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US 319:2003 UGANDA STANDARD
Seismic code of practice for structural designs

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Uganda National Bureau of Standards

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UGANDA STANDARD

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The following table will assist the user to update the standard

AMENDMENTS

Clause	Amendment No.	Date of Issue	Text affected

In order to keep abreast of technological development Uganda Standards are subject to periodic review.

NOTE:

1. **Compliance with this Standard does not, in itself confer immunity from legal obligations.**
2. **A Uganda standard does not purport to include all necessary provisions of a contract. Users are responsible for its correct application.**

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Contents

0.1 Foreword

Uganda National Bureau of Standards (UNBS) is a parastatal under the Ministry of Tourism, Trade and Industry established by the Act of Parliament of 1983, of the Laws of Uganda. UNBS is

(i.) a member of International Organisation for Standardisation (ISO);

(ii.) a contact point for the WHO/FAO Codex Alimentarius Commission on Food Standards, and

(iii.) the National Enquiry Point on TBT and SPS Agreements of the World Trade Organisation (WTO).

The work of preparing Uganda standards is carried out through Technical Committees. A Technical Committee is established to deliberate on standards in a given field or area and consists of representatives of consumers, traders, academicians, manufacturers, Government and other stakeholders.

Draft Uganda standards adopted by the Technical Committee are widely circulated to stakeholders and the general public for comments, which are reviewed before recommending them to the National Standards Council for declaration as national standards.

This Uganda Standard US 319:2001 was prepared by the Sub- Committee under the Building and Civil Engineering.Technical Committee UNBS/TC3;

0.2 Committee membership

The following organizations were represented on the Technical Committee:
Department of Civil Engineering, Makerere University Kampala
Uganda Seismic Safety Association.(USSA)
Ministry of Works, Housing, and Communication
Ministry of Health
Ministry of Local Government
National Housing Construction Cooperatiopn
Ministry of Disaster Preparedness and Refugees
Central Materials Laboratory, Ministry of Works, Housing, and Communication
Uganda Architects Association UAA)
Uganda Institute of Professional Engineers (UIPE)
Uganda Electricity Board
Department of Geological Surveys and Mines
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Code of practice for seismic structural designs

1 Scope

This code provides the basis for the design and construction of structures in seismic regions of Uganda. It also proposes operational rules for its application. Its purpose is to ensure, with adequate reliability, that in the event of earthquakes:

(i) Human lives are protected

(ii) Damages are limited

(ii) Critical facilities remain operational.

1.1 This code sets down requirements for the general structural design and seismic design loadings for structures within any of the following categories:

(a) All buildings having a floor area greater than 20 square metres

(b) Any building with a height greater than 5 metres

(c) All masonry or concrete walls greater than 1.5 metres in height

(d) All elevated tanks of up to 200 cubic metres capacity. Larger tanks should be subjected to a further study

(e) All buildings to which the general public has access.

(f) Unusual buildings or structures or those with unusual configuration or risk shall be designed in accordance with clause 6.2

The requirements are not intended to apply to:

(a) Large civil engineering works (e.g. large-span bridges, dams, earth structures)

(b) Buildings or structures greater than 90 metres in height (or having more than 30 storeys).

1.2 For the application of this Code reference shall be made to other relevant Seismic Design Codes in so far as this Code is not self sufficient.

2 Normative references

The following standard contains provisions which, though reference in this text constitute provisions of this standard. All standards are subject to revision and, since any reference to a standard is deemed to be a reference to the latest edition of that standard, parties to agreements based on this standard are encouraged to take steps to ensure the use of the most recent editions of the standard indicated below. Information on currently valid national and international standards may be obtained from the Uganda National Bureau of Standards Information and Documentation Center.

3. Definitions and symbols

3.1 **Analysis methods: seismic coefficient method (static analysis)** means a method of analysis using static loads to simulate the effects of earthquake ground motion.

3.1.2 **modal response spectrum method (dynamic analysis)** means a method of dynamic analysis in which a given earthquake design spectrum is applied to a mathematical model of the structure and the response of several modes are determined and combined**.**

3.2 **dead load** means the weight of all permanent components of a building that form the integral part of the structure.

3.2.1 **live load** means the load assumed or known to result from the occupancy or use of a building and includes the loads on floors, roofs (other than wind), balustrades and loads from movable goods, machinery, and plant, that are not an integral part of the building.

3.3 **diaphragm** means a member composed of a web (such as a floor slab), or a truss which distributes forces to the horizontal load resisting system.

3.4 **ductility** means the ability of the building/structure or member to undergo repeated and reversing inelastic deflection beyond the point of first yield while maintaining a substantial proportion of its initial maximum load carrying capacity.

