

Cómo han cambiado las disposiciones sísmicas: implicancias reales en el diseño estructural

Montagna, Leandro; Cerri, María Soledad; Etse, Guillermo^a

^aSAXUM engineered solutions, leandro.montagna@saxum.us, soledad.cerri@saxum.us, getse@saxum.us

Palabras clave: Sismo, criterio, códigos, casos reales.

RESUMEN

Las disposiciones sísmicas han evolucionado significativamente en las últimas décadas debido a avances en la sismología, mejores herramientas analíticas y la experiencia de grandes terremotos llevando hacia un aumento progresivo de la demanda sísmica. Este trabajo presenta una breve comparación de dicha evolución en normas estadounidenses y argentinas, y expone casos reales que visualizan las diferencias.

Se incluye un caso de estudio sobre la modificación de una torre de precalentamiento diseñada con códigos antiguos que debió ser reevaluada según normas actuales. Se discuten estrategias de refuerzo y los desafíos de actualizar estructuras existentes. Además, se presenta un segundo caso enfocado en prácticas de diseño sísmico en Argentina, mostrando la adaptación de metodologías internacionales a contextos locales.

El objetivo del trabajo es aportar al entendimiento de los criterios de diseño sísmicos y sus implicancias prácticas, para asistir la toma de decisiones en diseño y rehabilitación estructural.

ABSTRACT

Seismic provisions have evolved significantly over the past few decades due to advances in seismology, improved analytical tools, and lessons learned from major earthquakes leading towards increasing seismic demand. This paper presents a brief comparison of this evolution in the American and the Argentinian standards, and presents real cases where the differences are clearly visualized.

A real case study is included on the modification of a pre-heater tower which was originally designed under older codes and had to be reassessed using current standards. Retrofit strategies are discussed, as well as the challenges associated with upgrading existing structures. Additionally, a second case study is presented focusing on seismic design practices in Argentina, illustrating how international methodologies are adapted to local contexts.

The objective is to advance the understanding of seismic design criteria and their practical implications, supporting a more informed decision-making in both new design and structural rehabilitation projects.

Organiza:

TECHNICAL BACKGROUND RELATED TO CASE STUDIES

Evaluation of Existing Structures Subject to Alterations According to U.S. Codes

In the United States, the design of new structures is governed by the building code adopted by the corresponding state or local jurisdiction. In most cases, these regulations are based on a specific edition of the International Building Code (IBC), supplemented by jurisdiction-specific amendments that modify selected provisions.

A comparable framework applies to existing structures; however, in this case, the applicable regulations typically refer to a version of the International Existing Building Code (IEBC). The IEBC establishes design and evaluation requirements for several categories of intervention, including repairs, alterations, additions, and changes in occupancy.

For alteration works, the IEBC classifies interventions into three levels, each associated with specific requirements for structural assessment and seismic compliance.

Level 1 alterations include the removal and replacement or the covering of existing materials, elements, equipment or fixtures using new materials, elements, equipment or fixtures that serve the same purpose.

Level 2 alterations include the addition or elimination of any door or window, the reconfiguration of any system, or the installation of any additional equipment, and shall apply where the work area is equal to or less than 50 percent of the building area.

Level 3 alterations apply where the work area exceeds 50 percent of the building area.

The IEBC requires compliance with the IBC provisions when an alteration increases design lateral loads, introduces a prohibited structural irregularity as defined in ASCE 7, or reduces the capacity of any existing lateral-force-resisting element. However, for Level 2 alterations, the code permits the use of reduced seismic loads, specifically allowing a 25% reduction relative to the loads prescribed by the IBC. No such reduction is permitted for Level 3 alterations.

When evaluating the lateral-force-resisting system of an existing structure, it is essential to determine the extent of the discrepancy between the seismic demand considered in the original design and that required under current code provisions. Seismic demand will be primarily influenced by revisions to the mapped accelerations at the specific geographic location, as well as by the extent to which the original design assumptions—particularly the response modification factor (R)—can be substantiated under current code requirements.

Changes in seismic demand associated with mapped accelerations

A general increase in mapped accelerations is frequently observed when transitioning from UBC-based provisions to modern ASCE 7/IBC frameworks; however, this trend is not uniform and exhibits significant dependence on geographic location, structural period range, and site class.

Table 1 provides a summary of the seismic design approaches adopted in various building codes over the past several decades.

Building Code	Referenced code for loads	Hazard Basis	Probability of exceedance
UBC 1976 to 1997	none	Pre-USGS spectral map era (Zone-based seismic design)	10% in 50 years
IBC 2000	ASCE 7-98	UHGM from USGS 1997	2% in 50 years
IBC 2003	ASCE 7-02	UHGM from USGS 2002	2% in 50 years
IBC 2006 IBC 2009	ASCE 7-05	UHGM using USGS 2002	2% in 50 years
IBC 2012 IBC 2015	ASCE 7-10	Risk-targeted MCE_R using USGS 2008	Derived from 2% in 50-year hazard, adjusted for 1% collapse risk
IBC 2018 IBC 2021	ASCE 7-16	Risk-targeted MCE_R using USGS 2014	Derived from 2% in 50-year hazard, adjusted for 1% collapse risk
IBC 2024	ASCE 7-22	Risk-targeted MCE_R using USGS 2018	Derived from 2% in 50-year hazard, adjusted for 1% collapse risk

Table 1 – Evolution of American codes in seismic design approach

Prior to 1997, seismic provisions were generally based on a hazard level corresponding to a 10% probability of exceedance in 50 years, consistent with a design philosophy primarily oriented toward life-safety performance. The 1997 NEHRP Provisions changed the performance objective to “collapse prevention”, adopting the Maximum Considered Earthquake (MCE) hazard level associated with a 2% probability of exceedance in 50 years. This transition introduced the use of the 2/3 reduction factor applied to the MCE ground motion, intended to reflect a lower-bound estimate of the inherent margin against collapse in structures designed in accordance with the provisions.

