
Guidelines for the simplified design of reinforced concrete bridges

*Lignes directrices pour la conception simplifiée des ponts en béton
armé*





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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. 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. 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.

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

Introduction

The aim of this International Standard is to provide rules for the design and construction of relatively short span concrete bridges. This International Standard is developed for countries that do not have existing national standards on this subject and to offer to local regulatory authorities an alternative for the design of relatively small bridges that abound in urban overpasses and over creeks and rivers everywhere. This International Standard shall not be used in place of a national standard unless specifically considered and accepted by the national standards body or other appropriate regulatory organization. The design rules are based in simplified worldwide-accepted strength models. This International Standard is self-contained; therefore, loads, simplified analysis procedures and design specifications are included, as well as minimum acceptable construction practice guidelines.

The minimum dimensional guidelines contained in this International Standard 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 numerous regions of the world which lie in earthquake prone areas. The earthquake resistance for zones with high seismic hazard 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, in place of piers or frames that can be used in zones with intermediate, low or no significant earthquake hazard.

This International Standard 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 International Standard and provide foolproof procedures. Notwithstanding, the economic implications of the conservatism inherent in approximate procedures as a substitute for sound and experienced engineering should be a matter of concern to the designer that employs the document, and to the owner that hires him.

Guidelines for the simplified design of reinforced concrete bridges

1 Scope

This International Standard can be used as an alternative to the development of a National Concrete Bridge Design and Construction Code, or equivalent document in countries where no national design codes are available by themselves, or as an alternative to the National Concrete Bridge Design and Construction Code in countries where specifically considered and accepted by the national standards body or other appropriate regulatory organization, and applies to the planning, design and construction of structural concrete bridges to be used in new bridges of restricted span length, height of piers, and type.

The purpose of these guidelines is to provide sufficient information to perform the design of the structural concrete bridge that complies with the limitations established in 6.1. The rules of design as set forth in this International Standard are simplifications of more elaborate requirements.

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

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

Designs and details for new bridges should address structural integrity by considering the following:

- the use of continuity and redundancy to provide one or more alternate paths;
- structural members and bearing seat widths that are resistant to damage or instability;
- external protection systems to minimize the effects of reasonably conceived severe loads.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 3010, *Basis for design of structures — Seismic actions on structures*

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 6934-1, *Steel for the prestressing of concrete — Part 1: General requirements*

ISO 6934-3, *Steel for the prestressing of concrete — Part 3: Quenched and tempered wire*

ISO 6934-4, *Steel for the prestressing of concrete — Part 4: Strand*

ISO 6934-5, *Steel for the prestressing of concrete — Part 5: Hot-rolled steel bars with or without subsequent processing*

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 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 9597, *Cement — Test methods — Determination of setting time and soundness*

ISO 10144, *Certification scheme for steel bars and wires for the reinforcement of concrete structures*

ISO 3766:2003, *Construction drawings — Simplified representation of concrete reinforcement*

3 Terms and definitions

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

3.1

abutment

end support of a bridge superstructure

NOTE Abutments are used to transmit the reaction of superstructure to the foundations, to retain the earth filling and to connect the superstructure to the approach roads.

3.2

acceleration of gravity, g

acceleration produced by gravity at the surface of the earth

NOTE For the application of these guidelines its value can be approximated to $g \approx [10] \text{ m/s}^2$.

3.3

admixture

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

3.4**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 or mortar

3.5**anchorage**

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

3.6**backfill**

material used for refilling any hole that has been excavated

3.7**bar diameter, nominal**

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

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

3.8**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

3.9**bearing capacity of the soil**

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

NOTE Its value is defined at the working stress level.

3.10**bearing – elastomeric**

device constructed partially or wholly from elastomer to transmit loads and accommodate movements between a bridge and its supporting structure

3.11**bending moment**

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

3.12**boundary elements**

portions along wall edges strengthened by longitudinal and transverse reinforcement

NOTE Boundary elements do not necessarily require an increase in thickness of the wall.

3.13**bridge**

structure carrying a road, path or railway over an obstacle

3.14**caisson**

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

3.15**cantilever**

element that extends beyond its support and is supported on one end only

3.16

cement

material as specified in the corresponding referenced ISO standards, which, when mixed with water, has hardening properties

NOTE Used either in concrete or by itself.

3.17

clearance

distance by which one thing clears another; the space between them

3.18

column

vertical member used primarily to support axial compressive loads

3.19

collector elements

elements that serve to transmit the inertia forces within the diaphragm to members of the lateral-force resisting system

3.20

combined footing

footing that transmits to the supporting soil the load carried by several columns or structural concrete walls

3.21

compression reinforcement

reinforcement provided to resist compression stresses induced by flexural moments acting on the member section

3.22

concrete

mixture of portland cement and any other hydraulic cement, fine aggregate, coarse aggregate, and water, with or without admixtures

3.23

concrete mix design

choice and proportioning of the ingredients of concrete

3.24

concrete specified compressive strength, f'_c

compressive cylinder strength of concrete used in design and evaluated in accordance with the appropriate ISO standard, expressed in megapascals (MPa)

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

3.25

confinement hook

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

3.26

confinement stirrup or tie

closed stirrup, tie or continuously wound spiral

NOTE A closed stirrup or tie can be made up of several reinforcement elements each having confinement hooks at both ends. A continuously wound spiral should have a confinement hook at both ends.

3.27**corrosion**

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

3.28**cover, concrete**

thickness of concrete between surface of any reinforcing bar and the nearest face of the concrete member

3.29**crosstie**

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

NOTE The hooks should engage peripheral longitudinal bars. The 90° hooks of two successive crossties engaging the same longitudinal bars should be alternated end for end.

3.30**crown**

highest point of a convex structure, such as an arch or a vault

3.31**curb**

edge where a raised pavement/sidewalk/footpath, road median, or road shoulder meets an unraised street or other roadway

3.32**curing**

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

NOTE 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.

3.33**deformed reinforcement**

steel reinforcement that has deformations in its surface to increase its bond to the concrete.

NOTE The following steel reinforcement should be considered deformed reinforcement under these guidelines: deformed reinforcing bars, deformed wire, welded plain wire fabric, and welded deformed wire fabric conforming to the appropriate ISO standards.

3.34**depth of member, h**

vertical size of a cross section of a horizontal structural element

3.35**design load combinations**

combinations of factored loads and forces as specified in these guidelines

3.36**design strength**

product of the nominal strength multiplied by a strength reduction factor

3.37**development length**

length of embedded reinforcement required to develop the design strength of reinforcement at a critical section

3.38

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

3.39

differential settlement

when the foundation of different parts of a structure settle different amounts

3.40

drainage

natural or artificial removal of surface and sub-surface water from a given area

NOTE Drainage is a system that carries water or sewage away from a place.

3.41

durability

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

3.42

effective depth of section, d

distance measured from extreme compression fiber to centroid of tension reinforcement

3.43

embedment length

length of embedded reinforcement provided beyond a critical section

3.44

factored loads and forces

specified nominal loads and forces multiplied by the load factors prescribed in these guidelines

3.45

fire protection of reinforcement

amount of concrete cover necessary for protection of the reinforcement against the effects of the high temperatures produced by fire

NOTE The concrete cover is a function of the number of hours of exposure to the fire.

3.46

flange

top or bottom part of an I or T shaped section separated by the web

3.47

flexural

pertaining to the flexure bending moment

3.48

flexural reinforcement

reinforcement provided to resist the tensile stresses induced by flexural moments acting on the member section

3.49

footing

that portion of the foundation which transmits loads directly to the soil

NOTE May be the widening part of a column, a structural concrete wall or several columns, in a combined footing.

3.50**formwork**

temporary construction to contain concrete in a plastic state while it is cast and setting, 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 to the underlying soil, or to contain it

3.52**foundation beam**

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

3.53**foundation mat**

continuous slab laid over the ground as part of the foundation and that transmits to the underlying soil the loads from the structure

3.54**girder**

main horizontal support beam, usually supporting other beams

3.55**gravity loads**

loads that act downward and are caused by the acceleration of gravity, g , acting on the mass of the elements that cause the dead and live loads

3.56**hydrostatic pressure**

pressure at a specific elevation exerted by a body of water at rest or, in the case of groundwater, the pressure at a specific elevation due to the weight of water at higher levels in the same zone of saturation

NOTE Hydrostatic pressure increases linearly with depth.

3.57**hydrodynamic pressure**

pressure at a specific elevation exerted by a body of water at rest or, in the case of groundwater, during an earthquake and that results from the dynamic response of the water itself

3.58**hook**

bend at the end of a reinforcing bar

NOTE They are defined by the angle that the bend forms with the bar as either 90°, 180° or 135° hooks.

3.59**Interface Friction Angle**

angle of friction at the interface (or the skin friction) between cohesionless soil and another material

3.60**Internal Friction Angle**

angle measured between the normal force and resultant force that is attained when failure just occurs in response to a shearing stress

NOTE 1 It is a measure of the ability of a unit of rock or soil to withstand a shear stress.

NOTE 2 Its value is determined experimentally.

3.61

joist

T-shaped beam used in parallel series directly supporting deck loads, and supported in turn by larger girders, beams, or bearing structural concrete walls

3.62

lap splice

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

3.63

lateral-force resisting system

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

3.64

lightweight aggregate concrete

concrete made with coarse granular material that weighs less than the granular material used in normal weight concrete

NOTE This type of concrete is not covered by these guidelines.

3.65

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)

3.66

live loads

static and dynamic effects, in terms of forces applied on the structure, produced by the use of the bridge by pedestrians and/or vehicles and not including construction or environmental loads

3.67

load effects

forces and deformations produced in structural members by the applied loads

3.68

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

3.69

loads

forces or other actions that result from the weight of all bridge materials, pedestrians, vehicles, environmental effects, differential movement, and restrained dimensional changes

3.70

longitudinal reinforcement

reinforcement that is laid parallel to the longitudinal axis of the element, generally to account for flexural effects

3.71

mass

quantity of matter in a body

3.72

mesh wire

welded-wire fabric reinforcement

3.73**modulus of elasticity**

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

3.74**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 in the upper part of the element section

3.75**negative reinforcement**

in horizontal or nearly horizontal elements, the flexural reinforcement required for negative moment and that is placed in the upper part of the section of the element

3.76**nominal loads**

magnitudes of the loads specified in these guidelines (dead, live, soil, wind, snow, rain, flood, and earthquake)

3.77**nominal strength**

capacity of a structure or member to resist the effects of loads, as determined by computations using specified material strengths and dimensions and the formulas set forth by these guidelines

NOTE Specified material strengths 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.

