

Eurocode 4: Design of composite steel and concrete structures —

Part 2: Composite bridges

**(together with United Kingdom
National Application Document)**

ICS 93.040

Committees responsible for this Draft for Development

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British Cement Association
British Constructional Steelwork Association
British Precast Concrete Federation
Concrete Society
County Surveyors' Society
Department of the Environment, Transport and the Regions (DETR) —
Highways Agency
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Railtrack plc
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UK Steel Association
Welding Institute

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National foreword

This Draft for Development has been prepared by Subcommittee B/525/10 and comprises the English language version of ENV 1994-2:1997, *Eurocode 4: Design of composite steel and concrete structures — Part 2: Composite bridges*, as published by the European Committee for Standardization (CEN), and the National Application document (NAD) for use with the ENV for the design of bridges to be constructed in the United Kingdom (UK).

ENV 1994-2:1997 results from a programme of work sponsored by the European Commission to make available a common set of rules for the structure and design of building and civil engineering works.

This publication is not to be regarded as a British Standard.

An ENV is made available for provisional application, but does not have the status of a European Standard. The aim is to use the experience gained to modify the ENV so that it can be adopted as a European Standard (EN).

The values for certain parameters in the ENV Eurocodes may be set by CEN members to conform to the requirements of national regulations. These parameters are designated by □ (boxed values) in the ENV. The values to be used in the UK are tabulated in this NAD.

During the ENV period of validity, reference should be made to the supporting documents listed in the NAD.

The purpose of the NAD is to provide essential information, particularly in relation to safety, to enable the ENV to be used for bridges constructed in the UK. The NAD takes precedence over corresponding provisions in the ENV.

The Building Regulations 1991, Approved Document A 1992 (published December 1991) [1], draws designers' attention to the potential use of ENV Eurocodes as an alternative approach to Building Regulation compliance. ENV 1994-2:1997 has been thoroughly examined over a period of several years and is considered to offer such an alternative approach when used in conjunction with this NAD.

Users of this document are invited to comment on its technical content, ease of use and any ambiguities or anomalies. These comments will be taken into account when preparing the UK national response to CEN on the question of whether the ENV can be converted to an EN.

Comments should be sent in writing to BSI, 389 Chiswick High Road, London W4 4AL, quoting the document reference, the relevant clause and, where possible, proposed revision, within two years of the issue of this document.

Compliance with ENV 1994-2:1997 and this NAD does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, and inside front cover, pages i to xvii, a blank page, an inside back cover, the ENV title page, pages 2 to 98, and a back cover.

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National Application Document

for use in the UK with ENV 1994-2:1997

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National Application Document**

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Introduction

This National Application Document (NAD) has been developed from:

- a) a textual examination of ENV 1994-2:1997;
- b) a calibration against UK practice, supporting standards and test data;
- c) trial calculations.

1 Scope

This NAD provides information required to enable ENV 1994-2:1997 (hereafter referred to as EC4-2) to be used with ENV 1994-1-1:1992, as qualified by its NAD, for the design of bridges to be constructed in the UK. Where there is conflict between the NADs for ENV 1994-1-1 and ENV 1994-2, the NAD for ENV 1994-2 is to govern.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this NAD. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS EN ISO 13918, *Welding — Studs and ceramic ferrules for arc stud welding*.

BS EN ISO 14555, *Welding — Arc stud welding of metallic materials*.

ENV 1991-1, *Eurocode 1: Basis of design and actions on structures — Part 1: Basis of design*.

ENV 1991-2-1, *Eurocode 1: Basis of design and actions on structures — Part 2-1: Actions on structures — Densities, self-weight and imposed loads*.

ENV 1991-2-3, *Eurocode 1: Basis of design and actions on structures — Part 2-3: Actions on structures — Snow loads*.

ENV 1991-2-4, *Eurocode 1: Basis of design and actions on structures — Part 2-4: Actions on structures — Wind actions*.

ENV 1991-2-6, *Eurocode 1: Basis of design and actions on structures — Part 2-6: Actions on structures — Actions during execution*.

ENV 1991-3, *Eurocode 1: Basis of design and actions on structures — Part 3: Traffic loads on bridges*.

ENV 1998-2, *Eurocode 8: Design provisions for earthquake resistance of structures — Part 2: Bridges*.

ENV 206, *Concrete — Performance, production, placing and compliance criteria*.

ENV 1090-5, *Execution of steel structures — Part 5: Supplementary rules for bridges*.

ENV 1991-2-5, *Eurocode 1: Basis of design and actions on structures — Part 2-5: Actions on structures — Thermal actions*.

ENV 1991-2-7, *Eurocode 1: Basis of design and actions on structures — Part 2-7: Actions on structures — Accidental actions due to impact and explosions*.

ENV 1992-1-1, *Eurocode 2: Design of concrete structures — Part 1: General rules and rules for buildings*.

ENV 1992-1-3, *Eurocode 2: Design of concrete structures — Part 1-3: General rules — Precast concrete elements and structures*.

ENV 1992-1-4, *Eurocode 2: Design of concrete structures — Part 1-4: General rules — Lightweight aggregate concrete with closed structure.*

ENV 1992-1-6, *Eurocode 2: Design of concrete structures — Part 1-6: General rules — Plain concrete structures.*

ENV 1992-2, *Eurocode 2: Design of concrete structures — Part 2: Concrete bridges.*

ENV 1993-1-1, *Eurocode 3: Design of steel structures — Part 1-1: General rules and rules for buildings.*

ENV 1993-1-3, *Eurocode 3: Design of steel structures — Part 1-3: General rules — Supplementary rules for cold formed thin gauge members and sheeting.*

ENV 1993-1-5, *Eurocode 3: Design of steel structures — Part 1-5: General rules — Supplementary rules for planar plated structures without transverse loading.*

ENV 1993-2, *Eurocode 3: Design of steel structures — Part 2: Steel bridges.*

ENV 1994-1-1, *Eurocode 4: Design of composite steel and concrete structures — Part 1.1: General rules and rules for buildings.*

ENV 10080, *Steel for the reinforcement of concrete — Weldable ribbed reinforcing steel B500 — Technical delivery conditions for bars, coils and welded fabric.*

ISO 3898, *Bases for design of structures — Notations — General symbols.*

3 Partial safety factors, combination factors and other values

- a) The values for combination factors (ψ) for bridges should be those given in Tables 3 and 4 of the NAD for use with ENV 1991-3:1994.
- b) The values for partial safety factors (γ) should be those given in ENV 1994-1-1 and ENV 1994-2, except as modified by the relevant UK NADs.
- c) Other values should be those given in ENV 1994-2 as modified by Table 1 of this NAD.

