REVISION OF INTERNATIONAL STANDARD ISO 3010 BASES FOR DESIGN OF STRUCTURES-SEISMIC ACTIONS ON STRUCTURES

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SUMMARY

The International Standard "ISO 3010 Bases for design of structures - Seismic actions on structures" was published in 1988 through the activity of the working group of ISO/TC98. TC98 deals with "Bases for design of structures." The aim of TC98 is to create a coherent system of International Standards in the field of buildings and civil engineering works. ISO 3010 includes principles for the determination of seismic actions on structures and seismic design. The revision of ISO 3010 began in 1995 and the committee draft ISO/CD 3010 for the revision was made in February 1999. Several new items have been included, e.g. response control systems, foundations, estimation of paraseismic influences. This paper introduces the activities of TC98, ISO 3010 and its revision.

INTRODUCTION

The International Standard "ISO 3010 Bases for design of structures - Seismic actions on structures" [ISO, 1988] was published in 1988 through the activity of the working group of ISO/TC98. TC98 deals with "Bases for design of structures." The aim of TC98 is to create a coherent system of International Standards in the field of buildings and civil engineering works. The system forms a basis for regional and national standard bodies which prepare their standards for particular types of structure and structural materials. ISO 3010 includes principles for the determination of seismic actions on structures and seismic design. Since it does not give any specific values for factors to determine seismic loadings, it is not possible to design a structure only according to ISO 3010. Although its annex gives useful information to determine the values for those factors. The standard, however, includes almost all items and factors to be considered. Therefore it is a useful document for establishing a new code or revising an old code. These features of ISO 3010 remain the same in the revision. The revision began in 1995, since then the convenor of the working group is the author. The committee draft ISO/CD 3010 [ISO/TC98, 1999] for the revision was made in February 1999. The draft has been sent for voting and comments to all member bodies which belong to TC98. The activity on the revision is still continuing and the modification wil be made according to their comments. This paper introduces the activities of TC98, ISO 3010 and its revision.

ISO/TC98

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies. The work of preparing International Standards is normally carried out through ISO technical committees (TC's). Currently there are approximately 200 TC's. Each TC has several sub-committees (SC's) and there are approximately 600 SC's in ISO. Each SC usually has several working groups. In ISO there are about 2000 WG's.

ISO/TC98 is one of the TC's and TC98 deals with "Bases for design of structures." Among many ISO/TC's related to buildings and construction, TC98 is one of the basic committees whose work lies behind much of what goes on in the building industry. The aim of TC98 is to create a coherent system of International Standards in the field of buildings and civil engineering works. The system forms a basis for regional and national standard bodies which prepare their standards for particular types of structure and structural materials. Since TC98 was

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established in 1961, its secretariat has been in the Polish Committee for Standardization. In TC98 there are 21 participating members and 37 observers (one member or one observer from each country). TC98 has three main tasks which are shared among three SC's; (1) terminology and symbols, (2) reliability of structures, and (3) loads, forces and other actions on structures [Brandt, 1998].

SC1-Terminology and Symbols

SC1 deals with the definitions and explanations of the terms used in the standards and other documents which are prepared by TC98. The terms need to be well understood and correctly used without ambiguity. Since very often the meanings of certain terms are different from their meaning in the everyday language. Similar terms have slightly different meanings in different languages. Thus the task of establishing a coherent system of terms is very important. SC1 also concerns symbols with their subscripts and superscripts that are used in mathematical formulae and in technical drawings.

SC2 - Reliability of Structures

The reliability of structures is understood as a combination of their safety and serviceability. These are verified in two separate groups of limit states, i.e. (1) ultimate limit state and (2) serviceability limit state. In both limit states, all parameters like loads, material properties, structural dimensions, etc. are considered as random variables. Because complete knowledge of statistical distributions of these parameters is lacking, the randomness is considered by a system of partial factors.

