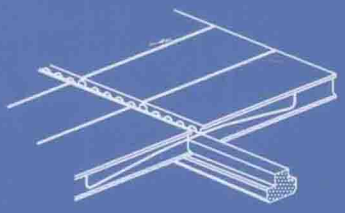
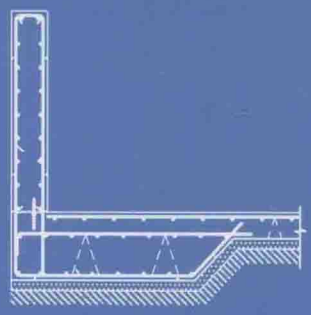
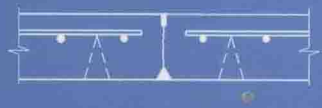
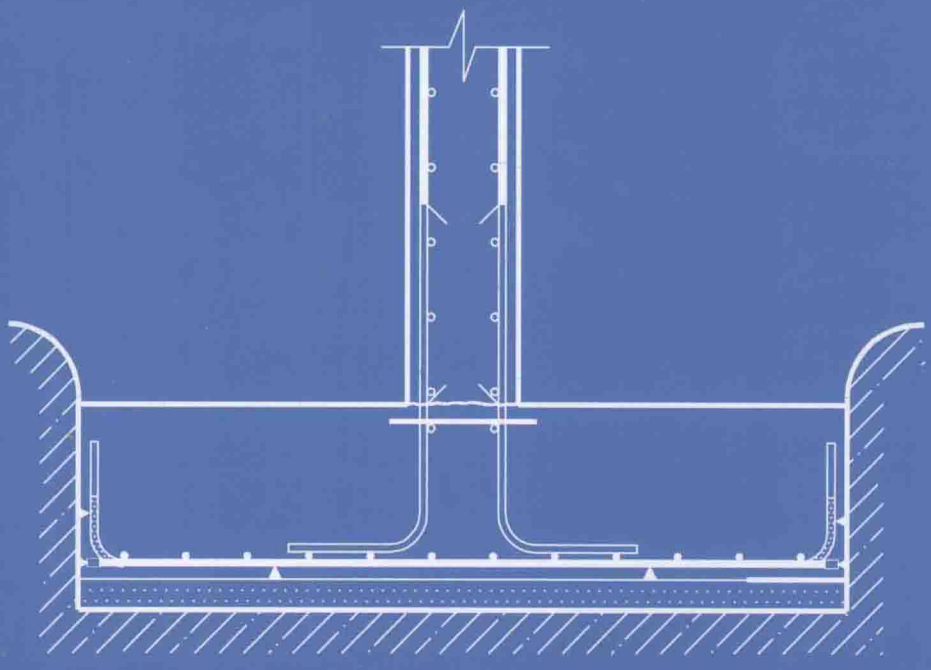





MANUAL FOR DETAILING REINFORCED CONCRETE STRUCTURES TO EC2



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Manual for Detailing Reinforced Concrete Structures to EC2

Detailing is an essential part of the design process. This thorough reference guide for the design of reinforced concrete structures is largely based on Eurocode 2 (EC2), plus other European design standards such as Eurocode 8 (EC8), where appropriate.

With its large format, double-page spread layout, this book systematically details 213 structural elements. These have been carefully selected by José Calavera to cover relevant elements used in practice. Each element is presented with a whole-page annotated model along with commentary and recommendations for the element concerned, as well as a summary of the appropriate Eurocode legislation with reference to further standards and literature. The book also comes with a CD-ROM containing AutoCAD files of all of the models, which can be directly developed and adapted for specific designs.

Its accessible and practical format makes the book an ideal handbook for professional engineers working with reinforced concrete, as well as for students who are training to become designers of concrete structures.

José Calavera is Honorary President of the Technical Institute of Materials and Construction (INTEMAC – Instituto Técnico de Materiales y Construcciones) and Emeritus Professor, School of Civil Engineering, Polytechnic University of Madrid.

Foreword

The aim of this book is to present a fairly full and systematic description of the construction details used in concrete structures.

While I paid particular attention to construction details in my previous books, all dealing primarily with structural design and engineering, I was naturally unable to address the issue in depth in any of them.

I have decided to do so today, acknowledging the importance of detailing and convinced that it is one of the areas of expertise that professionals must quickly learn to master. Construction details have a substantial impact not only on the quality of both the design and the building processes, but on concrete structure maintenance and durability as well.

Forty-five to fifty per cent of the problems arising around concrete structures are widely known to be attributable to the design stage. That half of those problems are due to errors in, or the lack of, construction details is a fact much less generally recognised.

