
Guidelines for the simplified design of structural reinforced concrete for buildings

*Lignes directrices pour la conception simplifiée du béton armé pour
les structures de bâtiments*





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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 71, *Concrete, reinforced concrete and prestressed concrete*, Subcommittee SC 5, *Simplified design standard for concrete structures*.

This second edition cancels and replaces the first edition (ISO 15673:2005), which has been technically revised with the following changes.

- recent research available in concrete frame and wall buildings as a result of poor structural behaviour observed during recent earthquakes have changed the design and detailing requirements for these type of buildings in seismic prone areas;
- concrete structural design criteria has been unified in almost all countries in order to use similar, if not identical load combinations with the same load factors, as well as strength reduction factors; this is a substantial change and has been changing in recent years in order to simplify and unify design criteria for different construction materials such as timber, steel, masonry and lastly concrete;
- concrete cover requirement have been updated to most recent international building code standards.

Introduction

This document is developed for countries that do not have existing national standards. This document should not be used in place of a national standard unless specifically considered and accepted by the national standard body or other appropriate regulatory organization. The design rules are based in simplified worldwide-accepted strength models. This document is self-contained; therefore, actions (loads) and simplified analysis procedures are included, as well as minimum acceptable construction practice guidelines.

The minimum dimensional guidelines contained in this document are intended to account for undesirable side effects that will require more sophisticated analysis and design procedures. Material and construction guidelines are aimed at site mixed concrete, as well as ready-mixed concrete, and steel of the minimum available strength grades.

The earthquake resistance guidelines are included to account for the fact that numerous underdeveloped regions of the world lay in earthquake prone areas. The earthquake resistance is based upon the employment of structural concrete walls (shear walls) that limit the lateral deformations of the structure and provide for its lateral strength.

This document contains guidelines that can be modified by the national standards body due to local design and construction requirements and practices. These guidelines that can be modified are included using [*boxed values*]. The authorities in each member country are expected to review the “boxed values” and may substitute alternative definitive values for these elements for use in the national application of the document.

A great effort was made to include self-explanatory tables, graphics, and design aids to simplify the use of this document and provide foolproof procedures. Notwithstanding, the economic implications of the conservatism inherent in approximate procedures as a substitution to sound and experienced engineering is to be a matter of concern to the designer that employs this document, and to the owner that hires him/her.

The purpose of these guidelines is to provide a registered civil engineer or architect with sufficient information to perform the design of the structural reinforced concrete that comprises the structural framing of a low-rise building that complies with the limitations established in [6.1](#). The rules of design as set forth in the present document are simplifications of the more elaborate requirements.

Although the guidelines contained in this document were drawn to produce, when properly employed, a reinforced concrete structure with an appropriate margin of safety, these guidelines are not a replacement of sound and experienced engineering judgement. In order for the resulting structure to attain the intended margin of safety, this document should be used as a whole, and alternative procedures should be employed only when explicitly permitted by the guidelines. The minimum dimensioning guides provided replace, in most cases, more elaborate procedures as those prescribed in the National Building Code, and the eventual economic impact is compensated by the simplicity of the procedures prescribed in this document.

The professional performing the structural design under these guidelines should meet the legal requirements for structural designers in the country of adoption possess a minimum appropriate knowledge of structural mechanics, statics, strength of materials, structural analysis, and reinforced concrete design and construction.

Guidelines for the simplified design of structural reinforced concrete for buildings

1 Scope

This document provides guidelines for the design and construction of low-rise concrete building structures of small area to be built in the less developed areas of the world.

This document is applicable to the planning, design and construction of structural reinforced concrete structures to be used in new low-rise buildings of restricted occupancy, number of stories, and area.

This document can be used as an alternative to the development of a National Concrete Building Code, or equivalent document in countries where no national design codes are available by themselves, or as an alternative to the National Concrete Building Code in countries where specifically considered and accepted by the national standard body or other appropriate regulatory organization.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 679, *Cement — Test methods — Determination of strength*

ISO 863, *Cement — Test methods — Pozzolanicity test for pozzolanic cements*

ISO 2103, *Loads due to use and occupancy in residential and public buildings*

ISO 2633, *Determination of imposed floor loads in production buildings and warehouses*

ISO 4354, *Wind actions on structures*

ISO 6274, *Concrete — Sieve analysis of aggregates*

ISO 6782, *Aggregates for concrete — Determination of bulk density*

ISO 6783, *Coarse aggregates for concrete — Determination of particle density and water absorption — Hydrostatic balance method*

ISO 6935-1, *Steel for the reinforcement of concrete — Part 1: Plain bars*

ISO 6935-2, *Steel for the reinforcement of concrete — Part 2: Ribbed bars*

ISO 6935-3, *Steel for the reinforcement of concrete — Part 3: Welded reinforcement*

ISO 7033, *Fine and coarse aggregates for concrete — Determination of the particle mass-per-volume and water absorption — Pycnometer method*

ISO 9194, *Bases for design of structures — Actions due to the self-weight of structures, non-structural elements and stored materials — Density*

ISO 10144, *Certification scheme for steel bars and wires for the reinforcement of concrete — Welded-wire reinforcement*

ISO 29581-1, *Cement — Test methods — Part 1: Analysis by wet chemistry*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 acceleration of gravity

g
acceleration produced by gravity at the surface of the Earth

Note 1 to entry: For the application of these guidelines, its value can be approximated to *g* approximately [10] m/s².

3.2 admixture

material other than water, *aggregate* (3.3), or hydraulic cement, used as an ingredient of *concrete* (3.20) and added to concrete before or during its mixing to modify its properties

3.3 aggregate

granular material, such as sand, gravel, crushed stone, and iron blast-furnace slag, used in conjunction with a cementing medium to form a hydraulic cement *concrete* (3.20) or mortar

3.4 anchorage

device used to anchor a non-structural element to the structural framing

3.5 bar diameter

<nominal> approximate diameter of a steel reinforcing bar, often used as a class designation

Note 1 to entry: For deformed bars, it is common practice to use the diameter of a plain bar having the same area.

3.6 base of structure

level at which earthquake motions are assumed to be imparted to a building

Note 1 to entry: This level does not necessarily coincide with the ground level.

3.7 beam

horizontal, or nearly horizontal, structural member supported at one (such as a cantilever) or more points, but not throughout its length, transversely supporting a load, and subjected primarily to flexure

3.8 bearing capacity of the soil

maximum permissible stress on the *foundation* (3.51) soil that provides adequate safety against bearing failure of the soil, or *settlement* (3.90) of the foundation of such magnitude as to impair the structure

Note 1 to entry: Its value is defined at the *working stress* (3.122) level.

3.9 bending moment

product of a force and the distance to a particular axis, producing bending effects in a structural element

3.10**boundary elements**

portions along wall edges strengthened by longitudinal and *transverse reinforcement* ([3.117](#))

Note 1 to entry: Boundary elements do not necessarily require an increase in thickness of the wall.

3.11**buildings**

structures, usually enclosed by walls and a roof, constructed to provide support or shelter for an intended *occupancy* ([3.76](#))

3.12**caisson**

foundation pile of large diameter, built partly or totally above ground and sunk below ground usually by digging out the soil inside

3.13**cement**

material which, when mixed with water, has hardening properties, used either in *concrete* ([3.20](#)) or by itself

3.14**center of mass**

geometric place where all the *mass* ([3.68](#)) of the floor would be located in plan (assuming the floor diaphragm as an infinite rigid body in its own plane)

3.15**center of rigidity**

geometric place located in plan and established assuming that the floor diaphragm is an infinite rigid body in its own plane, where applying an horizontal force, in any direction, no diaphragm rotation is presented around a vertical axis

3.16**column**

vertical member used primarily to support axial compressive *loads* ([3.66](#))

3.17**collector elements**

elements that serve to transmit the inertia forces within the diaphragm to members of the *lateral-force resisting system* ([3.60](#))

3.18**combined footing**

footing ([3.49](#)) that transmits the load carried by several *columns* ([3.16](#)) or *structural concrete walls* ([3.110](#)) to the supporting soil

3.19**compression reinforcement**

reinforcement ([3.85](#)) provided to resist compression stresses induced by *bending moments* ([3.9](#)) acting on the member section

3.20**concrete**

mixture of portland cement or any other hydraulic cement, fine aggregate, coarse aggregate, and water, with or without *admixtures* ([3.2](#))

3.21**concrete mix design**

choice and proportioning of the ingredients of *concrete* ([3.20](#))

3.22

concrete, specified compressive strength of

f'_c

compressive cylinder strength of *concrete* (3.20) used in design

Note 1 to entry: It is expressed in megapascals (MPa).

Note 2 to entry: Whenever the quantity f'_c is under a radical sign $\left(\sqrt{f'_c}\right)$, the positive square root of numerical value only is intended and result has units of megapascals (MPa).

3.23

confinement hook

hook (3.56) on a *stirrup* (3.105), *hoop* (3.57), or *crosstie* (3.28) having a bend not less than 135° with a six-diameter (but not less than 75 mm) extension that engages the *longitudinal reinforcement* (3.67) and projects into the interior of the stirrup or hoop

3.24

confinement stirrup or tie

closed *stirrup* (3.105), *tie* (3.115) or continuously wound spiral

Note 1 to entry: A closed stirrup or tie can be made up of several *reinforcement* (3.85) elements each having *confinement hooks* (3.23) at both ends. A continuously wound spiral should have a confinement hook at both ends.

3.25

contraction joint

formed, sawed, or tooled groove in a concrete structure to create a weakened plane and regulate the location of cracking resulting from the dimensional change of different parts of the structure

3.26

corrosion

gradual degradation or weakening of metal from its surface that requires the presence of humidity and oxygen, and is helped by the presence of other materials

3.27

cover

<concrete> thickness of *concrete* (3.20) between the surface of any reinforcing bar and the nearest face of the concrete member

3.28

crosstie

continuous reinforcing bar having a 135° *hook* (3.56) at one end and a hook not less than 90° at least a six-diameter extension at the other end

Note 1 to entry: The hooks should engage peripheral longitudinal bars. The 90° hooks of two successive crossties engaging the same longitudinal bars should be alternated end by end.

3.29

curing

process of keeping the *concrete* (3.20) damp for a period of time, usually several days, starting from the moment it is cast, in order for the *cement* (3.13) to be provided with enough water to harden and attain the intended strength

Note 1 to entry: Appropriate curing will greatly reduce shrinkage, increase strength of concrete, and should reduce surface cracking. Curing time will depend on temperature and relative humidity of surrounding air, the amount of wind, the direct sunlight exposure, the type of concrete mix employed, and other factors.

3.30

curtain wall

walls that are part of the façade or enclosure of the building

3.31**deformed reinforcement**

steel *reinforcement* (3.85) that has deformations in its surface to increase its bond to the *concrete* (3.20)

Note 1 to entry: The following steel reinforcement should be considered deformed reinforcement under these guidelines: deformed reinforcing bars, deformed *wire* (3.121), welded plain wire reinforcement, and welded deformed wire reinforcement conforming to the appropriate ISO standards.

3.32**depth of member**

h

vertical size of a cross section of a horizontal structural element

3.33**design load combinations**

combinations of factored *loads* (3.66) and forces

3.34**design strength**

product of the *nominal strength* (3.74) multiplied by a *strength reduction factor*, ϕ (3.107)

3.35**development length**

length of embedded reinforcement required to develop the *design strength* (3.34) of *reinforcement* (3.85) at a critical section

3.36**development length for a bar with a standard hook**

shortest distance between the critical section (where the strength of the bar is to be developed) and a tangent to the outer edge of the 90° or 180° *hook* (3.56)

3.37**differential settlement**

when the *foundation* (3.51) of different parts of a structure settle different amounts

3.38**drift**

difference between the horizontal displacements of two consecutive levels

3.39**durability**

characteristic of a structure to resist gradual degradation of its serviceability in a given environment for the design service life

3.40**effective depth of section**

d

distance measured from the extreme compression fibre to the centroid of tension *reinforcement* (3.85)

3.41**embedment length**

length of embedded *reinforcement* (3.85) provided beyond a critical section

3.42**essential facilities**

buildings and other structures that are intended to remain operational in the event of extreme environmental loading from wind, snow, or earthquakes

3.43**factored loads and forces**

specified nominal *loads* (3.66) and forces multiplied by the load factors

3.44

fire protection of reinforcement

amount of concrete cover necessary for protection of the *reinforcement* ([3.85](#)) against the effects of the high temperatures produced by fire

Note 1 to entry: The concrete cover is a function of the number of hours of exposure to the fire.