3.5 **primary elements** means elements forming part of the basic load resisting structure, such as beams, columns, diaphragms, or shear walls necessary for the survival of the building when subjected to specified loads.

3.6 **secondary elements** means elements such as intermediate or secondary beams, partition walls, panels, or veneers, although not necessary for the survival of the building as a whole but which may be subjected to stress due to the loading applied directly to them or to stresses induced by the deformations of the primary elements.

3.7 **frame** means a system composed of interconnected members functioning as a complete self-contained unit with or without the aid of horizontal diaphragms or floor bracing **systems.**

3.8 **moment resisting frame** means a load-carrying frame in which the members and joints are capable of resisting horizontal loads through bending moments.

3.9 **horizontal load resisting system** means that part of the structural system to which the horizontal loads prescribed by this code are assigned.

3.10 **level of lateral restraint** is the level at which the ground motion of the earthquake is transmitted to the structure by interaction between the foundation materials and the foundation elements by friction and bearing.

3.11 **set back** means any offset horizontally in from the plane of an exterior wall of a structure.

3.12 **shear wall** means a wall of any material required to resist horizontal loads through the transfer of shear forces.

3.13 **storey** means the space between two adjacent floors or platform levels.

3.14 Notation (symbols)

The notation/symbols used in this code shall have the following meanings:

b	maximum horizontal dimension of the building at the particular level measured perpendicular to the direction of loading
C	basic seismic coefficient for the seismic coefficient method
$C(T_i)$	ordinate of the basic response spectrum for translational period T_i
C_d	design horizontal seismic coefficient in clause in 9
$C_d(T_d)$	ordinate of the design spectrum for translational period T_i
DL	dead load
D'	overall length of the building at the base in the direction under consideration (m)
d_i	horizontal displacement of the centre of mass at level *i* under the horizontal seismic loading specified by this Code (i.e. F_i)
E	earthquake load
e_d	design eccentricity of the seismic load at a particular level
e_c	computed eccentricity of the centre of mass from the centre of rigidity
F_i	horizontal seismic force applied at a level designated as *i*
F_p	design seismic force for elements and components designated in accordance with clause 13
g	acceleration due to gravity; to be taken as 9.81 m/s^2
H	height to the top of the main portion of the building or the eaves of the building (m)
h_I	height to the level designated as *i* from the level of lateral restraint
I	importance factor of the building
K	structural performance factor appropriate for the particular structural type
K_p	component seismic performance coefficient
LL	design live load
P	structural response factor
S	modal combination factor
T_I	natural period of the first mode of the structure in seconds

T_i translational period of vibration for mode i in seconds

V total horizontal seismic base shear

W_i proportion of W_t contributed by level i

W_p weight of element, component or item of equipment

W_t total of the gravity loads W_i above the level of lateral restraint

Z seismic zoning factor

4. General principles of design and detailing for ductility

4.1 Structural system

Buildings shall be designed with clearly defined and identifiable load path(s) to transfer the inertial forces generated in an earthquake to the supporting soils.

4.2 Ductility

Buildings and all their seismic load resisting elements should be designed and detailed to perform in a ductile manner.

Satisfactory ductility can be assumed if the structure will withstand, without significant loss of vertical and/or lateral load carrying capacity, the lateral deflections specified in clause **10.1** applied through the reversals (cycles).

For the purpose of this code the above general requirements may be assumed to be adequately met if the specific requirements of detailing for ductility are complied with.

4.3 Energy dissipation

In addition to the provision of adequate ductility, structures should also be designed to prevent the concentration of the demand for ductility in a few members, except where special provisions are made to increase the ductility available in those members.

The demand for ductility should be spread throughout the structure so that the earthquake induced energy is dissipated uniformly.

For the purpose of this code the above general requirements may be assumed to be adequately met if the specific requirements of Table 4 are complied with.

4.4 Symmetry

The seismic load resisting elements of a structure should be located, as nearly as practicable, symmetrically about the centre of mass of the structure.

Re-entrant angles are critical points of weakness and should be carefully designed with respect to clause **4.1** and where re-entrant angles cannot be avoided reference shall be made to clause **6.2**.

4.5 Uniformity of storey stiffness

Significant changes in the stiffness over the height of the building should be avoided.

4.6 Floor diaphragms and bracing

The horizontal bracing system or diaphragm at each floor shall be designed to distribute forces to the individual elements of the horizontal load resisting system in proportion to their rigidities.

4.7 Interconnection of floors and roof

Concrete and masonry walls shall be anchored to all floors or roofs that are required to provide them with horizontal support or stability. Such anchorage shall be designed for the loads determined from clause **13,** or a minimum load of 3 kN per meter of wall, whichever is greater. The spacing of such anchors shall not exceed one metre unless the wall is designed to span between them.