Detailing is always the outcome of a synthesis of four areas of knowledge:

- a command of the theory underlying structural concrete engineering
- on-site professional practice
- experimental information obtained from laboratory trials
- the experience obtained in forensic engineering studies.

The extraordinary complexity resulting from such diversity is deftly reflected in the expression 'the art of detailing', which alludes to the mix of technical skill and creativity entailed in good detailing.

Someone inevitably decides how details are to be built: otherwise construction could not proceed. But the task is actually incumbent upon the designer. The further 'downstream' the detailing is done, the greater is the risk of malfunction.

This book begins with an introductory chapter that summarises specifications on concrete cover, reinforcing bar placement and spacing, hook bending radii, anchorages and bar welding. It also briefly discusses questions that have been scantily addressed in most countries' codes, such as how bars should be tied or spacers and chairs placed.

The second chapter is a description of the 213 construction details that comprise the book. Divided into 15 groups, they embrace what I believe to be a sufficient range of issues arising in reinforced concrete construction.

In this chapter each page on the left shows a drawing of a construction detail. The Notes set out on the page opposite on the right contains further information, as specified below.

(a) A series of Recommendations that supplement and help to interpret the drawing, in some cases with concise reference to specific engineering questions.

(b) Reference to Statutory Legislation in the European Union.

(c) Reference to Recommended Alternative Codes to enable the reader to fill in the gaps where no statutory legislation is in place in the European Union, or in a number of specific cases, to resort to variations of interest.

(d) Finally, a list of Specific References that deal explicitly and directly with the detail in question.

Version 2005 AutoCAD software is furnished with the book to enable designers to adapt each detail to the reinforcing bars used in their designs and print the results on a printer or plotter.

In closing, I owe a word of thanks to the people who collaborated in the preparation of this book. My gratitude goes to Antonio Machado for coordinating the draughting, Maribel González and Mercedes Julve for the typing; and Antonio Machado, Fernando Marcos and Julio César López for draughting the details from my sketches, which were not always as carefully drawn as would have been desired.

Many thanks as well to Margaret Clark and Mc LEHM Language Services for the translation of my original Spanish manuscript into English.

I am also indebted to Jorge Ley for his assistance in many respects.

Lastly, I wish to express my very special gratitude to Taylor & Francis for the support received in connection with the publication of this book, and particularly to Tony Moore and Siobhán Poole for their assistance.

José Calavera
Madrid, March 2011

The author

José Calavera graduated in civil engineering in 1960 and earned his doctorate in the field in 1967, both from the School of Civil Engineering, Polytechnic University of Madrid. From 1960 to 1967 he headed the Engineering Department at Tetracero, a Spanish producer of ribbed bars for reinforced concrete.

In 1967 he founded the Technical Institute of Materials and Construction (INTEMAC – Instituto Técnico de Materiales y Construcciones), an independent quality control organisation that covers design, materials and workmanship in both building and civil engineering. He is presently the Institute's Honorary President.

In 1982 he was appointed Professor of the Building and Precasting Department at the School of Civil Engineering, Polytechnic University of Madrid, where he is now Emeritus Professor.

He is a Fellow of the American Concrete Institute (ACI), the American Society of Civil Engineers (ASCE) and the International Association for Bridge and Structural Engineering (IABSE). He holds the International Federation for Structural Concrete's (FIB) Medal of Honour, and has been awarded the Italian Association of the Prefabrication Prize for Outstanding Achievement in Engineering and the Eduardo Torroja Medal.

He has written 15 books in Spanish, one in Italian and two in English on structural concrete-related subjects. His most prominent designs include the Fuente Dé Aerial Cableway, the roof over the Real Madrid Sports Centre and the space frame roofs over the National Livestock Market at Torrelavega. He is also a renowned specialist in forensic engineering.

Author's curriculum vitae

José Calavera

- PhD in Civil Engineering.
- BSc in Civil Engineering.
- Emeritus Professor of Building and Prefabrication at the School of Civil Engineering, Polytechnic University of Madrid.
- Honorary President of the Technical Institute of Materials and Construction (INTEMAC – Instituto Técnico de Materiales y Construcciones).
- Member of the Commission on Prefabrication of the International Federation for Structural Concrete (Fédération Internationale du Béton – FIB).
- Member of the Working Group 2.2 on Design by Testing of the Commission 2 on Safety and Performance Concepts of the International Federation for Structural Concrete (FIB).
- Editor for Europe of the international Council on Tall Buildings.

