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Buildings and civil engineering works — Seismic resilience assessment and strategies — Compilation of relevant information

Bâtiments et ouvrages de génie civil — Eevaluation de la résilience sismique et stratégies — Compilation des informations pertinentes

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Foreword

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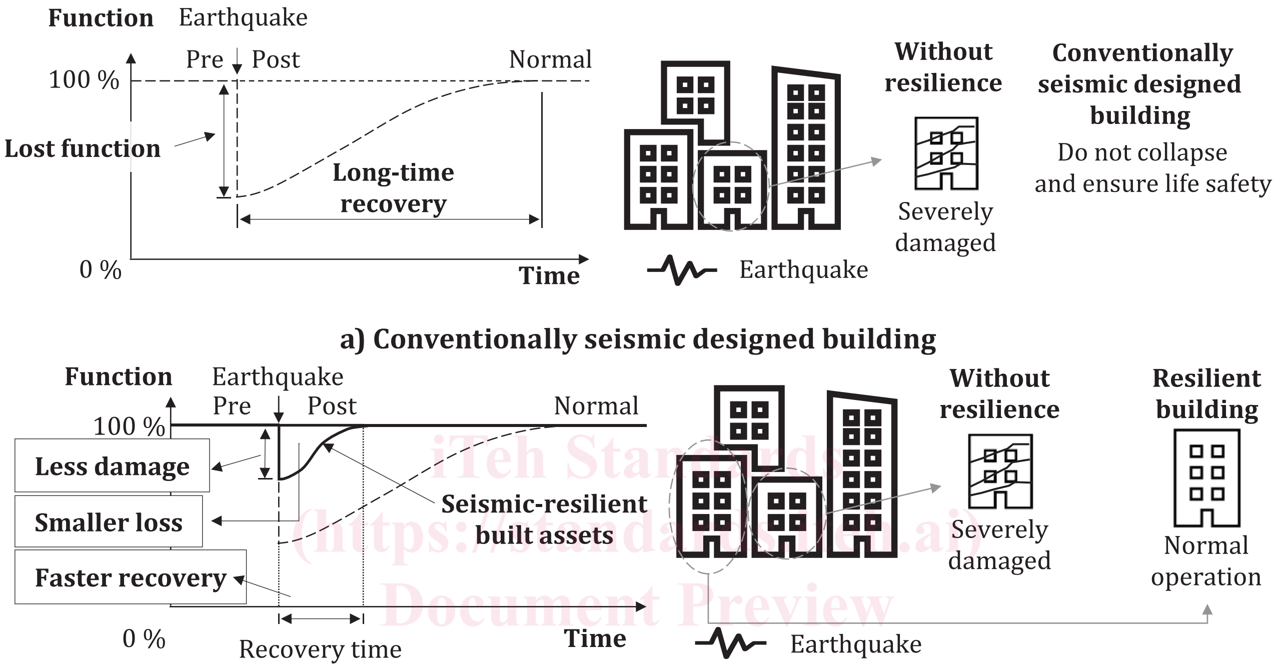
This document was prepared by Technical Committee ISO/TC 59, *Buildings and civil engineering works*.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

With the issue of the "Sendai Framework for Disaster Risk Reduction 2015–2030"[1], resilience for disaster risk reduction has become a global consensus. Seismic resilience, as a critical capacity for built assets, needs to be prioritized. It considers the social, environmental and economic aspects based on conventional seismic design, ensuring the desired recovery time, tolerable losses and minimal casualties while preventing collapse.

As a typical example, the conventionally designed building shown in Figure 1 a) underwent severe damage and lost key functions during an earthquake. By contrast, the building in Figure 1 b), which was designed for seismic resilience, sustained minimal damage and rapidly regained full postearthquake functionality.



b) Seismic-resilient building

Figure 1 — Comparison between buildings designed based on conventional seismic design and seismic-resilient design concepts

Consequently, seismic resilience has emerged as a critical global concern that necessitates prioritization. Some countries have standards for assessing and boosting resilience; however, many still overlook its importance because of inadequate knowledge sharing. ISO documents on the seismic resilience of buildings and civil engineering works play a critical role in raising awareness worldwide. The development of this document assists in gathering information on assessment frameworks, metrics and guidelines for improving seismic resilience.

