
**Simplified design of prestressed
concrete bridges —**

**Part 2:
Box-girder bridges**

*Conception simplifiée des ponts en béton précontraint —
Partie 2: Ponts à poutres caissons*





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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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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

The aim of this document is to provide rules for the design and construction of relatively short span prestressed concrete box girder bridges. This document 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 document may 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 design models. This document 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 document are intended to account for undesirable side effects that 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 on 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 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 included 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 design of prestressed concrete bridges —

Part 2: Box-girder bridges

1 Scope

This document provides information to perform the design of the prestressed concrete box girder bridge for road that complies with the limitations established in 6.1. The rules of design as set forth in the document are simplifications of more elaborate requirements. Among several erection methods of box girder bridges, the provisions of this document are mainly applicable to full staging method (FSM).

Designs and details for new road bridges 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; and
- external protection systems to minimize the effects of reasonably conceived severe loads.

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

3 Terms and definitions

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

ISO and IEC maintain terminology 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

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

3.2

anchorage

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

3.3

B-region

portion of a member in which it is reasonable to assume that strains due to flexure vary linearly through section

3.4
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

3.5
clearance

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

3.6
compression reinforcement

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

3.7
specified compressive strength of concrete

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

Note 1 to entry: 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).

3.8
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

3.9
cover

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

3.10
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 1 to entry: The hooks should engage peripheral longitudinal bars. The 90° hooks of two successive crossties engaging the same longitudinal bars should be alternated end for end.

3.11
D-region

portion of a member with a force discontinuity or a geometric discontinuity

3.12
deformed reinforcement

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

Note 1 to entry: The following steel reinforcement should be considered deformed reinforcement according to this document: deformed reinforcing bars, deformed wire, welded plain wire fabric, and welded deformed wire fabric conforming to the appropriate ISO standards.

3.13
design strength

product of the nominal strength multiplied by a strength reduction factor

3.14
development length

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

3.15**diaphragm**

transverse stiffener which is provided between girders in order to maintain section geometry, to resist lateral forces, and to transfer loads to support

3.16**duct**

material creating a conduit in a concrete member to accommodate the prestressing steel of a post-tensioning tendon

3.17**durability**

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

3.18**effective depth**

distance measured from extreme compression fibre to centroid of tension reinforcement

3.19**factored load**

specified nominal load multiplied by the load factors prescribed in this document

3.20**girder**

main horizontal support beam, usually supporting other beams

3.21**hook**

bend at the end of a reinforcing bar

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

3.22**jacking force**

<prestressed concrete> temporary force exerted by the device that introduces tension into the tendons

3.23**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

3.24**lap splice**

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

3.25**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)

3.26**live load**

static and dynamic effect, 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

3.27**load effect**

force and deformation produced in structural members by the applied loads

3.28

load combination

combination of factored loads and forces as specified in this document

3.29

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

3.30

load

force or other action that results from the weight of all bridge materials, pedestrians, vehicles, environmental effects, differential movement, and restrained dimensional changes

3.31

longitudinal reinforcement

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

3.32

mesh wire

welded-wire fabric reinforcement

3.33

nominal load

magnitude of the loads specified in this document (dead, live, soil, wind, snow, rain, flood, and earthquake)

3.34

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 Formulae set forth in this document

Note 1 to entry: 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.

3.35

permanent load

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

Note 1 to entry: All other loads are variable loads (see also [3.33](#)).

3.36

post-tensioning

method of prestressing reinforced concrete in which tendons are tensioned after the concrete has attained a specified minimum strength or a specified minimum age

3.37

prestressing steel

high-strength steel elements such as wire, bar, or strands used to impart prestress forces to concrete

3.38

pretensioning

method of prestressing in which prestressing steel is tensioned before the concrete is placed

3.39

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 this document

3.40**service load**

load specified by this document (without load factors)

3.41**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

3.42**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

3.43**slab**

deck

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

3.44**spiral reinforcement**

continuously wound reinforcement in the form of a cylindrical helix

3.45**stirrup**

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

Note 1 to entry: 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 [3.48](#).

