# GB

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# Unified standard for reliability design of building structures

建筑结构可靠性设计统一标准

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# Unified standard for reliability design of building structures

## 1 General provisions

**1.0.1** This standard is hereby formulated, in order to unify the basic principles, basic requirements, basic methods of the reliability design of building structures of various materials, so that the structure meets the requirements of sustainable development, as well as the requirements of safety, reliability, economic reasonableness, advanced technology, quality assurance.

**1.0.2** This standard is applicable to the design of the entire structure, the components that make up the structure, and the foundation. It is applicable to the design of the construction stage and use stage of the structure. It is applicable to the reliability assessment of existing structures. The reliability assessment of existing structures can be carried out, in accordance with the provisions of Appendix A of this standard.

**1.0.3** This standard is formulated, based on the principles of the current national standard "Unified standard for reliability design of engineering structures" GB 50153. It is the basic requirement for the reliability design of building structures.

**1.0.4** The design of building structures should adopt the limit state design method, based on probability theory and expressed by partial factors. When there is a lack of statistical data, the design of building structures can be based on reliable engineering experience or necessary experimental research, OR it can be carried out, using the empirical methods such as allowable stress or single safety factor.

**1.0.5** When formulating load standards for building structures, structural design standards for various materials, and other related standards, it shall comply with the basic criteria, which are stipulated in this standard; meanwhile formulate corresponding specific provisions.

**1.0.6** In addition to complying with the provisions of this standard, the building structure design shall also comply with the provisions of the relevant national standards, which are currently in force.

## 2 Terms and symbols

### 2.1 Terms

#### 2.1.1 Structure

action.

**2.1.12 Load case**

A set of consistent load arrangements, that simultaneously consider fixed variable actions, permanent actions, free actions, as well as deformations and geometric deviations, for a specific verification purpose.

**2.1.13 Limit states**

A certain state, beyond which the entire structure or a part of the structure cannot meet a certain functional requirement, which is specified in the design. This specific state is the limit state of the function.

**2.1.14 Ultimate limit states**

A state, which corresponds to the deformation in which a structure or structural member reaches its maximum bearing capacity OR is unsuitable for continued bearing.

**2.1.15 Serviceability limit states**

A state, where a structure or structural member reaches a specified limit for normal use.

**2.1.16 Irreversible serviceability limit states**

Serviceability limit states, where the consequences of actions, which is generated and exceeds the normal use requirements, after removal, cannot be restored.

**2.1.17 Reversible serviceability limit states**

Serviceability limit states, where the consequences of actions, which is generated and exceeds the normal use requirements, after removal, can be restored.

**2.1.18 Durability limit states**

A state corresponding to the deterioration of a structure or structural member under environmental influence, that reaches a certain specified limit or mark of durability performance.

**2.1.19 Resistance**

The ability of a structure or structural member, to withstand the effects of action and environmental influences.

**2.1.20 Structural integrity: structural robustness**

When accidental events such as fire, explosion, impact or human error occur, the ability of the entire structure to remain stable, without causing damage that is disproportionate to the cause.

**2.1.21 Key member; key element**

Structural members, on which the ultimate limit state performance of the structure depends.

**2.1.22 Progressive collapse**

Initial local damage, propagating from member to member, eventually leads to the collapse of the entire structure or a portion of the structure that is disproportionate to the cause.

**2.1.23 Reliability**

The ability of a structure to complete a predetermined function, within a specified time and under specified conditions.

**2.1.24 Degree of reliability; reliability**

The probability, that a structure will complete a predetermined function, within a specified time and under specified conditions.

**2.1.25 Probability of failure $p_f$**

The probability that a structure will fail to perform its intended function.

**2.1.26 Reliability index β**

A numerical index, that measures structural reliability. The reliability index β is the inverse function of the standard normal distribution function, which has a negative failure probability $p_f$.

**2.1.27 Basic variable**

A defined set of variables representing physical quantities, which are used to characterize actions and environmental influences, properties of materials and geotechnical materials, as well as geometric parameters.

**2.1.28 Performance function**

A function of basic variables, that represents a structural function.

**2.1.29 Probability distribution**

The statistical rules of the values of random variables, which are generally expressed by probability density functions or probability distribution functions.

**2.1.30 Statistical parameter**

The reaction of a structure or structural member, which is caused by an action.

**2.1.40 Single action**

An action, which can be considered as an action that is statistically independent in time and space, from any other actions on the structure.

**2.1.41 Permanent action**

An action, that always exists within the design service life and whose change in magnitude is negligible as compared with the average value; OR an action whose change is monotonous and tends to a certain limit.

