Engineers Ireland

Structural Eurocodes

EC 6: Design of Masonry Structures

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Current Irish and British Masonry Design Standards

Unreinforced Masonry

IS 325 : Part 1 Structural use of unreinforced masonry

BS 5628 : Part 1 Structural use of unreinforced masonry

IS 325 : Part 2 Masonry construction

BS 5628 : Part 3 Use of masonry — Materials and components, design and workmanship

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Current Irish and British Masonry Design Standards *Cont.*

Reinforced Masonry

BS 5628 : Part 2 Structural use of reinforced and prestressed masonry

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Irish Building Regulations

Part A - Structure

Part B – Fire

Particular reference: Technical Guidance Document A

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What will not change?

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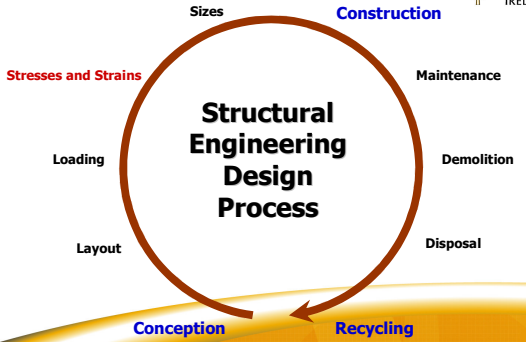

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Structural Design Aim

S — STABLE, STRONG, STIFF, SERVICEABLE

A — AESTHETIC

F — FUNCTIONAL

E — ECONOMIC

Structural Design Philosophy

Limit State Design

Basic Principles of Structural Mechanics

Changes

Design Guidance

IS EN 1996-1-1: *Rules for reinforced and unreinforced masonry*

IS EN 1996-1-2: *Structural fire design*

IS EN 1996-2: *Selection and execution of masonry*

IS EN 1996-3: *Simplified calculation methods for unreinforced masonry structures*

National Annexes

Each Part is entitled to have a National Annex (NA)

Reason:

The Eurocodes support National Building Regulations and other National requirements for regulated work.
However, they remain subservient to them.

National Regulations will set the appropriate level of safety through Nationally Determined Parameters.
These NDPs will be given in the NAs

Irish National Annexes

One for each Part

Drafts for Public Consultation published by NSAI on October 6th

Comments not later than December 1st

Supporting Standards

These deal with specifications for masonry units, mortar and ancillary components, and methods of test for masonry units and mortar

Examples:

IS EN 771: Specification for masonry units

IS EN 772: Methods of test for masonry units

IS EN 1996 Part 1-1

SCOPE

The following subjects are dealt with:

Section 1 – General
Section 2 – Basis of Design
Section 3 – Materials
Section 4 – Durability
Section 5 – Structural Analysis
Section 6 – Ultimate Limit State
Section 7 – Serviceability Limit State
Section 8 – Detailing
Section 9 - Execution

IS EN 1996 Part 1-1

Annexes *– These supply supplementary information.*

There are 10 No. (A to J incl.)

All are Informative

Thus the material therein does not have any status – it is included merely for information

IS EN 1996 Part 1-1

Principles and Application Rules

– as for the other Structural Eurocodes

Nationally Determined Parameters

These NDPs are given in the Irish Annexes

Symbols

These are given in the form of Latin or Greek letters.

Many are similar to those used in the current Irish and British codes

Refer to Clause 1.6 for the full list

IS EN 1996 Part 1-1

Basis of Design

Limit State - as for the other Structural Eurocodes

The two principal categories relevant to the design of masonry structures are: DURABILITY and STRENGTH

Durability (Section 4)- selection of the units and mortars for particular structural types and exposure classes.

Strength (Section 6) - ultimate limit state. In order to assess the effects of various actions (loads), it is necessary to estimate the design values of the actions and the design strength of the materials

IS EN 1996 Part 1-1

Vertical Resistance

Design compressive strength, $f_d = f_k/\gamma_M$

f_k , the characteristic strength is a function of:

- *Group number of the masonry unit*
- *Normalised strength of the masonry unit*
- *Compressive strength of the mortar*

γ_M , the partial factor for materials is a function of:

- *Category of manufacturing control*
- *Class of execution control*

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IS EN 1996 Part 1-1

Group Number {Cl 3.1 (3)}

Four groups – 1, 2, 3 and 4

Group 1 < 25% voids

Group 2 voids between 25% and 60%

Groups 3 and 4 generally not relevant to Ireland

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IS EN 1996 Part 1-1

Normalised mean compressive strength of units, f_b (cl 3.1.2)

Why? Because of differences in the size of units and in test procedures throughout Europe

- *IS 20 - Blocks are tested on edge in a wet condition using soft board capping => mean compressive strength*
- *IS EN 772-1 requires blocks to be ground or mortar capped – gives higher strength*
- *Annex A of IS EN 772-1 proposes a method of deriving normalised strength from mean strength – takes account of whether the blocks were tested on edge or on flat and whether tested in wet or air dry condition*

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IS EN 1996 Part 1-1

Example re a 5N standard size solid concrete block (440 x 100 x 215):

Mean strength per IS 20 - block tested on edge and in a wet condition using soft board capping = 5N

Equivalent mean strength per EN 772-1 = 6.5N

Equivalent mean strength per EN 772-1 - block on flat. Not tested but multiplied by a factor of 1.6 (Douglas, J.G., EOLAS, Dublin 1985) = 10.4N

Normalised strength per EN 772-1 – Two multiplying factors are taken from the EN: 1.2 to convert to the air dry condition and a shape factor, δ, which allows for the height and width of the units (Table A1).