3.46**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 1 to entry: Including the probability of understrength members due to variations in material strengths and dimensions, approximations in the design Formulae, 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.

3.47**tendon**

an assembly consisting of a tensioned element (such as a wire, bar, rod, strand, or a bundle of these elements) used to impart compressive stress in concrete, along with any associated components used to enclose and anchor the tensioned element

3.48**tie**

loop of reinforcing bar or wire enclosing longitudinal reinforcement

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

3.49**transfer length**

the length from the end of the member where the tendon stress is zero to the point along the tendon where the prestress is fully effective

3.50**transverse reinforcement**

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

3.51**yield strength**

specified minimum yield strength or yield point of reinforcement

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

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

4 Symbols and abbreviated terms

Symbol	Explanation	Unit
a	depth of equivalent uniform compressive stress block	mm
a_{eff}	lateral dimension of the effective bearing area measured parallel to the larger dimension of the cross-section	mm
a_l	lateral dimension of the anchorage device or group of devices in the direction considered	mm
A	maximum area of the portion of the supporting surface that is similar to the loaded area and concentric with it and does not overlap similar areas for adjacent anchorage devices	mm ²
A_a	fraction of acceleration of gravity	—
A_b	effective bearing area	mm ²
A_c	area of concrete section	mm ²
A_{conf}	bearing area of the confined concrete in local zone	mm ²
A_g	gross area of section of element	mm ²
A_{plate}	anchor bearing plate area	mm ²
A_{ps}	area of prestressing steel	mm ²
$A_{\text{ps,s}}$	area of prestressing steel corresponding to concrete top slab	mm ²
A_s	area of longitudinal tension reinforcement	mm ²
A_s'	area of longitudinal compression reinforcement	mm ²
$A_{s,\text{st}}$	area of shrinkage and temperature reinforcement in each direction and each face	mm ² /mm
A_v	area of shear reinforcement (stirrup) within a distance s	mm ²
b	width of section of the member	mm
b_{eff}	lateral dimension of the effective bearing area measured parallel to the smaller dimension of the cross-section	mm
b_w	web width of girder or beam	mm
d	effective depth of reinforcement	mm
d'	distance from extreme compression fibre to centroid of compression reinforcement	mm
d_b	nominal diameter of reinforcing bar or strand	mm
d_{burst}	distance from anchorage device to the centroid of the bursting force	mm
d_{ce}	one-half the effective length of the failure plane in shear and tension for a curved element	mm
d_p	effective depth of prestressing tendon	mm
e_a	eccentricity of the anchorage device or group of devices with respect to the centroid of the cross-section; always taken as positive	mm
E	modulus of elasticity	MPa