3.78**pedestal**

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

3.79**permanent loads**

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

NOTE All other loads are variable loads (see also nominal loads).

3.80**pile**

slender timber, concrete or structural steel element embedded in the ground to support loads

3.81**plain reinforcement**

smooth surfaced steel reinforcement, or reinforcement that does not conform to the definition of deformed reinforcement

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 in the lower part of the element section

3.83**positive reinforcement**

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

3.84

railing

structure made of rails and upright members that is used as a guard or barrier or for support

3.85

reaction

resistance to a force or load, or upward resistance of a support such as a structural concrete wall or column against the downward pressure of a loaded member such as a beam

3.86

reinforcement

steel bars, wire, or mesh wire, used for reinforcing the concrete where tensile stresses are expected, due either to the applied loads, or to environmental effects such as variation of temperature

3.87

required factored strength

strength of a member or cross section required to resist factored loads or related internal moments and forces in such combinations as are stipulated by these guidelines

3.88

retaining wall

wall built to hold back earth

3.89

selfweight

weight of the structural element, caused by the material that composes the element

3.90

service load

load specified by these guidelines (without load factors)

3.91

settlement

downward movement of the supporting soil

3.92

shear

internal force acting tangential to the plane where it acts

NOTE Also called diagonal tension.

3.93

shear reinforcement

reinforcement designed to resist shear

3.94

shores

vertical or inclined support members designed to carry the weight of the formwork, concrete, and construction loads above

3.95

shrinkage and temperature reinforcement

reinforcement normal to flexural reinforcement provided for shrinkage and temperature stresses in structural solid slabs and footings where flexural reinforcement extends in one direction only

3.96

skew

difference or deviation from an expected or optimal value; in the case of bridges, deviation of the longitudinal axis of the deck with respect to a line perpendicular to the length of the abutments

3.97**slab**

upper flat part of a reinforced concrete deck carried by supporting joists or beams or girders

3.98**solid slab**

slab of uniform thickness that does not have voids to make it lighter or that has voids with size less than $[0,6]$ times the slab thickness

3.99**span length**

horizontal distance between supports of a horizontal structural element

NOTE Such as a slab, joist, beam, or girder.

3.100**specifications**

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

3.101**specified lateral earthquake forces**

lateral forces corresponding to the appropriate distribution of the design base shear force prescribed by these guidelines, for earthquake-resistant design

3.102**specified wind forces**

nominal pressure of wind to be used in design performed in accordance with these guidelines

3.103**spiral reinforcement**

continuously wound reinforcement in the form of a cylindrical helix

3.104**spread footing**

isolated footing that transmits to the supporting soil the load carried by a single column

3.105**stirrup**

reinforcement used to resist shear and torsion stresses in a structural member

NOTE Typically bars, wires, or welded wire fabric (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. (The term "stirrups" is usually applied to lateral reinforcement in girders, beams, and joists; the term "ties" to those in columns and walls, perhaps because they are intended also as confinement for the longitudinal reinforcement.) See also tie.

3.106**strength reduction factor**

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

NOTE 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 being considered, and to reflect the importance of the element in the structure.

3.107**stress**

intensity of force per unit area

3.108

structural concrete

all concrete used for structural purposes including plain, reinforced and prestressed concrete

3.109

structural concrete walls

walls proportioned to resist combinations of shear, moments, and axial forces

NOTE A "shearwall" is a "structural wall".

3.110

structural diaphragms

structural members, such as deck slabs, which transmit inertia induced by earthquake motions

3.111

support

structural element that provides support to another structural element

3.112

tie

loop of reinforcing bar or wire enclosing longitudinal reinforcement

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

3.113

tie elements

elements which serve to transmit inertia forces and prevent spacing of bridge components such as footings and walls

3.114

transverse reinforcement

reinforcement located perpendicular to the longitudinal axis of the element, comprising stirrups, ties, spiral reinforcement, among others

3.115

wall

member, usually vertical and whose length and height are much larger than its thickness

3.116

water table

groundwater level

point under surface of the ground where the ground is completely saturated with water

3.117

web

thin vertical portion of an I or T shaped section that connects the flanges

3.118

weight

vertical downward force exerted by a mass when subjected to the acceleration of gravity

NOTE The weight is equal to the value of the mass multiplied by the acceleration of gravity, g .

3.119

wire

reinforcing bar of small diameter

3.120**working stress**

allowable stress to be used with unfactored loads

3.121**yield strength, f_y**

specified minimum yield strength or yield point of reinforcement

NOTE 1 The yield strength is expressed in units of megapascals (MPa).

NOTE 2 Applicable International Standards specify that the yield strength or yield point be determined in tension.

4 Symbols and abbreviated terms

The following symbols and abbreviated terms are used in these guidelines.

Symbol	Explanation	Unit
a	depth of equivalent uniform compressive stress block	mm
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 center to center 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_{ss}	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
α	coefficient of thermal expansion for concrete	
α_A	inclination of the critical failure surface for minimum active earth pressure conditions	
α_P	inclination of the critical failure surface for maximum passive earth pressure conditions	
α_A	inclination of the critical failure surface for minimum total active earth pressure conditions	
α_P	inclination of the critical failure surface for maximum total passive earth pressure conditions	
a_h	amplitude of the harmonic base acceleration	
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

Symbol	Explanation	Unit
b_0	perimeter of critical section for punching shear in slabs	mm
d	effective depth, should be taken as the distance from extreme compression fiber to centroid of tension reinforcement	mm
d'	distance from extreme compression fiber to centroid of compression reinforcement	mm
d_b	nominal diameter of reinforcing bar or wire	mm
d_c	distance from extreme tension fiber 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	
δT	longitude change due to thermal expansion	
ΔT	temperature variation	
δ	interface friction angle	
ΔPAE	dynamic component of the total active thrust on retaining walls	
ΔPPE	dynamic component of the total passive thrust on retaining walls	
ΔPeq	dynamic thrust on non yielding walls	
ΔMeq	dynamic overturning moment on non yielding walls	
E	load effects of earthquake, or related internal moments and forces	
E_c	modulus of elasticity of concrete	MPa
ϕ	internal friction angle	
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
f_{cu}	extreme fiber 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_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_p	dynamic thrust factors for non yielding walls	
F_m	dynamic overturning moment factors for non yielding walls	
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

Symbol	Explanation	Unit
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 deck I, measured from deck finish of the story to deck 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	
H_P	height of the support which forces are being evaluated	
I_c	moment of inertia of the column section	m^4
I_P	about an axis on the bridge deck perpendicular to the bridge length, of the pier	m^4
K_A	active earth pressure coefficient	
K_P	passive earth pressure coefficient	
K_{AE}	total active earth pressure coefficient	
K_{PE}	total passive earth pressure coefficient	
k_v	vertical pseudostatic force on yielding walls	
k_h	horizontal pseudostatic force on yielding walls	
l	span of structural element or length of span measured center-to-center 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	
max.	maximum	
min.	minimum	
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
M_n	nominal flexural moment strength at section	N · mm
M_r	flexural moment strength at section	N · mm

Symbol	Explanation	Unit
M_{pr}	probable flexural moment strength of the element at the joint face computed using f_{yp} and $= 1$	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
ΣM_c	sum of lowest flexural strengths ($\phi \cdot M_n$) of columns framing into a joint	N · m
ΣM_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}	nominal compression axial load strength at section at balanced conditions	N
P_{cu}	factored compression load on wall boundary element, including earthquake effects	
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
ΣP_u	sum of all factored concentrated design loads within the span	N
P_A	active thrust on a retaining wall	
P_P	passive thrust on a retaining wall	
P_{AE}	total Active thrust on a retaining wall including seismic effects	
P_{PE}	total Passive thrust on a retaining wall including seismic effects	
P_W	hydrodynamic thrust on retaining walls	
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_w	pore pressure ratio	
R_a	rain load, or related internal moments and forces	
R_u	total factored concentrated reaction from a supported structural element	N
ΣR_u	sum of all factored reactions from supported structural elements at the same story	N
s	center-to-center 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	

Symbol	Explanation	Unit
Ss	5 % damped spectral response accelerations	
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
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 horizontal reinforcement to the nominal shear strength at section	N
V _u	factored shear force at section	N
VT	shear force caused by thermal expansion	N
V	soil Poisson's Ratio	
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	
ρ _{max}	maximum permissible ratio of longitudinal flexural tension reinforcement	
ρ _{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.	
f _{cd}	compressive strength of concrete reduced by the material factor	MPa
f _{yd}	yield strength of reinforcement reduced by the material factor	MPa
γ _{mc}	material factor for concrete	
γ _{ms}	material factor for steel	

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 guides of chapter 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 guides of chapter 8, excluding the self weight of the structural elements.

5.1.3 Step C

Definition of an appropriate superstructure system, depending on the span lengths and the magnitude of the gravity loads, according to the guides of chapter 10.

5.1.4 Step D

Trial dimensions for the slab of the superstructure system. Calculation of the self weight of the system, and design of the elements that comprise it, correcting the dimension as required by the ultimate and serviceability limit states, complying with the guides of 10.4 for slab systems with beams.

5.1.5 Step E

Trial dimensions for the beams and girders and calculation of their self weight. Flexural and shear design of the beams and girders, correcting the dimension as required by the ultimate and serviceability limit states, complying with the guides include in 10.5.

5.1.6 Step F

Trial dimensions for the Substructure system and calculation of its self weight. Elements 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 guides of 11.5.

5.1.7 Step G

If lateral loads such as earthquake, wind, or lateral earth pressure exist, their magnitude is established using the guides in Chapter 8; otherwise the designer should proceed to Step I.

5.1.8 Step H

The loads at the foundation level are determined, and a definition of the foundation system is performed employing the guides of chapter 12. The structural elements of the foundation are designed.

