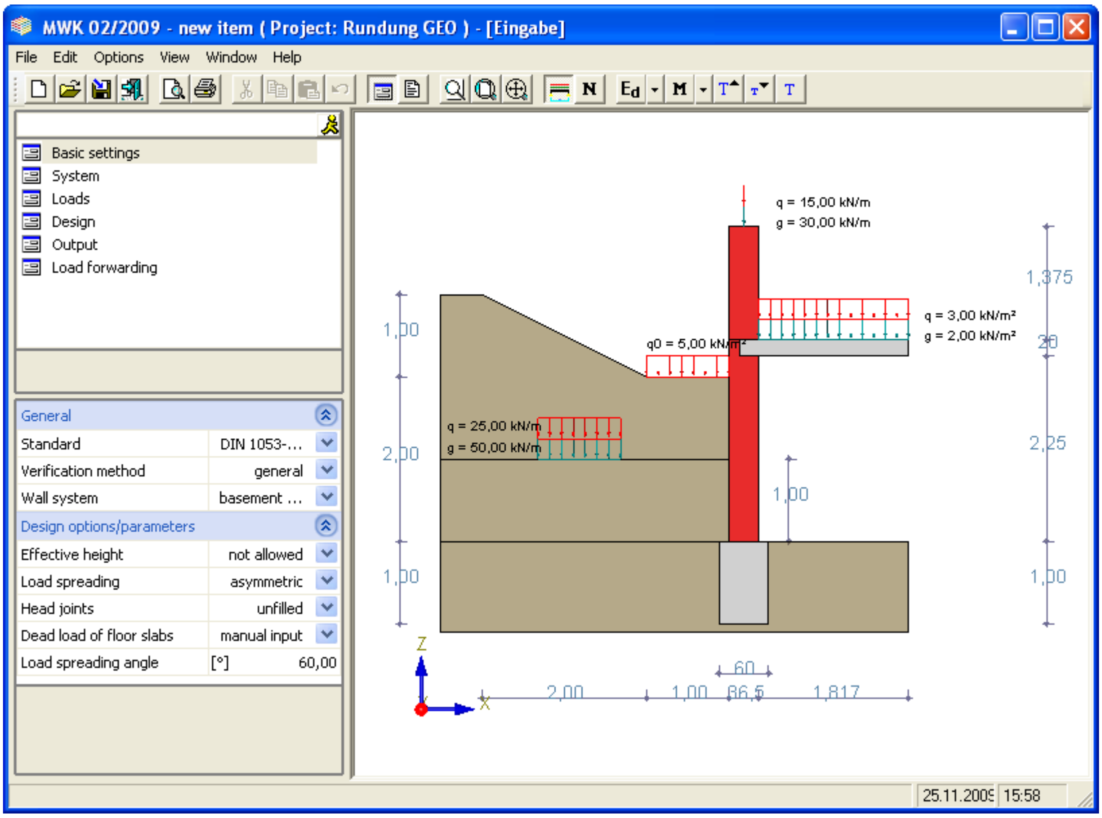
Basement Wall of Masonry MWK

User Manual for Frilo design applications



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MWK Manual, revision 1/2009

Frilo Application: MWK - Basement Wall of Masonry

This manual describes the work with the MWK application.

Contents

Application options

The MWK application performs structural safety analyses for basement walls of artificial masonry under earth pressure load in accordance with the simplified and the more accurate calculation method. You can perform the design either in accordance with

- DIN 1053-1:1996-11 (global safety concept) or
- DIN 1053-100:2007-09 (partial safety concept) or
- ÖNORM EN 1996-1-1:2006 (more accurate calculation method) in combination with ÖNORM B 1996-1-1:2009-03 or
- ÖNORM EN 1996-3:2006 (simplified calculation method) in combination with ÖNORM B 1996-3:2009-03 or
- BS EN 1996-1-1:2006 (more accurate calculation method) in combination with NA to BS EN 1996-1-1:2005 or
- BS EN 1996-3:2006 (simplified calculation method) in combination with NA to BS EN 1996-3:2006.

When applying the simplified calculation method, MWK checks compliance with the limits of application. If these limits are not adhered to, you can alternatively apply the more accurate calculation method.

You can select among the structural systems of an individual wall and a basement wall with a storey on top. In this case, it is always assumed that the wall to be verified is covered on its total top surface by a solid ceiling and supports it.

The basement wall to be verified can be exposed to the following loads

- vertical wall loads from storeys above
- vertical concentrated bearing loads at the wall head
- vertical ceiling loads
- horizontal earth pressure.

It is unusual to consider bracing loads in combination with basement walls, therefore, you cannot define loads parallel to the wall plane. For special cases, you should refer to the MWX application, if necessary.

MWK generates automatically the appropriate load cases and load case combinations depending on the defined action-effects and performs the necessary analyses, whereby the decisive load case combination is determined for each individual analysis.

Corresponding adjustment options allow you to control in detail the calculation and the output of system, load and result values.

Scope of performance

- General load situation including
  - loads applying to the ceiling
  - evenly distributed superimposed wall loads
  - concentrated bearing loads
  - wall loads perpendicular to the wall plane due to earth pressure. You can distinguish between active, increased active and earth pressure at rest in this connection.
- Analysis in accordance with the simplified and the more accurate calculation method.
- Detailed material definition
  - Material according to the selected design standard
  - Material database for masonry officially approved by the German Institute for Construction Technology DIBT for the design in accordance with DIN 1053-1 and DIN 1053-100
  - user-defined material for the calculation in accordance with DIN and EN
- Load transfer to strip foundations and edge strip foundations.
- Transfer of the system to the MWX application.

Basis of calculation

General notes

The standard series DIN 1053 in its current versions (DIN 1053-1; 1996-11 and DIN 1053-100:2007-09) constitutes the basis of calculation in the MWK application. In addition to this, the design can be performed in accordance with Eurocode 6, particularly its parts EN 1996-1-1, EN 1996-1-2 and EN 1996-3. The National Annexes for Austria and Great Britain are implemented in the current version of the application.

We like to draw your attention to our expert documentation about masonry construction that illustrates in detail the design procedure of masonry structures. The design in the MWK application is based on these procedures. Therefore, we are not going to deal with questions of design in this chapter but concentrate on the description of the calculation procedures of the design values determined by the effects of actions.

Design values of the action-effects

The term "design value" of an action or an effect of action such as internal forces and stresses was established with the introduction of the partial safety concept. In the following, the term "design value" refers to the effects of actions that are included in the analyses independently of whether they have been multiplied by partial safety coefficients or not. A moment applying to a wall/ceiling node, for instance, that is used in the design of a wall in accordance with DIN 1053-1 is considered as a design value in this respect.

Load cases for the calculation of the action-effects

Depending on the selected standard and calculation method, the application generates load cases based on the loads entered by the user. The selected standard and calculation method have an effect on the layout of the structural system (which varies for the simplified and the more accurate calculation method), on the one hand, and the calculation of the superposition factors that are included in the calculation together with the load cases (partial safety and combination coefficients for actions) on the other. As a rule, the load cases for permanent and transient actions are always generated separately.

For the generation of the load cases, it is distinguished between vertical and horizontal actions. Vertical actions include uniformly distributed and concentrated loads applying to the basement wall, horizontal actions due to earth pressure are classified as slab loading. The classification scheme is illustrated in detail in the table below. The symbols shown in the table are also used in the documentation and the printout of the load case combinations decisive for the analysis.

Consec. no.	Code	Description
1	$G_{v,Inf}$	Self weights of the structures and all permanent portions of the vertical wall and ceiling loads. Basic value (usually corresponds to $\gamma_{G,inf} = 1.0$).
2	$G_{v,sup}$	As above, however including the portion exceeding the basic value (for $\gamma_G = \gamma_{G,sup} - \gamma_{G,inf}$)
3	$G_{h,inf}$	Permanent portions of the horizontal wall loads due to earth pressure, only in combination with the more accurate calculation method. Basic value (usually corresponds to $\gamma_{G,inf} = 1.0$).
4	$G_{h,sup}$	As above, however including the portion exceeding the basic value (for $\gamma_G = \gamma_{G,sup} - \gamma_{G,inf}$)
5	Q_v	Variable portion of a single vertical load.
6	Q_h	Variable portion of a single horizontally applying load due to earth pressure (slab loading).

Permanent actions

The permanent actions distinguish themselves from the variable ones among other things by the fact that they have to be taken into account even when they act favourably.

When applying the partial safety concept in accordance with DIN 1053-100, the permanent actions are consequently included partially with their lower and partially with their upper values. Therefore, always two separate load cases are generated for the permanently vertically and the permanently horizontally acting loads, whereby the G_{sup} load cases are treated like variable load cases in the combinations of actions. This ensures that they are cancelled if they act favourably and only the lower values are taken into account. When applying the global safety concept in accordance with DIN 1053-1, the G_{sup} load cases are not generated because this is not necessary.

When applying the simplified calculation method, earth pressure is not included in the analysis. Therefore, the load cases $G_{h,inf}$ and $G_{h,sup}$ are only generated in combination with the more accurate calculation method.