The collated information includes the following:

— concept of seismic resilience and its development history; recent earthquake disasters have underscored the need for seismic resilience, as evidenced in a typical case;

— assessment tools for seismic resilience levels; standards, codes and documents were collected from various entities; these tools assess earthquake-related economic impacts, recovery times and casualties by providing assessment methods, data, information-acquisition methods and indicators;

— strategies for enhancing seismic resilience; these were collected from investigative documents focusing on constructing newly built resilient assets and retrofitting existing assets.

The compiled information serves as a valuable resource for stakeholders, guiding them in strategizing to enhance the seismic resilience of built assets, thereby minimizing earthquake-induced damage. This document can be useful for standard setters, policymakers, users, architects, engineers, and construction and manufacturing sectors.

Buildings and civil engineering works — Seismic resilience assessment and strategies — Compilation of relevant information

1 Scope

This document provides an index of typical existing information on the concept, assessment and strategy for seismic resilience of buildings and civil engineering works.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Abbreviated terms

ASCE	American Society of Civil Engineers
DS	damage state
FEMA	Federal Emergency Management Agency, an agency of the United States
GIS	geographic information system
MOHURD	Ministry of Housing and Urban-Rural Development, a ministry of the People's Republic of China
NIST GCR	National Institute of Standards and Technology of the United States, Grant/Contractor Reports
NZSEE	New Zealand Society for Earthquake Engineering
JSCE	Japan Society of Civil Engineers
PACT	Performance Assessment Calculation Tool provided in FEMA P-58[17]
PGA	peak ground acceleration
PGV	peak ground velocity
SPUR	San Francisco Bay Area Planning and Urban Research Association

5 Concept of seismic resilience

Seismic resilience includes the capacity to withstand, adapt to or promptly recover from earthquake damage to preserve or restore the intended functionality. The concept of seismic resilience is derived from the broader concept of resilience; and its developmental history is depicted in Figure 2.