5.1.9 Step I

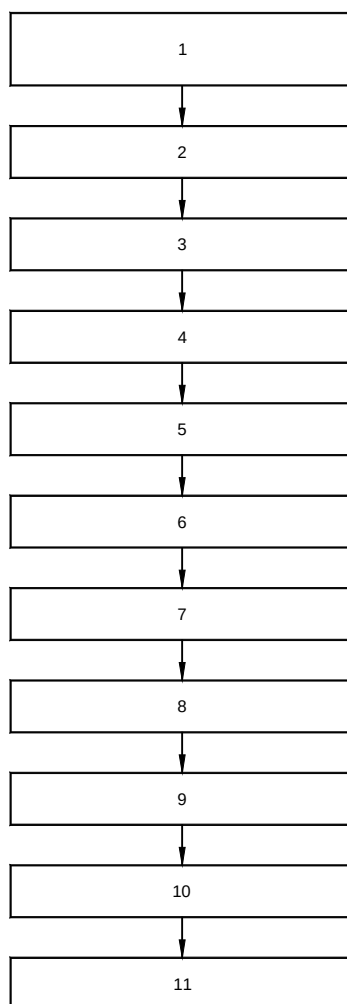
Preliminary location and trial dimensions for structural concrete walls capable of resisting the lateral loads established, using the guides of 13 for earthquake forces, the influence of their self weight is evaluated, and flexure and shear design of the structural concrete walls is performed, complying with the guides of 11.6.

5.1.10 Step J

Production of structural drawings.

5.1.11 Step K

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

**Key**

- | | | | |
|---|--|----|-----------------------------------|
| 1 | Step A: preliminary structure design | 7 | Step G: lateral forces definition |
| 2 | Step B: loads definition | 8 | Step H: foundations design |
| 3 | Step C: superstructure system definition | 9 | Step I: structural walls design |
| 4 | Step D: slab design | 10 | Step J: structural drawings |
| 5 | Step E: beams and girders design | 11 | Step K: structure construction |
| 6 | Step F: substructure design | | |

Figure 1 — Design and construction procedure

5.2 Design documentation

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

5.2.1 Calculation memoir

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

- a) The general structural requirements of the project, as required by 7.1.
- 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.

5.2.2 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 12.

5.2.3 Structural drawings

All the drawings required for construction of the bridge.

5.2.4 Specifications

The construction specifications required.

6 General Guides

6.1 Limitations

These guidelines should be employed only when the bridge being designed complies with all the limitations set forth in 6.1.1 to 6.1.12.

6.1.1 Permitted use

Bridges of mixed use should be permitted to be designed using these guidelines, but restricted to pedestrian and vehicular traffic. Bridges for trains are out of the scope of these guidelines.

6.1.2 Maximum number of spans

The maximum number of spans for a bridge designed using these guidelines should be as per Table 1.

Table 1 — Maximum allowed number of spans

	Number of spans
Bridge over water	[1]
Bridge for road overpass	[3]

6.1.3 Maximum span length

The maximum span length allowed is [30] m for each span.

6.1.4 Maximum difference in span length

Span should be approximately equal, with the larger of two adjacent spans not greater than the shorter by more than the percentage specified in Table 2.

Table 2 — Maximum difference in two consecutive span lengths

Total number of spans	Length difference. %
[1]	—
[2]	20
[3]	10

6.1.5 Maximum cantilever length

The maximum clear cantilever length for girders and beams should not exceed 3 m or 33 % of the length of the first adjacent interior span, whichever is smaller, in order to avoid cantilevers too long for the purposes of these guidelines, as greater lengths might require detailed structural analysis to verify serviceability conditions such as deformation, vibration and fatigue, among other criteria.

Continuous deck slab cantilevers over intermediate beam supports, may have lengths up to 80 % of the length of the adjacent span.

6.1.6 Maximum height of bridge

The height of the bridge supports, including abutments and piers, shall not exceed the values given in Table 3, according to seismic hazard level or wind intensity. At any rate, the difference between the various supports heights for the same bridge shall not exceed 20 %, as more detailed analysis would be required to assess the impact of such differences on stiffness and force distribution.

Table 3 — Maximum allowable support height

Seismic hazard level or wind intensity	Low	Intermediate	High
Maximum height, m	[15]	[12]	[10]

6.1.7 Maximum number of lanes

The maximum number of lanes for a vehicular bridge designed using these guidelines should be [2]. Up to [2] sidewalks may be considered in addition to the vehicle traffic lanes.

6.1.8 Width limitations

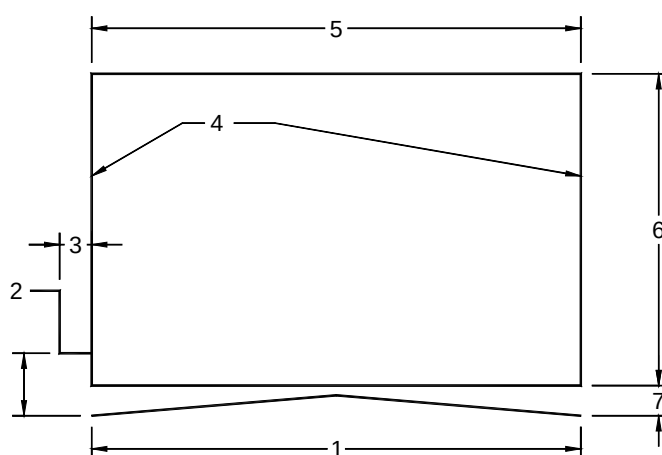
Pedestrian bridges should not have widths of less than [1.2] m.

Vehicular bridges should not have roadways with widths, excluding sidewalks, of less than [3] m or in excess of [8] m. Sidewalk should comply with a minimum width of [1] m, and neither should exceed half of the maximum lane width.

6.1.9 Clearances

The horizontal clearance shall be the clear width, and vertical clearance the clear height for the passage of vehicular traffic as shown in Figure 2.

The roadway width shall generally equal the width of the approach roadway section including shoulders. Where curbed roadway sections approach a structure, the same section shall be carried across the structure.



Key

- 1 roadway width
- 2 curb
- 3 brush or sidewalk if warranted (max. 2,75 m)
- 4 face of curb or barrier
- 5 horizontal clearance
- 6 vertical clearance
- 7 crown

Figure 2 — Clearance diagram for bridges

6.1.9.1 General Clearances

6.1.9.1.1 Vertical Clearance

Vertical clearance shall not be less than [5.50] m over the entire roadway width with an allowance of [0.3] m for resurfacing.

6.1.9.1.2 Horizontal clearance

Horizontal clearance shall be at least the dimension of the roadway width, including curbs where necessary.

6.1.9.2 Clearances for Underpasses

6.1.9.2.1 Width

The pier columns or walls for grade spacing structures shall generally be located a minimum of [9] m from the edges of the through traffic lanes. Where the practical limits of structure costs, type of structure, volume and design speed of through traffic, span arrangement, skew, and terrain make [9] m offset impractical, the pier may be placed closer than [9] m and protected by the use of guardrail or other barrier devices. The guardrail or other device shall be independently supported with the roadway face at least [0.70] m from the face of pier or abutment.

The face of the guardrail or other device shall be at least [0.70] m outside the normal shoulder line.

6.1.9.2.2 Vertical Clearance

A vertical clearance of not less than [5.50] m shall be provided between curbs, or if curbs are not used, over the entire width that is available for traffic.

6.1.9.3 Clearances for Depressed Roadways

6.1.9.3.1 Clearance between walls

The minimum width between walls for depressed roadways carrying two lanes of traffic shall be [9.00] m.

6.1.9.3.2 Curbs

Curbs, if used, shall match those of the approach roadway section.

6.1.10 Maximum skew angle

Bridges designed using these guidelines should have a low skew angle, not exceeding [15 °] for girder and slab bridges, and [30 °] for box girder bridges.

6.1.11 Maximum bridge horizontal curvature

Bridges designed using these guidelines should have a maximum length to horizontal curvature radius of [4 %].

6.1.12 Cross section variation

Bridges designed using these guidelines should have a constant cross section along the continuous portions of the bridge, except in cantilever sections.

6.1.13 Interaction between superstructure and substructure

No framing effect is permitted along the longitudinal axis of the bridge. No direct transmission of moments shall be allowed from the bridge deck to the columns, piers, abutments, or to any other element that carries the loads to the ground, due to gravity and to other loads longitudinal effects. The support at one of the abutments should be able to move freely in the deck longitudinal direction.

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 drift limit state,

Longitudinal drift limit state,

durability limit state,

fire limit state, and

fatigue limit state

Ultimate and serviceability limit states are to be verified through the different stages of design using the guidelines.

6.2.1 Deflection Serviceability Verification

6.2.1.1 Vehicular Bridges

The deflection of the floor structure must be less than $L/700$

6.2.1.2 Pedestrian bridges

A simplified design criterion for the resonance response is given by

$$\frac{a_p}{g} = \frac{P_0 \exp(-0.35 f_n)}{\beta W} \leq \frac{a_0}{g}$$

Where:

$\frac{a_p}{g}$: estimated peak acceleration (in units of g)

$\frac{a_0}{g}$: acceleration limit, which is equal to 5 % of gravity

f_n : natural frequency of floor structure

f_0 : constant force equal to 0.29 kN for floors and 0.41 kN for footbridges

W : effective weight of the floor

β : modal damping ratio The natural frequency of the floor structure must be greater than 3 Hz.

The natural period is given by

$$T = \frac{2\pi}{\omega} = 2\pi \sqrt{\frac{m}{k}}$$

The natural frequency is the inverse of the natural period,

$$f_n = \frac{1}{T} = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$

Taking into account that $k = F / \Delta$ and $m = F / g$, then:

$$f_n = \frac{1}{2\pi} \sqrt{\frac{Fg}{F\Delta}} \cong 0.16 \sqrt{\frac{9.81}{\Delta}}$$

Δ may be calculated as per annex B

Table 4 — Maximum allowable support height

1 Span	2 and 3 continuous spans
Δ	$(0.40-0.50)\Delta$

6.3 Ultimate limit state design format

6.3.1 General

The ultimate limit state corresponds to the condition when one or more parts of the structure reach a point where they are incapable of carrying any additional loads. Therefore, 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 are stipulated in these guidelines.