Such connections to walls shall also comply with the requirements of clause **13.2.**

4.8 Interconnection of foundations

Individual foundations of a building shall be interconnected in two directions, generally at right angles, by members designed for an axial tension and compression equal to 10% of the maximum vertical load on either foundation under seismic conditions.

If the axial load on one of the interconnected foundations is less than 20% of that on the other, the design axial load in the interconnecting elements shall be taken as 10% of the average vertical load on the two foundations under seismic conditions.

5 Design methods and load combinations

5.1 General

Design for earthquake actions shall be in accordance with either:

(a) The Working Stress Method (Elastic Method), or

(b) The Limit State Method.

5.2 Increase in allowable material stresses for the working stress method

Whenever earthquake forces are considered along with other design forces, the allowable material stresses may be increased by one third but shall not exceed the following limits:

(a) For steels with a definite yield stress, the yield stress itself

(b) For steels without a definite yield stress, 80% of the ultimate strength or the 0.2% proof stress whichever is smaller.

5.3 Increase in allowable soil bearing pressure

Whenever earthquake forces are considered along with other design forces, the allowable soil bearing pressures may be increased by up to 50%.

5.4 Design load combinations for the working stress method

The design loads including earthquake for the Working Stress Method shall be not less than whichever of the following load combinations gives the greatest effect:

$DL + LL + E$

$0.7DL + E$

5.5 Design load combinations for the limit state method

The design loads including earthquake for the Limit State Method shall be not less than whichever of the following load combinations gives the greatest effect:

$DL + 1.3LL + 1.25E$

$0.9DL + 1.25E$

6 Methods of analysis

6.1 General

Analysis for the design earthquake actions shall be in accordance with one of the following methods:

(a) The Seismic Coefficient Method (Static Analysis) as outlined in clause **11**, or,

(b) The Modal Response Spectrum Method (Dynamic Analysis) as outlined in clause **12**

6.2 Selection of method of analysis

For structures of up to 40 metres in height the method specified in clause **6.1 (a)** above may be used.

For all other structures the method specified in clause **6.1 (b)** shall be used. The buildings that fall in this second category shall be:

(a) Buildings with irregular configurations

(b) Buildings with abrupt changes in lateral resilience

(c) Buildings with abrupt changes in lateral stiffness with height

(d) Buildings with unusual shape, size or importance

7. Seismic weight

The seismic weight at each level, W_i, shall be taken as the sum of the dead loads and the seismic live loads between the mid-heights of adjacent storeys.

The seismic live loads shall be taken as the following percentages of the design live loads as follows:

(a) up to 3 kN/m^2 25%

(b) above 3 kN/m^2 and for vehicle garages 50%

(c) for roofs nil.

8 Periods of vibration

8.1 The period of vibration, T_i, shall be established from properly substantiated data, or computation, or both.

8.2 Where the Seismic Coefficient Method is used, the fundamental translation period in the

direction under consideration, T_l , shall be determined from:

$$T_l = 2\pi\sqrt{\frac{\sum W_i d_i^2}{g\sum F_i d_i}}$$

where d_i may be calculated ignoring the effects of torsion.

8.3 For the purposes of initial member sizing, the following approximate formulae for T_l, may be used:

(a) For framed structures with no rigid elements limiting the deflection:

$T_l = 0.085H^{\text{—}}$ for steel frames

$T_l = 0.\ 06H^{\text{—}}$ for concrete frames

(b) For other structures:

$$T_l = \frac{0.09H}{\sqrt{D'}}$$

If the T_l value calculated using these equations is greater than 120% of that finally calculated by the equation in clause **8.2,** the seismic forces shall be reassessed.

9 Seismic design actions

9.1 Lateral force coefficients and design spectra

9.1.1 The design horizontal seismic coefficient

The design horizontal seismic coefficient used in the Seismic Coefficient Method, C_d, shall be taken as:

$$C_d = CZIK$$

where

C is the basic seismic coefficient for the fundamental translational period in the direction under consideration (depending on the subsoil category);

Z is the seismic zone factor (depending on the local ground acceleration);

I is the structure importance factor; and

K is the structural performance factor (dependent on the type of structure).

9.1.2 The design spectrum

The design spectrum used in the Modal Response Spectrum Method, $C_d(T_i)$, shall be taken as:

$$C_d(T_i) = C(T_i)ZIK$$

where $C(T_i)$ is the ordinate of the basic response spectrum for the translational period, T_i ,*Z, I* and *K* remain as defined above in clause **9.1.1**

9.1.3 Basic seismic coefficient

The basic seismic coefficient, C, shall be determined from Figure 1 for the appropriate site subsoil category using the fundamental structural period determined in accordance with clause **8.3** for the direction under consideration.

