EUROCODE 6

Design of masonry structures

EUROCODE 6
Combined loading

Poul Christiansen
Danish Technological Institute

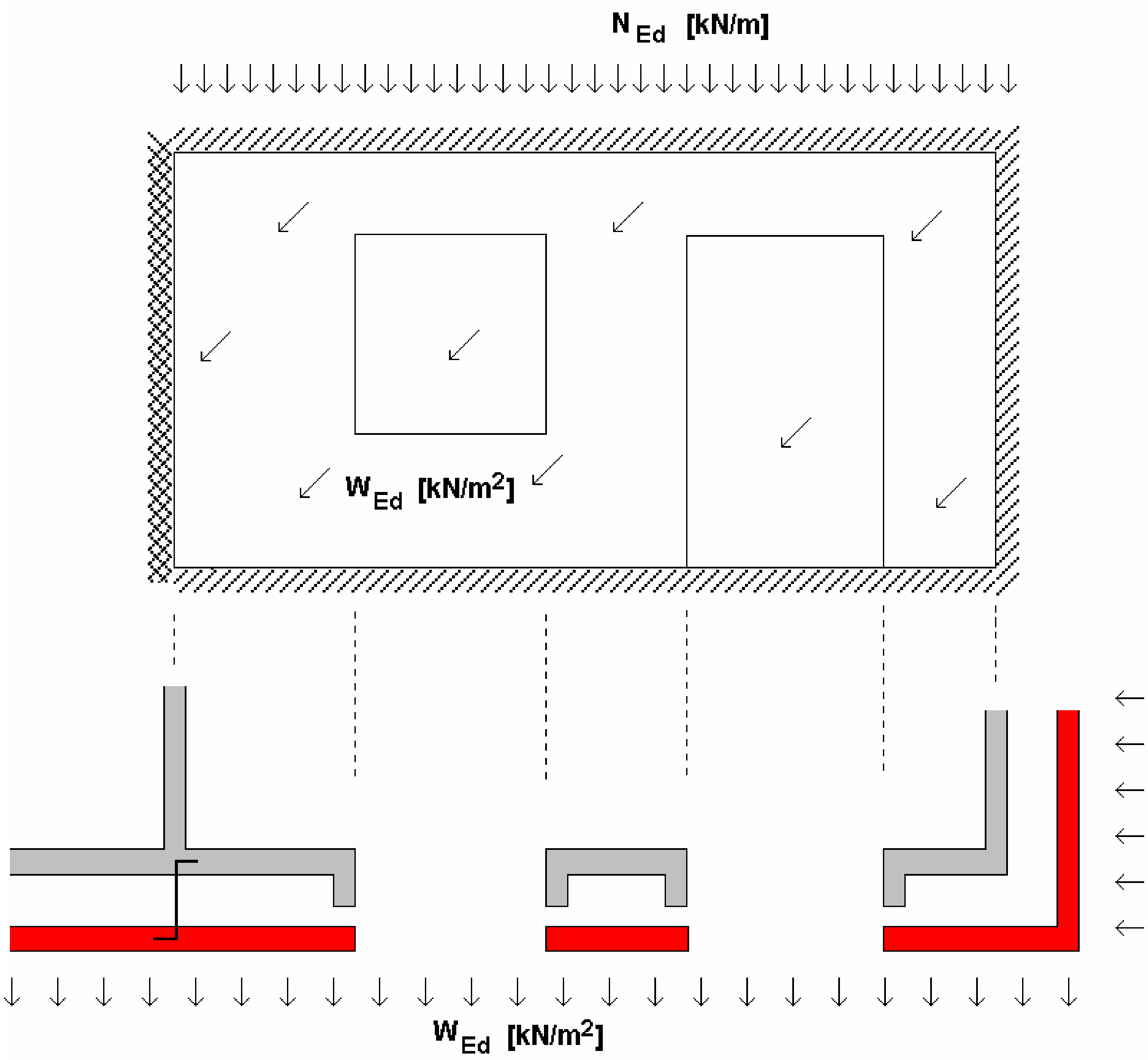
poul.christiansen@teknologisk.dk

Combined loading

Walls subjected to vertical and lateral load

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

Edges restrained or simply supported



Distribution of wind load between outer and inner leaf

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.

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

If 1. Either:

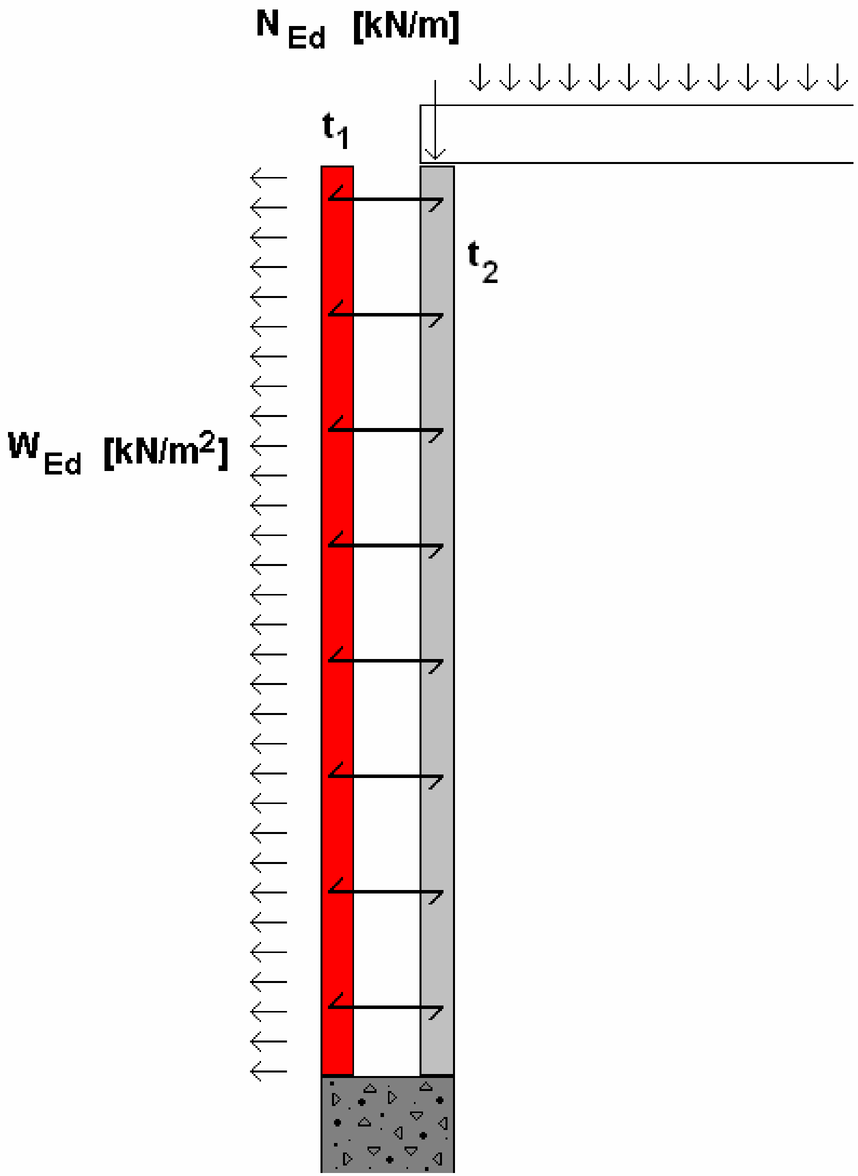
A. According to the stiffness

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

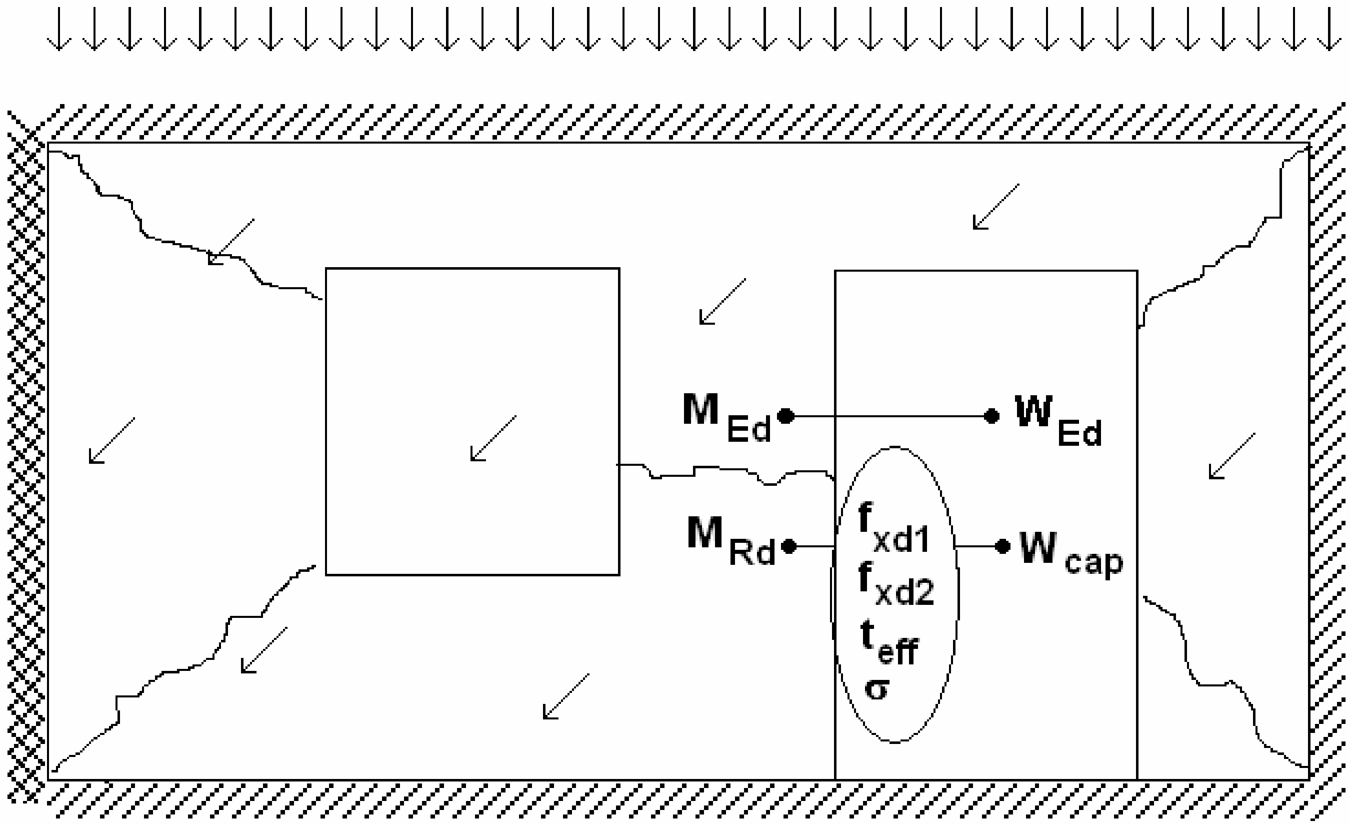
B. According to the capacity

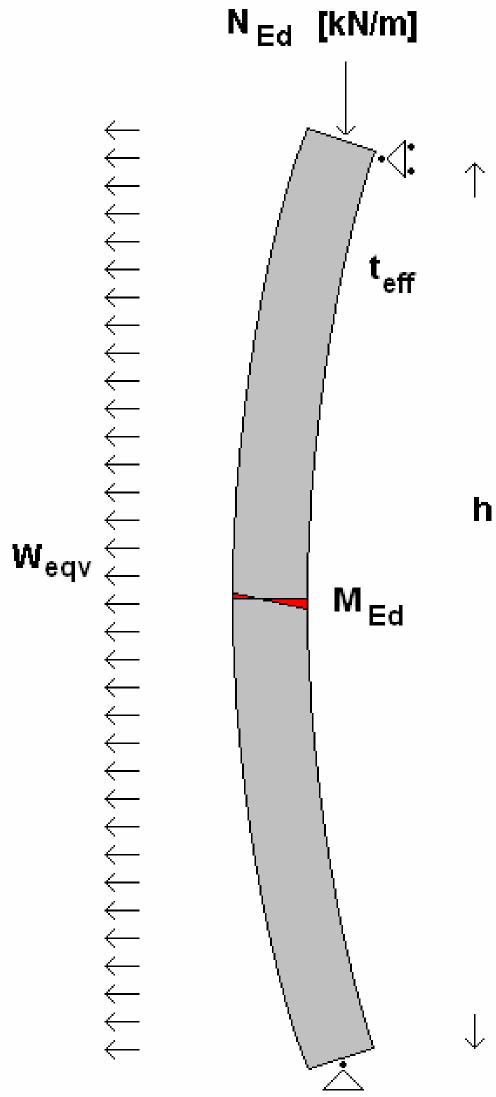
$W_{cap} = W_{cap,1} + W_{cap,2}$ (6.3.1 (6))