  Previously, he was:
  - Chairman of Commission VII on Reinforcement: Technology and Quality Control of the Euro-International Concrete Committee (Comité Euro-International du Béton – CEB).
  - Chairman of the Joint Committee on Tolerances (CEB – FIB).
  - Chairman of the Working Group on Precast Beam-Block Floor Systems of the International Federation for Structural Concrete (FIB).
  - Member of the Administrative Council of CEB.
  - Member of the Model Code CEB–FIB 1990 Drafting Committee.
  - Chairman of the Eurocode Drafting Committee for the Design of Concrete Foundations.
  - Chairman of the Working Group on Precast Prestressed Bridges of the International Federation for Structural Concrete (FIB).
  - Chairman of the Working Group on Treatment of Imperfections in Precast Concrete of the International Federation for Structural Concrete (FIB).
  - Chairman of Scientific-Technical Association of Structural Concrete (ACHE)
- Medal of the Spanish Technical Association for Prestressing (ATEP) (1978).
- Honorary Professor of the Civil Construction Faculty, Pontifical Catholic University of Chile (1980).
- Member of Honour of the Engineering Faculty, Pontifical Catholic University of Chile (1980).
- Elected Fellow of the American Concrete Institute (ACI) (1982).
- Medal of Honour of the Civil Engineering College (1987).
- Eduardo Torroja Medal (1990).
- Medal of the Spanish Road Association (1991).
- Honorary Doctorate of the Polytechnic University of Valencia (1992).

- Institutional Medal of the Lisandro Alvarado' Central Western University, Venezuela (1993).
- Medal of the International Federation for Structural Concrete (FIB) (1999).
- Medal of Honour of the Fundación García-Cabrerizo (1999).
- Award of the Spanish Group of IABSE (2000).
- Great Figures of Engineering Award of the Italian Association of Prefabrication (CTE) (2000).
- Award of the Spanish National Association of Reinforced Bars Manufacturers (ANIFER) (2001).
- Member of Honour of the Spanish Association of Structural Consultants (ACE) (2001).
- Honorary Member of the Academy of Sciences and Engineering of Lanzarote (2003).
- Member of Honour of the Argentine Structural Engineering Association (2004).
- Camino de Santiago Award of Civil Engineering (2004).
- Elected Fellow of IABSE (International Association for Bridge and Structural Engineering) (2006).
- Member of the Board of Trustees of the Fundación Juanelo Turriano (2006).
- Member of Honour of the Association of BSc Civil Engineers (2008).
- Best Professional Profile in Forensic Construction Engineering Award of the Latino American Association of Quality Control and Forensics Engineering (ALCONPAT) (2009).
- Elected Fellow of ASCE (American Society of Civil Engineers) (2009).
- Among his most important projects are the Fuente Dé Aerial Cableway (Cantabria), the space frame roofs of the Real Madrid Sports Centre and the Mahou Beer Factory (Madrid), the space frame roofs of the National Livestock Market of Torrelavega (Santander) and numerous industrial buildings, especially for paper manufacturers and the prefabrication of concrete and steel industry.
- He is author of 15 books in Spanish, two in English and one in Italian, three monographs and 176 publications on matters concerning structural design, reinforced and prestressed concrete, structural safety, prefabrication, quality control and pathology of structures. He has been thesis director for 27 doctoral theses.

Acknowledgements

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Manual de detalles constructivos en obras de hormigón armado, [Manual for detailing reinforced concrete structures], Madrid, 1993.

Cálculo de estructuras de cimentación [Foundation concrete design], 4th edn, Madrid, 2000.

Muros de contención y muros de sótano [Retaining walls and basement walls], 3rd edn, Madrid, 2000.

Cálculo, construcción, patología y rehabilitación de forjados de edificación [Design, construction, pathology and strengthening of slabs in buildings], 5th edn, Madrid, 2002.

Proyecto y cálculo de estructuras de hormigón [Structural concrete design], 2nd edn, Madrid, 2008.

Citations

- Symbols and abbreviations. The conventions adopted in Eurocode 2 (EC2) have been used as a rule, except in Group 15 (Special construction details for earthquake zones), where the Eurocode 8 (EC8) conventions were followed.

- For greater clarity and brevity, references are shown as a number in brackets, which matches the number under which the publication is listed in the References at the end of the book.

  For instance: (3) refers to the third reference, namely EN ISO 3766:2003, *Construction Drawings. Simplified Representation of Concrete Reinforcement.*

- References to sections of the book itself are cited directly.

  For instance: 1.2 refers to section 1.2, Tying bars, in Chapter 1, General rules for bending, placing, anchoring and welding reinforcing bars.