Table 1 — Values to be used in referenced clauses instead of boxed values

Reference in ENV 1994-2	Definition	Symbol	Condition	Value	
				Boxed EC4.2	UK NAD
2.3.3.1(5)	Partial safety factor for prestress imposed by jacking	γ_p	Ultimate	1.0	1.0
2.3.3.1(6)	Partial safety factor for nominal free shrinkage		Ultimate	1.0	1.0
Table 2.3	Partial safety factors for resistances and material properties for — structural steel — structural steel Class 4 compression — concrete — steel reinforcement and prestressing tendons — profiled steel sheeting	γ_a γ_{Rd} γ_c γ_s γ_{ap}	Ultimate fundamental	1.0 1.10 1.5 1.15 1.10	1.0 1.10 1.5 1.15 1.10
Table 2.3	Partial safety factors for resistances and material properties for — structural steel — structural steel Class 4 compression — concrete — steel reinforcement and prestressing tendons — profiled steel sheeting	γ_a γ_{Rd} γ_c γ_s γ_{ap}	Ultimate accidental	1.0 1.0 1.3 1.0 1.0	1.0 1.0 1.3 1.0 1.0
2.3.4(6)	Partial safety factor for materials at serviceability	γ_M	Serviceability	1.0	1.0
4.4.1.4(3)	Partial safety factor for structural steel in compression for Class 4 sections	γ_{Rd}	Ultimate	1.10	1.10
4.7.2(6)	Additional partial safety factor on shear connectors	γ_F	Ultimate	1.25	1.25
5.2(2)	Factor of $f_c(t)$	—	Serviceability	0.6	0.6
5.2(3)	Factor of f_{ck}	—	Serviceability	0.6	0.6
5.2(5)	Factor of f_{sk}	—	Serviceability	0.8	0.8
5.2(6)	Factor of f_{pk}	—	Serviceability	0.65	0.65
5.2(7)	Factor of $f_c(t)$	—	Serviceability	0.6	0.6
5.2(7)	Limit by which $0.6 f_c(t)$ may be exceeded during construction	—	Serviceability	10 %	10 %
6.1.5(4)	Partial safety factor for stud shear connectors	$\gamma_{Mf,v}$	Fatigue	1.0	1.0
6.3.2.1(1)	Partial safety factors for headed studs	γ_v	Ultimate	1.25	1.25

4 Loading codes

The loading codes to be used are (as qualified by the relevant UK NADs):

ENV 1991-1, *Eurocode 1: Basis of design and actions on structures — Part 1: Basis of design.*

ENV 1991-2-1, *Eurocode 1: Basis of design and actions on structures — Part 2-1: Densities, self-weight and imposed loads.*

ENV 1991-2-3, *Eurocode 1: Basis of design and actions on structures — Part 2-3: Snow loads.*

ENV 1991-2-4, *Eurocode 1: Basis of design and actions on structures — Part 2-4: Wind loads.*

ENV 1991-2-6, *Eurocode 1: Basis of design and actions on structures — Part 2-6: Loads and deformations imposed during execution.*

ENV 1991-3, *Eurocode 1: Basis of design and actions on structures — Part 3: Traffic loads on bridges.*

ENV 1998-2, *Eurocode 8: Design provisions for earthquake resistance of structures — Part 2: Bridges.*

ENV 1991-2-5, *Eurocode 1: Basis of design and actions on structures — Part 2-5: Thermal actions.*

ENV 1991-2-7, *Eurocode 1: Basis of design and actions on structures — Part 2-7: Accidental actions due to impact and explosions.*

Where any of the above codes have not been published, the UK supporting standard should be used as indicated in clause 5.

5 Reference standards

Standards including materials specifications and standards for construction are listed for reference purposes in Table 2. Published ISO and CEN standards are not included in Table 2.

Table 2 — References in ENV 1994-2 to other publications, together with additional relevant documents

Reference in EC4-2	Document referred to	Document title or subject area	Status	UK Document	DMRB Document ^a
1.1.2(6), 1.4.3(3), 1.6.1(1), 1.7(3), 2.2.1.1(4), 2.3.2.4(1), 2.3.3.2(5), 2.3.4(6), 2.4(4), 3.3.1(1), 3.3.1(2), 3.3.2(1), 3.3.5(1), 3.3.6(1), 4.1.1(2), 4.1.1(3), 4.4.2(1), 4.4.3(2), 4.6.2(1), 4.6.3(1), 4.6.3(2), 4.11(1), 4.11(3), 4.12.1(3), 4.12.2(2), 4.12.2(3), 4.12.2(4), 4.12.3(4), 4.12.5(3), 4.12.6(1), 5.2(8), 5.5(1), 6.1.5(2), 6.1.5(4), 6.1.5(5), 6.1.5(7), 6.5(1), K.4.4(1)	ENV 1993-2	Steel bridges	Published 1997	BS 5400-3	BD 13 [2]
1.1.2(8)	ENV 1090-5	Fabrication and erection of steel structures	Draft	BS 5400-6	Specification for Highway Works [3]
1.3(1), 2.3.3.2(3), 2.3.4(7), 3.1.2(1), 3.1.2(3), 3.1.3(1), 3.1.3(2), 3.1.4(1), 3.1.4.2(1), 3.1.5(1), 3.2.1(1), 3.2.2(1), 3.2.4(1), 3.6(1), 4.2.1(3), 4.2.2.3(1), 4.2.3(4), 4.4.1.3(3), 4.4.1.3(4), 4.4.1.4(3), 4.5.3.5(1), 4.7.2(1), 4.7.2(4), 4.7.2(5), 4.11(2), 5.2(7), 5.3.1(6), 5.3.2.2(1), 6.4.5(1), 6.6.2(1), 6.6.4(1), 6.6.5, 7.7.2(3), 7.7.3(2), 9.4.3.2(1), 9.4.3.2(2)	ENV 1992-1-1	Concrete structures	Published 1991	—	—
1.3(1), 1.4.3(4), 1.6.7(1), 1.6.8(1), 3.2.4(1), 4.3.2(2), 4.4.1.1(6), 4.4.3(1), 6.1.5(7), 6.5(1), 9.4.3.2(1), 9.4.3.3(2), 10.1(1), 10.1(2)	ENV 1993-1-1	Steel structures	Published 1992	—	—
1.4.2.7, 1.4.3(6), 2.3.3.2(4), 3.4(1), 4.6.2(2), 4.8.1(4), 6.3.2.1(2), 6.3.3(1), 6.4.3(1), 6.4.5(2), 6.6.3(1), 9.4.4(1), 10.3(1)	ENV 1994-1-1	Composite steel and concrete structures	Published 1994	—	—
1.4.3(1), 2.2.2.3(4), 2.2.5(1), 2.3.2.2(1), 2.3.3.1(3), 2.3.4(2), 4.5.3.4(5), 4.12.2(1), 4.12.2(2), 4.12.3(2), 4.12.4(7), 5.1.4.1(4), 5.4(5), 5.5(1), 6.1.5(6)	ENV 1991-3	Traffic loads on bridges	Published 1995	BS 5400-2	BD 37 [4]
^a DMRB Design Manual for Roads and Bridges.					