Symbol	Explanation	Unit
E_b	modulus of elasticity of the bearing plate material	MPa
E_c	modulus of elasticity of concrete	MPa
E_{ci}	modulus of elasticity of concrete when post-tensioned	MPa
E_{ct}	modulus of elasticity of concrete at transfer	MPa
E_p	modulus of elasticity of prestressing steel	MPa
f_b	stress in anchor plate at a section taken at the edge of the wedge hole or holes	MPa
f'_c	specified compressive strength of concrete	MPa
f'_{cd}	compressive strength of concrete reduced by the material factor	MPa
f'_{ci}	specified compressive strength of concrete at time of initial loading or prestressing	MPa
f'_{cr}	average (required) compressive strength of concrete	MPa
f_{cgp}	concrete stress at the centre of gravity of prestressing tendons due to the pre-stressing force immediately after transfer and the self-weight of the member at the section of maximum moment	MPa
f_{cpe}	compressive stress in concrete due to effective prestress forces only (after allowance for all prestress losses) at extreme fibre of section where tensile stress is caused by externally applied loads	MPa
$f_{c,QP}$	stress in the concrete adjacent to the tendons, due to self-weight and initial pre-stress and other quasi-permanent actions	MPa
f_{pe}	effective stress in the prestressing steel after losses	MPa
f_{pi}	prestressing steel stress immediately prior to transfer	MPa
f_{pj}	stress in the prestressing steel at jacking	MPa
f_{ps}	average stress in prestressing steel at the time for which the nominal resistance of the member is required	MPa
f_{pu}	tensile strength of prestressing strand and bar	MPa
f_{py}	yield strength of prestressing strand and bar	MPa
f_{pyd}	yield strength of prestressing strand and bar reduced by the material factor	MPa
f_r	modulus of rupture of concrete	MPa
f_s	stress in reinforcement	MPa
f'_s	stress in compression reinforcement	MPa
f_{se}	effective stress in the prestressing steel after losses	MPa
f_y	specified yield strength of reinforcement	MPa
f_{yd}	yield strength of reinforcement reduced by the material factor	MPa
f_{ys}	specified yield strength of transverse or spiral reinforcement	MPa
F_a	site coefficient	—
F_{u-in}	in-plane deviation force effect per unit length of tendon	N/mm
F_{u-out}	out-of-plane force effect per unit length of tendon	N/mm
g	acceleration of gravity	m/s ²
h	overall depth or thickness of the member	mm
h_s	height or thickness of top slab	mm
h_l	lateral dimension of the cross-section in the direction considered	mm
H	the largest height of bridge supports	m
H_r	average annual ambient relative humidity	%
I	second moment of area	mm ⁴
I_c	second moment of area of concrete	mm ⁴
I_D	second moment of area of deck	m ⁴
I_P	second moment of area of wall, frame or pier	m ⁴
K	wobble friction coefficient	/mm

Symbol	Explanation	Unit
l_c	longitudinal extent of confining reinforcement of the local zone	mm
l_d	development length for reinforcing bar and pretensioning strand	mm
l_{set}	Influencing distance of anchorage set	mm
L	span length	m
L_T	total length	m
m_T	total mass	kg
M_{cr}	cracking moment	N·mm
M_{dnc}	total unfactored dead load moment acting on the monolithic or non-composite section	N·mm
M_n	nominal flexural moment strength at section	N·mm
M_u	factored flexural moment at section	N·mm
n	number of anchorages in a row	—
n_b	projection of base plate beyond the wedge hole or wedge plate	mm
N	number of identical prestressing tendons	—
p	slope of prestressing force distribution due to friction	N/mm
P_r	bearing resistance of anchorages	N
P_t	tendon force	N
R	radius of curvature of the tendon at the considered location	mm
s	centre-to-centre spacing of reinforcements	mm
s_a	centre-to-centre spacing of anchorages	mm
s_c	clear spacing of reinforcements	mm
S_a	design response spectrum	—
S_c	section modulus for the extreme fibre of the composite section where tensile stress is caused by externally applied loads	mm ³
S_{nc}	section modulus for the extreme fibre of the monolithic or non-composite section where tensile stress is caused by externally applied loads	mm ³
t	time	days or h
t_b	average thickness of the bearing plate	mm
t_r	time of prestress release	h
T_{burst}	tensile force in the anchorage zone acting ahead of the anchorage device and transverse to the tendon axis	N
V_c	contribution of the concrete to the nominal shear strength at section	N
V_n	nominal shear strength at section	N
V_r	shear resistance per unit length of the concrete cover against pull-out by deviation forces	N/mm
V_s	contribution of the shear reinforcement (stirrup) to the nominal shear strength at section	N
V_u	factored shear force at section	N
w_e	equivalent lateral force	kN/m
w_s	seismic uniformly distributed load	kN/m
x	length of a prestressing tendon from the jacking end to any point under consideration	mm
z_{cp}	distance between centre of gravity of concrete section and tendons	mm
α	sum of the absolute values of angular change of prestressing steel path from jacking end, or from the nearest jacking end if tensioning is done equally at both ends, to the point under investigation	rad