9.1.4 Basic response spectrum

The basic response spectrum, $C(T_I)$, shall be determined from Figure 1 for the appropriate site subsoil category, and period, T_i.

9.1.5 Site subsoil category: rock or stiff, medium or soft soil sites

The site shall be classified into one of the following site subsoil categories:

Type I Rock or stiff soil sites.

Sites with bedrock, including weathered rock with an unconfined compression strength greater than 500 kN/m^2overlain by less than 20 m of :

(a) very stiff cohesive material with an unconfined compression strength greater than 100 kN/m^2, or

(b) very dense cohesionless material with N > 30, where N is the standard penetration (SPT) value.

Type II Medium soil sites

Sites not described as either Type I or Type III

Type III Soft soil sites

Sites where the depth of soil of a particular type exceeds the following values:

Table 1 Cohesive soils

Cohesive soil classification	Representative undrained shear strength (kN/m^2)	Minimum depth of soil (m)
Soft	12.5 - 25	20
Firm	25 - 50	25
Stiff	50 - 100	40
Very Stiff	100 - 200	60

Table 2 . Cohesionless soils

Cohesionless soils classification	Representative SPT values (N)	Minimum depth of soil (m)
Loose	4 - 10	40
Medium Dense	10 - 30	45
Dense	30 - 50	55
Very Dense	> 50	60
Gravels	> 30	100

Such sites will typically have a low amplitude natural period greater than 0.6 s.

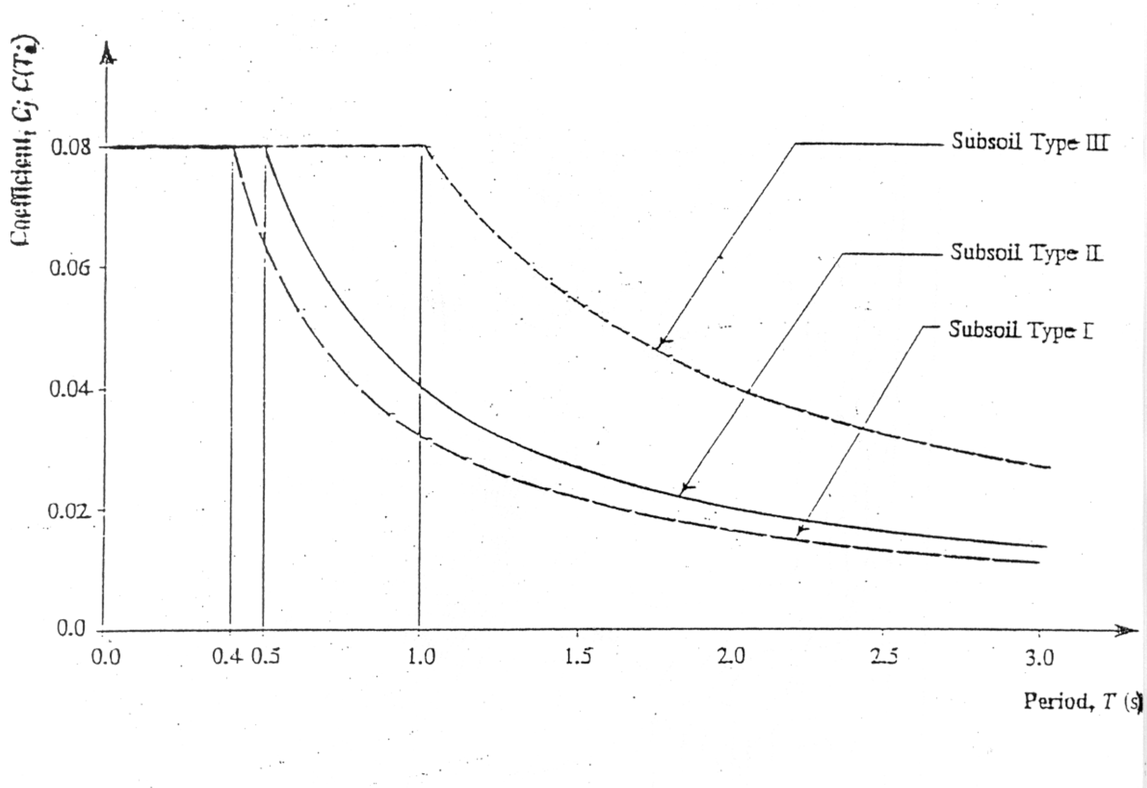

Figure.1: Basic seismic coefficient, *C* ,and Basic response spectrum, $C(T_i)$

9.1.6 Seismic zones and zoning factors

The map of Uganda is shown in Figure 2 indicating contours of ground acceleration, which shall be used for seismic action calculations.