Probably, one of the most important changes happened between ASCE 7-05 and ASCE 7-10. The basis for the mapped seismic hazards in ASCE 7-10 were significantly different from that of ASCE 7-05 and previous versions of the code. The significant changes include:

1. Probabilistic ground motions in ASCE 7-05 assume uniform hazard (2% in 50-year probability of exceedance, or MCE) across the U.S., whereas those in ASCE 7-10 assume a uniform risk (1% probability of structural collapse in 50 years, or MCE_R) across the U.S. This change was introduced to better align the provisions with the code’s objective of providing a more uniform level of structural performance.

Consequently, mapped ground motions decreased by as much as 30% in high-hazard regions of the Central and Eastern United States and coastal Oregon, while remaining nearly unchanged in most other parts of the country.

2. Deterministic ground motions (i.e. those based on modeling of specific slip scenarios of known faults) in ASCE 7-05 were based on 1.5 times the median response, whereas those in ASCE 7-10 are based on the 84th percentile (approximately 1.8 times the median).

3. Ground motion intensity in ASCE 7-05 was based on the geometric mean (square root of the product of motions in two orthogonal directions), whereas those in ASCE 7-10 are based on maximum ground motion direction.

The net result of these changes is a reduction in short period ground motions in Central and Eastern U.S. and little change elsewhere.

Changes in seismic demand associated with the Response Modification Factor

In addition to variations in seismic demand arising from revisions to mapped ground motion parameters, the demand on existing structures may be significantly influenced by the extent to which the original design assumptions—most notably the response modification factor (R)—can be rigorously justified in accordance with current code provisions.

The Uniform Building Code (UBC) does not incorporate explicit system selection restrictions based on Seismic Design Categories, as is the case in modern ASCE 7 provisions. Instead, the use of ductile lateral force-resisting systems was enforced indirectly through detailing requirements and other implicit constraints. As a result, the prohibition of specific structural systems and associated R-values was not codified in a clear and systematic manner.

Consequently, it is not uncommon to encounter existing structures—particularly in regions where mapped seismic accelerations have undergone significant revisions—designed with R-values that would not be permitted under current codes given the level of detailing provided. Even in cases where structures were originally intended to behave in a ductile manner in accordance with UBC provisions, modern codes have introduced substantially more stringent and explicitly defined detailing, testing, and qualification requirements.

Therefore, the direct adoption of the original R-values in the assessment of existing structures is often not justified. Achieving equivalence with current code expectations may necessitate significant retrofit interventions, particularly at critical regions such as beam-column connections and other components expected to undergo inelastic deformation.

The transition from the Uniform Building Code (UBC) to modern seismic design frameworks, as embodied in the International Building Code (IBC) and ASCE 7 in conjunction with the AISC Seismic Provisions, represents a significant evolution in the detailing requirements for steel structures eligible for high response modification factors (R). While UBC provisions incorporated the concept of ductile seismic systems, the associated detailing requirements were comparatively less explicit and, in many cases, not directly supported by extensive experimental validation.

In the UBC framework, ductile systems were defined primarily through general detailing principles, including requirements for continuity, strength, and stability of critical components such as beam-column joints and panel zones. However, connection performance was not rigorously standardized, and the assumed ductility underlying high R values relied to a considerable extent on engineering judgment and pre-Northridge design assumptions.

Following the 1994 Northridge earthquake, significant deficiencies in welded steel moment connections prompted a fundamental reassessment of seismic detailing practices. Modern provisions, as implemented through AISC 341 and AISC 358, introduced stringent requirements for connection qualification, including the mandatory use of prequalified connection details or the demonstration of adequate cyclic performance through physical testing. This shift marked a transition from presumed to explicitly verified ductility.

In addition, modern codes enforce capacity design principles in a systematic manner. Requirements such as strong-column/weak-beam relationships, explicit panel zone strength checks, and the use of expected material strength factors (e.g., R_y) ensure a controlled hierarchy of yielding mechanisms. These provisions are intended to confine inelastic behavior to designated ductile components while protecting critical elements such as columns and connections from premature failure.

For concentrically and eccentrically braced frames, similar advancements are evident. Modern provisions impose strict limits on member slenderness to control local buckling, define detailed requirements for gusset plate design to accommodate inelastic deformations, and establish explicit criteria for link beam behavior in eccentrically braced systems. Furthermore, the introduction of protected zones restricts the placement of attachments in regions expected to undergo significant inelastic demand.

Overall, the evolution from UBC to modern codes reflects a paradigm shift in seismic design philosophy. High response modification factors are no longer justified solely based on system type and general detailing, but rather on the demonstrated and enforceable ability of the structure to sustain stable, ductile inelastic behavior. This transition represents a move toward a more rational, performance-informed framework in which ductility is not assumed, but explicitly achieved through rigorous detailing, testing, and quality control.

Industrial structures under Argentinian Codes

The Argentinian seismic design code, *INPRES-CIRSOC 103*, is organized into multiple parts addressing different aspects of seismic analysis and structural design. This study focuses on the analysis of steel structure and, consequently, in the following parts:

- **Part I:** Governs the determination of seismic actions. It is broadly comparable to Chapters 11 and 12 of ASCE 7, as it establishes procedures for defining the design response spectrum and includes general seismic design provisions. Notably, INPRES-CIRSOC 103 adopts a zone-based seismic hazard approach, similar to that used in the Uniform Building Code (UBC).
- **Part IV:** Addresses the seismic design of steel structures. While largely comparable to AISC 341, it also incorporates parameters typically defined in ASCE 7, such as the response modification factor (R). This section classifies lateral force-resisting systems and prescribes detailing and design requirements for each.

