NOTHING BEATS A GREAT TEMPLATE

Preface

Content
Interactive design aids for masonry elements in accordance to BS EN 1996

Guidelines of use
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The examples provided have been created using VCmaster. All annotated and illustrated design aids can be used as a basis to create own templates. In order to do this a full version of VCmaster is necessary.

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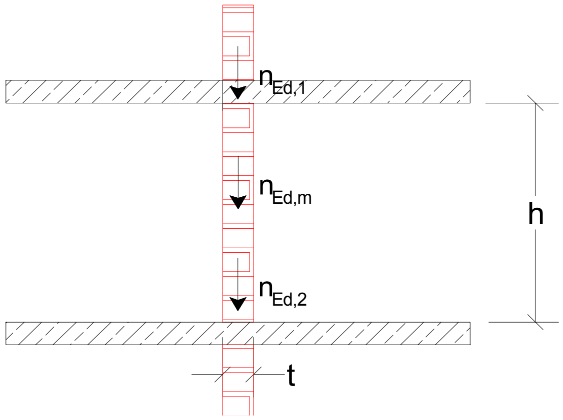
Chapter 1: Examples

Vertical load capacity of an intermediate wall



Data given

Effective thickness t_{ef} = 140.00 mm
Clear height h = 2800.00 mm
Effective heigth reduction factor ρ = 0.75
Total load for ULS N_{Ed} = 125.00 kN/m

Material properties

Control class = 2
Category = I
γ_m = 2.70

Reduction factor

Effective height h_{ef} = $\rho * h = 0.75 * 2800.00$ = 2100.00 mm

Slenderness λ = $\frac{h_{ef}}{t_{ef}} = \frac{2100.00}{140.00}$ = 15.00 < 27

Factor Φ_A = 1.00

Factor Φ_s = $A_1 * e^{(-0,5 * u^2)}$ = 0.747

Material selected

Structural units = Aggregate concrete
Classification group = 1
Type of mortar = general

Mean compressive strength of masonry unit f_b = 7.10 N/mm²
Compressive strength of mortar f_m = 6.00 N/mm²

Shape factor

Height of unit h = 215.00 mm

Width of unit w = 140.00 mm

δ = 1.300

$f_b = \delta * f_b = 1.300 * 7.10$ = 9.23 N/mm²

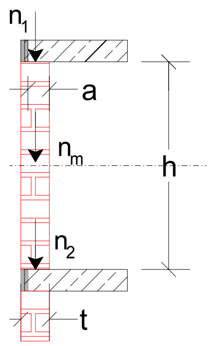
$f_k = K * f_b^{\alpha} * f_m^{\beta} = 0.55 * 9.23^{0.70} * 6.00^{0.30}$ = 4.46 N/mm²

$f_d = \frac{f_k}{\gamma_m} = \frac{4.46}{2.70}$ = 1.65

$N_{Rd} = \frac{f_d * t_{ef} * 10^3 * \Phi_A * \Phi_s}{10^3} = \frac{1.65 * 140.00 * 10^3 * 1.00 * 0.747}{10^3}$ = 172.56 kN

$\frac{N_{Ed}}{N_{Rd}} = \frac{125.00}{172.56}$ = **$0.72 \leq 1$**

Load capacity of an external wall (roof)



Data given

Effective thickness t_{ef} = 140.00 mm

Clear height h = 2800.00 mm

Effective heigth reduction factor ρ = 0.75

Total load for ULS N_{Ed} = 150.00 kN/m

Material properties

Control class	=	2
Category	=	I
γ_m	=	2.70

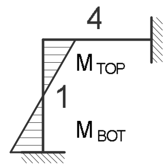
Slenderness

Effective height h_{ef} = $\rho * h = 0.75 * 2800.00$ = 2100.00 mm

Slenderness λ = $\frac{h_{ef}}{t_{ef}} = \frac{2100.00}{140.00}$ = 15.00 < 27

Factor Φ_A = 1.00

Moments at the top and at the bottom



Data given for the wall

Clear hight h_1 = h = 2800.00 mm

Depth of wall h = t_{ef} = 140.00 mm

Strength f_k = 4.05 N/mm²

E_1 = $f_k * 10^3$ = 4050.00 N/mm²

I_1 = $\frac{1000 * h^3}{12} = \frac{1000 * 140.00^3}{12}$ = $228.67 * 10^6$ mm^4

Data given for the roof

Load w_4 = 8.10 kN/m

Span of roof L_4 = 6500.00 mm

Roof or floor depth h = 200.00 mm

Concrete grade = C30/37

E_4 = 33000.00 N/mm²

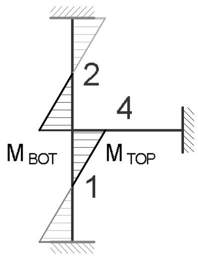
$$I_4 = \frac{850 * h^3}{12} = \frac{850 * 200.00^3}{12} = 566.67*10^6\ mm^4$$

Moment at the top

$$\eta = MAX\left(1 - \frac{\frac{E_4 * I_4}{L_4}}{4 * \frac{E_1 * I_1}{h_1}} ; 0.5\right) = 0.50$$

$$M_{top} = \eta * \frac{\frac{E_1 * I_1}{h_1}}{\frac{E_1 * I_1}{h_1} + \frac{E_4 * I_4}{L_4}} * \frac{-1 * w_4 * L_4^2}{12} = -1.47\ kNm/m$$

Moment at the bottom



Data given for the floor

Load w_4 = 10.00 kN/m

$$\eta = MAX\left(1 - \frac{\frac{E_4 * I_4}{L_4}}{4 * \left(\frac{E_1 * I_1}{h_1} + \frac{E_2 * I_2}{h_2}\right)} ; 0.5\right) = 0.50$$

$$M_{bot} = \eta * \frac{\frac{E_1 * I_1}{h_1}}{\frac{E_1 * I_1}{h_1} + \frac{E_2 * I_2}{h_2} + \frac{E_4 * I_4}{L_4}} * \frac{w_4 * L_4^2}{12} = 1.65\ kNm/m$$

$$M_{mid} = \frac{M_{bot} + M_{top}}{2} = \frac{1.65 + -1.47}{2} = 0.09\ kNm/m$$

Slenderness reduction factor

e_{top} = MAX($\frac{abs(1000 * M_{top})}{N_{Ed}} + \frac{h_{ef}}{450}$; 0.05 * t_{ef}) = 14.47 mm

