MASONRY CODES & STABILITY

WITH REFERENCE TO EARTHQUAKE DETAILING

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MASONRY CODES

- BS 5628 pt 1 – Design of Plain Masonry
- BS 5628 pt - Design of Reinforced & prestressed Masonry
- EC 6 ENV 1996-1-1 Rules for reinforced/ prestressed & un-reinforced masonry

(EN Date due 2003/4)

EC 8 ENV 1998-1-1; 1996

Design Provisions for Earthquake Resistance of Structures

Contents of EC6

Part 1: The design of masonry structures: General rules for buildings

Part 2: Design, selection of materials and execution of masonry

Part 3: Simplified calculation methods and simple rules for the design of masonry

Part 10: Fire performance of masonry structures

Of these, Part 1 is well advanced. Part 2 published 1998 and part 3 in 1999 as ENVs. Part 10 (now 1-2 published 1996) and part 1.3 on laterally loaded masonry are to be published with part 1 – 1, together with part 1-x: Complex shapes sections in masonry structures.

Scope of Part 1 – 1 of Eurocode 6

Part 1- 1 of Eurocode 6, DD ENV 1996 –1-1, containing principles & rules of applications, gives a general basis for the design of buildings and civil engineering works in unreinforced, reinforced, prestressed and confined masonry made with the masonry units laid in mortar.

- Section 1 : General
- Section 2 : Basis of design (EC 1)

Fundamental Combination

$$\xi\gamma_{G,j} G_{k,j} \quad + \quad \gamma_{Q,1} Q_{k,i} \quad + \quad \xi\gamma_{Q,i} \Psi_{O,i} Q_{k,i}$$

$$i > 1$$

Sum of factored Permanent loads	Factored dominant variable load	Sum of other factored variable loads

Scope of Part 1 – 1 of Eurocode 6 (cont.)

Section 3 : Materials

Section 4 : Design of masonry

Section 5 : Structural detailing (chases & recesses where essential should be placed within 🖮th of storey height)

Section 6 : Construction

Unreinforced masonry does not usually require the consideration of the Serviceability Limit State, as satisfying the Ultimate Limit State usually avoids cracking and deflection problems. This is not so for Reinforced Masonry, when both the Ultimate and Serviceability Limit States need to be addressed

Table 1 - Partial Safety factors γ_m characteristic loading & materials strength for normal design loads.

Ultimate Limit State	BS	EC	
permanent load	1.4	1.35	γ_G
imposed load	1.6	1.50	

Material	*Special Category BS*		*Normal Category BS*		*BS 5628*
Masonry		(EC6/B)		(EC6/C)	
Compression	2.5	(2.8)	3.1	(3.5)	Pt1
Compression/flexure	2.0	(2.8)	2.3	(3.5)	Pt 2
Flexure	2.8	(2.8)	3.5	(3.5)	Pt1
Shear	2.5	(2.5)	2.5	(3.5)	Pt1
Shear	2.0	(2.8)	2.0	(3.5)	Pt 2
Bond	1.5	(2.0)	1.5	-	Pt2
Strength of steel	1.15	(1.15)	1.15	-	Pt 2
Wall ties	3.0	(2.5)	3.0	(2.5)	Pt 1

When considering the probable effects of misuse or accident, the values given should be halved.
EC8 gives a γ_m of 1.7 and 2.0 for Categories B & C

Table 2 - Characteristic values of imposed loads on floors in buildings and Ψ values to EC1

Loaded areas	UDL (kN/M^2)	Conc. Load (kN)	Ψ_o	Ψ_1	Ψ_2
Domestic	2.0	2.0	0.7	0.5	0.3
Offices	3.0	2.0	0.7	0.5	0.3
Assembly With fixed seats	4.0 5.0	4.0 4.0	0.7 0.7	0.7 0.7	0.6 0.6
Storage	5.0	7.0	1.0	0.9	0.8
Wind			0.6	0.5	0.0

$\psi_{Ei} = \phi \cdot \psi_{2i}$ (where ψ varies from 0.5 – 1.0 depending on occupancy)

