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Resilience of buildings and civil engineering works

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Contents

Page

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

Resilience is not a new concept. It is widely used in many fields such as human psychology, ecology, disaster risk management and product specification.

With an increasing impact, resilience is contributing to sustainable development on humanitarian issues at the global level, focusing on providing the general public, including vulnerable groups, with an environment that can better adapt to future disaster risks.

In view of the increasing demand for resilience of building and civil engineering works, this document attempts to collect and summarize typical and relevant existing information to provide reference for research and standard preparation. Information is aggregated mainly on concept, disaster risk and countermeasure:

1) For concept, this document sorts out some perspectives of resilience in different contexts and definitions of resilience that have appeared in ISO documents.

2) For disaster risk, this document describes three categories of disaster risk closely related to buildings and civil engineering works, i.e. climate-induced, earthquake-induced and human-induced, and indexes some typical related reports and data.

3) For countermeasure, this document summarizes typical relevant information from the two dimensions of strategy and measurement. Some of this information is relatively mature, already in the form of standards, guidelines, etc., some are implemented in cases, and some are at the research stage.

Resilience of buildings and civil engineering works involves interested parties and participants which can include specialists in the field of building and civil engineering works (such as material manufacturers, engineers, architects, constructers and estimators, etc.), scientists, standard setters, investors and financial institutions, regulatory agencies, communities, residents and occupiers, government administrative departments, etc.

Resilience of buildings and civil engineering works

1 Scope

This document provides an index of typical existing information on concept, disaster risk and countermeasure for 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 terminological databases for use in standardization at the following addresses:

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

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

4 Concept

4.1 Perspectives in different contexts

Resilience is derived from the Latin word "resilio" for bounce[2] and in most cases its use retains this concept either literally or figuratively. The Oxford Dictionary of English gives two explanations of resilience, "the ability of a substance or object to spring back into shape" and "the capacity to recover quickly from difficulties"[3], which could be understood as mechanical and functional resilience respectively. Some domains also have understandings of resilience from different perspectives. Table 1 is a summary of some typical descriptions of resilience in different contexts, extracted from the literature found.

Table 1 — Resilience in different contexts

Context	Perspective	Citation
Ecology	A measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables.	Holling, C.S. 1973[4]
Risk management	Resilience is the capacity to cope with unanticipated dangers after they have become manifest, learning to bounce back.	Wildavsky, A.B. 1988[5]
	The ability to recoil effectively from adversity and enhancing the likelihood of exposure to adversity leading to growth.	Paton, D. and Johnston, D. 2001[6]
Building	A resilient built environment should be designed, located, built, operated and maintained in a way that maximises the ability of built assets, associated support systems (physical and institutional) and the people that reside or work within the built assets, to withstand, recover from, and mitigate for the impacts of extreme natural and human-induced hazards.	Bosher, L. 2008[7]
	Resilience is the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance.	Resilient Design Institute[8]

Table 1 *(continued)*

Context	Perspective	Citation
Urban	Urban resilience is the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience.	Rockefeller Foundation[9]
The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.		UNDRR[10]

4.2 Definitions in ISO documents

There are 26 hits when searching for definitions of “resilience” on the ISO Online Browsing Platform (ISO OBP). In material and product standards, different forms of mechanical resilience are defined. Standards dealing with systems, on the other hand, focus on forms of functional resilience appropriate to the systems. Table 2 shows examples of these two types of definitions in ISO documents.

Table 2 — Definitions in ISO documents

Type	Term	Definition	Source
Mechanical resilience	resilience	ability of ceramic fibres to spring back after compression to 50 % of thickness	ISO 836:2001, 113
	resilience	ability of a textile floor covering to regain thickness after a static or dynamic compression	ISO 2424:2007, 9.1.2.1
	rebound resilience	ratio between the returned and the applied energy of a moving mass which impacts a test piece	ISO 4662:2017, 3.1
	elasticity, noun springiness, noun resilience, noun	mechanical textural attribute relating to: the rapidity of recovery from a deforming force; and the degree to which a deformed material returns to its original condition after the deforming force is removed	ISO 5492:2008, 3.50

