Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 74 (1996)

Artikel: ENV: 1991-1: Eurocode 1: part 1: basis of design introduction, development and research needs
Autor: Gulvanessian, Haig
DOI: https://doi.org/10.5169/seals-56051

ENV 1991-1: EUROCODE 1: Part 1: Basis of Design Introduction, Development and Research Needs

Haig GULVANESSIAN
Professor & Civil Engineer
Building Research Establishment
Garston, Watford, UK

Haig Gulvanessian, born in 1941, is a graduate of the University of London. He is Head of the Structural Design Division at BRE and a Visiting Professor at Imperial College, London. He is Technical Secretary for the EC1 Committee and Chairman of the CEN/TC250 Interim Ad-Hoc Group on Basis of Design

Summary

This paper describes the concept and contents of ENV 1991:1 Eurocode 1 "Basis of Design". It also describes possible developments for the document that may be undertaken during its transposition to EN status, and suggests topics that may require research to aid the continued future developments of the document into the next millennium.

1 ENV 1991-1 - Eurocode 1:Part 1: Basis of Design

1.1 Introduction

Eurocode 1:Part 1: Basis of Design (hereafter called ENV 1991-1) was produced by a CEN/TC 250 Project Team (see Appendix A) and was published as an ENV in 1994 [1]. This part of the paper provides a brief description to ENV 1991-1. A theoretical background to ENV 1991-1 is given by Vrouwenvelder [2], and Gulvanessian and Holicky [3].

1.1.1 Objectives of ENV 1991-1

ENV 1991-1 describes the principles and requirements for safety, serviceability and durability of structures. It is based on the limit state concept used in conjunction with the partial factor method.

It will be used, for direct application, for the design of new structures, together with
- the other parts of Eurocode 1 and
- the design Eurocodes (Eurocodes 2 to 9).

ENV 1991-1 also give guidance for the aspects of structural reliability relating to safety, serviceability and durability for design cases not covered by Eurocodes 1 to 9 (eg other actions, structures outside the scope of the Eurocodes, other materials);

- different degrees of reliability required at national, regional or local level.

The required reliability relating to structural safety and serviceability may be achieved by the suitable combination of:
a) Measures relating to design which include serviceability requirements; the representative values of actions; the choice of partial factor; the consideration of durability; the consideration of the degree of robustness; the amount and quality of preliminary investigations of soils and possible environmental influences; the accuracy of the mechanical models used and the stringency of the detailing rules.
b) Measures relating to quality assurance to reduce the risk of hazards in gross human errors; design; and execution.

1.3.3 Design Situations
A relevant design situation is selected taking account of the circumstances in which the structure may be required to fulfil its function. ENV 1991-1 classifies design situations as follows:
- persistent situations (Conditions of normal use);
- transient situations (Temporary conditions eg during execution);
- accidental situations; and
- seismic situations.

1.3.4 Design Working Life
The design working life is the assumed period for which a structure is to be used for its intended purpose with anticipated maintenance but without major repair being necessary. Table 1, taken from the UK NAD [4] for ENV 1991-1 is a variation the table provided in ENV 1991-1.

Class	Notional design working life (years)	Examples
1	1-5	Temporary structures
2	25	Replaceable structural parts, e.g. gantry girders, bearings
3	50	Buildings and other common structures, other than those listed below
4	100	Monumental buildings, and other special or important structures
5	120	Bridges

Table 1. Design working life classification

1.3.5 Durability
The design should ensure that the durability of a structure or part of it in its given environment is such that it remains fit for use during the design working life given appropriate maintenance. Interrelated factors which should be considered to ensure an adequately durable structure are:
- the intended and possible use of the structure;
- the required performance criteria;

1.1.2 Intended Users

Due to the scope and objectives of ENV 1991-1 the document will be used by more categories of users than the other Eurocodes. The categories include:
- code drafting committees;
- clients (eg for the formulation of their specific requirements on reliability level and durability);
- designers and contractors (as for the other Eurocodes); and
- public authorities (eg to set safety criteria).