3.45

flange

top or bottom part of an I-shaped or T-shaped section separated by the *web* ([3.119](#))

3.46

flexural

pertaining to the flexure *bending moment* ([3.9](#))

3.47

flexural reinforcement

reinforcement ([3.85](#)) provided to resist the tensile stresses induced by flexural moments acting on the member section

3.48

floor system

structural elements that comprise the floor of a story in a building

Note 1 to entry: It includes the *beams* ([3.7](#)) and *girders* ([3.54](#)), the *joists* ([3.58](#)) (if employed), and the *slab* ([3.95](#)) that spans between them.

3.49

footing

portion of the *foundation* ([3.51](#)) which transmits *loads* ([3.66](#)) directly to the soil

Note 1 to entry: May be the widening part of a *column* ([3.16](#)), a *structural concrete wall* ([3.110](#)) or several columns, in a *combined footing* ([3.18](#)).

3.50

formwork

temporary construction to contain *concrete* ([3.20](#)) in a plastic state while casting and setting take place, and that forms the final shape of the element as the concrete hardens

3.51

foundation

any part of the structure that serves to transmit *loads* ([3.66](#)) to the underlying soil, or to contain it

3.52

foundation beam

beam ([3.7](#)) that rests on the *foundation* ([3.51](#)) soil and spans between *footings* ([3.49](#)), used either to support walls or to limit *differential settlement* ([3.37](#)) of the foundation

3.53

foundation mat

continuous *slab* ([3.95](#)) laid over the ground as part of the *foundation* ([3.51](#)) and that transmits to the underlying soil the *loads* ([3.66](#)) from the structure

3.54

girder

main horizontal support *beam* ([3.7](#)), usually supporting other beams

3.55

gravity loads

loads ([3.66](#)) that act downward and are caused by the *acceleration of gravity, g*, ([3.1](#)) acting on the *mass* ([3.68](#)) of the elements that cause the dead and *live loads* ([3.63](#))

3.56**hook**

bend at the end of a reinforcing bar

Note 1 to entry: They are defined by the angle that the bend forms with the bar as either 90°, 180° or 135° hooks.

3.57**hoop**

closed *stirrup* ([3.105](#)), *tie* ([3.115](#)), or continuously wound spiral

Note 1 to entry: A closed stirrup or tie can be made up of several *reinforcement* ([3.85](#)) elements, each having seismic *hooks* ([3.56](#)) at both ends. A continuously wound spiral shall have a seismic hook at both ends

3.58**joist**

T-shaped or I-shaped *beam* ([3.7](#)) used in parallel series directly supporting floor and ceiling *loads* ([3.66](#)), and supported in turn by larger *girders* ([3.54](#)), beams, or bearing *structural concrete walls* ([3.110](#))

3.59**lap splice**

splice between two reinforcing bars obtained by overlapping them for a specified length

3.60**lateral-force resisting system**

portion of the structure composed of members proportioned to resist forces related to earthquake effects

3.61**lightweight aggregate concrete**

concrete ([3.20](#)) made with coarse granular material that weighs less than the granular material used in normal weight concrete

Note 1 to entry: This type of concrete is not covered by these guidelines.

3.62**limit state**

condition beyond which a structure or member becomes unfit for service and is judged either to be no longer useful for its intended function (serviceability limit state) or to be unsafe (strength limit state)

3.63**live load**

loads ([3.66](#)) produced by the use and *occupancy* ([3.76](#)) of the building and do not include construction or environmental loads such as wind load, snow load, rain load, earthquake load, flood load, or dead load, without *load factors* ([3.65](#))

3.64**load effects**

forces and internal deformations produced in structural members by the applied *loads* ([3.66](#))

3.65**load factor**

factor that accounts for deviations of the actual load from the nominal load, for uncertainties in the analysis that transforms the load into a load effect, and for the probability that more than one extreme load will occur simultaneously

3.66**loads**

forces or other actions that result from the *weight* ([3.120](#)) of all building materials, occupants and their possessions, environmental effects, differential movement, and restrained dimensional changes

3.67

longitudinal reinforcement

reinforcement ([3.85](#)) that is laid parallel to the longitudinal axis of the element, generally to account for flexural effects

3.68

mass

quantity of matter in a body

3.69

mesh wire

welded-wire *reinforcement* ([3.85](#))

3.70

modulus of elasticity

ratio of normal stress to corresponding strain for tensile or compressive stresses below the proportional limit of the material

3.71

negative moment

flexural moment that produces tension stresses at the upper part of the section of a horizontal, or nearly horizontal element, and that requires placing negative *flexural reinforcement* ([3.47](#)) in the upper part of the element section

3.72

negative reinforcement

in horizontal or nearly horizontal elements, the *flexural reinforcement* ([3.47](#)) required for *negative moment* ([3.71](#)) and that is placed in the upper part of the section of the element

3.73

nominal loads

magnitudes of the *loads* ([3.66](#)) (dead, live, soil, wind, snow, rain, flood, and earthquake), without *load factors* ([3.65](#))

3.74

nominal strength

capacity of a structure or member to resist the effects of *loads* ([3.66](#)), as determined by theoretical computations using specified material strengths and dimensions, which in turn are derived from accepted principles of structural mechanics or by field tests or laboratory tests of scaled models, allowing for modelling effects and differences between laboratory and field conditions

3.75

non-structural elements

correspond to architectural, mechanical, and electrical components and systems permanently attached to the building

3.76

occupancy

purpose for which a building or other structure, or part thereof, is used or intended to be used

3.77

partitions

non-structural walls that are employed to divide spaces

Note 1 to entry: They do not support other parts of the building except themselves. When they are built in the exterior, sometimes they are referred to as *curtain walls* ([3.30](#)).

3.78

pedestal

upright compression member with a ratio of unsupported height to average least lateral dimension of less than 3

3.79**permanent loads**

loads (3.66) in which variations over time are rare or of small magnitude

Note 1 to entry: All other loads are variable loads; see also *nominal loads* (3.73).

3.80**pile**

slender timber, *concrete* (3.20) or structural steel element embedded in the ground to support *loads* (3.66)

3.81**plain reinforcement**

smooth surfaced steel *reinforcement* (3.85), or reinforcement that does not conform to the definition of *deformed reinforcement* (3.31)

3.82**positive moment**

flexural moment that produces tension stresses at the lower part of the section of a horizontal, or nearly horizontal element, and that requires placing positive *flexural reinforcement* (3.47) in the lower part of the element section

3.83**positive reinforcement**

in horizontal or nearly horizontal elements, the *flexural reinforcement* (3.47) required for *positive moment* (3.82) and that is placed in the lower part of the section of the element

3.84**reaction**

resistance to a force or load, or upward resistance of a *support* (3.112) such as a *structural concrete wall* (3.110) or *column* (3.16) against the downward pressure of a loaded member such as a beam

3.85**reinforcement**

steel bars, *wire* (3.121), or *mesh wire* (3.69), used for reinforcing the *concrete* (3.20) where tensile stresses are expected, due either to the applied *loads* (3.66), *differential settlement* (3.37) or to environmental effects such as variation of temperature

3.86**required factored strength**

strength of a member or cross section required to resist factored *loads* (3.66) or related internal moments and forces

3.87**retaining wall**

wall built to hold back earth

3.88**selfweight**

weight (3.120) of the structural element, caused by the material that composes the element

3.89**service load**

load (3.66), without *load factors* (3.65)

3.90**settlement**

downward movement of the supporting soil due to construction *loads* (3.66)

3.91

shear

internal force acting tangential to the plane where it acts or perpendicular to the elements longitudinal axis

Note 1 to entry: Also called diagonal tension.

3.92

shear reinforcement

reinforcement ([3.85](#)) designed to resist *shear* ([3.91](#))

3.93

shores

vertical or inclined *support* ([3.112](#)) members designed to carry the *weight* ([3.120](#)) of the *formwork* ([3.50](#)), *concrete* ([3.20](#)), and construction *loads* ([3.66](#)) above

3.94

shrinkage and temperature reinforcement

reinforcement ([3.85](#)) normal to *flexural reinforcement* ([3.47](#)) provided for shrinkage and temperature stresses in structural *solid slabs* ([3.97](#)) and *footings* ([3.49](#)) where flexural reinforcement extends in one direction only

3.95

slab

upper flat part of a reinforced *concrete* ([3.20](#)) floor carried by supporting *joists* ([3.58](#)), *beams* ([3.7](#)), walls or *columns* ([3.16](#))

3.96

slab on grade

slab ([3.95](#)) set directly on the ground that serves either as a internal traffic surface or as part of the *foundation* ([3.51](#))

3.97

solid slab

slab ([3.95](#)) of uniform thickness that does not have voids to make it lighter

3.98

span length

horizontal distance between *supports* ([3.112](#)) of a horizontal structural element, such as for a *slab* ([3.95](#)), *joist* ([3.58](#)), *beam* ([3.7](#)), or *girder* ([3.54](#))

3.99

specifications

written document describing in detail the scope of work, materials to be used, method of installation, and quality of workmanship

3.100

specified lateral earthquake forces

lateral forces corresponding to the appropriate distribution of the design base *shear* ([3.91](#)) force for earthquake-resistant design

3.101

specified wind forces

nominal pressure of wind to be used in design

3.102

spiral reinforcement

continuously wound *reinforcement* ([3.85](#)) in the form of a cylindrical helix

3.103**spread footing**

isolated *footing* (3.49) that transmits the load carried by a single *column* (3.16) to the supporting soil

3.104**stairway**

flight of steps leading from one level to another

3.105**stirrup**

reinforcement (3.85) used to resist *shear* (3.91) and torsion stresses in a structural member

Note 1 to entry: Typically bars, *wires* (3.121), or welded wire reinforcement (plain or deformed) either single leg or bent into L, U, or rectangular shapes and located perpendicular to or at an angle to *longitudinal reinforcement* (3.67). The term “stirrups” is usually applied to lateral reinforcement in *girders* (3.54), *beams* (3.7), and *joists* (3.58). The term “ties” apply to those in *columns* (3.16) and walls. See also *tie* (3.115).

3.106**story height**

vertical distance between the upper part of the *slab* (3.95) of a story and the upper part of the slab of the floor below

3.107**strength reduction factor**

ϕ

coefficient that accounts for deviations of the actual strength from the *nominal strength* (3.74), according to the manner and consequences of failure

Note 1 to entry: Including the probability of understrength members due to variations in material strengths and dimensions, approximations in the design equations, to reflect the degree of ductility and required reliability on the member under the *load effects* (3.64) being considered, and to reflect the importance of the element in the structure.

3.108**stress**

intensity of force per unit area

3.109**structural concrete**

all *concrete* (3.20) used for structural purposes including plain and reinforced concrete and prestressed concrete

3.110**structural concrete walls**

walls proportioned to resist combinations of *shear* (3.91), moments, and axial forces

Note 1 to entry: A “shearwall” is a “structural wall.”

3.111**structural diaphragms**

structural members, such as floor and roof *slabs* (3.95) which transmit inertial forces induced by earthquake motions

3.112**support**

structural element that provides support to another structural element

3.113**tank**

container for the storage of water or other fluids

3.114

temporary facilities

buildings or other structures that are to be in service for a limited time and have a limited exposure period for environmental loadings

3.115

tie

loop of reinforcing bar or *wire* ([3.121](#)) enclosing *longitudinal reinforcement* ([3.67](#))

Note 1 to entry: A continuously wound bar or wire in the form of a circle, rectangle, or other polygon shape without re-entrant corners is acceptable.