Other sections of INPRES-CIRSOC 103 address reinforced concrete, masonry (CMU), and other structural systems, which are outside the scope of this paper.

When evaluating seismic demand in Argentina—particularly in regions of high seismicity—several distinctions arise relative to standard U.S. practice that significantly influence design outcomes, especially for industrial structures:

1. There are no explicit provisions for the classification and design of *nonbuilding structures*.
2. There is no category equivalent to “steel systems not specifically detailed for seismic resistance.”
3. The effective seismic mass generally includes a portion of the imposed live load.

A key difference lies in the absence of a dedicated chapter for nonbuilding structures in INPRES-CIRSOC 103 Part IV 2005, unlike ASCE 7. Under ASCE 7, a *building* is defined as a structure intended for human occupancy or use (e.g., residential, commercial, or office spaces), whereas *nonbuilding structures* serve industrial, utility, or infrastructure functions and are not primarily occupied. Consequently, many industrial facilities fall within the nonbuilding category under ASCE 7.

ASCE 7 Chapter 15 provides specific seismic design criteria for nonbuilding structures, including modified response factors and flexibility to adopt intermediate R -values where systems do not fully comply with the detailing requirements of standard lateral systems. This allows for a more nuanced and practical design approach.

To illustrate the impact of provisions governing nonbuilding structures, consider an Ordinary Concentrically Braced Frame (OCBF). ASCE 7 Table 12.2-1 assigns a response modification factor of $R = 3.25$ for this system, whereas INPRES-CIRSOC 103 Part I Table 5.1 specifies $R = 3$. Both codes impose similar applicability limits, including a height restriction of approximately 35 ft (12 m) in regions of high seismicity.

When this height limit is exceeded and the structure may be classified as a nonbuilding structure, ASCE 7 Table 15.4-1 provides alternative design factors for the same lateral system, allowing reduced values of $R = 2.5$ or $R = 1.5$ depending on structural height. In contrast, under INPRES-CIRSOC provisions, the designer must either transition to

a more ductile system—such as a Special Concentrically Braced Frame (SCBF), which entails more stringent detailing requirements—or adopt an essentially elastic design approach. In the latter case, Part I (2018) permits the use of $R = 1.5$, whereas earlier editions require $R = 1$. Figure 1 and 2 shows tables discussed above.

Table 12.2-1 Design Coefficients and Factors for Seismic Force-Resisting Systems

Seismic Force-Resisting System	ASCE 7 Section Where Detailing Requirements Are Specified	Response Modification Coefficient, R^a	Overstrength Factor, Ω_o^b	Deflection Amplification Factor, C_d^c	Structural System Limitations Including Structural Height, h_n (ft) Limits ^d				
					Seismic Design Category				
					B	C	D ^e	E ^e	F ^f
B. BUILDING FRAME SYSTEMS									
1. Steel eccentrically braced frames	14.1	8	2	4	NL	NL	160	160	100
2. Steel special concentrically braced frames	14.1	6	2	5	NL	NL	160	160	100
3. Steel ordinary concentrically braced frames	14.1	3/4	2	3/4	NL	NL	35 ^g	35 ^g	NP ^h

Table 15.4-1 Seismic Coefficients for Nonbuilding Structures Similar to Buildings

Nonbuilding Structure Type	Detailing Requirements	R	Ω_o	C_d	Structural System and Structural Height, h_n , Limits (ft) ^a				
					Seismic Design Category				
					B	C	D ^b	E ^b	F ^c
Building frame systems:									
Steel special concentrically braced frames	AISC 341	6	2	5	NL	NL	160	160	100
Steel ordinary concentrically braced frame	AISC 341	3/4	2	3/4	NL	NL	35 ^d	35 ^d	NP ^e
With permitted height increase	AISC 341	2 1/2	2	2 1/2	NL	NL	160	160	100
With unlimited height	AISC 360	1.5	1	1.5	NL	NL	NL	NL	NL

Figure 1. Design coefficients for Ordinary Concentrically Braced Frames from ASCE 7 for buildings (Table 12.2-1) and for non-buildings similar to buildings (Table 15.4-1).

Tabla 5.1. (continuación) Factores de comportamiento

Nº	Tipo Estructural	R	C_d	Ω_o
Pórticos Arriostrados				
22	Especiales arriostrados concéntricamente	5	5,5	2
23	Convencionales arriostrados concéntricamente	3	3	2
24	Arriostrados excéntricamente	7	4	2

- Los PSCAC no podrán usarse en construcciones de altura total mayor que **12 m** en las **zonas sísmicas 4 y 3**. Se exceptúan los edificios con altura menor de **12 m** cuando el peso propio de las paredes, pisos y techos no supere **1 N/mm²**.
- No hay limitación de altura para las **zonas sísmicas 2 y 1**.

Figure 2. Design coefficients for Ordinary Concentrically Braced Frames from INPRES-CIRSOC 103 Part I 2018 (Table 5.1) and limitations to its use from INPRES-CIRSOC 130 Part IV 2005.

Current versions of INPRES-CIRSOC 103 Parts I and IV do not include a classification analogous to “steel systems not specifically detailed for seismic resistance”, commonly associated with $R \approx 3$ in ASCE 7 and AISC 341. As a result, designers are constrained to select either ductile systems or purely elastic design approaches, with no intermediate alternatives. This limitation has a pronounced impact in regions of low to moderate seismicity, where $R=3$ systems are permitted.