In this example (5.11) is used



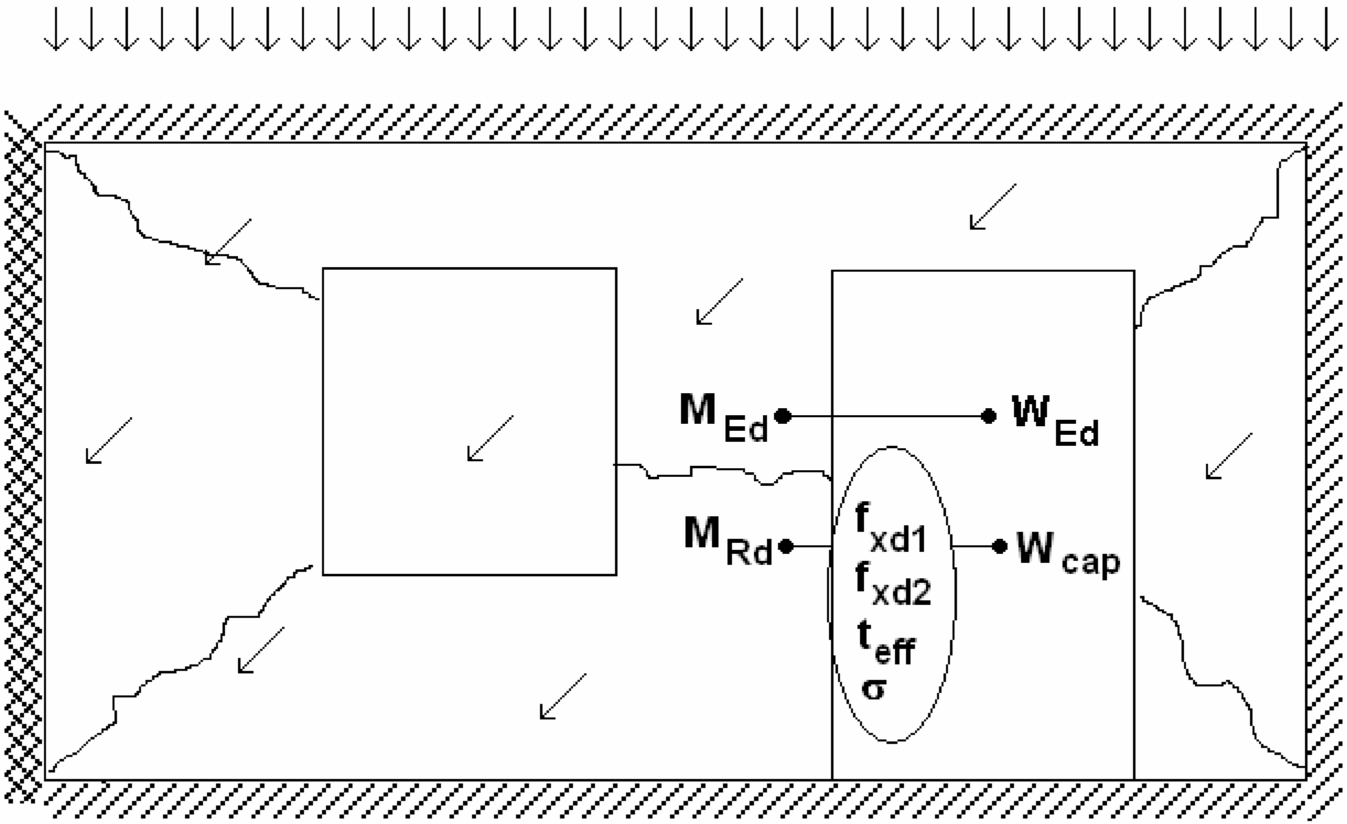
Horizontal and vertical load

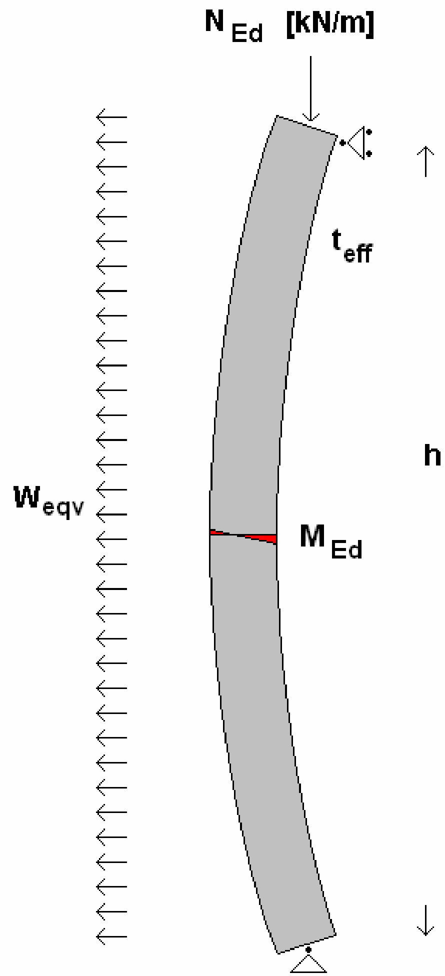




Yield line theory is relevant for openings, 3-4 sided walls.
Φ- method is relevant for 2. order effects and walls supported in top and buttom
The link between the methods is the equivalence of M_{Ed}.
Thus an equivalent windload is introduced: W_{eqv} (<> W_{ed}) (Annex I)

Determining w_{eqv}





The apparent flexural strength: $f_{xd1,app} = f_{xd1} + \sigma$ (6.16)

The moment of resistance: $M_{Rd} = (1/6)(t_{eff})^2 \times f_{xd1,app}$

Based on the yield line theory: W_{cap} is calculated