Table 2 — References in ENV 1994-2 to other publications *(continued)*

Reference in EC4-2	Document referred to	Document title or subject area	Status	UK Document	DMRB Document ^a
1.4.3(2), 1.6.1(1), 1.7(3), 2.2.1.1(4), 2.3.3.1(4), 2.4(3), 3.1.3(3), 4.1.1(2), 4.1.1(10), 4.5.3.4(3), 4.7.2(1), 4.8.2.5(2), 4.8.3.13(6), 4.12.1(2), 4.12.2(2), 4.12.2(5), 4.12.3(3), 4.12.5(1), 4.12.5(2), 4.12.6(1), 4.12.6(3), 4.12.6(4), 5.1.2(1), 5.1.2(2), 5.1.2(3), 5.2(2), 5.2(3), 5.2(5), 5.2(6), 5.2(7), 5.3.1(2), 5.3.1(7), 5.3.2.1(1), 5.3.2.2(2), 5.5(1), 6.4.1.2(2), 8.1(2), K.2(3), K.4.2(2), K.4.3(1), K.4.3(2), K.5.1(1), K.5.3(1), K.5.4(1), L.5.2(3)	ENV 1992-2	Concrete bridges	Published 1996	BS 5400-4	BD 24/92 [5]
1.4.3(5), 1.6.1(1), 2.2.1.1(4), 4.2.1(6), 4.2.2.1(2), 4.2.2.2(1), 4.2.2.2(6), 4.2.2.3(2), 4.3.1(11), 4.4.1.2(5), 4.4.1.4(1), 4.4.2(1), 4.4.3(3), 4.4.5, 4.4.6(1)	ENV 1993-1-5	Steel plated structures	Published 1997	BS 5400-3	BD 13/90 [2]
1.6.1(1)	ISO 3898	Basis for design of structures: general symbols	Published 1997	—	—
1.7(3), 2.2.5, 2.3.3.2(6), 2.3.4(2), 10.1(2)	ENV 1991-1	Basis of design	Published 1994	BS 5400-1	BD 15/92 [6]
1.7(3), 6.3.2.1(1), 9.4.3.1(1)	EN ISO 14555	Arc stud welding	Published 1998	BS EN ISO 14555	—
1.7(3), 3.5.2(7), 6.3.2.1(2), 9.4.3.1(1)	EN ISO 13918	Welding studs for arc stud welding	Published 1998	BS EN ISO 13918	—
2.2.2.2(7), 2.2.2.3(4)	ENV 1991-2-6	Loads and deformations during erection	Draft	BS 5400-2	BD 37/88 [4]
2.3.3.1(1)	ENV 1991	Basis of design and actions on structures	Various	BS 5400-2	BD 37/88 [4]
3.1.2(4), 3.1.2(5), 3.1.4.1(3), 3.1.4.2(1), 6.3.8(3)	ENV 1992-1-4	Lightweight concrete structures	Published 1996	—	—
^a DMRB Design Manual for Roads and Bridges.					

Table 2 — References in ENV 1994-2 to other publications (*concluded*)

Reference in EC4-2	Document referred to	Document title or subject area	Status	UK Document	DMRB Document ^a
3.1.3(2)	ENV 206	Concrete classes	Published 1990	—	—
3.1.6(1), 5.1.3(8), 6.2.5(1)	ENV 1991-2-5	Thermal actions	Draft	BS 5400-2	BD 37/88 [4]
3.2.2(1)	ENV 10080	Ribbed bars or wires	Published 1995	—	—
4.5.3.5(1)	ENV 1992-1-6	Plain concrete structures	Published 1994	—	—
4.11(5), 7.1.1(5)	ENV 1993-1-3	Cold formed thin gauge members and sheeting	Draft	—	—
8.4(3)	ENV 1992-1-3	Precast concrete	Published 1994	—	—
(ENV 1994-1-1) 9.1(4), ENV note at the end of 9.1	Reference standards or other documents	Responsibility or other requirements to the contractor	—	Contractor's obligations stated in contract documents, e.g. drawings specification bills of quantities contract	Specification for Highway Works [3]
^a DMRB Design Manual for Roads and Bridges.					

6 Additional recommendations

6.1 Guidance on EC4-2

NOTE 6.1.1 to 6.1.11 should be followed when designing in accordance with EC 4-2.