**2.1.42 Variable action**

An action, whose magnitude value changes with time, within the design service life, meanwhile whose change is not negligible, as compared with the average value.

**2.1.43 Accidental action**

An action, which may not necessarily appear within the design service life; however, once it occurs, it will have a large magnitude and a short duration.

**2.1.44 Seismic action**

The Action of earthquake vibrations on structures.

**2.1.45 Geotechnical action**

Actions, which are transmitted to a structure by rock, fill, or groundwater.

**2.1.46 Fixed action**

An action, which has a fixed spatial distribution in structure. When the magnitude and direction of the fixed action on a certain point of the structure are determined, the action of the fixed effect on the entire structure can be determined.

**2.1.47 Free action**

An action, which has arbitrary spatial distribution, within a structurally given range.

**2.1.48 Static action**

An action, which causes the acceleration produced by the structure to be negligible.

**2.1.49 Dynamic action**

An action, which causes the acceleration produced by the structure to be not negligible.

**2.1.50 Bounded action**

An action, whose boundary limit value cannot be surpassed BUT can be accurately or approximately grasped.

**2.1.51 Unbounded action**

An action, which has no clear boundary value.

**2.1.52 Characteristic value of an action**

The main representative value of an action. It can be determined, based on statistics of observation data, natural boundaries of action, or engineering experience.

**2.1.53 Design reference period**

The time parameter, which is selected to determine the value of variable effects, etc.

**2.1.54 Combination value of a variable action**

An action value, that makes the exceedance probability of the combined action be consistent with the exceedance probability of the standard value action, when the action appears alone; OR the action value that makes the structure have specified reliability index after combination. It can be represented by the reduction of the action standard value, by the combination value coefficient.

**2.1.55 Frequent value of a variable action**

The action value, which has a smaller ratio -- of the total time exceeded within the design reference period TO the design reference period; OR the action value in which the exceeded frequency is limited to the specified frequency. It can be represented by the reduction of the frequency value coefficient to the action standard value.

**2.1.56 Quasi-permanent value of a variable action**

The action value, which has a larger ratio -- of the total time exceeded within the design reference period TO the design reference period. It can be expressed by the reduction of the quasi-permanent value coefficient to the action standard value.

**2.1.57 Accompanying value of a variable action**

In an action combination, a variable action value that accompanies the dominant action. The accompanying value of a variable action can be a combined value, a frequent value, or a quasi-permanent value.

**2.1.58 Representative value of an action**

Action values, which are used in limit state design. It can be a standard value for an

Structural analysis of deformed structural geometry, using elastic theory analysis methods, based on linear stress-strain or bending moment-curvature relationships.

**2.1.69 First order or second order linear-elastic analysis with redistribution**

Structural analysis, which carries out first order or second order linear-elastic analysis that adjusts internal forces in structural design, coordinates with given external actions, does not perform explicit calculations of rotational capacity.

**2.1.70 First order non-linear analysis**

Structural analysis of the geometry of the initial structure, based on the nonlinear deformation characteristics of the material.

**2.1.71 Second order non-linear analysis**

Structural analysis of deformed structural geometries, based on nonlinear deformation characteristics of materials.

**2.1.72 first order or second elasto-plastic analysis**

Structural analysis, based on the bending moment-curvature relationship consisting of a linear elastic phase and a subsequent non-hardening phase.

**2.1.73 Rigid plastic analysis**

Structural analysis, which assumes that the bending moment-curvature relationship is inelastic deformation and no hardening stage, uses limit analysis theory to directly determine the ultimate bearing capacity of the geometry of the initial structure.

**2.1.74 Existing structure**

Various types of building structures, that already exist.

**2.1.75 Assessed working life**

The service life of an existing structure, under specified conditions, as estimated by the reliability assessment.

**2.1.76 Load testing**

A test, that evaluates the performance of a structure or structural member OR predicts its bearing capacity by applying loads.

## 2.2 Symbols

**2.2.1 Uppercase Latin letters:**

**3.3.4** The environmental impact shall be assessed, when designing the building structure. When the environment in which the structure is located has a greater impact on its durability, it shall take corresponding structural materials, design structures, protective measures, construction quality requirements, according to different environmental categories. etc.; formulate a regular inspection and maintenance system, during the use of the structure, so that the safety or normal use of the structure will not be affected by material deterioration, within its designed service life.

**3.3.5** The impact of the environment on the durability of the structure can be evaluated, through engineering experience, experimental research, calculation, inspection or comprehensive analysis. The durability limit state design can be carried out, in accordance with the provisions of Appendix C of this standard.