The actual moment due to (W_{ed}): $M_{Ed} = (W_{Ed} / W_{cap}) \times M_{Rd}$

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

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

Determining the effective thickness

The thickness can be formally altered:

When formula 5.11 is used:

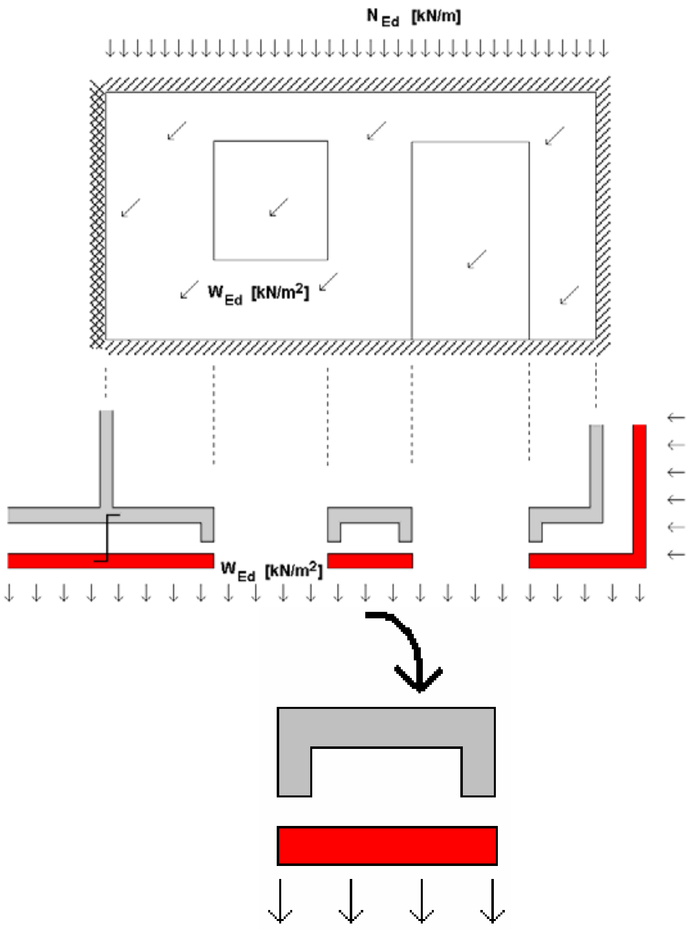
$$t_{ef} = \sqrt[3]{k_{tef}\, t_1^3 + t_2^3}$$

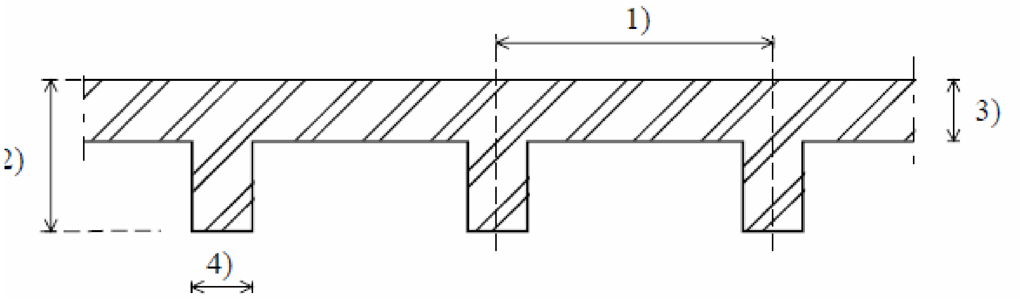
When table 5.1 is used:

Table 5.1 — Stiffness coefficient, ρ_t, for walls stiffened by piers, see figure 5.2

Ratio of pier spacing (centre to centre) to pier width	Ratio of pier thickness to actual thickness of wall to which it is bonded		
	1	2	3
6	1,0	1,4	2,0
10	1,0	1,2	1,4
20	1,0	1,0	1,0