1.2 Assumptions

The following assumptions are associated with the validity of the design principles of ENV 1991-1:
- The choice of the structural system and the design of a structure is made by appropriately qualified and experienced personnel.
- Execution is carried out by personnel having the appropriate skills and experience.
- Adequate supervision and quality control is provided is provided during execution of the work, ie in design offices, factories, plants and on site.
- The construction materials and products are used as specified in Eurocodes 1 to 9 or in the relevant supporting material or product specification.
- The structure will be adequately maintained.
- The structure will be used in accordance with the design assumptions.
- Design procedures are valid only when the requirements for the materials, execution and workmanship given in Eurocodes 2 to 6 and 9 are also complied with.

1.3 Requirements

1.3.1 Fundamental Requirements

The fundamental requirements stipulate that :
a) a structure shall be designed and executed in such a way that it will, during its intended life with appropriate degrees of reliability and in an economic way:
- remain fit for the use for which it is required (serviceability requirement); and
- sustain all actions and influences likely to occur during execution and use (safety requirement); and

b) a structure shall be designed and executed in such a way that it will not be damaged by events such as fire, explosion, impact or consequences of human errors, to an extent disproportionate to the original cause (robustness requirement). ENV 1991-1 gives ways of avoiding or limiting potential damage.

1.3.2 Reliability Differentiation

An appropriate degree of reliability for the majority of structures is obtained by design and execution according to Eurocodes 1 to 9, and appropriate quality assurance measures. A different level of reliability may be adopted (reliability differentiation) for structural safety or serviceability and this may depend on:
- the cause and mode of failure;
- the possible consequences of failure in terms of risk to life, injury, potential economic losses and the level of social inconvenience;
- the expense and procedures necessary to reduce the risk of failure; and

- the expected environmental influences;
- the composition, properties and performance of the materials;
- the choice of the structural system;
- the shape of members and the structural detailing;
- the quality of workmanship, and level of control;
- the particular protective measures; and
- the maintenance during the intended life.

1.3.6 Quality Assurance

Appropriate quality assurance measures should be taken in order to provide a structure which corresponds to the requirements and to the assumptions made in the design. These measures should include organisational measures and controls at the stages of design, execution, use and maintenance.

1.4 Principles of Limit State Design

1.4.1 Ultimate and Serviceability Limit States

Eurocodes use the concept of limit state design. Limit states are states beyond which the structure no longer satisfies the design performance requirements. ENV 1991-1 makes a distinction between ultimate limit states and serviceability limit states.

Ultimate limit states are those associated with collapse or with other forms of structural failure and concern
- the safety of the structure and its contents; and
- the safety of people.

Serviceability limit states correspond to conditions beyond which specified service requirements for a structure or structural element are no longer met and concern
- the functioning of the construction works or parts of them;
- the comfort of people; and
- the appearance.

The serviceability requirements should be determined in contracts and/or in the design.

1.4.2 Limit State Design

Limit state design is carried out by:
- setting up structural and load models for relevant ultimate and serviceability limit states to be considered in the various design situations and load cases; and
- verifying that the limit states are not exceeded when the design values for actions, material properties and geometrical data are used in models.

Design values are generally obtained by using the characteristic or representative values (see 1.5) in combination with partial and other factors (see 1.10).

1.5 Actions

An action (F) is:
- a direct action, ie force (load) applied to the structure; or
- an indirect action, ie an imposed or constrained deformation or an imposed acceleration

caused, for example, by temperature changes etc.

Actions are classified
- by their variation in time, permanent actions (G); variable actions (Q); and accidental actions (A);
- by their spatial variation, fixed actions (eg self-weight); free actions (eg wind and snow loads);
- by their nature and/or structural response, static actions; dynamic actions.

The characteristic values of an action is its main representative value.

The self weight of a structure can, be represented by a single characteristic value (G_k), provided the variability of G is small, and be calculated on the basis of the nominal dimensions and the mean unit mass. If the variability of G is not small, ENV 1991-1 stipulates the use of two values; an upper value ($G_{k,sup}$) and a lower value ($G_{k,inf}$). Ostlund [5] provides more information on this.

A variable action has the following representative values. The characteristic value (Q_k); the combination value ($\psi_0 Q_k$) ; the frequent value ($\psi_1 Q_k$); and the quasi-permanent value ($\psi_2 Q_k$). Values for ψ_0 , ψ_1 and ψ_2 are given in ENV 1991-1.