The basic requirement for ultimate limit state should be:

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

To allow for the possibility that the resistances may be less than computed, and the load effects may be larger than computed, material factors are to be used to reduce material strength and load factors, γ , generally greater than one, should be employed. Ultimate resistant force is obtained by reducing the specified yield strength for steel or reducing the specified compressive strength for concrete, or both, by means of dividing these values by the corresponding material factors:

$$R = f \left(\frac{f_{cd}}{\gamma_{mc}}, \frac{f_{yd}}{\gamma_{ms}} \right) \geq \gamma_1 S_1 + \gamma_2 S_2 + \gamma_3 S_3 + \dots \quad \text{Equation (2)}$$

R stands for strength and S stands for load effects based on the nominal loads prescribed by these guidelines. Therefore, the ultimate limit state design format requires that:

$$\text{Design Strength} \geq \text{Required Factored Strength} \quad \text{Equation (3)}$$

or

$$R = f \left(\frac{f_{cd}}{\gamma_{mc}}, \frac{f_{yd}}{\gamma_{ms}} \right) \geq U \quad \text{Equation (4)}$$

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

6.3.2 Required factored loads

The required factored load, U, should be computed by multiplying service loads, or forces, by load factors using the load factors and combinations in 8.9.1.

6.3.3 Design strength

The design strength provided by a member, its connections to other members, and its cross-sections, is then identified by the subindex r , and should be taken as the strength calculated in accordance with the requirements and assumptions for each particular force effect in each of the element types at the critical sections defined by these guidelines, based on the limit stress reduced according to each corresponding material as per Table 5:

Table 5 — Material factor

MATERIAL	
Concrete, γ_{mc}	[1.5]
Steel, γ_{ms}	[1.15]

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 thorough the observance of the limiting dimensions, cover, detailing, and construction requirements. For bridges, these serviceability conditions include effects such as:

permanent deformations, either of the structure or its foundations, that cause public concern or make the structure unfit for use; dynamic movements that cause discomfort or public concern;

dynamic movements that cause damage to non structural elements such as railings;

damage by scour;

flooding or scour of adjacent properties; and

damage due to corrosion or fatigue that is sufficient to cause significant reduction in the strength of the structure or in its service life.

7 Structural systems and layout

7.1 Description of the components of the structure

For the purposes of these guidelines, the bridge structure should be divided in the following components:

7.1.1 Superstructure system

The superstructure or deck system consists of the structural elements that comprise the portion of the bridge that receive directly the live load. In section 10, the different superstructure systems covered by these guidelines are described. The superstructure 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 piers, columns, or walls. The superstructure should also act as a diaphragm that carries through its plane the lateral loads from their point of application to the vertical elements of the lateral load resisting system.

7.1.2 Substructure system

The substructure system holds up the superstructure and carries the accumulated gravity loads all the way down to the foundation of the structure. The substructure acts also as the lateral load resisting system supporting and transmitting to the ground the lateral loads arising from earthquake motions, wind, and lateral earth pressure. The vertical elements of the lateral load resisting system collect the forces arising from the

superstructure and carry them down to the foundation, and through the foundation to the underlying soil. Under these guidelines the main vertical elements of the substructure system should be cantilever piers, or frames or structural concrete walls, and are described in section 11.

7.1.3 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. It includes elements such as spread footings, combined footings, foundation mats, retaining walls, grade beams, and deep foundations, such as piles and caissons, and their pile footings and caps among others. Foundation systems are described in section 12. Deep foundations are beyond the scope of these guidelines, and are not covered by it.

7.2 General program

7.2.1 Architectural program

It is advisable that an architect, an urban planner and a landscaper are involved in the project, but it is not mandatory. In any case, a general architectural program of the bridge should be coordinated between the owner and the structural designer before actual structural design begins, even if no architect is part of the project.

The general architectural program should be based on the following design aspects:

Location.

Alignment.

Roadway characteristics and details.

Bordering conditions.

Vistas and scenery.

Presence of open space and manufactured complexes.

Environmental and visual impact.

7.2.2 General structural guides for the project

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

Intended use for the bridge.

Nominal loads related to the use of the bridge.

Special loads required by the owner or competent authorities.

Design earthquake motions, if the bridge is located in a seismic zone.

Wind requirements for the site.

Requirements for rain, hail, ice and snow consideration.

Site information related to slopes and site drainage.

Allowable soil bearing capacity, and recommended foundation system derived from the geotechnical investigation, and additional restrictions related to expected soil settlements.

Environmental requirements derived from local seasonal and daily temperature variations, humidity, presence of deleterious chemicals and salts.

Availability, type, and quality of materials such as reinforcing steel, cement and aggregates.

Availability of materials for formwork erection.

Availability of testing facilities for concrete mix design and quality control during construction.

Availability of qualified workmanship.

7.3 Structural layout

7.3.1 General structural layout

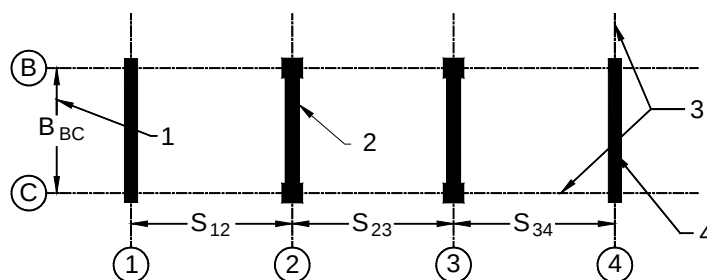
The structural designer should define a general structural layout in plan. See Figure 3. The general structural layout in plan should include:

Dimensioned grid for axes, or centerlines, in both principal directions in plan.

These axes should intersect at the location of the vertical supporting elements (columns, piers, structural concrete walls, and abutments).

Location in plan for all vertical supporting elements. These vertical supporting elements should be aligned vertically, and should be continuous all the way down to the foundation.

Horizontal distance between centerlines, S , which corresponds to the center-to-center span lengths, and horizontal distance B , which corresponds to the center-to-center breadth, of the superstructure system.



Key

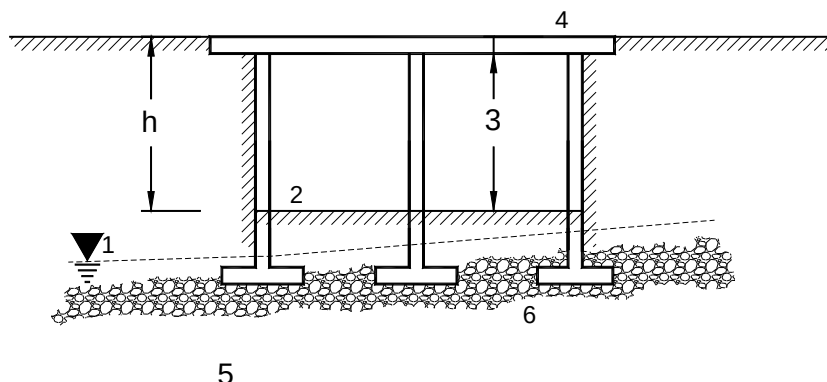
- 1 deck width
- 2 pier, frame or wall
- 3 centerlines grid
- 4 abutment

Figure 3 — General structural layout in plan

7.3.2 Vertical layout

The structural designer should define a general structural vertical layout. See Figure 4. This vertical layout should include all relevant information in height of the structure, including:

- Abutments, piers, frames or columns height, defined as the vertical distance from superstructure finish to the ground.
- Slope and shape of the terrain.
- Vertical clearance from roadway to superstructure lowermost surface, as specified by these guidelines or required by local highway specifications, whichever is larger.
- Supporting soil stratum depth, and water table depth.



Key

- 1 water table
- 2 roadway
- 3 clearance
- 4 overpass
- 5 Soil
- 6 bearing soil stratum

Figure 4 — Vertical layout of the bridge

7.4 Feasibility under the guidelines

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

The use of the bridge should be within the accepted uses of 6.1.1.

The number of spans should not exceed the maximum permissible, given in 6.1.2.

The span lengths should be within maximum lengths prescribed in 6.1.3.

The difference between adjacent spans should not exceed the limit of 6.1.4.

Cantilever lengths should be within maximum lengths prescribed in 6.1.5.

The height of the tallest support, measured from ground to superstructure finish, should not exceed the maximum permissible height given in 6.1.6, nor the difference between supports heights should exceed the limits given there.

The number of lanes should not exceed the maximum permissible, given in 6.1.7.

Pedestrian bridge decks and vehicular roadways should comply with width limitations given in 6.1.8.

Bridge clearances must be specified according to 6.1.9.

Bridge skew angle for girders and deck should not exceed the limit given in 6.1.10.

Bridge length to horizontal curvature ratio should not exceed limit given in 6.1.11.

Cross section variation along bridge length must comply with 6.1.12.

8 Actions (Loads)

8.1 General

This clause provides minimum load guides for the design of bridges under these guidelines. Loads and the appropriate load combinations should be used together.

Loads and forces explicitly considered in bridge design according to these guidelines are:

Dead loads

Live loads (Static and dynamic effects)

Longitudinal forces

Earth pressure

Wind loads

Earthquake inertial forces

Loads and forces implicitly considered are:

Thermal forces

Shrinkage forces

Skew stress effects

Elastomeric bearings shear resistance

Settlement of the ground

8.2 Dead loads

Bridge dead loads comprise the total weight of the structure, calculated as the sum of the weights of all structural and non-structural elements, including substructure elements, superstructure elements, deck surface, median permanent or removable structures, sidewalks, railings, and all other elements supported by the bridge like public utility services and ducts.

8.2.1 Structural elements

Dead loads due to structural elements, referred to as self weight, may be calculated as the sum of their weight, assuming the density of normal weight concrete as $[2.5] \text{ Mg/m}^3$. The use lower values for normal concrete density must be accompanied by supporting documents demonstrating that the value used does not reflect an average value, but rather a [95] percentile value for a normal distribution record of representative field data.

8.2.2 Non structural elements

Dead loads due to non structural elements may be calculated as the sum of their weights according to the density of their constitutive materials or to those specified by the producer in their technical data. Density values shown in Table 6 may be used for weight estimate.