- References to other construction details cite the designation shown at the top of each page.

  For instance: see CD – 01.02 refers to detail CD – 01.02, Wall footing supporting a brick wall.

- References to recommendations sometimes specify another CD. For instance: R-3 in 01.03 refers to Recommendation 3 in CD – 01.03. On occasion, the word 'recommendation' is written out in full, rather than as the abbreviation 'R'.

- References to formulas are placed in square brackets.

  For instance: [1.1] is the first formula in Chapter 1, item 1.1.1.

- The figures in Chapter 1 are designated as Figures 1-1 to 1-45.

- When figures are (very occasionally) shown in the Notes, they are designated by letters: (a), (b) and so on.

- The book is logically subject to EC2 specifications in particular and European Committee for Standardization (CEN) standards in general. When a given subject is not included in the CEN system of standards, explicit mention is made of that fact and an alternative standard is suggested.

- Inevitably, as in any code, the author's opinion occasionally differs from the criteria set out in CEN standards. Such recommendations are clearly labelled **AR** (author's recommendation). In these cases readers are invited to use their own judgement.

General notes

1. Chapter 1 summarises the specifications in Eurocode 2 on concrete cover, bar spacing, bending radii, spacer placement and welding, or alternative codes when no CEN standard is in place (for spacers and tying bars, for instance).

2. Many details assume a 2.5 cm or 1 ϕ cover (abbreviated throughout this book as a lower case r), which is the value for the most usual case, i.e. exposure classes XC2/XC3 in structural class S4. For other conditions, the cover can be changed as described in 1.1.3.

   The cover values in the drawings are the C_{min} *values. A further 10 mm must be added to accommodate the spacers.* (Members cast against the ground are an exception: in such cases the 7.5 cm specified includes the 10-mm margin.) The minimum cover value was not simply enlarged by 10 mm, because while this is the EC2 *recommended* value, countries are free to set their own value in their National Annexes.

3. Details on spacers and tying are indicative only. Their number and specific position are given in Chapter 1. The symbols for spacers and chairs are shown in Figure 1-21.

4. In some cases, more than one page was required to describe a detail. This is clearly specified in the heading ('1 of 2', for instance). In all such cases, the same Notes apply to both drawings and are repeated on the page opposite on the right for the reader's convenience.

5. In keeping with standard terminology in many English-speaking countries, in this book the word 'stirrups' has been used to designate transverse reinforcement in beams and 'ties' to signify transverse reinforcement in columns. In Eurocode EC2, the word 'links' is applied in both situations.

   In most structures these two types of reinforcement serve very different purposes, and perhaps for that reason, in (US) English, French and Spanish, different terms are used for each.

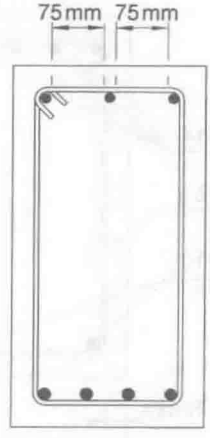
The three golden rules for pouring concrete on site

Construction details have a heavy impact on the actual quality of the concrete in a structure.

RULE No. 1

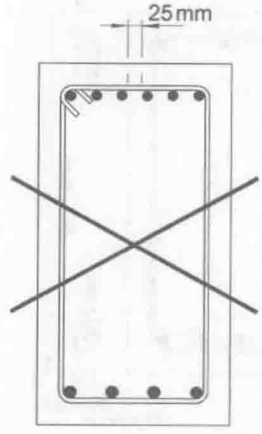
CONCRETE MUST BE CAST INTO ITS FINAL POSITION ACROSS AN ESSENTIALLY VERTICAL PATH

Horizontal paths must be avoided. This must be taken into consideration in the design drawings for reinforcing bar arrangements.



RIGHT

Figure (a)



WRONG

Figure (b)

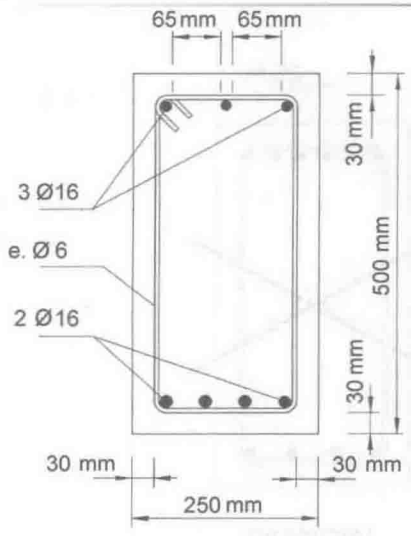
Figure (a) depicts the right way to reinforce a beam to ensure that the forms are filled speedily and satisfactorily. If the bars are arranged as depicted in Figure (b), the coarse aggregate will not pass readily between them. As a result, the concrete will have to flow horizontally, inducing segregation and lengthening the time needed to fill the formwork. Moreover, such arrangements leave insufficient space for the vibrator.