1.6 Material Properties

Properties of materials (including soil and rock) or products are represented by characteristic values which correspond to the value of the property having a prescribed probability on not being attained in a hypothetical unlimited test series. They generally correspond for a particular property to a specified fractile of the assumed statistical distribution of the property of the material in the structure.

1.7 Geometrical Data

Geometric data are represented by their characteristic value, or in the case of imperfections by their design value.

1.8 Structural Analysis

ENV 1991-1 provides principles which are common for structures of different type and material and the Section on Structural Analysis provides guidance on the modelling of static actions, dynamic actions and fire actions.

1.9 Design Assisted by Testing

Where calculation rules or material properties given in Eurocodes 1 to 9 are not sufficient or where economy may result from tests on prototypes, part of the design procedure may be performed on the basis of tests. ENV 1991-1 requires that tests are set up and evaluated in such a way that the structure has the same level of reliability to all possible limit states and design situations as achieved by design based on calculation procedures specified in Eurocodes 1 to 9.

1.10 Verification

In the partial factor method, it has to be verified that for all relevant design situations, the limit states are not exceeded when design values for actions, material properties and geometrical data are used in the design models. In particular ENV 1991-1 stipulates that
a) the effects of design actions do not exceed the design resistance of the structure at the ultimate limit state; and
b) the effects of design actions do not exceed the performance criteria for the serviceability limit state.

Actions are combined so that they produce the most unfavourable effect on the structure for the limit state being considered; actions which cannot occur simultaneously, for example, due to physical reasons, should not be considered together in combination.

For the ultimate limit state there are three types of combination of actions as follows:
- Fundamental (persistent and transient) situations
- Accidental situations
- Seismic situations.

ENV 1991-1 provides the partial factors for ultimate limit states in the persistent, transient and accidental situations for the following cases:
- Case A, which is for loss of static equilibrium
- Case B, which is for failure of the structure or structural elements, including those of the footing, piles, basement walls etc., governed by strength of structural material
- Case C which is for failure of the ground.

The design should be verified for each case A, B and C separately as relevant.

For the serviceability limit states there are three types of combinations .
- The characteristic (rare) combination used mainly in those cases when exceedance of a limit state causes a permanent local damage or permanent unacceptable deformation.
- The frequent combinations used mainly in those cases when exceedance of a limit state causes local damage, large deformations or vibrations which are temporary.
- The quasi-permanent combinations used mainly when log term effects are of importance.

ENV 1991-1 also provides simplified verifications for consideration of both the ultimate and serviceability limit states which may be used for particular cases.

2 Possible Changes to ENV 1991-1 at Transposition to EN 1991-1.

CEN/TC250, the committee responsible for the development of the Eurocodes set up an interim Ad-Hoc Group (see Appendix A) whose objectives were to formulate the method of working and terms of reference and objectives for use by a future Project Team for the transposition of ENV 1991-1 into an EN. This part of the paper provides a summary of the Ad-Hoc Group's recommendations [6]. It is intended that voting to transpose the document into an EN takes place in late 1998.

2.1 Layout and Organisation

The Ad-Hoc Group has recommended (figure 1) that the EN 1991-1 has;
- General sections applicable to all structures within the fields of application of the Structural Eurocodes defining requirements and criteria:
- Separate application parts, which will be derivations from the General sections specific for each structural type (eg buildings, bridges, towers and masts etc).