STABILITY

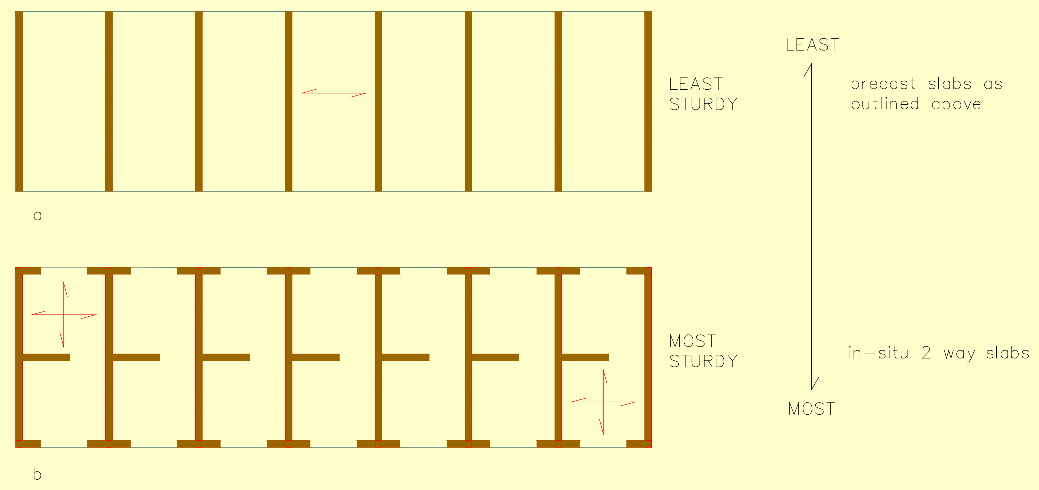


FIG 1

THE EXTENT OF DAMAGE SHOULD NOT BE DISPROPORTIONATE TO ITS CAUSE

BS 5628 specifies the minimum lateral load at 1.5% of the total characteristic DL above that level.

EC6 gives this at 1% of the combined vertical characteristic dead and imposed load at the particular floor divided by $\sqrt{h_{tot}}$

Their effect may be ignored if less onerous than other horizontal actions eg. wind

ACCIDENTAL DAMAGE

For buildings with 5 storeys or more & clear spans exceeding 9.00m:

BS 5628 pt 1 - Table 12 - 3 options given:

- **option 1 based on members being able to withstand a pressure of 34KN/m^2 in any direction**
- **option 3 prescribes horizontal & vertical ties as in BS 8110**
- **option 2 is a hybrid between options 1 & 3 where in masonry construction it may be difficult to provide vertical tying. Unless member defined as protected (can withstand pressure up to 34KN/m^2) the effect of removing one vertical member at a time is to be considered.**

TIEING PROVISIONS TO BS5628 pt 1

- **Vertical Tie the greater of :**

  $T = (34A/8000)\,(h/t)^2\,N$ or 100KN/m length

  where A is the area in mm^2

- **Horizontal Tile – in KN, is the lesser of:**

  $F_t = 20 + 4\,N_s$ (where N_s is the no of storeys)

  or 60 KN

- **Internal Ties in KN/m**

  $f_t' = F_t\,\{(G_k+Q_k)/7.5\} \times L_a/5$

- **External Wall or Column Tie in KN for columns & KN/m for walls is the lesser of**

  $2F_t$ or $(L/2.5)\,F_t$

The tie force is based on shear strength or friction

SEISMIC ZONING

Table 3 – Return Periods for Earthquake Intensity of the Maltese Islands

MM – Earthquake Intensity	*Return Period (years)*	*Base Shear Design % of g*
VI	**333**	**2 –5**
VII	**1800**	**5 –10**
VIII	**100,000**	**10- 20**

Design grd. acceleration for a return period of [475] yrs (EC8) taken between 0.05g – 0.8g.

Defined as a low seismicity zone as <0.10g (EC8)

< 0.10g, but > 0.4g EC 8 provisions to be catered for

MASONRY DESIGN CRITERIA FOR ZONES OF LOW SEISMICITY (EC8)

1. Shear walls in manufactured stones units

   $t \geq [175]$mm

   $h_{ef}/t \leq [15]$

2. A min of 2 parallel walls is placed in 2 orthogonal directions. The cumulative length of each shear wall > 30% of the length of the building. The length of wall resisting shear is taken for the part that is in compression.

3. For a design ground acceleration < 0.2g the allowed no of storeys above ground allowed is [3] for unreinforced masonry and [5] for reinforced masonry, however for low seismieity a greater no allowed.

4. Mortar Grade (III), (M5) although lower resistance may be allowed. Reinforced masonry type IV (M10). No need to fill perp. Joints.

