Budapest University of Technology and Economics

Department of Mechanics, Materials and Structures
English courses
Reinforced Concrete Structures
Code: BMEEPSTK601

Lecture no. 13:

REINFORCED CONCRETE WALLS, WALL SYSTEMS, TIE-BEAMS, LOCAL COMPRESSION

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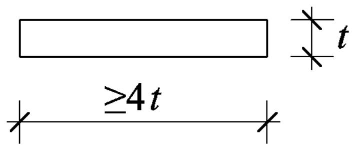
11. Local compression

Introduction, definition of walls

Walls are planar structures loaded in their plane, lying in general in vertical plane. Difference between columns and walls can be given geometrically by the condition:

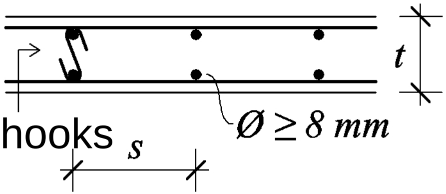
length of the horizontal cross-section of walls $\geq 4t$



1. Constructional rules

$t \geq 8$ cm

if $t < 100$ mm: one-layer reinforcement possible
if $t > 200$ mm: two-layer reinforcement necessary



S-hooks

column-like reinforcement at wall end

$s \leq \min(3t,\ 400\ \text{mm})$ $s_{horizontal} \leq 400$ mm

S-hooks: 4 pcs/m^2

$\rho_{min} = 0{,}3\%$ $\rho_{max} = 4\%$ $A_{s,horizontal} \geq 0{,}25\ A_{s,vertical}$

2. Resistance to axial compression

$N_R = \varphi N'_u$ $N'_u = A_c f_{cd} + A_s f_{yd}$

$\varphi = f\left(\frac{l_o}{h}\right)_{max}$ tabulated in the design aids

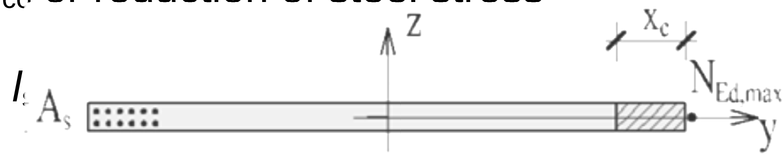
here in general $l_o = m$ = storey height, or in plane of the multistoreey wall: $l_o = 1{,}2H$, where H is the overall height of the wall

3. Resistance to eccentric compression

Two possibilities:

1. Only part of the wall section, concentric to the eccentric compression force is working, which is to be handled as subjected to axial compression (see above)
2. The wall section is handled like a column section, but the length of the part l_s subjected to tension is estimated – and corrected later if necessary

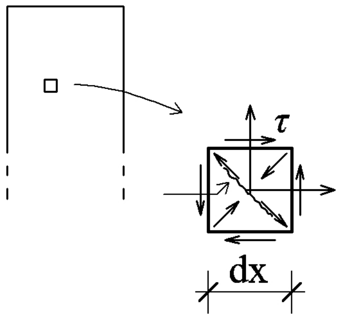
Check of steel stress ($x_c \leq x_{co}$ or reduction of steel stress necessary)



Correction of l_s if necessary l_s

4. Design of the wall reinforcement for shear

Numerical analysis of the wall disc results in shear stress distribution τ:



If $dx = s$ (spacing of the reinf.)

