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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 of the voluntary nature of standards, 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 71, *Concrete, reinforced concrete and pre-stressed concrete*, Subcommittee SC 5, *Simplified design standard for concrete structures*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document aims to provide rules for the design and construction of reinforced concrete (RC) wall structures. The design rules are based on the ratio of wall cross-sectional area to the floor area. Therefore, actions (loads) and simplified analysis procedures are included as well as minimum acceptable construction practice guidelines.

Reinforced concrete wall buildings (WRC) consist of bearing walls, wall girders, slabs, footing girders and foundations. These buildings have excellent seismic performance and fire-resistance and are low-priced construction compared to frame structures. This type of structure is one of the most popular buildings for residential apartment houses in the world.

Structural features of WRC buildings can be summarized as follows:

— high seismic performance (according to the damage of the past earthquakes, the damage ratio of WRC structures is much smaller than that of other types of structures);

— fire resistance (the performance is as good as that of RC buildings);

— economical superiority (bearing walls are as thick as wall girders).

Buildings designed according to this document will consequently:

a) for moderate earthquake motions, not produce cracks on bearing walls.

b) for extremely large earthquake motions, prevent from collapse and fall.

The charactersitics of this document to achieve the above performances are as follows:

1) Prevention of shear cracks developing in bearing walls during moderate earthquake motions

   The shear stress intensity in bearing walls during moderate earthquake motions on every storey and in every direction should be less than shear cracking stress of concrete being used, in order not to produce cracks in the bearing walls.

   Seismic shear force on every storey and in every direction should be set forth corresponding to moderate earthquake motions.

2) Prevention of buildings collapsing during extremely large earthquake motions

   The design storey shear force should be set forth corresponding to extremely large earthquake motions. However, this magnitude is reduced, considering the ductility of structures. The reduction value may be about 0,5 for this type of structures. Finally, for example, this magnitude for the first storey almost corresponds to half of the total weight of a building.

   In order to secure the structural safety in case of such storey shear, some structural specifications are prescribed in the structural design. The upper limits of average shear stress as well as the maximum storey drift angle are defined in order to control the shearing stress of the wall during the extremely large earthquake motions. That is one of such important specifications. Also, steel bar arrangement specifications and bearing wall arrangement/configuration, etc., are very important specifications to secure structural safety.

This document contains provisions that can be modified by the National Standards Body due to local design and construction requirements and practices. The specifications that can be modified are indicated using [“boxed values”]. The National Standards Body is expected to review the “boxed values” and may substitute alternative definitive values for these elements for use in the national application of this document.

Simplified structural design for reinforced concrete wall buildings

1 Scope

This document applies to reinforced concrete building consisting of load bearing walls of reinforced concrete buildings [such buildings are called reinforced concrete box-shaped wall buildings and (RC wall building)] or to the part of RC wall building which uses both this and other types of structure.

This document applies to RC wall building as follows:

— RC wall building with 5 or fewer aboveground storeys;

— eaves height of 16 m or less;

— storey height on each storey of 3 m or less;

— on the top storey, the storey height can be 3,3 m or less;

— if the roof has a slope, the sum of the storey height of the top storey and the height from the eaves to the ridge of 4 m or less.

Deep foundations, such as piles and caissons, and their pile footings and caps, are beyond the scope of this document, and are not covered by it.

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 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 4355, *Bases for design of structures — Determination of snow loads on roofs*

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 fabric*

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

ISO 15673, *Guidelines for the simplified design of structural reinforced concrete for buildings*

ISO 28842, *Guidelines for simplified design of reinforced concrete bridges*

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 28842 and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
base
level of a structure at which earthquake motions are assumed to be imparted to a building

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

3.2
load bearing wall
wall proportioned to resist combinations of shear, moments, and axial forces

Note 1 to entry: A "shear wall" is a "structural wall."

3.3
drift
difference between the horizontal displacements of two levels

3.4
factored load
specified nominal load multiplied by the appropriate load factor

3.5
floor system
set of structural elements that comprise the floor of a storey in a building

Note 1 to entry: It includes the beams and girders, the joists (if employed), and the slab that spans between them.

3.6
foundation girder
girder that rests on the foundation soil and spans between footings, used either to support walls or to limit differential settlement of the foundation

3.7
hoop
closed stirrup, tie, or continuously wound spiral

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

3.8
non-structural element
set of architectural, mechanical, and electrical components and systems permanently attached to the building

3.9
occupancy
purpose for which a building or other structure, or part thereof, is used or intended to be used

3.10
partition
non-structural wall that is employed to divide spaces

Note 1 to entry: Partitions do not support other parts of the building except themselves. When they are built in the exterior, they are sometimes referred as curtain walls.

3.11
slab on grade
slab set directly on the ground that serves either as an internal traffic surface or as part of the foundation

3.12
storey height
vertical distance between the upper part of the slab of a storey and the upper part of the slab of the floor below

3.13
storey drift angle
angle of the inter-storey drift divided by the storey height

3.14
diaphragm
structural member, such as floor and roof slabs, which transmits inertial induced by earthquake motions

3.15
wall area ratio
ratio of the total wall area in each direction to the floor area

4 Symbols

Symbol	Description	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_{fi}	area of the i-th floor	m^2
A_{g}	gross area of section of element	mm^2
a_{t}	area of longitudinal tension reinforcement	mm^2
A_{w}	area of shear reinforcement within a distance, s	mm^2
A_{wi}	sectional area of the structural wall in the x- or y- direction at the i storey	—
b	width of the section of the member	mm
b_{f}	effective width of the compression flange in a T shaped section	mm
d	effective depth, shall be taken as the distance from extreme compression fibre to centroid of tension reinforcement	mm
d_{b}	nominal diameter of reinforcing bar	mm
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	MPa
f_{s}	shear strength of concrete	—
f_{y}	specified yield strength of reinforcement, MPa	MPa
${}_{\mathrm{w}}f_{\mathrm{t}}$	specified yield strength of transverse or spiral reinforcement	
F	loads due to weight and pressures of fluids with well-defined densities and controllable maximum heights, or related internal moments and forces	—
G_i	shear modulus of concrete at the i-th storey	—
h	depth or thickness of structural element or overall thickness of member	mm
h_{bi}	average depth of wall girders in the x- or y-direction at the i-th storey	—
H_i	storey height at the i-th storey	—
h_{i}	average height of structural walls in the x- or y-direction at the i-th storey	—
h_0	clear vertical distance between lateral supports of columns and walls	mm

Symbol	Description	Unit
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	—
l	span of structural element or length of span measured centre-to-centre of beams or other supports	—
l_d	development length for reinforcing bar	mm
l_i	average length of structural walls in the x- or y-direction at the i-th storey	—
l_w	horizontal length of structural concrete wall	mm
L_i	ratio of the total wall length to the floor area at i-th floor	—
L_{0i}	minimum requirement of L_i	—
M	maximum bending moment in the wall girder	—
${}_{D}M_{A}$	design moment due to gravity load	—
M_{bE}	moment in of wall girder	—
M_E	moment due to seismic load	—
M_L	moment due to gravity load	—
m_w	mass of the non-structural wall	kg
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_n	nominal flexural moment strength at section	N·mm
M_r	flexural moment strength at section	N·mm
M_u	factored flexural moment at section	N·mm
M_u^-	factored negative flexural moment at section	N·mm
M_u^+	factored positive flexural moment at section	N·mm
n	design shear margin, which shall be greater or equal to 1,5	
P_d	non-factored dead load axial force at section or non-factored concentrated dead 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_{0n}	axial compressive strength at section	N
p_w	hoop ratio ($0{,}002 \leq p_w \leq 0{,}012$)	—
P_{wE}	axial force of structural wall	—
ΣP_u	sum of all factored concentrated design loads within the span	N
Q	maximum shear force in the wall girder	—
Q_E	design shear force due to seismic load	—
Q_L	design shear force due to gravity load	—
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	response modification factor	—
R_1	storey drift angle at the first storey	—
R_i	storey drift angle at the i-th storey	—
R_n	storey drift angle at the top storey	—
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

Symbol	Description	Unit
t	thickness of the wall	—
T	cumulative effect of temperature, creep, shrinkage, or differential settlement, or related internal moments and forces	—
U	required factored strength to resist factored loads or related internal moments and forces	—
V_{bE}	shear force of wall girder	—
V_E	shear force due to seismic load	—
V_c	contribution of the concrete to the nominal shear strength at section, N	N
V_L	shear force due to gravity load	—
V_i	storey shear in the *x*- or *y*- direction at the *i*-th storey	—
V_n	nominal shear strength at section	N
V_s	contribution of the horizontal reinforcement to the nominal shear strength at section	N
V_u	factored shear force at section	N
W	total weight	—
w_i	*i*-th floor mean weight	N/m^2
w_u	factored uniformly distributed design load per unit element length applied directly to the element	N/m
W_i	weight of *i*-th sotrey	N
W_u	total factored uniformly distributed design load per unit element length	kN/m
α	amplification factor according to the shear span $\alpha = \dfrac{4}{M/Qd+1}$ and $1 \le \alpha \le 2$	—
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	—
v	safety factor, 1/1,5 for gravity load and 1,0 for seismic load	—
ρ	ratio of longitudinal tension reinforcement, $\dfrac{A_s}{b \cdot d}$	—
ρ_s	ratio of spiral reinforcement	—
ρ_t	ratio of total longitudinal reinforcement area to gross concrete section area, $\dfrac{A_{st}}{b \cdot d}$	—
ρ_v	ratio of vertical reinforcement in structural concrete walls	—
g	gravity acceleration	—
$\overline{\tau}_{0i}$	standard average shear stress	MPa
$\overline{\tau}_i$	average shear stress in the *x*- or *y*- direction at the *i*-th storey $\overline{\tau}_i = \dfrac{V_i}{\Sigma A_{w,i}}$	—
$\Sigma A_{w,i}$	total sectional area of structural walls in the *x*- or *y*- direction at the *i*-th storey	—

5 Materials for reinforced concrete

5.1 General

All materials employed in the construction of the structure designed according to this document shall conform to ISO 15673.

5.2 Cement

Cement shall conform to the project specification.

5.3 Aggregates

Aggregates shall conform to the project specification.

5.4 Water

Water used in mixing concrete shall 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 project specification.

5.5 Admixtures

Admixtures shall conform to the project specification.

5.6 Storage of materials

Cement and aggregates shall be stored in such manner as to prevent deterioration and intrusion of foreign matter. Any material that has deteriorated or has been contaminated shall not be used for concrete.

5.7 Steel reinforcement

Steel reinforcement shall be deformed reinforcement, with the exceptions noted in 5.8. Welded-wire fabric shall be considered deformed reinforcement according to this document.

5.8 Deformed reinforcement

The maximum specified yield strength for deformed reinforcement shall be 400 MPa. Deformed reinforcing bars shall conform to ISO 6935-2. ISO 6935-2 covers grades RB 300 and RB 400 (300 MPa and 400 MPa characteristic upper yield stress, respectively) and nominal diameters of 6 mm, 8 mm, 10 mm, 12 mm, 16 mm, 20 mm, 25 mm, 32 mm and 40 mm. However, in this document, the nominal diameter of deformed reinforcement bars is limited to 25 mm (see 15.3).

5.9 Welded-wire fabric

The maximum specified yield strength for wires being part of welded-wire fabric shall be 400 MPa. Welded wire fabric shall conform to ISO 6935-3. In this document, the nominal diameter of wire for welded-wire fabric is limited to 10 mm (see 15.3).

5.10 Plain reinforcement

Plain reinforcement shall be permitted only for stirrups, ties, spirals, and when it is part of a welded-wire fabric. The maximum specified yield strength for plain reinforcement shall be 300 MPa. Plain reinforcing bars shall conform to ISO 6935-1. ISO 6935-1 covers grades PB 240 and PB 300 (240 MPa and 300 MPa characteristic upper yield stress, respectively) and nominal diameters of 6 mm, 8 mm, 10 mm, 12 mm, 16 mm and 20 mm. However, in this document, the nominal diameter of plain reinforcement bars is limited to 16 mm (see 15.3).

5.11 Concrete mixture specification

The procedure for concrete mixture proportioning shall conform to ISO 22965-1 and ISO 22965-2.

The compressive strength of concrete shall not be less than 18 MPa.

6 Design and construction procedure

6.1 Procedure

The design procedure comprises the following steps (see Figure 1):

a) Definition of the layout in plan and height of the structure, following the provisions of Clauses 7 and 8.

b) Calculation of all gravity loads and seismic loads that act on the structure using the provisions of Clause 9.

c) Preliminary location, and trial dimensions for structural concrete walls capable of resisting the lateral loads are established, using the provisions of Clauses 10 and 11 for earthquake forces, the influence of their self-weight is evaluated, and flexure and shear design of the structural concrete walls is performed.

d) Trial dimensions for the wall girders with the provisions of Clause 12. Trial dimensions for the floor slabs with wall girders/structural concrete walls. Calculation of the self-weight 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 provisions of Clause 14 for floor slabs with wall girders/structural concrete walls.