SC3 - Loads, Forces and Other Actions

SC3 elaborates the bases for various categories of loads, e.g. loads due to service loads in various types of buildings, forces caused by wind and by snow on roofs. The seismic actions are dealt with in WG1 which is not one of WG's in SC3 but belongs directly to TC98. The values of these actions can be given only in relatively large limits, because conditions vary considerably between countries. However, the bases for treatment of the actual data and methods of their measurement can be standardized.

TC98 cooperates with several international organizations. Their recommendations and guidelines are systematically used as a kind of pre-standardization documents. For the last few years, the most important partner has been European Committee for Standardization (CEN), and particularly its Technical Committee 250, Structural Eurocodes. Both parties can use their documents on a reciprocal basis and develop them into ISO standards and Eurocodes, respectively (Vienna Agreement) [ISO and CEN, 1998]. By an extensive use of common bases for design of structures, considerable economies in time, material and money can be achieved.

The ISO/TC98, its SC’s and WG’s, and their documents are shown in the Annex.

ISO 3010 AND ITS REVISION

The current ISO 3010 (the first edition in 1988) was elaborated in WG1 under TC98 as shown in Annex. The convenor was the late Professor Yutaka Osawa of the University of Tokyo and Professor Yutaka Matsushima of the University of Tsukuba succeeded him. The revision of the first edition began in 1995, since then the convenor of TC98/WG1 has been the author.

ISO 3010 had not been included in the Earthquake Resistant Regulations a World List, which is published by the International Association for Earthquake Engineering (IAEE) every four years when the World Conference on Earthquake Engineering (WCEE) is held. Therefore, it was not so visible to many people. However, ISO 3010 was for the first time included in the Seismic Regulations a World List - 1996 of IAEE [IAEE, 1996]. This hopefully made the standard familiar to researchers and engineers.

The standards prepared by TC98 serve as references in the field of buildings and construction and are frequently called as “Code for Code Writers.” As to ISO 3010, it includes only principles for the determination of seismic actions and for seismic design. It does not give any specific values for factors to determine design seismic forces. Therefore it is not possible to determine seismic loads or to design a structure only according to ISO 3010, although the annex of ISO 3010 gives information to determine those values. ISO 3010, however, includes almost all items and factors to be considered. Therefore it is a useful document for establishing a new code or revising old codes.

These features of the standard remain the same in the revision. The revision of the text is rather minor, but the annex is extensively modified to include the current knowledge on earthquake engineering. ISO/CD 3010 for the revision consists of ten sections, i. e. 1 Scope and field of application, 2 Normative references, 3 Terms and definitions, 4 Symbols and abbreviated terms, 5 Bases of seismic design, 6 Principles of seismic design, 7 Principles of evaluating seismic actions, 8 Evaluation of seismic actions in equivalent static analyses, 9 Evaluation of seismic actions in dynamic analyses, 10 Estimation of paraseismic influences. ISO/CD 3010 has ten informative annexes, i.e. A Load factors as related to reliability of structure, Seismic hazard zoning factor and representative values of earthquake ground motion intensity, B Structural factor, C Normalized design response spectrum, D Seismic force distribution factor and seismic shear distribution factor, E Seismic action components, F Torsional moments, G Dynamic response, E Damping ratio, F Response control systems, and K Paraseismic influences. Some important points of the revision are as follows: New sections are, e.g. “3 Terms and definitions,” “4 Symbols and abbreviated terms,” “6.6 Response control systems,” “6.7 Foundations,” “9.6 Evaluation of the analytical results,” and “10 Estimation of paraseismic influences.” Seismic actions are now considered to be variable, for the ultimate limit state and for the serviceability limit state, or may be considered to be accidental [ISO, 1998]. New formulae to give seismic shear forces are added. All symbols are modified according to ISO 3898 [ISO, 1997]. The coefficient of importance is modified into the load factor as related to reliability of structure. The previous standard base shear coefficient is revised into the representative value of earthquake ground motion intensity.

