03

Technical

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STAINLESS STEEL, A KEY STRUCTURAL ALLY IN SEISMIC EVENTS

1 INTRODUCTION: NATURE OF SEISMIC ACTION

A seismic event is the sudden release of energy accumulated in the Earth's crust, propagating in the form of seismic waves. From a structural engineering perspective, an earthquake is not merely ground motion, but a violent dynamic action that imposes horizontal and vertical accelerations on buildings, generating time-varying structural demands.

These events are concentrated mainly along tectonic plate boundaries, such as the Pacific Ring of Fire (Chile, Peru, Japan, Mexico, USA), continental collision zones (Himalayas), or regions with active faults (Turkey, Italy). Nevertheless, no region is completely free from seismic activity, making seismic-resistant design an essential requirement even in areas of moderate seismicity.

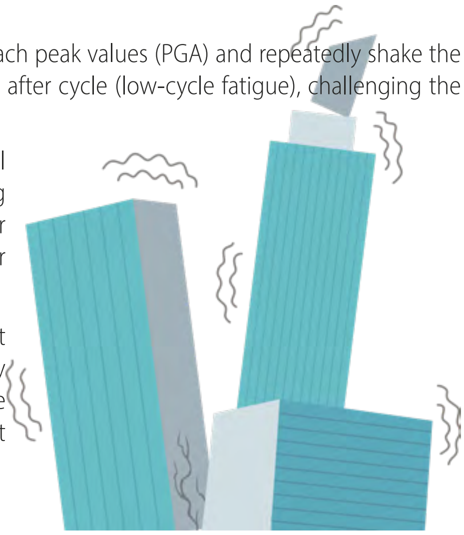
Inertial Forces and Fatigue

The impact of an earthquake at the base of a building is translated into inertial forces ($F = m \cdot a$). The greater the mass of the building, the greater the force it must resist. Unlike static loads (such as self-weight, furniture, etc.), seismic action is cyclic (back-and-forth) and subjects the structure to "instantaneous fatigue," a condition for which conventional materials are not always optimized.

2 THE THREE CRITICAL CHALLENGES

A seismic event subjects a structure to three simultaneous tests. To overcome these challenges, modern engineering defines specific parameters that the design must control:

1. **Cyclic Loads**: seismic events generate ground accelerations that reach peak values (PGA) and repeatedly shake the structure. These load reversals degrade the building's stiffness cycle after cycle (low-cycle fatigue), challenging the remaining strength of the materials.
2. **Large Deformations**: the structure experiences relative lateral displacements between floors, known as Drift. If the building displaces excessively in the lateral direction, it risks overturning under its own weight, a phenomenon technically known as Second-Order Effects (P-Delta effects).
3. **Energy Demand**: this is the ultimate challenge. The structure must be capable of absorbing and dissipating the immense kinetic energy of the earthquake. The goal is not merely to resist force, but to manage that energy through controlled damage (plastic deformation) without reaching collapse.



3 STAINLESS STEEL: HIGH-PERFORMANCE PROPERTIES

Historically valued for its corrosion resistance, stainless steel offers a combination of mechanical properties in response to these three challenges that positions it as an advanced structural solution for high-seismicity regions.

1 Strain Hardening and "Safety Reserve"

Most materials have a fixed failure point. Stainless steel behaves differently because it exhibits a characteristic stress–strain curve known as a "round-house" curve.

What does this mean? When an earthquake attempts to deform the building, stainless steel does not weaken; instead, it becomes stronger as deformation increases (a phenomenon known as strain hardening).

The benefit is the creation of an additional strength reserve (or overstrength) that was not considered in the initial calculations, providing the building with a vital margin of survival under violent shaking.

2 Energy Dissipation Capacity

Stainless steel is the ideal material for "structural fuses" (elements specifically designed to absorb damage) for two main reasons:

1. **High ductility**: austenitic grades exhibit exceptional elongation capacity (>40–50%), allowing the element to stretch significantly to accommodate large deformations without fracturing.
2. **Stable hysteresis**: an earthquake subjects the structure to repeated load cycles (back-and-forth motion) that typically degrade the resistance of conventional materials rapidly. Stainless steel, however, exhibits stable hysteresis, meaning that under cyclic loading, it maintains its energy dissipation capacity intact, cycle after cycle, without premature degradation. This ensures that the structure remains effective in dissipating energy throughout the entire seismic event, without "exhausting" its capacity too early.

3 Long-Term Reliability

Thanks to its high corrosion resistance, stainless steel preserves the integrity of the structural cross-section over time. This ensures that the seismic capacity of the building does not degrade due to material loss, guaranteeing that the performance of the original design remains valid throughout the entire service life of the structure (50–100 years).

4 REGULATORY FRAMEWORK AND DESIGN EFFICIENCY (EUROCODE 8)

Seismic design standards have evolved based on damage observed in historical earthquakes, raising requirements to prioritize the protection of human life. In Europe, the current standard is Eurocode 8 (EN 1998).

The code is currently progressing toward its new generation (prEN 1998-1-1), which introduces significant changes, shifting from force-based design to performance-based design.

During a seismic event, the objective is not for the structure to be indestructible or infinitely rigid (as this would attract unmanageable seismic forces), but rather to meet two key objectives depending on the earthquake's intensity:

- **Serviceability Limit State (SLS – "Damage Limitation")**: For frequent earthquakes, the structure must remain operational with minimal damage.
- **Ultimate Limit State (ULS – "No Collapse")**: In the event of a severe (rare) earthquake, the structure may sustain significant damage to dissipate energy, but it must not collapse, ensuring occupant survival.