Table 2 *(continued)*

Type	Term	Definition	Source
Functional resilience of system	resilience	ability of an organization to resist being affected by disruptions	ISO/IEC 27031:2011, 3.14
	resilience	ability to absorb and adapt in a changing environment	ISO 22300:2018, 3.192
	resilience fault tolerance	tolerance of a system to malfunctions or capacity to recover functionality after stress	ISO 18457:2016, 3.9
	organizational resilience	ability of an organization to absorb and adapt in a changing environment	ISO 22316:2017, 3.4
	resilience	ability to recover from security compromises or attacks	ISO/IEC 29180:2012, 3.2.10
	resilience	adaptive capacity of an organization in a complex and changing environment	ISO Guide 73:2009, 3.8.1.7 ISO 28002:2011, 3.44 ISO 18788:2015, 3.47 ISO 37101:2016, 3.33 ISO 37100:2016, 3.1.3 ISO 37123:2019, 3.6
	fault tolerance resilience	ability of a functional unit to continue to perform a required function in the presence of faults or errors	ISO/IEC 2382:2015, 2123055
	resilience	capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation	ISO 14080:2018, 3.1.3.6

According to the ISO OBP, there are currently some 320 standards in which reference is made to resilience, by title and/or content, although often without defining what is meant by the term. Below are some examples of ISO standards which explicitly focus on resilience. Two of these relate to mechanical resilience and one to functional resilience of systems:

— ISO 8307, prepared by ISO/TC 45, Rubber and rubber products;

— ISO 4662, prepared by ISO/TC 45, Rubber and rubber products;

— ISO 28002, prepared by ISO/TC 8, Ships and marine technology.

The following standard is concerned with mechanical resilience but refers to it as "elastic recovery":

— ISO 7389, prepared by ISO/TC 59/SC 8, Sealants.

5 Disaster risk

5.1 General

Since resilience is the ability to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard[10], it is necessary to understand the status of disaster risks, which is a prerequisite for the development of resilience standards for buildings and civil engineering works.

This document collects three categories of disaster risks closely related to buildings and civil engineering works: climate-induced, earthquake-induced and human-induced, and indexes some related reports and data sets of these disaster situations. Since the life of a building or civil engineering work will be tens or even hundreds of years, it is also necessary to pay attention to future possibilities of disaster risks.

5.2 Climate-induced

For climate-induced disaster risks, this document mainly collects some typical reports and data. From them, the following can be seen:

1) **The frequency and economic losses of global meteorological disasters have increased**: Under the background of global climate change, the frequency and economic losses of meteorological disasters have an obviously upward trend, being detrimental to the safety of human life and property and the sustainable economic and social development.

2) **The global climate risks will continue to rise**: Looking ahead to the next few decades of the 21st century, global climate risks will continue rising due to climate change and the increased exposure and vulnerability brought about by urbanization. Among them, changes of risks such as **high temperature, low temperature, heavy precipitation, tropical cyclone, drought** and **sea level rise** can have certain impact on buildings and civil engineering works. The attention to them has important implications for considering the resilience standard of buildings and civil engineering works in the long term. Table 3 shows projected changes of high temperature, low temperature, heavy precipitation, tropical cyclone, drought and sea level rise in the 21st century, extracted from the collected data.

Table 3 — Projected changes of global annual mean temperature, high temperature, low temperature, heavy precipitation, tropical cyclone, drought and sea level rise in the 21st century under different representative concentration pathway (RCP) scenarios relative to the period 1986-2005[30],[31],[32],[33]