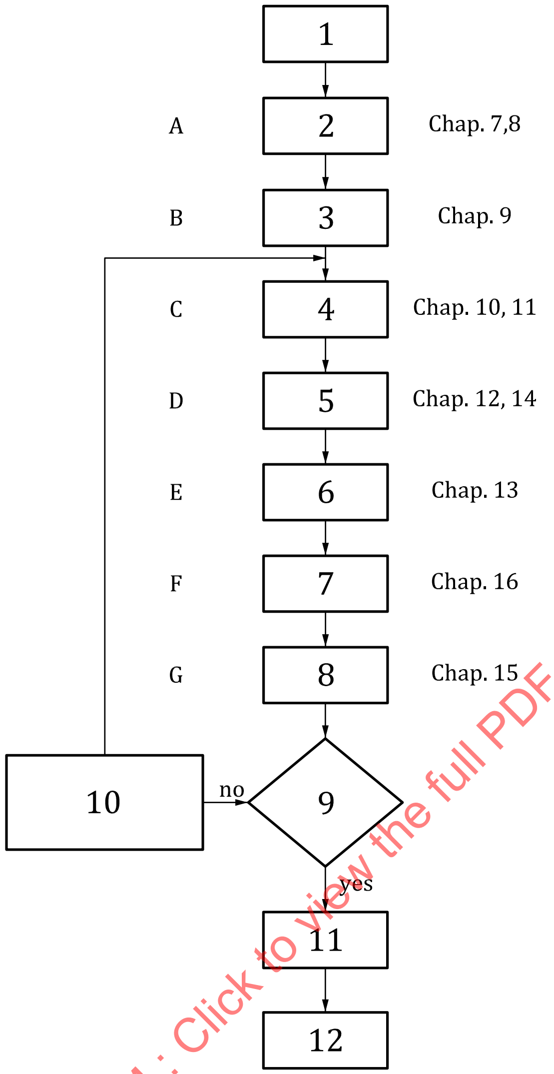
e) Joints between structural concrete wall and wall girders or foundation girders are designed.

f) The loads at the foundation level are determined, and a definition of the foundation system is performed employing the provisions of Clause 16. The structural elements of the foundation are designed.

g) Check the general reinforced concrete requirements using the provisions of Clause 15.

h) Production of the structural drawings.

i) The construction of the structure shall be performed complying with the local construction practice.



Key

1 start
2 definition of the structure
3 definition of the loads
4 structural concrete walls
5 wall grinders and floor slabs
6 joints
7 foundation
8 general RC requirements
9 are dimensions ok?
10 change member section or add structural members
11 structural drawings
12 construction

Figure 1 — Design procedure

6.2 Limit states

The design approach of this document is based on limit states. A limit state is a condition beyond which a structure or member becomes unfit for service and is deemed either to be no longer useful for its intended function or unsafe.

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

1) structural integrity limit state;

2) lateral load storey drift limit state;

3) durability limit state;

4) fire limit state;

5) ultimate and serviceability limit states.

6.3 Ultimate limit state design format

6.3.1 General

For the ultimate limit state design under seismic force, the structure and the structural members shall 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 are stipulated in this document.

The basic requirement for the ultimate limit state shall be that resistances are greater than or equal to load effects.

To allow for the possibility that the resistances can be less than computed, and the load effects can be larger than computed, strength reduction factors, ϕ, less than 1, and load factors, γ, generally greater than 1, shall be employed [see Formula (1)]:

$$\phi \cdot R_\text{d} \geq \gamma_1 \cdot S_\text{d1} + \gamma_2 \cdot S_\text{d2} + \cdots \tag{1}$$

where

R_d is the nominal strength;

S_d is load effects based on the nominal loads prescribed by this document.

ϕ is the strength reduction factor

Therefore, the ultimate limit state design format requires that design strength is greater than or equal to required factored strength:

6.3.2 Required factored strength

The required factored strength, U, shall be computed by multiplying service loads, or forces, by load factors using the load factors and combinations in Clause 9.

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, shall be taken as the nominal strength calculated in accordance with the requirements and assumptions of this document for each particular force effect in each of the element types at the critical sections defined by this document, multiplied by the following strength reduction factors, ϕ:

a) flexure, without axial load: ϕ = [0,90]

b) axial tension, and axial tension with flexure: ϕ = [0,90]

c) axial compression and axial compression with flexure: ϕ = [0,70]

d) shear and torsion: ϕ = [0,85]

e) bearing of concrete: ϕ = [0,70]

6.4 Serviceability limit state design format

Serviceability limit states under seismic force, 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 in this document, shall be obtained indirectly through the observance of the limiting dimensions, cover, detailing, and construction requirements. These serviceability conditions include effects such as:

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; and

f) excessive vibration.

6.5 Design documentation

6.5.1 General

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

6.5.2 Calculation memoir

The structural designer shall document all design steps in a calculation report. This memoir shall contain, as a minimum, the following:

a) the general structural requirements of the project, as required by Clause 8;

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.

6.5.3 Geotechnical report

The geotechnical report shall 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 9.7.7 and Clause 16.

6.5.4 Structural drawings

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

6.5.5 Specifications

The construction specifications required.

7 Limitations

7.1 General

This document shall be employed only when the building being designed complies with all the limitations set forth in 7.2 to 7.7.

7.2 Occupancy

On each aboveground storey of RC wall building, w_i shall satisfy Formula (2):

$$w_i = W_i \,/\, A_{fi} \leq 12\,000\ \text{N/m}^2 \tag{2}$$

7.3 Maximum number of storeys

The maximum number of storeys for a building designed according to this document shall be [5]. This number of storeys shall include the floor at the level of the ground and any basement. It shall not include the roof. The number of basements shall not exceed one.

7.4 Maximum storey height

The maximum storey height, measured from the floor finish to the floor finish of the storey immediately below, shall not exceed [3,3] m for the top storey and [3,0] m for other storeys. The maximum height of the top storey shall not exceed [4,0] m.

7.5 Minimum wall area ratio

The wall area ratio in the x- and y-directions shall not be less than 30 cm^2/m^2, respectively.

7.6 Upper limit of average shear stress

The average shear stress of structural wall at each storey, calculated with Formula (3), shall be less than or equal to the value listed Table 1:

$$\bar{\tau}_{0i} = 0{,}2 \times V_i \,/\, A_{w,i} \tag{3}$$

Table 1 — Upper limit $\bar{\tau}_{0i}$ (N/mm^2) of mean shear stress of load bearing walls ($t_i = t_{0i}$, $L_i = L_{0i}$) in the x- or y-direction on each storey.

i	n				
	5-storey construction	4-storey construction	3-storey construction	2-storey construction	Single-storey construction
5th storey	0,222	—	—	—	—
4th storey	0,308	0,201	—	—	—
3rd storey	0,409	0,282	0,180	—	—
2nd storey	0,392	0,373	0,253	0,157	—
1st storey	0,444	0,356	0,333	0,267	0,167

NOTE The values of $\bar{\tau}_{0i}$ given in the table apply to the case where normal concrete is used.

7.7 Maximum storey drift angle

Thestorey drift angle due to the design lateral load shall be less than or equal to 1/2 000.

8 Specific requirements

8.1 Structural systems

8.1.1 Floor system

The floor system consists of the structural elements that comprise the floor of a storey in a building. The different types of floor systems covered by this document are described in Clause 14. The floor system includes the wall girders, and the slab that spans between them.

8.1.2 Vertical supporting elements

The vertical supporting elements hold up the floor system at each storey, and carry the accumulated gravity loads down to the foundation of the structure. In this document, they can be structural concrete walls. Vertical supporting element shall comply with Clause 11.

8.1.3 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.

8.1.4 Lateral load resisting system

The lateral load resisting system comprises the structural elements that acting jointly support and transmit to the ground the lateral loads arising from earthquake motions, wind, and lateral earth pressure. The floor system shall 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 to the foundation, and through the foundation to the underlying soil. In this document, the main vertical elements of the lateral load resisting system shall be structural concrete walls.

8.1.5 Other structural elements

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

8.2 General program

8.2.1 Architectural program

A general architectural program of the building shall be coordinated with the structural designer before actual structural design begins. The general architectural program shall include, at least:

a) the plan shape and dimensions of all the floors of the building;

b) the elevation of the building, and its relationship with the terrain, including the basement, if any;

c) the 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) the use of internal spaces of the building, its subdivision, and means of separation, in all storeys;

e) the minimum architectural clear height in all floors;

f) the location of stairways, ramps, and elevators;

g) the type of building enclosures, internal partitions, architectural, and non-structural elements;

h) the 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.

8.2.2 General structural requirements for the project

Based in the general architectural program information, the structural designer shall define the general structural guides for the structure designed according to this document. These general structural guides shall include, at least:

a) the intended use of the building;

b) the nominal loads related to the use of the building;

c) the special loads required by the owner;

d) the design earthquake motions if the building is located in a seismic zone;

e) the wind requirements for the site;

f) the requirements for snow, hail or rain, as appropriate.

g) the fire requirements;

h) the type of roof, and appropriate loads when not built from reinforced concrete;

i) the site information related to slopes and site drainage;

j) the allowable soil bearing capacity, and recommended foundation system derived from the geotechnical investigation, and additional restrictions related to expected settlement;

k) the environmental requirements derived from local seasonal and daily temperature variations, humidity, presence of deleterious chemicals and salts;

l) the availability, type, and quality of materials such as reinforcing bars, cement, aggregates;

m) the availability of materials for formwork;

n) the availability of a testing lab for concrete mix design and quality control during construction;

o) the availability of qualified workmanship.

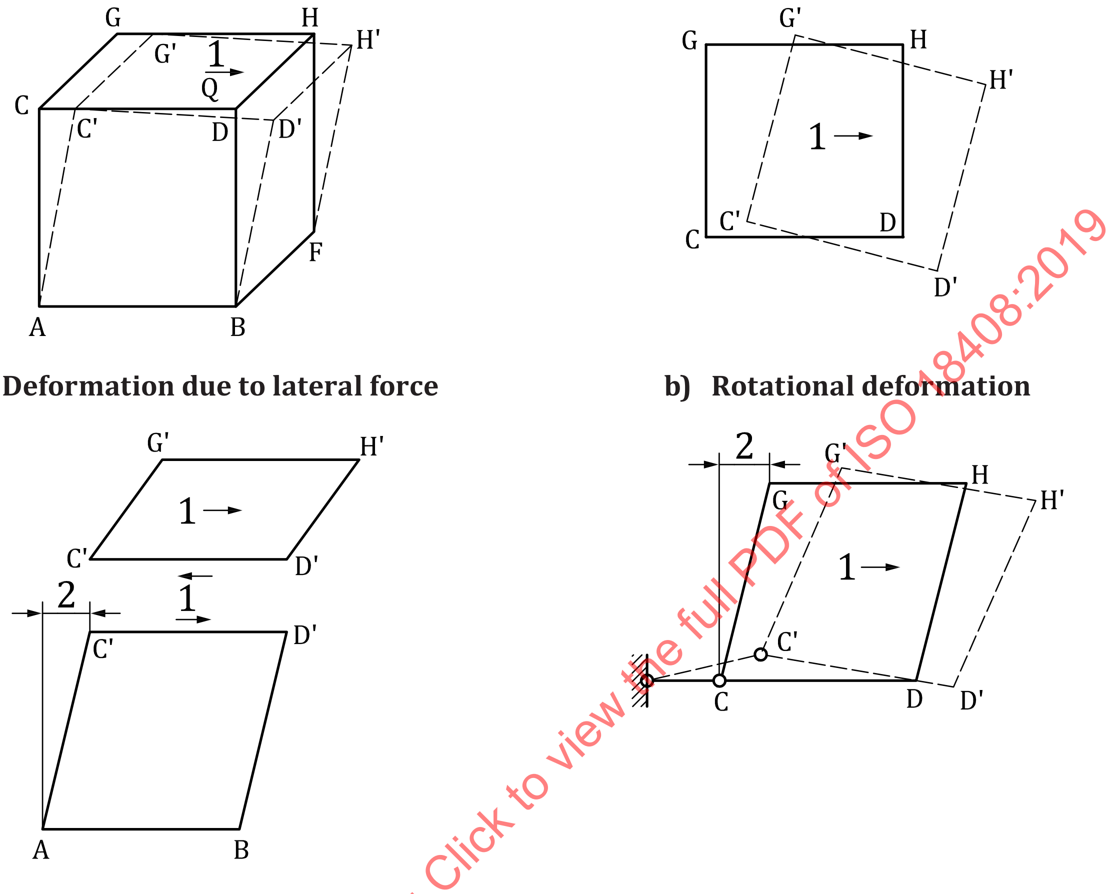
8.3 Structural layout

8.3.1 General structural layout

The bearing walls shall be arranged in good torsional balance on the plan of the building. An appropriate arrangement of bearing walls is the first step to a sound design of RC wall buildings. Basic matters about floor and elevation planning are given below as a guide in the design of RC wall buildings. The bearing walls shall be connected effectively by wall girders.

8.3.2 Floor planning of bearing walls

Figure 2 shows a box-shaped building in a deformed state subjected to seismic force, Q, on the roof slab surface, ABDC, BFHD, etc., representing bearing walls and CDHG a roof slab. Figure 2 b) shows the force received from the roof slab in relation to deformation, that is, a bearing wall deformed under a horizontal force. From the point of view of the roof slab, the resultant of horizontal forces, Q_i, received from the bearing walls is in equilibrium with the seismic force, Q. In this case, the bearing wall, i, is distorted. Supposing that the bearing wall has no resistance to distortion and cannot endure out-of-plane forces, the force, Q_i, in Figure 2 c) is parallel to AB and proportional to δ. Therefore, as shown in Figure 2 d), the bearing wall, i, can be replaced by an elastic member, IC, in which reaction Q_i develops against the displacement, δ. For each typical floor, the structural designer shall develop a structural floor layout.



a) **Deformation due to lateral force**

b) **Rotational deformation**

c) **Shear deformation**

d) **Total deformation**

Key

1 lateral force

2 lateral deformation

Figure 2 — Behaviour of rigid floor CDHG of a building having a bearing wall i on the plane of structure ABDC, and an elastic member IC supposed to support the rigid floor for representing this behaviour

8.3.3 Elevation planning of bearing walls

There are many cases where the designer pays much attention to the floor planning of bearing walls while being almost indifferent to their elevation planning. Since bearing walls are meant to transmit the seismic forces acting on the building to the ground through the foundation structure, their elevation planning shall be considered with care as well. The wall girder mutually connecting bearing walls is charged with the important duty of preventing the bearing walls from becoming floating or toppling and the shearing resistance of the bearing walls from decreasing by virtue of the moments and shearing forces at its boundary ends (see Figure 3). If this wall girder yields to bending in an early stage, the bearing walls become impossible to fully exhibit their own horizontal load-carrying capacity (see Figure 4). Noting that a large shear resistance can be expected only when the bearing walls are united into one integral body, the wall girders connecting the bearing walls shall be of sufficient rigidity and strength.