Symbol	Explanation	Unit
α_t	angle of inclination of a tendon force with respect to the centreline of the member; positive for concentric tendons or if the anchor force points toward the centroid of the section; negative if the anchor force points away from the centroid of the section	rad
γ	load factor	—
γ_{mc}	material factor for concrete	—
γ_{ms}	material factor for steel	—
Δf_{pA}	prestress loss due to anchorage set	MPa
Δf_{pES}	sum of all prestress losses or gains due to elastic shortening or extension at the time of application of prestress and/or external loads	MPa
Δf_{pF}	prestress loss due to friction	MPa
Δf_{pLT}	prestress losses due to long-term shrinkage and creep of concrete, and relaxation of the steel	MPa
Δf_{pR}	prestress loss due to relaxation of a strand	MPa
Δf_{pT}	total loss of prestress	MPa
Δl	anchorage set	mm
ϵ_{cs}	shrinkage strain	m/m
ϵ_{csu}	ultimate shrinkage strain	m/m
μ	curvature friction coefficient	/rad
ϕ	strength reduction factor	—
$\varphi(t, t_0)$	creep coefficient	—
φ_u	ultimate creep coefficient	—

5 Design and construction procedure

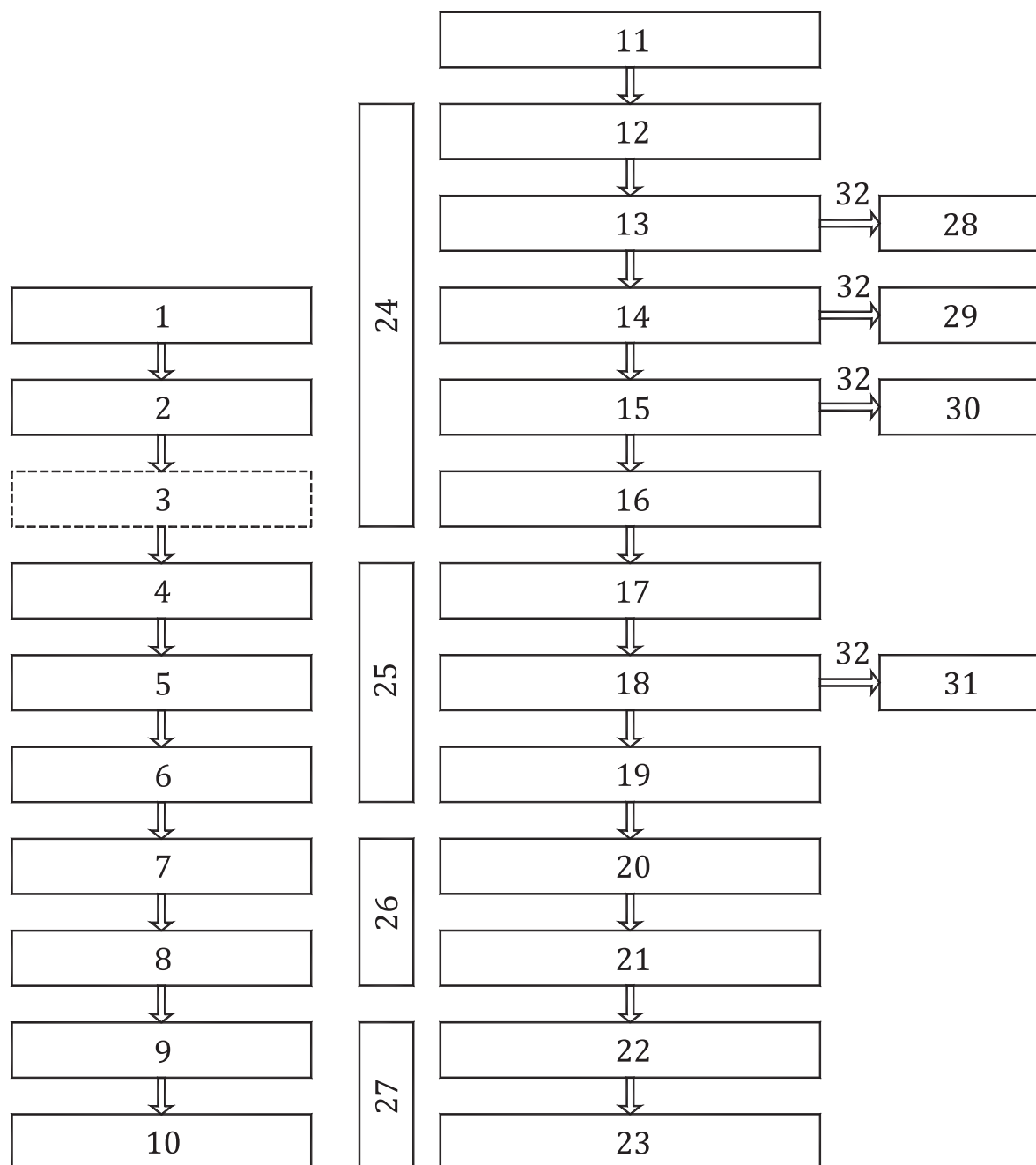
5.1 Procedure

5.1.1 General

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

- Step A: Definition of the layout in plan and height of the structure, according to the provisions of [Clause 7](#). Verify that the limitations of [6.1](#) are met.
- Step B: Calculation of all gravity loads that act on the structure using the provisions of [Clause 8](#), excluding the self-weight of the structural elements.
- Step C: Trial dimensions for the girders and calculation of their self-weight. Flexural and shear design of the girders, correcting the dimension as required by the ultimate and serviceability limit states.
- Step D: 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.
- Step E: If lateral loads such as earthquake, wind, or lateral earth pressure exist, their magnitude is established using the provisions in [Clause 8](#); otherwise the designer should proceed to Step G.
- Step F: The loads at the foundation level are determined, and a definition of the foundation system is performed. The structural elements of the foundation are designed.