The meeting of WG1 for the revision is held approximately twice a year. The previous meetings were held at Venice, Italy in October 1995, at Acapulco, Mexico in June 1996, at Copenhagen, Denmark in December 1996, at Cracow, Poland in June 1997, at Rotterdam, Holland in December 1997, at London, UK in June 1998, and at Paris, France in December 1998. Besides these meetings, the national working group have been organized in Japan, and its meetings have been held several times a year to prepare the draft. The committee draft ISO/CD 3010 for the revision of ISO 3010 was made in February 1999.

EVALUATION OF SEISMIC ACTION IN EQUIVALENT STATIC ANALYSES

The evaluation of seismic actions in equivalent static analyses in Section 8 of ISO/CD 3010 for the revision can be summarized as follows:

In the seismic analysis of structures based on a method using equivalent static loadings, the variable seismic actions for the ultimate limit state and for the serviceability limit state may be evaluated as follows.

a) Ultimate Limit State (ULS)

The design lateral seismic force of the ***i*** th level of a structure for ULS, $\boldsymbol{F}_{E,u,i}$, may be determined by

$$F_{E,u,i} = \gamma_{E,u}\ k_Z\ k_{E,u}\ k_D\ k_R\ k_{F,i} \sum_{j=1}^{n} F_{G,j} \qquad (1)$$

or the design lateral seismic shear force for ULS, $\boldsymbol{V}_{E,u,i}$, can be used instead of the above seismic force.

$$V_{E,u,i} = \gamma_{E,u}\ k_Z\ k_{E,u}\ k_D\ k_R\ k_{V,i} \sum_{j=i}^{n} F_{G,j} \qquad (2)$$

where,

$\gamma_{E,u}$ is the load factor as related to reliability of the structure for ULS;
$\boldsymbol{k}_Z$ is the seismic hazard zoning factor to be specified in the national code or other national documents;
$\boldsymbol{k}_{E,u}$ is the representative value of earthquake ground motion intensity for ULS to be specified in the national code or other national documents by considering the seismicity;
$\boldsymbol{k}_D$ is the structural factor to be specified for various structural systems according to their ductility, acceptable deformation, restoring force characteristics and overstrength;
$\boldsymbol{k}_R$ is the ordinate of the normalized design response spectrum, as a function of the fundamental natural period of the structure considering the effect of soil conditions and damping property of the structure;
$\boldsymbol{k}_{F,i}$ is the seismic force distribution factor of the ***i*** th level to distribute the seismic shear force of the base to each level, which characterizes the distribution of seismic forces in elevation, where $k_{F,i}$ satisfies the condition $\sum k_{F,i} = 1$

$\boldsymbol{k}_{V,i}$ is the seismic shear distribution factor of the $\boldsymbol{i}$ th level which is the ratio of the seismic shear factor of the $\boldsymbol{i}$ th level to seismic shear factor of the base, and characterizes the distribution of seismic shear forces in elevation, where $\boldsymbol{k}_{V,i} = 1$ at the base and usually becomes largest at the top;
$\boldsymbol{F}_{G,j}$ is the gravity load at the $\boldsymbol{j}$ th level of the structure;
$\boldsymbol{n}$ is the number of levels above the base.

b) Serviceability Limit State (SLS)

The design lateral seismic force of the $\boldsymbol{i}$ th level of a structure for SLS, $\boldsymbol{F}_{E,s,i}$, may be determined by

$$F_{E,s,i} = \gamma_{E,s}\, k_Z\, k_{E,s}\, k_R\, k_{F,i} \sum_{j=1}^{n} F_{G,j} \qquad (3)$$

or the design lateral seismic shear force of the $\boldsymbol{i}$ th level for SLS, $\boldsymbol{V}_{E,s,i}$, can be used instead of the above seismic force.

$$V_{E,s,i} = \gamma_{E,s}\, k_Z\, k_{E,s}\, k_R\, k_{V,i} \sum_{j=i}^{n} F_{G,j} \qquad (4)$$

where,
$\boldsymbol{\gamma}_{E,s}$ is the load factor as related to reliability of the structure for SLS;
$\boldsymbol{k}_{E,s}$ is the representative value of earthquake ground motion intensity for SLS to be specified in the national code or other national documents by considering the seismicity.