Another significant difference concerns the definition of *effective seismic weight*. ASCE 7 Section 12.7.2 defines this quantity as the sum of dead loads and other permanently attached components contributing to inertial effects during seismic events. In general, occupancy live loads are excluded, except where specifically justified.

Conversely, INPRES-CIRSOC 103 Part I requires inclusion of a portion of live loads in the effective seismic weight. Beyond maintenance loads, a minimum of 25% of the imposed floor live load must be considered. This distinction becomes particularly relevant in industrial structures, where dead loads are typically low—due to the use of grating or checkered plate flooring—while operational live loads can be substantial. Consequently, the effective seismic weight, and therefore the base shear, may be significantly higher under Argentinian provisions compared to ASCE 7.

When the typically lower response modification factor (R) permitted by INPRES-CIRSOC is combined with the higher effective seismic weight it prescribes, the resulting seismic demand for a given lateral force-resisting system is generally greater in Argentina than in the United States for an equivalent design response spectrum. This disparity may be further amplified when Part I (1991) is applied, as it specifies a damping ratio of 2% for industrial steel structures, which directly increases the seismic coefficient and, consequently, the design forces.

In addition to these technical differences, there are practical challenges associated with determining the applicable code edition. As in many countries, seismic design standards in Argentina are issued at the national level but require adoption by provincial authorities. This approval process can take several years, often resulting in the continued use of outdated code editions.

Depending on the jurisdiction, the applicable version of INPRES-CIRSOC 103 Part I may range from the 1991 edition to more recent revisions up to 2018. However, INPRES-CIRSOC 103 Part IV 2005 is widely adopted across provinces and remains the primary reference for steel seismic design.

A critical inconsistency arises because Part IV 2005, when used to design ductile steel systems, explicitly references Part I 1991 for the evaluation of seismic demand, incorporating certain modifications to align with its provisions. This implies that modern ductile designs may rely on seismic hazard definitions that do not reflect advances in seismology and ground motion characterization achieved over the past decades. Also implies that the ductile systems identified and the correspondent design parameters used for design, such as R , lack important updates. Moreover, to bypass this situation, is often the case that Part IV 2005, instead of being used with Part I 1991 as intended, is used in conjunction with newer versions, and inconsistencies rise during design.

The regulatory and methodological framework introduces notable challenges in achieving both consistency and technical accuracy in seismic design within Argentina.

CASE STUDY 01: PRE-HEATER TOWER

The first case study is related to a brownfield project that took place in a cement plant located at Leamington, Utah, see Figure 3. The client required to add and modify equipment at their pre-heater tower. The pre-heater tower contains the calciner and a series of cyclone separators used to preheat raw meal before it enters the rotary kiln. The modifications required to fit the new equipment led to the structural engineering verification of the existing steel structure. The structure dated from 1980 and have had several interventions in the years after, documented and undocumented changes.

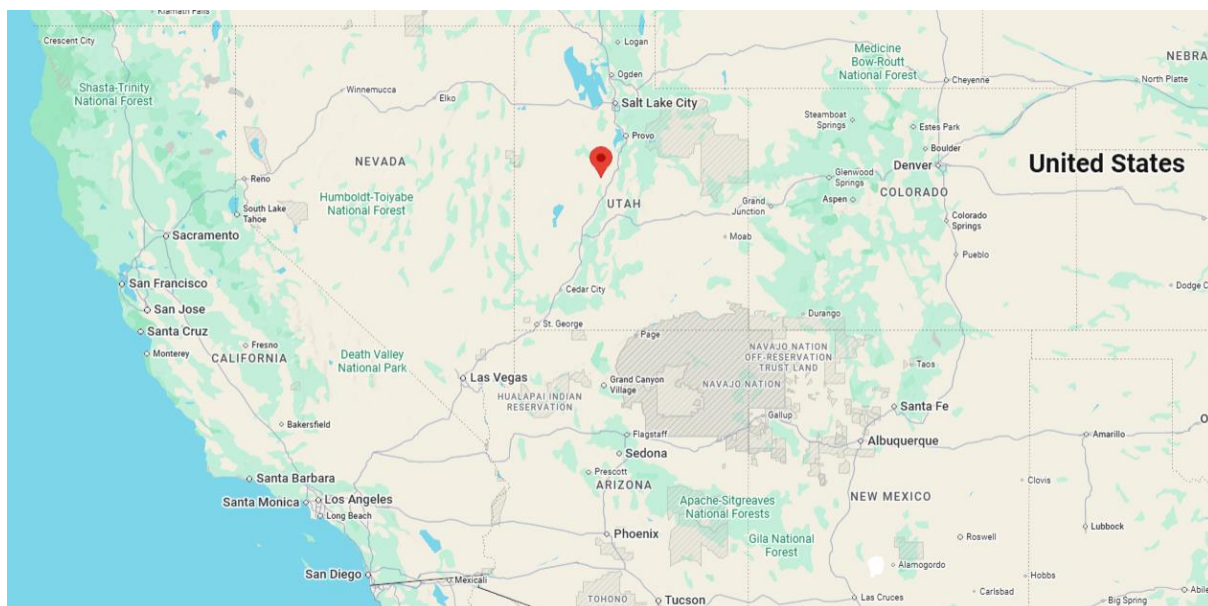


Figure 3. Project location

The tower is about 60m in height, has 10 main platform levels, plan dimensions are 11x16m approximately between main columns, and the lateral force resisting system is comprised of braced frames in both directions. See Figure 4.