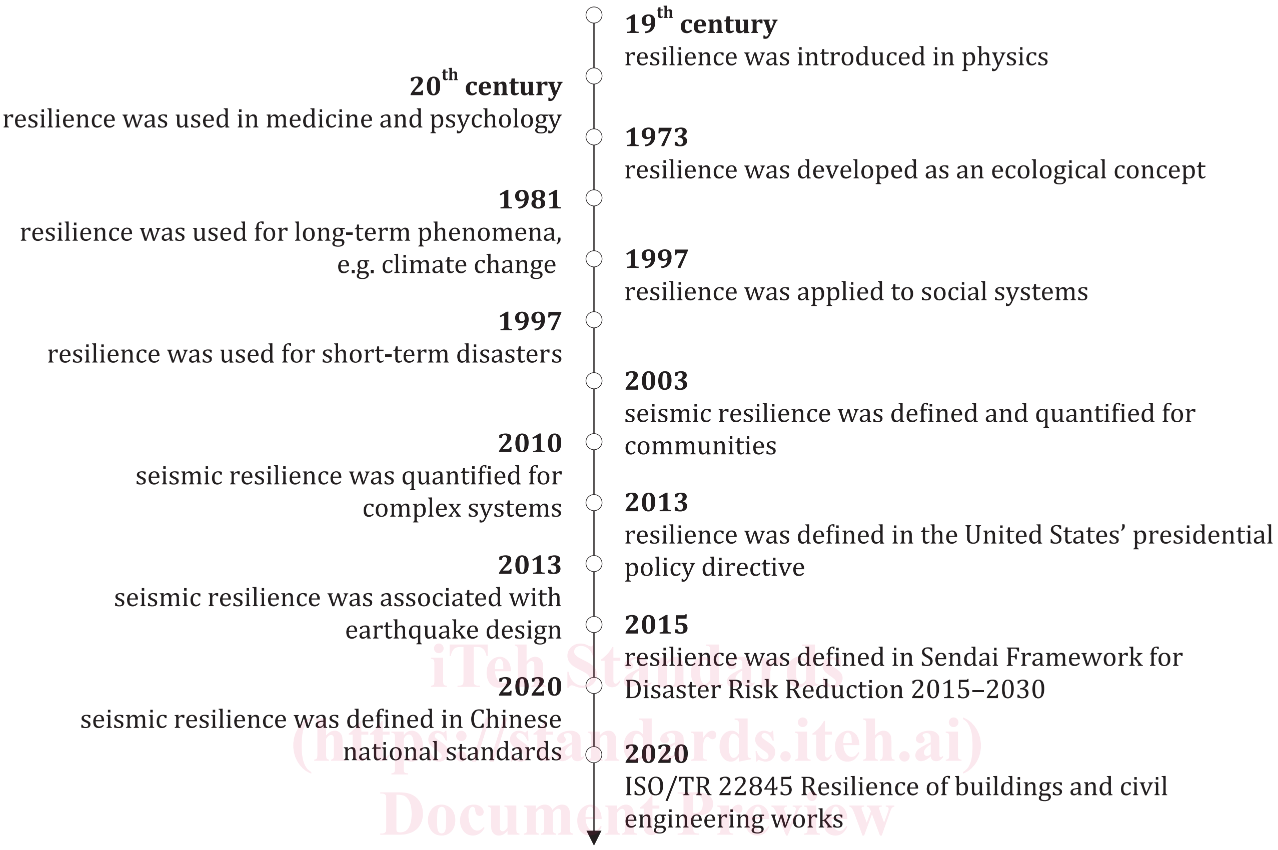


Figure 2 — Development of the concept of seismic resilience[2-15]

Seismic resilience was exemplified by the 2011 Christchurch earthquake.[16] On February 22, 2011, a strong earthquake hit Christchurch, New Zealand. Although many built assets in the struck area were constructed according to traditional seismic design for human safety, many minimally damaged assets were beyond economic repair and were demolished, resulting in significant economic losses and downtime. By contrast, a hospital located north of the area and built with a focus on seismic resilience endured the earthquake with slight damage and swiftly resumed operations.

In drawing lessons from the Christchurch earthquake, the focus is on the following two pivotal elements:

a) evaluating the current seismic resilience of built assets;

b) developing strategies to enhance their seismic resilience.

6 Assessment

6.1 General

Assessment is crucial for seismic resilience because it indicates the mechanical response of built assets under earthquake action, derives the induced losses and identifies the resilience level of the assets. Seismic resilience assessment[11,13,17] involves obtaining the seismic response in step 1 and assessing the resilience indicators in step 2 (see Figure 3). The datasets provide a foundation for this analysis. Figure 3 illustrates this method.