Note - $\boldsymbol{k}_{E,u}$ and $\boldsymbol{k}_{E,s}$ may be replaced by a unique representative $\boldsymbol{k}_E$ as specified in ISO 2394 in the verification procedure, by which the reliability of the structure and the consequences of failure, including the significance of the type of failure, are taken into account to specify the load factors $\boldsymbol{\gamma}_{E,u}$ and $\boldsymbol{\gamma}_{E,s}$.

Specific values for these factors are not given in the normative text of ISO/CD 3010. The annexes of ISO/CD 3010, however, describe informatively the factors as follows (Equation, table and figure numbers are the same as ISO/CD 3010):

Load Factors and Representative Values

$\boldsymbol{\gamma}_{E,u}$ and $\boldsymbol{\gamma}_{E,s}$ are, for example, listed in Tables A.1 and A.2 for a region of relatively high seismic hazard, along with the representative values of earthquake ground motion intensity $\boldsymbol{k}_{E,u}$ and $\boldsymbol{k}_{E,s}$. An example using unity load factor for normal degree of importance is shown in Table A.1, while a unique representative value $\boldsymbol{k}_E$ is used in Table A.2.

Structural Factor

The structural factor, $\boldsymbol{k}_D$, is to reduce design seismic forces or shear forces taking into account the effect of ductility, acceptable deformation, restoring force characteristics and overstrength (or overcapacity) of the structure.

The factor may be divided into two factors; namely $\boldsymbol{k}_{D\mu}$ and $\boldsymbol{k}_{Ds}$ and expressed as the product of them, where $\boldsymbol{k}_{D\mu}$ is related to ductility, acceptable deformation and restoring force characteristics, whereas $\boldsymbol{k}_{Ds}$ is related to overstrength.

Recent studies indicate that $\boldsymbol{k}_{D\mu}$ also depends on the natural period of vibration of the structure and possible reduction in strength remains minimal for structures having shorter fundamental natural periods. $\boldsymbol{k}_{Ds}$ is a function of the difference between the actual strength and calculated strength and varies according to the method of strength calculation. Quantification of these factors is yet a matter of debate, and one generic term $\boldsymbol{k}_D$ has been adopted in most codes. The structural factor, $\boldsymbol{k}_D$, may be, for example,

- 1/5 to 1/3 for systems with excellent ductility,
- 1/3 to 1/2 for systems with medium ductility,
- 1/2 to 1 for systems with poor ductility.

These ranges of $\boldsymbol{k}_D$ are under continuing investigation and may take other values in some circumstances.

Table A.1 – Example 1 for load factors $\gamma_{E,u}$ and $\gamma_{E,s}$, and representative values $k_{E,u}$ and $k_{E,s}$ (where $k_{E,u} \neq k_{E,s}$)

Limit state	Degree of importance	$\gamma_{E,u}$ or $\gamma_{E,s}$	$k_{E,u}$ or $k_{E,s}$	Return period for $k_{E,u}$ or $k_{E,s}$
Ultimate	a) High	1,5 – 2,0	0,4	500 years
	b) Normal	1,0		
	c) Low	0,4 – 0,8		
Serviceability	a) High	1,5 – 3,0	0,08	20 years
	b) Normal	1,0		
	c) Low	0,4 – 0,8		

Table A.2 – Example 2 for load factors $\gamma_{E,u}$ and $\gamma_{E,s}$, and representative value k_E

Limit state	Degree of importance	$\gamma_{E,u}$ or $\gamma_{E,s}$	$k_E = k_{E,u} = k_{E,s}$	Return period for k_E
Ultimate	a) High	3,0 – 4,0	0,2	100 years
	b) Normal	2,0		
	c) Low	0,8 – 1,6		
Serviceability	a) High	0,6 – 1,2		
	b) Normal	0,4		
	c) Low	0,16 – 0,32		