$\Phi_{s,top}$ = $1 - \frac{2 * e_{top}}{t_{ef}} = 1 - \frac{2 * 14.47}{140.00}$ = 0.793

e_{mid} = MAX($\frac{abs(1000 * M_{mid})}{N_{Ed}} + \frac{h_{ef}}{450}$; 0.05 * t_{ef}) = 7.00 mm

$\Phi_{s,mid}$ = $A_1 * e^{(-0,5 * u^2)}$ = 0.747

e_{bot} = MAX($\frac{abs(1000 * M_{bot})}{N_{Ed}} + \frac{h_{ef}}{450}$; 0.05 * t_{ef}) = 15.67 mm

$\Phi_{s,bot}$ = $1 - \frac{2 * e_{bot}}{t_{ef}} = 1 - \frac{2 * 15.67}{140.00}$ = 0.776

Φ_s = MIN($\Phi_{s,top}$; $\Phi_{s,mid}$; $\Phi_{s,bot}$) = 0.747

Material selected

Structural units = Aggregate concrete
Classification group = 1
Type of mortar = general

Mean compressive strength of masonry unit f_b = 7.10 N/mm²
Compressive strength of mortar f_m = 6.00 N/mm²

Shape factor
Height of unit h = 215.00 mm
Width of unit w = 140.00 mm

δ = 1.300

f_b = $\delta * f_b = 1.300 * 7.10$ = 9.23 N/mm²

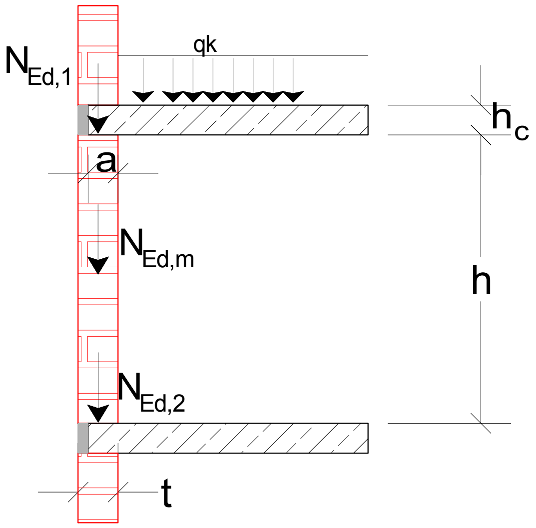
f_k = $K * f_b^{\alpha} * f_m^{\beta} = 0.55 * 9.23^{0.70} * 6.00^{0.30}$ = 4.46 N/mm²

f_d = $\frac{f_k}{\gamma_m} = \frac{4.46}{2.70}$ = 1.65

N_{Rd} = $\frac{f_d * t_{ef} * 10^3 * \Phi_A * \Phi_s}{10^3} = \frac{1.65 * 140.00 * 10^3 * 1.00 * 0.747}{10^3}$ = 172.56 kN

$\frac{N_{Ed}}{N_{Rd}} = \frac{150.00}{172.56}$ = **0.87 ≤ 1**

Load capacity of an external wall



Data given

Effective thickness t_{ef} = 140.00 mm

Clear height h = 2800.00 mm

Effective heigth reduction factor ρ = 0.75

Total load for ULS N_{Ed} = 150.00 kN/m

Material properties

Control class	=	2
Category	=	I
γ_m	=	2.70

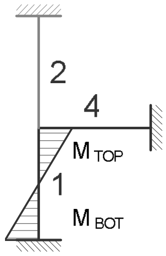
Slenderness

Effective height $h_{ef} = \rho * h = 0.75 * 2800.00$ = 2100.00 mm

Slenderness $\lambda = \frac{h_{ef}}{t_{ef}} = \frac{2100.00}{140.00}$ = 15.00 < 27

Factor Φ_A = 1.00

Moments at the top and bottom



Data given for the wall

Clear hight h_1 =	h	=	2800.00 mm
Depth of wall h =	t_{ef}	=	140.00 mm
Strength f_k =			4.05 N/mm²
E_1 =	$f_k * 10^3$	=	4050.00 N/mm²
I_1 =	$\frac{1000*h^3}{12} = \frac{1000*140.00^3}{12}$	=	$228.67*10^6$ mm^4

Data given for the floor

Load w_4 =			8.75 kN/m
Span L_4 =			5000.00 mm
Floor depth h =			200.00 mm
Concrete grade		=	C30/37
E_4		=	33000.00 N/mm²
I_4 =	$\frac{850*h^3}{12} = \frac{850*200.00^3}{12}$	=	$566.67*10^6$ mm^4

Moment at the top

$$\eta = MAX\left(1 - \frac{\frac{E_4 * I_4}{L_4}}{4*\left(\frac{E_1*I_1}{h_1}+\frac{E_2*I_2}{h_2}\right)}; 0.5\right) = 0.50$$

$$M_{top} = \eta * \frac{\frac{E_1*I_1}{h_1}}{\frac{E_1*I_1}{h_1}+\frac{E_2*I_2}{h_2}+\frac{E_4*I_4}{L_4}} * \frac{-1*w_4*L_4^2}{12} = -0.68 \text{ kNm/m}$$

Moment at the bottom

$$M_{bot} = \eta * \frac{\frac{E_1*I_1}{h_1}}{\frac{E_1*I_1}{h_1}+\frac{E_2*I_2}{h_2}+\frac{E_4*I_4}{L_4}} * \frac{0.5*w_4*L_4^2}{12} = 0.34 \text{ kNm/m}$$

$$M_{mid} = \frac{M_{bot}+M_{top}}{2} = \frac{0.34+-0.68}{2} = -0.17 \text{ kNm/m}$$

Slenderness reduction factor

e_{top} = MAX($\frac{abs(1000 * M_{top})}{N_{Ed}} + \frac{h_{ef}}{450}$; $0.05 * t_{ef}$) = 9.20 mm

$\Phi_{s,top} = 1 - \frac{2 * e_{top}}{t_{ef}} = 1 - \frac{2 * 9.20}{140.00}$ = 0.869

e_{mid} = MAX($\frac{abs(1000 * M_{mid})}{N_{Ed}} + \frac{h_{ef}}{450}$; $0.05 * t_{ef}$) = 7.00 mm