The seismic zoning factor, *Z*, shall be obtained from Figure 4 for the appropriate regions or locations. The seismic zoning factor, *Z*, shall be obtained from Figure 2 for the appropriate regions or locations. For purposes of design, the factors applicable shall be

Z_{max} = 1.0 for zone 1,*Z* = 0.8 for zone 2 and Z = 0.7 for zone 3.

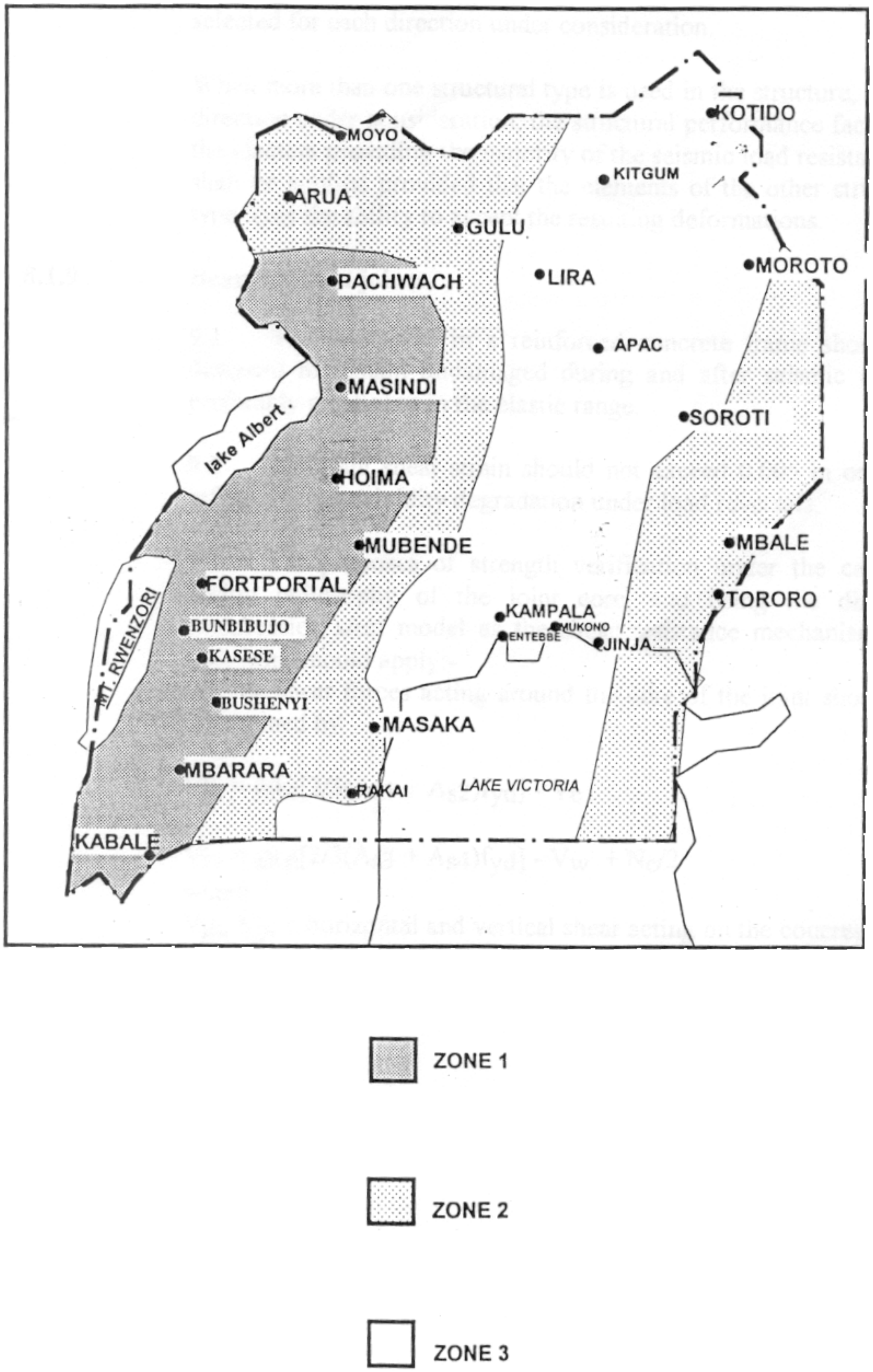

Figure 2. Seismic zoning of Uganda

9.1.7 Structure importance factor

The structural importance factor, *I*, for the structure shall be obtained from Table 2.

9.1.8 Structural performance factor

The minimum permissible value of the structural performance factor, *K*, shall be as given in Table 4.

In order to qualify for the *K* factors given in Table 4 the chosen structural type shall meet appropriate detailing requirements.

The structural type may be different in each of two directions in a building and in that case the appropriate value for *K* shall be selected for each direction under consideration.