6.1.1 Foreword

a) Paragraph (18)

The relevant authorities are the Technical Approval Authorities such as the Highways Agency, Highways Directorate of the National Assembly for Wales, Scottish Executive National Roads Directorate, Northern Ireland Department of Environment, Local Authorities (County Council Highways Departments etc.), Railtrack, London Underground, British Waterways Board, Docklands Light Railway, etc.

b) Paragraph (20)

All references to ENV 1994-1-1 in EC4-2 should be interpreted as being to ENV 1994-1-1 as qualified by its UK NAD.

6.1.2 Section 1. General

- a) Clause **1.1.2(2)P**
Unless otherwise agreed by the relevant authorities, the relevant clauses of ENV 1994-2 may be used for the design of cable stayed bridges and bridges incorporating unbonded tendons.
- b) Clause **1.2(5)**
Alternative design rules different from the Application Rules should not be used without the specific approval of the relevant authority.
- c) Clause **1.7(2)**
All references to any ENV should be interpreted as being to that ENV as qualified by its UK NAD.

6.1.3 Section 2. Basis of design

- a) Clause **2.2.1.2(2)**
Strength and stability should be checked for the construction stage where the partially constructed beam (particularly a steel beam acting non-compositely) supports the formwork and the imposed load of fresh concrete plus construction loads or temporary storage loads.

6.1.4 Section 3. Materials

- a) Clause **3.3.1(1)**
S420 and S460 steel should not be used in composite compression members.
- b) Clause **3.4(1)**
Profiled steel sheeting should not be used for composite slabs without the specific approval of the relevant authority. Profiled steel sheeting may be used as non-participatory permanent formwork.

6.1.5 Section 4. Ultimate limit states

- a) Clause **4.1.1(10)**
In most cases, the width of the local actions (being approximately equal to the width of a vehicle) will be less than the effective width and therefore not “comparable”.

Combinations of these global and local effects will therefore generally not need to be considered.
- b) Clause **4.2.2.2(2)**
For other types of shear connector, b_0 is measured from the edge of the connector.
- c) Clause **4.3.3(1)**
This clause defines the stress distribution to be used in determining the classification of webs, particularly at the boundaries between classes. Plastic distribution should be used for the Class 1/2 and Class 2/3 boundaries and elastic distribution for the Class 3/4 boundary.
- d) Clause **4.4.1.4(3)P**
Where the compression flange of structural steel is in an effective cross-section in Class 4 and is adequately restrained by shear connection to a reinforced concrete deck slab, the limiting stress may be taken as f_y/γ_a .
- e) Clause **4.4.2(1)P**
A contribution from the reinforced concrete part of the beam to the resistance to vertical shear should not be considered without the specific approval of the relevant authority.
- f) Clause **4.5.3.4**
For the majority of bridges, the methods given in paragraphs (3) and (4) will be appropriate.

- g) Clause **4.5.4(1)**
Non-linear global analysis which models the non-linear behaviour caused by yielding of structural steel, reinforcement or prestressing steel should not be used without the specific approval of the relevant authority.

In addition to the effects listed, consideration should also be given to the non-linear behaviour of concrete under load and the maximum allowable fabrication and construction tolerances of the composite member and its elements.
- h) Clause **4.6.2(2)**
Reference may also be made to annex F of ENV 1993-1-1:1992 in order to calculate M_{cr} .
- i) Clause **4.8.1(4)**
S420 and S460 steel should not be used in composite compression members.
- j) Clause **4.8.2.7(2)**
The design shear strength due to bond and friction for completely concrete encased sections should be taken as 0.4 N/mm^2 .
- k) Clause **4.8.3.13(8)**
Typographical error: **4.8.3.11(3)** for γ_{Ma} should read **4.8.3.2(1)**.
- l) Clause **4.12.3(3)**
The factored load model is only used for the verification of concrete and reinforcing and prestressing steel.
- m) Clauses **4.12.4, 4.12.6**
For the majority of bridges, the simplified method of assessment in **4.12.6** will be appropriate using the simplified methods of calculating the stress range $\Delta\sigma_E$ given in **4.12.4**; i.e. there will be no need to use annex L.
- n) Clause **4.12.4(8)**
 $M_{min,f}$ in last line should read $M_{min,F,E}$
- o) Clause **4.12.5(1)**
This generally means that no fatigue verification for concrete is required; see **5.2(3)** and ENV 1992-2:1996, **4.3.7.4** and Figure 4.134.
- p) Clause **4.12.6(3)**
Reference should also be made to ENV 1992-2:1996, **4.3.7.1** (102), as amended by its NAD, which lists circumstances where a fatigue verification is generally not necessary.

6.1.6 Section 5. Serviceability limit states

- a) Clause **5.1.2(2)**
For the appropriate design category, reference should be made to the NAD for ENV 1992-2.
- b) Clause **5.1.4.1(1)**
Torsional warping, distortional warping and distortional bending stresses should be considered in the design of box girders.
- c) Clause **5.1.4.1(4)**
A combination factor $\psi = 1$ means that the stresses due to global and local effects are added without any reduction.
- d) Clause **5.3.1(2)**
Reference should be made to the NAD for ENV 1992-2 for the appropriate design category to be used.
- e) Clause **5.3.1(4)**
Design crack width limits should either be in accordance with **5.3.1(6)**, **5.3.1(7)**, **5.3.2** and **5.3.3**, agreed with the client or as specified in the NAD to ENV 1992-2.

6.1.7 Section 6. Shear connection**a) Clause 6.2.4.3(5)**

The maximum shear force equation given may be used for stud shear connectors. For other types of connector, the maximum shear force per unit length is given by:

$$V_{d,max} = 2V_1(e_d + b_{eff} / 2)$$

b) Clause 6.3.2.1

The following text is intended as a note to **6.3.2.1**.