Variable vertical actions

When applying the simplified calculation method, only a single load case Q_v is generated from all vertical live loads acting over the total length of the wall. In addition to this, a separate load case Q_v is generated for each defined concentrated load in order to be able to dimension correctly the maximum eccentricity in the length direction of the wall when bracing loads act simultaneously.

When applying the more accurate calculation method, an individual load case is generated for each variable load that includes the vertical wall load with its full and the vertical ceiling load with half of its values in each case.

Variable horizontal actions due to earth pressure

The load cases Q_h are only generated in combination with the more accurate calculation method.

Load case combinations for the calculation of the action-effects

In masonry construction, a particular number of analyses is required due to the variety of possible system definitions and actions. For each of these analyses, one single decisive load case combination exists.

The table below gives an overview of the assignment of load case combinations to the corresponding analyses.

Code	Description
SigmaD	Analysis with compression stress
TauP	Analysis with slab shear
Ex	Limitation of the gaping joint through the thickness of the wall (slab loading of action). Only when designing in accordance with DIN 1053.

Calculation of the characteristic values of the bar action-effects

General notes

The characteristic values of the action effects are calculated separately for each load case. To do this, different structural systems are used depending on the action-effects to be verified. In general, the calculation of action-effects is performed on a plain equivalent system (bar theorem).

Particularities of masonry structures

The design of masonry components distinguishes itself by several particularities. One of these particularities is the approach to the calculation of the effects of actions.

Whereas only normal wall forces resulting from vertical loads must be calculated on the pinned bar in the simplified calculation method, you must define a frame system that allows the estimation of the bearing load reducing effect by the torsion of the ceiling bearings when applying the more accurate calculation method. Action-effects from horizontal loads may be calculated on the pinned bar whereby a redistribution of the wall moment to the head and foot moments up to full restraint is permissible when the balance is preserved and the cracking of cross sections is taken into consideration.

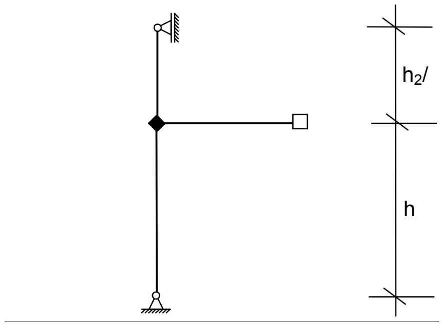
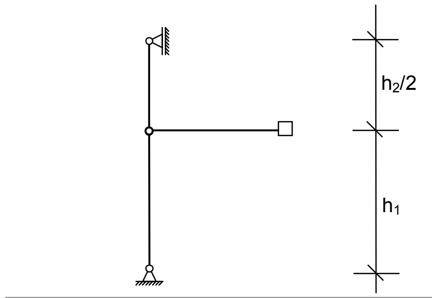
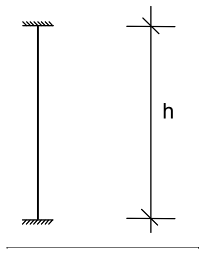
Therefore, the action-effects resulting from the torsion of the ceiling edges and those due to slab loading (earth pressure) must be calculated via different structural systems. We will explain this in detail below.

Structural systems for the more accurate analysis

The axial forces are calculated on a pinned bar. In MWK, the continuity of ceilings can be taken into account via continuity factors.

The moments in the wall/ceiling nodes are calculated on an equivalent bar system. The location of the zero point of the moment is assumed normally at half of the wall height of the wall above. The full wall height of the basement wall is included in the approach based on the assumption of a restrained wall foot.

Therefore, up to three structural systems are generated in combination with the more accurate calculation method. Subsequently, the action-effects are calculated separately for each load case on these systems (linearly elastic, first-order analysis, no shear deformations).

System options	Description	System sketch (based on an intermediate storey wall)
System I[1)]	Calculation of the foot and head moments due to torsion of the ceiling bearings. The wall and ceiling are linked via a rigid connection. The wall above is cut at half of the wall height and pinned at the section points[2]. The supported ceiling side is assumed either pinned, restrained or freely projecting depending on the user-defined bearing conditions.	
System II	Calculation of the normal wall forces as well as the bending and shear forces resulting from the horizontal wall loads due to earth pressure. The wall and the ceiling are linked via a pinned connection. The wall above is cut at half of the wall height and pinned at the section point². The supported ceiling side is pinned. The axial forces are modified in accordance with the continuity factors entered. The wall moments calculated on this system correspond to the unredistributed values.	
System III	Calculation of the moments of the fully fixed end resulting from horizontal wall loads (earth pres-sure). The nodes at the wall foot and wall head are restrained. This creates a bar that is restrained at two sides. The result of the calculation on this system are the moments of the fully fixed ends, i.e. the maximally redistributable moments at the wall foot and the wall head.	
1)	When performing the design, the bending moments and shear forces calculated on this system are reduced to 2/3 of their values (DIN 1053-1, Para. 7.2.2. or DIN 1053-100, Para. 9.2.2). When performing the design in accordance with EN 1996-1-1, the bending moments and shear forces are reduced to 2/3 of their values as well. Equation (C.2) is not used.	
2)	Applies only if the wall above is also defined.	

Structural systems for the simplified analysis

When applying the simplified calculation method, only axial forces have to be calculated on the bar system. Therefore, the calculation of the action-effects is limited to the conditions defined in system **II**.

Action-effects resulting from imposed loads on ceilings

When applying the more accurate method, the bending moments resulting from imposed vertical loads applying to the ceilings have to be calculated. This calculation is based on system I. The results of this calculation are on the safe side because the arithmetical restraint of the wall/ceiling node cannot be obtained due to the cracking of the cross sections and the resultant loss of rigidity. Therefore, the bending moments must not be reduced.

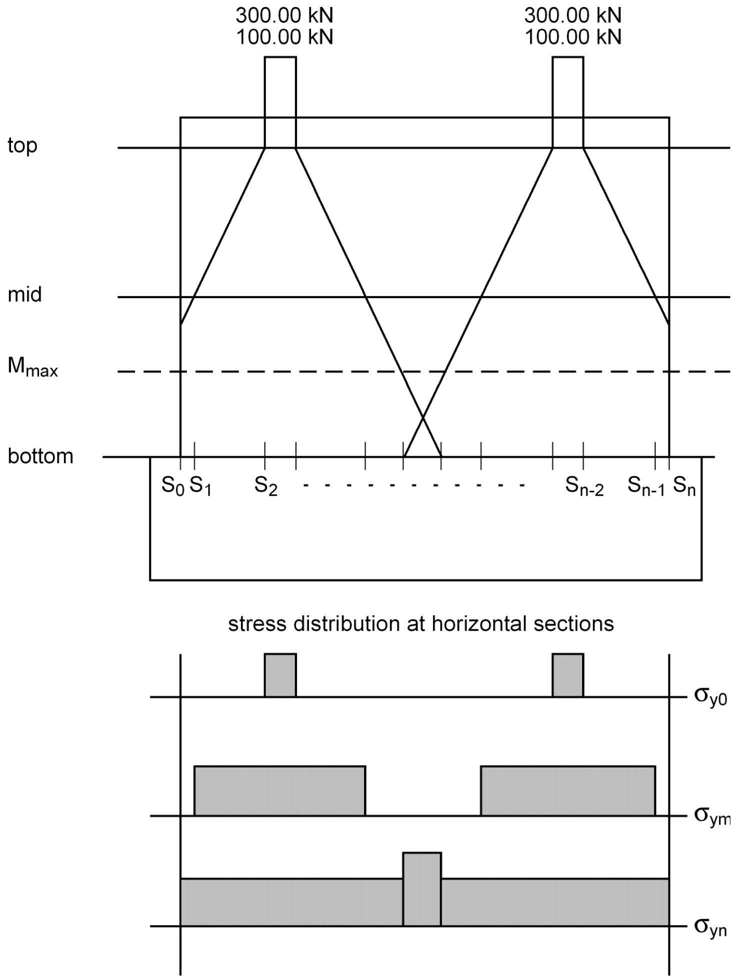
EN 1996-1-1, Annex C defines a reduction factor. The calculation of this factor however opposes to the action-effects calculation via bar models.

We therefore stick to the simple method prescribed by DIN 1053 that has proven its worth for many years now and according to which the bending moments and shear forces are reduced to 2/3 of their values.

Actions-effects resulting from concentrated loads

As a standard, the application assumes an angle of 60° for the distribution of the load. Notwithstanding literature (cf. ref. [4]), you can define a load propagation angle in the range of $45° \leq \alpha \leq 90°$. The concentrated loads produce exclusively normal wall forces. Possible eccentricities of concentrated loads cannot be taken into account.