Normalized Design Response Spectrum

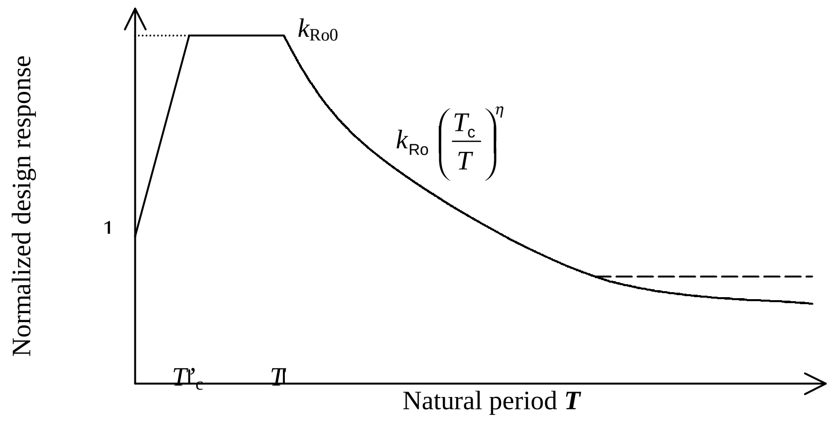

Figure C.1 - Normalized design response spectrum

The normalized design response spectrum can be interpreted as an acceleration spectrum normalized by the maximum ground acceleration for design purpose. It may be of the form as illustrated in Figure C.1. In the figure, k_R is the ordinate of the normalized design response spectrum, and k_{Ro} is a factor dependent on the soil profile and the characteristics of the structure, e.g. the damping of the structure. For a structure with a damping ratio of 0,05 resting on the average quality soil, k_{Ro} may be taken as 2 to 3. T is the fundamental natural period of the structure, T_c and T'_c are the corner periods as related to the soil condition, and η is an exponent that can vary between 1/3 and 1. T'_c may be taken as (1/5) to (1/2) of T_c. For example, T_c can be taken as

- 0,3 to 0,5 s for stiff and hard soil conditions,
- 0,5 to 0,8 s for intermediate soil conditions,
- 0,8 to 1,2 s for loose and soft soil conditions.

Seismic Force Distribution Factor and Seismic Shear Distribution Factor

The seismic force distribution factor, $\boldsymbol{k}_{F,i}$, may be determined by

$$k_{F,i} = \frac{F_{G,i}\ h_i^{\nu}}{\sum_{j=1}^{n} F_{G,j}\ h_j^{\nu}} \qquad \text{(D.1)}$$

where,
$\boldsymbol{F}_{G,i}$ is the gravity load of the structure at the ***i*** th level,
$\boldsymbol{h}_i$ is the height above the base to the ***i*** th level, and
n is the number of levels above the base.

The exponent ν may be taken as follows:

- $\nu = 0$ for very low buildings (up to two-storey buildings), or structures for which $T \leq 0{,}2$s,
- $\nu = 0$ to 1 for low-rise buildings (three to five-storey buildings), or structures for which $0{,}2\text{s} < T \leq 0{,}5$s,
- $\nu = 1$ to 2 for intermediate buildings, or structures for which $0{,}5\text{s} < T \leq 1{,}5$s,
- $\nu = 2$ for high-rise buildings (higher than 50 meters or more than fifteen-storey buildings), or structures for which $T > 1{,}5$s.