In Figure 3, bearing walls are arranged to be vertically continuous. This layout can be said to be safe for relatively low-storied buildings covered by this document.

For bearing walls not arranged to be vertically continuous, it is desirable to:

— fix them at their bottom by wall girders of sufficient rigidity and strength; and

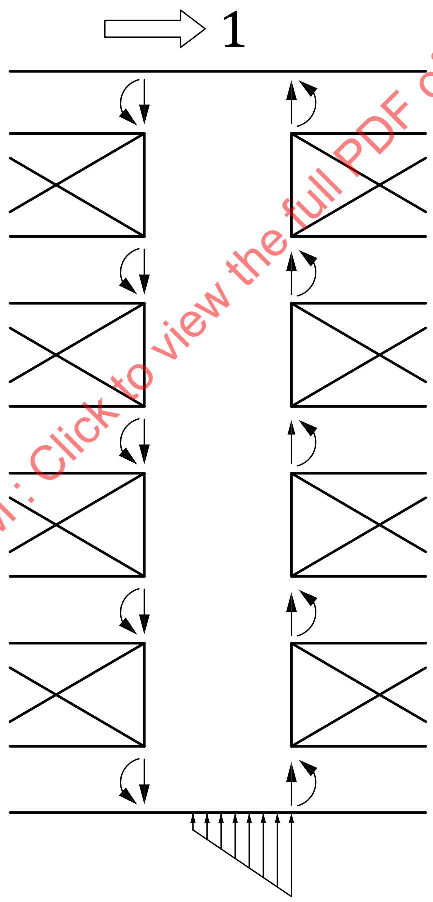
— provide vertical supports under the bottom of the bearing walls that can effectively prevent them from rotating.

These supports should be placed as close as possible to both sides of the bearing wall so that the rotation of the bearing wall is effectively checked. The following arrangements are conceivable:

a) arranging vertically bearing walls so that the top of the lower one is lapped on the bottom of the upper one;

b) placing a bearing wall perpendicular to the bearing walls;

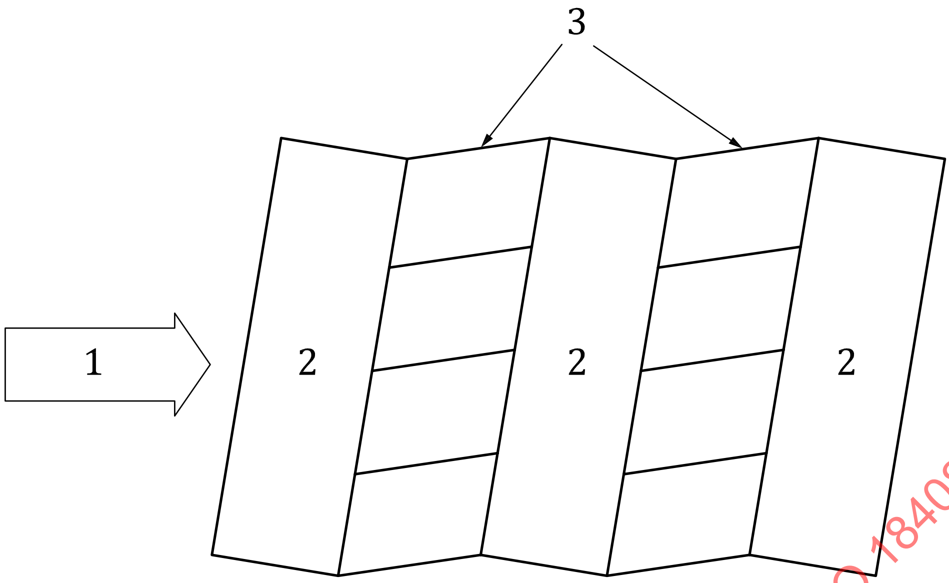
c) providing supports.



Key

1 seismic force

Figure 3 — Vertical layout of the building



Key

1 seismic force

2 multistorey bearing wall

3 wall girder

Figure 4 — Multi-storey bearing walls making hinges at the ends of the wall girders at the boundaries and forming the total collapse mode

9 Actions (loads)

9.1 General

9.1.1 Load factors and load combinations

9.1.1.1 General

The following load factors and combinations shall 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 "±" in alternating forces that can act in one direction or the opposite, shall be interpreted as the force with the sign that leads to the maximum (positive) or minimum (negative) value of U.

9.1.1.2 Dead and live load

Required factored strength, U, to resist dead load, L_D, and live load, L_L, shall be at least equal to Formula (4) or (5), whichever the greater:

$$U = [1{,}0] \cdot L_D \tag{4}$$

$$U = [1{,}0] \cdot L_D + [1{,}0] \cdot L_L \tag{5}$$

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

If resistance to structural effects of a specified rain load, L_R, snow load, L_S, or sloping roof live load, L_r, are required to be included by this document, the following combinations of L_D, L_L, and (L_R, L_S, or L_r) shall be investigated to determine the greatest required factored strength U as Fomulae (6) or (7):

$$U = [1,4] \cdot L_D + [1,7] \cdot L_L + [0,6] \cdot (L_R \ or \ L_S \ or \ L_r) \tag{6}$$

$$U = [1,4] \cdot L_D + [0,6] \cdot L_L + [1,7] \cdot (L_R \ or \ L_S \ or \ L_r) \tag{7}$$

but for any combination of L_D, L_L, and (L_R, L_S, or L_r), the required factored strength U shall not be less than the value obtained employing Formulae (4) and (5).

9.1.1.4 Wind

If this document requires to include the resistance to structural effects of a specified wind load, L_W, the following combinations of L_D, L_L, and L_W shall be investigated to determine the greatest required factored strength U as Fomulae (8) or (9):

$$U = [0,75] \cdot ([1,4] \cdot L_D + [1,7] \cdot L_L) \pm [1,3] \cdot L_W \tag{8}$$

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

$$U = [1,1] \cdot L_D + [1,3] \cdot L_L \pm [1,3] \cdot L_W \tag{9}$$

but for any combination of L_D, L_L, and L_W, the required factored strength U shall not be less than the value obtained employing Formulae (4) and (5).

9.1.1.5 Earthquake forces

If this document requires to include the resistance to specified earthquake forces, E, the following combinations of L_D, L_L and E shall be investigated to determine the greatest required factored strength U as Fomulae (10) or (11):

$$U = [0,75] \cdot ([1,4] \cdot L_D + [1,7] \cdot L_L) \pm [1,0] \cdot E = [1,1] \cdot L_D + [1,3] \cdot L_L \pm [1,0] \cdot E \tag{10}$$

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

$$U = [0,9] \cdot L_D \pm [1,0] \cdot E \tag{11}$$

but for any combination of L_D, L_L and E, the required factored strength, U, shall not be less than the value obtained employing Formulae (4) and (5).

9.1.1.6 Earth pressure

If the design procedure of this document requires to include the resistance to earth pressure, H, the required factored strength, U, shall be at least equal to Formula (12):

$$U = [1{,}4] \cdot L_D + [1{,}7] \cdot L_L + [1{,}7] \cdot H \tag{12}$$

except that where L_D or L_L reduce the effect of H, the following combination shall be employed as Formula (13)

$$U = [0{,}9] \cdot L_D + [1{,}7] \cdot H \tag{13}$$

For any combination of D, L and H, the required factored strength, U, shall not be less than the value obtained employing Formulae (4) and (5). When the building structure as a whole shall resist permanent uncompensated horizontal loads due to lateral soil pressure, ([1,7] · H) shall be added to U in Formulae (4), (5), (8), (9), (10), (11), (12), and (13).

9.1.1.7 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 this document, ([1,7] · F) shall be added to Formulae (4), (5), (10) and (12).

9.1.1.8 Other effects

Where structural effects, T, of differential settlement, shrinkage, or temperature change are significant in design, this standard cannot be applied.

9.2 Mass of materials

To define the mass of materials, the requirements of ISO 9194 shall be used.

9.3 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 shall be used. The weights shall be calculated with their densities of materials, but not less than the values listed in Table 2. 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, shall be included.

Table 2 — Minimum density, ρ, for evaluation of dead and live loads from material

Material	Density, ρ kg/m³	Material	Density, ρ kg/m³
Aluminum	2 702	Iron	
Bituminous products		Cast	7 151
Asphalt and tar	1 287	Wrought	7 628
Gasoline	667	Lead	11 283
Graphite	2145	Lime	
Paraffin	890	Hydrated, loose	509
Petroleum	842	Hydrated, compacted	715

Table 2 *(continued)*

Material	Density, ρ kg/m^3
Brass	8 359
Bronze	8 772
Cement, Portland, loose	1 430
Ceramic tile	2 384
Charcoal	191
Cinder fill	906
Coal, piled	795
Concrete, plain	2 288
Concrete, reinforced	2 384
Copper	8 836
Cork, compressed	222
Earth	
Clay, dry	1 001
Clay, damp	1 748
Clay and gravel, dry	1 589
Silt, moist, packed	1 526
Silt, moist, loose	1 240
Sand and gravel, dry, loose	1 589
Sand and gravel, dry packed	1 748
Sand and gravel, wet	1 907
Glass	2 543
Gravel, dry	1 653
Gypsum, loose	1 112
Gypsum, wallboard	795
Ice	906

Material	Density, ρ kg/m^3
Masonry, brick (solid portion)	1 828
Masonry, concrete (solid portion)	1 986
Masonry grout	2 225
Masonry, stone	2 574
Mortar cement or lime	2 066
Particleboard	715
Plywood	572
Sand	
Clean and dry	1 430
River dry	1 685
Steel	7 755
Stone	
Basalt, granite, gneiss	1 526
Limestone, marble, quartz	1 510
Sandstone	1 303
Shale	1 462
Terra cotta	
Voids filled	1 907
Voids unfilled	1 144
Tin	7 294
Water	
Fresh	985
Sea	1 017
Wood, seasoned	445
Zinc, rolled sheet	7 135

9.4 Live loads

For live loads, 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.

9.5 Specified snow load

The loads caused by the accumulation of snow shall be taken into account in the design of the roof when snow is expected, and ISO 4355 shall be employed.

9.6 Specified wind forces

For wind forces, ISO 4354 shall be employed.

9.7 Specified earthquake forces

9.7.1 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.

When calculating the mass of building materials, ISO 9194 shall be used.

For buildings designed according to this document, an equivalent lateral force applied directly to each storey shall be employed to represent the dynamic response of the structure to the ground acceleration.

9.7.2 Seismic hazard

A level of seismic hazard shall 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/s^2).

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 shall be estimated as Formula (14).

$$A_a = S_S / 375 \tag{14}$$

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 shall be equal to Z. When no national code exists for the site of the building considered, A_a shall be estimated from the seismic hazard maps shown in Figure 5.

9.7.3 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 than or equal to [0,05], shall be deemed as a no seismic hazard zone.