$\Phi_{s,mid} = A_1 * e^{(-0,5 * u^2)}$ = 0.747

e_{bot} = MAX($\frac{abs(1000 * M_{bot})}{N_{Ed}} + \frac{h_{ef}}{450}$; $0.05 * t_{ef}$) = 7.00 mm

$\Phi_{s,bot} = 1 - \frac{2 * e_{bot}}{t_{ef}} = 1 - \frac{2 * 7.00}{140.00}$ = 0.900

Φ_s = MIN($\Phi_{s,top}$; $\Phi_{s,mid}$; $\Phi_{s,bot}$) = 0.747

Material selected

Structural units = Aggregate concrete
Classification group = 1
Type of mortar = general

Mean compressive strength of masonry unit f_b = 7.10 N/mm²
Compressive strength of mortar f_m = 6.00 N/mm²

Shape factor
Height of unit h = 215.00 mm
Width of unit w = 140.00 mm

δ = 1.300

$f_b = \delta * f_b = 1.300 * 7.10$ = 9.23 N/mm²

$f_k = K * f_b^{\alpha} * f_m^{\beta} = 0.55 * 9.23^{0.70} * 6.00^{0.30}$ = 4.46 N/mm²

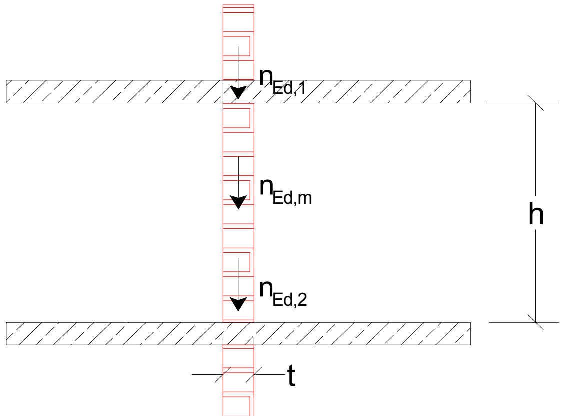
$f_d = \frac{f_k}{\gamma_m} = \frac{4.46}{2.70}$ = 1.65

$N_{Rd} = \frac{f_d * t_{ef} * 10^3 * \Phi_A * \Phi_s}{10^3} = \frac{1.65 * 140.00 * 10^3 * 1.00 * 0.747}{10^3}$ = 172.56 kN

$\frac{N_{Ed}}{N_{Rd}} = \frac{150.00}{172.56}$ = **0.87 ≤ 1**

Chapter 2: Simplified method

Vertical load capacity of an intermediate wall



Data given

Effective thickness t_{ef} = 140.00 mm

Clear height h = 2800.00 mm

Effective heigth reduction factor ρ = 0.75

Total load for ULS N_{Ed} = 200.00 kN/m

Material properties

Control class	=	2
Category	=	I
γ_m	=	2.70

Reduction factor

Effective height $h_{ef} = \rho * h = 0.75*2800.00$ = 2100.00 mm

Slenderness $\lambda = \dfrac{h_{ef}}{t_{ef}} = \dfrac{2100.00}{140.00}$ = 15.00 < 27

Factor Φ_A = 1.00

Factor $\Phi_s = 0.85 - 0.0011 * \left(\dfrac{h_{ef}}{t_{ef}}\right)^2 = 0.85 - 0.0011 * \left(\dfrac{2100.00}{140.00}\right)^2$ = 0.603

Material selected

Structural units	=	Aggregate concrete
Classification group	=	1
Type of mortar	=	general

Mean compressive strength of masonry unit f_b = 12.00 N/mm²

Compressive strength of mortar f_m = 6.00 N/mm²

Shape factor
Height of unit h = 215.00 mm
Width of unit w = 140.00 mm

δ = 1.300

$f_b = \delta * f_b = 1.300 * 12.00$ = 15.60 N/mm²

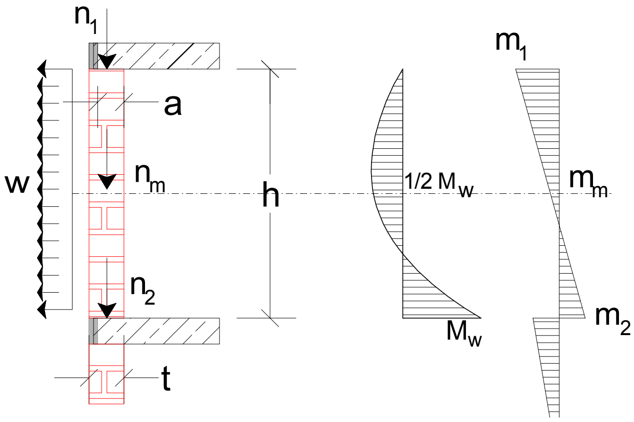
$f_k = K * f_b^{\alpha} * f_m^{\beta} = 0.55 * 15.60^{0.70} * 6.00^{0.30}$ = 6.44 N/mm²

$f_d = \frac{f_k}{\gamma_m} = \frac{6.44}{2.70}$ = 2.39

$N_{Rd} = \frac{f_d * t_{ef} * 10^3 * \Phi_A * \Phi_s}{10^3} = \frac{2.39 * 140.00 * 10^3 * 1.00 * 0.603}{10^3}$ = 201.76 kN/m

$\frac{N_{Ed}}{N_{Rd}} = \frac{200.00}{201.76}$ = **0.99 ≤ 1**

Load capacity of an external wall (roof)



Data given

Effective thickness t_{ef} = 140.00 mm

Clear height h = 2800.00 mm

Span of roof $l_{f,ef}$ = 5000.00 mm

Effective heigth reduction factor ρ = 1.00

Loading

Dead loads g_k = 15.00 kN/m

Imposed loads q_k = 10.00 kN/m

Windload q_{Ewd} = 0.60 kN/m²

Ultimate limit states

Total load for ULS $N_{Ed} = 1.35 * g_k + 1.50 * q_k$ = 35.25 kN/m

Material properties

Control class = 2

Category = I

γ_m = 2.70

Slenderness

Effective height $h_{ef} = \rho * h = 1.00 * 2800.00$ = 2800.00 mm

Slenderness $\lambda = \frac{h_{ef}}{t_{ef}} = \frac{2800.00}{140.00}$ = 20.00 < 27