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





Key

1) pier spacing
2) pier depth
3) thickness of wall
4) pier width

When using both formulas the expression will be:

$$t_{ef} = \sqrt[3]{k_{tef}\, t_1^3 + (\rho_t t_2)^3}$$

Determining the effective height

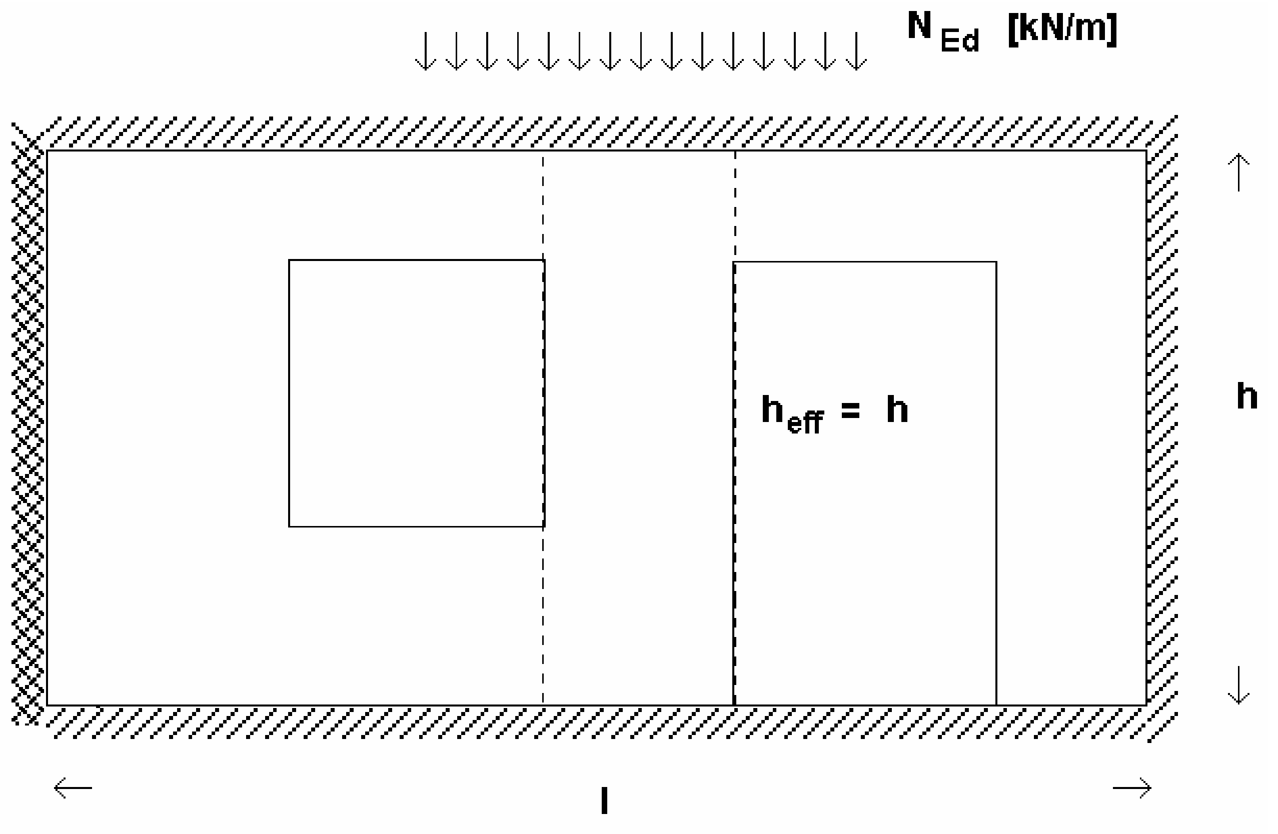
For this example the effective height will normally be set equal to the geometrically height. i.e.:

$$h_{eff} = h$$

In Eurocode 1996-1-1 there are rules for determining ρ_3 and ρ_4, i.e. the reduction factor for 3 and 4 sided supported walls (without openings). E.g.:

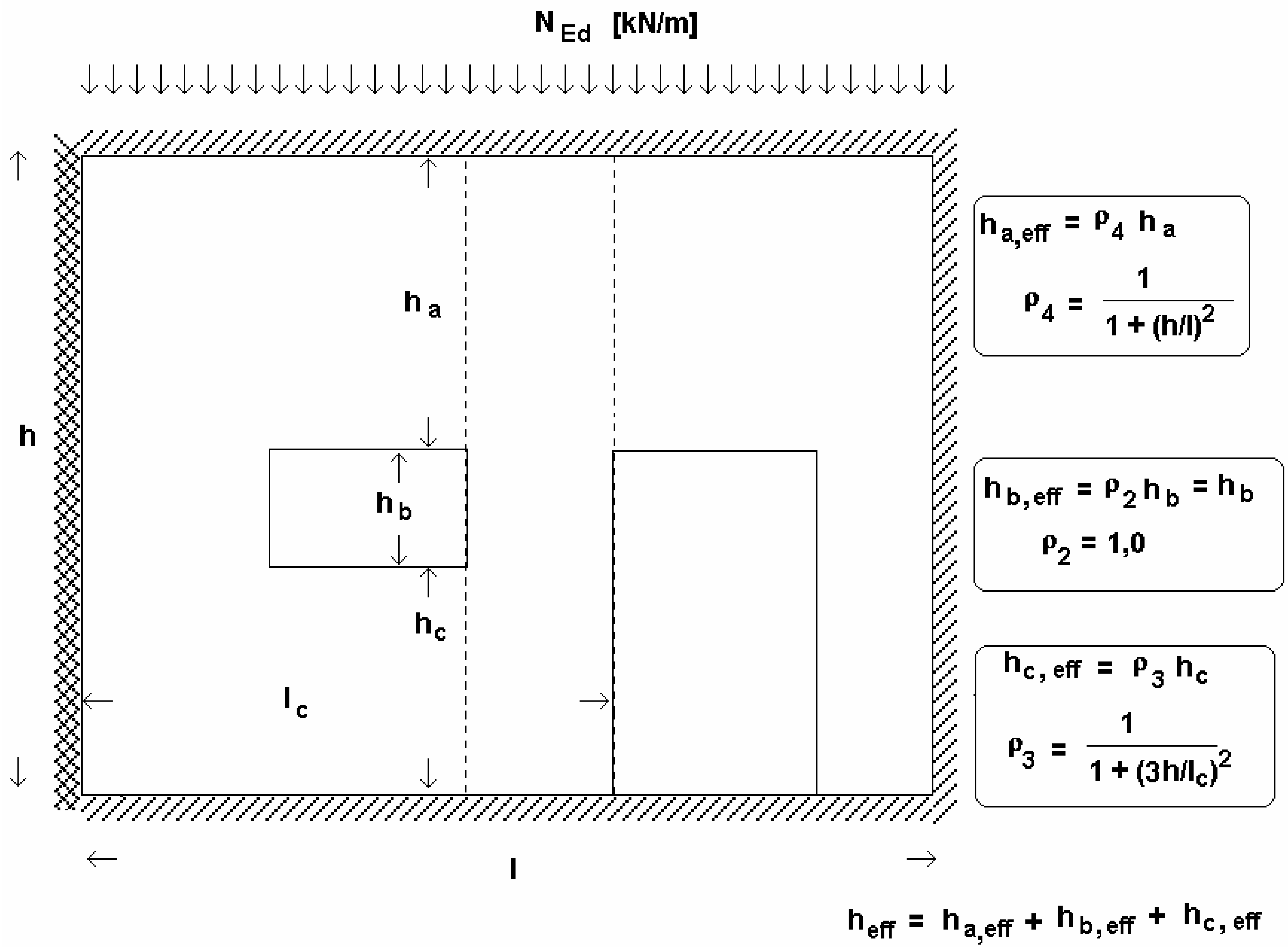
$$\rho_4 = \frac{1}{\left(1+\left(\frac{h}{l}\right)^2\right)} \qquad (5.8)$$