9.7.4 Low seismic hazard zones:

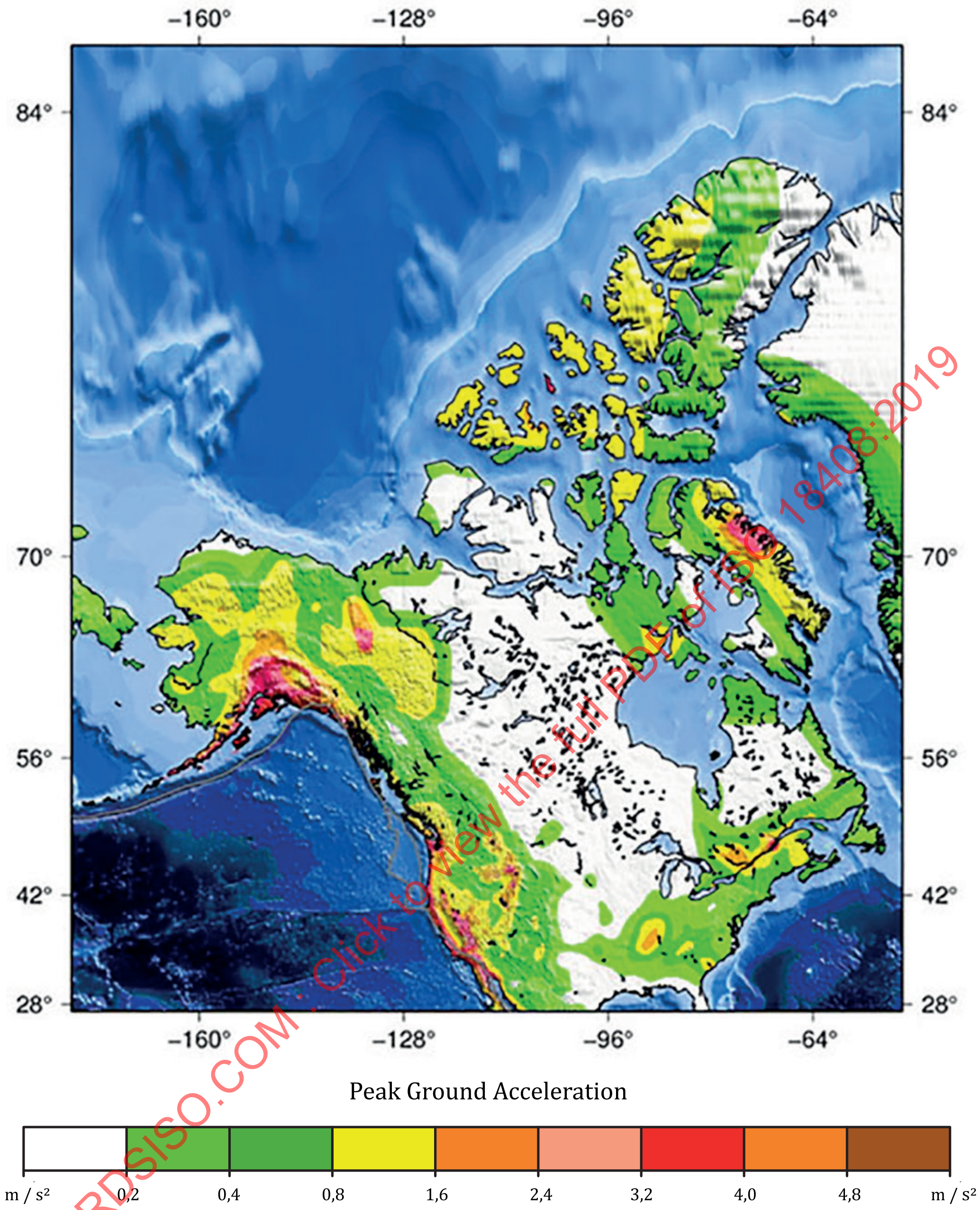
A zone where A_a is estimated as more than [0,05] but less than or equal to [0,10] shall be deemed as a low seismic hazard zone.

9.7.5 Intermediate seismic hazard zones:

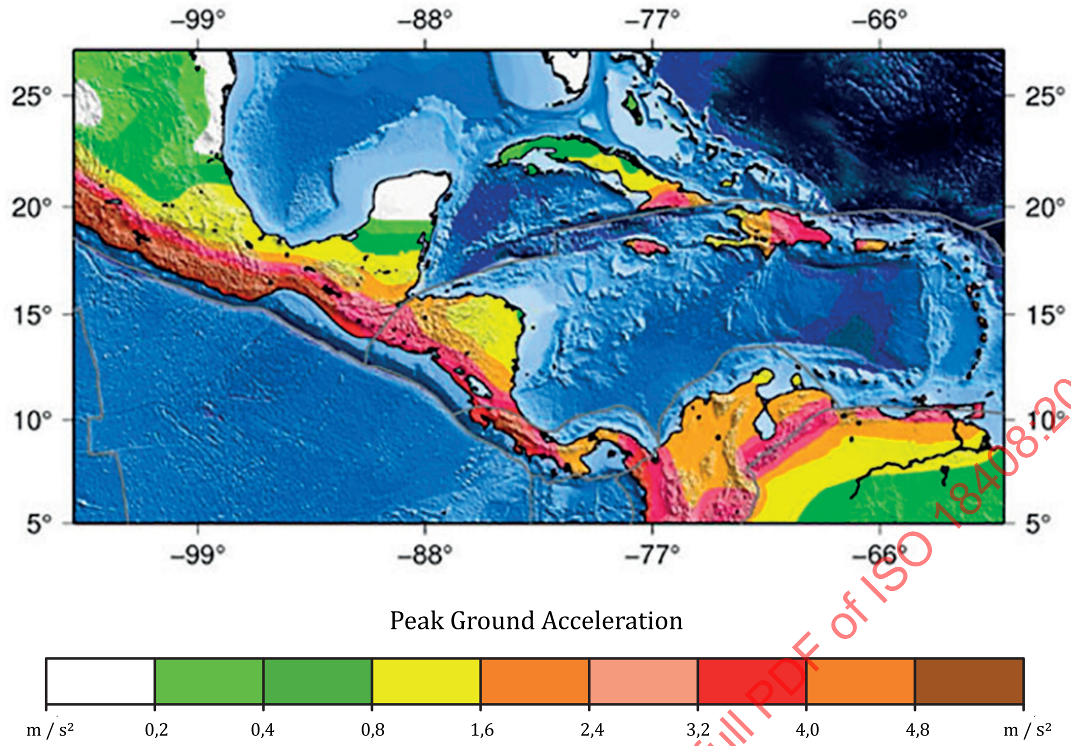
A zone where the value of A_a is estimated to be more than [0,10] but less than or equal to [0,20] shall be deemed as an intermediate seismic hazard zone.

9.7.6 High seismic hazard zones:

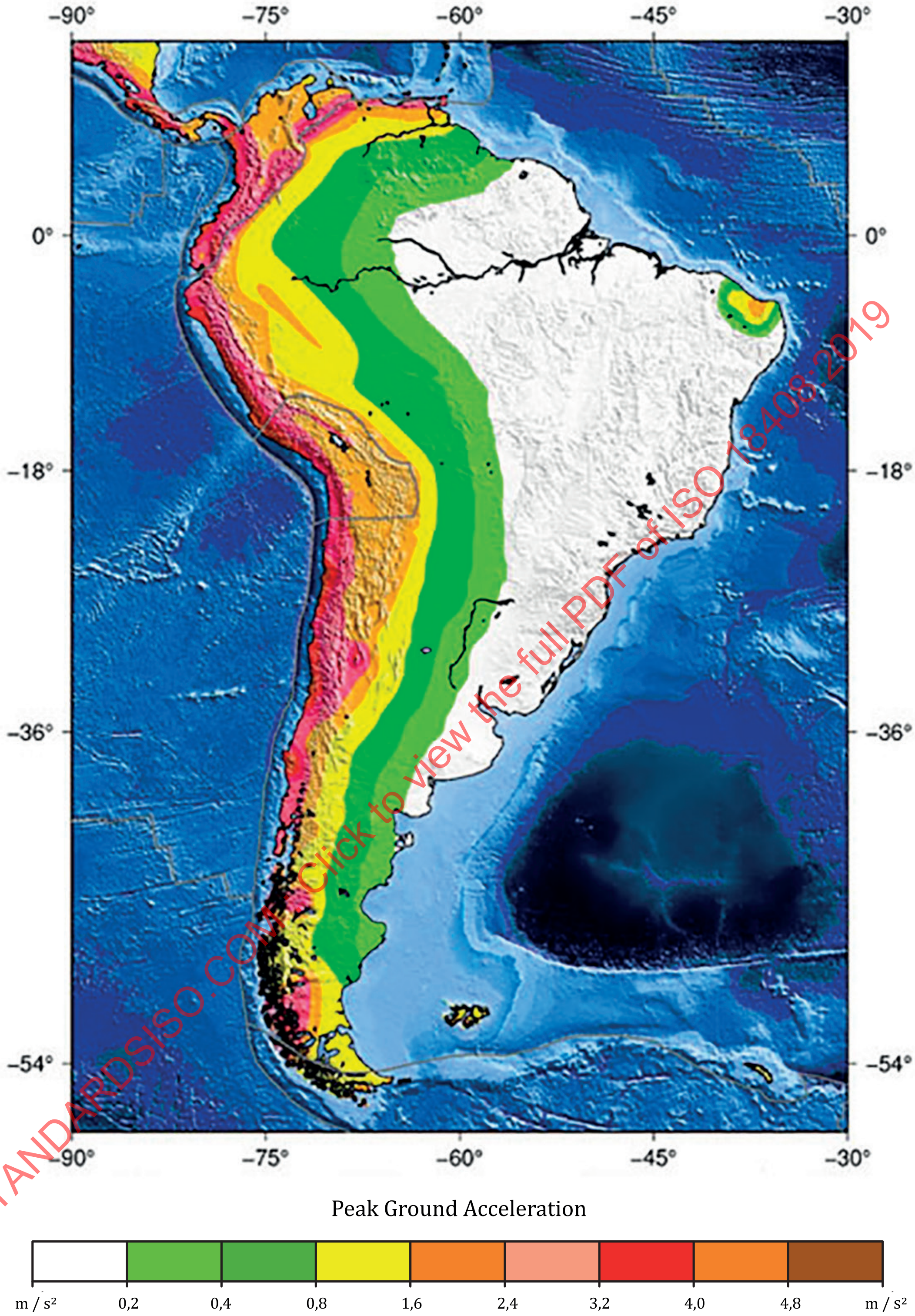
A zone where the estimated value of A_a exceeds [0,20] shall be deemed as a high seismic hazard zone.