Factor Φ_A = 1.00

Factor $\Phi_{s,i} = 0.85 - 0.0011 * \left(\frac{h_{ef}}{t_{ef}}\right)^2 = 0.85 - 0.0011 * \left(\frac{2800.00}{140.00}\right)^2$ = 0.410

Factor $\Phi_{s,ii} = 1.3 - \frac{l_{f,ef}}{8} = 1.3 - \frac{5.00}{8}$ = 0.675

Factor $\Phi_{s,iii}$ = 0.400

Φ_s = MIN($\Phi_{s,i}$; $\Phi_{s,ii}$; $\Phi_{s,iii}$) = 0.40

Material selected

Structural units	=	Aggregate concrete
Classification group	=	1
Type of mortar	=	general

Mean compressive strength of masonry unit f_b = 12.00 N/mm²

Compressive strength of mortar f_m = 6.00 N/mm²

Shape factor

Height of unit h = 215.00 mm

Width of unit w = 140.00 mm

δ = 1.300

$f_b = \delta * f_b = 1.300 * 12.00$ = 15.60 N/mm²

$f_k = K * f_b^{\alpha} * f_m^{\beta} = 0.55 * 15.60^{0.70} * 6.00^{0.30}$ = 6.44 N/mm²

$f_d = \frac{f_k}{\gamma_m} = \frac{6.44}{2.70}$ = 2.39

$N_{Rd} = \frac{f_d * t_{ef} * 10^3 * \Phi_A * \Phi_s}{10^3} = \frac{2.39 * 140.00 * 10^3 * 1.00 * 0.40}{10^3}$ = 133.84 kN

$\frac{N_{Ed}}{N_{Rd}} = \frac{35.25}{133.84}$ = **0.26 ≤ 1**

Minimum thickness

$N_{Ed} = g_k$ = 15.00 kN/m

$\alpha = \frac{N_{Ed}}{t_{ef} * 1000 * f_d} = \frac{15000}{140.00 * 1000 * 2.39}$ = 0.04 m^{-1}

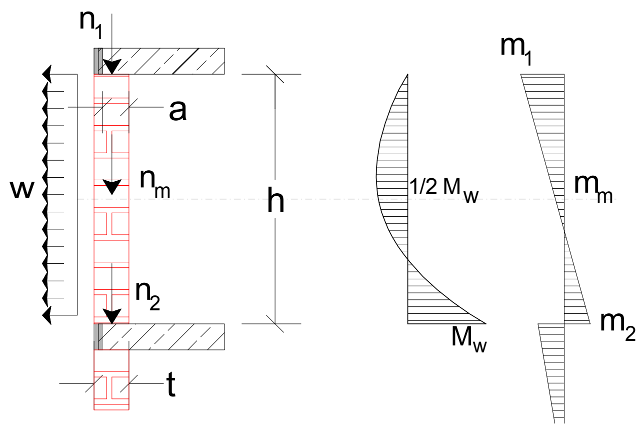
c_1 = 0.120

c_2 = 0.017

$t_{min} = \frac{c_1 * q_{Ewd} * 1 * h_{ef}^2}{N_{Ed}} + c_2 * h_{ef} = \frac{0.120 * 0.60 * 1 * 2.80^2}{15.00} + 0.017 * 2.80$ = 0.085 m

$\frac{t_{min}}{t_{ef}} = \frac{85}{140.00}$ = **0.61 ≤ 1**

Load capacity of an external wall



Data given

Effective thickness t_{ef} = 140.00 mm

Clear height h = 2800.00 mm

Span of floor $l_{f,ef}$ = 5000.00 mm

Effective heigth reduction factor ρ = 1.00

Loading

Dead loads g_k = 50.00 kN/m

Imposed loads q_k = 30.00 kN/m

Windload q_{Ewd} = 0.60 kN/m²

Ultimate limit states

Total load for ULS $N_{Ed} = 1.35 * g_k + 1.50 * q_k$ = 112.50 kN/m

Material properties

Control class = 2

Category = I

γ_m = 2.70

Slenderness

Effective height $h_{ef} = \rho * h = 1.00 * 2800.00$ = 2800.00 mm

Slenderness $\lambda = \frac{h_{ef}}{t_{ef}} = \frac{2800.00}{140.00}$ = 20.00 < 27

Factor Φ_A = 1.00

Factor $\Phi_{s,i} = 0.85 - 0.0011 * \left(\frac{h_{ef}}{t_{ef}}\right)^2 = 0.85 - 0.0011 * \left(\frac{2800.00}{140.00}\right)^2$ = 0.410

Factor $\Phi_{s,ii} = 1.3 - \frac{l_{f,ef}}{8} = 1.3 - \frac{5.00}{8}$ = 0.675

Φ_s = MIN($\Phi_{s,i}$; $\Phi_{s,ii}$) = 0.41

Material selected

Structural units = Aggregate concrete
Classification group = 1
Type of mortar = general

Mean compressive strength of masonry unit f_b = 12.00 N/mm²
Compressive strength of mortar f_m = 6.00 N/mm²

Shape factor
Height of unit h = 215.00 mm
Width of unit w = 140.00 mm

δ = 1.300

$f_b = \delta * f_b = 1.300 * 12.00$ = 15.60 N/mm²

$f_k = K * f_b^{\alpha} * f_m^{\beta} = 0.55 * 15.60^{0.70} * 6.00^{0.30}$ = 6.44 N/mm²

$f_d = \frac{f_k}{\gamma_m} = \frac{6.44}{2.70}$ = 2.39

$N_{Rd} = \frac{f_d * t_{ef} * 10^3 * \Phi_A * \Phi_s}{10^3} = \frac{2.39 * 140.00 * 10^3 * 1.00 * 0.41}{10^3}$ = 137.19 kN