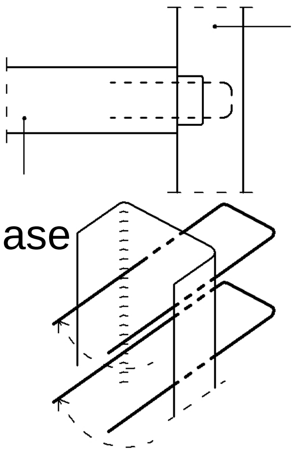
$$\tau dxt = \tau st = A_s f_{yd}$$

$$\rightarrow A_s = \frac{\tau st}{f_{yd}} \quad \text{(one bar)}$$

$$a_s = \frac{\tau 1000t}{f_{yd}} \quad (\text{mm}^2/\text{m})$$

5. Shear connection between columns and walls and between walls concreted in two different construction phases

If – due to formwork placing technology used – construction of T-joints of rc walls is made in two different construction phases, U-bars to improve shear connection are placed in metal plate sheathing in the the wall concreted first, and then bent to horizontal position before the 2nd phase of construction

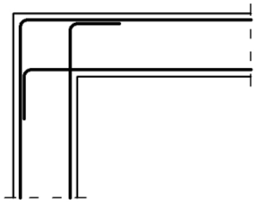


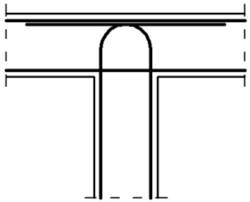
1st phase

2nd phase

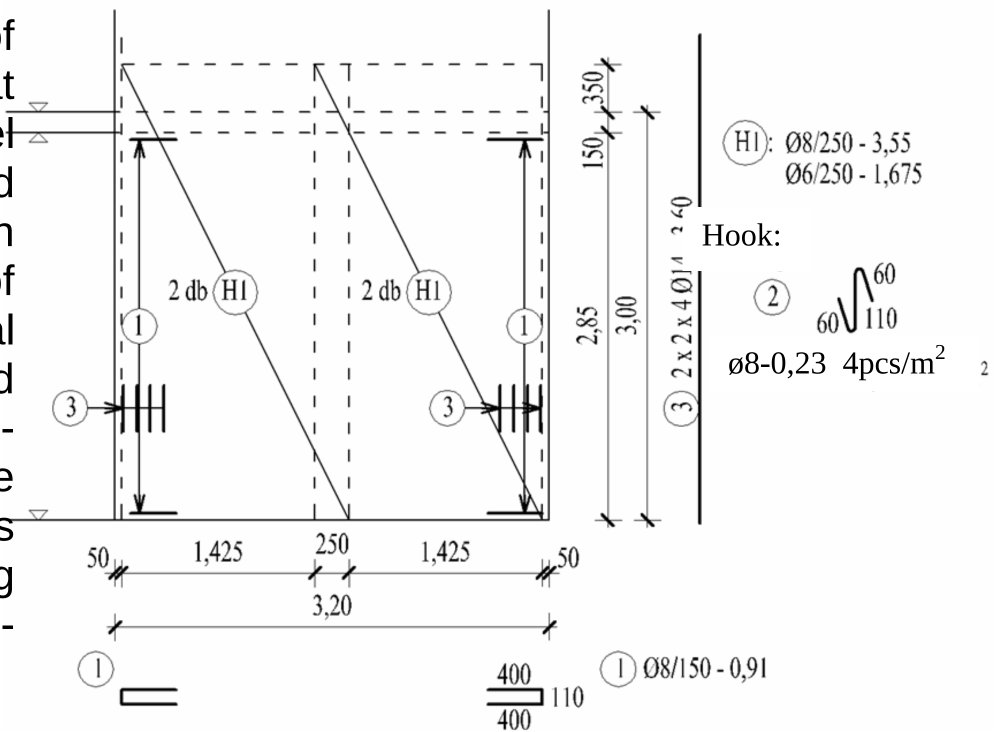
6. Reinforcement details of rc walls

Horizontal section of corner and T-joints of monolithic rc walls – constructed in the same phase, showing the correct detailing of the interconnecting bars: the bars can not be bent at the internal corner, because when subjected to tenshion they would split the concrete there





Reinforcement system of an rc wall section at ground floor level showing doublesided welded meshes H1 with transverse overlap of 250 mm (the vertical overlap is 350 mm) and elements of the column-like reinforcement at the wall extremities. Hooks no. 2 are interconnecting the the two reinforcement layers