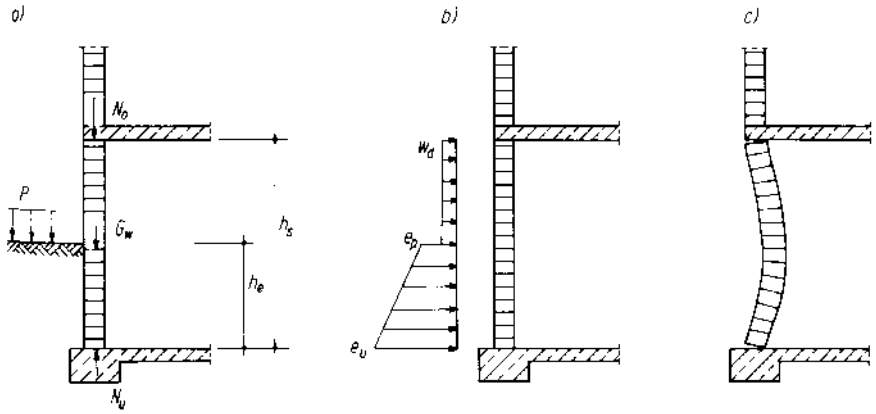
If a wall is exposed to effects of actions resulting from concentrated loads, the sections in all supporting points along the wall length axis are calculated. In this case, the supporting points are the section points of the left and right legs of the load propagation triangles with the respective level lines. The level lines mark the head, the half of the wall height and the foot of the wall and also the line where the maximum bending moment applies, if any.



Redistribution of moments

Fundamental theoretical considerations

The shear forces from horizontal loads such as earth pressure or wind are calculated on the pinned single-span beam. The subsequent analysis is based on the greatest bending moment.
The design on the basis of the maximum bending moment is surely on the safe side because the favourably acting axial forces are not considered. They result from the fact that a horizontal load causes an inward or outward deflection and there is no free torsion of the basement wall between the foundation and the basement ceiling. Restraint moments occurring at the wall head and foot reduce the bending moment calculated on the single-span beam.



Deflection of basement slab and foundation not shown.

The maximum value of the restraint moment is determined by the requirement that the cross sections may only crack up to their centre. Therefore, the following restraint moments can be considered:

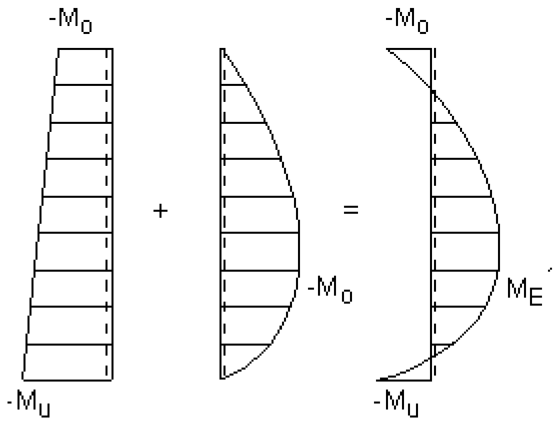
At the wall head: $M_o = -N_o \cdot \frac{d}{3}$

At the wall foot: $M_u = -N_u \cdot \frac{d}{3}$

Legend:
- No axial force applying to the wall head
- Nu axial force applying to the wall foot
- d wall thickness

Due to the action of vertical loads, the cross sections may already present cracks. You should therefore take existing eccentricities at the wall head and foot into consideration.

In addition to the horizontal loads, the favourably acting restraint moments are applied as external loads to the structural system of the single-span beam for the calculation of the action-effects. The action-effects decisive for the design result subsequently from the superposition of the bending moments.



The restraint moments to be considered are calculated as follows:

$$M_o = \pm N_o \cdot (\frac{d}{3} \pm e_o)$$

$$M_u = \pm N_u \cdot (\frac{d}{3} \pm e_u)$$

whereby e_o and e_u are the nominal eccentricities resulting from vertical loads.

You should note in this connection that the head and foot moments do not exceed the values of the moments of the fully fixed ends because a greater redistribution is not possible. Due to this fact, the moments assumed by the MWK application result from the following equations:

$$M_o = \max[-N_o(\frac{d}{3} - e_o), M_{vo}]$$

$$M_u = \max[-N_u(\frac{d}{3} - e_u), M_{vu}]$$

whereby M_{vo} and M_{vu} are the moments of the fully fixed end resulting from the respective horizontal loads.

If the cross sections at the wall head and foot are already cracked up to their centre, no redistribution of moments can take place any longer.

The shear forces calculated on the single-span beam are modified according to the calculated restraint moments and subsequently superimposed with the shear forces resulting from ceiling torsion.

Simplified method:
When applying the simplified method, you cannot define horizontal loads. Therefore, a moment redistribution is not relevant.

Calculation of the design values of the action-effects

The bar action-effects of the described load cases are available as characteristic values. They are combined to design values of the bar action-effects giving consideration to the stipulations of the applicable design standard.

Subsequently, the bar action-effects (they produce constant effects of actions over the total wall length) are superimposed with the related action-effects (kN/m, kNm/m) resulting from load propagation under concentrated loads. If required, the maximum related axial force is determined giving consideration to the eccentricities through the length of the wall and the gaping joints. The analyses are based on this axial force.

Basic parameters

General notes

Standard

Defines the standards that constitute the basis of the structural safety analysis.

Method of analysis

Specification whether the simplified or the more accurate calculation method is used for the analysis of the wall.

DIN 1053-1 and also DIN 1053-100 describe a simplified and a more accurate calculation method for the analysis of basement walls of masonry. The design in accordance with EN 1996-1-1 is based on the more accurate method. A simplified procedure that is in its essential parts comparable to that of DIN 1053 is not included in EN 1996-3.

When the simplified method is selected, the application checks whether the limiting conditions on which the analysis is based are complied with. In the case of non-compliance, a corresponding message is displayed and no analysis is performed. The user must manually switch over to the more accurate method in this case.

Wall system

This option allows you to define the structural system that constitutes the basis of the analysis of the masonry wall in question in accordance with the following table:

Option	Description
Individual wall	Single-storey masonry structure consisting of a single basement wall exposed to earth pressure. The basement wall is built on a foundation or floor slab and supports the basement ceiling.
Basement wall	Basement wall with at least one storey on top. The basement wall is built on a foundation or floor slab and supports the basement ceiling. You must define the wall above for the calculation of the node moments.

Calculation parameters

Reduction of the effective length

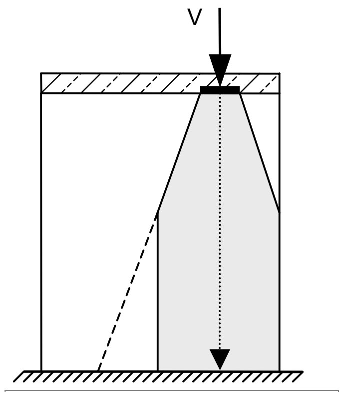
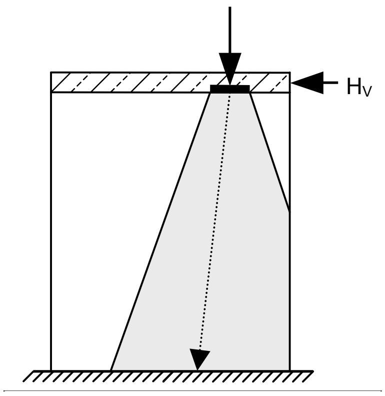
Specification whether a reduction of the effective length of the wall is permissible with regard to the standard limiting conditions.

Where prescribed masonry made of standard bricks is concerned a reduction of the effective length is always permissible if the specific limiting conditions are complied with. Where masonry according to approval is concerned the reduction of the effective length might be excluded by the approval.

The user must inform himself/herself about existing approvals and their contents and make the corresponding adjustments.

Load propagation

Specification whether the load propagation under concentrated loads must always be assumed as being symmetrical or may also be asymmetrical. The selection of the correct option is only relevant when the load propagation area is limited by the vertical wall ends. If asymmetrical load propagation is permitted, the absorption of the deflection forces generated by the inclination of the load path must be ensured by adjacent bracing wall plates.

Value	Description	System sketch
Symmetrical	Only the symmetrical portion of the load propagation area is included in the calculation of the related axial force.	
Asymmetrical	The full load propagation area is taken into consideration in the calculation of the related axial force. The absorption of the generated drive force H_V must be ensured by adjacent wall plates.	

Transversal joint solidification

Specification whether the transversal joints of the masonry bond are solidified. This option has an effect on the magnitude of the bond shear resistance of the masonry.

Ceiling self weight

This option allows the user to select whether the construction weight of the supporting layer of the ceiling should automatically be included in the calculation by MWK or not. This option is only relevant when the wall loads are already included in the ceiling loads.

Load propagation angle

This option allows you to define the load propagation angle for concentrated loads (definition IAW DIN 1053). The default setting is 60°. For masonry according to approval, a greater distribution angle might be required.

If you select masonry according to approval when entering the material, the value for the load propagation angle stored in the material database is automatically filled in.

If the consideration of the load propagation is not permissible, you can handle this case by selecting a load propagation angle of 90°.

Execution supervision (only in combination with BS EN 1996)

EN 1996-1-1, A(1) allows each national state that applies this standard to prescribe individual partial safety coefficients for resistances that depend on the verification of the execution. Currently, Great Britain profits from this option in the British National Annex. The corresponding class must be selected when this NA is applied.