$\frac{N_{Ed}}{N_{Rd}} = \frac{112.50}{137.19}$ = **0.82 ≤ 1**

Minimum thickness

$N_{Ed} = g_k$ = 50.00 kN/m

$\alpha = \frac{N_{Ed}}{t_{ef} * 1000 * f_d} = \frac{50000}{140.00 * 1000 * 2.39}$ = 0.15 m^{-1}

c_1 = 0.1300

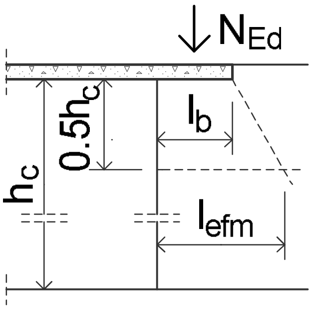
c_2 = 0.0205

$t_{min} = \frac{c_1 * q_{Ewd} * 1 * h_{ef}^2}{N_{Ed}} + c_2 * h_{ef} = \frac{0.1300 * 0.60 * 1 * 2.80^2}{50.00} + 0.0205 * 2.80$ = 0.070 m

$\frac{t_{min}}{t_{ef}} = \frac{70}{140.00}$ = **0.50 ≤ 1**

Chapter 3: Concentrated loads

Lintel bearing



Data given

Clear Heigth h =	2800.0 mm
Heigth of lintel h_{beam} =	200.0 mm
Distance to the nearest edge a_1 =	0.0 mm
Length of bearing l_b =	425.0 mm
Wall thickbness t =	140.0 mm
Single load N_{Ed} =	100.00 kN
Load from floor and above q_d =	75.00 kN/m

Material properties

Mean compressive strength of masonry unit f_b =	12.00 N/mm²
Characteristic self-weight of units g_{unit} =	2.70 kN/m²
Compressive strength of mortar f_m =	6.00 N/mm²

Structural units	=	Aggregate concrete
Classification group	=	1
Type of mortar	=	general
Control class	=	2
Category	=	II

γ_m = 3.00

Capacity of bearing area under the load

max.f = IF(group = "1" ; 1.5 ; 1.00) = 1.50

Required $f_{b,requ} = MAX\left(\frac{N_{Ed}}{1.2 * l_b * t} ; \frac{N_{Ed}}{max.f * l_b * t}\right)$ = 1.40 N/mm²

At this level the load is carried on a length l_{efm} of wall

$h_c = h - h_{beam} = 2800.0 - 200.0$ = 2600.0 mm

Length $l_{efm} = l_b + \frac{0.5 * h_c}{\tan(60)} = 425.0 + \frac{0.5 * 2600.0}{\tan(60)}$ = 1175.56 mm

Weight of Wall $N_{wall} = 1.35 * g_{unit} * \left(\frac{h_c}{2} + h_{beam}\right) * l_{efm}$

$= 1.35 * 2.70 * \left(\frac{2.6}{2} + 0.2\right) * 1.17556$ = 6.43 kN

From above $N_{above} = q_d * (l_{efm} - l_b) = 75.00 * (1.17556 - 0.425)$ = 56.29 kN

Ultimate design load $F = N_{Ed} + N_{wall} + N_{above} = 100.00 + 6.43 + 56.29$ = 162.72 kN

Reduction factor

Effective height h_{ef} = $0.75 * h = 0.75 * 2800.0$ = 2100.00 mm

Slenderness λ = $\frac{h_{ef}}{t} = \frac{2100.00}{140.0}$ = 15.00 < 27

Factor Φ_A = 1.00

Factor Φ_s = $0.85 - 0.0011 * \left(\frac{h_{ef}}{t}\right)^2 = 0.85 - 0.0011 * \left(\frac{2100.00}{140.0}\right)^2$ = 0.603

Required f_d and f_k

σ = $\frac{F}{l_{efm} * t} = \frac{162720}{1175.56 * 140.0}$ = 0.99 N/mm²

Required value $f_{d,requ}$ = $\frac{\sigma}{\Phi_A * \Phi_s} = \frac{0.99}{1.00 * 0.603}$ = 1.64 N/mm²

Required value $f_{k,requ}$ = $f_{d,requ} * \gamma_m = 1.64 * 3.00$ = 4.92 N/mm²

Units selected

Shape factor
Height of unit h = 215.00 mm
Width of unit w = 140.00 mm

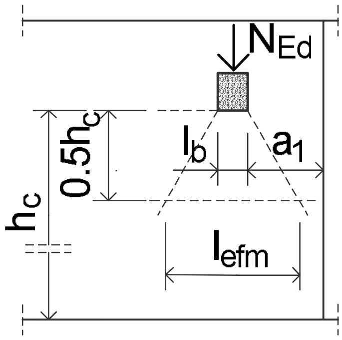
δ = 1.300

f_b = $\delta * f_b = 1.300 * 12.00$ = 15.60 N/mm²

f_k = $K * f_b^{\alpha} * f_m^{\beta} = 0.55 * 15.60^{0.70} * 6.00^{0.30}$ = 6.44 N/mm²

$\frac{f_{k,requ}}{f_k} = \frac{4.92}{6.44}$ = **0.76 ≤ 1**

Beam bearing on a wall



Data given

Clear Heigth h =	2800.0 mm
Span of floor $l_{f,ef}$ =	5000.0 mm
Width of beam b_{beam} =	200.0 mm
Heigth of beam h_{beam} =	300.0 mm
Distance to the nearest edge a_1 =	2000.0 mm
Wall thickbness t =	140.0 mm
Single load N_{Ed} =	100.00 kN
Load from floor and above q_d =	30.00 kN/m

Material properties

Mean compressive strength of masonry unit f_b =	12.00 N/mm²
Characteristic self-weight of units g_{unit} =	3.00 kN/m²
Compressive strength of mortar f_m =	6.00 N/mm²

Structural units	=	Aggregate concrete
Classification group	=	1
Type of mortar	=	general
Control class	=	2
Category	=	I
γ_m	=	2.70

Capacity of bearing area under the load

$h_c = h - h_{beam} = 2800.0 - 300.0 = 2500.0$ mm

max.f = IF(group = "1" ; 1.5 ; 1.00) = 1.50

Design load N = $N_{Ed} + q_d * b_{beam} = 100.00 + 30.00 * 0.2 = 106.00$ kN

$$\text{Required } f_{b,requ} = \text{MAX}\left(\frac{N}{\left(1.2 + \frac{0.4 * a_1}{h_c}\right) * b_{beam} * t} ; \frac{N}{\text{max.f} * b_{beam} * t} \right) = 2.52 \text{ N/mm}^2$$

At this level the load is carried on a length l_{efm} of wall

Length l_{efm} = $b_{beam} + \frac{h_c}{\tan(60)} = 200.0 + \frac{2500.0}{\tan(60)}$ = 1643.38 mm