NOTE The minimum ultimate tensile strength of the material of a headed stud is usually specified in the UK as 495 N/mm².

c) Clause 6.3.2.2(2)

Where the force $F_{t,Sd}$ exceeds 0.1 P_{Rd} , the following interaction criterion may be used for normal density concrete:

$$(T_u / T_{Rd})^{5/3} + (P_u / P_{Rd})^{5/3} \leq 1$$

where

T_u = tension applied to stud at ultimate;

P_u = shear applied to stud at ultimate;

$$T_{Rd} = 1.33h (h/d + 1.5) (f_{ck}')^{1/2} d/\gamma_v \leq (\pi/4)f_u d^2/\gamma_v.$$

T_u should not exceed 0.5 T_{Rd} . Attention should be given to ensuring that tension on a group of studs does not result in a group failure and that the tension can be satisfactorily distributed into the section.

d) Clause 6.3.4(5)

The leg length of the weld between a block connector and the plate to which it is attached should not exceed half the thickness of the plate.

e) Clause 6.3.6(3)

The leg length of the weld between a block connector with anchor or hoop and the plate to which it is attached should not exceed half the thickness of the plate.

f) Clause 6.3.7(3)

The leg length of the weld between an angle connector and the plate to which it is attached should not exceed half the thickness of the plate.

g) Clause 6.5(1)

Friction grip bolts as shear connection should not be used without the specific approval of the relevant authority.

h) Clause 6.5(2)

For the coefficient of friction to be used between steel and concrete, see **6.1.9a)** of this NAD.

i) Clause 6.5(3)

The category of bolted connection in accordance with ENV 1993-1-1:1992, **6.5.3.1** may usually be taken as Category B, i.e. no slip at serviceability.

j) Clause 6.5(4)

Detailing of friction grip bolts should be in accordance with ENV 1994-1-1:1994, **6.5.4**.

k) Figure 6.12

In the diagram showing potential surface of shear failure type c-c, the hoop should have been shown extending above the A_b reinforcement in order to give a 30 mm clear distance in accordance with ENV 1994-1-1:1994, **6.4.1.1**.

l) Clause **6.6.2(2)**

In beams where the design loading causes transverse sagging bending in the slab in the region of the shear connectors, account should be taken of the effect of this where the shear plane does not cross the whole depth of the slab but does intersect with the reinforcement required to resist the tension caused by this sagging bending (types b-b and c-c in Figure 6.12 but not a-a and d-d).

The area of reinforcement A_e should be taken as:

$$A_e = 2 A_{\text{tension}}$$

where

A_{tension} = area of reinforcement required to resist tension

m) Clause **6.6.2(2)**

In beams where the design loading causes transverse tension in the slab (for example, transverse composite beams in the deck of a composite tied arch), consideration should be given to the effect of this tension in calculating the area of reinforcement available to resist longitudinal shear for shear failure types a-a, b-b, c-c and d-d in Figure 6.12.

6.1.8 Section 7. Composite slabs with profiled steel sheeting and composite plates

a) Clause **7.1.1(5)**

Profiled steel sheeting should not be used for composite slabs without the specific approval of the relevant authority. If profiled steel sheeting is used, the applicability of **7.1** to **7.6** as well as **3.4**, **4.2.1(4)**, **6.3.3**, **6.4.3**, **6.6.3**, **9.4.4**, **10.3** and annex E should be agreed with the relevant authority.

Profiled steel sheeting may be used as non-participatory permanent formwork for slabs.

6.1.9 Section 8. Decks with precast concrete slabs

a) Clause **8.4(2)**

For steel surfaces blasted with shot or grit and either spray-metallized with aluminum or with loose rust removed and no pitting, the friction coefficient between slab and steel beam may be taken as 0.5.

6.1.10 Section 9. Execution

a) Clause **9.3**

In particular, consideration should be given to:

i) The stability of non-composite steelwork, see ENV 1994-1-1:1994, **9.3** and **6.1.3a**) of this NAD.

ii) The out-of-balance loading that may occur during concreting or the placing of precast slabs. If the concrete is placed in the bay on one side of a beam and not on the other, a torsional load may be applied to the beam which could affect its stability.

6.1.11 Annex Ca) Clause **C.6.2(1)**

In equation C.10, $(h - 2t_f)t_w^2$ should read $(h - 2t_f)^2 t_w$

6.1.12 Annex Ka) Clause **K.4.3(1)**

A contribution from the reinforced concrete part of the beam to the resistance to vertical shear should not be considered without the specific approval of the relevant authority.

6.1.13 Annex L

- a) This annex will not generally need to be used for normal design purposes. Most clauses in the code give alternative methods that do not require the use of this annex.

6.2 Recommendations on subjects not covered in EC4-2**6.2.1 Design resistance of channels as shear connectors**

The design resistance of a channel connector may be determined from the following (assuming the web of the channel is vertical with the shear applied nominally perpendicular to the web):

$$P_{Rd} = 20 b h^{3/4} f_{ck}^{1/3} / \gamma_v$$

where

- P_{Rd} is in newtons (N);
 b is the length of the channel in millimetres (mm);
 h is the height of the channel in millimetres (mm);
 f_{ck} is the characteristic cylinder strength of concrete in newtons per millimetres squared (N/mm²).

The partial safety factor γ_v should be taken as 1.25 for the ultimate limit state.

The recommendations for channel dimensions are as follows:

- The height h of the channel should not exceed 20 times web thickness nor 150 mm.
- The width b of the channel should not exceed 300 mm.
- The underside of the top flange of the channel should not be less than 30 mm clear above the bottom reinforcement.
- The leg length of the weld connecting the channel to the plate should not exceed half the plate thickness.

Use of a channel section may be deemed to prevent uplift of the concrete slab in accordance with ENV 1994-2:1997, **6.1.1(4)**.

6.2.2 Aerodynamic stability

The aerodynamic stability of the bridge should be checked in accordance with DMRB publication BD 49/93 [7].

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English version

Eurocode 4: Design of composite steel and concrete structures - Part 2: Composite bridges

Eurocode 4: Calcul des structures mixtes acier-béton -
Partie 2: Ponts mixtes

Eurocode 4: Bemessung und Konstruktion von
Verbundtragwerken aus Stahl und Beton - Teil 2:
Verbundbrücken

This European Prestandard (ENV) was approved by CEN on 11 August 1997 as a prospective standard for provisional application.

The period of validity of this ENV is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the ENV can be converted into a European Standard.