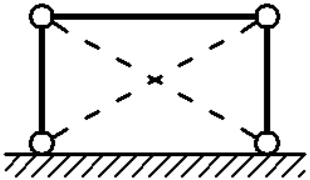
7. Stiffening wall systems
-ways of bracing
-rigidity of sheared-walls and bracing frames
-stiffening wall systems

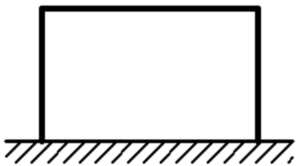
Beside solid sheared-walls, bracing of buildings can be assured by use of

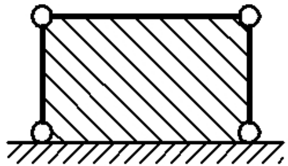
diagonals (Andrew-crosses, characteristic for steel constructions)

rigid frames

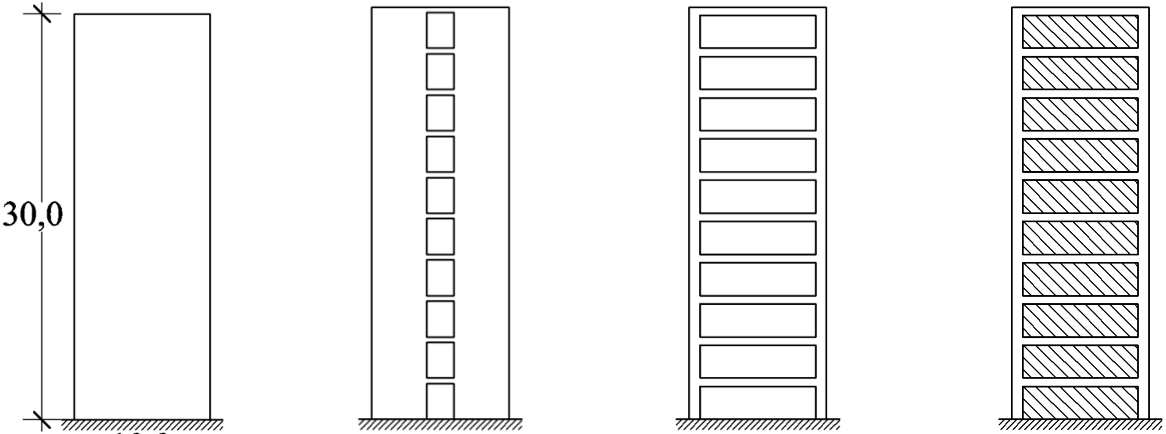
frame filling walls







The effectiveness of elements of the rc bracing system of multistorey buildings is very much depending from the level of being broken through



solid rc wall	couple-sheared wall	rc frame	rc frame + frame filling wall
k= 100	*k*= 20	*k*= 2	

Displacement rgidity *k*: the magnitude of a horizontal force causing unit displacement at top

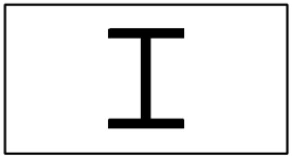
Straight bracing walls have negligible rigidity in direction perpendicular to their plane. Cosequently, the bracing wall system should have *minimum three members*, because any planar force system can be equilibrated by three forces acting in the plane, if they

- -are *not lying along one line* and the
- - do *not intersect each other in one point*

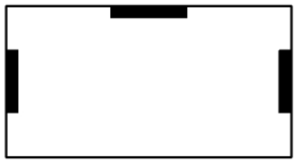
The effectiveness of the bracing wall system can be increased by