Ductility Classification

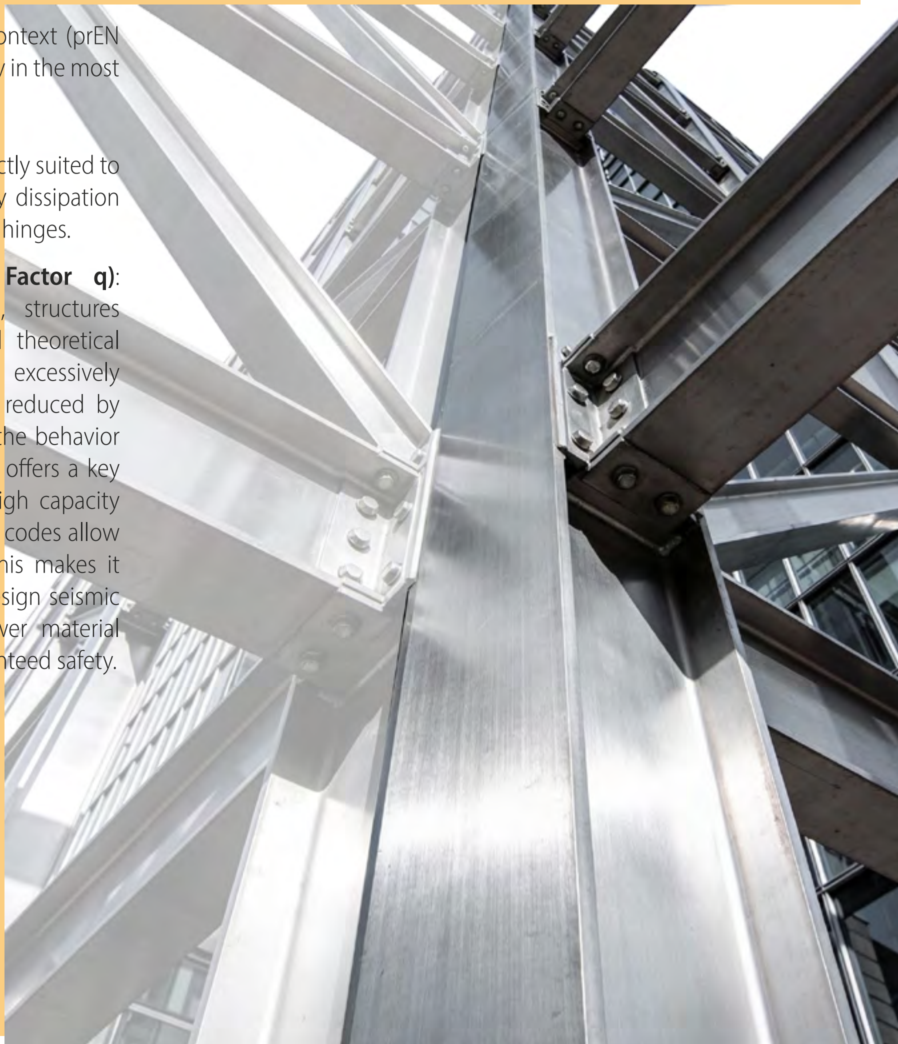
To meet the "No Collapse" objective, Eurocode 8 classifies structures according to the amount of energy they are required to dissipate:

- **DCL (Low)**: Elastic design, limited energy dissipation (low-seismicity areas).
- **DCM (Medium)**: Energy dissipation through localized plastic deformations.
- **DCH (High)**: Structures designed to develop global plastic mechanisms (plastic hinges) capable of absorbing large amounts of energy.

The Vital Role of Stainless Steel

Within the current and future regulatory context (prEN 1998-1-1), stainless steel stands out precisely in the most demanding category:

- **High Ductility Class (DCH)**: It is perfectly suited to designs that require maximum energy dissipation through the formation of stable plastic hinges.
- **Design Optimization (Behavior Factor q)**: In current seismic design practice, structures are not calculated to resist the full theoretical seismic force, as this would require excessively large elements. Instead, this force is reduced by dividing it by a coefficient known as the behavior factor (q). This is where stainless steel offers a key economic advantage: thanks to its high capacity for plastic deformation without failure, codes allow the assignment of a high q-factor. This makes it possible to significantly reduce the design seismic forces, achieving structures with lower material consumption while maintaining guaranteed safety.



5 SELECTION GUIDE: TAILORED SOLUTIONS

The wide variety of stainless steel grades allows the material to be adapted to specific structural needs:

Family / Grade	Main Characteristic	Recommended Seismic Application
Austenitics (300 Series: 304, 316)	Maximum ductility and superior plastic deformation capacity.	Ideal for energy dissipators, bracing, and "fuse" elements (Class DCH) to manage Energy Demand.
Duplex (Grade 2205)	High mechanical strength and higher yield strength.	Ideal for columns and facades. Its high strength helps limit Drift and P-Delta effects, lightening the seismic mass (m).

Although seismic engineering has evolved significantly by learning from past disasters, specific regulations for stainless steel (based on Eurocode 8) are still adapting to formally recognize these advantages. However, the evidence is clear: in High Ductility Class structures, where large energy dissipation is required, stainless steel is a technically optimal option.

Investing in stainless steel in seismic zones goes beyond an economic or aesthetic decision; it is an investment in resilience. When facing the forces of nature, having a material that provides an additional safety reserve, does not weaken over time, and can deform without breaking is the key to moving from mere resistance to true structural survival.

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