The design criteria used for the original design of the structure established that the seismic loads were to be determined following UBC 1979, using seismic zone 3. Other parameters for the original design were presumed with the objective of estimating the seismic coefficient considered for the original design:

Horizontal Force Factor $K = 1.33$

Numerical coefficient $Z = 0.75$

Characteristic site period $T_s = 1.0 \text{ s}$

The new design criteria, agreed with Customer to verify the condition of the existing structure when considering the required modifications and the new equipment loads, is according to the last applicable edition of the Utah Building Code and IEBC 2021, which is based on ASCE 7-16. Given the size of the modifications, the alteration was classified as level 2 according to IEBC and reduced seismic loads were considered. A new geotechnical report indicated Site class D for this location and the following design parameters were considered:

The mapped MCE_R spectral response acceleration parameter:

at short periods $S_s = 0.6$

at a period of 1 s $S_1 = 0.204$

Seismic Design Category $SDC = D$

Design coefficients and factors for OCBF (Table 15.4-1):

Response modification factor $R = 1.5$

Overstrength factor $\Omega_0 = 1$

Deflection amplification factor $C_d = 1.5$

The response modification factor was chosen as 1.5, given the type and height of the structure, and the Seismic Design Category.

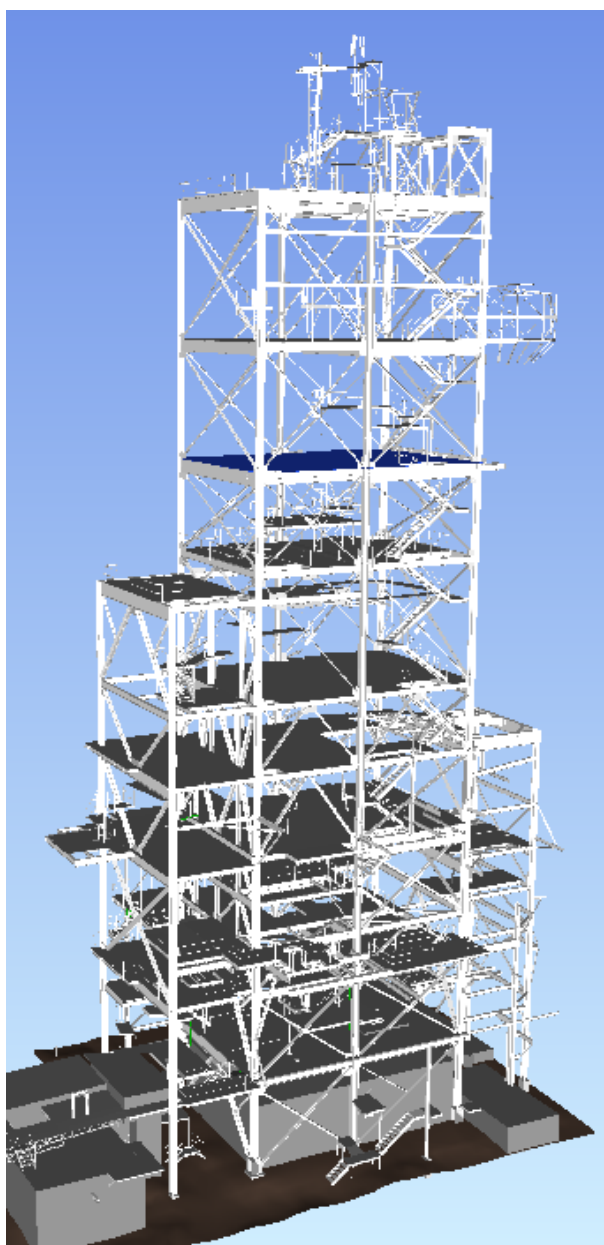


Figure 4. Pre-heater tower – existing structure

A straightforward comparison between the codes, UBC 1979 and IEBC 2021, is difficult to frame given the difference in the approach. Figure 5 shows a comparison between the seismic coefficient calculated according to UBC 1979, used for the original design of the structure, and the seismic coefficient to be used today considering IEBC 2021 to bring the structure up to code considering the alterations. Additionally, the seismic coefficient calculated according to IEBC 2015 is added for reference.