- -symmetric arrangement of the walls
- -placing the walls near the contour of the building

good arrangement

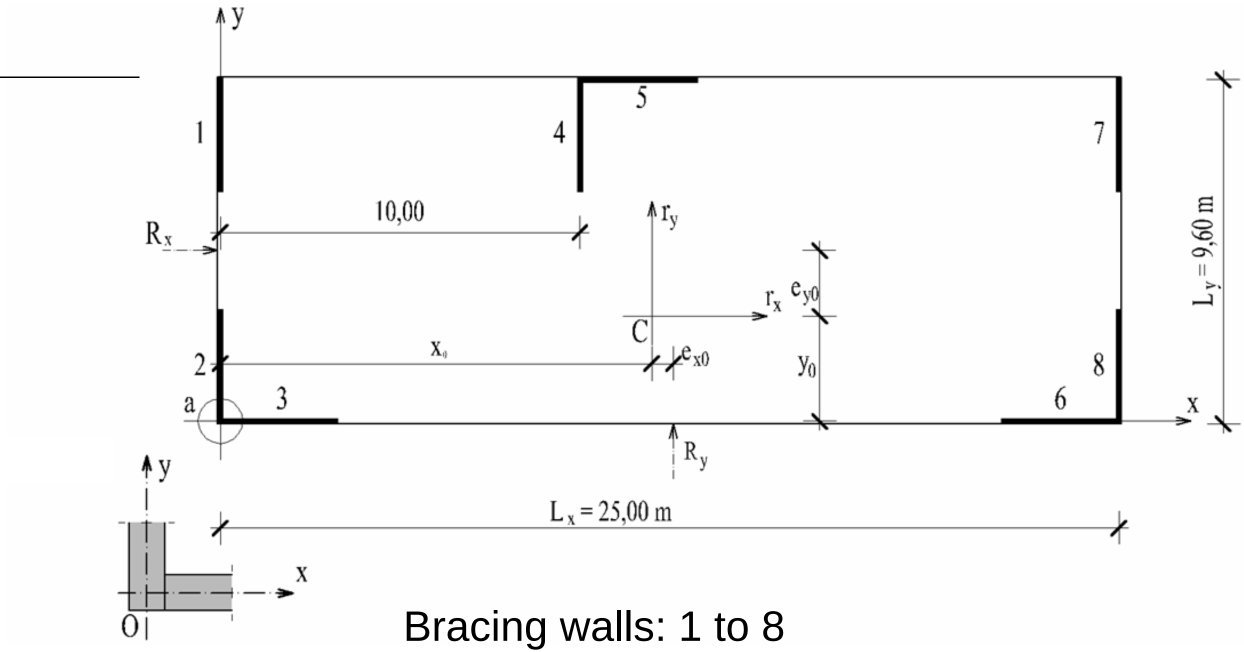


better arrangement



If the number of bracing walls is greater than 3, as a safe approximation, the three most rigid bracing walls can be considered by checking the system.

8. Distribution of horizontal loads between elements of the wall system

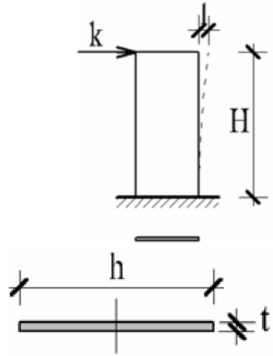


Bracing walls: 1 to 8

C: center of rigidities

Resultant of wind forces: R_y and R_x

In the plane of the bracing wall units: $k = \frac{3EI}{H^3}$



As $E = E_{c,eff}$ = const. and H= const, rigidity of the wall units *is proportional to* $I = \frac{th^3}{12}$.

Position of the center of rigidities (C):

$$x_0 = \frac{\Sigma(I_{xi} x_i)}{\Sigma I_{xi}} \qquad y_0 = \frac{\Sigma(I_{yj} y_j)}{\Sigma I_{yj}}$$

The polar inertia I_ω of the rigidities with respect to the center C:

$$I_\omega = \Sigma(I_{yi}.r_{yi}^2) + \Sigma(I_{xj} r_{xj}^2)$$

i = 1,2,…,n for walls in x – direction

j = 1,2,…,m for walls in y – direction

and r : is the perpendicular ditance of the wall unit from the center of rigidities

Moments of the wind load resultants with respect to C:

$R_x.e_{yo}$ where: $R_x = q_{wx,d} H L_y$ and $e_{yo} = 0,5L_y - y_o$

and $R_y e_{xo}$ where: $R_y = q_{wy,d} H L_x$ and $e_{xo} = 0,5L_x - x_o$

$q_{wx,d}$ and $q_{wy,d}$ are the design value of the wind load in x- and y-directions respectively (sum of wind pressure and suction) in kN/m^2

The forces absorbed by the bracing walls in x and y-directions:

From R_x in walls in x –direction:

$$S_{xi}^{R_x} = R_x \left(\frac{I_{yi}}{\Sigma I_{yi}} + e_{yo} \frac{r_{yi} I_{yi}}{I_\omega} \right) \qquad i = 1,2,\ldots,n$$

From R_x in walls in y-direction:

$$S_{xj}^{R_x} = R_x e_{yo} \frac{r_{xj} I_{xj}}{I_\omega} \qquad j = 1,2,\ldots,m$$

9. **Determination of the design eccentrricity of the compression force in walls**

$$e = e_e + e_i + e_2 \qquad e_e = \frac{M_{Ed}}{N_{Ed}}$$

e_i can be substituted by the effect of an additional horizontal force H_i:

$$H_i = \theta_i\,(N_b - N_a)$$

N_b-N_a is the applied vertical force on level *i*

$$\theta_i = \alpha_n \alpha_m \theta_o$$

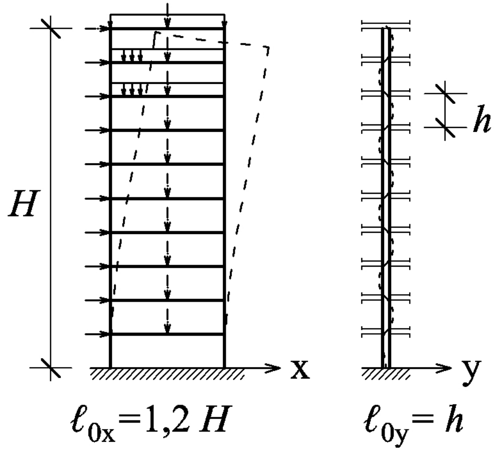
$$\alpha_n = 2/\sqrt{\ell} \geq \frac{2}{3}$$

$$\alpha_m = \sqrt{0{,}5(1+1/m)}$$

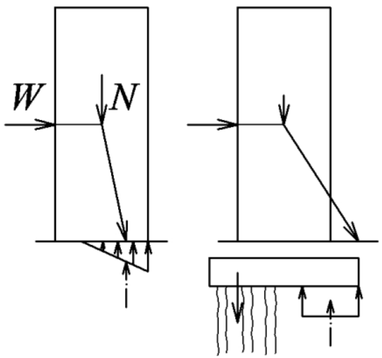
$$\theta_o = \frac{1}{200}$$

where ℓ is the height of the wall in m, *m* is the number of pralallel bracing walls

e_2/d is tabulated in the design aids in function of the slanderness ratio ℓ_o / d of the wall in the plane under consideration:



Equilibration of the eccentric force at basement level can be done as detailed in point 3



10. Tie-beams

They are designed for better distribution of loads and effects, in extreme cases to prevent progres-sive collapse by providing alternative load paths after local damage.

- -Peripheral and internal ties at floor levels
- -Vertical ties where required

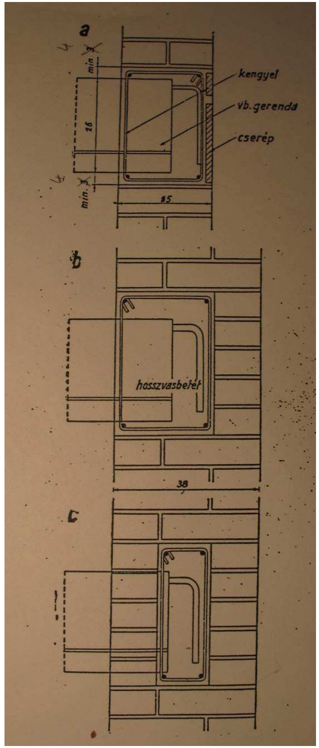
Independent ties for diff. dilatation joints