To implement openings following procedure can be used.



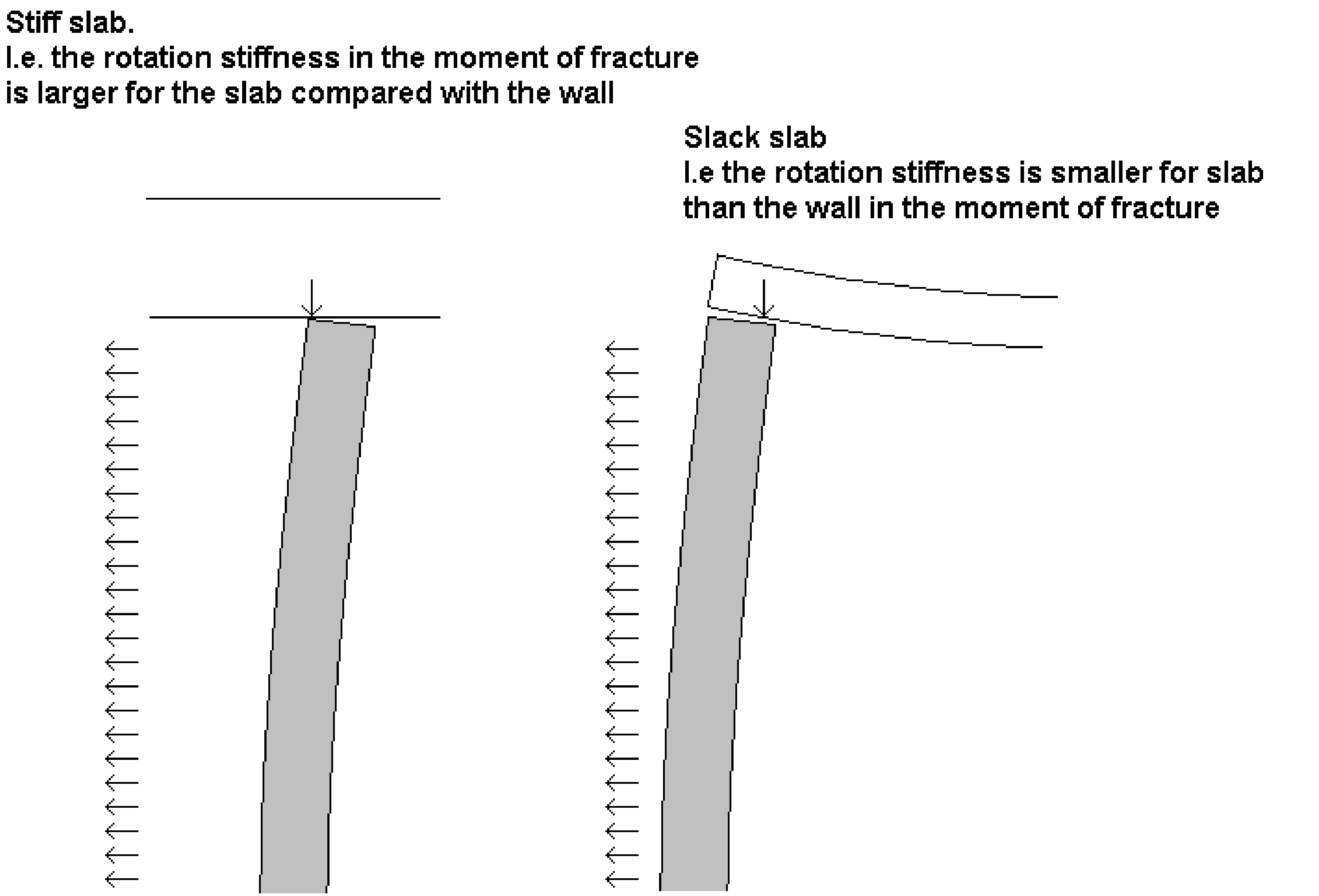
Determining the effective height

The effective height is determined in sections



Determining of the eccentricity

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.