- g) Step G: Preliminary location and trial dimensions for structural concrete walls capable of resisting the lateral loads established, the influence of their self-weight is evaluated, and flexural and shear design of the structural concrete walls is performed.
- h) Step H: Production of structural drawings.
- i) Step I: Construction of the structure should be performed complying with the local construction and practice.



Key

- | | | | |
|---|--|----|---|
| 1 | step A: preliminary design of structure | 17 | structural modelling and analysis |
| 2 | step B: definition of loads | 18 | check of allowable stress (serviceability limit state) |
| 3 | construction stage analysis (FSM: full staging method) | 19 | check of flexural strength and minimum rebar (ultimate limit state) |
| 4 | step C: design of girders | 20 | design of central diaphragm |
| 5 | step D: design of substructure | 21 | design of end diaphragm |
| 6 | step E: definition of lateral forces | 22 | design of local zone |
| 7 | step F: design of foundations | 23 | design of general zone |
| 8 | step G: design of structural walls | 24 | longitudinal design |
| 9 | step H: structural drawings | 25 | transverse design |

10	step I: construction of structure	26	design of diaphragm
11	design conditions and assumption of section	27	design of anchorage zone
12	structural modelling and analysis	28	redesign of prestressing tendons
13	check of stress limitations (serviceability limit state)	29	redesign of section and prestressing tendons
14	check of deflection (serviceability limit state)	30	redesign of section and prestressing tendons
15	flexural design (ultimate limit state)	31	redesign of section
16	shear and torsion (ultimate limit state)	32	N.G. (no good)

Figure 1 — Design and construction procedure

5.2 Design documentation

5.2.1 General

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

5.2.2 Calculation report

The structural designer should document all design steps in a calculation report. This report 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 and assumptions employed;
- d) grade, strength and fabrication standards for all structural materials;
- e) presentation of all design computations; and
- f) sketches of the reinforcement layout for all structural elements.

