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Simplified design of prestressed concrete bridges —

Part 1:
I-girder bridges

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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 I-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 on 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 1:
I-girder bridges

1 Scope

This document provides information to perform the design of the prestressed concrete I-girder bridge for road that complies with the limitations established in 6.1. The rules of design set forth in this document are simplifications of more elaborate requirements.

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 terminological databases for use in standardization at the following addresses:

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

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

3.1
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
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* (3.31), and subjected primarily to flexure

3.4
clearance
distance by which one thing clears another; the space between them

3.5
compression reinforcement
reinforcement provided to resist compression stresses induced by flexural moments acting on the member section

3.6
specified compressive strength
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' in 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).

3.7
confinement hook
hook (3.22) on a *stirrup* (3.46), hoop, or *crosstie* (3.11) having a bend not less than 135° with a six-diameter (but not less than 75 mm) extension that engages the *longitudinal reinforcement* (3.32) and projects into the interior of the stirrup or hoop

3.8
confinement stirrup
closed *stirrup* (3.46), *tie* (3.49) or continuously wound spiral

Note 1 to entry: A closed stirrup or tie can be made up of several reinforcement elements each having *confinement hooks* (3.7) at both ends. A continuously wound spiral should have a confinement hook at both ends.

3.9
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

3.10
cover
thickness of concrete between surface of any reinforcing bar and the nearest face of the concrete member

3.11
crosstie
continuous reinforcing bar having a 135° *hook* (3.22) 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.

3.12
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 in 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* (3.35) multiplied by a *strength reduction factor* (3.47)

3.14
development length
length of embedded reinforcement required to develop the *design strength* (3.13) of reinforcement at a critical section

3.15
development length
<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* (3.22)

3.16
duct
material creating a conduit in a concrete member to accommodate the *prestressing steel* (3.38) of a *post-tensioning* (3.37) *tendon* (3.48)

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
embedment length
length of embedded reinforcement provided beyond a critical section

3.20
factored loads
specified *nominal loads* (3.34) (forces) multiplied by the *load factors* (3.30) prescribed in this document

3.21
girder
main horizontal support *beam* (3.3), usually supporting other beams

3.22
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.

3.23
jacking force
temporary force in prestressed concrete, exerted by the device that introduces tension into the *tendons* (3.48)

3.24
joist
T-shaped *beam* (3.3) used in parallel series directly supporting deck *loads* (3.31), and supported in turn by larger *girders* (3.21), beams, or bearing structural concrete walls

3.25
lap splice
splice between two reinforcing bars obtained by overlapping them for a specified length

3.26
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)

3.27
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* (3.31)

3.28
load combination
combination of *factored loads* (3.20) and forces as specified in this document

3.29
load effect
force and deformation produced in structural members by the applied *loads* (3.31)

3.30
load factor
factor that accounts for deviations of the actual *load* (3.31) from the *nominal load* (3.34), for uncertainties in the analysis that transforms the load into a *load effect* (3.29), and for the probability that more than one extreme load will occur simultaneously

3.31
load
force or other action that results from the weight of all bridge materials, pedestrians, vehicles, environmental effects, differential movement, and restrained dimensional changes

3.32
longitudinal reinforcement
reinforcement that is laid parallel to the longitudinal axis of the element, generally to account for flexural effects

3.33
mesh wire
welded-wire fabric reinforcement

3.34
nominal load
magnitude of the *loads* (3.31) specified in this document (dead, live, soil, wind, snow, rain, flood, and earthquake)

3.35
nominal strength
capacity of a structure or member to resist the effects of *loads* (3.31), 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.

3.36
permanent load
load (3.31) in which variations over time are rare or of small magnitude

Note 1 to entry: All other loads are variable loads (see also 3.34).

3.37
post-tensioning
method of prestressing reinforced concrete in which *tendons* (3.48) are tensioned after the concrete has attained a specified minimum strength or a specified minimum age

3.38
prestressing steel
high-strength steel elements such as wire, bar, or strands used to impart prestress forces to concrete

3.39
pretensioning
method of prestressing in which *prestressing steel* (3.38) is tensioned before the concrete is placed

3.40
required factored strength
strength of a member or cross-section required to resist *factored loads* (3.20) or related internal moments and forces in such combinations as are stipulated by this document

3.41
service load
load (3.31) specified by this document [without *load factors* (3.30)]

3.42
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

3.43
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

3.44
slab (deck)
upper flat part of a reinforced concrete deck carried by supporting *joists* (3.24), *beams* (3.3) or *girders* (3.21)

3.45
spiral reinforcement
continuously wound reinforcement in the form of a cylindrical helix

3.46
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* (3.32). (The term "stirrups" is usually applied to lateral reinforcement in *girders* (3.21), *beams* (3.3) and *joists* (3.24). The term "ties" to those in columns and walls, perhaps because they are intended also as confinement for the longitudinal reinforcement.) See also 3.49.

3.47
strength reduction factor
coefficient that accounts for deviations of the actual strength from the *nominal strength* (3.35), 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* (3.29) being considered, and to reflect the importance of the element in the structure.

3.48
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

3.49
tie
loop of reinforcing bar or wire enclosing *longitudinal reinforcement* (3.32)

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.

3.50
transfer length
length from the end of the member where the *tendon* (3.48) stress is zero to the point along the tendon where the prestress is fully effective

3.51
transverse reinforcement
reinforcement located perpendicular to the longitudinal axis of the element, comprising *stirrups* (3.46), *ties* (3.49), *spiral reinforcement* (3.45), among others

3.52
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_0	acceleration limit	g
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_p	peak acceleration	g
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_{cc}	area of the confined column core, in a column with spiral reinforcement, measured centre to centre of the spiral	mm^2
A_{conf}	bearing area of the confined concrete in local zone	mm^2
A_{cv}	area of concrete section resisting shear transfer	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
$A_{ps,d}$	area of prestressing steel corresponding to concrete deck	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_{ss}	area of spiral reinforcement	mm^2

Symbol	Explanation	Unit
A_{st}	total area of longitudinal reinforcement	mm^2
A_v	area of shear reinforcement (stirrup) within a distance s	mm^2
A_{vf}	area of interface shear reinforcement	mm^2
A_{vpc}	area of additional reinforcement across the interface shear plane	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_f	effective width of the compression flange in a T-shaped section	mm
$b_{g,uf}$	width of upper flange of girder	mm
b_{vi}	width of interface	mm
b_w	web width of girder or beam	mm
c_i	cohesion factor at interface	MPa
d	effective depth of reinforcement	mm
d'	distance from extreme compression fiber 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_c	distance from extreme tension fiber to centroid of tension reinforcement	mm
d_{cc}	centre-to-centre diameter of spiral	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
d_v	distance between the centroid of the tension steel and the mid-thickness of the slab to compute a factored interface shear stress	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
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
$f_{c,d}'$	specified compressive strength of concrete deck	MPa
f_{cd}'	compressive strength of concrete reduced by the material factor	MPa
$f_{c,g}'$	specified compressive strength of concrete girder	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 prestressing force immediately after transfer and the self-weight of the member at the section of maximum moment	MPa
$f_{c,QP}$	stress in the concrete adjacent to the tendons, due to self-weight and initial prestress and other quasi-permanent actions	MPa
f_{nf}	natural frequency of floor structure	1/s
f_{pe}	effective stress in the prestressing steel after losses	MPa