Table 6 — Density values for materials used in bridge construction

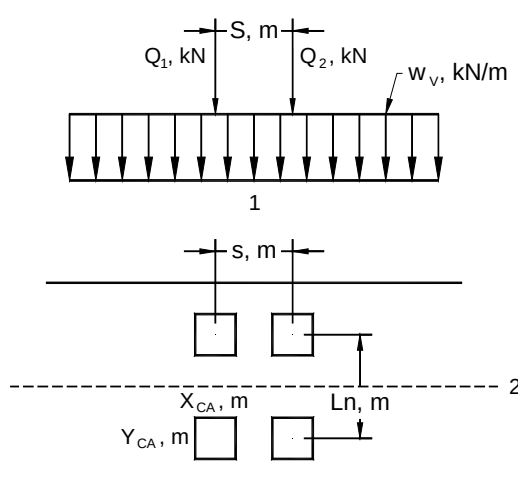
Material	Density, Mg/m ³
Steel	[7.9]
Timber	[0.8]
Reinforced concrete	[2.5]
Compacted filling soil	[1.9]
Loose filling soil	[1.6]
Stone masonry	[2.7]
Concrete masonry	[2.3]
Clay masonry	[1.4]
Asphalt	[1.8]

8.3 Live loads

Bridge live loads comprise the weights of all loads that might be applied to the superstructure according to the bridge use.

8.3.1 Vehicular bridges

Live load for vehicular bridges should be taken as a distributed load, w_v , and concentrated loads Q_1 and Q_2 , distributed as in Figure 5.



Key

- 1 Vertical Load pattern
- 2 Plan Load distribution

Figure 5 — Vehicular live loads for a two-lane bridge

Vehicular live loads should be applied on a standard lane [3] m wide, regardless of the actual width of the bridge deck. Bridges with roadways widths exceeding [5.5] m should be considered two lane bridges and have dissimilar loads applied on each lane. Values for vehicular live loads are prescribed in Table 7. Data on overloads may be applied.

For a single span bridge, critical load occurs when Q_1 is applied at the center of the span. For two and three span bridges, critical load may occur when Q_1 and Q_2 are not applied simultaneously on all spans. Positions of Q_1 and Q_2 shall be varied as to obtain critical condition.

Table 7 — Vehicular live loads values

Number of lanes	Lane	w_v (kN/m)	Q_1 (kN)	Q_2 (kN)	S (m)	X_{CA} (m)	Y_{CA} (m)	L_n (m)
1	1	[30]	[150]	[0]	[0]	[0.4]	[0.4]	[2]
2	1	[27]	[150]	[150]	[1.2]	[0.4]	[0.4]	[2]
	2	[8]	[100]	[100]	[1.2]	[0.4]	[0.4]	[2]

When light vehicular traffic is anticipated, the values given in Table 7 may be reduced as per Table 8. However, the application of these factors shall be accompanied with readily visible warning signs stating the restrictions for light trucks or for automobile only use. Appropriate physical barriers may be required as needed.

Table 8 — Vehicular live loads reduction factors

Restrictions	Light trucks	Only automobiles
Barriers to restrict heavier loads	[0.8]	[0.5]
No traffic physical restrictions	[0.8]	[0.8]

8.3.2 Pedestrian bridges

Pedestrian live loads of 5 kN/m² should be applied on the deck walkable area, as to cause the most unfavorable effects. Additionally, a truck load should be considered to account for maintenance equipment, unless the bridge width is less than 2 m or vehicle entrance is prevented by permanent barriers. The truck load, shown in Figure 6 and Table 9 should not be applied simultaneously with the distributed pedestrian load.

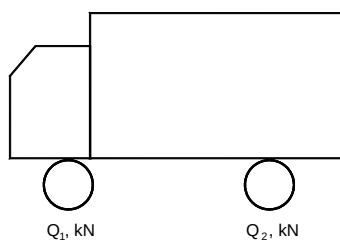


Figure 6 — Pedestrian bridge truck

Table 9 — Truck loads

Walkable width, m	Q_1	Q_2
2 to 3	[10]	[40]
More than 3	[20]	[80]

8.3.3 Dynamic effect of live loads

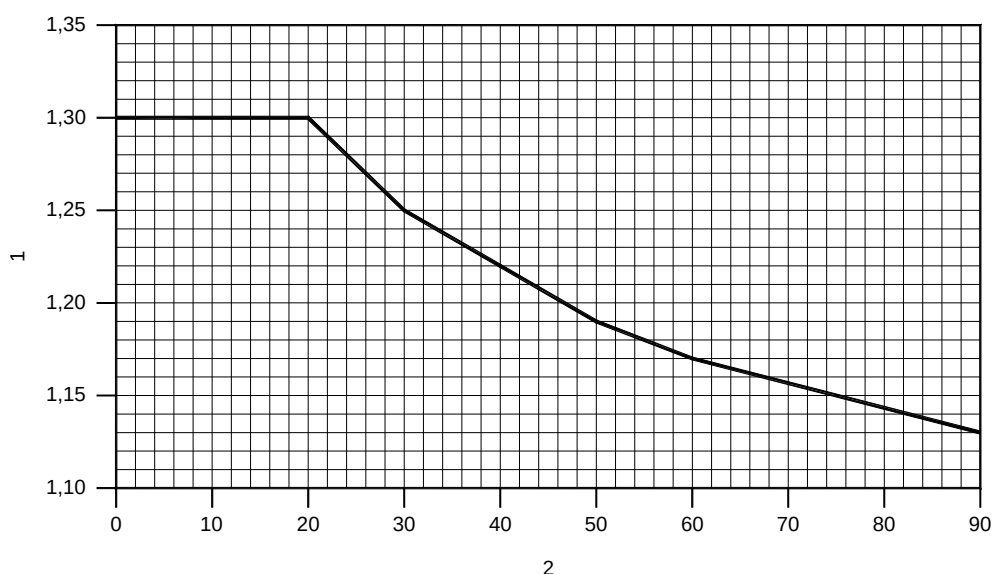
To account for the dynamic effects, such as impacts due to deck surface irregularities, vehicular live loads should be increased by the dimensionless factor given in Figure 7 according to the loaded area as to produce the most unfavorable effect on each element.

For shear design always increase the live load by 1.3.

For slab and superstructure joints design increase the live load by 1.2.

For local analysis (joists, slabs, etc.) increase the live load by 1.2.

Pedestrian live loads need not be increased.



Key

- 1 live load dynamic effect factor
- 2 loaded length, m

Figure 7 — Live load dynamic effect factor

8.4 Longitudinal forces

Axial loads and moments due to traffic should also be considered as applied longitudinally, and within the plane of the deck, on the superstructure, without the dynamic effect increase. Axial loads should be taken as [5] % of live loads. Moments should be calculated using a lever arm of [2] m.

Only superstructure axial loads are transmitted to the substructure.

8.5 Earth pressure

Forces due to earth pressure acting on abutments, or on retaining walls that are part of the bridge substructure, should be calculated and applied adequately to substructure elements.

Under no circumstance earth pressure should be taken as less than an equivalent fluid weight of [5] kN/m³.

8.6 Wind loads

Wind loads on bridges complying with the limitation set forth in 6.1 do not control the structure's design and need not be taken into account except in regions prone to hurricane, cyclone or typhoon winds, where a wind load case needs to be taken into account as per Table 10.

Table 10 — Wind loads for hurricane, cyclone or typhoon prone areas:

Load condition	Load direction	Load, kN/m ²
Load on structure*	Transverse	[2.5]
	Longitudinal	[0.6]
Load on live load*	Transverse	[1.5]
	Longitudinal	[0.4]

* Both longitudinal and transverse loads should be applied simultaneously.

8.7 Earthquake inertial forces

8.7.1 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 bridge.

The requirements of the National corresponding Standard should be met when calculating the mass of bridge building materials. When no National Standard is available, the requirements of ISO 9194 may be used. Table 6 of these guidelines may also be used to determine bridge masses.

For bridges which may be designed under these guidelines, an equivalent lateral force applied directly to the substructure and superstructure elements may be employed to represent the dynamic response of the structure to the ground acceleration.

8.7.2 Seismic hazard

A level of seismic hazard should be defined for the bridge in terms of the intensity of the effective peak ground horizontal acceleration in rock at the structuresite. 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 seconds, denoted as A_a , and usually expressed as a fraction of the acceleration of gravity, g (Acceleration of gravity may taken as 9.81 m/s^2).

For the purpose of the scope of these guidelines, the values for A_a must be taken from the National corresponding 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 seconds, 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 bridge being considered, A_a may be estimated from the seismic hazard maps shown in Figure 8.

8.7.3 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.

8.7.4 Low seismic hazard zones:

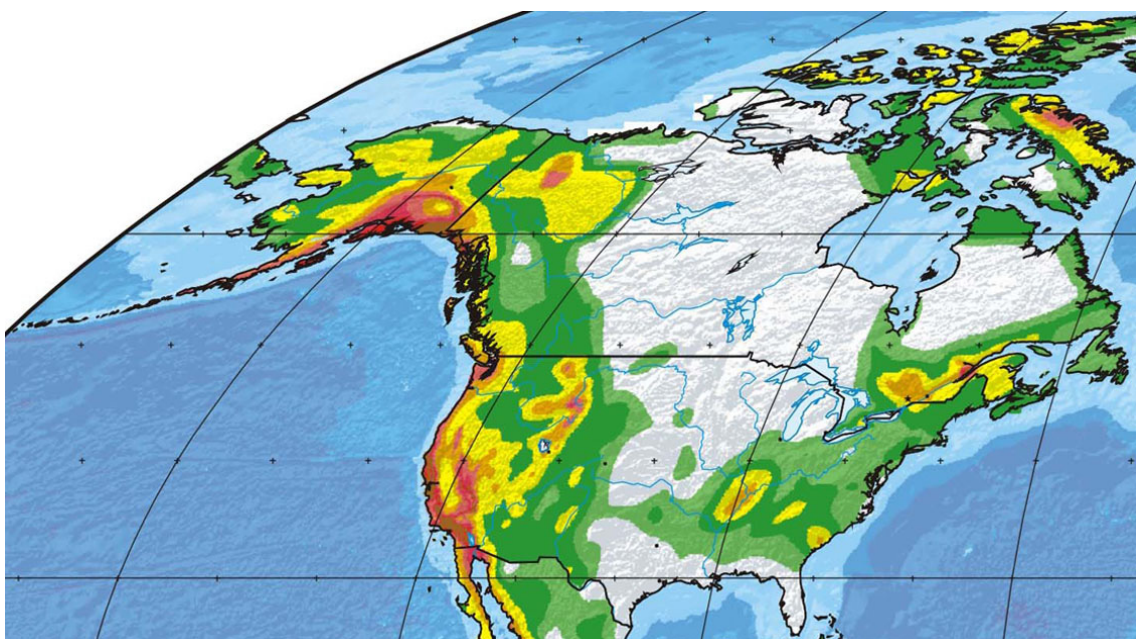
A zone where the value of A_a is estimated as more than [0.05] but less or equal to [0.10] may be deemed as a **low seismic hazard** zone.