System options

Walls

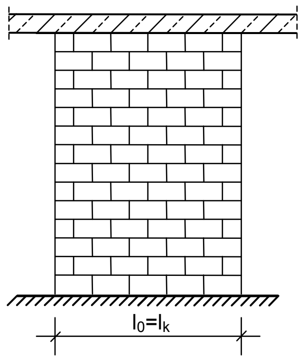
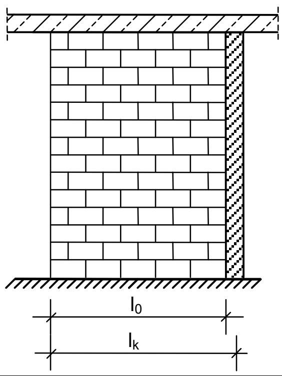
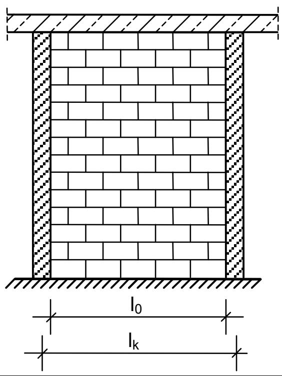
Material

The option displays a dialog that allows you to define prescribed masonry, select masonry according to approval or enter a user-defined material if DIN 1053 war selected for the design.

If EN 1996 was selected, the input dialog for a user-defined material is displayed by default to provide for special national regulations.

Storage

Specification whether the wall is supported on one, two, three or four sides.

Option	Description	System sketch
On two sides	The wall is retained at the head and foot to prevent lateral shift	
On three sides	The wall is retained at the head, the food and one vertical side to prevent lateral shift.	
On four sides	The wall is retained at the head, the food and both vertical sides to prevent lateral shift.	

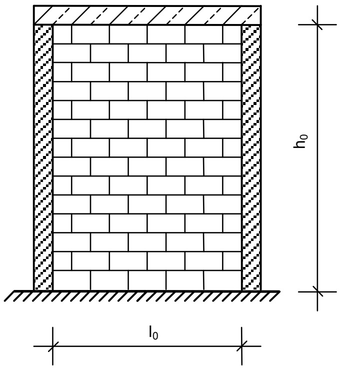
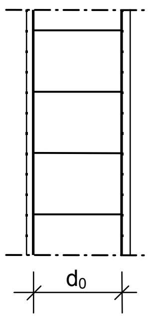
(l_k = arithmetical wall length for the effective length calculation, l_0 = clear wall length for the load distribution/analysis)

In addition to the number of retained sides, also the thicknesses of the retaining wall plates must be entered. The application checks internally whether the wall thicknesses are relevant in regard to the selected design standard. **The minimum lengths of these walls stipulated by DIN 1053-1 and DIN 1053-100 or EN 1996-1-1 are not checked. The user must do this manually!**

Based on the number of effective supports the effective wall length l_k is calculated.

Geometry of the wall

The option defines the decisive dimensions of masonry walls. Fore more details, see the table below.

Value	Description	System sketch
h_0	Clear wall height	
l_0	Clear (=arithmetical) wall length, which is the basis of the load distribution.	
d_0	Thickness of a single-leaf wall or thickness of the bearing layer of a multi-leaf wall	

Spacing of transversal bracing walls

Option	Description
d_1	Thickness of the bracing wall at the left vertical wall end.
d_2	Thickness of the bracing wall at the right vertical wall end.

g_z

Self weight addition for the wall lining, for instance.

Text

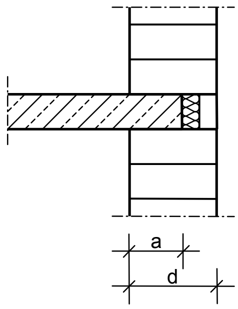
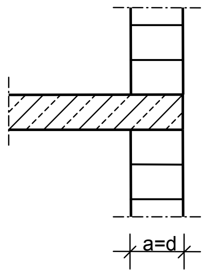
Text for the description of the wall or the name of the storey. It appears in the output.

Basement ceiling

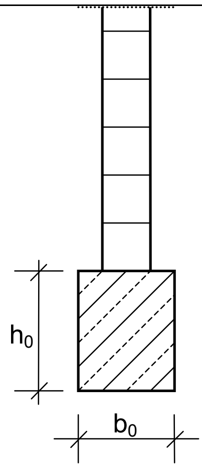
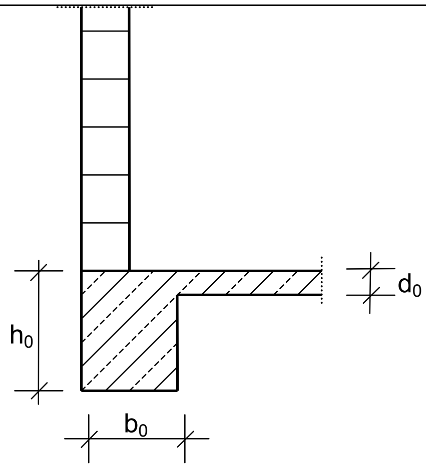
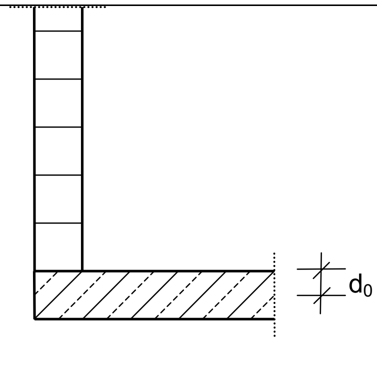
Modulus of elasticity

Arithmetic or characteristic value of the modulus of elasticity of the ceiling.

Geometry of the ceiling

Option	Description	System sketch
Bearing length [a]	Bearing length of the basement ceiling: **Note: Is only relevant for the calculation of the effective length. No local effects resulting from partly supported ceiling slabs are verified!**	 
Thickness [d]	Thickness of the basement ceiling	
Span [l]	Span of the basement ceiling: Distance from the right edge of the wall surface to the supporting node	
Width [b]	Affected width of the basement ceiling: **Note: The value must be equal to or greater than the clear wall length!**	
Supports	Support conditions of the basement ceiling: pinned or restrained (defines an equivalent structural system for the calculation of the node moments and the automatic calculation of the continuity factors of ceiling loads, if applicable).	

Foundation

Type	Geometry
Strip foundation	
Edge strip foundation	
Floor slab	

Loads

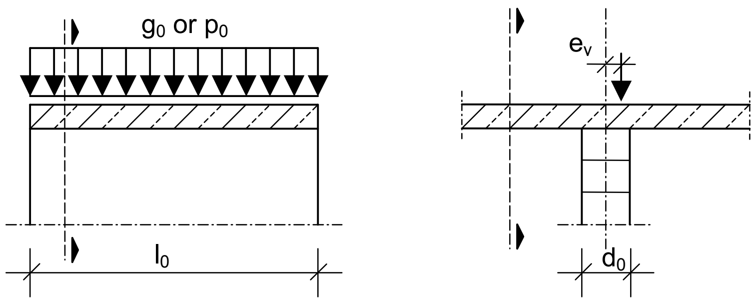
Vertical wall loads

Type

Specification whether the load is a uniformly distributed or concentrated load.

Concentrated loads are always assumed to act centrically in transverse direction and simultaneously over the total wall thickness. You can assign an eccentricity through the thickness of the wall to uniformly distributed loads.

<table>
<tr><td>Uniformly distributed load:

Uniformly distributed load (applies always over the total wall length)</td><td>
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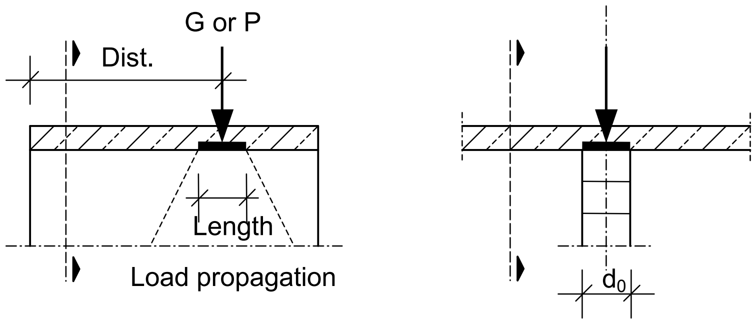
<tr><td>Concentrated load:

Overlapping of load contact areas of several concentrated loads is not permissible.</td><td>
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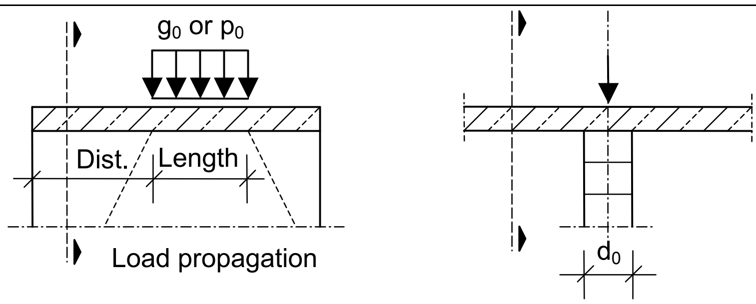
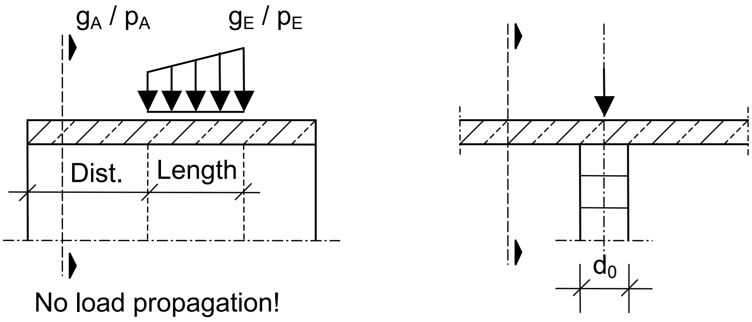
<tr><td>Line-section load[1)]

Constant linear load distributed over a section of the wall length.</td><td>
</td></tr>
</table>

Trapezoidal load[2]: Corresponds to a line-section load with variable load coordinates	 No load propagation!
1)	The definition of line-section loads serves to map bearing reactions from walls above that are also exposed to concentrated loads, if applicable. A line-section load does not correspond to a partial area compression due to load introduction in the sense of the standard. Therefore, no partial area compression analyses are performed for these loads. Another difference to concentrated loads resides in the fact that these are assumed to apply always at the wall head. Note: Load propagation is assumed under line-section loads.
2)	As the line-section load, the trapezoidal load serves to map bearing reactions that are however linearly variable in each section. An example are bearing forces resulting from FE slab calculations due to vertical and horizontal loads or from eccentrically arranged walls above. Note: No load propagation is assumed under trapezoidal loads.