3.116

tie elements

elements which serve to transmit inertia forces and prevent separation of such building components as *footings* ([3.49](#)) and *walls* ([3.118](#))

3.117

transverse reinforcement

reinforcement ([3.85](#)) located perpendicular to the longitudinal axis of the element, comprising *stirrups* ([3.105](#)), *ties* ([3.115](#)), *spiral reinforcement* ([3.102](#)), among others

3.118

wall

member, usually vertical, used to enclose or separate spaces

3.119

web

thin vertical portion of an I-shaped or T-shaped section that connects the *flanges* ([3.45](#))

3.120

weight

vertical downward force exerted by a *mass* ([3.68](#)), when subjected to the *acceleration of gravity* ([3.1](#))

Note 1 to entry: The weight is equal to the value of the mass multiplied by the acceleration of gravity, *g*.

3.121

wire

reinforcing bar of small diameter

3.122

working stress

allowable *stress* ([3.108](#)) to be used with unfactored *loads* ([3.66](#))

3.123

yield strength

f_y

specified minimum yield strength or yield point of *reinforcement* ([3.85](#))

Note 1 to entry: The yield strength is expressed in units of megapascals, MPa.

Note 2 to entry: Applicable International Standards specify that the yield strength or yield point be determined in tension.

4 Symbols and abbreviated terms

4.1 Symbols

Symbol	Explanation	Unit
a	depth of equivalent uniform compressive stress block	mm
a_m	acceleration magnifying factor	
a_x	acceleration at floor level	
A_a	effective peak horizontal acceleration coefficient	
A_b	area of an individual reinforcement bar or wire	mm ²
A_c	loaded area of bearing on concrete or the area of the confined column core, in a column with spiral reinforcement, measured centre to centre of the spiral,	mm ²
A_g	gross area of section of element	mm ²
A_j	effective cross-sectional area within a joint for shear evaluation or area of additional hanger reinforcement, where beams are supported by girders or other beams	mm ²
A_s	area of longitudinal tension reinforcement	mm ²
A'_s	area of longitudinal compression reinforcement	mm ²
$A_{s,min}$	minimum area of longitudinal tension reinforcement	mm ²
A_{se}	total extreme steel area in a column or structural concrete wall for computation of the balanced moment strength	mm ²
A_{si}	total side steel area in a column or structural concrete wall for computation of the balanced moment strength	mm ²
A_{st}	total area of longitudinal reinforcement	mm ²
A_{su}	wind exposed surface area	m ²
A_v	area of shear reinforcement within a distance s	mm ²
b	width of compression face of member, or width of the section of the member	mm
b_c	width of the column section, or largest plan dimension of capital or drop panel, for punching shear evaluation	mm
b_{col}	dimension of column section in the direction perpendicular to the girder span	m
b_f	effective width of the compression flange in a T-shaped section	mm
b_w	web width in a T-shaped section, or web width of girders, beams or joists, or thickness of the web in a structural concrete wall	mm
b_0	perimeter of critical section for punching shear in slabs	mm
d	effective depth, should be taken as the distance from extreme compression fibre to centroid of tension reinforcement	mm
d'	distance from extreme compression fibre to centroid of compression reinforcement	mm
d_b	nominal diameter of reinforcing bar or wire	mm
d_c	distance from extreme tension fibre to centroid of tension reinforcement or diameter of the confined core of column with spiral reinforcement	mm
d_p	diameter of pile, at footing base	mm
D	dead loads, or related internal moments and forces	
E	load effects of earthquake, or related internal moments and forces	
E_c	modulus of elasticity of concrete	MPa
f'_c	specified compressive strength of concrete	MPa
$\sqrt{f'_c}$	positive square root of specified compressive strength of concrete	The result should have units of MPa
f_{cd}	compressive strength of concrete reduced by the material factor	MPa

Symbol	Explanation	Unit
f_{cu}	extreme fibre factored compressive stress at edges of structural walls	MPa
f_y	specified yield strength of reinforcement	MPa
f_{yd}	yield strength of reinforcement reduced by the material factor	MPa
f_{ypr}	probable specified maximum strength of reinforcement	MPa ($f_{ypr} = 1,25 \cdot f_y$)
f_{ys}	specified yield strength of transverse or spiral reinforcement	MPa
f_{ysd}	yield strength of transverse or spiral reinforcement reduced by the material factor	MPa
F	loads due to weight and pressures of fluids with well-defined densities and controllable maximum heights, or related internal moments and forces	
F_a	site soil coefficient	
F_i, F_x	design wind or seismic force applied at level i or x , respectively	kN
F_{iu}, F_{xu}	factored design lateral force applied to the wall at level i or x , respectively	N
F_s	non-structural walls seismic force	N
h	depth or thickness of structural element or overall thickness of member	mm
h_b	vertical distance measured from the bottom of the supporting girder to the bottom of the supported beam	mm
h_{col}	dimension of column section in the direction parallel to the girder span	m
h_c	height of the column section	mm
h_f	slab thickness	mm
h_i, h_x	height above the base to level i or x , respectively	m
h_n	clear vertical distance between lateral supports of columns and walls	mm
h_{pi}	story height of floor i , measured from floor finish of the story being evaluated to floor finish of the story immediately below	mm
h_s	total height of the supporting girder	mm
h_w	height of entire structural concrete wall from base to top	mm
H	loads due to the weight and pressure of soil, water in soil, or other materials, or related internal moments and forces	
I_c	moment of inertia of the column section	m ⁴
l	span of structural element or length of span measured centre-to-centre of beams or other supports	
l_a	length of clear span in the short direction of two-way slabs, measured face-to-face of beams or other supports	m
l_b	length of clear span in the long direction of two-way slabs, measured face-to-face of beams or other supports	m
l_d	development length for reinforcing bar	mm
l_m	length of clear span in the direction that moments, shears and reinforcement are being determined, measured face-to-face of supports	m
l_j	clear spacing between joists	m
l_n	length of clear span in the long direction of two-way construction, measured face-to-face of supports in slabs without beams, and face-to-face of beams or other supports in other cases or length of clear span, measured face-to-face of supports in slabs without beams, and face-to-face of beams or other supports in other cases	mm
l_w	horizontal length of structural concrete wall	mm
l_o	column confinement length	
L	live loads, or related internal moments and forces	
L_r	sloping roof live load, or related internal moments and forces	
m_w	mass of the nonstructural wall	kg

Symbol	Explanation	Unit
M_{bn}	nominal flexural moment strength at section at balanced conditions	N mm
M_{br}	flexural moment strength at section at balanced conditions	N mm
M_{iu}, M_{xu}	factored story moment caused by lateral loads at story i or x , respectively	N mm
M_n	nominal flexural moment strength at section	N mm
M_r	flexural moment strength at section	N mm
M_{pr}	probable flexural moment strength of the element at the joint face computed using f_{ypr} and $\phi = 1$	N · m
M_u	factored flexural moment at section	N · m
M_u^-	factored negative flexural moment at section	N · m
M_u^+	factored positive flexural moment at section	N · m
$\sum M_c$	sum of lowest flexural strengths ($\phi \cdot M_n$) of columns framing into a joint	N · m
$\sum M_g$	sum of flexural strengths ($\phi \cdot M_n$) of girders framing into a joint	N · m
ΔM_u	factored unbalanced moment at a column-girder joint or factored unbalanced moment at a wall-girder joint	N · m
P_d	non factored dead load axial force at section or non factored concentrated dead load applied directly to the element	N
P_{bn}	nominal compression axial load strength at section at balanced conditions	N
P_{br}	compression axial load strength at section at balanced conditions	N
P_{cu}	factored compression load on wall boundary element, including earthquake effects	N
P_l	non factored live load axial force at section or non factored concentrated live load applied directly to the element	N
P_n	nominal axial load strength at section	N
$P_{n(max)}$	maximum compression nominal axial load strength at section	N
P_{tn}	axial tension strength at section	N
P_{tu}	factored tension force on wall boundary element, including earthquake effects	
P_u	factored axial load at section or factored concentrated design load applied directly to the element or factored axial load on column or wall	N
P_{0n}	axial compressive strength at section	N
$\sum P_u$	sum of all factored concentrated design loads within the span	N
q_d	non-factored dead load per unit area	N/m ²
q_l	non-factored live load per unit area	N/m ²
q_u	factored load per unit area	N/m ²
r_u	factored uniformly distributed reaction from the slab on the supporting girder, beam or structural concrete wall	N/m
R_a	rain load, or related internal moments and forces	
R_m	nonstructural wall seismic force reduction factor	
R_u	total factored concentrated reaction from a supported structural element	N
$\sum R_u$	sum of all factored reactions from supported structural elements at the same story	N
s	centre-to-centre spacing of transverse reinforcement measured along the axis of the element or spacing between stirrups or vertical spacing between bars of skin reinforcement or spacing of longitudinal or transverse reinforcement or clear distance between webs	mm
S	snow load, or related internal moments and forces	
T	cumulative effect of temperature, creep, shrinkage, or differential settlement, or related internal moments and forces	
T_u	factored torsional moment at section	N · mm

Symbol	Explanation	Unit
U	required factored strength to resist factored loads or related internal moments and forces	
V_c	contribution of the concrete to the nominal shear strength at section	N
ΔV_e	factored design shear force from the development of the probable flexural capacity of the element at the faces of the joints	N
V_{iu}, V_{xu}	factored story shear caused by lateral loads at story i or x , respectively	N
V_n	nominal shear strength at section	N
V_s	contribution of the transverse reinforcement to the nominal shear strength at section	N
V_u	factored shear force at section	N
w_d	non-factored uniformly distributed dead load per unit element length applied directly to the element	N/m
w_l	non-factored uniformly distributed live load per unit element length applied directly to the element	N/m
w_u	factored uniformly distributed design load per unit element length applied directly to the element	N/m
W	wind loads, or related internal moments and forces	
W_u	total factored uniformly distributed design load per unit element length	kN/m
α_a	fraction of the load that travels in the short direction in two-way slabs-on-girders	
α_b	fraction of the load that travels in the long direction in two-way slabs-on-girders	
α_s	constant used to compute nominal punching shear strength in slabs	
β	ratio of clear spans in long to short direction of two-way slabs	
ϕ	strength reduction factor	
ρ	ratio of longitudinal tension reinforcement	$\frac{A_s}{b \cdot d}$
ρ'	ratio of longitudinal compression reinforcement	
ρ_h	ratio of horizontal reinforcement in structural concrete walls	
$\rho_{\max}$	maximum permissible ratio of longitudinal flexural tension reinforcement	
$\rho_{\min}$	minimum permissible ratio of longitudinal flexural tension reinforcement	
ρ_s	ratio of spiral reinforcement	
ρ_t	ratio of total longitudinal reinforcement area to gross concrete section area	$\frac{A_{st}}{b \cdot d}$
ρ_v	ratio of vertical reinforcement in structural concrete walls	

4.2 Abbreviated terms

col.	column
deg.	degrees
max.	maximum
min.	minimum
No.	number

5 Design and construction procedure

5.1 Procedure

The design procedure comprises the following steps. See [Figure 1](#).

5.1.1 Step A

Definition of the layout in plan and height of the structure, following the guidelines of [Clause 7](#). Verification that the limitations of [6.1](#) are met.

5.1.2 Step B

Calculation of all gravity loads that act on the structure using the guidelines of [Clause 8](#), excluding the selfweight of the structural elements.

5.1.3 Step C

Definition of an appropriate floor system, depending on the span lengths and the magnitude of the gravity loads, according to the guidelines of [Clause 10](#).

5.1.4 Step D

Trial dimensions for the slab of the floor system. Calculation of the selfweight of the system, and design of the elements than comprise it, correcting the dimension as required by the strength and serviceability limit states, complying with the guidelines of [Clause 11](#) for slab systems with beams.

5.1.5 Step E

Trial dimensions for the beams and girders. Calculation of their selfweight. Flexural and shear design of the beams and girders, correcting the dimension as required by the strength and serviceability limit states, complying with the guidelines of [Clause 12](#).

5.1.6 Step F

Trial dimensions for the columns. Calculation of their selfweight. Column slenderness verification and design for combination of axial load and moment, and shear; correcting the dimension as required by the strength and serviceability limit states, complying with the guidelines of [Clause 13](#).

5.1.7 Step G

If lateral loads such as earthquake, wind, or lateral earth pressure exist, their magnitude is established using the guidelines of [Clause 8](#); otherwise, the designer should proceed to Step I.