5.2.3 Geotechnical report

The geotechnical report should record, as a minimum, the soil investigation performed, the definition of the allowable bearing capacity of the bearing soil, the lateral soil pressures required for design of any soil retaining structure, side friction, end bearing capacity, and lateral soil stiffness required for design of deep foundation and all other information.

5.2.4 Structural drawings

All the drawings required for construction of the bridge.

5.2.5 Specifications

The construction specifications required.

6 General provisions

6.1 Limitations

6.1.1 General

This document should be employed only when the bridge being designed complies with all the limitations set forth in [6.1.2](#) to [6.1.14](#).

6.1.2 Permitted use

Design of bridges of mixed use using this document should be permitted, but restricted to pedestrian and vehicular traffic. Bridges for trains are beyond the scope of this document.

6.1.3 Maximum number of spans

The maximum number of spans for a bridge designed according to this document should be as per [Table 1](#).

Table 1 — Maximum allowed number of spans

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

6.1.4 Recommended span length

The recommended span length is from [40] m to [60] m for each span.

6.1.5 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, %
[2]	20
[3]	15

6.1.6 Maximum cantilever length

The maximum clear cantilever length for girders should comply with [10.3.3](#) in order to avoid cantilevers too long for the purposes of this document, as greater lengths can require detailed structural analysis to verify serviceability conditions such as deformation, vibration and fatigue, among other criteria.

6.1.7 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. 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]

6.1.8 Maximum number of lanes

The maximum number of lanes for a vehicular bridge designed according to this document should be [4]. Up to [2] sidewalks may be considered in addition to the vehicle traffic lanes.

6.1.9 Width limitations

Pedestrian bridges should not have widths of less than [1,5] m.

Vehicular bridges should not have roadways with widths, excluding sidewalks, of less than [3] m or in excess of [14] m. Sidewalk should comply with a minimum width of [1,7] m.

6.1.10 Clearances

6.1.10.1 General

The horizontal clearance shall be the clear width, and vertical clearance the clear height for the passage of vehicular traffic.

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.

6.1.10.2 General clearances

6.1.10.2.1 Vertical clearance

Vertical clearance shall not be less than [5,5] m over the entire roadway width with an allowance of [0,3] m for resurfacing.

6.1.10.2.2 Horizontal clearance

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

6.1.10.3 Clearance for underpasses

6.1.10.3.1 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 [0,7] m from the face of pier or abutment. The face of the guardrail or other device shall be at least [0,7] m outside the normal shoulder line.

6.1.10.3.2 Vertical clearance

A vertical clearance of not less than [5,5] m shall be provided between curbs, or if curbs are not used, over the entire width that is available for traffic.

6.1.10.4 Clearance for depressed roadways

6.1.10.4.1 Clearance between walls

The minimum width between walls for depressed roadways carrying two lanes of traffic shall be [9] m.

6.1.10.4.2 Curbs

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

6.1.11 Maximum skew angle

Bridges designed according to this document should have a low skew angle, not exceeding [30]°.

6.1.12 Maximum bridge horizontal curvature

Bridges designed according to this document should have a maximum length to horizontal curvature radius of [4] %.

6.1.13 Cross-section variation

Bridges designed according to this document should have a constant cross-section along the continuous portions of the bridge, except in cantilever sections.

6.1.14 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 allow movement in the deck longitudinal direction.

6.2 Limit states

The design approach of this document 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 document.

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 this document.

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

$$R \geq S \quad (1)$$

where

R is the resistance;

S is the load effect.