Weight of Wall N_{wall} = $1.35 * g_{unit} * \left(\frac{h_c}{2} + h_{beam}\right) * l_{efm}$

$= 1.35 * 3.00 * \left(\frac{2.5}{2} + 0.3\right) * 1.64338$ = 10.32 kN

From above N_{above} = $q_d * l_{efm} = 30.00 * 1.64338$ = 49.30 kN

Ultimate design load F = $N_{Ed} + N_{wall} + N_{above} = 100.00 + 10.32 + 49.30$ = 159.62 kN

Reduction factor

Effective height $h_{ef} = 1.00 * h = 1.00 * 2800.0$ = 2800.00 mm

Slenderness λ = $\frac{h_{ef}}{t} = \frac{2800.00}{140.0}$ = 20.00 < 27

Factor Φ_A = 1.00

Factor $\Phi_{s,i}$ = $0.85 - 0.0011 * \left(\frac{h_{ef}}{t}\right)^2 = 0.85 - 0.0011 * \left(\frac{2800.00}{140.0}\right)^2$ = 0.410

Factor $\Phi_{s,ii}$ = $1.3 - \frac{l_{f,ef}}{8} = 1.3 - \frac{5.0}{8}$ = 0.675

Factor $\Phi_{s,iii}$ = 0.400

Φ_s = MIN($\Phi_{s,i}$; $\Phi_{s,ii}$; $\Phi_{s,iii}$) = 0.400

Required f_d and f_k

σ = $\frac{F}{l_{efm} * t} = \frac{159620}{1643.38 * 140.0}$ = 0.69 N/mm²

Required value $f_{d,requ}$ = $\frac{\sigma}{\Phi_A * \Phi_s} = \frac{0.69}{1.00 * 0.400}$ = 1.73 N/mm²

Required value $f_{k,requ}$ = $f_{d,requ} * \gamma_m = 1.73 * 2.70$ = 4.67 N/mm²

Units selected

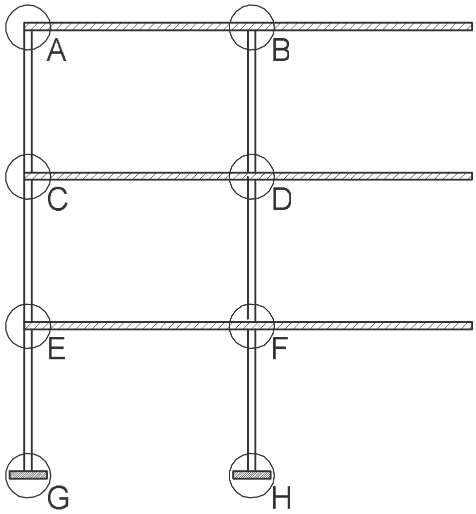
Shape factor
Height of unit h = 215.00 mm
Width of unit w = 140.00 mm

δ = 1.300
f_b = $\delta * f_b = 1.300 * 12.00$ = 15.60 N/mm²
f_k = $K * f_b^{\alpha} * f_m^{\beta} = 0.55 * 15.60^{0.70} * 6.00^{0.30}$ = 6.44 N/mm²

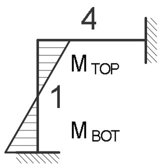
$\frac{f_{k,requ}}{f_k} = \frac{4.67}{6.44}$ = **0.73 ≤ 1**

Chapter 4: Formulas for moments

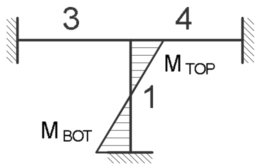
Content: Formulae for the moment of a wall panel



Overview



load



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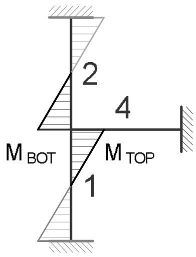

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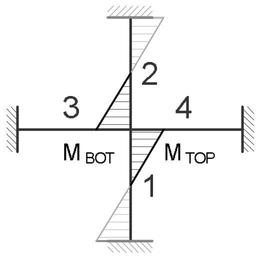

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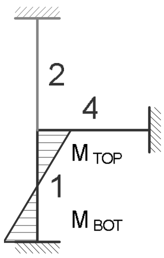
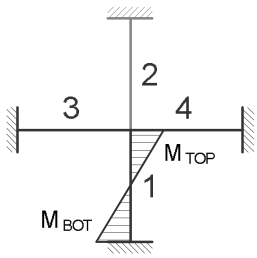
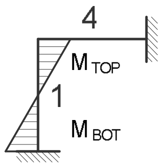


load



load

Formula for the moment of a wall panel (A)



Data given for the wall

Clear hight h_1 = 2800.00 mm

Depth of wall h = 215.00 mm

Strength f_k = 4.05 N/mm²

$E_1 = f_k * 10^3 = 4050.00$ N/mm²

$$I_1 = \frac{1000 * h^3}{12} = \frac{1000 * 215.00^3}{12} = 828.20 * 10^6 \text{ mm}^4$$

Data given for the roof

Load w_4 = 10.00 kN/m

Span of roof L_4 = 5000.00 mm

Roof or floor depth h = 200.00 mm

Concrete grade = C30/37

E_4 = 33000.00 N/mm²

$$I_4 = \frac{1000 * h^3}{12} = \frac{1000 * 200.00^3}{12} = 666.67 * 10^6 \text{ mm}^4$$

Moment at the top

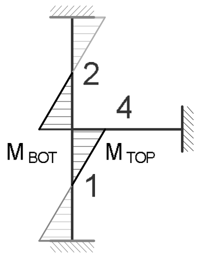
$$\eta = MAX\left(1 - \frac{\frac{E_4 * I_4}{L_4}}{4 * \frac{E_1 * I_1}{h_1}} ; 0.5\right) = 0.50$$

$$M_{TOP} = \eta * \frac{\frac{E_1 * I_1}{h_1}}{\frac{E_1 * I_1}{h_1} + \frac{E_4 * I_4}{L_4}} * \frac{-1 * w_4 * L_4^2}{12} = -2.23 \text{ kNm/m}$$

Moment at the bottom

$$M_{BOT} = \eta * \frac{\frac{E_1 * I_1}{h_1}}{\frac{E_1 * I_1}{h_1} + \frac{E_4 * I_4}{L_4}} * \frac{w_4 * L_4^2}{12} * 0.5 = 1.11 \text{ kNm/m}$$