8.7.5 Intermediate seismic hazard zones:

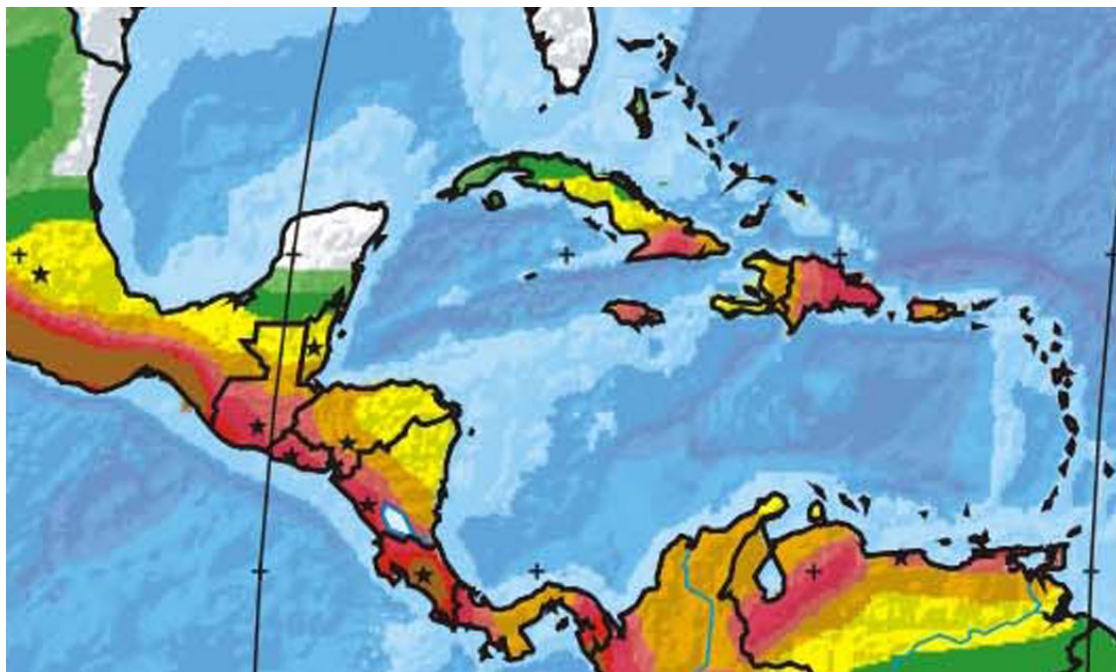
A zone where the value of A_a is estimated as more than [0.1] but less or equal to [0.20] may be deemed as a **intermediate seismic hazard** zone.

8.7.6 High seismic hazard zones:

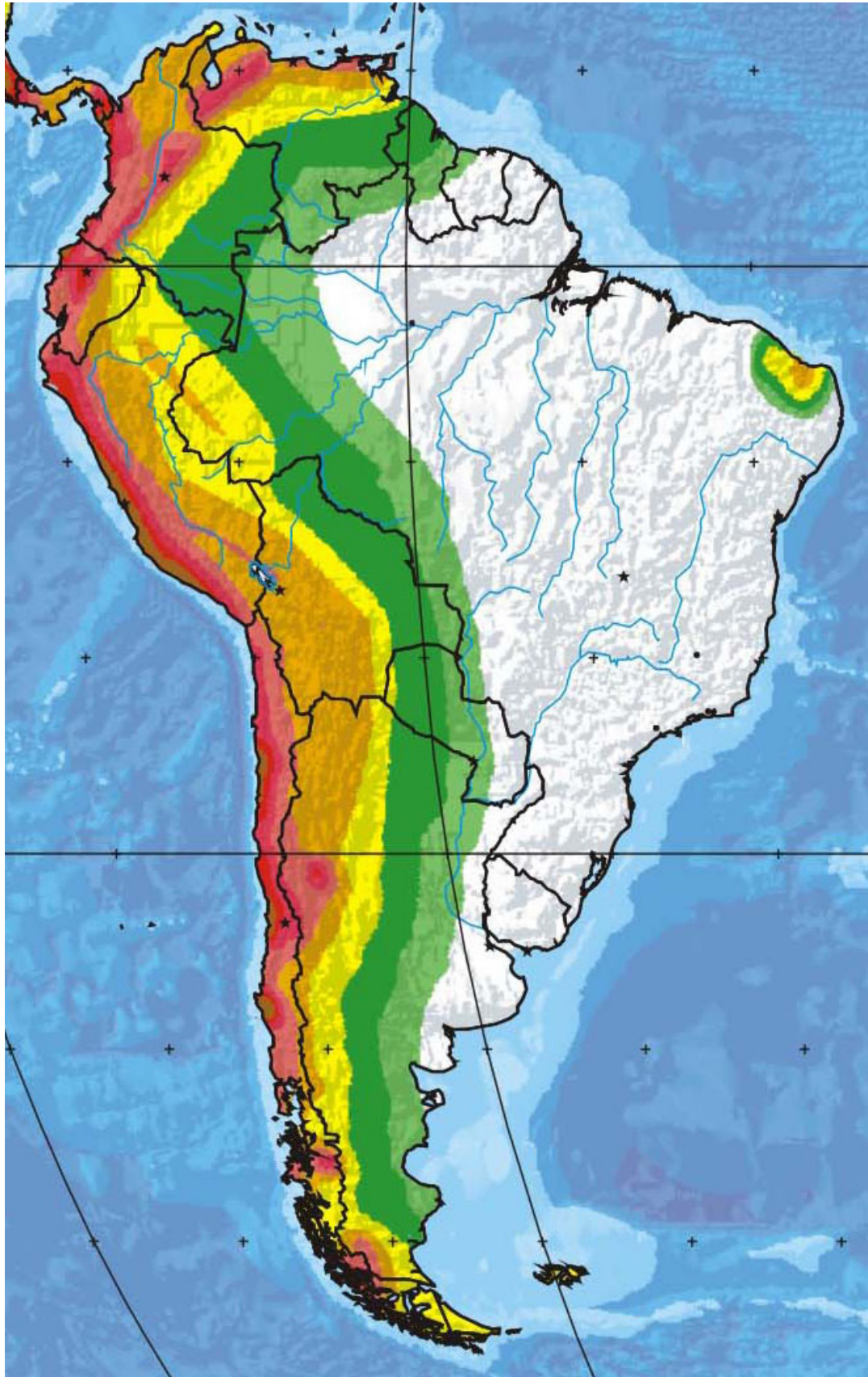
A zone where the estimated value of A_a exceeds [0.20] may be deemed as a **high seismic hazard** zone.