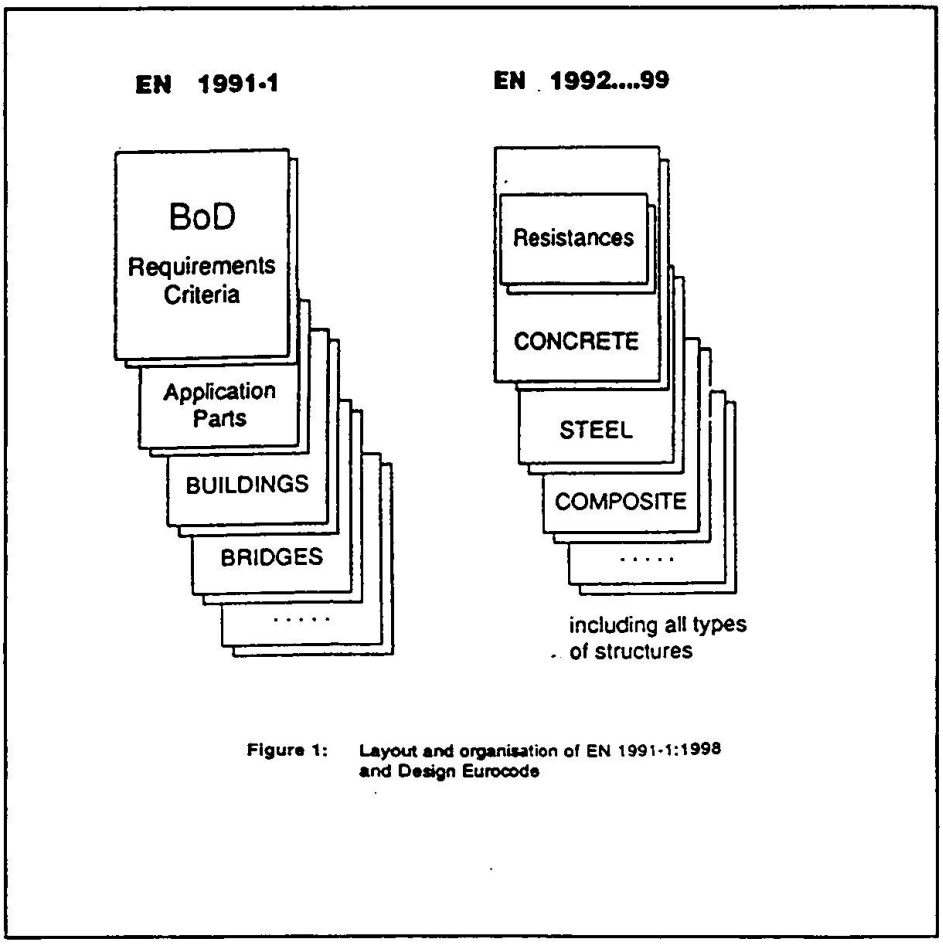

Figure 1: Layout and organisation of EN 1991-1:1998 and Design Eurocode

Figure 1. Proposed layout and organisation of EN 1991-1 and the EN design Eurocodes.

This recommendation will ensure that the document is more user-friendly; and application parts of various types of structures can be added at future dates without amendments to the main part of the document.

2.2 Scope and Contents

The Ad-Hoc Group recommended that the EN 1991-1 should include in addition to its present contents the material independent clauses from Chapters 2 of Eurocodes 2 to 9 from where these clauses will be removed.

This recommendation has the following merits:
a) One document will provide the framework of principles and partial combination factors for all types of structures and materials.
b) Technical decisions for all material independent matters will be taken by one committee and this will avoid contradictions between the various Eurocodes.
c) The same organisation and framework for all the Eurocodes.

2.3 Specific technical points for consideration for change

The Ad-Hoc Group have recommended to proceed in two steps. The first step, defined as the document for voting for EN in 1998 should only include improvements that the AD-Hoc Group feel are achievable within the timescale. The second step, defined as the first revision of the EN after five years, is to further develop the document. The proposed programme of work for the two steps is shown in Table 2.

In addition to the items in Table 2:
- the Ad-Hoc Group considered recommending the production of further guidance on Classification of Structures. The AD-Hoc group recognised that political and legal rules may inhibit a normative introduction of classification in Member States. However, considering that most failures occur due to deficiencies in the design and execution process of a project or poor maintenance and not because a partial factor was on the `low side' the Ad-Hoc Group have recommended the production of a new Informative annex to introduce a system where depending on the type of construction works and consequences of its failure, different design supervision and inspection classes can be recommended.
- the Ad-Hoc Group considered the need for guidance for the selection of γ_M values in the design Eurocodes and recommended in the long term for comprehensive guidance from which Eurocodes can select γ_M for appropriate components considering the conditions of quality control and the manufacturing process.

2.4 Experience in Use

The Ad-Hoc Group recommend that the various NADs to ENV 1991-1 and other experiences with the application of the document be considered when producing the EN 1991-1.