Distance

Distance of the line of action of a concentrated load from the left wall edge or distance of the left load ordinate of a line-section load or trapezoidal load.

G / Q or g_0 / q_0

Permanent (G/g) and variable (Q/q) portions of the vertical wall load. Linear loads are specified in [kN/m], concentrated loads in [kN].

Load length

The length of the contact area of the concentrated load through the length of the wall or the length of the load introduction area of a line-section or trapezoidal load.

e_y

Eccentricity of the impact plane of a load through the thickness of the wall. Only available over the total length of the wall in combination with uniformly distributed linear loads.

The maximum eccentricity of the load is limited to $d_0/3$ for walls immediately underneath the top ceiling, otherwise to $d_0/2$. (The optional specification of an eccentricity is particular relevant for the definition of partly supported ceiling slabs with a very low bearing length.

ActGrp

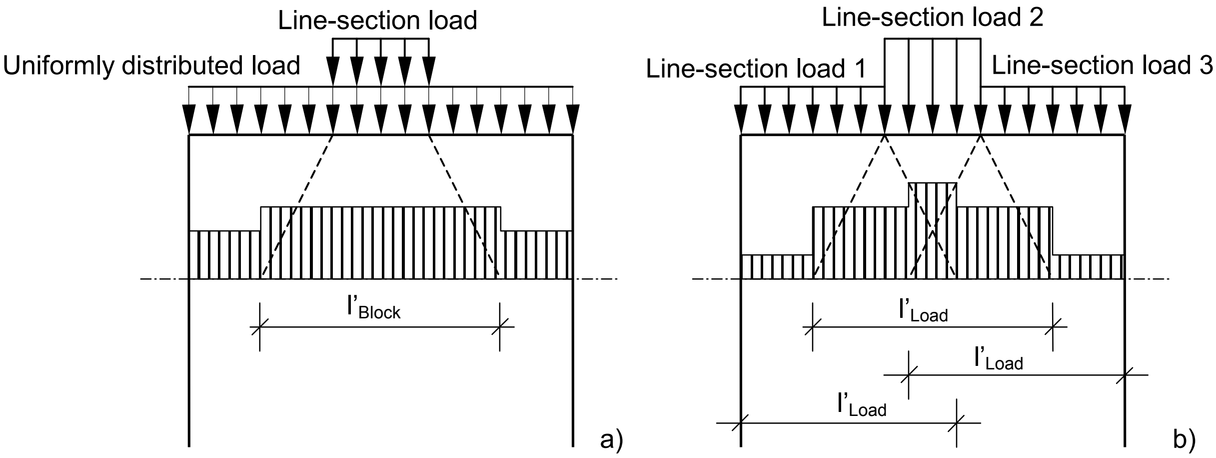
Number of the action group of the variable load portion. The permanent load portion is always assigned to the permanent action. When the analysis is performed in accordance with DIN 1053-1, the assignment of an action group can be dispensed with.

Text

You can optionally enter a short note or item description that appears in the output.

Note concerning the use of line-section loads

When using line-section loads, it should be noted that the load propagation under each line-section load is assumed separately, i.e. without considering the neighbour loads. In some cases, unrealistic overlapping of the load propagation cones might result (see the following illustration). You should therefore define the load train rather in the form of a pyramid than segment by segment. If load propagation should completely be dispensed with, load sections can be assembled from trapezoidal loads.



Ill. 1: Use of line-section loads: a) correct load propagation in compliance with design practices b) unrealistic overlapping of the load propagation cones

Ceiling loads

Type

Specification of the load type. Currently, only uniformly distributed loads are supported.

ActGrp

Number of the action group of the variable load portion. The permanent load portion is always assigned to the permanent action. When the analysis is performed in accordance with DIN 1053-1, the assignment of an action group can be dispensed with.

Text

You can optionally enter a short note or item description that appears in the output.

Load values

Value	Description
g	Permanent or variable load portion in [kN/m²]
q	Variable load portion in [kN/m²]

Continuity factors

[ES1]The fact that tensile strength must not be assumed perpendicular to the horizontal joints in the analysis of masonry structures is responsible for a typical feature of masonry that higher superimposed loads (compressive axial forces) do not necessarily produce a higher loading rate of the wall cross section (resistance to slab loading). Lower superimposed loads might produce the premature failure of the wall. Therefore, the continuity of the ceiling must be taken into consideration under certain circumstances.

DIN 1053-1 and DIN 1053-100 provide simplified regulations stipulating in which cases the continuity of ceiling slabs could be neglected. In order to transfer this concept in a general manner to the design procedure, so-called continuity factors are included in the definition of ceilings in MWK. The continuity factor is defined as follows:

f = relation of the bearing force applying on top of the wall (resulting from the load) to the amount of the loading (resultant).

Value	Description
Fac g	Continuity factor (Winkler coefficient) for the permanent load portion
Fac q	Continuity factor (Winkler coefficient) for the variable load portion

<u>Example 1:</u>

The ceiling system is a two-span beam with equal spans l under a uniformly distributed load q.

$$\text{Fac} = 0.438 \cdot q \cdot l / (q \cdot l) = 0.438$$

<u>Example 2:</u>

As example 1, however with a restraint at the bearings on the opposite side.

$$\text{Fac } q_{le} = \text{Fac } q_{ri} = 1.000/2 \cdot q \cdot l / (q \cdot l) = 0.500$$

If the equivalent frame system is also suitable for the determination of the ceiling bearing forces, the switch "Continuity factors ... from ceiling geometry" provides for the automatic generation of the continuity factors from the geometry and the bearing conditions of the defined ceilings.

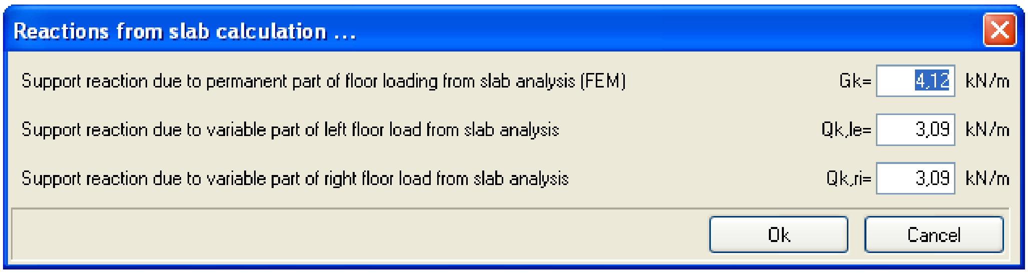
Attention: *This command has an effect only on the current ceiling load, i.e. you must repeat it for each additional ceiling load.*

Setting bearing forces resulting from slab calculation by default

Whereas the effects resulting from the ceiling torsion are already included in the reduction factors when applying the simplified calculation method, these bearing load-reducing impacts must be taken into consideration in the more accurate calculation process via the calculation of the moments at the wall/ceiling nodes using corresponding equivalent systems (simplified frame system).

In many cases, the ceiling bearing forces are however not calculated on the equivalent system but during the ceiling design via FEM. As long as the limiting criteria for the application of the simplified calculation method are complied with, these bearing forces could be used directly in the design of the wall (input in MWK as vertical wall loads).

It becomes more difficult when the more accurate calculation method must be applied. In this case, equivalent systems have to be generated. The load situation on the ceilings is decisive for the determination of the moments at the wall/ceiling nodes as well as the axial forces. These axial forces are however hardly identical to the actually calculated bearing forces. In order to solve this problem, continuity factors have been introduced that could be used in the calculation of the axial forces.