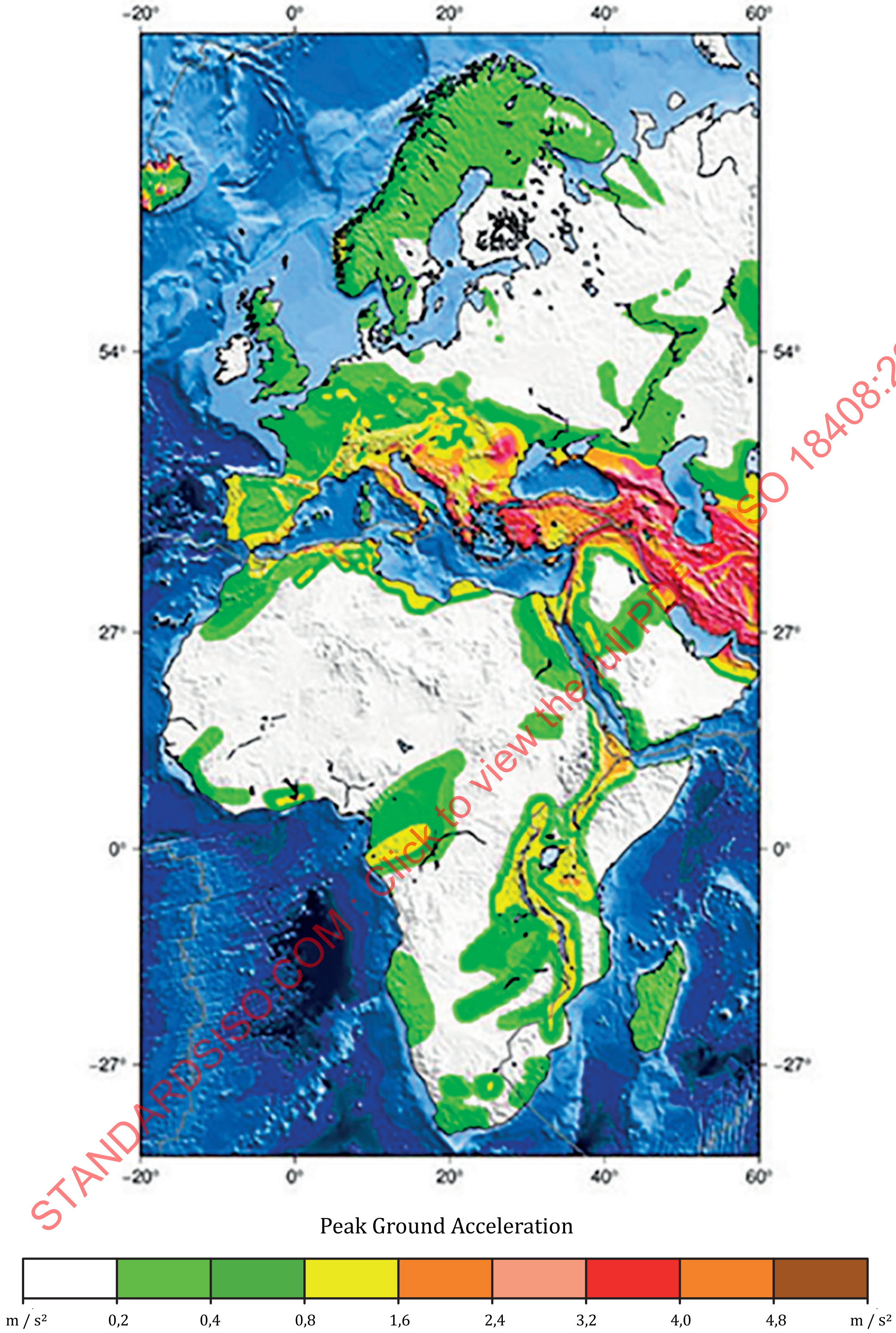
a) North America



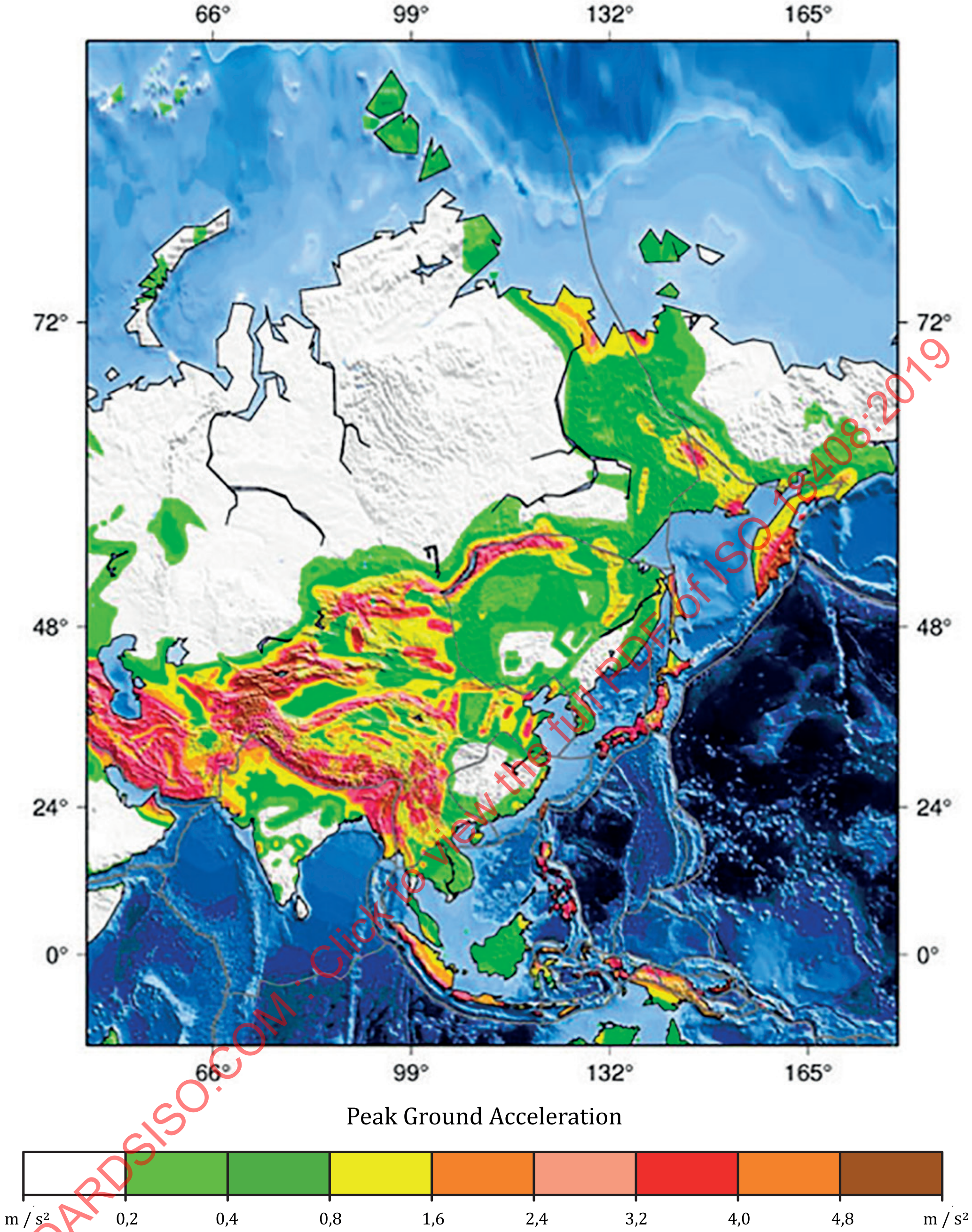
b) Central America and the Caribbean



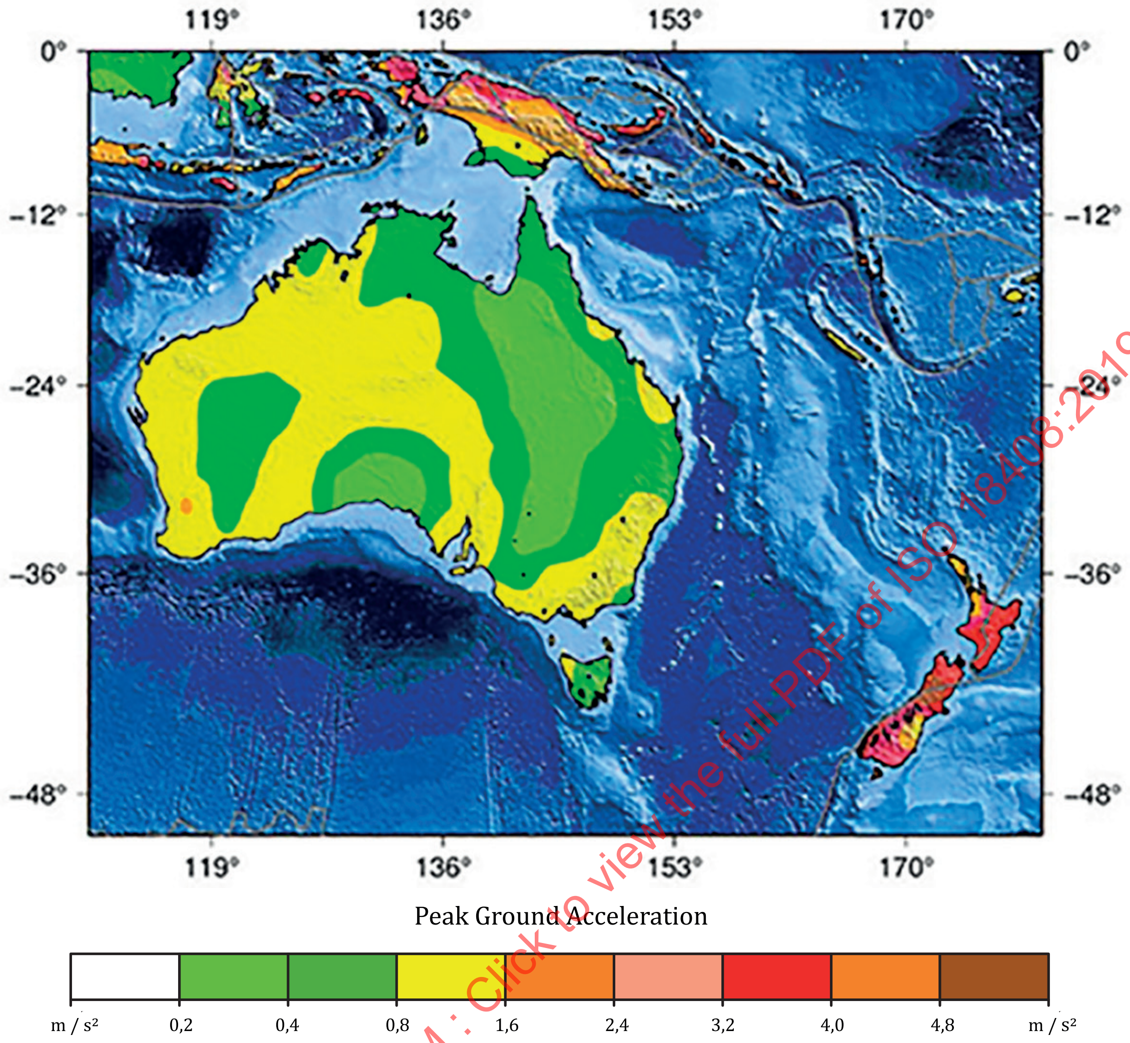
c) South America



d) Europe and Africa


66°
99°
132°
165°
72°
48°
24°
0°
Peak Ground Acceleration
m / s²
0,2
0,4
0,8
1,6
2,4
3,2
4,0
4,8
m / s²

e) Asia



f) Oceania

Figure 5 — Global seismic hazard map

9.7.7 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 N value from the standard penetration test > 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: 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; and

— Seismically vulnerable soils: sites where the soil profile contains soil having one or more of the following characteristics are not covered in 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; and

  — soft to medium-stiff clays with more than 40 m of thickness.

Soil exploration to obtain the needed values for soil classification shall be conducted by an engineer familiar with these processes.

9.7.8 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 9.7.7. Linear interpolation can be used between values of A_a in Table 3.

Site effect of seismically vulnerable soils, as described in 9.7.7, are beyond the scope of this document.

Table 3 — Site soil coefficient

Soil profile	Site coefficient, F_a, for short periods of vibration				
	A_a < [0,1]	A_a = [0,2]	A_a = [0,3]	A_a = [0,4]	A_a > [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]

9.7.9 Design response spectral ordinates

For buildings complying with the limitations presented in Clause 7, natural periods of vibration shall 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 damping ratio of 5 % of critical, expressed as a fraction of the acceleration of gravity, shall be calculated in the short periods of vibration range, using Formula (15):

$$S_a = 2{,}5 A_a F_a \tag{15}$$

9.8 Seismic design base shear

9.8.1 Seismic-resistant structural system

The seismic-resistant structural system shall be reinforced concrete walls that support gravity load and also lateral load.

9.8.2 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 $R = 2{,}0$.

9.8.3 Computation of the seismic design base shear

The seismic design base shear, Vs, equivalent to the total horizontal inertial effects caused by the seismic ground motions, shall be determined using Formula (16).

$$Vs = S_a \cdot W / (R \cdot 2{,}5) \tag{16}$$

where

S_a is determined from Formula (15);

R is the response modification factor determined from 9.8.2;

W is the total weight of the building;

2,5 is the linear analysis modification factor.

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/m^2.

9.8.4 Vertical distribution of the design seismic forces and the design storey shear 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. Storey shear force, V_i, shall be determined using Formula (19).

$$F_x = C_{vx} \cdot V_s \tag{17}$$

$$C_{vx} = \frac{w_x \cdot h_x}{\sum_{i=1}^{n} (w_i \cdot h_i)} \tag{18}$$

$$Vi = \sum_{x=i}^{n} Fx \tag{19}$$

10 Analysis

10.1 Method of analysis for moment, shear and axial force of members

10.1.1 General

Moment, shear and axial force of structural walls and wall girders of frames shall be determined by the elastic two- or three-dimensional frame analysis.

10.1.2 Simplified method

For the gravity load, instead of a more accurate method of frame analysis, the following approximate moment and shear shall be used in the design of structural walls and wall girders.

1) No moment and shear in structural wall except for very slender outer end structural walls.

2) Moment and shear in wall girder determined under the condition of the fixed ends.

For the earthquake load, the following approximate moment, shear and axial force determined by the average shear stress method shall be used in design of structural walls and wall girders.

1) Shear in structural wall at the *i* storey, V_{wEi}, in the x- or y-direction determined by Formula (20):

$$V_{wEi} = \bar{\tau}_i \cdot A_{wi} \tag{20}$$

2) Moment in structural wall, M_{wE}, determined by the shear, V_{wEi}, and a inflection point height ratio, η_i (i = 1, n) calculated by Formulae (21) to (31) of the n units, which is led by the equilibrium condition of moment and the conformity condition of the rotation angle at each node of n-storey of each partial frame.

In case of 1-storey frame;

$$\left(1+\frac{A_1}{B_1}+\frac{A_1}{B_0}\right)\eta_1=\frac{A_1}{B_1}+\eta_1^* \tag{21}$$

In case of 2-storey frame;

$$\begin{cases}\left(1+\frac{A_2}{B_2}+\frac{A_2}{B_1}\right)\eta_2+\left(-\frac{A_2}{B_1}\frac{V_{wE1}H_1}{V_{wE2}H_2}\right)\eta_1=\frac{A_2}{B_2}-\frac{A_2}{B_1}\frac{V_{wE1}H_1}{V_{wE2}H_2}+\eta_2^* \\ \left(-\frac{A_1}{B_1}\frac{V_{wE2}H_2}{V_{wE1}H_1}\right)\eta_2+\left(1+\frac{A_1}{B_1}+\frac{A_1}{B_0}\right)\eta_1=\frac{A_1}{B_1}+\eta_1^*\end{cases} \tag{22}$$

In case of n-storey frame ($n \geq 3$);

$$\begin{cases}\left(1+\frac{A_n}{B_n}+\frac{A_n}{B_{n-1}}\right)\eta_n+\left(-\frac{A_n}{B_{n-1}}\frac{V_{wEn-1}H_{n-1}}{V_{wEn}H_n}\right)\eta_{n-1}=\frac{A_n}{B_n}-\frac{A_n}{B_{n-1}}\frac{V_{wEn-1}H_{n-1}}{V_{wEn}H_n}+\eta_n^* \text{ for } i=n \\ \left(-\frac{A_i}{B_i}\frac{V_{wEi+1}H_{i+1}}{V_{wEi}H_i}\right)\eta_{i+1}+\left(1+\frac{A_i}{B_i}+\frac{A_i}{B_{i-1}}\right)\eta_i+\left(-\frac{A_i}{B_{i-1}}\frac{V_{wEi-1}H_{i-1}}{V_{wEi}H_i}\right)\eta_{i-1} \\ =\frac{A_i}{B_i}-\frac{A_i}{B_{i-1}}\frac{V_{wEi-1}H_{i-1}}{V_{wEi}H_i}+\eta_i^* \text{ for } >i>1 \\ \left(-\frac{A_1}{B_1}\frac{V_{wE2}H_2}{V_{wE1}H_1}\right)\eta_2+\left(1+\frac{A_1}{B_1}+\frac{A_1}{B_0}\right)\eta_1=\frac{A_1}{B_1}+\eta_1^* \text{ for } i=1\end{cases} \tag{23}$$

where

H_i is the structural storey height of the i storey (see Figure 6);

η_i is the inflection point height ratio, namely the ratio of the height of the inflection point of the structural wall to the structural storey height at the i storey;

η_i^* is the ratio of the height of the midpoint of the flexible length of the structural wall to the structural storey height at the i storey (see Figure 7).

$$\eta_i^* = \frac{1-\alpha_i+\beta_i}{2} \tag{24}$$

where α_i and β_i are the ratios of the length of the upper and lower rigid regeon of the structural wall to the structural storey height at the i storey, and shall be zero or more;

$$\alpha_i = \frac{D_{bi}/2 - D_{wi}/4}{H_i} \tag{25}$$

$$\beta_i = \frac{D_{bi-1}/2 - D_{wi}/4}{H_i} \tag{26}$$

where D_{wi} and D_{bi} are the depth of the structural wall and the wall girder at the i storey;

