

# STEEL CONSTRUCTION FACT SHEET

## Seismic design of steel buildings



Many parts of the world are subjected to seismic activity. In these areas, unless buildings are designed to resist forces resulting from earthquakes, significant structural damage or complete collapse may occur.

The use of structural steel as the principal structural material provides the opportunity to take advantage of the lower mass of steel buildings and the ability of the material to deform plastically and absorb energy while doing so. Energy absorbing components can easily be incorporated in a structural solution.

### Earthquakes

Most major earthquakes occur close to the borders of the main tectonic plates that cover the Earth. These plates move relative to each other but due to friction, stresses build up until eventually and suddenly, the plates yield; this is an earthquake.

Shock waves from the earthquake propagate through the ground causing horizontal and vertical ground accelerations. The ground motions are applied to the foundations of buildings and cause the building to sway leading to structural damage and, in extreme cases, collapse. The building sways at its natural frequency and the oscillations can build over time increasing the lateral loads.

The horizontal accelerations are more important because they result in lateral forces which are more significant than the vertical forces

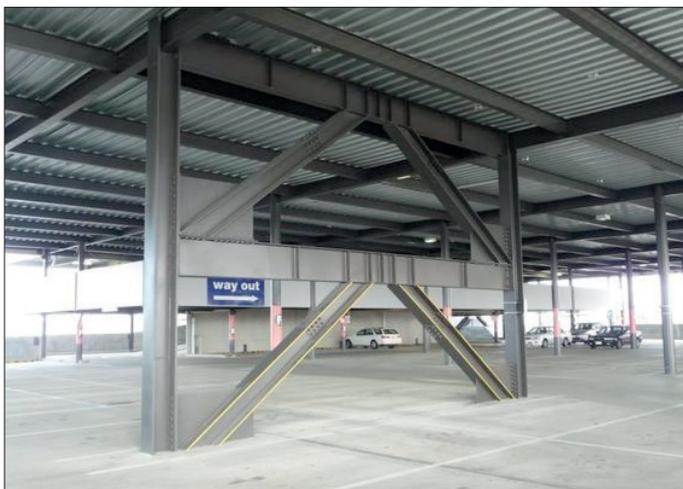


Figure 1. Example of a steel frame with eccentric bracing

and generally, buildings are better at resisting vertical (gravity) loads than horizontal loads.

Earthquakes can be characterised in several ways. Most of us are familiar with the Richter scale which measures the total energy liberated by a seismic event. However, in terms of earthquake engineering, the ground acceleration is the most useful parameter. Important design parameters include:

- The Peak Ground Acceleration (PGA), which is a measure of the maximum acceleration of the ground during an earthquake.
- The acceleration response spectrum, which is a plot of the dynamic acceleration response of the structure.

### Steel structures

Experience has shown that properly designed steel structures perform well when subjected to earthquakes. Significant structural damage and collapse, and associated casualties and loss of life, have mostly been associated with older masonry and concrete buildings which were not seismically engineered.

The key advantages of steel-framed buildings are:

- The ductility of steel and steel frames
- The flexibility and low weight of steel buildings.

### Ductility

A key principle in the design of earthquake resistant buildings, is to develop ductile behaviour within the building structure. A ductile structure is able to dissipate significant energy during an earthquake thereby reducing damage to the building.

A ductile structure is intentionally designed so that selected parts of the structure can undergo plastic deformations without failure during an earthquake.

Steel structures are particularly good at dissipating energy from earthquakes due to:

- the ductility of steel as a material
- the many possible ductile mechanisms achievable in structural steel elements and their connections
- reliable geometrical and physical properties.

Structural arrangements such as eccentrically braced frames, are designed so that the bracing member frames into a beam eccentric to the column and the short length of beam deforms plastically and absorbs energy.

## Flexibility and low weight

Steel structures are lighter and more flexible than concrete structures.

As earthquake forces are associated with inertia, they are related to the mass of the structure and therefore reducing the mass inevitably leads to lower seismic design forces. Indeed some steel structures are sufficiently light that seismic design is not critical.

A typical, multi-storey steel-framed building is 60-70% lighter than an equivalent concrete framed building.

Although steel is strong, it is also flexible. Flexibility is one of the most important aspects of buildings in areas that are prone to earthquakes. The flexibility of steel allows a building to survive moderate seismic activity easily without sustaining any real structural damage.

## Seismic evaluation

Because of the economic and human cost of earthquakes over the past century, significant effort has been invested in understanding and assessing the effects of earthquakes on buildings and developing codes to govern the design and construction of earthquake resistant buildings.

Several methods can be used to analyse the response of a structure subjected to an earthquake. The choice of method depends on the structure and on the objectives of the analysis and include:

1. The standard method used in design is the modal response using a design spectrum. This is a linear method in which the inelastic behaviour is considered in the definition of the design spectrum, through the use of a behaviour factor.
2. The 'lateral force' method is a simplified version of the modal response method and is a static analysis which can only be employed for regular structures which respond essentially in one single mode of vibration.
3. The 'Pushover' analysis is a non-linear static analysis carried out under constant gravity loads and monotonically increasing horizontal loads.

4. Non-linear time-history analysis is a dynamic analysis obtained through direct numerical integration of the differential equations of motion. The earthquake action is represented by accelerograms. This type of analysis is used for research and code background studies.

## Seismic design of steel structures

The guiding principles governing conceptual seismic design are:

- structural simplicity
- uniformity, symmetry and redundancy
- bi-directional resistance and stiffness (torsional resistance and stiffness)
- use of strong and stiff diaphragms at storey levels
- use of adequate foundations.

Performance-based seismic design is now commonly adopted by designers. Performance objectives are identified for different magnitude earthquakes and the building structure is designed to achieve these objectives.

The commonly adopted structural steel forms adopted for earthquake resistance include:

- Moment resisting frames
- Frames with concentric bracing
- Frames with concentric bracing and dissipative connections
- Frames with eccentric bracing
- Composite steel-concrete solutions including braced and moment resisting frames, walls and columns.

Innovations such as steel plate cores, which also absorb energy by deforming in shear; energy absorbing cross bracing and allowing column bases to lift off are easy to implement in steel buildings.

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## Further information

Guidance on earthquake resistant design of steel structures is most advanced in countries that are most susceptible to seismic activity including USA, Japan and parts of Europe. Many engineering and academic texts are available including:

*Facts for Steel Buildings number 3: Earthquakes and seismic design*, AISC, 2009.

*Seismic design of steel structures*, V. Gioncu and F. Mazzolani, CRC press, 2013.

*Earthquake Resistant Steel Structures*, ArcelorMittal Commercial Sections.

*Steel structures: Analysis and design for vibrations and earthquakes*, K.M. Ghosh, Whittles Publishing, 2011.

## Notes to editors

Globally, construction is the most important sector for steel industry consuming, by weight, around 50% of global output.

The range of steel construction products is vast and includes:

- Hot-rolled sections and steel plate are used in building structures
- Galvanised steel coil is used for steel studs, cladding and floor decking, etc.
- Rebar used to provide tensile strength in reinforced concrete.

In some markets, the use of structural steel is commonplace but in others it is seen as a new and relatively unproven technology. Often designers and decision-makers are not convinced about the suitability of steel structures in their market due to their limited knowledge of the material's performance, the wealth of experience and guidance available on steel construction and the wider benefits that steel construction brings. This series of factsheets aims to change this by providing facts (and dispelling myths) about the properties and benefits of structural steel.

This factsheet is one of a series of five focussing on multi-storey buildings.