For a 440 x 100 x 215 unit, δ = 0.785 (0.8). Thus the normalised compressive strength for such a block on flat = 10.4 x 1.2 x 0.8 = 9.984 (10N)

(EC 6 Study for Irish National Annex; LeeMcCullough, Consulting Engineers)

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IS EN 1996 Part 1-1

Compressive strength of Mortar (cl 3.2)

Clause 3.2.2 (1) states that " Mortars should be classified by their compressive strength, expressed as the letter M followed by the compressive strength in N/mm²"

Refer to Table NA.2 of the Irish NA

Example ex the table:

A prescribed mortar, designation (iii) consisting of

1 part lime to 1 part cement to 5 or 6 parts sand (i.e. 1:1:5 to 6) has a compressive strength class of M4, where the 4 is the compressive strength in N/mm² at 28 days

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IS EN 1996 Part 1-1

Category of unit - manufacturing control {cl 3.1(2)}

Depending on the manufacturing control, masonry units may be Category I or Category II.

Definitions are given in EN 771-1 to 6

Category I – manufacturing quality control is such that the probability of the units not reaching the declared compressive strength is less than 5%

Category II – those not complying with the Category I level of confidence

Note: It is the manufacturer's responsibility to declare the category of unit supplied

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IS EN 1996 Part 1-1

Class of execution control {cl 2.4.3(1)P}

The Code allows for up to 5 classes of execution control, but the Irish NA gives only 2, namely, class 4 (special) and class 5 (normal). These are given in Table NA.1 of the Annex

Relevant values of γ_M for the Ultimate Limit State are given in the Table.

Example:

Using units of Category I and prescribed mortar,

γ_M = 2.5 for class 4 execution control and = 2.7 for class 5 control

IS EN 1996 Part 1-1

Characteristic compressive strength of masonry (cl 3.6.1.2)

$f_k = K f_b^{\alpha} f_m^{\beta}$ E (3.1)

f_m is the compressive strength of the mortar, in N/mm²

f_b is the normalised mean compressive strength of the units, in the direction of the applied action effect, in N/mm²

K is a constant obtained from Irish NA Table NA.3

α and β are constants

For masonry made with general purpose mortar, α = 0.7 and β = 0.3

IS EN 1996 Part 1-1

Design of unreinforced walls subjected to mainly vertical loading (cl 6.1)

Requirement: $N_{Ed} \leq N_{Rd}$ E (6.1)

Where $N_{Rd} = \Phi_{i,m} t f_k / \gamma_M$

N_{Ed} is the design value of the vertical load and N_{Rd} is the vertical resistance of the wall

Φ is a capacity reduction factor for slenderness and eccentricity.

Φ_i at the top or bottom of the wall and

Φ_m in the middle (refer to Annex G)

IS EN 1996 Part 1-1

Design of unreinforced walls subjected to lateral loading (cl 6.3)

Requirement: $M_{Ed} \leq M_{Rd}$ E (6.14)

For lateral resistance using flexural strength, $M_{Rd} = (f_{xk1} / \gamma_M + \delta_d) Z$

f_{xk1} = characteristic flexural strength of masonry bending about an axis parallel to the bed joints

δ_d = design vertical load per unit area

Z = section modulus of the plan shape of the wall

IS EN 1996 Part 1-1

Design of laterally loaded wall panels

Two approaches given:

The first relies on the flexural strength of the masonry (see above) and makes use of yield line analysis to provide bending moment coefficients (refer to Annex E). The approach is similar to that used in the current Irish and British codes

The second is an approach based on arching (cl 6.3.2)

Method 1

Since failure of a panel may take place about both axes, there will be two design moments and two corresponding moments of resistance

IS EN 1996 Part 1-1

Design of laterally loaded wall panels – Method 1 cont.

Design moments and moments of resistance:

Plane of failure parallel to the bed joints:

$M_{Ed1} = \alpha_1 W_{Ed} l^2$ per unit length of wall, and $M_{Rd1} = (f_{xk1} / \gamma_M) Z$

(Ignoring any vertical load e.g. self weight)

Plane of failure perpendicular to the bed joints:

$M_{Ed2} = \alpha_2 W_{Ed} l^2$ per unit height of wall, and $M_{Rd2} = (f_{xk2} / \gamma_M) Z$

Note: $\alpha_1 = \mu\alpha_2$ where μ is the orthogonal ratio = f_{kx1} / f_{kx2}

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REFERENCES

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eurocode6.org
Includes introductory publications and design examples

Joint Research Centre website:
http://eurocodes.jrc.ec.europa.eu/showpage.php?id=334

The Concrete Centre website:
http://www.concretecentre.com/main.asp?page=728
Select "Design Aids" in the drop down menu for "I am looking for publications in_____". This will give you a number of free to download examples for "How to design masonry structures to Eurocode 6".

Manual for the design of plain masonry in building structures to Eurocode 6 – Institution of Structural Engineers

Eurocode for Masonry EN1996-1-1 and EN1996-2 – Guidance and Worked Examples – International Masonry Society

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I Hear and I Forget

I See and I Remember

I Do and I Understand

(Confucius, circa 500 B.C.)

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DESIGN EXAMPLES

Example 1 Vertical loaded wall

Example 2 Laterally loaded wall

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