsed building engineer.

Design development and requirements

The parts and components engineer develops the schematic into detailed design that in part relies on the determination of horizontal earthquake forces specific to each part and component (F_c), which follows AS 1170.4 Section 8 (2007).

F_c of parts and components is determined using the particular seismic load factors of the building identified by the endorsed building structural engineer in the structural design of the building.

These factors are:

- Z = hazard factor
- k_p = probability factor
- $C_h(0)$ = spectral shape factor, which relates to the site sub-soil classification

Seismic design procedure for parts and components

Accordingly, the parts and components engineer determines the specific design factors of the considered parts or components in accordance with subsection 8.3 Simple Method:

- I_c = component importance factor (careful consideration must be given if this is proposed to be different to the building importance factor)
- a_x = height amplification factor at height h_x at which the component is attached
- a_c = component amplification factor
- R_c = component ductility factor
- W_c = seismic weight of the component

These specific design factors of parts or components (I_c, a_x, a_c, R_c and W_c), along with the three seismic load factors (Z, k_p and $C_h(0)$), are used to determine the design force F_c applied to each part or component. F_c is used in the design of the component and its fixtures to slab soffit and walls:

$$F_c = [k_p Z C_h(0)] a_x [I_c a_c / R_c] W_c \geq 0.05 W_c$$

Alternatively and in accordance with subsection 8.2 Method, using design accelerations, the structural engineer provides floor accelerations ($a_{floor,i}$) determined in the equivalent static analysis (ESA) or dynamic analysis, as per AS 1170.4 Sections 6 and 7, respectively. For ESA, the acceleration of the i^{th} floor ($a_{floor,i}$) is determined by dividing the horizontal equivalent static design force (F_i) of the i^{th} floor by its total floor mass ($m_i = W_i / g$):

$a_{floor,i} = F_i / m_i = [F_i / W_i] g$ where g is the gravitational acceleration.

For dynamic analysis, accelerations are obtained from the results of the modal response spectrum or the time-history analysis. The use of $a_{floor,i}$, in accordance with subsection 8.2, produces more economic design of parts and components than when using subsection 8.3. Accordingly, the design F_c applied to each part or component is:

$$F_c = a_{floor,i} [I_c a_c / R_c] W_c \leq 0.5 W_c$$

Conclusion

In conclusion, the seismic design of buildings in Australia, in accordance with the NCC structural provisions, is mandated for all primary and secondary elements. Conducting robust building design incurs minimal costs compared to the overall project cost, ensuring the safe use of buildings. These minimal costs are less than the annual insurance premiums paid for the first year of the building’s lifetime. This could potentially change the attitude of reinsurers, who currently impose higher premiums on Australian buildings for not addressing inherent seismic risks in their design. In other words, building insurance should either be reduced or at least not increased annually at current rates.