**3.3.6** The division of environmental categories and the corresponding requirements for design, construction, use, maintenance shall comply with the relevant national standards.

## 3.4 Reliability management

**3.4.1** In order to ensure that the building structure has the specified reliability level, in addition to design calculations, it shall control the material properties, construction, quality, use and maintenance of the structure accordingly. Specific control measures shall comply with Appendix D of this standard, as well as the special provisions of relevant standards for survey, design, construction, maintenance.

**3.4.2** The design of building structures must be undertaken by technicians, that have appropriate qualifications.

**3.4.3** The design of the building structure shall comply with the current national regulations on load, earthquake resistance, foundation, structural design standards of various materials.

**3.4.4** The design of the building structure shall take necessary protective measures against accidental effects, environmental impacts, etc., that the structure may be subject to.

**3.4.5** The materials and construction and fabrication processes, which are used in building structures, shall be subject to quality control; meanwhile accepted in accordance with the relevant national standards.

**3.4.6** The building structure shall be used according to the purpose specified in the design. It shall check the structural condition regularly; carry out necessary maintenance and repairs. When the purpose of use needs to be changed, it shall review the design and take corresponding technical measures.

## 5.3 Environmental influences

**5.3.1** Environmental influences can be divided into permanent influences, variable influences, accidental influences.

**5.3.2** The environmental influences of the structure shall be described quantitatively; when there is no condition for quantitative description, it can be described qualitatively through methods such as grading the degree of environmental influences on the structure; meanwhile corresponding technical measures shall be taken in the design.

# 6 Properties of materials, geotechnics and geometrical quantities

## 6.1 Properties and geotechnics of materials

**6.1.1** The physical and mechanical properties of materials and rock and soil, such as strength, elastic modulus, deformation modulus, compression modulus, internal friction angle, cohesion, etc., shall be determined, through the test, according to the current relevant national test method standards.

**6.1.2** When using the test results of standard samples to determine the actual material properties in the structure, it shall also consider the differences between actual structure and standard samples, between the actual working conditions and standard test conditions. The relationship between the material properties in the structure and the material properties of the standard sample shall be expressed, through a conversion coefficient or function, based on the corresponding comparative test results, OR determined based on engineering experience. The uncertainty of the material properties in the structure shall be composed of the uncertainty of the material properties of the standard sample and the uncertainty of the conversion coefficient or function.

**6.1.3** Material properties should be described by a random variable probability model. Various statistical parameters and probability distribution types of material properties shall be determined, based on test data, using hypothesis inspection methods of parameter estimation and probability distribution. The significance level of the inspection can be 0.05.

**6.1.4** The probability distribution of material strength should adopt normal distribution or lognormal distribution.

**6.1.5** The standard value of material strength can be determined according to the 0.05 fractile of its probability distribution. The standard values of physical properties, such as material elastic modulus and Poisson's ratio, can be determined according to the 0.5

fractile of their probability distribution.

**6.1.6** When the test data is insufficient, the standard values of material properties can be determined by the specified values of relevant standards, OR can be determined through engineering experience, after analysis and judgment.

**6.1.7** Geotechnical performance indicators, foundation bearing capacity, pile foundation bearing capacity, etc. shall be measured, through direct or indirect methods such as in-situ test and indoor test, considering the influences from such factors as disturbance by drilling sampling, difference between indoor & outdoor test conditions and actual building structural conditions, errors generated from the formula used, combining the engineering experience.

**6.1.8** The standard values of geotechnical properties should be determined, based on the results of in-situ tests and indoor tests, in accordance with the provisions of relevant standards. When conditions permit, the standard values of geotechnical properties can be determined according to a certain fractile of its probability distribution.

## 6.2 Geometric quantities

**6.2.1** The geometric parameters of the structure or structural members should be described, by a random variable probability model. Various statistical parameters and probability distribution types of geometric parameters shall be determined, based on the observation data of the geometric dimensions of the structure or structural members, under normal production conditions, using parameter estimation and probability distribution hypothesis inspection methods.

**6.2.2** When the observation data is insufficient, the statistical parameters of the geometric parameters can be determined, through analysis and judgment, based on the tolerances specified in the relevant standards.

**6.2.3** When the variability of geometric parameters has little impact on the structural resistance and other properties, the geometric parameters can be used as deterministic variables.

**6.2.4** The standard value of the geometric parameter can be determined, by the nominal value specified in the design, OR based on a certain fractile of the probability distribution of the geometric parameter.

# 7 Structural analysis and design assisted by testing

## 7.1 General requirements

**7.1.1** Structural analysis can be carried out, by calculation, model test or prototype test.

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