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 of concrete, or both, by means of dividing these values by the corresponding material factors [see [Formula \(2\)](#)]:

$$R = f \left(\frac{f_c'}{\gamma_{mc}}, \frac{f_y}{\gamma_{ms}} \right) \geq \gamma_1 S_1 + \gamma_2 S_2 + \gamma_3 S_3 + \dots \quad (2)$$

where

R is the strength;

S is the load effect based on the nominal loads prescribed by this document.

Therefore, the ultimate limit state design format shall meet [Formula \(3\)](#) or [Formula \(4\)](#):

$$R_d \geq U \quad (3)$$

$$R_d = f \left(\frac{f_c'}{\gamma_{mc}}, \frac{f_y}{\gamma_{ms}} \right) \geq U \quad (4)$$

where

R_d is the design strength;

U is the required factored strength;

$$U = \gamma_1 S_1 + \gamma_2 S_2 + \dots$$

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 [8.10.1](#).

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 this document, based on the limit stress reduced according to each corresponding material as per [Table 4](#):

Table 4 — Material factor

Material	Factor
Concrete, γ_{mc}	[1,5]
Steel, γ_{ms}	[1,5]

A more detailed explanation on the material factor is provided in [Annex A](#).

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. Compliance with the serviceability limit state in this document should be obtained indirectly through 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 that is sufficient to cause significant reduction in the strength of the structure or in its service life.

On the other hand, fatigue can be separately considered in the fatigue limit state design format.

7 Structural systems and layout

7.1 Description of the components of the structure

7.1.1 General

For the purposes of this document, the bridge structure should be divided in the following components.

7.1.2 Superstructure system

The superstructure consists of the structural elements that comprise the portion of the bridge that directly receive the live load. The superstructure system corresponds to the box girder in box girder bridges. 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.

7.1.3 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. According to this document the main vertical elements of the substructure system should be cantilever piers, frames or structural concrete walls, and are described in [Clause 15](#).

7.1.4 Foundation

The foundation comprises all structural elements that serve to transmit loads from the structure to the underlying supporting soil, or are in contact with the soil, or serve to contain it. 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.

7.2 General guide

7.2.1 Architectural guide

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 guide 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 guide 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; and
- environmental and visual impact.

7.2.2 General structural guides for the project

Based on the general architectural guide information, the structural designer should define the general structural guides for the structure being designed according to this document. 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;

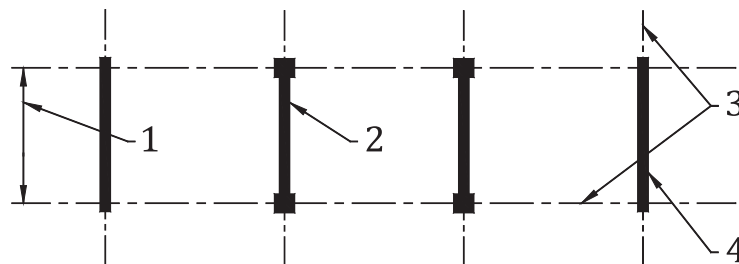
- availability, type, and quality of materials such as reinforcing steel, cement and aggregates;
- availability of materials for formwork erection;
- availability of testing facilities for concrete mix design and quality control during construction; and
- availability of qualified workforce.

7.3 Structural layout

7.3.1 General structural layout

The structural designer should define a general structural layout in plan (see [Figure 2](#)). The general structural layout in plan should include:

- dimensioned grid for axes, or centrelines, 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; and
- horizontal distance between centrelines, S , which corresponds to the centre-to-centre span lengths, and horizontal distance, B , which corresponds to the centre-to-centre breadth, of the superstructure system.



Key

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

Figure 2 — General structural layout in plan

7.3.2 Vertical layout

The structural designer should define a general structural vertical layout (see [Figure 3](#)). 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 this document or local highway specifications, whichever is larger; and
- supporting soil stratum depth, and water table depth.