Concrete should not be dumped in a pile for subsequent spreading with vibrators. Rather, it should be poured in each and every spot where it is needed.

RULE No. 2

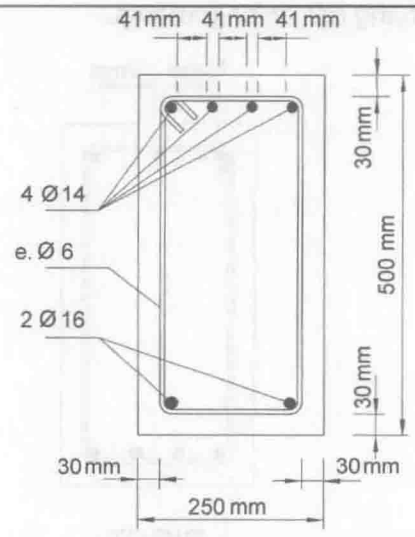
THE VIBRATOR MUST BE ABLE TO REACH THE BOTTOM REINFORCEMENT

Figure (c) shows the right way to reinforce a beam. With 65-mm spacing (somewhat smaller on site due to the height of the ribs), a standard 50-mm vibrator will be able to reach the bottom reinforcement. The solution depicted in Figure (d) is wrong, for it leaves insufficient room for the vibrator.



RIGHT. The vibrator can be readily introduced into the beam and the joint.

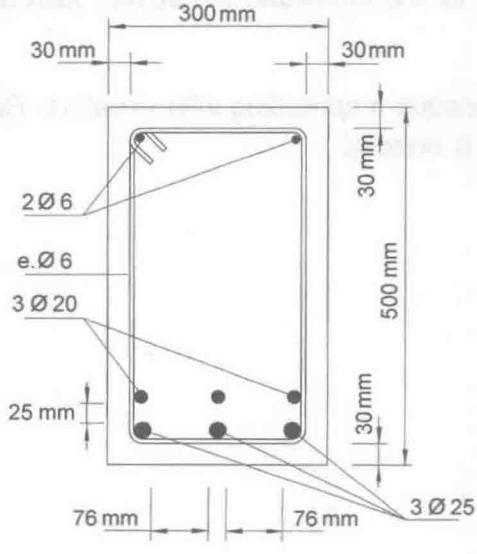
Figure (c)



WRONG. The vibrator cannot be introduced into the beam or the joint.

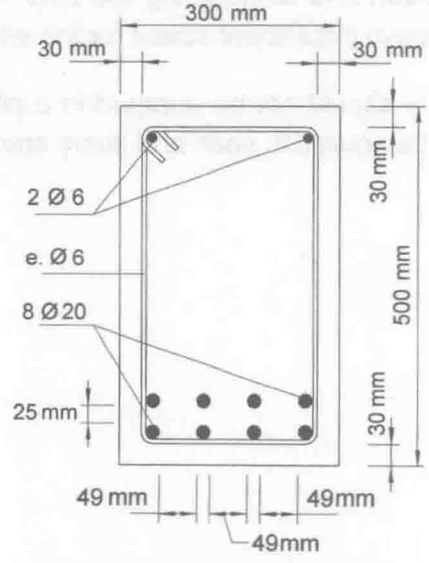
Figure (d)

Figures (e) and (f) show two further cases in which the vibrator is able, or unable, to reach the bottom reinforcement.



RIGHT. The vibrator reaches the bottom layer of reinforcement.

Figure (e)



WRONG. The vibrator cannot reach the bottom layer of of reinforcement.

Figure (f)

RULE No. 3

CONCRETE CONSISTENCY MUST BE IN KEEPING WITH THE REINFORCEMENT ARRANGEMENT. AS A GENERAL RULE THE CONCRETE SLUMP SHOULD BE NO SMALLER THAN 60 mm

Unless the reinforcement is arranged very openly and spaciously or powerful vibration methods are used, overly dry concrete is characterised by the following.

- The required strength can be reached in test specimens (but not on site) with a lower proportion of cement. The real strength of concrete can be lower.
- Since the control specimens can be compacted with no difficulty, the laboratory trials will furnish good information.
- *In situ* placement and a good surrounding of the reinforcement will be difficult to achieve and the loose consistency will lower actual on-site strength.

Contents