3 Future Research Needs

To aid future development of ENV 1991-1 and the related parts of the other Eurocodes, particular organisations (eg BRE, TNO, TU Munchen) intend to submit a proposal to the European Commission. The main objective of this proposal will be to create a network

Item	Current Situation and Need for Improvement	First Step (EN 1991-1:1998)	Second Step (EN 1991-1:5 yr revision)
Serviceability Limit State	The requirements relating to serviceability criteria are well defined but the verification rules need improvement.	The basic concepts for serviceability needs broadening to define more accurately the purpose of the appropriate verifications with regard to the fundamental requirement.	Develop material independent performance criteria for the application parts of Basis of Design.
Static Equilibrium	The guidance provided on static equilibrium is general and broader information on treating static equilibrium for all types of structures is required.	Definition of static equilibrium, with broadening of the concept of static equilibrium in EN 1991-1 to take account of all types of structures during the execution process and normal use.	Development of specific rules for all the application parts of EN 1991-1
Durability	The main requirement for defining durability is the design working life and the guidance provided needs improving.	Table 2.1 to be developed in order to provide useful information for the design of structures and structural components.	
Fatigue Verification	ENV 1991-1 provides an Annex for fatigue which should be brought into the main text.	Transfer Annex B of ENV 1991-1 to the main text with any appropriate rules from the design Eurocodes.	Development of rules for the application parts of ENV 1991-1: Basis of Design
Structural Analysis	The current guidance provided has to be broadened to be useful in design and to form a basis for harmonisation of the information in the design Eurocodes.	The information in the design Eurocodes on structural analysis should be brought together and harmonised into ENV 1991-1 with advice on the application of these methods.	
Annex A	Annex A is user-unfriendly and can lead to unsafe designs if used wrongly; it should clarified,improved and completed.	Completely re-edit and provide explanations for the between γ_m's in the design Eurocodes; and if possible harmonise with a common equation.	
Soil Structure / interaction	Application rules in Table 9.2 but ENV 1991-1 does not provide principles on this topic.	More precise explanation should be given for the field of application for cases B & C of Table 9.2.	Produce comprehensive rules together with CEN/TC250/SC7.

Table 2: Programme of work for items needing improvement

whose aims will be to have regular contact between the member states on
- the use of ENV 1991-1 in practice;
- exchange of information on prenormative research projects being carried out at present in the individual member states, CEB, CIB, ECCS, JCSS etc with the aim of avoiding repetition and pooling expertise; and
- to consider research needs and to develop proposals for research projects on topics that will aid the further development of ENV 1991-1.

Topics that will fall within the scope of the proposed network are
- durability and life cycle aspects, and designing and constructing to achieve durability;
- serviceability requirements
- background of partial factor and load combination rules;
- development of an alternative probabilistic model code;
- basis of design for the assessment of existing structures, repair and maintenance decisions;
- risk analysis procedures;
- advanced non-linear and dynamic structural analysis and code checking;
- the behaviour of structural systems and design for robustness; and
- supervision, inspection and quality control.
- soil structure interaction

4 Conclusions

It is intended to commence the work for the transposition of ENV 1991-1 from ENV into an EN in the near future. The TC 250 Ad-Hoc Group on Basis of Design has produced a recommended Action Plan assuming voting for the transposition takes place in late 1998.

Appendix A

The CEN/TC250 Project Team that produced ENV 1991-1 was, G Breitschaft (Convenor); H Gulvanessian; N Krebs Overson; J C Leray, R S Narayanan; L Ostlund; G Sedlacek; and T Vrouwenvelder

The CEN/TC 250 Interim Ad-Hoc Group, Basis of Design was, H Gulvanessian (Convenor); J A Calgaro, J Grumberg; T Hagberg; P Luchinger; and P Spehl.

References

[1] ENV 1991-1: Eurocode 1: Basis of Design and Actions on Structures: Part 1: Basis of Design. CEN 1994.

[2] Vrouwenvelder, A., Eurocode 1, Basis of Design, Background Information, IABSE Conference on Basis of Design and Actions on Structures, Delft, IABSE, 1996.

[3] Gulvanessian H and Holicky M. Handbook for Eurocode 1: Basis of Design. To be published by Thomas Telford Publications, 1996.

[4] UK National Application Document for ENV 1991:1. To be published by BSI, 1996.

[5] Ostlund L. Actions. IABSE Conference on Basis of Design and Actions on Structures, Delft, IABSE 1996.