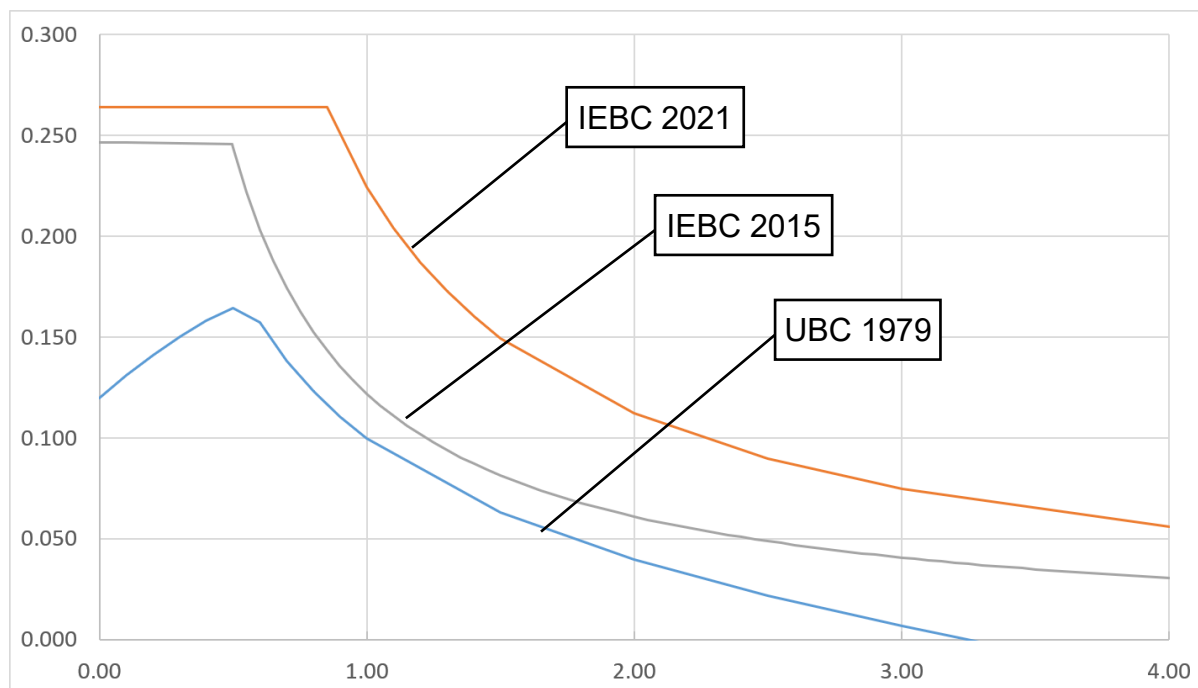


Figure 5. Seismic coefficient to UBC 1979, IEBC 2015 & IEBC 2021

Considering the structure's natural period is around 1.3s, Figure 5 shows that higher seismic loads must be considered to check the existing frames.

Table 2 summarizes the seismic coefficient obtained following the different codes for the case of the pre-heater tower.

Parameter	UBC 1979	IBC 2015 (ASCE 7-10)	IBC 2021 (ASCE 7-16)	Change
Cs	0.075	0.094	0.173	↑ 130%

Table 2 – PHT seismic coefficient to UBC 1979, IEBC 2015 & IEBC 2021

A mild increase is seen when comparing UBC 1979 with IEBC 2015, but when comparing with IEBC 2021 seismic demand goes up significantly. The difference is explained in the change of the Mapped accelerations in the Hazard Maps associated with each code.

IEBC 2015 is based on ASCE 7-10 which uses USGS 2014 Hazard maps, meanwhile IEBC 2021 is based on ASCE 7-16 which uses USGS 2018 Hazard Maps. Table 3 shows the main differences between the values obtained from the Hazard Maps.

Parameter	IBC 2015 (ASCE 7-10)	IBC 2021 (ASCE 7-16)	Change
S_s	0.541	0.601	↑ 11%
S_1	0.174	0.204	↑ 17%

Table 3 - Main seismic design parameters

Table 3 shows an increase in the mapped acceleration, especially for the parameter at a period of 1 second. This is no surprise, Mapped MCE_R spectral response accelerations have been risen consistently code after code in some locations, but now, for this particular case, S_1 is above 0.20 and according to ASCE 7-16 section 11.4.8, a Ground Motion Hazard Analysis (GMHA) is required. To avoid performing a GMHA, the exception listed for Site Class D at ASCE 7-16 section 11.4.8 was implemented.

A ground motion hazard analysis is not required for structures on Site Class D sites with S_1 greater than or equal to 0.2, provided the value of the seismic response coefficient C_s is determined by Eq. (12.8-2) for values of $T \leq 1.5T_s$ and taken as equal to 1.5 times the value computed in accordance with either Eq. (12.8-3) for $TL \geq T > 1.5T_s$ or Eq. (12.8-4) for $T > TL$. Considering this and the natural period of the structure it translates to approximately a 50% increase in the seismic demand.

The increase in seismic demand necessitated costly structural retrofits to accommodate the required modifications, resulting in the project being placed on hold. This is a perfect example of the severe impact that code updates might have on existing industrial structures, leading in some cases to strongly conditioned re-utilization.

CASE STUDY 02: MINING PROJECT IN ARGENTINA

SAXUM was tasked to review the seismic design criteria recommended by a third party for a renowned Mining Project in a high seismic risk zone of Argentina. Main goal was to perform a value engineering aimed at reducing the design seismic excitations in the framework of the specification of the currently valid local codes.

The following main items were pointed out during the review:

- Seismic design criteria developed through a hybrid approach combining provisions from both American and Argentine codes for a project located in Argentina. The referenced codes were IBC 2018 and INPRES-CIRSOC 103 Part I 1991.
- The use of site-specific response spectra for buildings falling within the scope of the code, such as industrial structures.
- The use of values for the response modification factor “R” which are not validated in the applicable codes.

Applicability of Foreign Codes

Considering the advantages outlined in the Technical Background regarding the use of ASCE 7 as the main code to develop the seismic design criteria—and likely influenced by the engineering firm’s familiarity with American standards—the third party adopted a design approach based on a combination of Argentine and U.S. codes.

The primary issue arising from this approach concerns the applicability of foreign standards. Given that the mining project is entirely located in Argentina, the governing regulation for seismic design should be INPRES-CIRSOC 103. In particular, for the Province of San Juan, the applicable and approved codes are INPRES-CIRSOC 103 Part I (2013) and Part IV (2005). Although hybrid design approaches are often adopted in practice, it is essential to clearly define the governing standard.

The objectives and scope of INPRES-CIRSOC are clearly established in Part 1, sections 1.1 and 1.2.:

“1.1. OBJETIVOS Este Reglamento establece los requisitos básicos a cumplir en el diseño, cálculo, ejecución, reparación y refuerzo de las construcciones y de sus partes componentes con el objeto de considerar en ellas el efecto sísmico. ...”