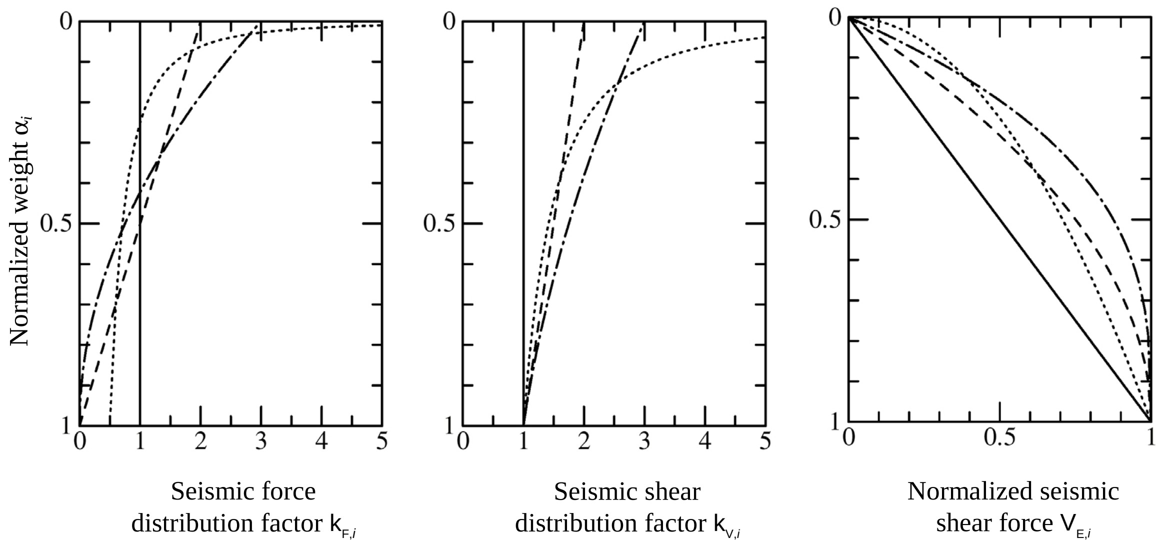

Figure D.1 - Distribution of seismic force parameters

Since Equation (D.1) does not give an appropriate distribution for high-rise buildings, even if the exponent ν becomes two (see dash dotted curves of Figure D.1), the seismic force distribution factor, $\boldsymbol{k}_{F,i}$, for high-rise buildings may be determined by

$$k_{F,n} = \rho \qquad \text{(D.2)}$$

$$k_{F,i} = (1-\rho)\frac{F_{G,i}\ h_i}{\sum_{j=1}^{n} F_{G,j}\ h_j} \qquad \text{(D.3)}$$

where, ρ is the factor to give a concentrated force at the top and approximately $\rho = 0{,}1$.

Since Equations (D.2) and (D.3) do not always give an appropriate distribution and a concentrated force at the top is not practical for buildings with setbacks, it is preferable using the seismic shear distribution factor, $k_{V,i}$, instead of seismic force distribution factor $k_{F,i}$. The factor $k_{V,i}$ is interpreted as the shear factor of the ***i*** th level normalized by the base shear factor.

The seismic shear distribution factor $k_{V,i}$ may be determined by

$$k_{V,i} = 1 + k_1(1-\alpha_i) + k_2\left(\frac{1}{\sqrt{\alpha_i}} - 1\right) \qquad \text{(D.4)}$$

where,
k_1 and k_2 are factors from 0 to 1 and determined mainly by the height or the fundamental natural period of the structure,
α_i is the normalized weight and given by

$$\alpha_i = \frac{\sum_{j=i}^{n} F_{\mathrm{G},j}}{\sum_{j=1}^{n} F_{\mathrm{G},j}} \qquad \text{(D.5)}$$

The normalized weight is used instead of the height of levels above the base, because the normalized weight is more convenient and rational to express distributions of seismic force parameters. The ordinate in Figure D.1 is the normalized weight.

Distributions of seismic force parameters given by Equation (D.4) are shown as solid lines in Figure D.1 for k_1 = 0 and k_2 = 0 (uniform distribution of seismic forces), as dashed curves in Figure D.1 for k_1 = 1 and k_2 = 0 (inverted triangular distribution of seismic forces), and as dotted curves in Figure D.1 for k_1 = 0 and k_2 = 1 (distribution for shear type structure subjected to white noise excitation). Therefore, the factors k_1 and k_2 may be taken as follows:

- $k_1 \cong 0$ and $k_2 \cong 0$ for very low buildings,
- $k_1 \cong 1$ and $k_2 \cong 0$ for low-rise buildings,
- $k_1 \cong 0{,}5$ and $k_2 \cong 0{,}5$ for intermediate buildings,
- $k_1 \cong 0$ and $k_2 \cong 1$ for high-rise buildings.