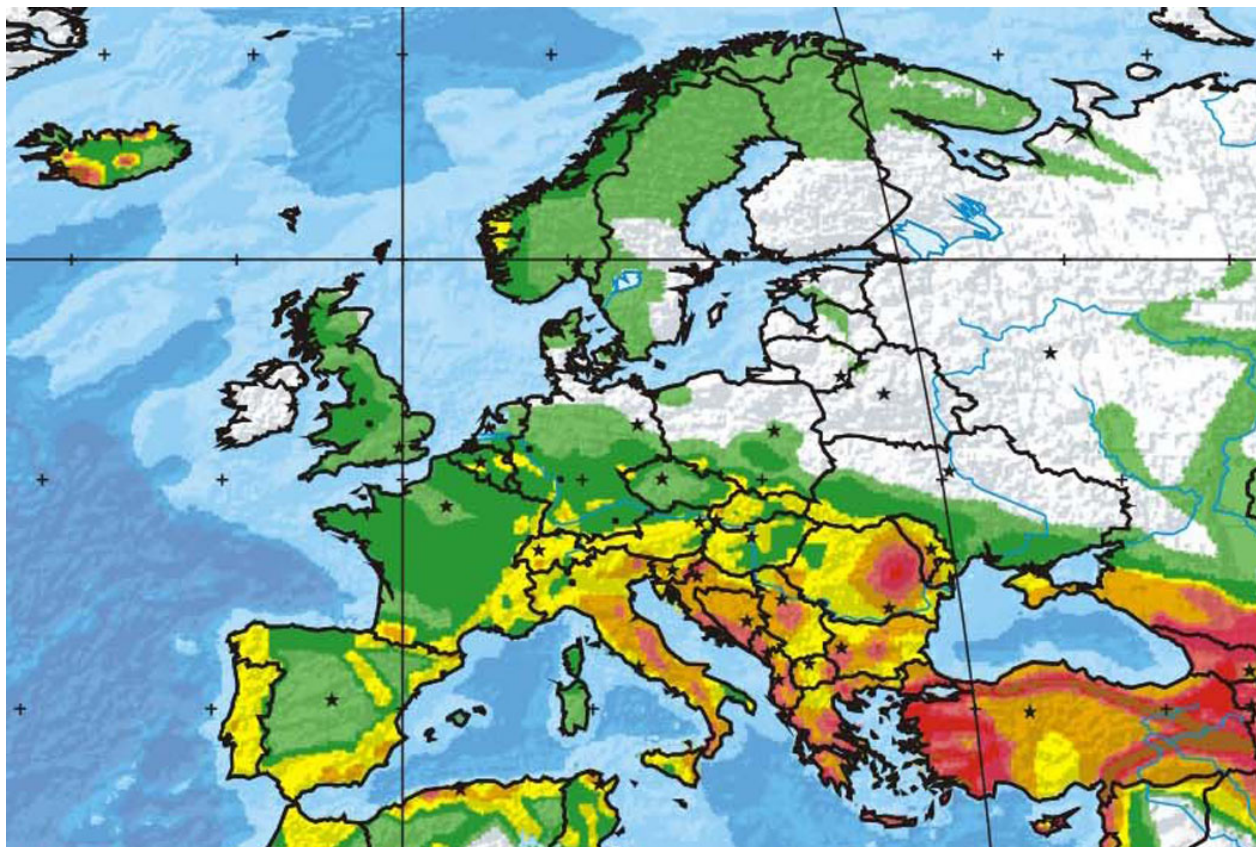
a) North America



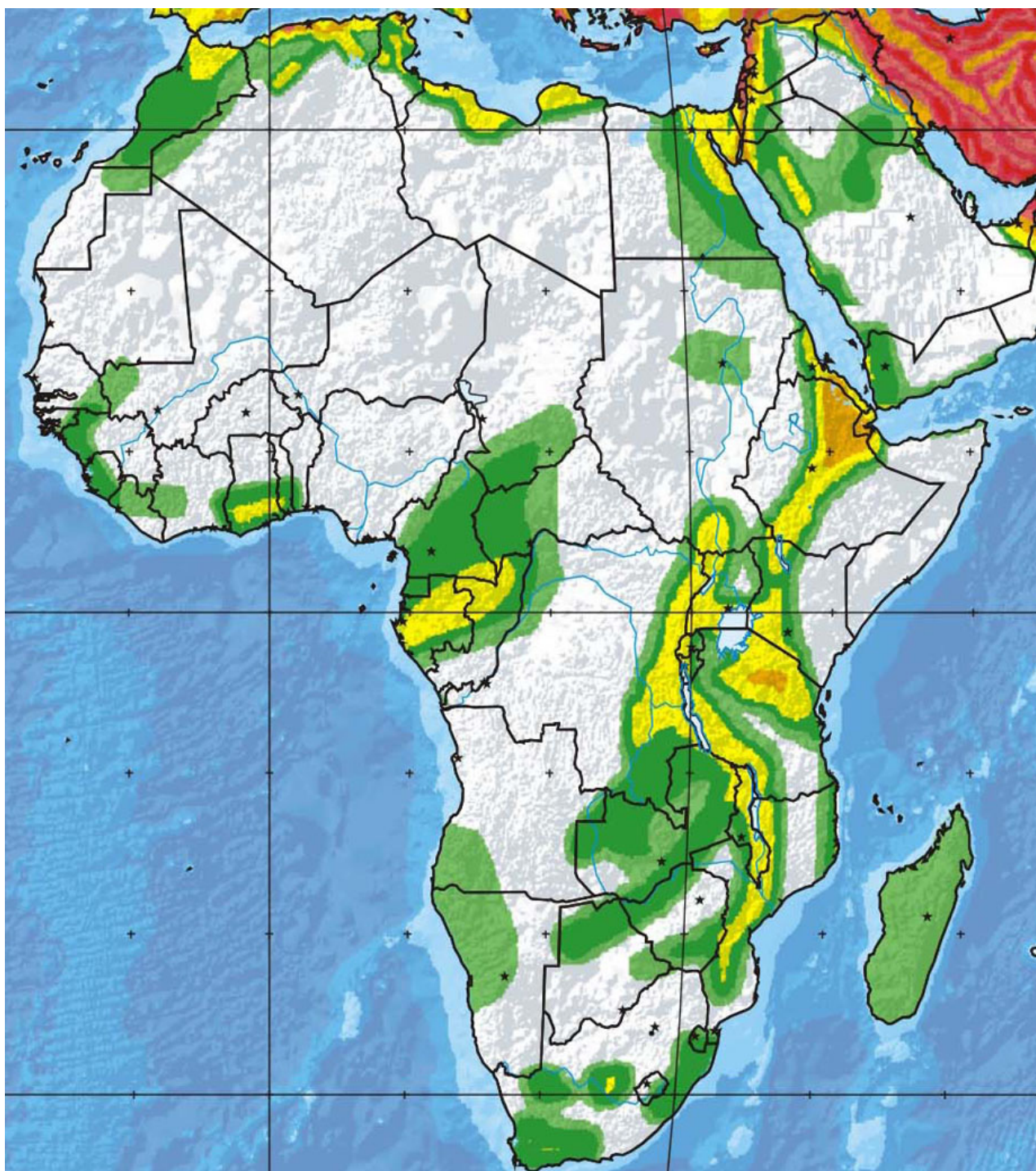
b) Central America and the Caribbean



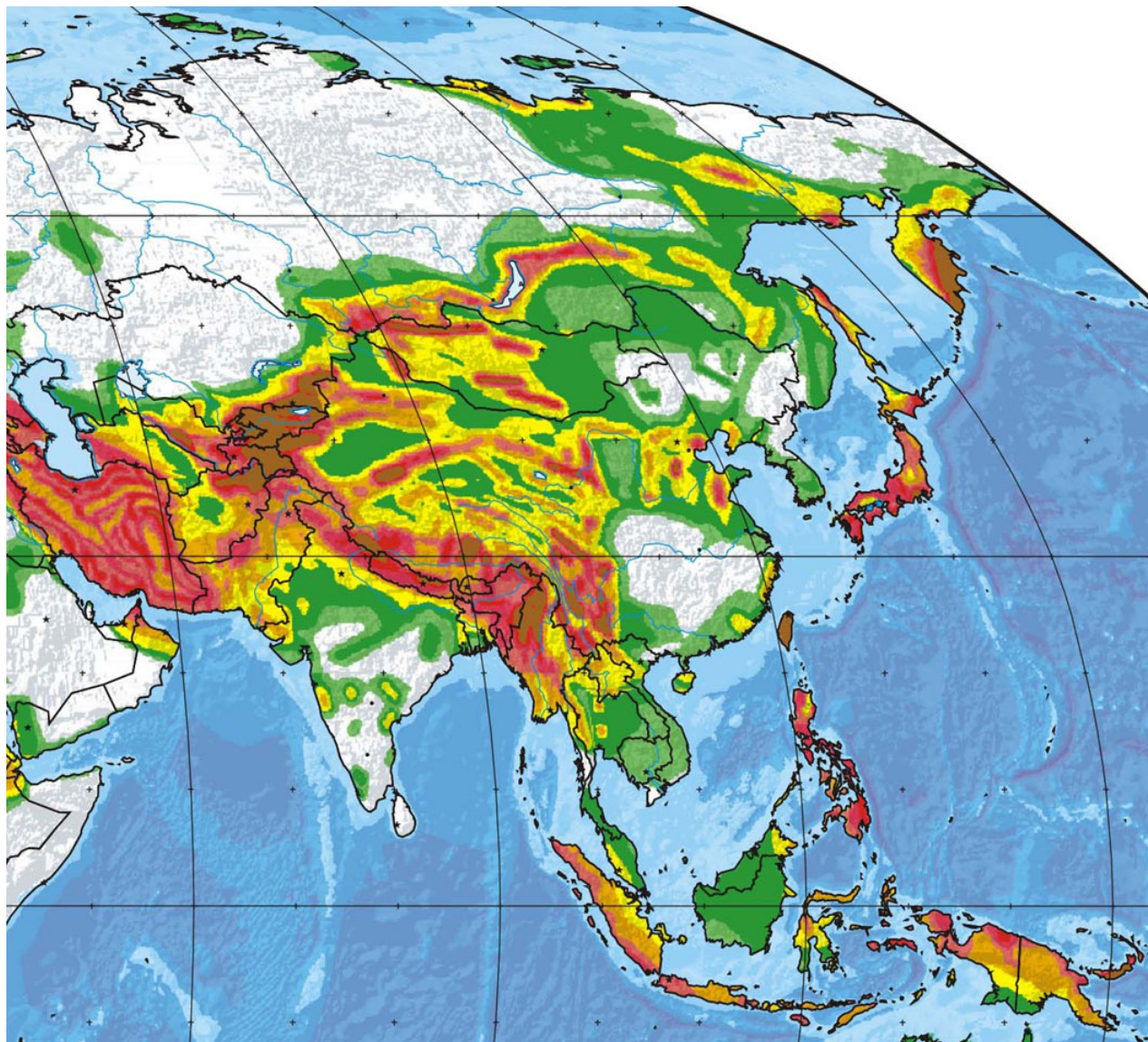
c) South America



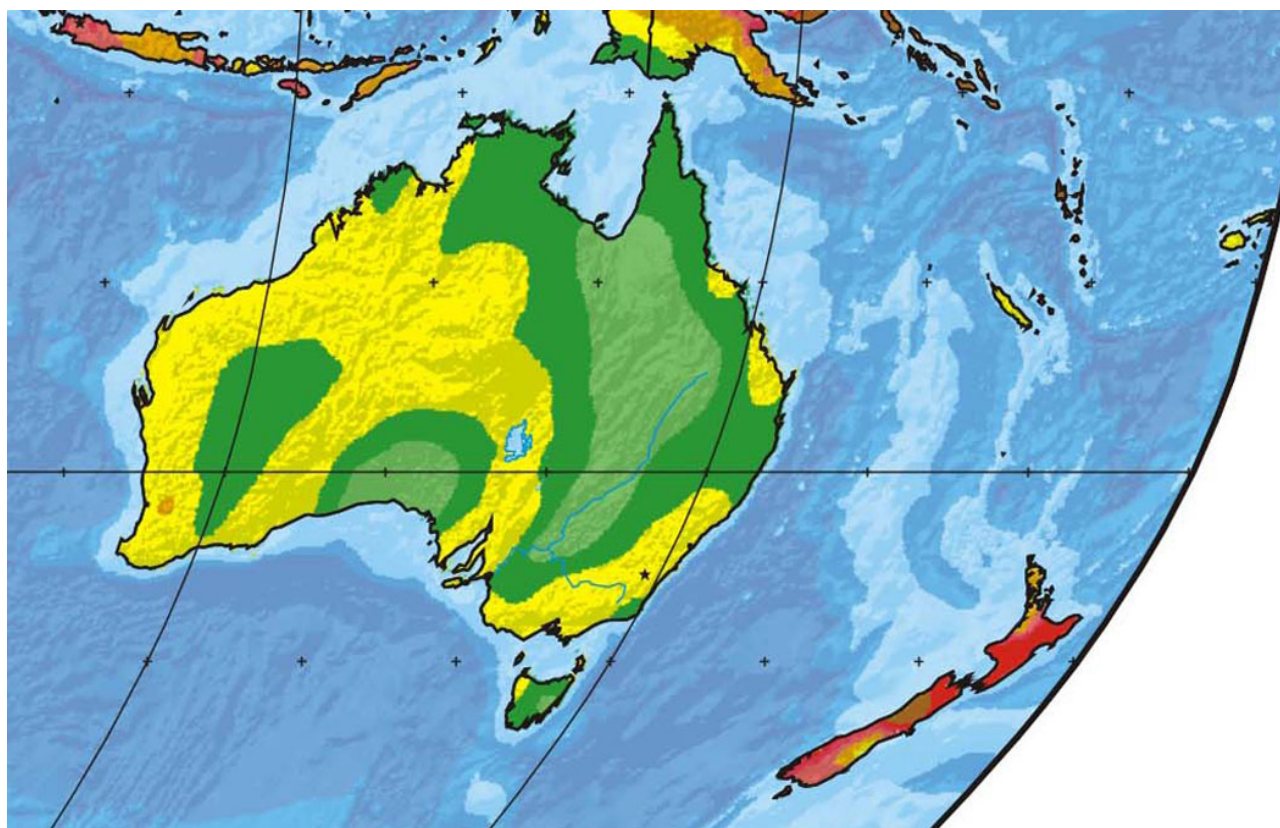
d) Europe



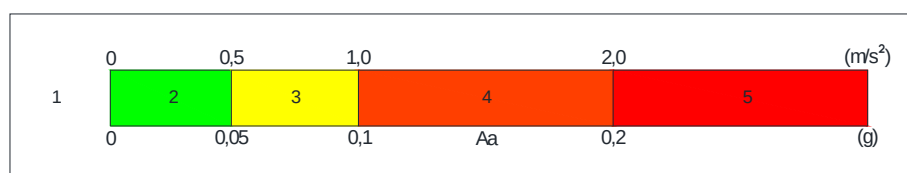
e) Africa



f) Asia



g) Oceania

**Key**

- 1 seismic hazard
- 2 no
- 3 low
- 4 intermediate
- 5 high

Figure 8 — Global Seismic Hazard Map**8.7.7 Soil profile types**

Based on the type of soil present at the bridge 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 $(1\,500 \text{ m/s} \geq v_s > 750 \text{ m/s})$;

Soil Profile S_C : soft weathered or fractured rock, or dense or stiff soil, where the measured shear wave velocity is in the range ($750 \text{ m/s} \geq v_s > 350 \text{ m/s}$), or, in the upper 30 m, the standard penetration test resistance has an average value of $N > 50$ or a shear strength for clays $s_u \geq 100 \text{ kPa}$;

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 ($350 \text{ m/s} \geq v_s > 180 \text{ m/s}$), 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 ($50 \text{ kPa} \leq s_u < 100 \text{ kPa}$);

Soil Profile S_E : a soil profile where the measured shear wave velocity $v_s \leq 180 \text{ m/s}$, or the standard penetration test resistance has an average value $N \leq 15$ 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 ($s_u < 25 \text{ kPa}$) clays; and

Seismically vulnerable soils: sites where the soil profile contains soil having one or more of the following characteristics are beyond the scope of these guidelines:

- 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 to classify must always be conducted by a designer familiar with these processes.

8.7.8 Site effects

Site effects shall be described through the site coefficient for short periods of vibration, F_a . The values of the site coefficient for short periods of vibration, F_a , shall be determined from Table 11 as a function of A_a , and the soil profile type from 8.7.7. Linear interpolation can be used between values of A_a in Table 11.

Site effect of seismically vulnerable soils, as described in 8.7.7, are beyond the scope of these guidelines and designs should be made under the National Standard or other applicable standards.

Table 11 — Site coefficient, F_a .

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]	[2.70]	[1.20]	[0.90]	[0.90]

8.7.9 Design response spectral ordinates

For bridges 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 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 Equation 5:

$$S_a = 2.5A_g F_a \quad \text{Equation (5)}$$

8.7.10 Seismic equivalent uniformly distributed load

A seismic uniformly distributed load, w_s , equivalent to the total horizontal inertial effects caused by the seismic ground motions, distributed along the length of the bridge, should be determined using Equation 6:

$$w_s = \frac{m_T g S_a}{L_T} \quad \text{Equation (6)}$$

This distribution is considered as uniformly distributed load, as simple as it is possible, from the viewpoint of simplified design because the distribution of lateral forces has a little effect on the inertia force of substructure.