Formula for the moment of a wall panel (C)



Data given for the wall

Clear hight h_1 = 2500.00 mm
Clear hight h_2 = 2500.00 mm
Depth of wall h = 215.00 mm
Strength f_k = 4.05 N/mm²

E_1 = $f_k * 10^3$ = 4050.00 N/mm²

$$I_1 = \frac{1000*h^3}{12} = \frac{1000*215.00^3}{12} = 828.20*10^6 \text{ mm}^4$$

Parameter of the wall 2 are the same as wall 1: $E_1 = E_2$ and $I_1 = I_2$

Data given for the floor

Load w_4 = 7.50 kN/m
Span of floor L_4 = 5000.00 mm
Floor depth h = 200.00 mm

Concrete grade = C30/37

E_4 = 33000.00 N/mm²

$$I_4 = \frac{1000*h^3}{12} = \frac{1000*200.00^3}{12} = 666.67*10^6 \text{ mm}^4$$

Moment at the bottom

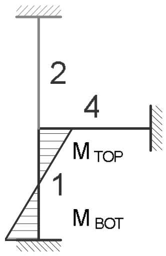
$$\eta = MAX\left(1 - \frac{\frac{E_4*I_4}{L_4}}{4*\left(\frac{E_1*I_1}{h_1}+\frac{E_2*I_2}{h_2}\right)}; 0.5\right) = 0.59$$

$$M_{BOT} = \eta * \frac{\frac{E_1*I_1}{h_1}}{\frac{E_1*I_1}{h_1}+\frac{E_2*I_2}{h_2}+\frac{E_4*I_4}{L_4}} * \frac{w_4*L_4^2}{12} = 1.75 \text{ kNm/m}$$

Moment at the top

$$M_{TOP} = \eta * \frac{\frac{E_1*I_1}{h_1}}{\frac{E_1*I_1}{h_1}+\frac{E_2*I_2}{h_2}+\frac{E_4*I_4}{L_4}} * \frac{-1*w_4*L_4^2}{12} = -1.75 \text{ kNm/m}$$

Formula for the moment of a wall panel (E)



Data given for the wall

Clear hight h_1 = 2500.00 mm
Clear hight h_2 = 2500.00 mm
Depth of wall h = 215.00 mm
Strength f_k = 4.05 N/mm²

$E_1 = f_k * 10^3 = 4050.00$ N/mm²

$I_1 = \frac{1000 * h^3}{12} = \frac{1000 * 215.00^3}{12} = 828.20 * 10^6$ mm^4

Parameter of the wall 2 are the same as wall 1: $E_1 = E_2$ and $I_1 = I_2$

Data given for the floor

Load w_4 = 7.50 kN/m
Span of floor L_4 = 5000.00 mm
Floor depth h = 200.00 mm

Concrete grade = C30/37

E_4 = 33000.00 N/mm²

$I_4 = \frac{1000 * h^3}{12} = \frac{1000 * 200.00^3}{12} = 666.67 * 10^6$ mm^4

Moment at the top

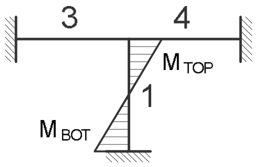
$$\eta = MAX\left(1 - \frac{\frac{E_4 * I_4}{L_4}}{4 * \left(\frac{E_1 * I_1}{h_1} + \frac{E_2 * I_2}{h_2}\right)}; 0.5\right) = 0.59$$

$$M_{TOP} = \eta * \frac{\frac{E_1 * I_1}{h_1}}{\frac{E_1 * I_1}{h_1} + \frac{E_2 * I_2}{h_2} + \frac{E_4 * I_4}{L_4}} * \frac{-1 * w_4 * L_4^2}{12} = -1.75 \text{ kNm/m}$$

Moment at the bottom

$$M_{BOT} = \eta * \frac{\frac{E_1 * I_1}{h_1}}{\frac{E_1 * I_1}{h_1} + \frac{E_2 * I_2}{h_2} + \frac{E_4 * I_4}{L_4}} * \frac{0.5 * w_4 * L_4^2}{12} = 0.87 \text{ kNm/m}$$

Formula for the moment of a wall panel (B)



Data given for the wall

Clear hight h_1 = 2500.00 mm
Depth of wall h = 215.00 mm
Strength f_k = 4.05 N/mm²

E_1 = $f_k * 10^3$ = 4050.00 N/mm²

$I_1 = \frac{1000*h^3}{12} = \frac{1000*215.00^3}{12}$ = $828.20*10^6$ mm^4

Data given for the floor or roof

Load w_3 = 3.75 kN/m
Load w_4 = 7.50 kN/m
Span of floor L_3 = 5000.00 mm
Span of floor L_4 = 5000.00 mm
Floor depth h = 200.00 mm

Concrete grade = C30/37

E_3 = 33000.00 N/mm²

$I_3 = \frac{1000*h^3}{12} = \frac{1000*200.00^3}{12}$ = $666.67*10^6$ mm^4

Parameter of the floor 4 are the same as wall 3: $E_4 = E_3$ and $I_4 = I_3$

Moment at the top

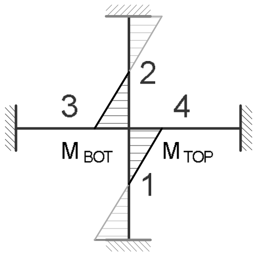
$$\eta = \text{MAX}\left(1 - \frac{\frac{E_3*I_3}{L_3} + \frac{E_4*I_4}{L_4}}{4*\left(\frac{E_1*I_1}{h_1}\right)}; 0.5\right) = 0.50$$

$$M_{TOP} = \eta * \frac{\frac{E_1*I_1}{h_1}}{\frac{E_1*I_1}{h_1} + \frac{E_3*I_3}{L_3} + \frac{E_4*I_4}{L_4}} * \left(\frac{w_3*L_3^2}{12} - \frac{w_4*L_4^2}{12}\right) = -0.52 \text{ kNm/m}$$

Moment at the bottom

$$M_{BOT} = \eta * \frac{\frac{E_1*I_1}{h_1}}{\frac{E_1*I_1}{h_1} + \frac{E_3*I_3}{L_3} + \frac{E_4*I_4}{L_4}} * \left(\frac{w_4*L_4^2}{12} - \frac{w_3*L_3^2}{12}\right) * 0.5 = 0.26 \text{ kNm/m}$$