Translation: This Regulation establishes the basic requirements to be met in the design, calculation, execution, repair and reinforcement of constructions and their component parts in order to consider the seismic effect in them.

“1.2. ALCANCES Este Reglamento se aplica a todas las construcciones nuevas que se ejecuten dentro del territorio de la República Argentina. Además, se aplica a la rehabilitación de las construcciones existentes y a la reparación de construcciones que resultaran dañadas por la acción de los sismos. El presente Reglamento servirá de lineamiento fundamental en los aspectos pertinentes para aquellas construcciones u obras de extraordinaria importancia que por su naturaleza requieran estudios especiales.”

Translation: This Regulation applies to all new constructions that are carried out within the territory of the Argentine Republic. It also applies to the rehabilitation of existing buildings and the repair of buildings that were damaged by the action of earthquakes.

This Regulation will serve as a fundamental guideline in the pertinent aspects for those constructions or works of extraordinary importance that, due to their nature, require special studies.

In conclusion, Argentine codes should be adopted as the primary reference for the development of design criteria, and appropriately supplemented with IBC or other international standards for structural systems or aspects not explicitly addressed in local regulations.

Site-Specific Response Spectra

Following the philosophy of the Argentine seismic design code INPRES-CIRSOC 103, structures and facilities that do not pose significant risk to human life or the environment are not required to undergo a detailed, site-specific seismic hazard assessment. Instead, the seismic demand may be taken directly from the code-prescribed provisions.

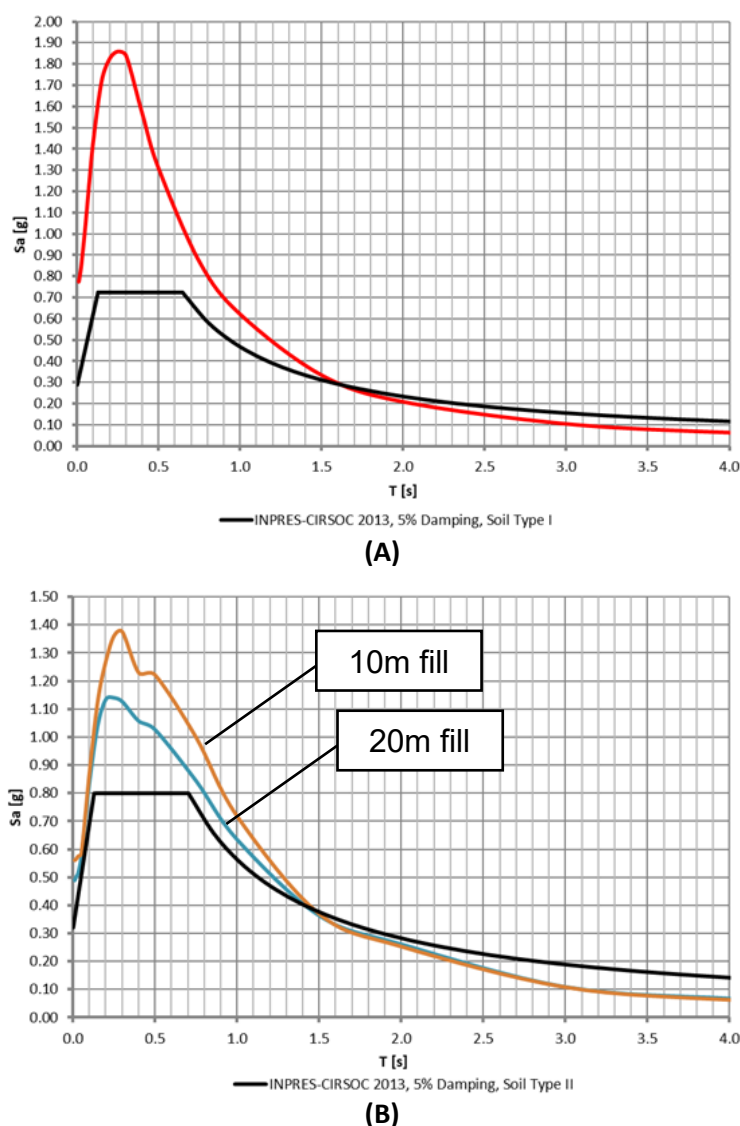


Figure 6. INPRES-CIRSOC 103 response spectra and site-specific response spectra proposed by Third Party for Soil Type I (A) and II (B).

Organiza:

A comparison between the spectrum defined by INPRES-CIRSOC 103 and the site-specific response spectra provided in the design criteria (see Figure 6) indicates that the code-based approach results in a noticeable reduction in seismic demand. This reduction is particularly significant within the period range commonly associated with industrial structures.

Response Modification Factor “R”

The seismic design criteria specified the use of global ductility factors (μ), which are equivalent to the response modification factor (R), defined in Section 8.3 of INPRES-CIRSOC 103 Part I 1991. This code does not establish design factors rigorously, especially for steel structures, and leaves the decision to the engineering judgement and experience.

However, in the province of San Juan, the design of ductile frames is governed by the code INPRES-CIRSOC 103 Part IV 2005. While this document references INPRES-CIRSOC 103 1991, it introduces specific amendments, including revisions to the response modification factor.

To ensure consistency between the selected R factor and the detailing requirements prescribed in Part IV 2005, the R value should be adopted from Table 4.1 of INPRES-CIRSOC 103 Part IV 2005, rather than from the provisions of Part I 1991. This was a fundamental conflict in the seismic design criteria.

In practice, the design based on IBC 2018 adopts a response modification factor of $R = 2.5$, as specified in ASCE 7 Table 15.4-1 for Ordinary Concentrically Braced Frames (OCBF) and Ordinary Moment Frames (OMF). These systems are associated with a permitted height limit of up to 160 ft (48 m), which generally encompasses typical industrial structures. Additionally, the effective seismic weight is determined in accordance with ASCE 7 provisions.