5.1.8 Step H

Preliminary location, and trial dimensions for structural concrete walls capable of resisting the lateral loads are established, using the guidelines of [Clause 16](#) for earthquake forces, the influence of their selfweight is evaluated, and flexure and shear design of the structural concrete walls is performed, complying with the guidelines of [Clause 14](#).

5.1.9 Step I

The loads at the foundation level are determined and a definition of the foundation system is performed employing the guidelines of [Clause 15](#). The structural elements of the foundation are designed.

5.1.10 Step J

Production of the structural drawings.

5.1.11 Step K

The construction of the structure should be performed complying with the local construction and practice.

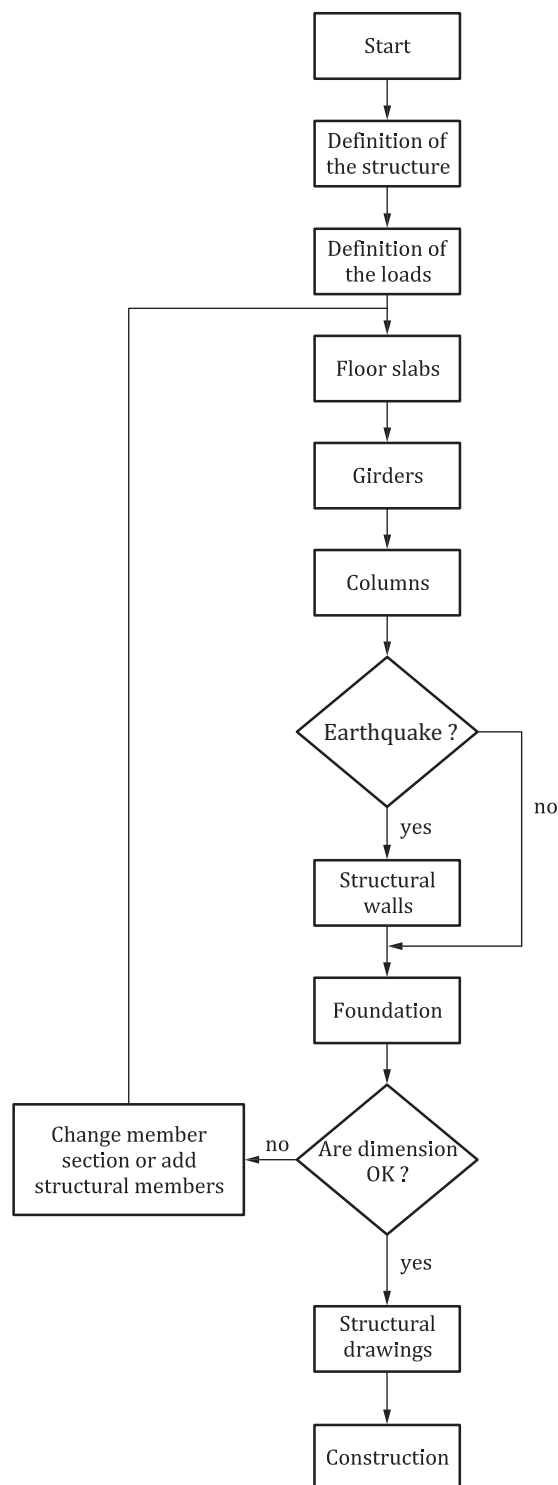


Figure 1 — Design procedure under the standard

5.2 Design documentation

5.2.1 General

The design steps should be fully recorded in the following documents.

5.2.2 Calculation memoir

The structural designer should document all design steps in a calculation memoir. This memoir should contain, at least the following:

- a) the general structural requirements of the project, as required by [Clause 7](#);
- b) a description of the structural system employed;
- c) loads employed;
- d) grade, strength and fabrication standards for all structural materials;
- e) presentation of all design computations;
- f) sketches of the reinforcement layout for all structural elements.

5.2.3 Geotechnical report

The geotechnical report should record, as a minimum, the soil investigation performed, the definition of the allowable bearing capacity of the bearing soil, the lateral soil pressures required for design of any soil retaining structure, and all other information required in [Clause 15](#).

5.2.4 Structural drawings

All the drawings required for construction of the structure of the building.

5.2.5 Specifications

The construction specifications required.

6 General guides

6.1 Limitations

These guidelines should be employed only when the building being designed complies with all the limitations set forth from [6.1.1](#) to [6.1.10](#).

6.1.1 Occupancy

6.1.1.1 Permitted uses and occupancies

The intended use of the building being designed should be permitted for the occupancy groups and subgroup as presented in [Table 1](#).

Table 1 — Permitted occupancies

Occupancy group		Occupancy subgroup	Permitted
Group A – Assembly	A-1	Churches, theatres, stadiums, coliseums, gymnasiums	NO
	A-2	Building having an assembly room with capacity less than 100 people and not having a stage	[YES]
Group B – Business	B	Building for use as offices, professional services, containing eating and drinking establishments with less than 50 occupants	[YES]
Group E – Educational	E-1	Classrooms for schools up to high-school	[YES]
	E-2	Classrooms for universities	[YES]
Group F – Industrial	F-1	Light industries not employing heavy machinery	[YES]
	F-2	Heavy industries employing heavy machinery	NO
Group G – Garages	G-1	Garages for vehicles with carrying capacity up to 2 000 kg	YES
	G-2	Garages for trucks of more than 2 000 kg carrying capacity	NO
Group H – Health	H-1	Nurseries for day care of infants	[YES]
	H-2	Health care centers for ambulatory patients	[YES]
	H-3	Hospitals	NO
Group M – Mercantile	M	Display and sale of merchandise	YES
Group R – Residential	R-1	Hotels	[NO]
	R-2	Houses and apartment buildings	YES
Group S – Storage	S-1	Storage of light materials	YES
	S-2	Storage of heavy or hazardous materials	NO
Group U – Utility	U	Utilities, water supply systems, power generating plants	NO

6.1.1.2 Mixed occupancy

Buildings of mixed occupancy should be permitted to be designed using these guidelines when all the types of occupancy in the building are permitted by [Table 1](#).

6.1.2 Maximum number of stories

The maximum number of stories for a building designed using these guidelines should be [5]. This number of stories should include the floor at the level of the ground and any basement, and should not include the roof. The number of basements should not exceed one.

6.1.3 Maximum area per floor

The maximum area per floor should not exceed [500] m².

6.1.4 Maximum story height

The maximum story height, measured from finished floor to finished floor of the story immediately below, should not exceed [4] m.

6.1.5 Maximum span length

The maximum span length for girders, and beams, measured centre to centre of the supports, should not exceed [10] m.

6.1.6 Maximum difference in span length

Spans should be approximately equal, with the larger of two adjacent spans not greater than the shorter by more than 20 % of the larger span.

6.1.7 Minimum number of spans

The minimum number of spans in each of the two principal directions in plan of the building should not be less than two. It should be permitted to use one span in buildings of one or two stories, but the span length should not exceed [5] m.

6.1.8 Maximum cantilever span

The maximum clear span length for girders, beams and slabs in cantilever should not exceed 1/3 of the span length of the first interior span of the element, in order to avoid cantilevers too long for the purposes of these guidelines.

6.1.9 Maximum slope for slabs, girders, beams and joists

It should be permitted to use sloping slabs, girders, beams and joists, but the slope of the structural element should not exceed 15°, except in members that make part of stairways.

6.1.10 Maximum slope of the terrain

The slope of the terrain where the building is located should not exceed, in any direction, a value that will produce a rise of the terrain, in the length of the building in that direction, of more than the story height of the first floor of the building, without exceeding a slope of [30°].

6.1.11 Distance between centre of mass and centre of rigidity

The distance between centre of mass and centre of rigidity shall be kept small to reduce the risk of global torsion of the structure.

6.2 Limit states

The design approach of the present guidelines is based on limit states, where a limit state is a condition beyond which a structure or member becomes unfit for service and is judged either to be no longer useful for its intended function or to be unsafe.

The following limit states are considered implicitly in the design procedure:

- structural integrity limit state;
- lateral load story drift limit state;
- durability limit state;
- fire limit state;
- ultimate and serviceability limit states.

6.3 Ultimate limit state design format

6.3.1 General

For the ultimate limit state design, the structure and the structural members should be designed to have design strength at all sections at least equal to the required strengths calculated for the factored loads and forces in such combinations as stipulated in these guidelines. Alternatively to the use of strength reduction factors, material factors may be used as described in [Annex A](#).

The basic requirement for ultimate limit state should be as given in [Formula \(1\)](#):

$$\text{Strength} \geq \text{Load effects} \quad (1)$$

To allow for the possibility that the actual strength may be less than computed and the load effects may be larger than computed, strength reduction factors, ϕ , less than 1,0, and load factors, γ , generally greater than 1,0, should be employed, as given in [Formula \(2\)](#):

$$\phi \cdot R_n \geq \gamma_1 \cdot S_1 + \gamma_2 \cdot S_2 + \dots \quad (2)$$

where

R_n is the nominal strength;

S is the load effects based on the nominal loads prescribed by these guidelines.

Therefore, the ultimate limit state design format requires that:

$$\text{Design strength} \geq \text{Required factored strength} \quad (3)$$

or

$$\phi (\text{Nominal strength}) \geq U \quad (4)$$

where the required factored strength is $U = \gamma_1 \cdot S_1 + \gamma_2 \cdot S_2 + \dots$

6.3.2 Required factored strength

The required factored strength, U , should be computed by multiplying service loads, or forces, by load factors using the load factors and combinations described in [8.1.1](#).

6.3.3 Design strength

The design strength provided by a member, its connections to other members, and its cross-sections, in terms of flexure, axial load, and shear, should be taken as the nominal strength calculated in accordance with the requirements and assumptions of these guidelines for each particular force effect in each of the element types at the critical sections defined by these guidelines, multiplied by the following strength reduction factors ϕ .

- | | |
|--|-----------------|
| a) Flexure, without axial load | $\phi = [0,90]$ |
| b) Axial tension and axial tension with flexure | $\phi = [0,90]$ |
| c) Axial compression and axial compression with flexure: | |
| 1) columns with ties and structural concrete walls | $\phi = [0,65]$ |
| 2) columns with spiral reinforcement | $\phi = [0,70]$ |
| d) Shear and torsion | $\phi = [0,75]$ |
| e) Bearing of concrete | $\phi = [0,65]$ |

6.4 Serviceability limit state design format

Serviceability limit states correspond to conditions beyond which specified performance requirements for the structure, or the structural elements, are no longer met. The compliance with the serviceability limit state under these guidelines should be obtained indirectly through the observance of the limiting

dimensions, cover, detailing, and construction requirements. These serviceability conditions include effects such as the following:

- a) lack of durability due to long-term environmental effects, including exposure to aggressive environment or corrosion of the reinforcement;
- b) dimensional changes due to variations in temperature, relative humidity, and other effects;
- c) excessive cracking of the concrete;
- d) excessive horizontal deflections;
- e) excessive vertical deflections;
- f) excessive vibration.

7 Specific guides

7.1 Structural systems and layout

The definition of the structure comprises the steps shown in [Figure 2](#).