CEN members are required to announce the existence of this ENV in the same way as for an EN and to make the ENV available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the ENV) until the final decision about the possible conversion of the ENV into an EN is reached.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Central Secretariat: rue de Stassart, 36 B-1050 Brussels

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Foreword

rep.

Objectives of the Eurocodes

- (1) The Structural Eurocodes comprise a group of standards for the structural and geotechnical design of buildings and civil engineering works.
- (2) They cover execution and control only to the extent that is necessary to indicate the quality of the construction products, and the standard of the workmanship, needed to comply with the assumptions of the design rules.
- (3) Until the necessary set of harmonised technical specifications for products and for methods of testing their performance is available, some of the Structural Eurocodes cover some of these aspects in informative annexes.

Background to the Eurocode Programme

- (4) The Commission of the European Communities (CEC) initiated the work of establishing a set of harmonised technical rules for the design of building and civil engineering works which would initially serve as an alternative to the different rules in force in the various Member States and would ultimately replace them. These technical rules became known as the 'Structural Eurocodes'.
- (5) In 1990, after consulting their respective Member States, the CEC transferred the work of further development, issue and updating of the Structural Eurocodes to CEN, and the EFTA Secretariat agreed to support the CEN work.
- (6) CEN Technical Committee CEN/TC 250 is responsible for all Structural Eurocodes.

Eurocode programme

- (7) Work is in hand on the following Structural Eurocodes, each generally consisting of a number of parts :

EN 1991	Eurocode 1	Basis of design and actions on structures
EN 1992	Eurocode 2	Design of concrete structures
EN 1993	Eurocode 3	Design of steel structures
EN 1994	Eurocode 4	Design of composite steel and concrete structures
EN 1995	Eurocode 5	Design of timber structures
EN 1996	Eurocode 6	Design of masonry structures
EN 1997	Eurocode 7	Geotechnical design
EN 1998	Eurocode 8	Design of structures for earthquake resistance
EN 1999	Eurocode 9	Design of aluminium alloy structures

- (8) A separate sub-committee has been formed by CEN/TC250 for each of the Eurocodes listed above.
- (9) This Part of ENV 1994 is being published as a European Prestandard (ENV) with an initial life of three years.

- (10) This Prestandard is intended for experimental application and for submission of comments.
- (11) After approximately two years CEN members will be invited to submit formal comments on this Prestandard to be taken into account in determining future action.
- (12) Meanwhile feedback and comments on this Prestandard should be sent to the Secretariat of Sub-committee CEN/TC250/SC4 at the following address :

National Standards Authority of Ireland, Glasvenin, Dublin 9, Ireland
Telephone international 353 1 807 38 00
Fax international 353 1 807 38 38

or to your national Standards Organisation.

National Application Documents

- (13) In view of the responsibilities of authorities in member countries for safety, health and other matters covered by the essential requirements of the Construction Products Directive (CPD), certain safety elements in this ENV have been assigned indicative values which are identified by □ ("boxed values"). The authorities in each member country are expected to review the "boxed values" and may substitute alternative definitive values for these safety elements for use in national application.
- (14) Some of the necessary supporting European or International Standards may not be available by the time this Prestandard is issued. It is therefore anticipated that a National Application document (NAD) giving any mandatory values to be substituted for "boxed" values, referencing compatible supporting Standards and providing guidance on the national application of this Prestandard, will be issued by each member country or its Standards Organisation.
- (15) It is intended that this Prestandard will be used in conjunction with the particular NAD valid in the country in which the bridge is to be located.

Matters specific to this prestandard

- (16) The scope of Eurocode 4 is defined in clause 1.1 of ENV 1994-1-1:1992 and the scope of this part of Eurocode 4 is defined in 1.1.2.
- (17) Bridges are essentially public works, for which :
- the European Directive 93-37/CEC on Public Procurement is particularly relevant, and
 - public authorities have responsibilities as owners.

Within this context this Prestandard has been established with two main objectives :

- to be sufficiently precise and comprehensive for contractual use,
 - to be sufficiently flexible to allow the intervening parties fully to exert their technical responsibilities.
- (18) Because of the responsibilities of relevant authorities for bridges, it has been anticipated that, for the application of this Part, it will be supplemented by :

- general complementary rules and options to be provided by National Application Documents (NAD - see (14)) and
- complementary and/or modifying specifications for particular projects.

Wherever this Prestandard mentions "unless otherwise specified", it is intended that the relevant authorities (to be identified, if relevant, in the particular NADs) will remain free to intervene at each of these two levels. It is the same where this Prestandard refers to the "client", if the client is not the relevant authority itself.

(19) Concerning the treatment of γ_M for structural steel, 0.5.2 of ENV 1994-1-1:1992 is applicable.

(20) The framework and structure of this Part 2 correspond to ENV 1994-1-1:1992. However, ENV 1994-2:1997 contains Principles and Application Rules which are specific to composite bridges.

(21) Some Principles and Application Rules in ENV 1994-1-1:1992 are modified or replaced. The new provisions are identified by the symbols *mod.* or *rep.*, respectively.

(22) Where a new Principle or Application Rule is added, it is identified by the symbol *add.*

(23) Any clause, subclause, or paragraph of ENV 1994-1-1:1992 that is neither modified or replaced, is applicable. These provisions are not repeated in this ENV 1994-2:1997.

(24) For the application of this Part 2 it is assumed that the intervening parties :

- select from ENV 1991-3:1995 the relevant traffic load models and take the necessary complementary decisions about actions,
- define, with regard to the type of bridge under consideration (see 1.1.2) and the environmental conditions of exposure, the verification criteria for the serviceability limit states.

1. General

1.1 Scope

1.1.2. Scope of ENV 1994-2:1997

rep.

- (1) P ENV 1994-2:1997 gives a general basis for the design of composite bridges.
- (2) P In addition ENV 1994-2:1997 gives a specific basis for the design of composite structures and members for bridges such as road, railway, and pedestrian bridges, and detailed rules for composite bridge structures such as beam and slab bridge decks, box girders, trusses and columns that support bridge decks.
- (3) No application rules are given for the use of unbonded tendons or for cable stayed bridges.
- (4) P For the use of composite slabs in bridges, see 7.1.1.
- (5) P For the use of filler beam decks, see annex K.
- (6) P Provisions for the design of high strength cables, bearings and expansion joints are given in annexes A, B and E of ENV 1993-2:1997.
- (7) P The implicit inclusion of a type of bridge or a form of structure (as defined in 1.4.1(2)) does not imply that all details of its design are covered comprehensively.
- (8) For the execution of steel structures, reference should be made to ENV 1090-5.