However, these criteria cannot be directly replicated within the Argentine regulatory framework. Local codes do not explicitly address nonbuilding structures, and both OCBF and OMF systems are restricted to a maximum height of 35 ft (12 m) in regions of high seismicity, thereby preventing most of the typical industrial structures from being considered. As a result, the available alternatives are either to adopt an essentially elastic design approach, or to adopt other applicable ductile lateral systems such as Special Concentrically Braced Frames (SCBF) or Special Moment Frames (SMF), both of which require significantly different and more demanding detailing provisions.

This incompatibility rendered the direct application of the original seismic design criteria impractical. Proposed alternative criteria were evaluated and, although they incorporate certain improvements, they lead either to much higher seismic demands—resulting in larger steel and concrete quantities—or to reduced seismic forces accompanied by more stringent detailing requirements and additional design limitations. This incompatibility is partly attributable to the limited updating of Argentine standards in keeping pace with international codes, as well as to the incomplete incorporation of advancements arising from ongoing scientific and technological developments.

CONCLUSIONS

1. The evolution of seismic design codes in both the United States and Argentina has resulted in an increase in the seismic demands in some locations, primarily due to updates in seismic hazard maps.
2. The reassessment of existing structures designed under older regulations may reveal substantial differences between the seismic actions originally considered and those required by current codes, often leading to the need for technically and economically significant retrofit interventions.
3. For existing industrial steel structures, the justification of the response modification factors originally used represents one of the main challenges in seismic evaluation, as current requirements for ductility, detailing, and connection qualification are considerably more stringent than those in force at the time of construction.
4. The preheater tower case study demonstrated that the combined effect of updated seismic hazard conditions, modern design criteria, and current code restrictions can increase seismic demand compared to the original design basis, potentially compromising the technical and economic feasibility of expansion projects.
5. The transition from design approaches based largely on assumed ductility to methodologies supported by explicit performance requirements, testing, and quality control has improved the reliability of expected seismic behavior, although it has also increased the complexity of design and retrofit processes.
6. The Argentine regulatory framework presents significant differences relative to ASCE 7 for industrial structures, particularly regarding nonbuilding structures, the selection of lateral force-resisting systems, and the definition of effective seismic mass, which often results in higher seismic demands for the same reference seismic hazard.
7. The absence of a specific classification for industrial or nonbuilding structures within INPRES-CIRSOC 103 limits the possibility of adopting intermediate approaches between elastic design and highly ductile systems, thereby reducing the flexibility available to optimize industrial projects.
8. The combined use of national and international standards requires a clear definition of the governing code and a careful review of the compatibility between design criteria, behavior factors, and detailing requirements, thereby avoiding inconsistencies that may affect safety or design efficiency.
9. The mining project case study showed that strict compliance with local regulations may lead to design solutions that differ significantly from those obtained using ASCE 7, affecting both seismic demand levels and associated construction requirements.
10. Continued efforts are needed to update and harmonize Argentine seismic provisions by systematically incorporating international advances in seismic hazard characterization, industrial structural design, and behavior-based reduction factors, with the objective of improving technical consistency and project competitiveness.
11. The cases analyzed demonstrate that code updates are not merely theoretical changes but have direct consequences on investment decisions, retrofit strategies, and expansion projects for critical industrial facilities.

REFERENCES

International Conference of Building Officials (ICBO), *Uniform Building Code (UBC 1979)*, Whittier, CA, USA: ICBO, 1979.

International Code Council, *International Existing Building Code (IEBC 2015)*, Washington, DC, USA: International Code Council, 2015.

International Code Council, *International Existing Building Code (IEBC 2021)*, Washington, DC, USA: International Code Council, 2021.

American Society of Civil Engineers, *Minimum Design Loads for Buildings and Other Structures (ASCE/SEI 7-05)*, Reston, VA, USA: American Society of Civil Engineers, 2006.

American Society of Civil Engineers, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE/SEI 7-16)*, Reston, VA, USA: ASCE, 2017.

Instituto Nacional de Prevención Sísmica (INPRES) and Centro de Investigación de los Reglamentos Nacionales de Seguridad para las Obras Civiles (CIRSOC), *Normas Argentinas para Construcciones Sismorresistentes: INPRES-CIRSOC 103-1991, Parte I – Construcciones en General*, Argentina, Aug. 1991.

Instituto Nacional de Prevención Sísmica (INPRES) and Centro de Investigación de los Reglamentos Nacionales de Seguridad para las Obras Civiles (CIRSOC), *Reglamento Argentino para Construcciones Sismorresistentes: Parte I – Construcciones en General (INPRES-CIRSOC 103-I)*, Argentina, 2013.

Instituto Nacional de Prevención Sísmica (INPRES) and Centro de Investigación de los Reglamentos Nacionales de Seguridad para las Obras Civiles (CIRSOC), *Reglamento Argentino para Construcciones Sismorresistentes: INPRES-CIRSOC 103, Parte I – Construcciones en General*, Argentina, 2018.

Instituto Nacional de Prevención Sísmica (INPRES) and Centro de Investigación de los Reglamentos Nacionales de Seguridad para las Obras Civiles (CIRSOC), *Reglamento Argentino para Construcciones Sismorresistentes: INPRES-CIRSOC 103, Parte IV – Construcciones de Acero*, Argentina, 2005.

International Code Council, *International Building Code (IBC 2018)*, Washington, DC, USA: International Code Council, 2018.