When more than one structural type is used in the structure, for the direction under consideration, the structural performance factor for the element providing the majority of the seismic load resistance shall be applied provided that the elements of the other structural type have the ability to accept the resulting deformations.

Table 3. Structural importance factors

Importance category	Type of buildings	Importance factor I
I	Building whose integrity during and after earthquakes is of vital importance for civil protection, e.g. ,hospitals , power stations , power plants , etc	1.5
II	Building whose seismic resistance is of importance in view of the consequences associated with collapse , e.g. schools , assembly halls , cultural institutions, etc	1.5
III	Buildings of minor importance for public safety , e.g agricultural buildings	1.0
IV	High risk structures and facilities, e.g. gas/ petroleum facilities cities, toxic/acid containers, etc	2.0

Table 4. Structural performance factor *K*

Item	Structural type	Structural performance factor K
1(a)	Ductile moment–resisting frame	1.0
1(b)	Frame as in 1(a) with reinforced concrete shear walls	1.0
2(a)	Frame as in 1(a) with either steel bracing members detailed for ductility or reinforced concrete infill panels	1.5
2(b)	Frame as in 1(a) with masonry infills	2.0
3	Diagonally braced steel frame with ductile bracing acting in tension only	2.0
4	Cable-stayed chimney	3.0
5	Structures of minimal ductility including reinforced concrete frames not covered by 1 or 2 above and masonry bearing wall structures	4.0

9.2 Direction of forces and design eccentricity

9.2.1 Direction of forces

For structures with seismic resisting systems located along two perpendicular directions, the specified forces may be assumed to act separately along each of these two horizontal directions. For other buildings, different directions of application of the specified forces shall be considered so as to produce the most unfavourable effect in any structural element.

9.2.2 Design eccentricity

The design eccentricity shall be related to the computed eccentricity of the centre of mass from the centre of rigidity, e_c ; and the maximum horizontal dimension of the building at the particular level measured perpendicular to the direction of loading, *b.*

The design eccentricity, e_d, shall be determined as follows:

(a) If e_c, is less than 0.1*b* and the building is 4 storeys or less in height:

e_d may be taken as equal to 0

(b) If e_c , is less than 0.3*b* and clause **9.2.2**(a) does not apply, then:

$e_d = e_c + 0.1b$ or $e_d = e_c - 0.1b$ whichever is the most severe.

(c) If e_c is greater than 0.3*b*, the structure should be analysed using a three-dimensional modal response spectrum analysis with the mass at each level displaced by ± 0.1*b.*

9.3 Vertical seismic forces

The effect of the vertical components of seismic motion need not be considered in design of a structure except as specified in clause**13.** where consideration of vertical forces is required , the design vertical seismic coefficient shall be taken as one half of the horizontal seismic coefficient given in clause **9.1.1**

9.4 Beam –column joints

9.4.1 The joint core in a reinforced concrete frame should be designed to remain undamaged during and after seismic action; preferably remaining in the elastic range.

9.4.2 The joint shear strain should not exceed 0.005 in order to safeguard rigidity degradation under load reversals.

9.4.3 For purposes of strength verification under the capacity design philosophy of the joint core, and using the diagonal compression strut model as the shear resistance mechanism, the following should apply:-

(a) The shear forces acting around the core of the joint should be determined by:

$$V_{jh} = gR_d\left[\tfrac{2}{3}(A_{s1} + A_{s2})f_y d\right] - V_c$$

$$V_{jv} = gR_d\left[\tfrac{2}{3}(A_{s3} + A_{s4})f_{yd}\right] - V_w + \tfrac{N_c}{2}$$

where

V_{jh}, is the horizontal shear acting on the concrete core of the joint

V_{jv} is the vertical shear acting on the concrete core of the joint

A_{s1} and A_{s2} are the right and left beam top reinforcement, respectively

A_{s3} and A_{s4} are the upper and lower column reinforcement respectively

f_{yd} is the design strength of steel reinforcement

V_c, andV_w are the shear force on the column and beam, respectively

gR_d is the partial safety factor based on ductility, which can be assumed to have a value of 1.20

(b) The shear stress level:

$$t_{jh} = \tfrac{V_{jh}}{b_j h_{jc}} = \left[\frac{\left(gR_d\left[\tfrac{2}{3}(A_{s1} + A_{s2})f_{yd}\right] - V_c\right)}{\left(b_j h_{jc}\right)}\right] \le t_{max,}$$

t_{max} is the joint core shear strength , which can be expressed as t_{ma} =20 t_{Rd} or $0.7(f_{ck})^{2/3}$

9.4.4 A good design should endeavour to promote the fact that an increase in column axial load improves the shear strength of joints.