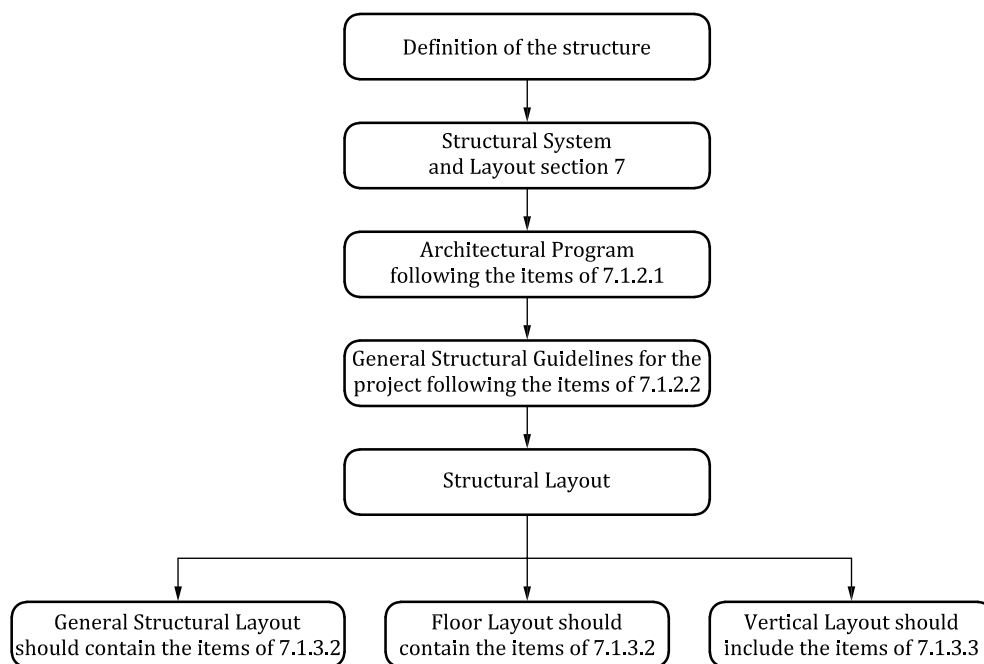


Figure 2 — Definition of the structure

7.1.1 Description of the components of the structure

7.1.1.1 General

For the purposes of these guidelines, the building structure should be divided in the following components.

7.1.1.2 Floor system

The floor system consists of the structural elements that comprise the floor of a story in a building. In [Clause 10](#), the different types of floor systems are covered by these guidelines. The floor system

includes the girders, beams, and joists (if employed), and the slab that spans between them, or the slab, when it is directly supported on columns, as in slab-column systems.

7.1.1.3 Vertical supporting elements

The vertical supporting elements that hold up the floor system at each story, and carry the accumulated gravity loads all the way down to the foundation of the structure. Under these guidelines, they can be either columns or structural concrete walls.

7.1.1.4 Foundation

The foundation comprises all structural elements that serve to transmit loads from the structure to the underlying supporting soil, or are in contact with the soil, or serve to contain it. This includes elements such as spread footings, combined footings, foundation mats, basement and retaining walls, grade beams, and slabs on grade, among others. Deep foundations, such as piles and caissons, and their pile footings and caps, are beyond the scope of these guidelines and are not covered herein.

7.1.1.5 Lateral load resisting system

The lateral load resisting system comprises the structural elements that, acting together, support and transmit to the ground the lateral loads arising from earthquake motions, wind, and lateral earth pressure. The floor system should act as a diaphragm that carries in its plane the lateral load from the point of application to the vertical elements of the lateral load resisting system. The vertical elements of the lateral load resisting system, in turn, collect the forces arising from all floors and carry them down to the foundation, and through the foundation to the underlying soil. Under the requirements of these guidelines, the main vertical elements of the lateral load resisting system should be structural concrete walls.

7.1.1.6 Other structural elements

Other structural elements that are part of the structure of the building are stairways, ramps, water tanks, and slabs on grade.

7.1.2 General programme

7.1.2.1 Architectural programme

A general architectural programme of the building should be coordinated with the structural designer before actual structural design begins. The general architectural programme should include, at least, the following items:

- a) plan shape and dimensions of all the floors of the building;
- b) elevation of the building and its relationship with the terrain, including the basement, if any;
- c) type of roof, its shape and slopes, the type of water-proofing, the means to facilitate the runoff of water from rain and melting snow or hail, and the location of drainage gutters;
- d) use of internal spaces of the building, its subdivision, and means of separation, in all stories;
- e) minimum architectural clear height in all floors;
- f) location of stairways, ramps, and elevators;
- g) type of building enclosure, internal partitions, architectural, and non-structural elements;
- h) location of ducts and shafts for utilities such as power supply, lighting, thermal control, ventilation, water supply, and waste water, including enough information to detect interference with the structural elements.

7.1.2.2 General structural guides for the project

Based in the general architectural programme information, the structural designer should define the general structural input information for the structure being designed under these guidelines. These general structural guides should include, at least, the following items:

- a) intended use of the building;
- b) nominal loads related to the occupation of the building;
- c) special loads required by the owner;
- d) [design earthquake motions, if the building is located in a seismic zone];
- e) wind requirements for the site;
- f) requirements for [snow], [hail], or rain;
- g) fire protection requirements;
- h) type of roof, and appropriate loads when not built from reinforced concrete;
- i) site information related to slopes and site drainage;
- j) allowable soil bearing capacity, and recommended foundation system derived from the geotechnical investigation, and additional restrictions related to expected settlement;
- k) environmental requirements derived from local seasonal and daily temperature variations, humidity, presence of deleterious chemicals and salts;
- l) availability, type, and quality of materials such as reinforcing bars, cement, aggregates;
- m) availability of materials for formwork;
- n) availability of a testing lab for concrete mix design and quality control during construction;
- o) availability of qualified workmanship.

7.1.3 Structural layout

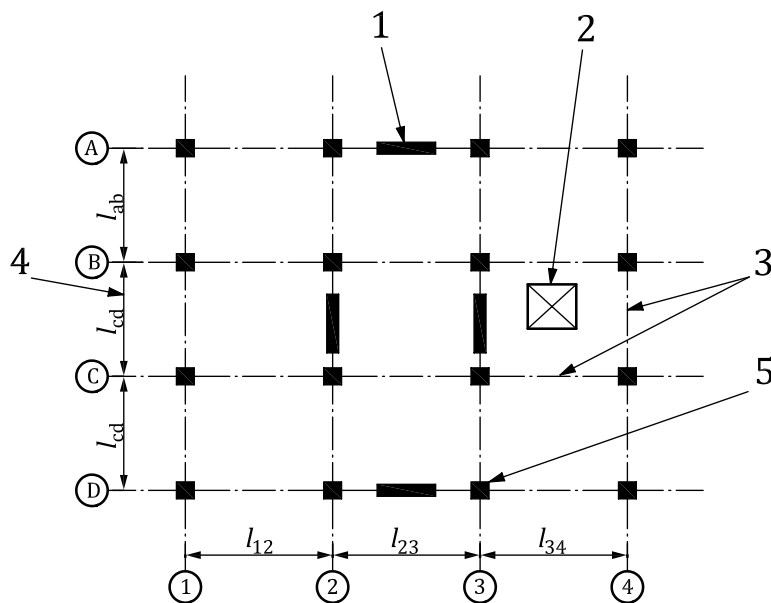
7.1.3.1 General structural layout

The structural designer should define a general structural layout in plan. This general layout should include all information, in plan, that is common to all levels of the structure. See [Figure 3](#).

The general structural layout in plan should include the following.

- a) A dimensioned grid of axis, or centrelines, in both principal directions in plan.
- b) These axis should intersect at the location of the vertical supporting elements (columns and structural concrete walls).
- c) Location in plan of all vertical supporting elements, columns and structural concrete walls. These vertical supporting element should be aligned vertically, and should be continuous all the way down to the foundation. Walls that separate spaces, built of reinforced concrete, can be made into structural concrete walls if they are continuous all the way down to the foundation and have no openings for windows or doors.
- d) Location of all duct, shafts, elevators, and stairways, that are continuous from floor to floor.
- e) Horizontal distance between centrelines, l , which corresponds to the centre-to-centre span lengths of the floor system.

f) In seismic zones, the location and distribution of all structural concrete walls.



Key

- 1 wall
- 2 shaft
- 3 centreline grid
- 4 span length
- 5 column

Figure 3 — General structural layout in plan

7.1.3.2 Floor layout

For each typical floor, the structural designer should develop a structural floor layout (see [Figure 4](#)). This layout should contain the following:

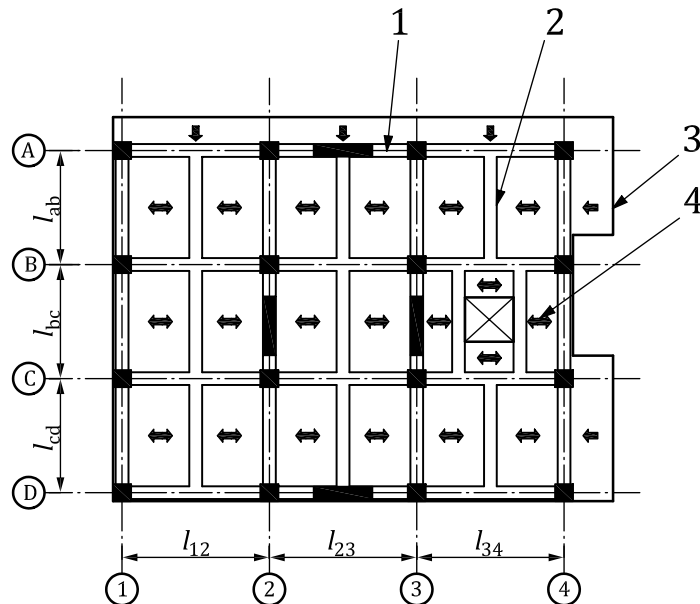
- a) the superposition of the floor perimeter on the general grid of axis;
- b) girder and beam location, or column and middle strips for slab-column systems;
- c) additional information including all substantial architectural openings in the floor;
- d) an approximate load path from all floor areas to the supporting beams and girders.

7.1.3.3 Vertical layout

The structural designer should define a general structural vertical layout (see [Figure 5](#)). This vertical layout should include all relevant information in elevation of the structure, including the following:

- a) number of stories;
- b) for all floors, the story height, defined as the vertical distance from finished floor to finished floor of the floor immediately below;
- c) slope and shape of the roof;
- d) architectural vertical clearance from floor finish to ceiling, as required by the use of the building;

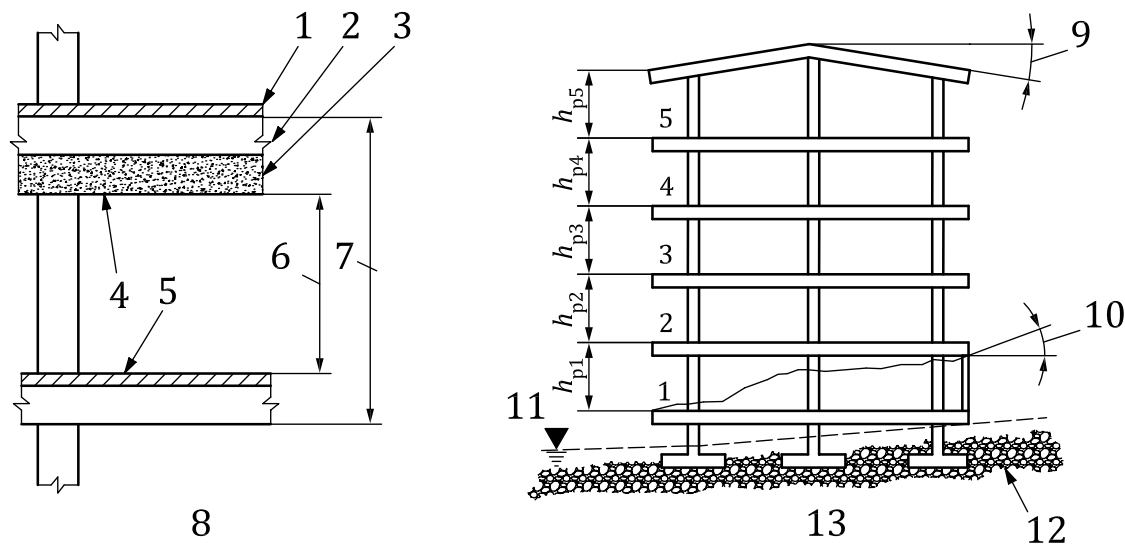
- e) vertical space necessary to accommodate horizontal/vertical service elements for power, water supply and drainage, heating, ventilation, and air conditioning;
- f) slope of the terrain, and its relationship to the ground floor or basement, if any;
- g) supporting soil stratum depth, and water table depth.



Key

- 1 gider
- 2 beam
- 3 structural perimeter
- 4 load path

Figure 4 — Typical floor structural layout

**Key**

- | | | | |
|---|----------------------------------|----|-----------------------|
| 1 | floor finish | 8 | floor section details |
| 2 | slab | 9 | max. slope 15° |
| 3 | service elements | 10 | max. slope 30° |
| 4 | ceiling | 11 | water table |
| 5 | floor finish | 12 | bearing soil stratum |
| 6 | architectural vertical clearance | 13 | building elevation |
| 7 | h_{pi} story height | | |

Figure 5 — Vertical layout of the building**7.1.4 Feasibility under the guidelines**

Based on the layout information, the structural designer should verify the feasibility of performing the structural design under the guidelines. The compliance with the following limitations should be verified.