A_i is the rotational stiffness of the structural wall at the i storey;

$$A_i = \frac{E_i I_{wi}}{H_i\left(1-\alpha_i-\beta_i\right)} \tag{27}$$

where

E_i is Young's modulus of concrete at the i storey;

I_{wi} is the secondary moment of area of the structural wall at the i storey;

B_i is the total of the rotatinal stiffness of the right and left wall garders at the i-th storey of n-storey partial frame (see Figure 8);

$$B_i = \sum \frac{6E_i \cdot I_{bi}}{L} \frac{1}{3\left(1-r_i+s_i\right)\left(1-r_i-s_i\right)+\left(1+\omega_i\right)\left\{\dfrac{6\kappa \cdot E_i \cdot I_{bi}}{G_i \cdot A_{bi} \cdot L^2}\left(1-r_i-s_i\right)-\left(1+2r_i^3+2s_i^3-3r_i^2-3s_i^2\right)\right\}} \tag{28}$$

where

L is the structural span length;

I_{bi} is the secondary moment of area of the wall girder at the i storey;

A_{bi} is the sectional area of the wall girder at the i storey;

κ is the shape factor of section on shear deformation (= 1,2);

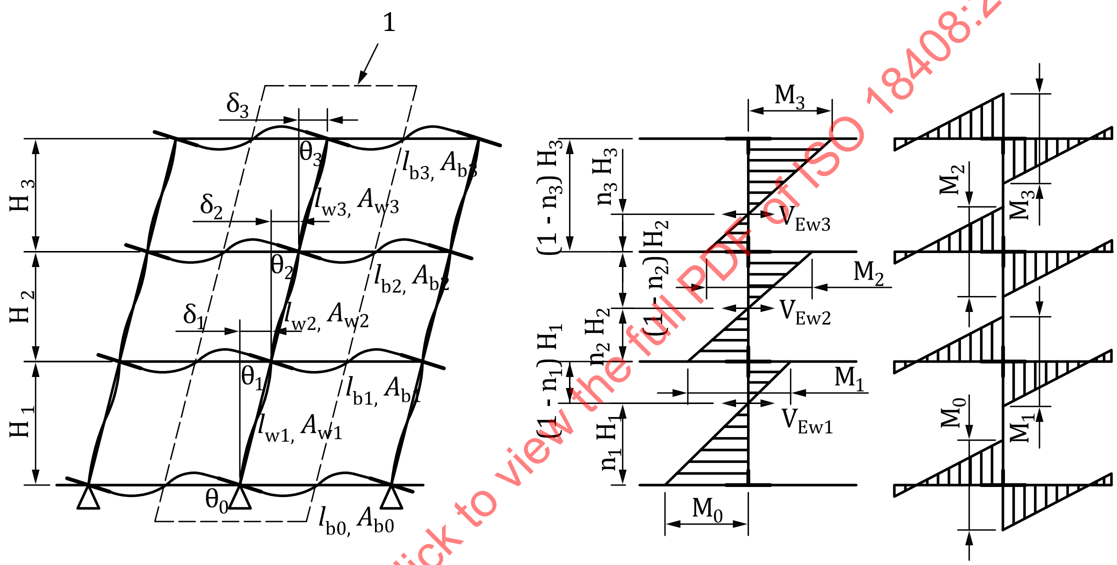
r_i, s_i the ratio of the length of the left and right rigid region of the wall girder at the i storey to the structural span length, and shall be zero or more;

$$r_i = \frac{D_{wi,A}/2 - D_{bi}/4}{L} \quad (29)$$

$$s_i = \frac{D_{wi,B}/2 - D_{bi}/4}{L} \quad (30)$$

ω_i is the ratio of M_{Bi} to M_{Ai} in Figure 8;

$$\omega_i = \frac{1 - r_i + s_i}{1 + r_i - s_i} \quad (31)$$



Key

1 partial frame

Figure 6 — Moment distribution and deformation of a partial frame

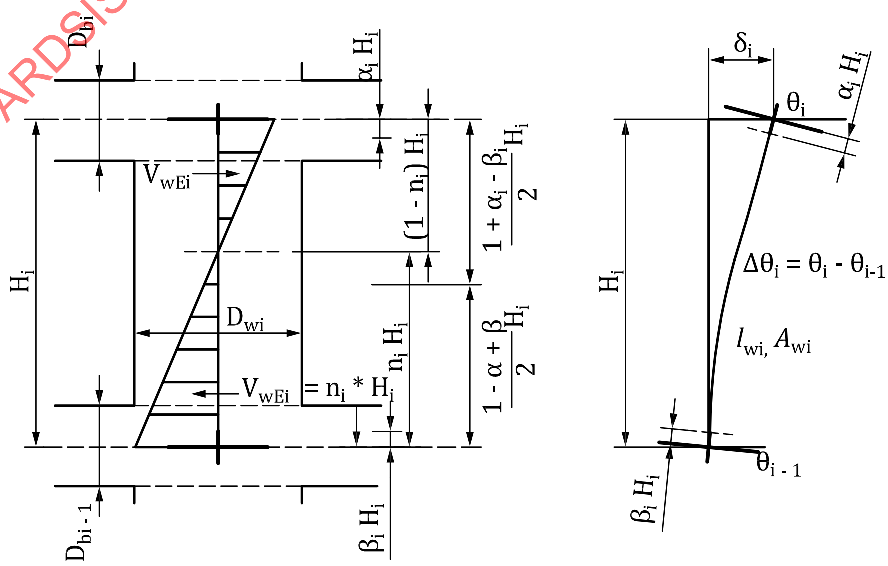
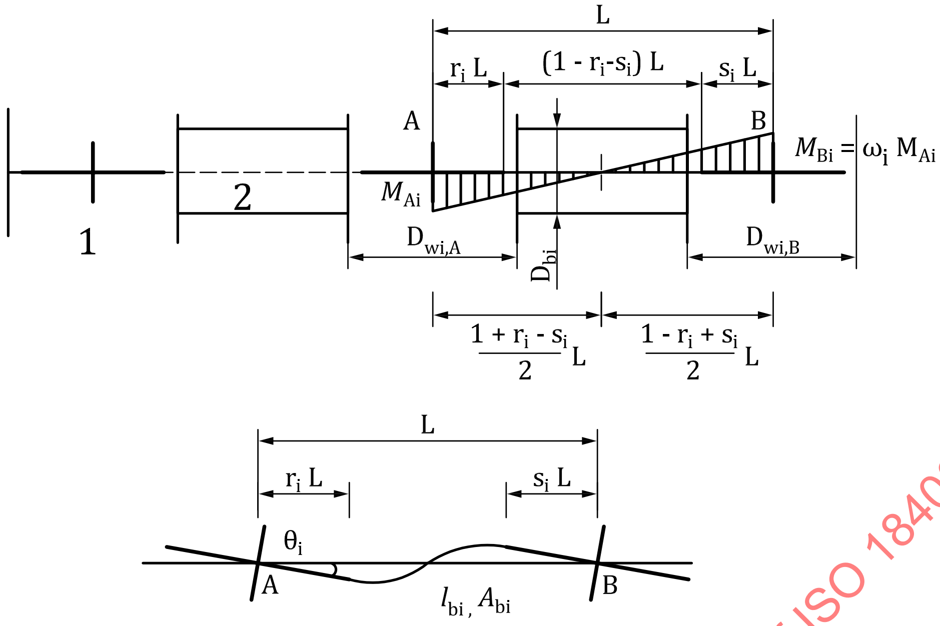


Figure 7 — Moment distribution and deformation of a structural wall



Key

1 structural wall

2 wall girder

Figure 8 — Moment distribution and deformation of a wall girder

3) Moment in wall girder, M_{bE}, determined by dividing the moment at the node, M_i (see Figure 9) of the structural wall depending on the ratio of the rotational stiffness of the right and the left wall girder.

4) Shear in wall girder, V_{bE}, determined by the above moment distribution.

5) Axial force in structural wall, P_{wE}, determined by the above shear of the wall girders.

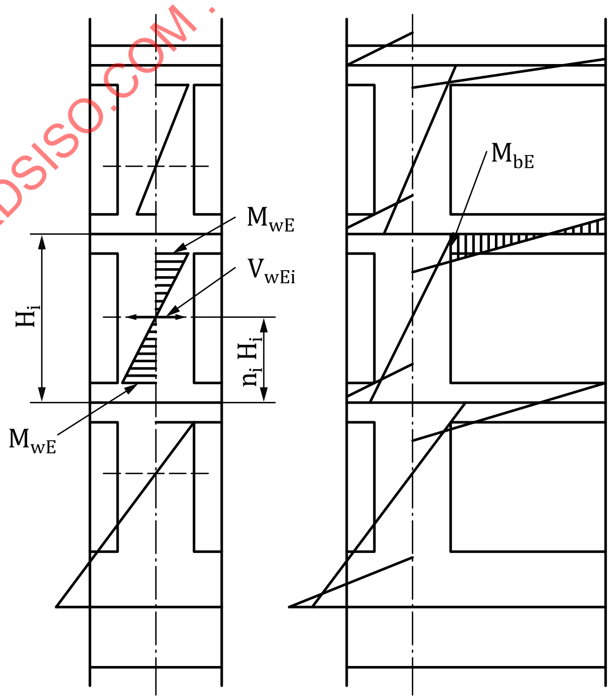


Figure 9 — Shear force V_{wEi}, moment M_{wE} in structural wall and moment M_{bE} in wall girder

10.2 Method of analysis for storey drift angle

10.2.1 General

Storey drift angle induced by earthquake load shall be calculated by the elastic two- or three-dimensional frame analysis.

10.2.2 Simplified method

Formulae (32) to (40) shall be used to check for the limitation of the storey drift angle for an approximate storey drift angle, R_i, at the ith (i = 1, n) storey.

$$R_i = \frac{\Delta_i}{H_i} \tag{32}$$

where

R_i is the storey drift angle at the ith storey of the building in the x- or y-direction;

Δ_i is the storey drift at the ith storey of the building in the x- or y-direction;

$$\Delta_i = \frac{V_i}{\Sigma k_i} \tag{33}$$

Where

Σk_i is the lateral stiffness of the i storey of the building in the x- or y-direction, and is the total of k_i of all partial frames in the x- or y-direction;

k_i is the lateral stiffness of the i storey of the partial frame;

$$k_i = \frac{V_{wEi}}{\delta_i} \tag{34}$$

where δ_i is the lateral drift of the i storey of the partial frame (see Figure 6 and 7);

$$\delta_i = \delta_{fi} + \delta_{si} + \theta_{i-1} H_i + \Delta\theta_i \alpha_i H_i \tag{35}$$

Where

δ_{fi} is the flexural deformation of the structural wall at the i storey of the partial frame;

$$\frac{1{,}4D + 1{,}7L}{A_g} \le [0{,}3] f'_c \tag{36}$$

δ_{si} is the shear deformation of the structural wall at the i storey of the partial frame;

$$\delta_{si} = \frac{\kappa V_{wEi} H_i \left(1 - \alpha_i - \beta_i\right)}{G_i A_{wi}} \tag{37}$$

θ_i is the rotation angle of the upper node of the structural wall at the i storey of the partial frame;

$$\theta_i = \theta_{i-1} + \Delta\theta_i \tag{38}$$

where θ_0 is the rotation angle at the base of the partial frame;

$$\theta_0 = \frac{V_{wE1} H_1 \eta_1}{B_0} \tag{39}$$

$\Delta\theta_i$ is the rotational deformation of the structural wall at the *i* storey of the partial frame;

$$\Delta\theta_i = \frac{V_{wEi} H_i}{Ai}\left(\eta_i - \eta_i^*\right) \tag{40}$$

11 Structural concrete walls

11.1 General

The design of structural concrete walls shall be performed using the provisions of Clause 11. Both in-plane and out-of-plane effects on reinforced concrete structural walls are covered.

11.2 Design load definition

The design load for structural concrete walls shall be established from the provisions of Clause 10. The loads that shall be included in the design are:

a) tributary live and dead loads from the tributary structural elements from each floor located above. Tributary loads shall be established from the provisions of Clause 9 and the particular guides of each tributary element type;

b) self weight of the structural concrete wall;

c) lateral forces from wind, earthquake or soil lateral pressures.

11.3 Dimensional guides

11.3.1 General

In addition to the appropriate guides of this subclause, structural concrete walls shall comply with the general dimensional guides presented in 7.5 and 7.6. Structural concrete wall section shape shall be rectangular, T-, L-, or cross-shaped. Structural concrete walls shall be aligned vertically and continuous over the total height of the structure.

11.3.2 Limiting dimensions

11.3.2.1 Minimum thickness of structural concrete walls

For the purposes of this document, the thickness of structural concrete walls shall not be less than 150 mm (see Figure 10) nor 1/25 of the length of the wall, l_w, and at changes of thickness in contiguous storeys.

Aspect ratio of l_w/h_0 shall be greater than 0,3 (see Figure 11).