In Equation 6, m_T stands for the total mass of the bridge that is not directly absorbed by the supports, including all structural elements, intermediate walls, piers, columns, etc., excluding footings and abutments, g is the force of gravity, S_a is the design spectrum ordinate, and L_T is the total length of the bridge.

8.7.11 Fundamental mode shape

For bridges complying with the limitations set forth in 6.1, dynamic response may be assumed to be dominated by the fundamental mode characteristics. The fundamental mode shape for each one of the possible cases of one, two or three spans, is shown in Figure 9.

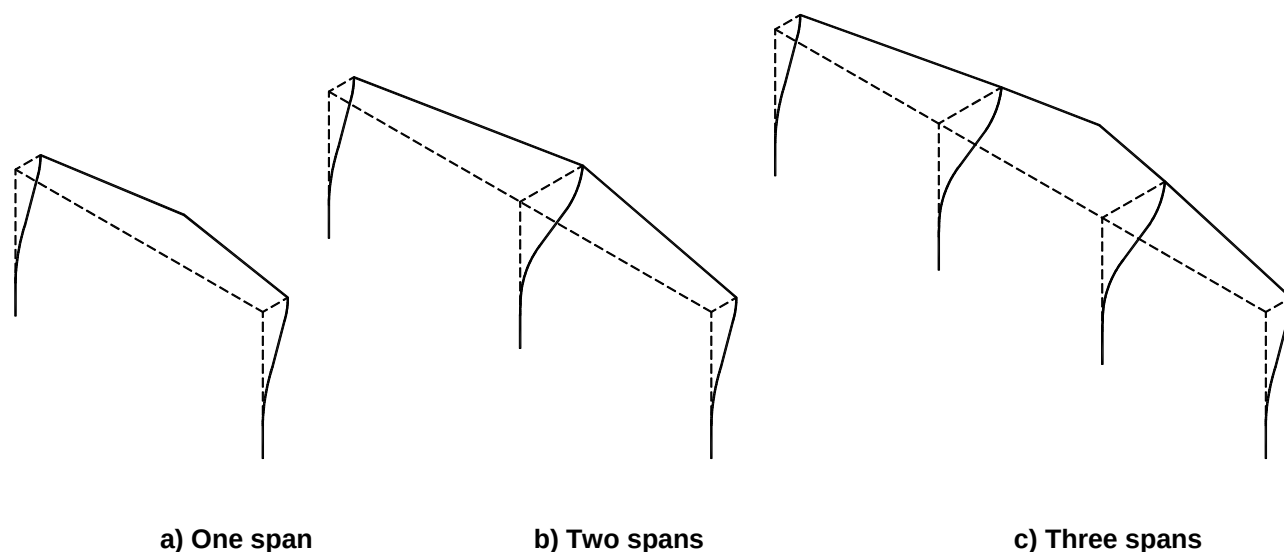


Figure 9 — Fundamental mode shape.

The fundamental shape for each case and for each span is described by a function $u(x)$, as per Table 12.

Table 12 — Unitary deformation distribution.

Number of spans	Span	$u(x)$
1	Single span	$16 \frac{x^2}{L^4} (2Lx - L^2 - x^2)$
2	First span	$\left[16 \frac{x^2}{L^4} (2Lx - L^2 - x^2) + \frac{I_D H^4 x}{I_P L^5} \right] \left(\frac{I_P L^4}{I_D H^4} \right)$
	Second span	$\left[16 \frac{x^2}{L^4} (2Lx - L^2 - x^2) + \frac{I_D H^4 (L-x)}{I_P L^5} \right] \left(\frac{I_P L^4}{I_D H^4} \right)$
3	First span	$\left[16 \frac{x^2}{L^4} (2Lx - L^2 - x^2) + \frac{I_D H^4 x}{I_P L^5} \right] \left(\frac{I_P L^4}{I_D H^4} \right)$
	Second span	$\left[16 \frac{x^2}{L^4} (2Lx - L^2 - x^2) + \frac{I_D H^4 x}{I_P L^5} + \frac{I_D H^4 (L-x)}{I_P L^5} \right] \left(\frac{I_P L^4}{I_D H^4} \right)$
	Third span	$\left[16 \frac{x^2}{L^4} (2Lx - L^2 - x^2) + \frac{I_D H^4 (L-x)}{I_P L^5} \right] \left(\frac{I_P L^4}{I_D H^4} \right)$

In Table 12, x stands for any point along the considered span, L is the span's length in meters, H is the largest height of the bridge supports in meters, I_D is the moment of inertia of the deck section in m^4 , for bending within its plane, due to horizontal forces, and I_P is the moment of inertia of the wall, frame or pier, in m^4 , for bending due to horizontal forces.

8.7.12 Lateral equivalent design forces

The equivalent lateral force, w_e , applied directly to the substructure and superstructure elements, employed to represent the dynamic response of the structure to the ground acceleration, should be determined using Equation 7:

$$w_e = w_s u(x) \quad \text{Equation (7)}$$

In Equation 7, w_s is a uniformly distributed load caused by the seismic ground motions, as specified in 8.7.10, and $u(x)$ is the function describing the fundamental mode shape, as specified in 8.7.11.

8.8 Thermal Forces

Longitude change due to thermal expansion, δ_T , must be calculated for a continuous deck, as per Equation 8, at each vertical support.

$$\delta_T = \alpha \Delta_T L_C \quad \text{Equation (8)}$$

The value for the coefficient of thermal expansion for concrete, α , depends mainly on the type of aggregate used; accepted values range from $10 \times 10^{-6} \text{ m/m/}^\circ\text{C}$ to $13.5 \times 10^{-6} \text{ m/m/}^\circ\text{C}$. A value of $[11.5 \times 10^{-6}] \text{ m/m/}^\circ\text{C}$ may be used for α in Equation 8. ΔT is the maximum daily variation in temperature recorded at the site of the bridge. In lieu of this information, the designer may use the data provided in Table 13. Classification of temperature region for the bridge site should be made according to Figure 10.