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- WRI speaks on its cooperation with ISO
- Progress on road safety management standard

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BUILDING THE FUTURE TODAY

Building **reliable structures**

by Andrzej M. Brandt, Chair of ISO/TC 98, Bases for design of structures, *and Chair of ISO/TC 98/ SC 2,* Reliability of structures

Reliability is a powerful term. Whether using it to describe a facility, a piece of equipment, a procedure, an information source or even a person, it generally denotes an expectation that certain performance standards are met. When we attribute it to something or someone, we expect a low risk of failure.

ISO 2394:1998, *General principles on reliability for structures*, follows this widely accepted definition, describing building reliability as the ability of a structure or structural element to fulfil specified requirements throughout its service life, for which it has been designed. In simple terms, the structure should be strong, stable and ready for use.

Building safety has undoubtedly been a consideration since humans began constructing shelters sometime in our earliest pre-history. The first known formal code for building safety – engraved on the sides of a stone that is now on display in the Louvre Museum in Paris – was issued nearly 4 000 years ago by the Babylonian King Hammurabi. Hammurabi's building code placed responsibility for structural safety clearly on the builder, and prescribed harsh punishment for shoddy work: if a building collapsed and killed its owner, the builder would be put to death.

The dome of the Pantheon in Rome, Italy – durability and reliability proven over 20 centuries.

More than safety

Safety and structural strength requirements developed over the centuries, emerging as standards and building codes in different parts of the world. But the addition of serviceability to safety standards took place only in recent decades, requiring builders to ensure that buildings performed throughout the entire lifetime of the structure.

The Eiffel tower in Paris, France – an example of structural optimization and rational reliability.

This means for instance that deformation and deflection from various types of loads that the building is subject to must be kept within defined limits. Further, cracking of structural and even non-structural elements, as well as discoloration or degradation from chemical or biological processes, must not occur. Similarly, the structure must not experience excessive vibration, even if there is no actual risk of structural collapse.

These requirements are considered as Serviceability Limit States (SLS) under the precepts of the structural engineering design methodology known as Limit State Design (LSD).

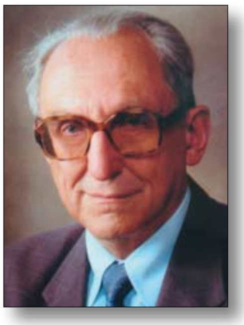
Ultimate Limit States (ULS), on the other hand, dictate that a structure must not collapse when subjected to the peak design load or stress for which it was designed. A structure is deemed to satisfy the ULS criteria if all factored bending, shear and tensile or compressive stresses are below the factored resistance calculated for the section under consideration.

A spider's web, an extremely reliable structure comprised of multiple elements.

A ULS failure of a structure means that it cannot perform its intended function because of some form of a collapse. SLS failures do not include structural collapse, but rather the inability of the structure to perform its intended functions.

Both SLS and ULS requirements are included in the generally adopted approach to LSD for structures, in which reliability is a central consideration.

About the author



Andrzej M. Brandt is a retired Professor of Technical Science at the Institute of Fundamental Technological Research of the Polish Academy of Sciences in Warsaw. His main research interests are in optimization and design of building structures, in mechanical behaviour of cement-based materials and testing methods of their properties. He has published over 110 research papers, over 20 books and coordinated several research projects on these subjects. He has lectured at technological universities in Canada, France, Japan, the United Kingdom, the USA and other countries

Several International Standards have been published under the ISO technical committee ISO/TC 98, *Bases for design of structures,* using that format, starting with the basic standard ISO 2394:1986, *General principles on reliability of structures*, and its revised version published in 1998. This standard is now generally accepted around the world and provides the basis for standardization in different regions and countries.

The most common failure

It should be noted here that the reliability of a building or a bridge does not depend exclusively upon safety and serviceability, but can be affected by other factors as well. For example, a malfunctioning heating system in a building or failure of the pipes that evacuate rainwater from a bridge may render these structures unusable. Here, reliability is considered only with respect to load-bearing structures, i.e. to the complete structure and to its structural elements, excluding all other types of equipment in the facility.

The most common causes of structural failures are human errors during the building process, usually involving a coincidence of multiple errors and their cumulative result. LSD includes methods and procedures for detecting and eliminating these sources of errors, or at least reducing their effects.

The probability that errors do occur in the building process may be significantly reduced by the intelligent and efficient application of various procedures such as inspections, monitoring and controlling at all stages. ISO standards indicate how these procedures should be applied for different building and civil engineering facilities and under different uses.

Long lasting

The issue of durability is not considered directly in ISO 2394, although general recommendations are specified for four design classes relating to building lifetime. Still, the importance of durability of structures has been widely recognized in recent years, driven by the high costs of repair and replacement of substandard buildings. Durability has therefore become an inherent part of construction requirements, and lifecycle design now includes reliability considerations – an issue addressed by the ISO standard ISO 15686, *Buildings and constructed assets – Service life planning*.

ISO/TC 98 has developed several standards on the reliability of structures in recent years, including:

- ISO 23469:2005, *Bases for design of structures – Seismic actions for designing geotechnical works*;
- ISO 10137:2007, *Bases for design of structures – Serviceability of buildings and walkways against vibrations*;
- ISO 21650:2007, *Actions from waves and currents on coastal structures*.

Other standards in this field are under preparation.

A new standard, ISO 13823:2008, *General principles on the design of structures for durability,* includes durability as a third limit state together with ULS and SLS. This work, carried out in ISO TC 98/SC 2, *Reliability of structures,* appears to be an important complement to the other ISO standards mentioned above.

Building on solid ground

It is not possible at this point for a single standard, no matter how carefully and competently elaborated, to solve all questions related to standardization and the reliability of building and civil engineering structures. However, the requirements for durability introduced in 2008 are an important step in the right direction, and relate closely to the concept of sustainable development.

Buildings and other constructed facilities will require less energy and resources if they perform adequately throughout their designed lifetime and do not require early replacement. Conversely, frequent repair and restoration lead to additional energy inputs, financial losses and inconveniences for the public.

The principles of sustainable development are closely tied to the economics of energy and other resources to be left for generations to come. Standardization provides a powerful approach to support humans in meeting their needs while preserving the environment for the future.