Temperature	RCP2.6		RCP4.5		RCP8.5	
	Mid-21st century	Late 21st century	Mid-21st century	Late 21st century	Mid-21st century	Late 21st century
	(1,0 ± 0,3) °C	(1,0 ± 0,4) °C	(1,4 ± 0,3) °C	(1,8 ± 0,5) °C	(2,0 ± 0,4) °C	(3,7 ± 0,7) °C
High temperature	The 1-in-20-year extreme daily maximum temperature will likely increase by about 1 °C to 3 °C and 2 °C to 5 °C by the mid- and late 21st century respectively, depending on different regions and emission scenarios. A 1-in-20-year hottest day is likely to become a 1-in-2 and 1-in-5-year event by the end of 21st century for the high and low emission scenarios respectively. The heat related risks increase with greater degrees of warming. 13,8 % of the world population would be exposed to severe heat waves at least once every 5 years under 1,5 °C of global warming, with a threefold increase (36,9 %) under 2 °C warming.					
Low temperature	Cold days and cold nights are very likely to become much less frequent. Further decrease in the number of cold days/nights and an increase in overall temperature of cold extremes would occur under 1,5 °C of global warming compared to under the present-day climate (1 °C of warming), with further changes occurring towards 2 °C of global warming. And in some regions, cold-related mortality is projected to decrease with increasing temperatures.					
Heavy precipitation	A 1-in-20-year annual maximum daily precipitation amount is likely to become a 1-in-5 to 1-in-15-year event by the end of the 21st century in most regions under higher emission scenarios. Projected increase in heavy precipitation will contribute to rain-generated local flooding in some catchments or regions. Over the global land monsoon region, an estimated 25 % (18 % to 41 %) and 36 % (22 % to 46 %) of area and population, respectively, could be relieved from the baseline 1-in-20 year events over the present-day level, if global warming were limited to 1,5 °C instead of 2 °C.					
Tropical cyclone	The global frequency of tropical cyclones will either decrease or remain essentially unchanged in 21st century. Average tropical cyclone maximum wind speed will likely increase, although it is possible that increases will not occur in all ocean basins. There is limited evidence that the global number of tropical cyclones will be less under 2 °C of global warming compared to under 1,5 °C of warming, but with an increase in the number of very intense cyclones. In coastal regions, increases in heavy precipitation associated with tropical cyclones combined with increased sea levels can lead to increased flooding.					

Table 3 *(continued)*

Drought	Droughts will intensify in the 21st century in some seasons and areas, and "extreme" drought is projected to act as the normal climatological state by the end of the 21st century under the high emission scenarios in many mid-latitude locations. Duration of droughts are also projected to increase in some regions of the world.		
Sea level rise	0,4 m (0,26 m to 0,55 m) rise by the late 21st century	0,47 m (0,32 m to 0,63 m) rise by the late 21st century	0,63 m (0,45 m to 0,82 m) rise by the late 21st century

Meanwhile, there are some online map tools for visualizing global or national climate projections. Some of them show changes in risks such as temperature, precipitation and sea level rise in different periods of the 21st century under different emission scenarios. These projections can play a supporting role in the decision-making of investment, standards and design for the resilience of buildings and civil engineering works.

Some countries and organizations have proposed initiatives and action plans to address climate change, targeting parts of cities, communities, buildings, infrastructure, etc., which can have certain implications for the resilience of buildings and civil engineering works.

5.3 Earthquake-induced

For earthquake-induced disaster risks, this document mainly collects some typical data on seismic risk. From them, the following can be seen:

1) **The global seismic risk remains severe:** Earthquake is one of the most catastrophic natural hazards to human beings. With rapid urbanization in recent years, an increasing amount of population as well as property will be exposed to seismic risks[34]. At the same time, aging and changes in strength and stiffness can also impair the seismic safety and serviceability of the existing engineering structure[35].

2) **It is challenging to meet the demand for resilience in traditional seismic resistance methods:** In certain recent earthquakes, although some buildings did not collapse, they could hardly be repaired due to the severe damage, causing enormous economic loss and substantial social impact. For example, after the Christchurch earthquake in New Zealand on February 22, 2011, none of the 51 tallest buildings in the city collapsed owing to the rigorous seismic standards of New Zealand. Nonetheless, 37 of these tall buildings had to be demolished due to their severe damage and potentially high costs to repair[34]. Furthermore, similar conditions occurred in the Great East Japan earthquake on March 11, 2011, and in the Haiti earthquake on January 12, 2010.

These issues indicate that resilience enhancement of buildings and communities is essential, which is illustrated in Figure 1.