9.5 Columns

Non ductile failure of columns shall be avoided. Columns shall be designed to have adequate overstrength to avoid the formation of plastic hinge mechanisms, except as permitted by clause **4.3.4.** Column overstrengths shall be sufficient to allow for the following

(a) Inelastic effects leading to a distribution of beam flexural overstrenght into columns different from the distribution derived from elastic analysis; and

(b) Column axial loads appropriate to the simultaneous formation of beam plastic hinges in several storeys.

10 Deformation due to earthquake forces

10.1 Derivation of design lateral deformation

The design lateral deformation, shall be taken as the deformations resulting from the application of the forces or design spectrum as specified in clause **11** or **12** respectively, multiplied by the factor 5/K.

10.2 Building separations

10.2.1 To boundaries

Above ground level, each building of greater than 3 storeys shall have a separation from the boundary, except adjacent to a designed street or public way, of not less than the design lateral deflection determined in accordance with clause **10.1** or 0.002h_i, or 25 mm whichever is greater.

10.2.2 Within site

Parts of buildings or buildings on the same site which are not designed o act as an integral unit shall be separated from each other by a distance of not less than the sum of the design lateral deflections determined in accordance with clause **10.1** or 0.004h_i , or 50 mm whichever is greater.

10.2.3 Separation space width

Separation spaces shall be detailed and constructed to remain clear of debris and other obstructions. The width of such spaces shall be sufficient to allow for all constructional tolerances.

10.3 Inter-storey deflections

The ratio of the inter-storey deflection to the corresponding storey height shall not exceed 0.010 nor shall the inter-storey deflection exceed 60 mm.

11 Seismic coefficient method

11.1 Horizontal seismic base shear

11.1.1 The horizontal seismic shear force acting at the base of the structure, in the direction being considered, shall be:

$$V = C_d W_t$$

where C_d is as defined in clause **9.1.1** and

W_t is the total of the gravity loads above the level under consideration.

11.2 Horizontal seismic forces

11.2.1 The horizontal seismic force at each level *i* shall be taken as

where W_i , and h_i refer to the weight and height at level *i* of the building, as defined in the symbols

$$F_i = \frac{V W_i h_i}{\sum W_i h_i}$$

notation provided that:

(a) Where the height to width ratio of the horizontal load resisting system is equal or greater than 3, then 0.1*V* shall be considered as concentrated at the top storey and the remaining 0.9*V* shall be distributed in accordance with the equation above.

(b) For chimneys and smoke-stacks resting on the ground, 0.2*V* shall be considered as concentrated at the top and the remaining 0.8*V* shall be distributed in accordance with the equation above,

(c) For elevated tanks, the force F_i is equal to *V* and acts through the centre of gravity of the total weight of the structure and contents.

11.2.2 The set of equivalent static forces specified in this clause shall be assumed to act simultaneously at each level in the direction being considered and shall be applied through points eccentric to the centre of rigidity as specified in clause **9.2.2**.

12 Modal response spectrum method

12.1 Design spectrum

The design spectrum used for the Modal Response Spectrum Method shall be as given in clause **9.1.2.**

The relative response of each contributing mode *I* shall be determined by multiplying the mode response by the value of $C\ (T_i)$ from clause **9.1.2.**

12.2 Number of modes to be considered -

A sufficient number of modes shall be considered to ensure that at least 90% of the mass is participating in the direction under consideration.

12.3 Combination of modal effects

12.3.1 An established method shall be used for the combination of modal effects.

12.3.2 The combination method shall take into account the effect of closely spaced modes. Modes shall be considered to be closely spaced if their frequencies are within 15%.

12.4 Torsion

12.4.1 General

An analysis for torsional effects may be conducted by the static method as given in clause **12.4.2**

For structures where e_c, is greater than 0.3*b*, torsional effects should be evaluated using three-dimensional analysis.

12.4.2 Static analysis for torsional effects

For a static analysis for torsional effects, the applied torsion at each level shall use either the forces calculated by the Seismic Coefficient Method or the combined storey inertial forces found in a translational two-dimensional modal response spectrum analysis, and a design eccentricity, e_d calculated in accordance with clause **9.2.2.**

Torsional effects shall be combined with the translational effects by direct summation, with signs chosen to produce the most adverse combined effects in the element under consideration.

13 Design requirements for secondary structural elements

13.1 General

All architectural elements and mechanical and electrical systems shall meet the requirements of clause **13** as these may be a safety hazard in the event of an earthquake or may be required to be functional immediately following an earthquake.

Contents of museums and similar items of historical or artistic value that are non-functional items should be restrained against seismic loads. Specialist advice should be obtained for detailing such restraints.

13.2 Connections

All elements, components or equipment shall be positively connected to the structure to resist the specified seismic loads. Friction due to gravity shall not be used to provide the required resistance to horizontal loads.