Formula for the moment of a wall panel (D)



Data given for the wall

Clear hight h_1 = 2500.00 mm
Clear hight h_2 = 2500.00 mm
Depth of wall h = 215.00 mm
Strength f_k = 4.05 N/mm²

$E_1 = f_k * 10^3 = 4050.00\ N/mm^2$

$$I_1 = \frac{1000*h^3}{12} = \frac{1000*215.00^3}{12} = 828.20*10^6\ mm^4$$

Parameter of the wall 2 are the same as wall 1: $E_1 = E_2$ and $I_1 = I_2$

Data given for the floor

Load w_3 = 2.50 kN/m
Load w_4 = 7.50 kN/m
Span of floor L_3 = 5000.00 mm
Span of floor L_4 = 5000.00 mm
Floor depth h = 200.00 mm

Concrete grade = C30/37

E_3 = 33000.00 N/mm²

$$I_3 = \frac{1000*h^3}{12} = \frac{1000*200.00^3}{12} = 666.67*10^6\ mm^4$$

Parameter of the floor 4 are the same as wall 3: $E_4 = E_3$ and $I_4 = I_3$

Moment at the bottom

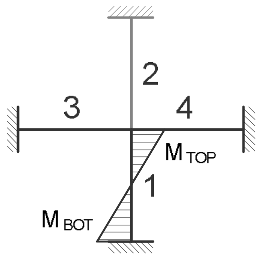
$$\eta = MAX\left(1 - \frac{\frac{E_3*I_3}{L_3} + \frac{E_4*I_4}{L_4}}{4*\left(\frac{E_1*I_1}{h_1} + \frac{E_2*I_2}{h_2}\right)}; 0.5\right) = 0.50$$

$$M_{BOT} = \eta * \frac{\frac{E_1*I_1}{h_1}}{\frac{E_1*I_1}{h_1} + \frac{E_2*I_2}{h_2} + \frac{E_3*I_3}{L_3} + \frac{E_4*I_4}{L_4}} * \left(\frac{w_4*L_4^2}{12} - \frac{w_3*L_3^2}{12}\right) = 0.61\ kNm/m$$

Moment at the top

$$M_{TOP} = \eta * \frac{\frac{E_1*I_1}{h_1}}{\frac{E_1*I_1}{h_1} + \frac{E_2*I_2}{h_2} + \frac{E_3*I_3}{L_3} + \frac{E_4*I_4}{L_4}} * \left(\frac{w_3*L_3^2}{12} - \frac{w_4*L_4^2}{12}\right) = -0.61\ kNm/m$$

Formula for the moment of a wall panel (F)



Data given for the wall

Clear hight h_1 = 2500.00 mm
Clear hight h_2 = 2500.00 mm
Depth of wall h = 215.00 mm
Strength f_k = 4.05 N/mm²

$E_1 = f_k * 10^3$ = 4050.00 N/mm²

$$I_1 = \frac{1000 * h^3}{12} = \frac{1000 * 215.00^3}{12} = 828.20*10^6\ mm^4$$

Parameter of the wall 2 are the same as wall 1: $E_1 = E_2$ and $I_1 = I_2$

Data given for the floor

Load w_3 = 2.50 kN/m
Load w_4 = 7.50 kN/m
Span of floor L_3 = 5000.00 mm
Span of floor L_4 = 5000.00 mm
Floor depth h = 200.00 mm

Concrete grade = C30/37

E_3 = 33000.00 N/mm²

$$I_3 = \frac{1000 * h^3}{12} = \frac{1000 * 200.00^3}{12} = 666.67*10^6\ mm^4$$

Parameter of the floor 4 are the same as wall 3: $E_4 = E_3$ and $I_4 = I_3$

Moment at the top

$$\eta = MAX\left(1 - \frac{\frac{E_3 * I_3}{L_3} + \frac{E_4 * I_4}{L_4}}{4 * \left(\frac{E_1 * I_1}{h_1} + \frac{E_2 * I_2}{h_2}\right)}; 0.5\right) = 0.50$$

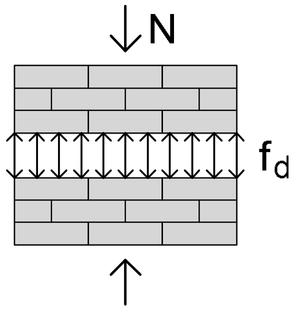
$$M_{TOP} = \eta * \frac{\frac{E_1 * I_1}{h_1}}{\frac{E_1 * I_1}{h_1} + \frac{E_2 * I_2}{h_2} + \frac{E_3 * I_3}{L_3} + \frac{E_4 * I_4}{L_4}} * \left(\frac{w_3 * L_3^2}{12} - \frac{w_4 * L_4^2}{12}\right) = -0.61\ kNm/m$$

Moment at the bottom

$$M_{BOT} = \eta * \frac{\frac{E_1 * I_1}{h_1}}{\frac{E_1 * I_1}{h_1} + \frac{E_2 * I_2}{h_2} + \frac{E_3 * I_3}{L_3} + \frac{E_4 * I_4}{L_4}} * \left(\frac{w_4 * L_4^2}{12} - \frac{w_3 * L_3^2}{12}\right) * 0.5 = 0.30\ kNm/m$$

Chapter 5: Material

Compressive strength of masonry



Material properties

Structural units	=	Clay
Classification group	=	1
Type of mortar	=	general

Mean compressive strength of masonry unit f_b = 12.00 N/mm²
Compressive strength of mortar f_m = 6.00 N/mm²

Values of constants

K	=	0.50
α	=	0.70
β	=	0.30

Shape factor

Height of unit h = 65.00 mm

Width of unit w = 102.50 mm

δ = 0.845

$f_b = \delta * f_b = 0.845 * 12.00$ = 10.14 N/mm²

Compressive strength

Characteristic compressive strength

$f_k = K * f_b^{\alpha} * f_m^{\beta} = 0.50 * 10.14^{0.70} * 6.00^{0.30}$ = 4.33 N/mm²

Control class = 2
Category = I

γ_m = 2.70

Design compressive strength

$f_d = \frac{f_k}{\gamma_m} = \frac{4.33}{2.70}$ = 1.60