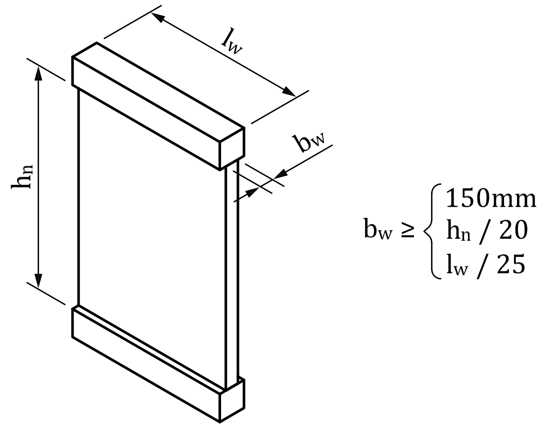
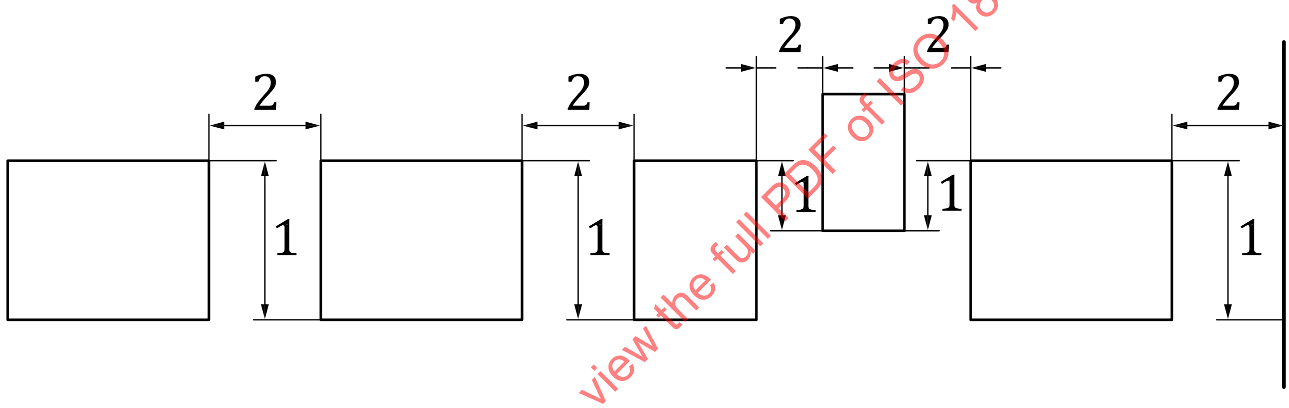


Figure 10 — Minimum cross-section dimensions for rectangular structural concrete walls



Key

1 height of opening along wall edge, h_0

2 length of the wall, *l*w

Figure 11 — Geometrical definition of bearing wall, $l_w \geq 0{,}3\ h_0$

The wall length is defined in the loading direction.

11.3.2.2 Distance between lateral supports

It shall be considered that lateral restraint is provided by the floor system in the two horizontal directions at all levels that are supported by the wall (see Figure 10). The clear distance between vertical lateral supports, h_n, for structural concrete walls shall not exceed 20 times the thickness of the structural concrete wall.

11.3.2.3 Beams on top of walls

The structural wall shall be connected with beams or girders. These beams or girders shall comply with the provisions of Clause 12 and be reinforced as collector elements following the provisions of Clause 16.

11.4 Details of reinforcement

11.4.1 General

For the purposes of this document, the reinforcement of structural concrete walls shall be of the types described in this subclause and shall comply with the provisions of Clause 15.

Walls reinforced with low ductility reinforcement such as welded wire mesh are restricted to use in no- or low-seismic hazard zones.

11.4.2 Shear reinforcement

11.4.2.1 Description

Vertical reinforcement shall consist in one or two layers of bars or welded-wire fabric placed parallel with the faces of the walls. The amount of vertical reinforcement shall be that required to resist the simultaneous action of a combination of factored axial load and factored moments at the section acting about the two main axis of the section of the structural concrete wall.

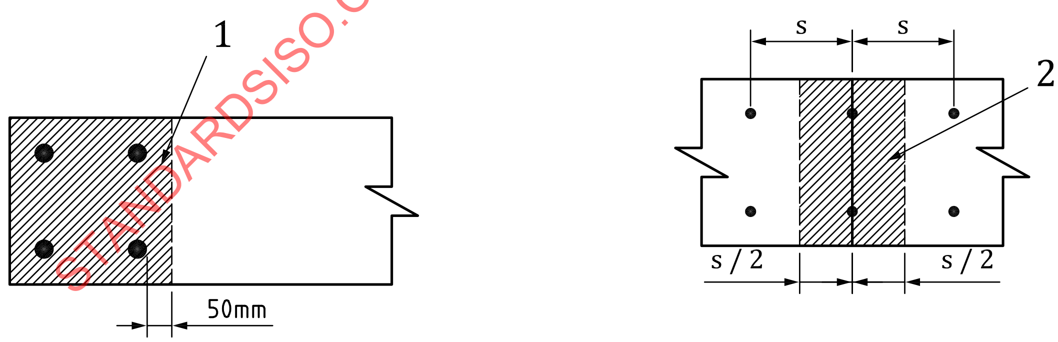
11.4.2.2 Minimum and maximum shear reinforcement area

a) In the bearing wall, shear reinforcement shall be placed in the horizontal and vertical directions and the ratio of the reinforcement to unit vertical or horizontal cross-sectional area of concrete (called the shear reinforcement ratio hereafter) shall be equal to or higher than the values given in Table 4, respectively.

Table 4 — Shear reinforcement ratio of bearing walls

Storey		Shear reinforcement ratio (%)
Aboveground storeys	Single-storey building and the top storey of 2-storey building	0,15
	First storey of 2-storey building and the top storey and the storey adjacent to the top storey of 3-, 4- or 5-storey building	0,20
	Other storeys	0,25
Basement		0,25

b) Horizontal and vertical reinforcement shall be D10 or more, and the spacings of horizontal and vertical reinforcement shall be 30 cm or less, respectively, over the projected area of a bearing wall. If a double re-bar arrangement is used, the spacings of horizontal and vertical reinforcement on either side shall not exceed 45 cm, respectively.



a) Vertical reinforcement ratio at edge portion; total area of vertical reinforcements in the are of "1"/area of "1"

b) Vertical reinforcement ratio at center portion; total area of vertical reinforcements in the area of "2"/area of "2"

Key

1 vertical reinformcent area

2 central reinforcement area

Figure 12 — Computation of the vertical reinforcement ratio

11.4.2.3 Reinforcement splicing

Lap splices of vertical wall reinforcement shall comply with the lap splice length of 15.7.2. It shall be permitted to lap-splice all the vertical reinforcement at any given section, except at the supported element of the floor system.

11.4.2.4 End anchorage of reinforcement

Vertical reinforcement at the upper end of the structural concrete walls, and at the foundation elements that transmit the loads to the underlying soil shall extend to the extreme edge and terminate with a standard hook.

11.4.3 Flexural reinforcement

In the structurally important portions of a bearing wall such as the wall ends, intersections, and the vertical edges of an opening, bending reinforcement shall be placed in the re-bar arrangements shown in Table 5 or in a re-bar arrangement having a steel quantity equal to or larger than them. However, reinforcement 1-D13 shall be used for bearing walls on the top storey whose thickness is less than 18 cm and which has an orthogonal bearing wall. On the top storey, the height of an opening edge shall be 2,8 m or less.

Table 5 — Bending reinforcement at the edge, etc. of bearing walls

Storey	Bending reinforcement at edge, etc. of bearing wall	
	$h_0 \leq 1$ m	$h_0 > 1$ m
Single-storey building	1 mm – 13 mm	1 mm – 13 mm
Both storeys of two-storey building and the top storey of 3-, 4- or 5-storey building	1 mm – 13 mm	2 mm – 13 mm
Second storey counted from the top storey of 3-, 4- or 5-storey building	2 mm – 13 mm	2 mm – 13 mm
Basement of single-storey or two-storey building First storey and basement of 3-storey building Second and first storeys and basement of 4-storey building Third and second storeys of 5-storey building	2 mm – 13 mm	2 mm – 16 mm
First storey and basement of 5-storey building	2 mm – 16 mm	2 mm – 19 mm
NOTE This table is calculated with concrete strength of 18 MPa.		

1) The reinforcement used for the horizontal edges of an opening shall be designed according to Clause 6 as well as shall be D13 or more.

2) For bearing walls of 180 mm thick or more, reinforcement shall be placed in a double re-bar arrangement.

3) At the intersection of a bearing wall with the floor, reinforcement D13 or more shall be placed. At the corners of an opening, diagonal reinforcement having a cross-sectional area greater than or equal to or half of the reinforcement shown in Table 5 and having a diameter no less than D10 shall be placed. Regarding the reinforcement at the corners of an opening, it is permitted to place greater than or equal to the equivalent amount of reinforcement in vertical and horizontal direction that is 0,35 times or more of the amount shown in Table 5 in stead of placing diagonal reinforcement.

4) The intersection of a bearing wall with a wall girder or beam perpendicular to it shall detail to ensures safe transfer of the load from above to the wall or other parts.

5) If the wall portion above or under the opening is not of a structure equivalent to or stronger than the bearing wall, the height of such a portion shall be added to height of the opening edge along the bending reinforcement.

12 Wall girders

12.1 General

The design of girders, beams and joists shall be performed employing the requirements of this clause. The guides apply to wall girders supported on concrete structural walls.

12.2 Design strength

12.2.1 Flexural strength

The flexural strength, M_A, shall be greater than or equal to the design bending moment, ${}_DM_A$, as shown in Formula (41). Flexural strength is calculated with Formula (42).

$${}_DM_A \leq M_A \tag{41}$$

$$M_A = v \cdot a_t \cdot f_t \cdot j \tag{42}$$

where

${}_DM_A$ is equal to M_L for gravity load, or to $M_L + M_E$ for seismic load;

M_L is the moment due to gravity load and calculated in Clause 10;

M_E is the moment due to seismic load and calculated in Clause 10;

v is the strength reduction factor, 1/[1,5] for gravity load and 1,0 for seismic load;

a_t is the total area of of longitudinal tension reinforcement (mm^2);

f_t is the design strength of main bar (N/mm^2);

j is the distance between centres of tension and compression

12.2.2 Shear strength

The shear strength, Q_A, shall be greater than or equal to the design shear force, ${}_DQ_A$, as shown in Formula (43). Shear strength is calculated with Formula (44).

$${}_DQ_A \leq Q_A \tag{43}$$

$$Q_A = v \cdot b \cdot j \cdot \{\alpha \cdot f_s + 0{,}5 \cdot {}_wf_t\,(p_w - 0{,}002)\} \tag{44}$$

where

${}_DQ_A$ $= Q_L$ for gravity load;

$= \min\left(Q_L + n \cdot Q_E, Q_L + \sum M_y / \lambda'\right)$ for seismic load;

Q_L is the design shear force due to gravity load ρ_t and calculated in Clause 10 as V_{bL};

Q_E is the design shear force due to seismic load and calculated in Clause 10 as V_{bE};

n is the design shear margin ($1{,}5 \leq n$);

$\sum M_y / \lambda'$	is the shear force due to yielding at both ends of the girder;
v	is the strength reduction factor, 1/1,5 for gravity load and 1,0 for seismic load;
b	is the width of the section of the member;
α	is the amplification factor according to the shear span;

$$\alpha = \frac{4}{M / Qd + 1} \text{ and } 1 \leq \alpha \leq 2$$

M	is the maximum bending moment in the wall girder;
Q	is the maximum shear force in the wall girder;
d	is the effective depth of the wall girder;
f_s	is the shear strength of the concrete;
$_w f_t$	is the specified yield strength of transverse or spiral reinforcement;
p_w	is the hoop ratio ($0{,}002 \leq p_w \leq 0{,}012$).

12.3 Details of reinforcement

12.3.1 General

For the purposes of this document, the reinforcement of wall girders shall be of the types described and shall comply with 12.3.2 and 12.3.3.

12.3.2 Vertical reinforcement

12.3.2.1 Description

Vertical reinforcement for wall girders shall consist of stirrups that surround the longitudinal reinforcement and are placed perpendicular to the longitudinal axis of the element at varying intervals along the axis. The stirrup shall consist of single or multiple vertical legs. Each vertical leg shall engage a longitudinal bar either by bending around it when the stirrup continues, or by the use of a standard stirrup hook (see 15.5) surrounding the longitudinal bar at the end of the stirrup. See Figure 11. For the purposes of this document all stirrups in wall girders shall be closed stirrups with 135° hooks, as shown in Figure 13. Only stirrup shapes of Figure 13 a) and g) shall be used in medium and high seismic zones.

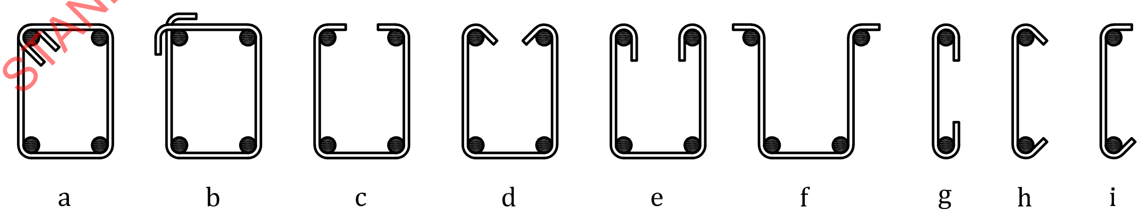


Figure 13 — Typical stirrup shapes

12.3.2.2 Minimum vertical reinforcement area

The minimum diameter of the vertical reinforcement is 9 mm. The amount of the vertical reinforcement shall be greater than the amount of vertical reinforcement in the connected shear wall.

12.3.2.3 Maximum spacing of vertical reinforcement

Vertical reinforcement shall not be spaced further apart than a quarter of the height of the wall girder.