- The use of the building should be within the accepted occupancies of [6.1.1](#), and if of mixed use, all types of intended occupancies should be within those permitted.
- The number of stories should not exceed the maximum permitted, given in [6.1.2](#).
- The area of the largest floor should not exceed the maximum permitted area of [6.1.3](#).
- The story height of the tallest story, measured from finish-to-finish, should not exceed the maximum permissible story height given in [6.1.4](#).
- The span lengths should be within the maximum span length prescribed in [6.1.5](#).
- The difference between adjacent spans should not exceed the limits of [6.1.6](#).
- The number of spans in both directions, and in all floors, should not be less than two, as required in [6.1.7](#), or within the exceptions stated there.
- No girder, beam or slab cantilever, should exceed the limits of [6.1.8](#).
- No sloping girder, beam, joist, or slab should have a slope greater than the maximum permitted value of [6.1.9](#).

- j) The slope of the terrain, at the building site, should not exceed the maximum prescribed in [6.1.10](#).

8 Actions (loads)

8.1 General

This subclause provides minimum load requirements for the design of buildings under these guidelines. Loads and the appropriate load combinations, should be used together.

8.1.1 Load factors and load combinations

The following load factors and combinations should be employed to obtain the required factored strength of the structural member or element, U , as stated in [6.3.1](#). In the following load combinations set forth to obtain the required factored strength U , the symbol $\pm$ in alternating forces that can act in one direction or the opposite, should be interpreted as the force with the sign that leads to the maximum (positive) or minimum (negative) value of U .

8.1.1.1 Dead and live load

Required factored strength, U , to resist dead load, D , and live load, L , should be at least equal to the greater of

$$U = [1, 4] \cdot D \quad (5)$$

$$U = [1, 2] \cdot D + [1, 6] \cdot L \quad (6)$$

8.1.1.2 Rain load, snow load, and sloping roof live load

If resistance to structural effects for a specified rain load, R_a , snow load, S , or sloping roof live load, L_r , are required to be included by the requirements of the present guidelines, the following combinations of D , L , and (R_a , S , or L_r) should be investigated to determine the greatest required factored strength U as given in [Formula \(7\)](#) and [Formula \(8\)](#):

$$U = [1, 2] \cdot D + [1, 6] \cdot L + [0, 5] \cdot (R_a \text{ or } S \text{ or } L_r) \quad (7)$$

$$U = [1, 2] \cdot D + [1, 0] \cdot L + [1, 6] \cdot (R_a \text{ or } S \text{ or } L_r) \quad (8)$$

but for any combination of D , L , and (R_a , S , or L_r), the required factored strength U should not be less than the value obtained employing [Formula \(5\)](#) and [Formula \(6\)](#).

8.1.1.3 Wind

If resistance to structural effects for a specified wind load, W , is required to be included by the requirements of the present guidelines, the following combinations of D , L , R_a , S , L_r and W should be investigated to determine the greatest required factored strength U as given in [Formula \(9a\)](#) and [Formula \(9b\)](#):

$$U = [1, 2] \cdot D + [1, 0] \cdot L \pm [1, 6] \cdot W + [0, 5] \cdot (R_a \text{ or } S \text{ or } L_r) \quad (9a)$$

$$U = [1, 2] \cdot D + [0, 8] \cdot W + [1, 6] \cdot (R_a \text{ or } S \text{ or } L_r) \quad (9b)$$

where load combinations should include both full value and zero value of L to determine the more severe condition, and

$$U = [0, 9] \cdot D \pm [1, 6] \cdot W \quad (10)$$

but for any combination of D , L , and W , the required factored strength U should not be less than the value obtained employing [Formula \(5\)](#) and [Formula \(6\)](#).

8.1.1.4 Earthquake forces

If resistance to specified earthquake forces, E , is required to be included by the requirements of the present guidelines, the following combinations of D , L , and E should be investigated to determine the greatest required factored strength U , as given in [Formula \(11\)](#):

$$U = [1, 2] \cdot D + [1, 0] \cdot L \pm [1, 0] \cdot E + [0, 2] \cdot S \quad (11)$$

where load combinations should include both full value and zero value of L to determine the more severe condition, and

$$U = [0, 9] \cdot D \pm [1, 0] \cdot E \quad (12)$$

but for any combination of D , L , and E , the required factored strength U should not be less than the value obtained employing [Formula \(5\)](#) and [Formula \(6\)](#).

8.1.1.5 Earth pressure

If resistance to earth pressure, H , is required by the design procedure of these guidelines, the required factored strength U should be at least equal to

$$U = [1, 2] \cdot D + [1, 6] \cdot L + [1, 6] \cdot H \quad (13)$$

except that where D or L reduce the effect of H , the combination given in [Formula \(14\)](#) should be employed

$$U = [0, 9] \cdot D + [1, 6] \cdot H \quad (14)$$

For any combination of D , L and H , the required factored strength U should not be less than the value obtained employing [Formula \(5\)](#) and [Formula \(6\)](#). When the building structure as a whole should resist permanent uncompensated horizontal loads due to lateral soil pressure, $[1, 6] \cdot H$ should be added to the right side of [Formula \(10\)](#) and [Formula \(12\)](#).

8.1.1.6 Weight and pressure of fluids

If resistance to loadings due to weight and pressure of fluids with well-defined densities and controllable maximum heights, F , is required by the design procedure of these guidelines, $[1, 4] \cdot F$ should be added to the right side of [Formula \(5\)](#) and $[1, 2] \cdot F$ should be added to the right side of [Formula \(6\)](#).

8.1.1.7 Other effects

Where structural effects T from differential settlement, shrinkage, or temperature change are significant in design, the design should not be preformed using this document and the appropriate standard of each country should be employed.

8.1.2 Mass of materials

For defining the mass of materials, the requirements of the corresponding national standard should be met. When no national standard is available, the requirements of ISO 9194 shall be used.

8.1.3 Dead loads

Dead loads consist of the weight of all material of construction incorporated into the building, including, but not limited to structure, walls and partitions, floors, roofs, ceilings, stairways, ramps, finishes, cladding, and other incorporated architectural and structural systems, and fixed service equipment. In determining dead loads for purposes of design, the actual weights of materials and constructions should be used. In determining dead loads for purposes of design, the weight of fixed service equipment, such as plumbing stacks and risers, electrical feeders, and heating, ventilating, and air conditioning systems, should be included. See [Table 2](#).

Table 2 — Minimum density, ρ , for evaluation of dead loads from materials

Material	Density, ρ (kg/m ³)	Material	Density, ρ (kg/m ³)
Aluminium	2 702	Iron	
Bituminous products		Cast	7 151
Asphalt and tar	1 287	Wrought	7 628
Gasoline	667	Lead	11 283
Graphite	2 145	Lime	
Paraffin	890	Hydrated, loose	509
Petroleum	842	Hydrated, compacted	715
Brass	8 359	Masonry, brick (solid portion)	1 828
Bronze	8 772	Masonry, concrete (solid portion)	1 986
Cement, Portland, loose	1 430	Masonry, grout	2 225
Ceramic tile	2 384	Masonry, stone	2 574
Charcoal	191	Mortar cement or lime	2 066
Cinder fill	906	Particleboard	715
Coal, piled	795	Plywood	572
Concrete, plain	2 288	Sand	
Concrete, reinforced	2 384	Clean and dry	1 430
Copper	8 836	River dry	1 685
Cork, compressed	222	Steel	7 755
Earth		Stone	
Clay, dry	1 001	Basalt, granite, gneiss	1 526
Clay, damp	1 784	Limestone, marble, quartz	1 510
Clay and gravel, dry	1 589	Sandstone	1 303
Silt, moist, packed	1 526	Shale	1 462
Silt, moist, loose	1 240	Terra cotta	
Sand and gravel, dry, loose	1 589	Voids filled	1 907
Sand and gravel, dry packed	1 748	Voind unfillles	1 144
Sand and gravel, wet	1 907	Tin	7 294
Glass	2 543	Water	
Gravel, dry	1 653	Fresh	985

Table 2 (continued)

Gypsum, loose	1 112	Sea	1 017
Gypsum, wallboard	795	Wood, seasoned	445
Ice	906	Zinc, rolled sheet	7 135

8.1.4 Live loads

For live loads, the requirements of the corresponding national standard should be met. When no national standard is available, the requirements of ISO 2103 shall be used. For buildings in industrial and storage facilities, the requirements of ISO 2633 shall be consulted for the determination of realistic live loads.

8.1.5 Specified snow load

When due to geographical latitude or altitude, or their combination, if snow is expected to fall, the loads caused by its accumulation should be taken into account in the design of the roof. The requirements of the corresponding national standard should be met and when no national standard is available, it shall be permitted to employ the requirements ISO 4355.

8.1.6 Specified wind forces

For wind loading, the requirements of the corresponding national standard should be met. When no national standard is available, the requirements of ISO 4354 shall be employed.

8.1.7 Specified earthquake forces

8.1.7.1 General

Inertial forces due to earthquakes depend on the mass of the structure and on the structural response to ground acceleration which, in turn, is a function of the seismic hazard and of the soil characteristics at the site of the building.

The requirements of the corresponding national standard should be met when calculating the mass of building materials. When no national standard is available, the requirements of ISO 9194 may be used.

For buildings which may be designed under these guidelines, an equivalent lateral force applied directly to each story may be employed to represent the dynamic response of the structure to the ground acceleration.

8.1.7.2 Seismic hazard

A level of seismic hazard should be defined for the building in terms of the intensity of the effective peak ground horizontal acceleration in rock at the building site. The peak rock acceleration is calculated as the median spectral acceleration for one degree of freedom systems, with short periods of structural vibration, i.e. periods not exceeding 0,15 s, denoted as A_a , and usually expressed as a fraction of the acceleration of gravity, g (acceleration of gravity may be taken as 10 m/s²).

For the purpose of the scope of these guidelines, the values for A_a should be taken from the corresponding national standard having jurisdiction over the site of the considered existing structure. When the national code defines the maximum seismic ground motion for each considered site based on spectral response accelerations at 5 % of critical damping, S_s , A_a may be estimated as the value of S_s for a period of 0,15 s, divided by 375 ($A_a = S_s/375$). When the national code defines the maximum seismic ground motion for each considered site based on a seismic zone factor Z , the value of A_a should be taken equal to Z . When no national code exists for the site of the building being considered, A_a may be estimated from the seismic hazard maps shown in [Figure 6](#).

8.1.7.3 No seismic hazard zones

A zone of the world where the value of the peak rock acceleration, A_a , expressed as a percentage of the acceleration of gravity, is estimated as less or equal to [0,05], may be deemed as a ***no seismic hazard*** zone.