FIG 2 -Masonry Improved Sturdiness for Aseismic Design

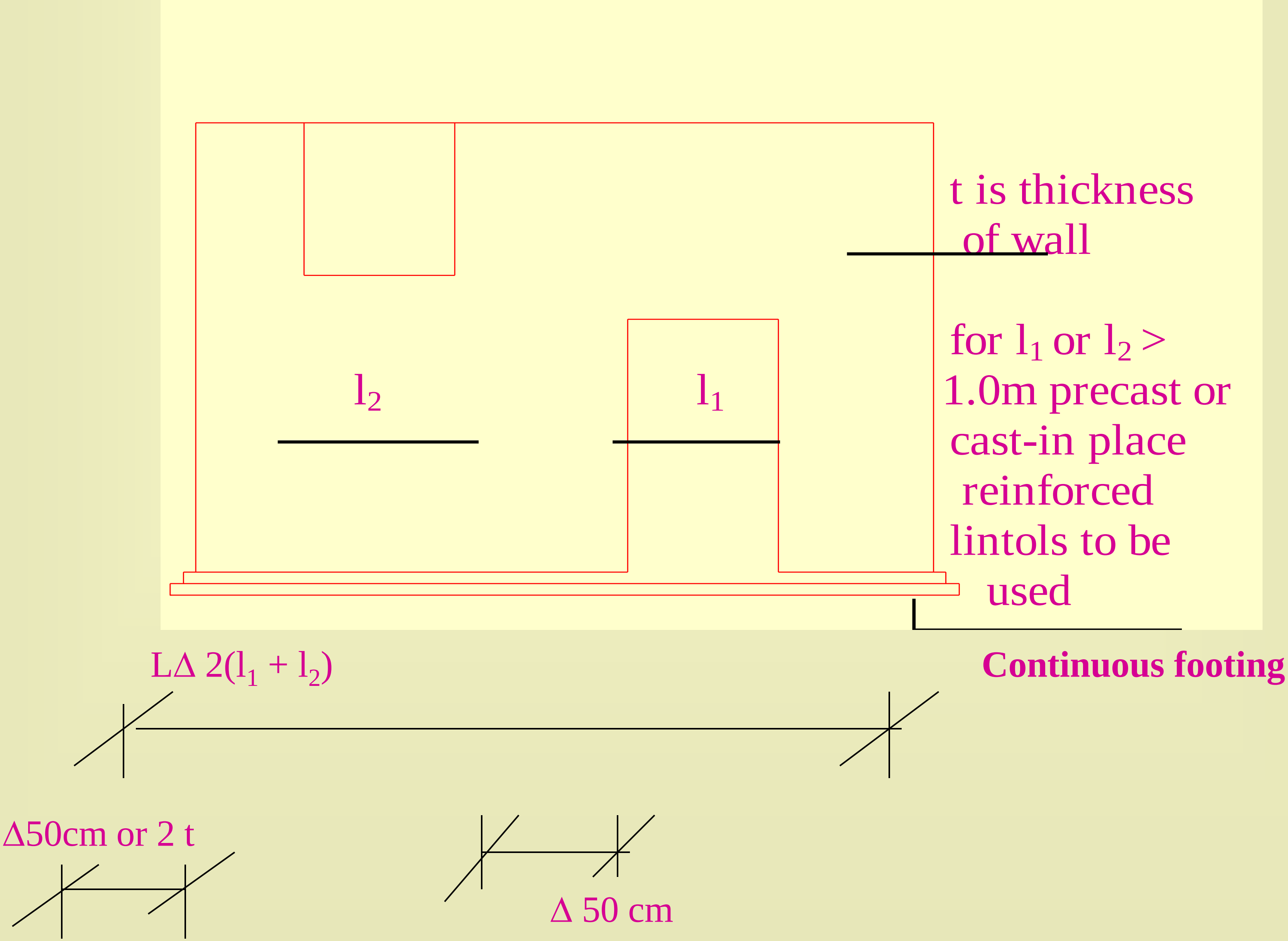
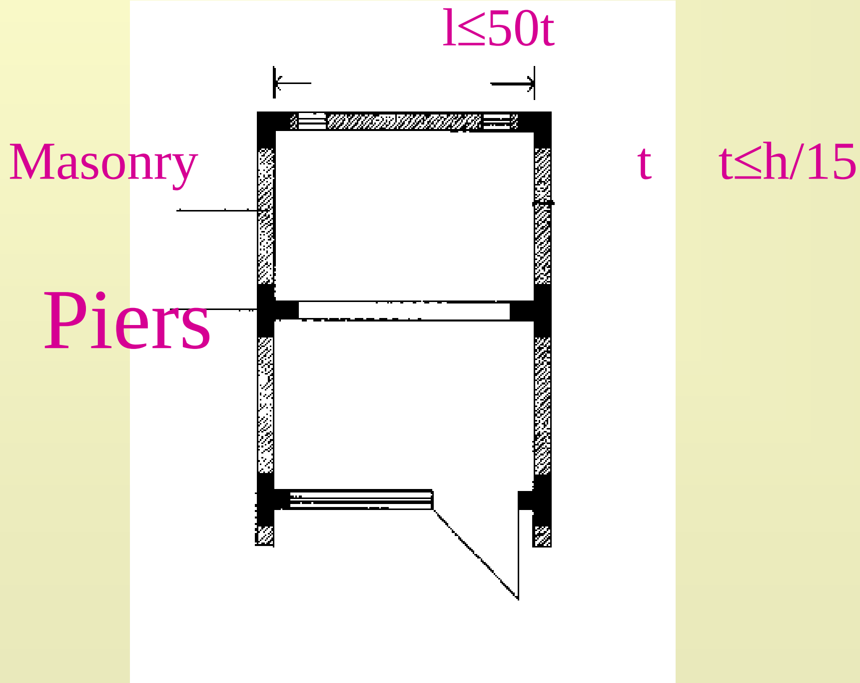