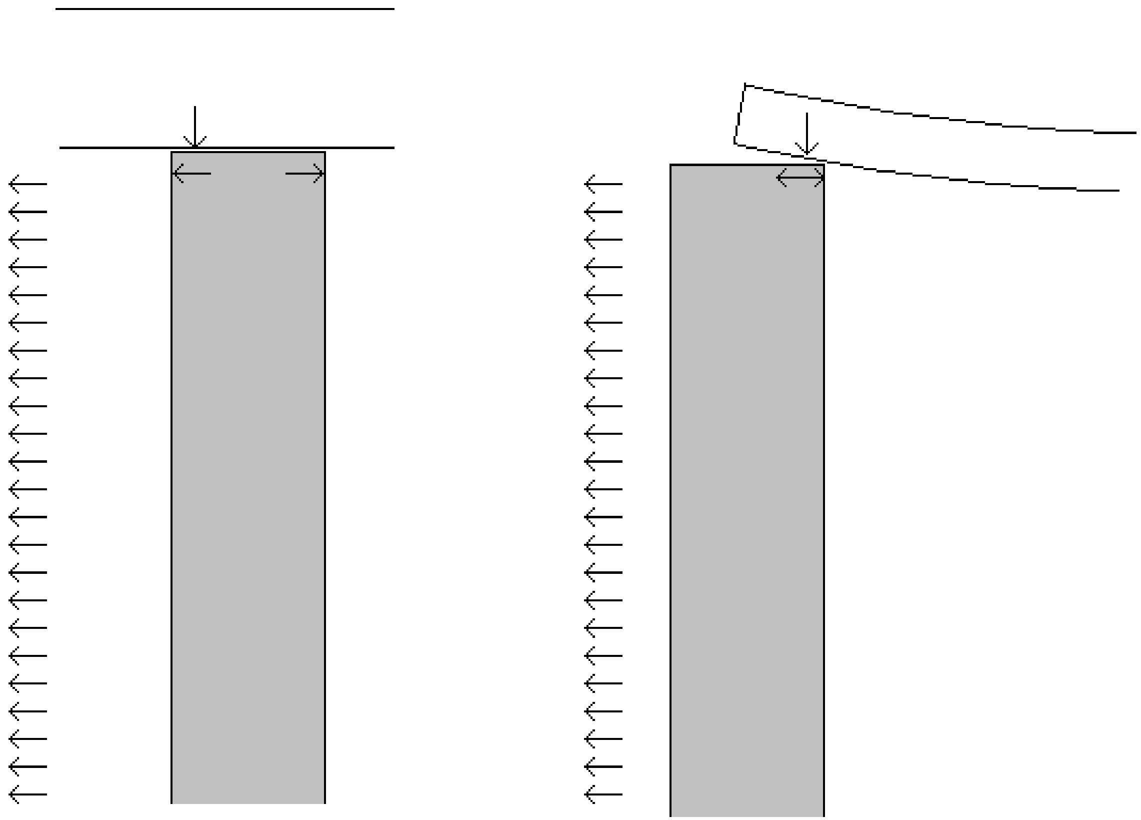


Determining of the eccentricity

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.