1.1.3 Further Parts of ENV 1994

Clause 1.1.3 does not apply.

1.2 Distinction between principles and application rules

- (3) P The principles are identified by the letter P following the paragraph number.
mod.
- (6) In this Part, Application Rules have only a paragraph number, e.g. as this paragraph.
mod.

NOTE : Tables and figures have the same status as the paragraphs to which they relate.

1.3 Assumptions

rep.

- (1) P The assumptions given in clause 1.3(1) of ENV 1992-1-1:1991 and 1993-1-1:1992 are applicable.
- (2) P The design procedures are valid only when the requirements for execution and workmanship given in Section 9 are also complied with.
- (3) P For numerical values identified by □, see Foreword paragraph (13).

1.4 Definitions

1.4.2 Special terms used in this Part

rep.

1.4.2.1 Frame : A structure or portion of a structure, comprising an assembly of directly connected structural members, designed to act together to resist load. This term covers both plane frames and three-dimensional frames.

1.4.2.2 Filler beam deck : see K.1.(1) P

1.4.2.3 Composite member : A structural member with components of concrete and of structural or cold-formed steel, interconnected by shear connection so as to limit the longitudinal slip between concrete and steel and the separation of one component from the other.

1.4.2.4 Composite bridge : A bridge in which at least some of the principal members are composite members.

1.4.2.5 Propped structure or member : A structure or member where the weight of concrete elements is applied to the steel elements which are supported within the span, or is carried independently until the concrete elements are able to resist stresses.

1.4.2.6 Unpropped structure or member : A structure or member in which the weight of concrete elements is applied to the steel elements which are unsupported within the span.

1.4.2.7 Shear connection : An interconnection between the concrete and steel components of a composite member that has sufficient strength and stiffness to enable the two components to be designed as parts of a single structural member.

NOTE : The concept of partial shear connection as used in ENV 1994-1-1:1992 is not applicable to bridges.

Except as provided in 4.8.2 and annex K shear connection means mechanical shear connection that does not rely on bond or adhesion at interfaces between steel and concrete.

1.4.2.8 Composite column : A composite member subjected mainly to compression and bending. Only columns with cross-sections of the types defined in 4.8.1 are treated in this Eurocode.

1.4.2.9 Composite beam : A composite member subjected mainly to bending.

1.4.2.10 Continuous composite beam : A beam with three or more supports, in which the steel section is either continuous over internal supports or is jointed by full-strength and rigid connections, with connections between the beam and each support such that it can be assumed that the support does not transfer significant bending moment to the beam.

1.4.2.11 Global analysis : The determination of a consistent set of internal forces and moments in a structure which are in equilibrium with a particular defined set of actions on the structure, and are based on the properties of the materials.

1.4.2.12 Clearance gauge : The maximum height authorised for vehicles running under a bridge.

1.4.2.13 Composite plate : Composite member subjected mainly to bending, consisting of a flat plate connected to a concrete slab, in which both the length and width are much greater than the thickness.

1.4.3 Other definitions

add.

- (1) P The definitions of clause 1.4 of ENV 1991-3:1995 apply.
- (2) P The definitions of clause 1.4 of ENV 1992-2:1996 apply.
- (3) P The definitions of clause 1.4 of ENV 1993-2:1997 apply.
- (4) P For the verifications relating to fatigue, the definitions given in 9.1.5 of ENV 1993-1-1:1992 apply.
- (5) P The definitions of clause 1.4 of ENV 1993-1-5:1997 apply.
- (6) For isostatic effects and hyperstatic effects of shrinkage and differential temperature, see 2.2.2.1(4) of ENV 1994-1-1 : 1992.

1.5 S.I. Units

- (2) For calculations, the following units are recommended :

mod.

- Forces and loads : kN or MN units
- unit mass : kg/m³
- unit weight : kN/m³
- stresses and strengths : N/mm² (= MN/m² or MPa)
- moments (bending) : kNm or MNm

1.6 Symbols used in Part 2

rep.

1.6.1 General

- (1) Only the main symbols are defined in this Section. Symbols which are used only in small parts of this Eurocode are defined where they appear.

NOTE : The following list of symbols include the principal combinations of symbols and subscripts in this Eurocode. The list does not include symbols used in one place only, nor those symbols used in ENV 1992-2:1996, ENV 1993-2:1997 and ENV 1993-1-5:1997 but not directly in this Part.

NOTE : The notation used is based on ISO 3898:1987.

1.6.2 Latin upper case letters

- A* Accidental action; Area
- C* Fixed value; Factor
- E* Effect of actions; Modulus of elasticity
- F* Action; force
- G* Permanent action; shear modulus
- I* Second moment of area
- K* Stiffness factor (*I/L*)

L	Length; Span; System length
M	Moment in general; Bending moment
M_{Rd}	Design value of the resisting bending moment
M_{sd}	Design value of the applied internal bending moment
N	Axial force; Number of shear connectors, Number of cycles
P	Prestressing
P_R	Shear resistance of a shear connector
Q	Variable action
R	Resistance
S	Internal forces and moments (with subscripts d or k)
V	Shear force
W	Section modulus
X	Value of a property of a material