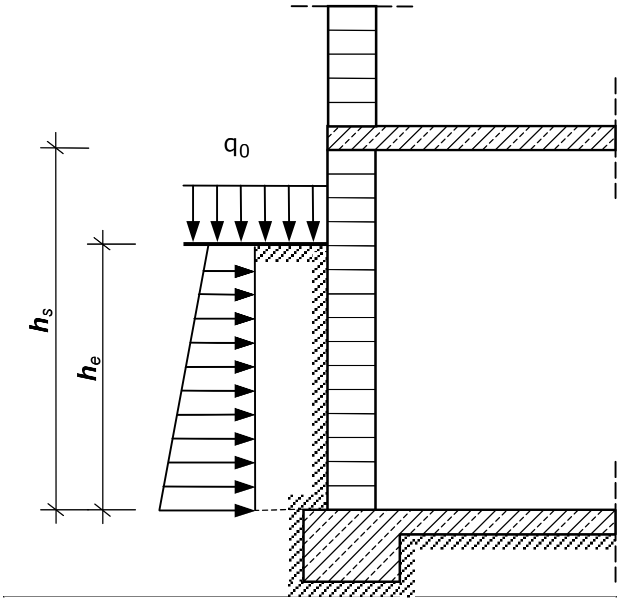
The dialog shown above allows you to enter the bearing forces in [kN/m] resulting from the ceiling calculation separately for load portions resulting from permanent loads and those resulting from imposed loads on the basement ceiling. The application calculates equivalent continuity factors from these bearing forces and the specified loads on the basement ceiling as follows:

Continuity factor for the permanent load portion on the right ceiling side $$f_{Gk,lre} = 0{,}5 \cdot \frac{G_k}{g_{k,re} \cdot l_{re}}$$

Continuity factor for the variable load portion on the right ceiling side $$f_{Qk,re} = 0{,}5 \cdot \frac{Q_{kre}}{q_{k,re} \cdot l_{re}}$$

Soil parameters

Height of earthfill he



Angle of wall friction δ

Specification of the surface finish of the basement wall. This indication is required for the calculation of the angle of wall friction.

Wall surface finish	Angle of wall friction		
	DIN 4085 Table AAA.1	**ÖNORM B 4434 Table 2**[1)]	**BS 8002**
Interlocked Concrete surfaces that directly interlock with adjacent ones.	$\delta = \varphi_k'$	$\delta = \frac{2}{3} \cdot \varphi_k'$	
Rough Untreated surfaces of steel, concrete or timber	$\delta = \frac{2}{3} \cdot \varphi_k'$		
Less rough Wall linings made of plastic boards	$\delta = \frac{1}{2} \cdot \varphi_k'$		
Smooth Greasy backfills, sealing layers	0		

Specific weight of the soil γ

Arithmetic or characteristic value of the specific weight of the adjacent soil.

Effective friction angle

Specification of the effective inner friction angle of the soil that is used for the assessment of the shear resistance of the soil.

Cohesion

Specification of the effective cohesion of the soil that is used for the assessment of the shear resistance of the soil.

Earth pressure equation

Specification of the factor for the calculation of the stress condition under increased active earth pressure.

The equation is as follows: $E'_a = E_a \cdot \mu + E_0 \cdot (1-\mu)$.
The following is true for the active earth pressure: $\mu = 1$
The following is true for the earth pressure at rest: $\mu = 0$
The following is true for the increased active earth pressure: $0 < \mu < 1$

Earth pressure pattern

Specification whether the earth pressure pattern is included in the form of a triangular distribution or an equivalent constant earth pressure load.

Compaction earth pressure

Specification whether compaction earth pressure should be included and if so, in which manner.

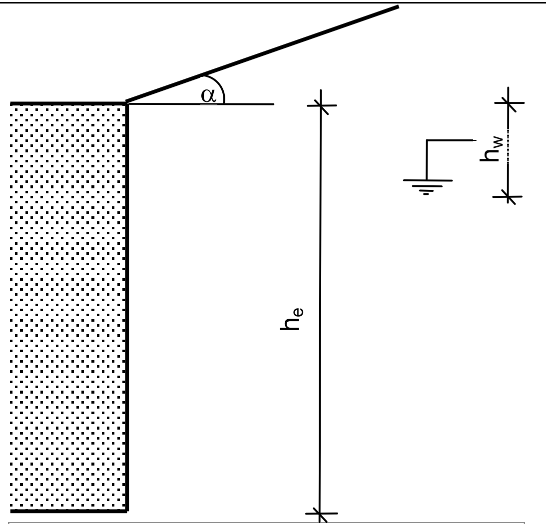
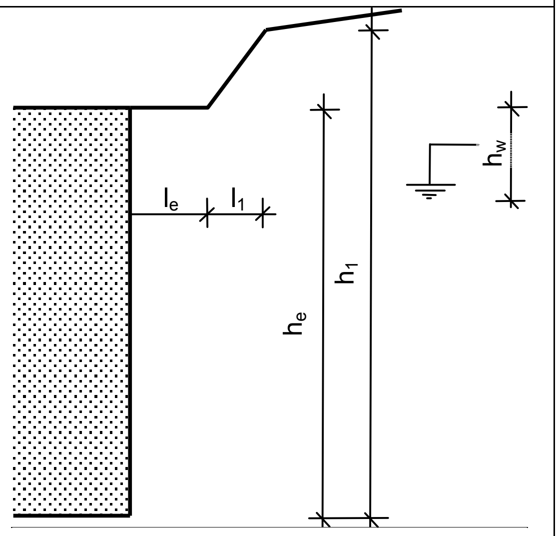
<table>
<tr><th>Option</th><th colspan="2">Comment</th></tr>
<tr><td>None</td><td colspan="2">No compaction earth pressure is included.</td></tr>
<tr><td rowspan="2">DIN 4085</td><td colspan="2">The compaction earth pressure is calculated in accordance with DIN 4085.</td></tr>
<tr><td>b</td><td>Specification of the width of the compaction area in [m].</td></tr>
<tr><td rowspan="2">ÖNORN B 4434</td><td colspan="2">The compaction earth pressure is calculated in accordance with ÖNORN B 4434.</td></tr>
<tr><td>V</td><td>Vertical compaction load as linear load in [kN/m].</td></tr>
<tr><td>IAW Franke</td><td colspan="2">The compaction earth pressure is calculated in accordance with Franke for light compaction based on the approach stipulated by DIN 4085. According to this method, a compaction earth pressure of 15 kN/m² may be used for yielding as well as non-yielding walls instead of the values stipulated by DIN 4085 if lightweight compaction machinery (vibrating plates with a mass not exceeding 250 kg) is used exclusively.</td></tr>
<tr><td rowspan="4">IAW Spotka</td><td colspan="2">DIN 4085 (1987), Supplement 1 justifies the compaction approach by Spotka for medium compaction power. The validity of the approach is limited to compaction machinery with a compaction width of 50 cm maximum and centrifugal forces not exceeding 15 kN. The effective depth z_t depends on the vibration load and results to z_t = 0.35 m for vibration loads ≤1.2 kN, otherwise to z_t = 0.60 m.</td></tr>
<tr><td>Vibration load < 1.2 kN</td><td></td></tr>
<tr><td>Vibration load > 1.2 kN</td><td></td></tr>
<tr><td>b</td><td>Width of the compaction equipment in [m].</td></tr>
</table>

When the design is performed in accordance with DIN 1053-1 and DIN 1053-100 or BS EN 1996-1-1, the compaction earth pressure is included as stipulated by DIN 4085. When the design is performed in accordance with ÖNORM EN 1996-1-1, the compaction earth pressure is included as stipulated by ÖNORM B 4434.

Water and slope

Type of slope

Specification whether the terrain is sloped and if so, in which manner.

Continuous	
Broken	

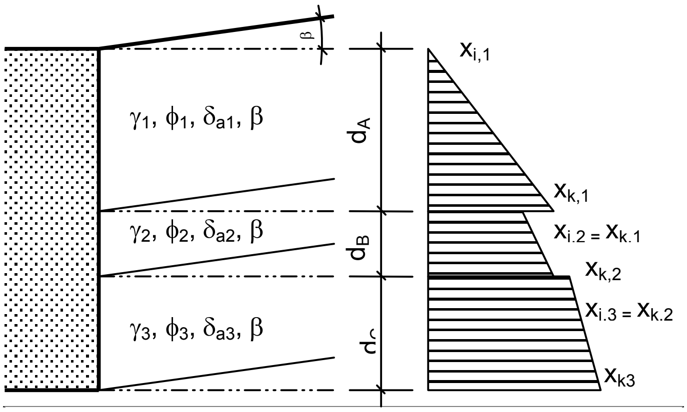
Soil layers

Designation

Designation of the soil layer.

xi / xk

Starting and end coordinate of the soil layer, measured from the ground surface.



Gamma/Gamma'

Arithmetic value of the specific earth weight and the specific weight under buoyancy.

phi'

Effective inner friction angle of the soil layer.