Fig 3- Example of overcoming unsymmetrical requirements when large opening required on one side

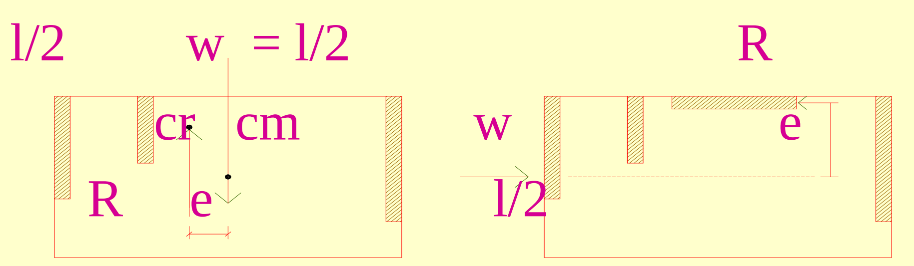
Forming stiffening piers at [7] m centres



Crack width Classification

Category	Damage Extension	Action
0 No Damage	Hairline crack widths 0.1mm	No action needed
1 Light non-structural damage	Fine cracks on plaster. Typical crack widths up to 1 mm	Not necessary to evacuate the building.
2 Moderate structural damage	Small cracks on masonry walls. Generalized failures in non-structural elements such as cornices and chimneys. Typical crack widths up to 5mm.	Not necessary to evacuate the building. Ensure conservation, such as external re-pointing to and erasing/adjusting of sticky doors
3 Severe structural damage	Large and deep cracks, in masonry wall, chimneys, tanks, stair. The structure resistance capacity is partially reduced. Typical cracked widths exceed 15mm.	The building must be evacuated and shored. It can be re-occupied after retrofitting.
4 Heavy structural damage	Wall pieces fall down, interior and exterior walls break and lean out of plumb. Typical crack widths exceed 25mm.	The building must be evacuated and shored. It must be demolished or major retrofitting work is needed before being re-occupied.

FIG 4 - Accounting for Torsional Diaphragm effects



Calculated Torsion $M_1 = W_e$ distributed into 3 walls according to angular rotation and displacement.

$M_1 = W_e$ (distributed into the orthogonal walls by couple action)

The distribution of the total base shear may be modified where the shear is neither reduced more than 30% or increased more than 50% (EC8)

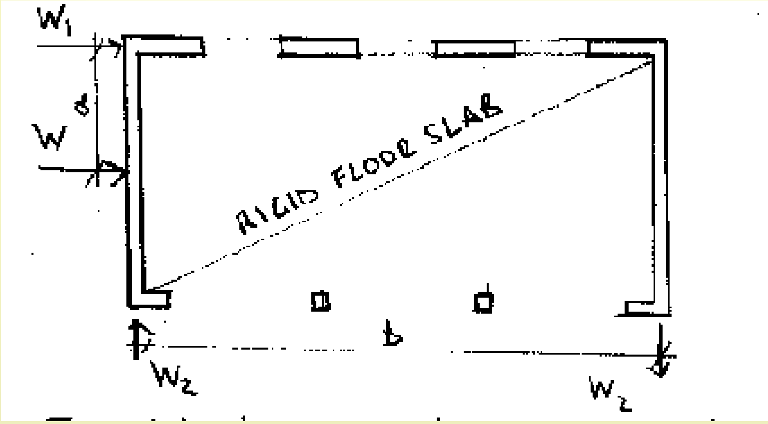
EC6 states that due to reduced stiffness due to cracking 15% re-distribution permissible.