CONCLUDING REMARKS

The activity on the revision of ISO 3010 is still continuing and the committee draft ISO/CD 3010 for the revision was made in February 1999. The ISO/CD 3010 has been sent for voting and comments to all members and observers according to the ISO regular procedure. Comments from member bodies and observers will be discussed within the WG and the modification will be made, if necessary. The final step is the voting of the members, which will be in the next year. Any comments on the revision of the standard are appreciated. Please contact the author (e-mail : yuji@eng.hokudai.ac.jp).

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ANNEX

ISO/TC98, its SC's and WG's, and their documents

TC98 Bases for design of structures (Brandt/Poland)

WG1 Seismic actions on structures (Ishiyama/Japan)
ISO 3010 Bases for design of structures - Seismic actions on structures (1988-07-01)
ISO/CD 3010 Bases for design of structures - Seismic actions on structures (1999)
(revision of ISO 3010:1988)

SC1 Terminology and symbols (Laravoire/France)
WG1 Teminology and symbols (Laravoire/France)
ISO 3898 Bases for design of structures - Notations - General symbols, 3rd edition (1997-08-15)
WG2 (disbanded) Notations for telex and line printers
WG3 (merged into WG1) General principles on reliability of structures - list of equivalent terms – vocabulary
ISO 8930 General principles on reliability for structures - List of equivalent terms, Trilingual edition (1987-12-15)
ISO/CD 8930 General principles on reliability for structures - List of equivalent terms
(revision of ISO 8930:1987)

SC2 Reliability of structures (Brandt/Poland)
WG1 General principles on reliability for structures (Ostlund/Sweden)
ISO 2394 General principles on reliability for structures, 3rd edition (1998-06-01)
WG2 (disbanded) Serviceability of buildings against vibration (Rainer/Canada)
ISO 10137 Bases for design of structures - Serviceability of buildings against vibration (1992-04-15)
WG3 (dormant) Statistical methods for quality control of building materials and components (Holicky/ Czechoslovakia)
ISO 12491 Statistical methods for quality control of building materials and components (1997-05-01)
WG4 (disbanded) Design by testing (Lewicki/Poland)
WG5 (disbanded) Combination of actions on structures (Murzewski/Poland)
WG6 Assessment of existing structures (Mihashi/Japan)
ISO/CD 13822 Bases for design of structures - Assessment of existing structures (1999)

SC3 Loads, forces and others actions (Gulvanessian/UK)
ISO/TR 6116 Actions on structures (1981)
ISO 2103 Loads due to use and occupancy in residential and public buildings (1986)
WG1 Determination of snow loads on roofs (Apeland/Norway)
ISO 4355 Bases for design of structures - Determination of snow load on roofs, 2nd edition (1998-12-01)
WG2 (dormant) Wind actions on structures (Hirtz/Germany)
ISO 4354 Wind actions on structures (1997-07-01)
WG3 (disbanded) Permanent actions (Hungary)
ISO 2633 Determination of imposed floor loads in production buildings and warehouses (1974-04-01)
ISO 9194 Bases for design of structures - Actions due to the self-weight of structures, non-structural elements and stored materials – Density (1987-12-15)
WG4 Accidental actions due to human activities (Holand/Norway)
ISO/DIS 10252 Accidental actions due to human activities (1995)
WG5 (disbanded) Loads due to bulk materials (Germany)
ISO 11697 Bases for design of structures - Loads on structures from bulk materials (1995-06-15)
WG6 Atmospheric iceloads on structures (Stottrup-Andersen/Denmark)
ISO/TR 9492 Bases for design of structures - Temperature climatic actions (1987)
ISO/CD 12494 Atmospheric iceloads on structures (1998)

SC4 (disbanded) Deformations of buildings (UK)
ISO 4356 Bases for design of structures - Deformations of buildings at the serviceability limit states (1977-11-15)

(abbreviations)
CD: Committee Draft, DIS: Draft International Standard, SC: Sub Committee, TC: Technical Committee, TR: Technical Report, WG: Working group.