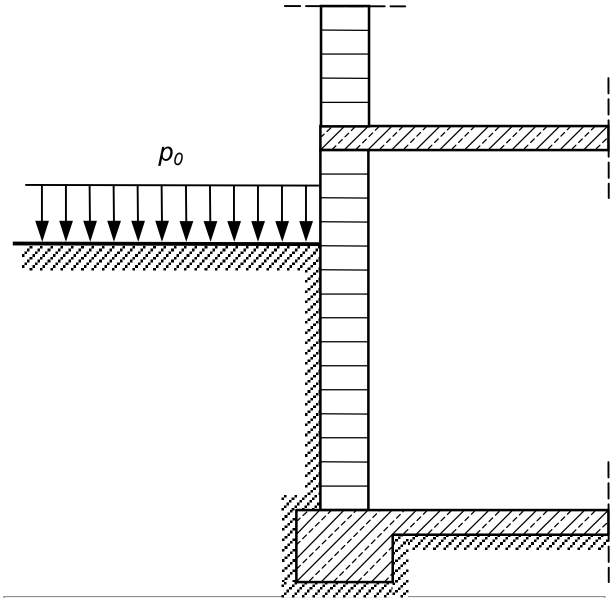
c'

Effective cohesion of the soil layer.

Live load evenly distributed over the soil surface

p0

An infinitely expanding and evenly distributed variable surface load is assumed and assigned to a group of actions.



ActGrp

Number of the action group of the evenly distributed live load. When the analysis is performed in accordance with DIN 1053-1, the assignment of an action group can be dispensed with.

Linear or concentrated load acting on the ground surface

Type

Specification whether the load is a linear or concentrated load. A linear load acts over the total wall lengths.

Load values

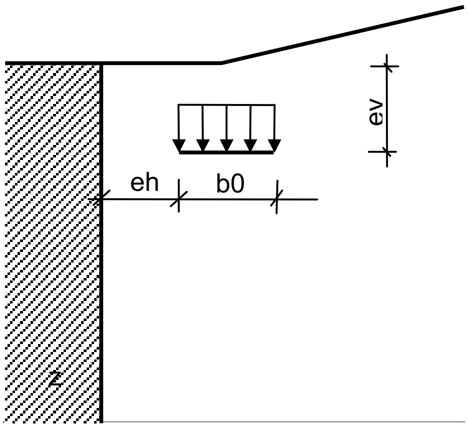
Value	Description
G / g0	Permanent load portion in [kN] or [kN/m²]
Q / q0	Variable load portion in [kN] or [kN/m²]

b0

Width of the linear load.

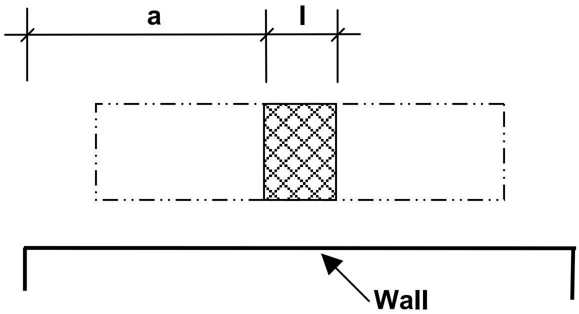
eh / ev

Horizontal distance of the linear or concentrated load to the outer edge of the basement wall and vertical distance of these loads to the ground surface.



l / a

Length of the linear load [l]. Distance of the concentrated load to the left wall edge {a].



ActGrp

Number of the action group of the variable load portion. The permanent load portion is always assigned to the permanent action. When the analysis is performed in accordance with DIN 1053-1, the assignment of an action group can be dispensed with.

Text

You can optionally enter a short note or item description that appears in the output.

Analysis

Verification points

MWK performs the following analyses provided that the user has defined loads producing corresponding effects of actions.

The analysis implying the simplified calculation method is performed at half of the filling height and the normal forces of the load propagation under concentrated loads are taken into consideration.

The analyses based on the more accurate calculation method are performed at the decisive points of the wall as there are the head, half of the height, the foot and, in addition, at the horizontal section where a local maximum eccentricity occurs through the thickness of the wall. (If this horizontal section does not coincide with half of the wall height. The buckling analysis always produces less favourable results in this case).

Analysis based on the simplified method in accordance with DIN 1053

Limiting criteria

It is permissible to replace the more accurate analysis of a basement wall with consideration of earth pressure by a simplified analysis of the axial compressive force in the wall if the following criteria are complied with:

1. The clear height of the basement does not exceed 2.6 m.
2. The wall has a minimum thickness of 24 cm.
3. The basement ceiling acts as a plate (reinforced concrete ceiling supported by the entire top surface of the wall) or the walls are braced with verified ring beams. It is important in this connection that the horizontal loads from the ceiling or the ring beam can be transferred down to the subsoil. Therefore, the basement layout must be designed in such manner that it provides sufficient rigidity. If this is not evident a priori, an analysis of the bracing wall plates has to be performed.
4. The loading that applies to the ground surface in proximity to the wall does not exceed 5 kN/m². Particularly during the construction phase, it should be ensured that this limiting load is not exceeded due to the storage of construction material or the set-up of construction machinery in proximity to the wall.
5. The earthfill must not exceed the clear basement wall height. A filling height up to the top level of the basement ceiling is compensated by safety margins in the calculation model.
6. The ground surface is unsloped or only slightly sloped in the area where impacts have an effect on the wall.

You should note in addition that compaction earth pressure, presence of ground water, concentrated loads and the specific weight of the soil γ>20 kN/m³ are not included in the design approach. Construction phases during which the earth has already been backfilled before the full superimposed load applies are particularly critical.

Analysis

The analysis of the bearing capacity of the basement wall is performed in view of the earth pressure loading and the applying vertical loads. Therefore, evidence must be established

1. that the axial force acting inside the wall compensates the bending effects due to earth pressure and thus prevents the cracking of the wall. This evidence is a critical load criterion of the required minimum axial compressive force.
2. that the axial force acting inside the wall does not produce breakage of the masonry. This evidence is a critical load criterion of the resisting maximum axial compressive force.

DIN 1053-1	DIN 1053-100
Critical load criterion of the required minimum compressive force	
$\min N = \frac{\gamma_e \cdot h_s \cdot h_e^2}{20 \cdot d} \leq N_{1,u}$	$N_{1,lim,d} = \frac{\gamma_e \cdot h_s \cdot h_e^2}{20 \cdot d} \leq N_{1,Ed,inf}$
Critical load criterion of the resisting maximum compressive force	
$N_{1,o} \leq \frac{\beta_R}{\gamma_w} \cdot \frac{d}{3}$	$N_{1,Ed,sup} \leq \eta \cdot \frac{f_k}{\gamma_M} \cdot \frac{d}{3}$

The variables refer to

$\min N$	Minimum axial compressive force that must apply at half of the filling height.	$N_{1,lim,d}$	Design value of the minimum compressive force
$N_{1,u}$	Axial compressive force produced by the self weight at half of the filling height	$N_{1,Ed,inf}$	The lower design value of the axial compressive force applying at half of the filling height
$N_{1,o}$	Axial compressive force produced by the full load applying at half of the filling height.	$N_{1,Ed,sup}$	The upper design value of the axial compressive force acting at half of the filling height.

Consideration of the biaxial load transfer

If the basement wall is braced at a distance b it acts like a slab in regard to the earth pressure and a biaxial load transfer can be assumed. In this case, it is permissible to reduce the minimum compressive forces. The regulation presented in the tables below was taken from DIN 1053-1 and is also included in DIN 1053-100 without any changes.

Wall thickness d [cm]	$N_o / N_{o,lim,d}$ [kN/m] with a filling height h_e of 1.0 m	1.5 m	2.0 m	2.5 m
24.0	6	20	45	75
30.0	3	15	30	50
36.5	0	10	25	40
49.0	0	5	10	30
It is permissible to linearly interpolate the intermediate values.				

Table 1: Minimum superimposed load for basement walls applying at the wall head

DIN 1053-1		DIN 1053-100	
Critical load criterion of the required minimum compressive force			
$b \leq h_s$	$\frac{1}{2} \cdot \min N_o \leq N_{o,inf}$	$b \leq h_s$	$\frac{1}{2} \cdot N_{o,lim,d} \leq N_{o,Ed,inf}$
$2 \cdot h_s < b$	$\left[\frac{1}{2} \cdot (b - h_s) + 0{,}5\right] \cdot \min N_o \leq N_{o,inf}$	$2 \cdot h_s < b$	$\left[\frac{1}{2} \cdot (b - h_s) + 0{,}5\right] \cdot N_{o,lim,d} \leq N_{o,Ed,inf}$
$h_s \leq b$	$\min N_o \leq N_{o,inf}$	$h_s \leq b$	$N_{olim,d} \leq N_{o,Ed,inf}$

Analysis based on the more accurate method in accordance with DIN 1053

Verification point	Analyses	Comment
Wall head	Axial compressive stress	
	Shear stress due to slab shear	
	Gaping joint through the thickness of the wall	
	Bearing stress under concentrated loads	
Half of the wall height	Axial compressive stress	Incl. impact of undesired horizontal concentrated load H=0.5 kN, if applicable
	Gaping joint through the thickness of the wall	
Max. eccentricity through the thickness of the wall	Axial compressive stress	Without consideration of an undesired eccentricity
	Gaping joint through the thickness of the wall	
Wall foot	Axial compressive stress	
	Shear stress due to slab shear	
	Gaping joint through the thickness of the wall	

Analyses in accordance with EN 1996-1-1

The analysis in accordance with EN 1996-1-1 is based on the more accurate calculation method. The following analyses are performed:

Verification point	Analyses
Wall head	Resistance of cross sections to axial loads
	Shear resistance with plate and slab shear
	Partial area compression under concentrated loads
Half of the wall height	Resistance of cross sections to axial loads
Max. eccentricity through the thickness of the wall	Resistance of cross sections to axial loads
Wall foot	Resistance of cross sections to axial loads
	Shear resistance with plate and slab shear

Analyses in accordance with EN 1996-3

Limiting criteria

The limiting criteria for the decision whether the simplified analysis is permitted are similar to that of DIN 1053. It is pointed out in addition that no greater concentrated loads may act on the soil in the area where they could have an impact on the basement wall and no action due to ground water may apply.