8.1.7.4 Low seismic hazard zones

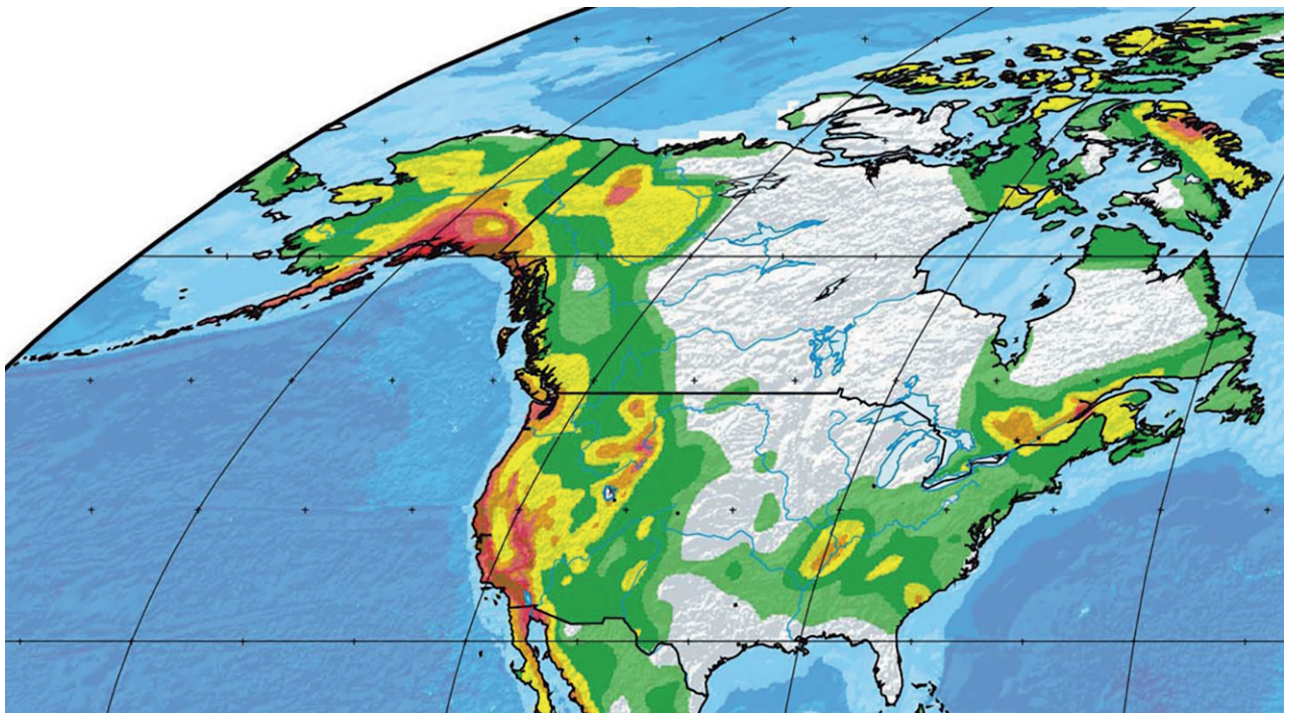
A zone where the value of A_a is estimated as more than [0,05] but less or equal to [0,10], may be deemed as a ***low seismic hazard*** zone.

8.1.7.5 Intermediate seismic hazard zones

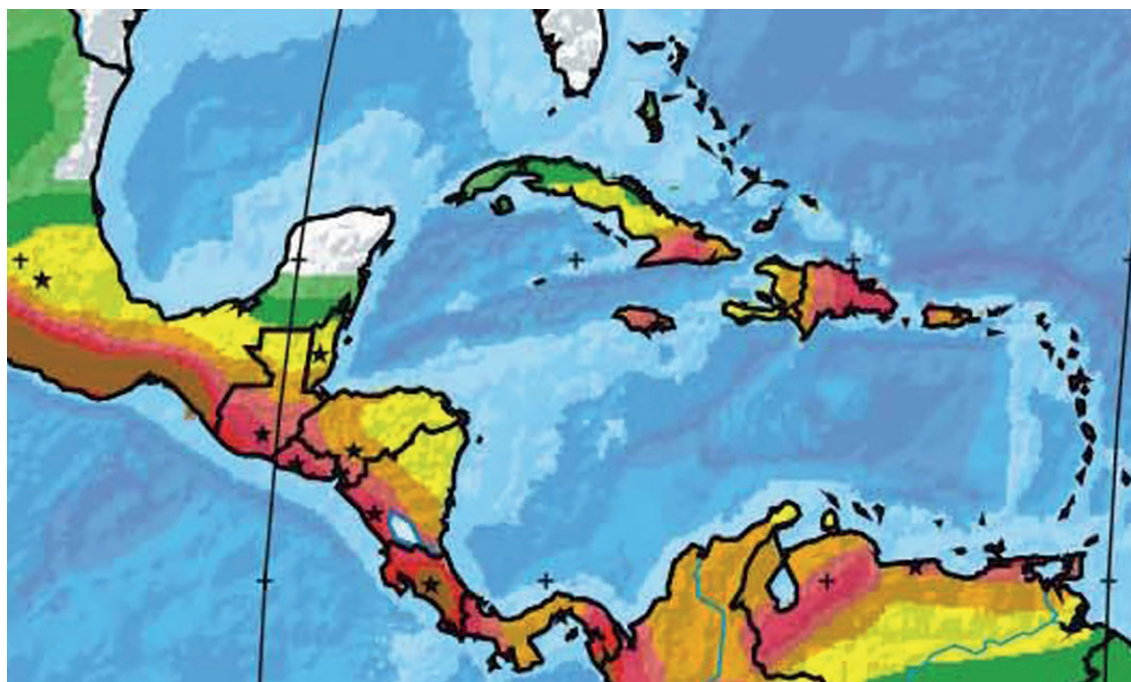
A zone where the value of A_a is estimated as more than [0,1] but less or equal to [0,20], may be deemed as an ***intermediate seismic hazard*** zone.

8.1.7.6 High seismic hazard zones

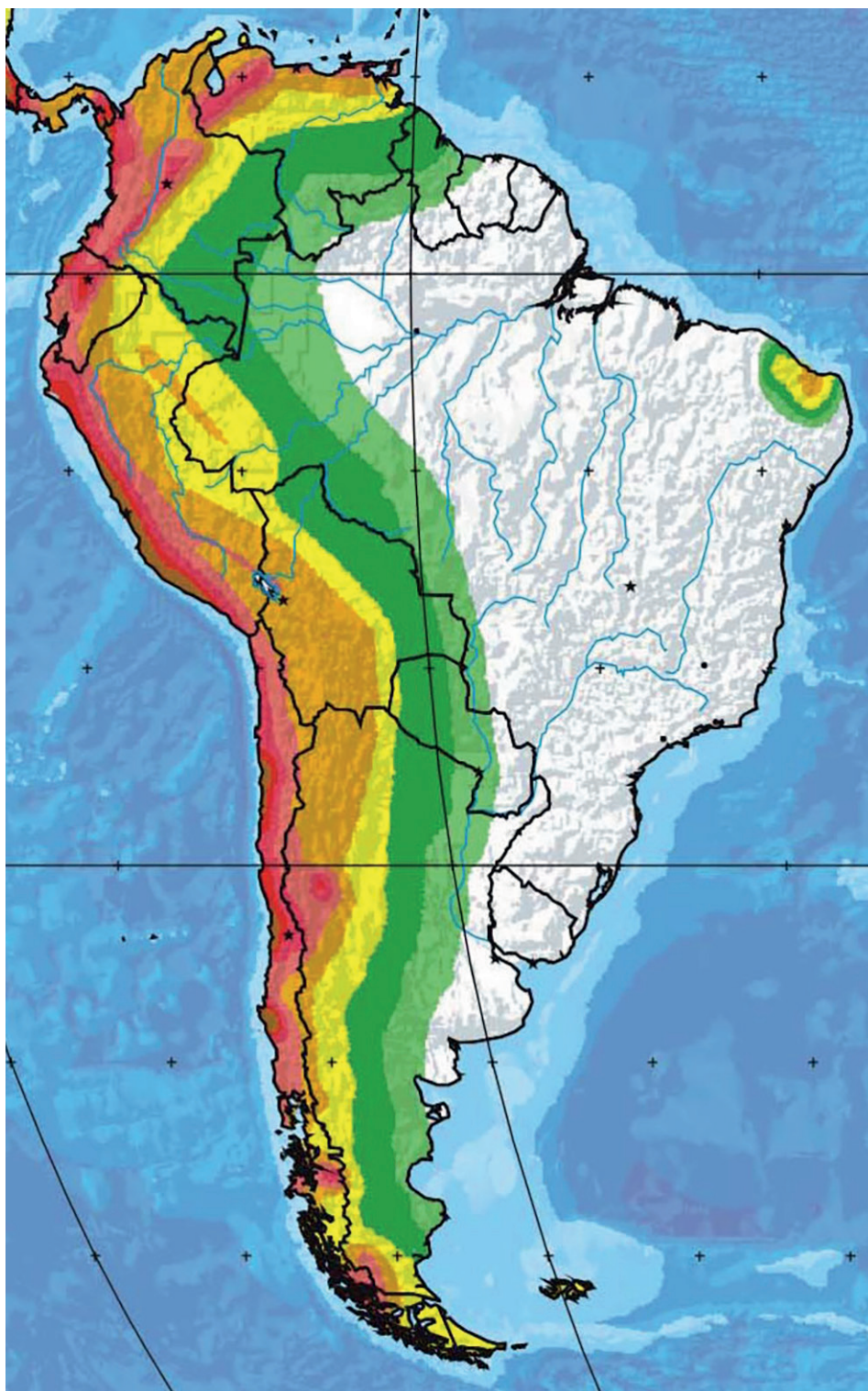
A zone where the estimated value of A_a exceeds [0,20] may be deemed as a ***high seismic hazard*** zone.