1.6.3 Greek upper case letters

Δ	Difference in (precedes main symbol)
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1.6.4 Latin lower case letters

a	Constant; Distance; Geometrical data; Constant
b	Width; Breadth
c	Distance; Outstand; Thickness of concrete cover
d	Diameter; Depth
e	Eccentricity
f	Strength (of a material)
f_{ck}	Characteristic compressive strength of concrete
f_{sk}	Characteristic tensile yield strength of reinforcement
f_u	Specified ultimate tensile strength of the material of a stud, a bolt, a rivet ...
f_y	Nominal tensile yield strength of structural steel
f_{yp}	Characteristic (nominal) tensile yield strength of profiled steel sheeting
h	Height
i	Radius of gyration
k	Coefficient; Factor
l	(or ℓ or L) Length; Span; Buckling length (Note : l can be replaced by L or by ℓ (handwritten) for certain lengths or to avoid confusion with 1 (numeral).)
m	Factor for composite slabs; Slope constant of fatigue strength curve
n	Modular ratio
r	Radius
s	Spacing; Distance
v	Longitudinal shear force per unit length
w	Crack width
xx, yy, zz	Rectangular axes

1.6.5 Greek lower case letters

α	Angle; Ratio; Coefficient of linear thermal expansion; Factor
β	Angle; Ratio; Factor
γ	Partial safety factor (always with appropriate subscript : e.g., F, G, Q, A, M, Ma, a, ap, c, s, v, Rd)
δ	Steel contribution ratio; Deflection
ε	Strain; Coefficient

η	Coefficient
θ	Angle; Slope
λ	(or $\bar{\lambda}$) Factor for range of stress; Slenderness ratio
μ	Coefficient of friction; Moment ratio
ν	Poisson's ratio
ρ	Unit mass; Reinforcement ratio
τ	Shear stress
φ	Diameter of a reinforcing bar
χ	Reduction factor (for buckling)
ψ	Factors defining representative values of variable actions; Stress ratio
ξ	Ratio of bonding strength

1.6.6 Subscripts

A	Accidental
a	Structural steel
b	Buckling; Bolt; Beam; Bottom
c	Compression; Concrete; Composite cross section
cr	(or crit) Critical; Cracking
cs	Concrete shrinkage
d	Design
dst	Destabilising
eff	Effective
E	Equivalent
e	Effective (with further subscript)
el	Elastic
f	Flange ; Fatigue
F	Fatigue
G	Permanent (referring to actions)
h	Haunch; Horizontal
i	Index (replacing a numeral)
inf	Inferior; Lower
k	Characteristic
l	(or ℓ) Longitudinal
LT	Lateral - torsion
M	Material
m	Allowing for axial force; Mean
nom	Nominal
P	Prestressing
p	(possibly supplementing a) Profiled steel sheeting
pl	Plastic
Q	Variable (referring to actions)
R	Resistance
r	Reduced
S	Internal force; Internal moment
s	Reinforcing steel
se	Neglecting concrete in stress calculation
st	Steel
stb	Stabilising
sup	Superior; Upper
t	Tension; Tensile, Transversal; Top
ten	Tension

ts	Tension stiffening
u	Ultimate
v	Vertical; Related to shear connection
w	Web
x	Axis along member
y	Major axis of cross-section
z	Level arm
0,1,2, etc...	Particular values

1.6.7 Use of subscripts

- (1) Reference should be made to 1.6.6 of ENV 1993-1-1:1992.

1.6.8 Conventions for member axes

- (1) Reference should be made, if relevant, to 1.6.7 of ENV 1993-1-1:1992.

1.7 Normative references

add.

- (1) This European Prestandard incorporates, by dated and undated references, provisions from other publications. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Prestandard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

- (2) When using ENV 1994-2:1997, reference should be made to the following ENVs, where relevant:

ENV 1090-1	Execution of steel structures Part 1: General rules and rules for buildings
ENV 1090-5	Execution of steel structures Part 5: Supplementary rules for bridges and plated structures.
ENV 1991-1	Eurocode 1: Basis of design and actions on structures Part 1: Basis of design
ENV 1991-2-1	Eurocode 1: Basis of design and actions on structures Part 2.1: Densities, self-weight and imposed loads
ENV 1991-2-4	Eurocode 1: Basis of design and actions on structures Part 2.4: Wind loads
ENV 1991-2-5	Eurocode 1: Basis of design and actions on structures Part 2.5: Thermal actions
ENV 1991-2-6	Eurocode 1: Basis of design and actions on structures Part 2.6: Loads and deformations imposed during execution
ENV 1991-2-7	Eurocode 1: Basis of design and actions on structures Part 2.7: Accidental actions
ENV 1991-3	Eurocode 1: Basis of design and actions on structures Part 3: Traffic loads on bridges
ENV 1992-1-1	Eurocode 2: Design of concrete structures Part 1.1 : General rules and rules for buildings
ENV 1992-1-3	Eurocode 2: Design of concrete structures Part 1.3 :General rules - Precast concrete elements and structures
ENV 1992-1-4	Eurocode 2: Design of concrete structures

	Part 1.4 :General rules - Lightweight aggregate concrete with closed structure
ENV 1992-1-5	Eurocode 2: Design of concrete structures Part 1.5 :General rules - Structures with unbonded and external prestressing tendons
ENV 1992-1-6	Eurocode 2: Design of concrete structures Part 1.6 :General rules - Plain concrete structures
ENV 1992-2	Eurocode 2: Design of concrete structures Part 2: Concrete bridges
ENV 1992-3	Eurocode 2: Design of concrete structures Part 3: Concrete foundations
ENV 1993-1-1	Eurocode 3: Design of steel structures Part 1.1: General rules and rules for buildings
ENV 1993-1-3	Eurocode 3: Design of steel structures Part 1.3: Supplementary rules for cold formed thin gauge members and sheeting
ENV 1993-1-5	Eurocode 3: Design of steel structures Part 1.5: Supplementary rules for the strength and stability of planar plated structures
ENV 1993-2	Eurocode 3: Design of steel structures Part 2: Steel bridges
ENV 1994-1-1	Eurocode 4: Design of composite steel and concrete structures Part 1.1: General rules and rules for buildings
ENV 1997-1	Eurocode 7: Geotechnical design Part 1: General rules
ENV 1998-2	Eurocode 8: Earthquake resistant design of structures Part 2: Bridges

(3) P The reference standards are those in ENV 1991-1:1994, ENV 1992-2:1996 and ENV 1993-2:1997. Stud welding shall be in accordance with prEN ISO 14555 'Welding - Arc stud welding of metallic materials' and prEN ISO 13918 'Welding-Studs for arc stud welding'.