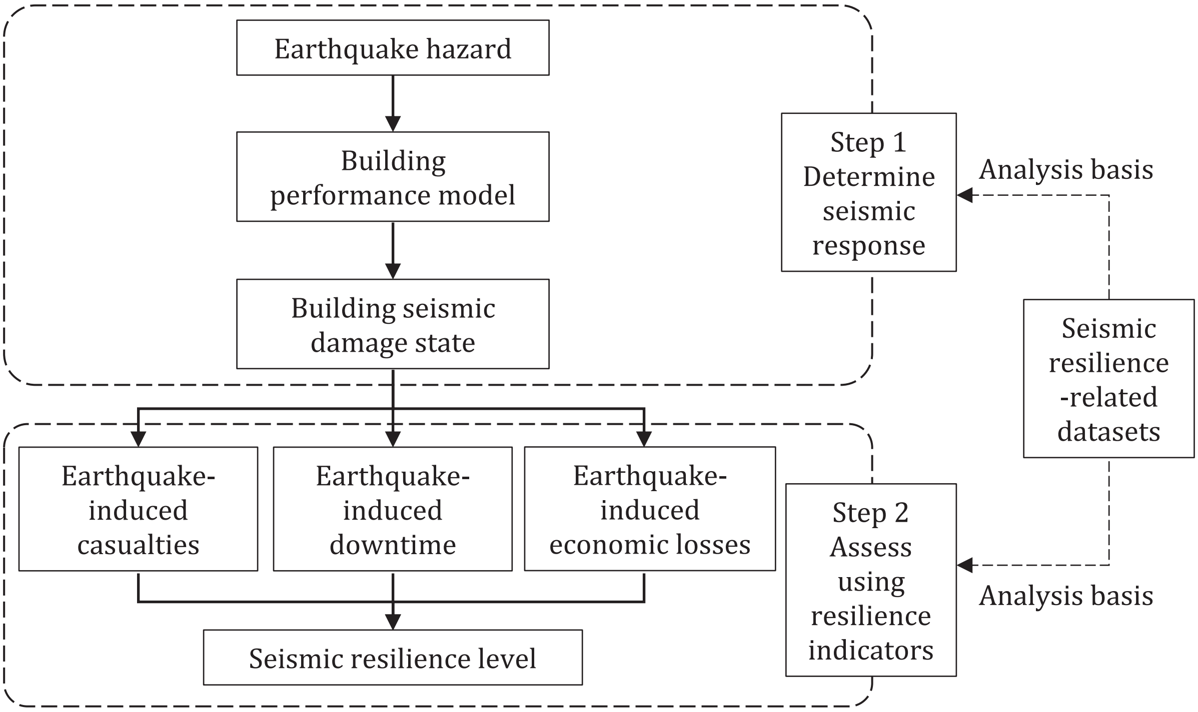


Figure 3 — Method for assessing seismic resilience

Methods for assessing seismic resilience are now well-developed globally, with contributions from organizations, such as FEMA,[17,18] Arup,[11] ASCE,[19] MOHURD,[13] NZSEE,[20] and JSCE.[21] Some standards provide comprehensive introductions to seismic resilience assessment methods, whereas others focus on specific critical aspects of the assessment process. Tables 1 to 3 summarize the main steps outlined in these standards.

Table 1 — Determining seismic response

	FEMA P58[17]	Hazus 5.1[18]	ASCE/SEI 41-17[19]	REDi[11]	GB/T 38591-2020[13]	NZSEE[20]	JSCE[21]
Earthquake hazard	√	√	√		√	√	√
Building performance model	√	√	√		√		
Building seismic damage state	√	√	√		√		

Table 2 — Assessment using resilience indicators

	FEMA P58[17]	Hazus 5.1[18]	ASCE/SEI 41-17[19]	REDi[11]	GB/T 38591-2020[13]	NZSEE[20]	JSCE[21]
Casualties	√	√			√		
Downtime	√	√		√	√		
Economic loss	√	√		√	√		
Seismic resilience level	√			√	√		

Table 3 — Seismic resilience-related datasets

	FEMA P58[17]	Hazus 5.1[18]	ASCE/SEI 41-17[19]	REDi[11]	GB/T 38591-2020[13]	NZSEE[20]	JSCE[21]
Datasets	√	√			√		

The following are some detailed examples of the seismic resilience assessment procedure.

EXAMPLE 1 The flowchart of the performance assessment methodology based on FEMA P58 encompasses:

a) establishing the building performance model;

b) specifying earthquake hazards;

c) analyzing building responses;

d) formulating collapse fragility;

e) evaluating performance[17].

EXAMPLE 2 REDi[11] adapted the PACT (FEMA P-58[17]) loss assessment method to incorporate practical repair strategies, delays caused by "impeding factors" and utility disruption times. This update enables forecasting of the time to reoccupancy, functional recovery or full recovery. Users select the desired recovery state for downtime analysis through calculations considering the building components impeding the selected recovery state.

EXAMPLE 3 GB/T 38591-2020[13] outlines a building assessment procedure that includes:

a) integrating building data;

b) building a structural model;

c) deriving engineering demand parameters from nonlinear time-history analysis;

d) assessing damage states using fragility data;

e) estimating the repair time, repair costs and casualties for a specific earthquake level;

f) assessing the seismic resilience level based on the estimated index.

EXAMPLE 4 Hazus 5.1[18] offers a community assessment procedure comprising:

a) selecting the study area;

b) establishing the earthquake hazard scenario;

c) incorporating local soil and geological data;

d) integrating local inventory data;

e) applying Hazus formulae;

f) calculating direct economic loss, casualties and shelter needs;

g) evaluating postearthquake fire impacts;

h) quantifying and characterizing debris.

6.2 Determining seismic response

6.2.1 Earthquake hazard

Earthquake hazards serve as inputs for analyzing seismic responses. These hazards can be characterized by the response spectrum and ground motion history.

EXAMPLE 1 FEMA P-58[17] outlines performance assessment types based on ground motion intensity.

— Intensity-based assessments utilize user-defined acceleration-response spectra, such as code design spectra.

— Scenario-based assessments use spectra from specific earthquake magnitudes and distances calculated using ground-motion prediction equations (attenuation relationships).

— Time-based assessments rely on seismic hazard curves and the corresponding spectra selected for a particular annual exceedance probability.