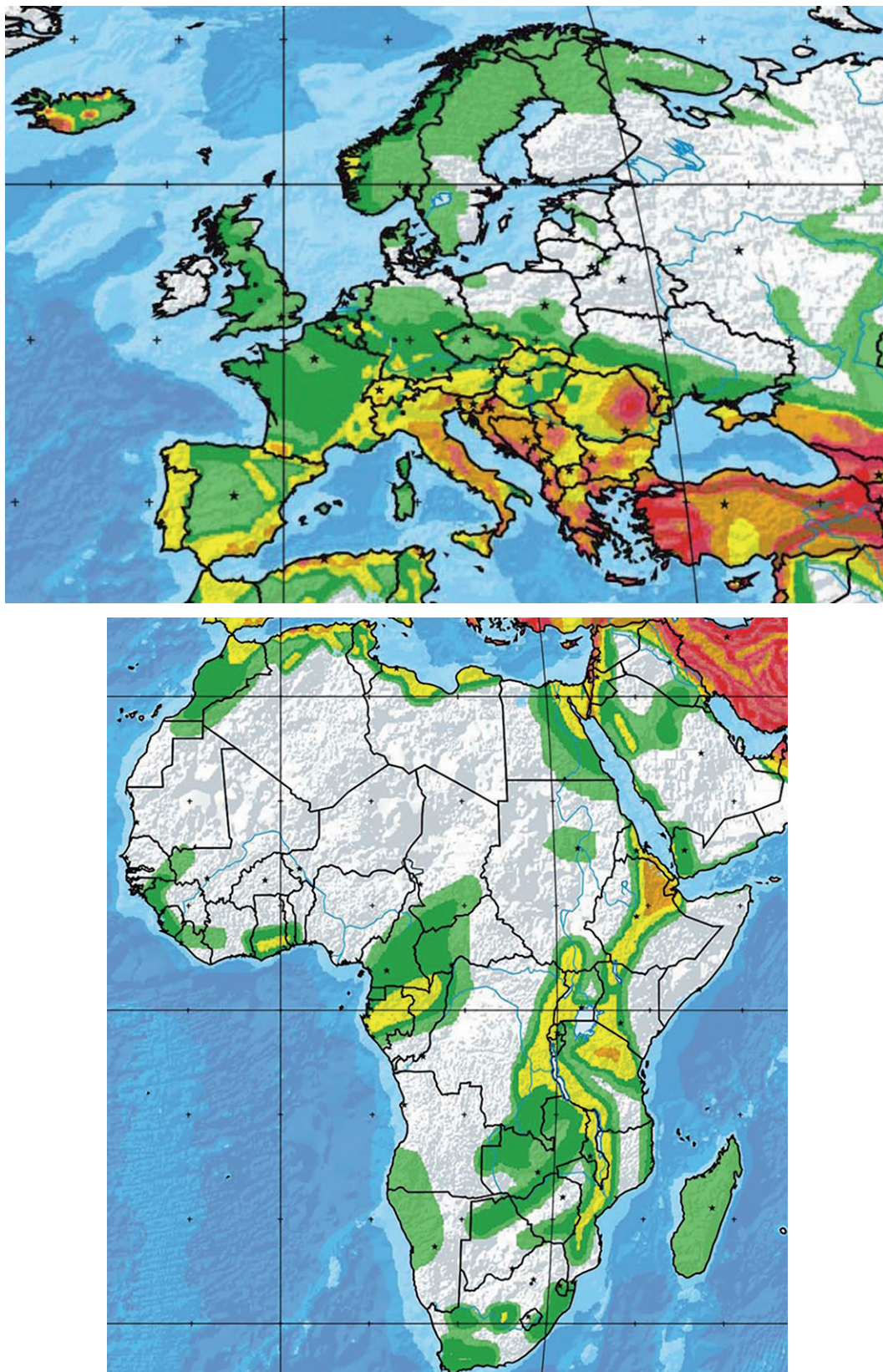
a) North America



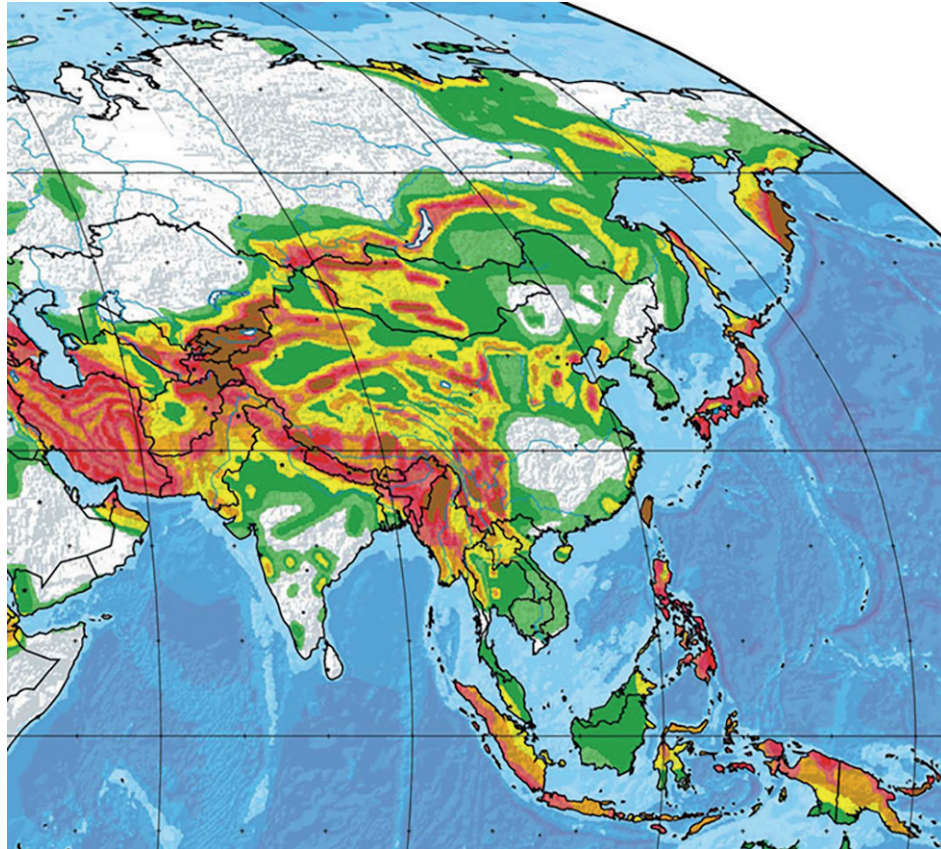
b) Central America and the Caribbean



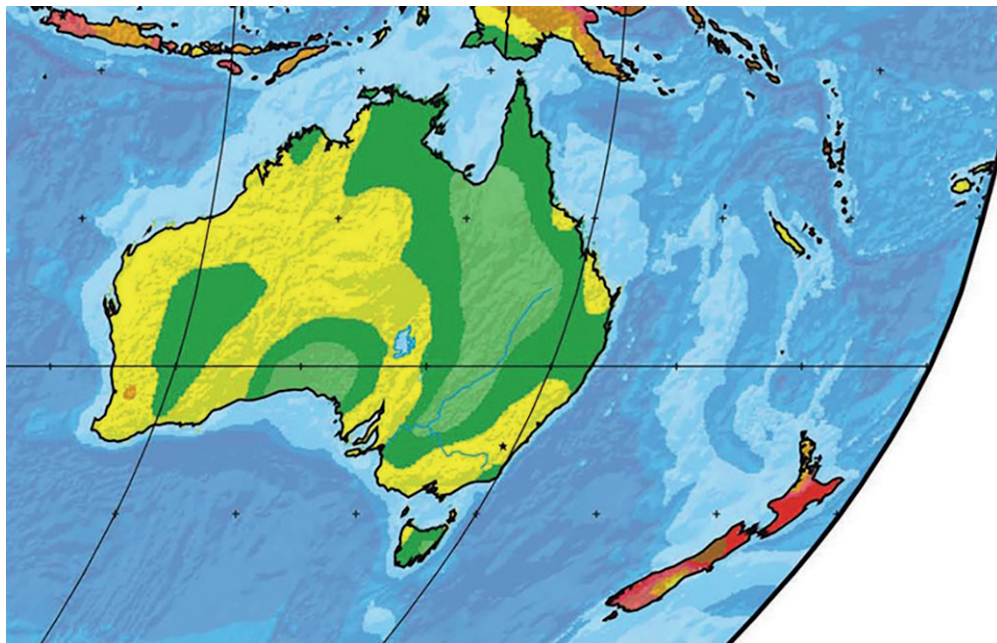
c) South America



d) Europe and Africa



e) Asia



f) Oceania

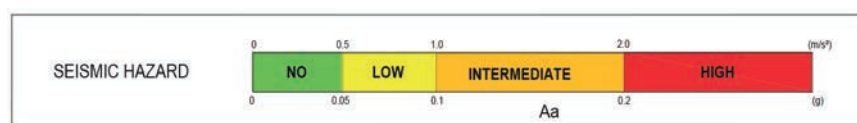


Figure 6 — Global seismic hazard map

8.1.7.7 Soil profile types

Based on the type of soil present at the building site, the soil profile shall be classified as one of the following.

- Soil Profile S_A : hard rock with a measured shear wave velocity, $v_s > 1\,500$ m/s.
- Soil Profile S_B : rock with moderate fracturing and weathering with a measured shear wave velocity in the range ($1\,500$ m/s $\geq v_s > 750$ m/s).
- Soil Profile S_C : soft weathered or fractured rock, or dense or stiff soil, where the measured shear wave velocity is in the range (750 m/s $\geq v_s > 350$ m/s), or, in the upper 30 m, the standard penetration test resistance has an average value of $N > 50$ or a shear strength for clays $s_u \geq 100$ kPa.
- Soil Profile S_D : predominately medium-dense to dense, or medium stiff to stiff soil, where the measured shear wave velocity is in the range (350 m/s $\geq v_s > 180$ m/s), or where, in the upper 30 m, the standard penetration test resistance has an average value in the range ($15 < N \leq 50$), or a shear strength for clays in the range (50 kPa $\leq s_u < 100$ kPa).
- Soil Profile S_E : a soil profile where the measured shear wave velocity $v_s \leq 180$ m/s, or the standard penetration test resistance has an average value $N < 15$ in the upper 30 m, or has more than 3,5 m of plastic ($PI > 20$), high moisture content ($w > 40$ %) and low shear strength ($s_u < 25$ kPa) clays.
- Seismically vulnerable soils: sites where the soil profile contains soil having one or more of the following characteristics are beyond the scope of this document:
 - soils vulnerable to potential failure or collapse under seismic motions, such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soil;
 - peats, highly organic clays, or both, with more than 3 m of thickness;
 - very high plasticity clays ($PI > 75$) with more than 8 m of thickness;
 - soft to medium-stiff clays with more than 40 m of thickness.

Soil exploration to obtain the needed values to classify should always be conducted by an engineer familiar with these procedures.

8.1.7.8 Site effects

Site effects shall be described through the site soil coefficient for short periods of vibration, F_a . The values of the site soil coefficient for short periods of vibration, F_a , shall be determined from [Table 3](#) as a function of A_a , and the soil profile type from [8.1.7.7](#). Linear interpolation can be used between values of A_a in [Table 3](#).

Site effect of seismically vulnerable soils, as described in [8.1.7.7](#), are beyond the scope of this document and designs should be made under the national standard or other applicable standards.

Table 3 — Site soil coefficient

Soil profile	Site coefficient, F_a , for short periods of vibration				
	$A_a \leq [0,1]$	$A_a = [0,2]$	$A_a = [0,3]$	$A_a = [0,4]$	$A_a \geq [0,5]$
S_A	[0,80]	[0,80]	[0,80]	[0,80]	[0,80]
S_B	[1,00]	[1,00]	[1,00]	[1,00]	[1,00]
S_C	[1,20]	[1,20]	[1,10]	[1,00]	[1,00]
S_D	[1,60]	[1,40]	[1,20]	[1,10]	[1,00]
S_E	[2,50]	[1,70]	[1,20]	[0,90]	[0,90]

8.1.7.9 Design response spectral ordinates

For buildings complying with the limitations set forth in [6.1](#), natural periods of vibration may be assumed to fall within the range of short periods for which response to ground motion is constant.

The ordinates of the elastic design response spectrum, S_a , for a 5 % critical damping ratio, expressed as a fraction of the acceleration of gravity, shall be calculated in the short periods of vibration range, using [Formula \(15\)](#):

$$S_a = 2,5 A_a F_a \quad (15)$$

8.1.8 Seismic design base shear

8.1.8.1 Seismic-resistant structural system

The seismic-resistant structural system shall be classified as a dual building frame system, where an essentially complete moment-resistant space frame provides support for gravity loads, and the resistance to lateral loads is provided by reinforced concrete walls and the moment-resisting space frame provides only a minimum collateral lateral load resistance.

8.1.8.2 Energy-dissipation capacity of the seismic-resistant structural system

The energy-dissipation capacity in the inelastic range of the seismic-resistant structural system, described by the response modification factor, shall have a value of $R = 5,0$.

8.1.8.3 Computation of the seismic design base shear

The seismic design base shear, V_s , equivalent to the total horizontal inertial effects caused by the seismic ground motions, shall be determined using [Formula \(16\)](#):

$$V_s = \frac{S_a \cdot W}{R} \quad (16)$$

Where S_a shall be determined from [Formula \(15\)](#), R is the response modification factor determined from [8.1.8.2](#), and W corresponds to the total weight of the building.

W shall include the total weight of the structure, plus the weight of all non-structural elements, such as walls and partitions, permanent equipment, tanks and the contained liquid, in storage occupancies 25 % of the live load and the snow load when the snow load exceeds 1,5 kN/m².

8.1.8.4 Vertical distribution of the design seismic forces

The total seismic design base shear shall be distributed over the height of the building using [Formula \(17\)](#) and [Formula \(18\)](#). At each floor level designated as x , F_x shall be applied over the area of the building in accordance with the mass distributions at that level.

$$F_x = C_{vx} \cdot V_s \quad (17)$$

and

$$C_{vx} = \frac{W_x \cdot H_x}{\sum_{i=1}^n (w_i \cdot h_i)} \quad (18)$$

9 General reinforced concrete requirements

9.1 General

This subclause contains the guides that are common to the reinforced concrete structural elements covered by this document. They include guides for materials, concrete cover to reinforcement, details and limits on the amount of reinforcement, and the procedures for defining the design strength of members subjected to flexural moments, axial loads with or without flexure, and shear.

9.2 Additional requirements

The designer should comply with the additional requirements for each individual element type described in [Clause 10](#) to [Clause 16](#).

9.3 Materials for reinforced concrete

9.3.1 General

All materials employed in the construction of the structure designed following these guidelines shall conform to the International Standards listed below.

9.3.2 Cement

Cement shall conform to the following International Standards or corresponding national cement standards:

- ISO 679;
- ISO 29581-1;
- ISO 863.

9.3.3 Aggregates

Aggregates shall conform to the following International Standards or corresponding national aggregate standards:

- ISO 6274;
- ISO 6782;
- ISO 6783;
- ISO 7033.

9.3.4 Water

Water used in mixing concrete should be potable, clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials, or other substances deleterious to concrete or reinforcement, and shall conform to the applicable International Standards, specifically ISO 12439 or corresponding national concrete mixing water standard.

9.3.5 Steel reinforcement

9.3.5.1 General

Steel reinforcement should be deformed reinforcement, with the exceptions noted in [9.3.5.4](#), and shall conform to the following limitations, and comply to the corresponding International Standard,