In this connection, we like to draw your attention to an essay by Vassilev and Jäger that explains the background of the critical load criteria and their consequences based on the procedure according to Mann/Bernhardt. In addition to this, questions concerning the inclusion of the earth pressure are dealt with and statical constructive measures are proposed if the analysis could not be performed.

It is permissible to replace the more accurate analysis of a basement wall with consideration of earth pressure by a simplified analysis of the axial compressive force in the wall if the following criteria are complied with:

1. The clear height of the basement does not exceed 2.6 m.
2. The wall has a minimum thickness of 20 cm.
3. The basement ceiling acts as a plate (reinforced concrete ceiling supported by the entire top surface of the wall) or the walls are braced with verified ring beams. It is important in this connection that the horizontal loads from the ceiling or the ring beam can be transferred down to the subsoil. Therefore, the basement layout must be designed in such manner that it provides sufficient rigidity. If this is not evident a priori, an analysis of the bracing wall plates has to be performed under certain conditions.
4. In the area of the basement wall affected by earth pressure, the loading on the ground surface must not exceed 5 kN/m². Particularly during the construction phase, it should be ensured that this limiting load is not exceeded due to the storage of construction material or the set-up of construction machinery in proximity to the wall. In addition to this, no concentrated load exceeding 15 kN may apply in a range of 1.5 m from the wall measured in horizontal direction.
5. The earthfill must not exceed the clear basement wall height. A filling height up to the top level of the basement ceiling is compensated by safety margins in the calculation model.
6. The ground surface is unsloped or only slightly sloped in the area where impacts have an effect on the wall.
7. No hydrostatic pressure may apply to the wall. Consequently, there should be no presence of ground water.
8. You should note in addition that compaction earth pressure is not considered in the design approach. The equation for the calculation of the minimum superimposed load is based on non-cohesive soil (c'=0) with a friction angle of $\phi' = 30°$.
9. From point of view of construction, it should be ensured that the shear forces can be transferred via each bed joint and therefore sliding planes due to horizontal obstruction are prevented. The analysis is based on a friction coefficient of 0.6. If this value is used, the slab shear at the wall head cannot become decisive for the design even in the most unfavourable case.
10. When bituminous sheeting is used the transfer of the shear forces could be taken for granted. In other cases, an analysis of the slab shear should be performed based on the actual friction coefficient.

Analysis

In the simplified analysis of a basement wall, evidence should be established

1. that the axial force acting inside the wall compensates the bending effects due to earth pressure and thus prevents the cracking of the wall. This evidence is a critical load criterion for the required minimum axial compressive force.
2. that the axial force acting inside the wall does not produce breakage of the masonry. This evidence is a critical load criterion for the resisting maximum axial compressive force.

Critical load criterion

of the required minimum compressive force	of the resisting maximum compressive force
$$N_{Ed,min} = \frac{\gamma_e \cdot h_s \cdot h_e^2}{\beta \cdot d} \le N_{1,Ed,inf}$$	$$N_{1,Ed,sup} \le N_{Ed,max} = f_d \cdot \frac{t}{3}$$

The variables refer to

$N_{Ed,min}$ Minimum axial compressive force that must apply at half of the filling height.

$N_{1,Ed,inf}$ The lower design value of the axial compressive force applying at half of the filling height

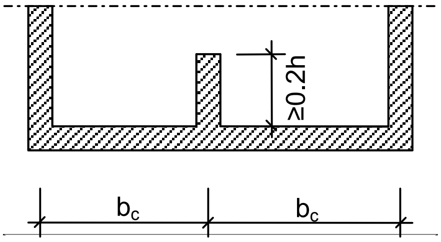
$N_{1,lim,d}$ Design value of the minimum compressive force

$N_{1,Ed,sup}$ The upper design value of the axial compressive force acting at half of the filling height.

$\beta = 20$ for $b_c \ge 2 \cdot h_s$

$\beta = 60 - 20 \cdot \frac{b_c}{h_s}$ for $h < b_c < 2 \cdot h_s$

$\beta = 40$ for $b_c \le h_s$



Consideration of the biaxial load transfer

The above-mentioned analysis is based on the equations known from DIN 1053. According to the stipulations of DIN 1053-1, the effect of the horizontal load transfer may be taken into consideration for walls under low loading that are retained at both vertical edges. If the basement wall is braced at a distance b_c it acts as a plate in regard to the earth pressure and a biaxial load transfer can be assumed. In this case, it is permissible to reduce the minimum compressive forces. If the analysis is performed in accordance with EN 1996-3 this effect is taken into consideration by the introduction of factor β.

Output

General notes

Option	Description
System graph	Output of a graphical representation of the total system
Legends	When you select this option, all tables and legends are described in detail in the output. This option is not available with abbreviated print-ing.

System options

Option	Description
Comment	Output of the comments on the system.
Basement wall	Output of the geometry and the material parameters of the basement wall.
Material parameters	Output of the characteristic strength values.

Loads

Option	Description
Comment	Output of the comments on the system.
Actions	Output of the actions including their partial safety factors and combina-tion coefficients.
Wall loads	Output of the vertical loads that apply directly to the wall head. The self weights and self weight additions are put out together with the walls.
Ceiling loads	Output of the vertical loads that act directly on the ceilings.
Soil parameters	Output of the soil parameters defined by the user.
Horizontal loads	Output of the horizontal loads due to earth pressure.
Earth pressure graph	Output of the earth pressure pattern.

Results

Option	Description
Comment	Output of the comments on the calculation results.
Load case combinations	Output of the load case combinations on which the analyses are based.
Action-effects	Output of the design values of the action-effects on which the analyses are based.
Gaping joint	Analysis of the gaping joint through the thickness and the length of the wall. Structural safety analysis IAW DIN 1053-1 and DIN 1053-100.
Compression loading	Output of the analysis of the compression load resistance. Always included under normal conditions.
Slab shear	Output of the slab shear analysis.

Result graphs

Option	Description
Action-effect drawings	Output of the action-effect drawings for each analysis in the ultimate limit state.

Load transfer

A feature for the transfer of loads to the analysis applications

- FDS Strip Foundation
- FDR Edge Strip Foundation

is implemented in MWK. The feature allows the user to use the bearing forces of walls in the lowest storey for the analysis of the foundations immediately underneath.

After selection of the appropriate foundation application it is launched automatically and the loading is generated in the form of the concentrated load cases used in MWK. The user must simply add the foundation specific details and check the transferred load values.

Due to the specific functionalities of each of the two foundation applications, the load treatment is handled via different procedures, which are described below.

Strip foundation FDS

The FDS application processes only bar action-effects (no tiered behaviour of the related axial force over the wall length resulting from the load propagation, for instance), i. e. the application is limited to

1. short walls that are expected to have a rigid kinematics through the length of the wall,
2. walls with a constant behaviour of the bearing reactions through the length of the wall. (Eccentricities through the length of the wall are not available!)

Therefore, only bearing reactions resulting from axial forces, or more precisely, the resultant of the axial force and the bending moment through the length of the wall (causing gaping in this direction) are transferred. FDS cannot process shear forces through the length of the wall (no slide stability analyses are performed).

Restraint moments and shear forces resulting from slab loading are not transferred either because no feature for the limitation of the restraint moments (in accordance with the relocation rule for the resultant force introduced in masonry construction) is implemented in FDS.

If bending moments around the longitudinal foundation axis should become decisive due to the selected foundation dimensions, the user must manually add the corresponding values to the transferred loads via the input dialog of FDS.

Edge strip foundation FDR

The foundation application FDR performs the design on a strip of 1 m width, i. e. variable load behaviour over the foundation length is disregarded. The design of the foundation must take place at the point of the highest and/or decisive loading.

If several concentrated loads apply and cause a tiered behaviour of the bearing force over the wall length you do not know beforehand, for reasons of load combinatorics, which point will become decisive for the foundation analysis (probably there is a different load factor for each concentrated load).

When loads are transferred by MWK, the transferred data are on the safe side due to the assumption that the load propagation areas of all concentrated loads overlap at the wall foot. Overlapping actually occurs when the maximum distance between the two outer concentrated loads does not exceed the 1.2-fold value of the clear wall height (based on a load propagation angle of 60°). Otherwise, the user can delete individual load cases from the automatically generated load combinations in FDR on his own responsibility.

Restraint moments and shear forces resulting from slab loading are not transferred because no feature for the limitation of the restraint moments (in accordance with the relocation rule for the resultant force introduced in masonry construction) is implemented in FDR. As already mentioned above, plate loading cannot be taken into account either.

If bending moments around the longitudinal foundation axis should become decisive due to the selected foundation dimensions, the user must manually add the corresponding values to the transferred loads via the input dialog of FDR.