Connections to ornamentation, veneers, appendages and exterior panels including anchor bolts, shall be corrosion-resisting and ductile, with adequate anchorages. In the case of precast concrete panels, anchorages shall be attached to, or hooked around, panel reinforcing.

13.3 Separation from structural system

Interaction with the structural system shall be avoided where specified in clause **13.6.2.**

13.4 Service cut-offs

If continued operation of a facility during strong seismic motions is foreseen to present an excessive risk, an automatic shut-off system, which will operate at a pre-determined ground acceleration, not exceeding 0.2 g, shall be provided. In such cases, all equipment required for safe shutdown shall be capable of resisting the shut-off level irrespective of other requirements of this Section.

13.5 Design forces

All elements and components shall be designed for seismic force F_p, in any direction given by :

$$F_p = C_p P K_p W_p$$

For all elements supported by the structure, C_p is equal to C_d for the structure determined in accordance with clauses **9.1.1** or **9.3** as appropriate.

For elements supported on the ground and independent of the structure, C_p is equal to C_d determined in accordance with clause **9.1.1** using the element fundamental period.

13.5.1 Structured response factor

The structural response factor, *P*, reflects the distribution and amplification of the ground motion by the structure supporting the particular component and shall be taken as:

$$P = 1.0 + \frac{h_i}{H}$$

where *P* shall be taken as 1.0 for structures supported directly on the ground.

The *P* factor for more important elements of the structure should be calculated from a more detailed analysis using the Modal Response Spectrum Method.

13.6 Separation of elements

13.6.1 Applicable elements

The requirements of **13.6.2** for the separation of elements shall apply to the following:

(a) Elements such as stairways, rigid partitions and non- structural masonry walls of part or full height.

(b) Flexible partitions not capable of altering the intended structural behaviour but required to have a fire resistance rating, provided that this need not apply when it can be shown that the partition retains its fire resistance after being subjected to the specified deformation.

(c) Precast concrete claddding and other cladding of similar

(d) Glass windows and other rigid, brittle, exterior cladding

Elements which can accept inter-storey deflections of 4 times those calculated in accordance with clause**10** without being damaged and without affecting the structure need not comply with the separation requirements of clause **13.6.2**

13.6.2 Separation requirements

Requirements for the separation from the structure of elements listed in clause **13.6.1** shall be as follows

13.6.2.1 Ratio of inter–storey deflection to the storey height not exceeding 0.0012: no requirement for separation

13.6.2.2 Ratio of inter–storey deflection to the storey height exceeding 0.0012 but not grater than 0.015 or 60 mm. In this case the elements shall be positively separated from the structure so as to allow the structure to deform as calculated in accordance with clause **10** without the elements coming into contact with the structure or with adjacent elements. A minimum separation of 10 mm shall be maintained between the structure and the vertical surfaces of the element. Construction tolerances shall not reduce the required separations.

14 Guidelines for low cost seismic resistant housing

14.1 Low cost or affordable housing

Low cost or affordable housing shall be taken to mean hosing within 20% of ones regular income

14.2 Basics: Site and building form

Choice of site and building form are fundamentals to low cost earthquake resistant housing. The site should not be on or close to steep hillsides.

Building forms should be simple, regular and symmetrical; both horizontally and vertically.

14.3 Walls

Walls of houses should be relatively light. Frame structures should have light infill walls. Bamboo reinforced earth walls perform well during earthquakes. Conventional masonry walls should be tied together with strong continuos ring beams on top and near the foundation. Corners of masonry walls should be strengthened or reinforced with columns.

14.4 Door and window opening

Door and window openings shall be small and not less than 50 cm from the corners of buildings or other openings . glass panes should in general be minimised or avoided

14.5 Roofs

Roofs should be as light as possible, but firmly tied to the supporting structure and / or to the building ring beam . Roof shapes shall be compact and symmetrical with small spans. Galvanised corrugated iron sheets should be preferred to tiles in earthquake prone areas

For low cost construction , roofs should be grass thatched reinforced with bamboo poles

14.6 Building materials

The materials to be used for low cost earthquake resistant housing shall be selected from wooden poles, timber, bamboo, ferrocement (i.e. chicken wire mesh with cement mortar), corrugated iron sheets, grass, papyrus and other robust and durable vernacular materials . These materials shall be protected from moisture and bilologiocal hazards such as termite attack.

Heavy building materials such as stones should in general be avoided.

14.7 General precautions

Good workmanship and regular inspections of critical parts of housing for maintenance and repairs are essential to ensure resistant housing. Protective measures against fire should always be considered and provided. Houses should be built on good soils and good foundations.

Seismic resistant construction should be light, ductile and flexible. Other general building regulations should also be followed in addition to the earthquake resistant regulations.

Annex A (informative)

Bibliography