The interval of eccentricity for stiff slabs is the bearing length

The interval of eccentricity for slack slabs is ½ the bearing length

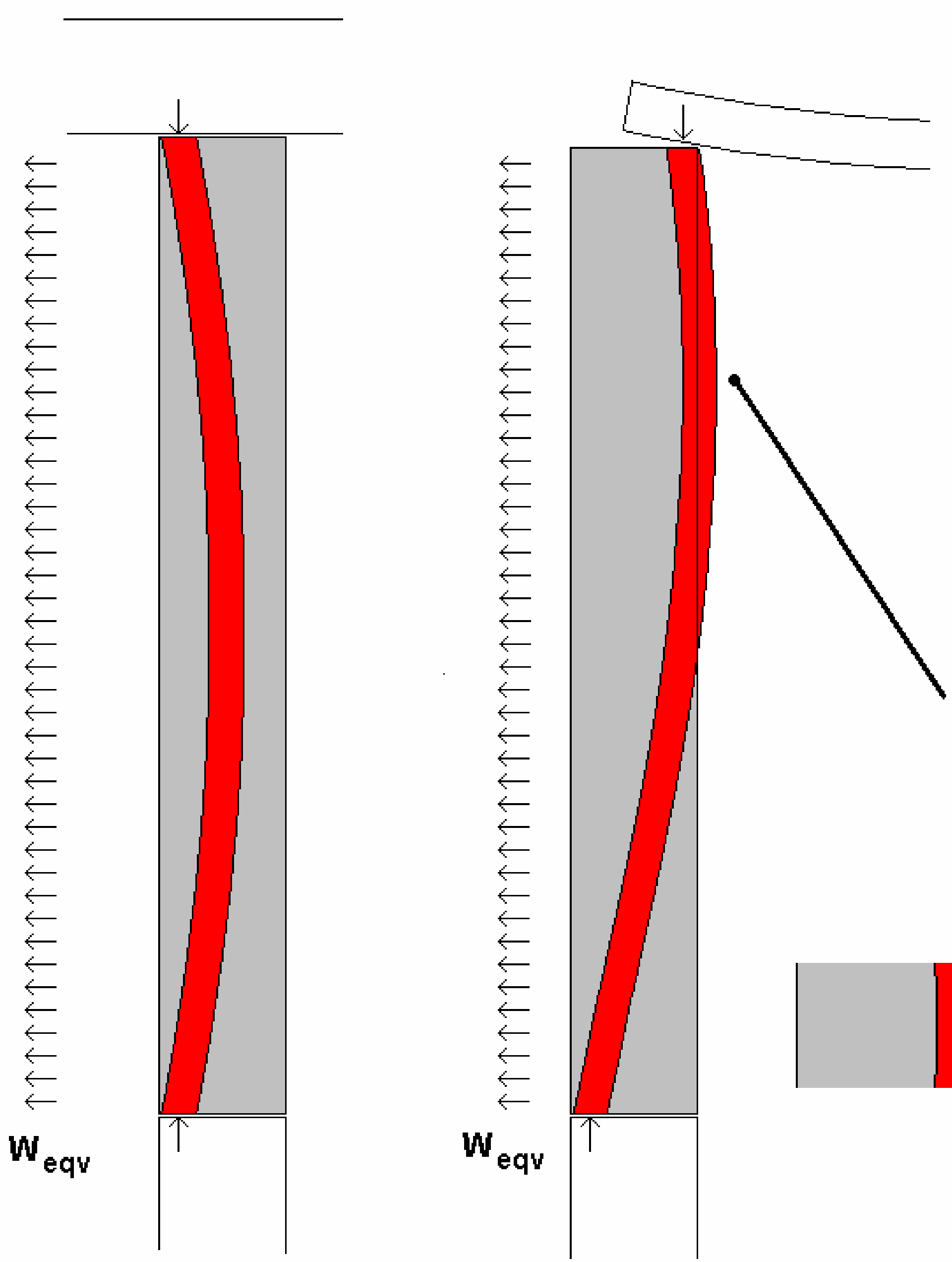


Determination of the compression zone

Determination of the compression line/ zone after determining h_{eff}, t_{eff}, W_{eqv}, etc is done by the usually statically methods.

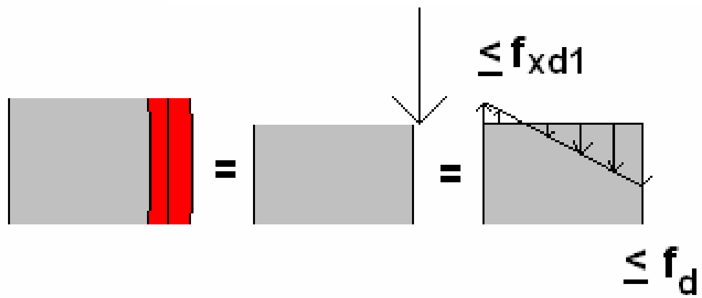
Wide of the compression zone is determined by f_d

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.

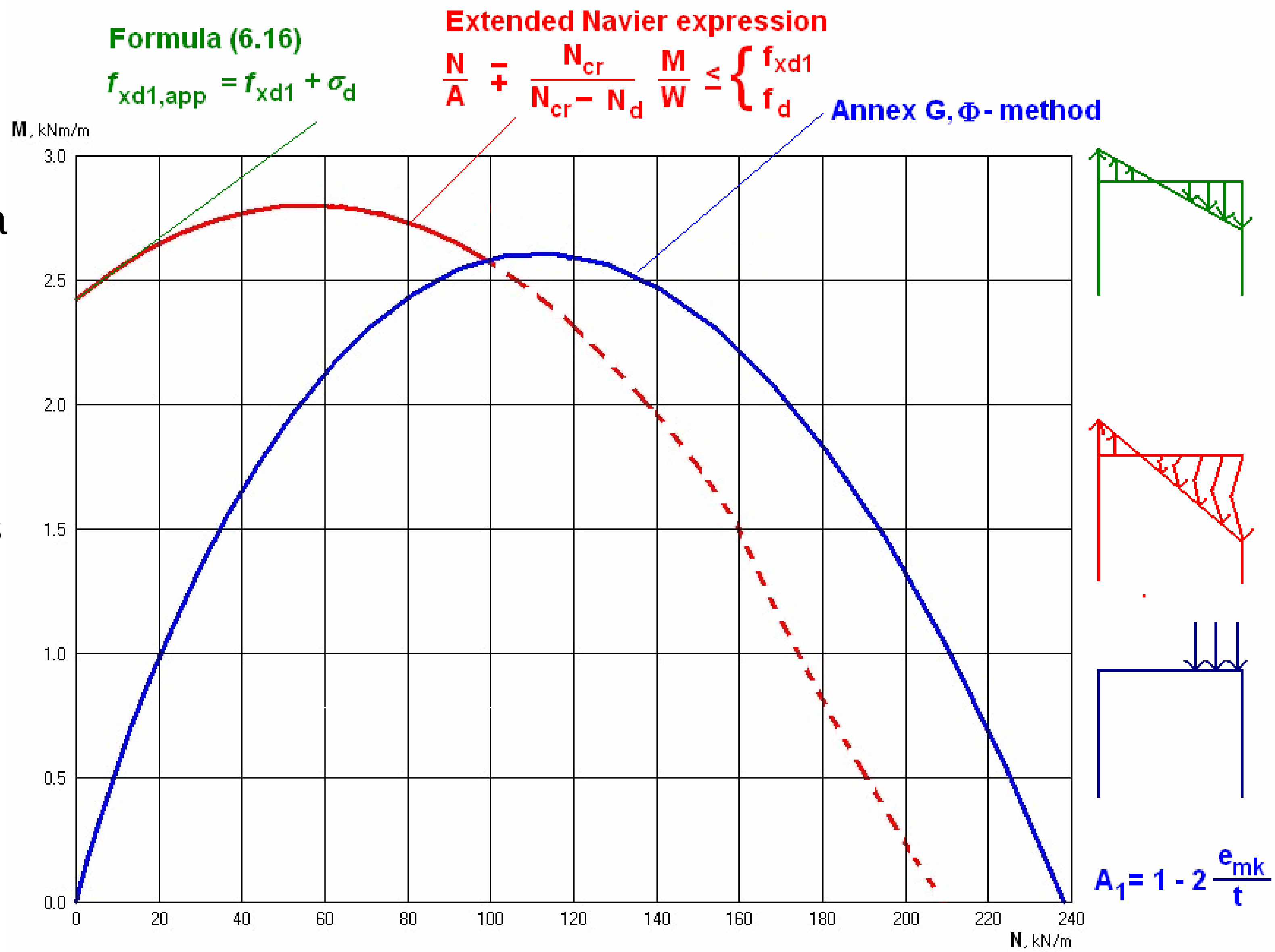
Here an area where the neccessity for f_{xd1} is actual



Determining the load capacity

To cover the spectra of eccentricities Φ_{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