BICC Building Industry Consultancy Council	Project STRUCTURAL REGIDITY – CPD MASONRY	Job ref
	Part of Structure: DISTRIBUTION INTO SHEAR WALLS	Sheet No PO1
	Drawing ref: Done by DHC	Date: 02/02

Calculations	Output

OPEN FRONTED BUILDINGS

(frequently employed on the grd. Flr with large shop windows)



The relatively thin columns at front are of little use in resisting horizontal load.

The total horizontal force W, is resisted by back wall if strong enough – where $W_1 = W$

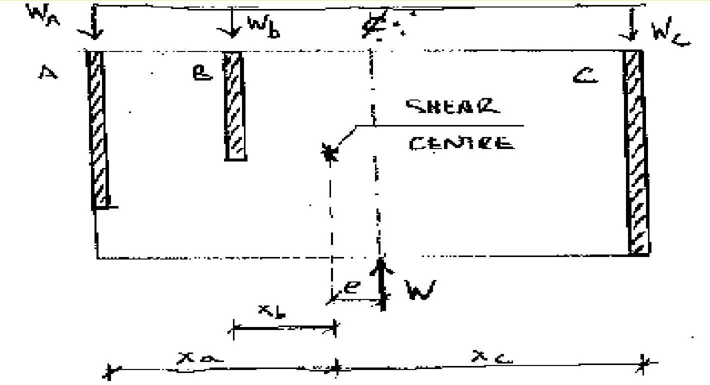
Then by couple action

$W_a = W_2 b$

$W_2 = W_a/b$

BICC Building Industry Consultative Council	Project: STRUCTURAL RIGIDITY CPD MASONRY	Job ref:
	Part of Structure: DISTRIBUTION INTO PARALLEL SHEAR WALLS	Sheet No: Po2
	Drawing ref: Done by: DHC	Date 02/02

Calculations



Because of bending & shear the walls deform as cantilevers, with equal deflections at slab level.

The shear deflection is normally neglected if height:width >5

The Shear Centre is the centroid of MI's.

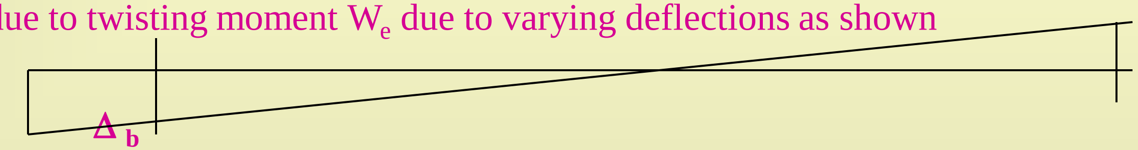
In a symmetrical distribution

$W_A = WI_A/\Sigma I$

$W_B = WI_B/\Sigma I$

$W_C = WI_C/\Sigma I$

However due to twisting moment W_e due to varying deflections as shown

Δ_A  Δ_b Δ_c

The adjusted loading works out at

$$W_n = \frac{WI_n}{\Sigma I} \qquad \frac{Wex_n I_n}{\Sigma I\, x^2}$$

Output

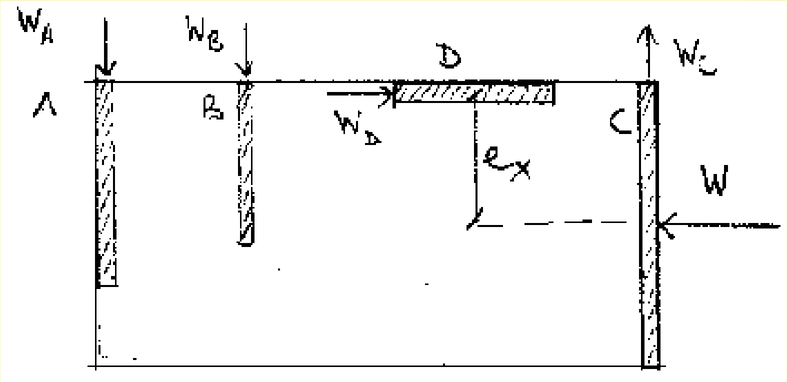
Ref:

An introduction to load bearing brick design

A.W. Hendry

BICC Building Industry Consultative Council	Project: STRUCTURAL RIGIDITY – CPD MASONRY	Job Ref:
	Part of Structure: LONGITUDINAL SHEAR WALL DISTRIBUTION	Sheet No. P03
	Drawing ref: Done by: DHC	Date: 02/02

Calculations	Output



The horizontal load W may be resisted by Wall D.

Because of the eccentricity e_x, a couple produces a moment We_x to be resisted by walls A,B & C given by:

$$W_n = \frac{We\,X_n\,I_n}{\Sigma\, I\, x^2}$$

where e, x_n are as defined before