They work generally in tension

Min. reinforcement: 4ϕ10 long. bars +ϕ8/200 links

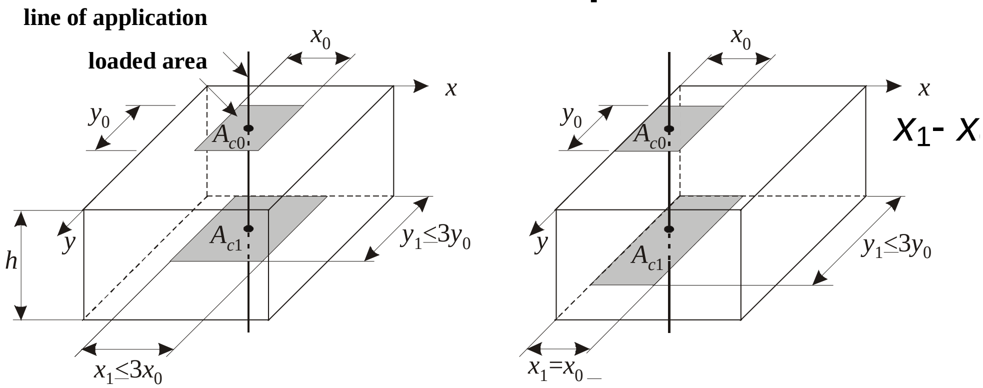
Functions of tie beams:

- -absorb tension due to thermal expansion, uneven settlement, damage of the struture
- -partial restraint of prefabricated floor beams
- -distribution of concentrated loads
- -lintel above openings with additional steel



Column ties 4 cm^2/column
Corner columns should be tied in two directions

11. Local compression



Due to the spatial stress state, the capacity force can be determined from the expression:

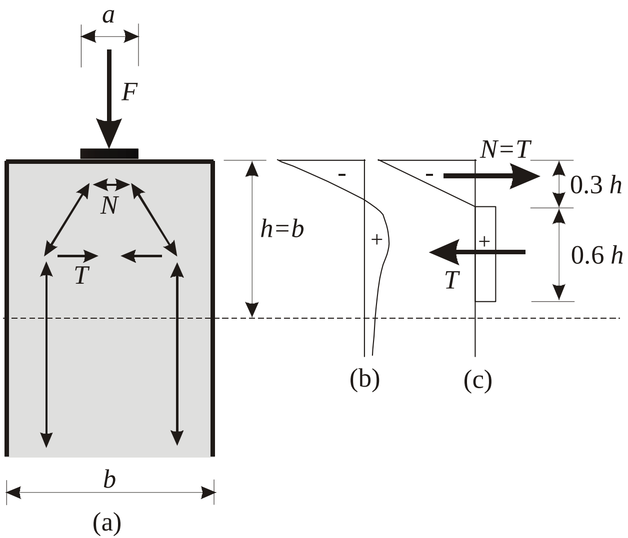
$$F_{Rd} = A_{c0}\ \alpha\, f_{cd} \quad \text{where} \quad \alpha = \min\left\{ \begin{array}{c} \sqrt{A_{c1} / A_{c0}} \\ 3 \end{array} \right\}$$

$x_1 - x_0 \leq h$ and $y_1 - y_0 \leq h$

(The spreading angle is maximum 45 degrees)

In case of several spot-like loaded areas, the areas A_{c1} can not intersect each other.

The diagonal spreading of compression stresses may split the concrete in vertical plane, which should be impeded by horizontal reinforcement designed for:



$$T = \frac{1}{4}\left(1 - \frac{a}{b}\right)F$$

and distributed between 0,3*h* to 0,9*h* depth.