EUROCODE 6
Design of masonry structures
EUROCODE 6
Combined loading

Poul Christiansen
Danish Technological Institute

poul.christiansen@teknologisk.dk
Walls subjected to vertical and lateral load

Walls supported by 2 – 3 – 4 edges and with openings

Edges restrained or simply supported
Either:
1. A distribution between the outer and inner leaf.

   or

2. The total wind load applied on the inner leaf, when (5.11) is used.

\[ t_{ef} = \sqrt{\frac{3}{2}} k_{tef} t_1^3 + t_2^3 \]

If 1. Either:
A. According to the stiffness

\[ W_{Ed,1} = W_{Ed,1} \times \frac{(EI)_1}{(EI)_1 + (EI)_2} \]

B. According to the capacity

\[ W_{cap} = W_{cap,1} + W_{cap,2} \quad (6.3.1 \ (6)) \]

In this example (5.11) is used
Horizontal and vertical load

Yield line theory is relevant for openings, 3-4 sided walls. Φ- method is relevant for 2. order effects and walls supported in top and bottom. The link between the methods is the equivalence of $M_{Ed}$. Thus an equivalent windload is introduced: $W_{eqv} \Leftrightarrow W_{ed}$ (Annex I)
The apparent flexural strength: \( f_{xd1,app} = f_{xd1} + \sigma \) (6.16)

The moment of resistance: \( M_{Rd} \)

Based on the yield line theory: \( W_{cap} \)

The actual moment due to \( (W_{ed}) \):

Link: \( (1/8) \times h^2 \times W_{eqv} = M_{Ed} / W_{cap} \times M_{Rd} \)

Finally:

\[ (8/h^2) \times (W_{Ed} / W_{cap}) \times M_{Rd} \]
The thickness can be formally altered:

When formula 5.11 is used:

\[ t_{ef} = \frac{3}{3} k_{t_{ef}} t_1^3 + t_2^3 \]

When table 5.1 is used:

<table>
<thead>
<tr>
<th>Ratio of pier spacing (centre to centre) to pier width</th>
<th>Ratio of pier thickness to actual thickness of wall to which it is bonded</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>1.0</td>
</tr>
<tr>
<td>10</td>
<td>1.0</td>
</tr>
<tr>
<td>20</td>
<td>1.0</td>
</tr>
</tbody>
</table>

NOTE: Linear interpolation between the values given in table 5.1 is permissible.

When using both formulas the expression will be:

\[ t_{ef} = \frac{3}{3} k_{t_{ef}} t_1^3 + (\rho_t t_2)^3 \]
For this example the effective height will normally be set equal to the geometrically height. i.e.:

$$h_{eff} = h$$

In Eurocode 1996-1-1 there are rules for determining $\rho_3$ and $\rho_4$, i.e. the reduction factor for 3 and 4 sided supported walls (without openings). E.g.:

$$\rho_4 = \frac{1}{1 + \left(\frac{h}{l}\right)^2}$$  \hspace{1cm} (5.8)

To implement openings following procedure can be used.
The effective height is determined in sections

\[ h_{\text{eff}} = h_{a,\text{eff}} + h_{b,\text{eff}} + h_{c,\text{eff}} \]

\[ h_{a,\text{eff}} = \rho_4 \, h_a \]

\[ \rho_4 = \frac{1}{1 + (h/l)^2} \]

\[ h_{b,\text{eff}} = \rho_2 \, h_b = h_b \]

\[ \rho_2 = 1.0 \]

\[ h_{c,\text{eff}} = \rho_3 \, h_c \]

\[ \rho_3 = \frac{1}{1 + (3h/l_c)^2} \]
The main issue when regarding the eccentricity at the top (and the bottom) is the stiffness of the slab in the moment of fracture. The eccentricity can in practice be $t/2$ in **favour** of the construction or $t/2$ in **disfavour** of the construction. The implication for the load capacity is large.

- **Stiff slab.**
  - I.e. the rotation stiffness in the moment of fracture is larger for the slab compared with the wall

- **Slack slab**
  - I.e. the rotation stiffness is smaller for slab than the wall in the moment of fracture
The Danish approach is to define an interval of eccentricity producing an interval for the compression stress. For stiff slabs, foundation, etc the interval is the bearing length. For slack slabs it is half the bearing length.
Determination of the compression zone after determining $h_{\text{eff}}$, $t_{\text{eff}}$, $W_{\text{equiv}}$, etc is done by the usually statically methods.

Wide of the compression zone is determined by $f_d$.

The shape of the compression zone is an affinity to the moment.

The slack slabs with an eccentricity in disfavour to the construction gives a decreased load capacity.

Here an area where the necessity for $f_{xd1}$ is actual.
To cover the spectra of eccentricities $\Phi_{fl}$ is introduced in 6.3.1 (4) (ii).

Here the extended Navier expression is used to cover the area of "small N" and "large M"
Thank you for listening

Any later comments, etc to the papers:

poul.christiansen@teknologisk.dk

Computer program on the Internet for designing according to EN1996-1-1:

www.ec6design.com