12.3.3 Longitudinal reinforcement

12.3.3.1 Description

Longitudinal reinforcement shall be placed at the top and bottom of the wall girder so that the wall girder can carry bending moments due to vertical and lateral loads. The ends of the lateral reinforcement shall be anchored properly to the connected structural elements such as shear wall and perpendicular girders.

12.3.3.2 Minimum reinforcement area

The minimum bar arrangement is 1-D13 (2-D13 if the width of the wall girder is greater than 200 mm).

12.3.3.3 Maximum flexural reinforcement ratios

12.3.3.4 Minimum number of reinforcement bar in a layer

If the thickness of the wall is greater than or equal to 200 mm, at least two bars shall be arranged in a layer.

12.3.3.5 Use of compression reinforcement in girders, beams, and joists

12.3.3.5.1 Tension reinforcement less than maximum

If the ratio of tension reinforcement, ρ, is less than ρ_{max} as given in 12.3.3.4, the effect of reinforcement in the compression face of the element shall be permitted to be disregarded.

12.3.3.5.2 Shallow doubly reinforced sections

If the ratio of $\frac{d'}{d}$ is greater than the values given in Table 6 the compression reinforcement shall be considered not to be effective. It is permitted to interpolate for different values of f_y.

Table 6 — Maximum values of $\frac{d'}{d}$ for compression reinforcement to be effective

f_y (MPa)	240	300	400
$\frac{d'}{d}$	0,320	0,250	0,150

12.3.3.6 End anchorage of reinforcement

The positive flexural reinforcement at the end of the wall girder shall extend to the edge and end with a standard hook.

12.3.3.7 Width of wall girders

The thickness of wall girder shall be greater than or equal to the thickness of the shear wall that supports the girder.

12.3.3.7.1 Depth of wall girders

The depth of wall girders shall be greater than or equal to 450 mm in principle. Only the depth of the wall girder above an entrance door shall be greater than or equal to 350 mm.

13 Wall — Wall girder joints

13.1 General

When the joints between wall and wall girder or foundation girder (referred to as joints) have opening, the ultimate shear strength of joint shall be provided shown as 13.2 to avoid brittle failure of the joint.

13.2 Design strength

1) Joints capacity shall conform to Formula (45). Otherwise, the wall at the lower level connecting to this joint will experience a brittle failure.

$$Q_{psu} \geq \beta_p \cdot {}_D Q_{up} \tag{45}$$

Ultimate shear strength of joints Q_{psu} shall be computed with Formulae (46) to (50).

$$Q_{psu} = k \cdot \Phi \cdot F_j \cdot b_j \cdot D_j \tag{46}$$

where

$Q_{p,su}$ is the ultimate shear strength of joints (N);

κ is the shape factor of joints shall not be taken as greater than the values specified below:

κ = 1,0 : interior joints confined on all four faces;

κ = 0,7 : exterior joints confined on three faces;

κ = 0,4 : knee joints confined on two faces;

ϕ is the correction factor for the effect of transverse wall girders:

ϕ = 1,00 joints with transverse beams on the both sides;

ϕ = 0,85 other joints;

F_j is the standard value (N/mm^2) of the joint shear strength shall not be taken as greater than $0{,}8 \times \sigma_B{}^{0{,}7}$

σ_B is the concrete compressive strength(N/mm^2);

b_j is the effective width of joints (mm) as per Formula (47):

$$b_j = b_b + b_{a1} + b_{a2} \tag{47}$$

b_b is the wall girder width;

b_{a1}, b_{a2} are the smaller of one-quarter of wall length (L_w/4) and one-half of the distance between girder and wall face on either side of girder (b_i/2);

D_j is the joint length for an interior connection, or development length of anchored girder bars with 90-degree hook for exterior and knee joints, shall reduce the diameter of opening from D_j (mm);

β_p is the amplification factor to avoid shear failure of joints shall be taken as greater than 1,1;

${}_DQ_{up}$ is the maximum shear force acting in the joints at ultimate limit state. It shall be taken as greater than the values specified Formula (48):

$$ {}_D Q_{up} = T_{bu1} + C_{bu2} - Q_{wm} \tag{48}$$

T_{bu1} is the tensile stress of upper longitudinal reinforcements in wall girder or foundation beam connecting to the right (or left) side of the joint at ultimate limit state, as per Formula (49):

$$T_{bu1} = \sum a_{t1} \cdot \sigma_y \tag{49}$$

a_{t1} is the cross-section area of upper longitudinal reinforcements in wall girder or foundation beam connecting to the right (or left) side of the joint and includes slab reinforcements in effective width of wall girder or foundation beam when tensile stress acts in the slab;

σ_y is the yield strength of above reinforcements (N/mm^2);

C_{bu2} is the compressive stress of bottom longitudinal reinforcements in wall girder or foundation beam connecting to the right (or left) side of the joint at ultimate limit, as per Formula (50):

$$C_{bu2} = \sum a_{t2} \cdot \sigma_y \tag{50}$$

a_{t2} is the cross-section area of bottom longitudinal reinforcements in wall girder or foundation beam connecting to the right (or left) side of the joint and includes slab reinforcements in effective width of wall girder or foundation beam when tensile stress acts in the slab;

σ_y is the yield strength of above reinforcements (N/mm^2);

Q_{wm} is the maximum shear force of upper storey connecting to the joints at ultimate limit state, shall be obtained using 2,5 Q_E in 10,2 (N).

13.3 Development length for reinforcing bars

The diameter of longitudinal reinforcements in wall girder passing through the joints and assuming that the end of wall girder develops a flexural hinge shall conform to Formula (51).

$$\frac{D_w}{d_b} > \frac{f_s}{3{,}6(1{,}5 + 0{,}1 f'_c)} \tag{51}$$

where

D_w is the depth of wall girder with longitudinal bar passing through joints (mm);

d_b is the nominal diameter of reinforcing bar or wire (mm);

f'_c is the specified compressive strength of concrete for design (N/mm^2);

f_s is the shear strength of concrete (N/mm^2).

13.4 Details of reinforcement

When the joints have small openings, two reinforcements with larger than 13 mm in diameter for two layers or one reinforcement with larger than 13 mm in diameter for one layer shall be arranged vertically and horizontally around the openings. The vertical reinforcements in bearing wall shall pass through the joints.

14 Floor slab

14.1 General

The design of solid slabs supported by wall girders or structural concrete walls in their edges shall be performed employing the provisions of Clause 14 or ISO 15673.

14.2 Design load definition

14.2.1 Loads to be included

The design load for two-way solid slabs and slab cantilevers supported by girders or structural concrete walls shall be established from the requirements of Clause 9. The gravity loads that shall be included in the design are:

a) dead loads: self-weight of the structural element, flat non-structural elements, standing non-structural elements, and fixed equipment loads, if any;

b) live loads;

c) if the slab is part of the roof system, the appropriate values of roof live load, rain load and snow load, shall be employed.

14.2.2 Dead load and live load

The values of q_d for dead load and q_l for live load shall be in N/m^2. q_d shall include the self-weight of the solid slab, at 24 N/m^2 per mm of thickness, and the weight of the flat and standing non-structural elements also in N/m^2. If the slab is part of the roof system, the specified snow loads in Clause 9 shall be included, if appropriate.

14.2.3 Factored design load

The value of the factored design load, q_u in N/m^2, shall be the greatest value among the values obtained combining q_d and q_l using Formulae (4) and (5). If the slab is part of a roof system, it should be the greatest value among the values obtaind using Formulae (4) to (7).

14.3 Two-way solid slabs supported on wall girders or structural concrete walls

14.3.1 Dimensional guides

Two-way solid slabs having wall girders or structural concrete walls in all edges shall comply with the minimum thickness, t, specified in Formula (52) nor less than [80] mm. The size of tensile reinforcement used in a slab shall be not less than 9 mm for a plain bar, nor less than 10 mm for a deformed bar. The spacing of bars shall be as specified in Table 7 in a region subjected to maximum positive or negative bending moment.

$$t = 0{,}02\left(\frac{\lambda - 0{,}7}{\lambda - 0{,}6}\right)\left(1 + \frac{w_p}{10} + \frac{\lambda_x}{10\,000}\right) \tag{52}$$

where

λ_x is the effective span length in the short span direction (mm);

λ_y is the effective span length in the long span direction (mm);

NOTE "Effective span length" is a clear span length between wall girders or structural concrete walls.

λ Is the ratio of λ_y to λ_x;

w_p is the sum of live load and weight of finishing (kN/m^2).

Table 7 — Spacing of slab reinforcement

Short direction	not more than 200 mm
Long direction	not more than 300 mm and not more than three times of slab thickness

14.3.2 Design strength

14.3.2.1 Flexural strength

Flexural strength, M_s, shall be greater than or equal to the design bending moment, ${}_DM_s$ as given in Formula (53). Flexural strength is calculated with Formula (54).

$$ {}_D M_s \leq M_s \tag{53}$$

$$ M_s = \phi \cdot a_t \cdot f_t \cdot j \tag{54}$$

where

${}_DM_s$ is the bending moment due to gravity load;

ϕ is the strength reduction factor, (1/1,5);

a_t is the area of longitudinal tension reinforcement (mm^2);

f_t is the design strength of main bar (N/mm^2);

j is the distance between centres of tension and compression.

14.3.2.2 Shear strength

The shear strength, Q_s, shall be greater than or equal to the design shear force, ${}_DQ_s$ as given in Formula (55). Shear strength is calculated with Formula (56).

$$ {}_D Q_s \leq Q_s \quad {}_D Q_A \leq Q_A \tag{55}$$

$$ Q_s = \phi \cdot b \cdot t_s \cdot f_s \tag{56}$$

where

$_DQ_s$, $_DQ_A$ are the shear force due to gravity load for long-sustained loading and short-sustained loading, respectively;

ϕ is the strength reduction factor, 1/1,5;

B is the width of slab;

f_s is the shear strength of the concrete;

t_s is the thickness of the slab.

14.3.3 Design bending moment

For a two-way slab fixed along the four edges and subjected to uniform load, the bending moment shall be calculated by Formulae (57) to (60) (see Figure 14). The design positive and negative bending moment, $_DM_s$, for two-way solid slabs shall be calculated using Formulae (57) and (60).

The maximum negative moment, M_{x1}, along edges and the maximum positive moment, M_{x2}, at centre in the short span direction, x-direction (per unit width):

$$M_{x1} = -w_x \cdot l_x^2 / 12 \tag{57}$$

$$M_{x2} = -w_x \cdot l_x^2 / 18 \tag{58}$$

The maximum negative moment, M_{y1}, at edges and maximum positive moment at centre, M_{y2}, in the long span direction, y-direction (per unit width):

$$M_{y1} = -w \cdot l_x^2 / 24 \tag{59}$$

$$M_{y2} = w \cdot l_x^2 / 36 \tag{60}$$

where

$w_x = w \cdot l_y^4 / \left(l_x^4 + l_y^4 \right)$

w is the total uniform load per unit area;

l_x is the effective span length in the short span direction;

l_y is the effective span length in the long span direction.

The effective span length is measured from a net span between the inner edges of the supports. The bending moment in the slab strip with the width of $l_x/4$ along an edge shall be reduced to one-half of M_{x1} and M_{x2} that are computed in each direction by Formulae (57) and (60).

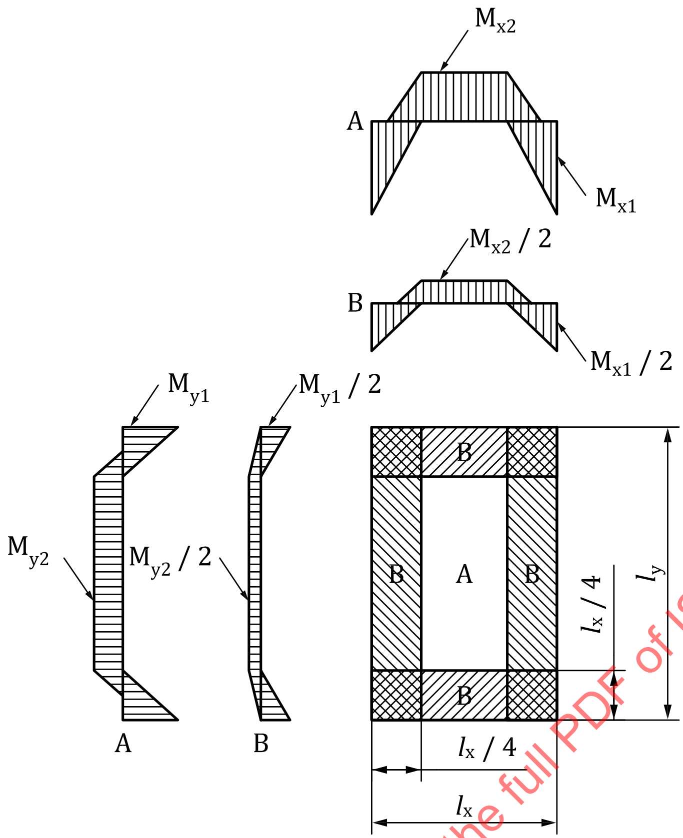


Figure 14 — Design bending moment of two-way slab fixed along four edges

14.4 End anchorage of reinforcement

Flexural reinforcement perpendicular to a discontinuous edge shall be anchored with a standard hook into the edge wall girder or structural concrete wall that provides support at the edge, complying with required development length guide in 15.7.

15 General reinforced concrete requirements

15.1 General

This clause contains the guides that are common to the reinforced concrete structural elements covered by this document. They include the guides for concrete cover of reinforcement and reinforcement details.

15.2 Cover concrete depth

15.2.1 Minimum concrete cover

The minimum concrete cover shall be provided for reinforcement according to Figures 15 to 18.