FRILO Software
A NEMETSCHEK COMPANY

Masonry Applications
MWK+/MWM+/MWP+/MWX+

FRILO Software GmbH

www.frilo.eu

info@frilo.eu

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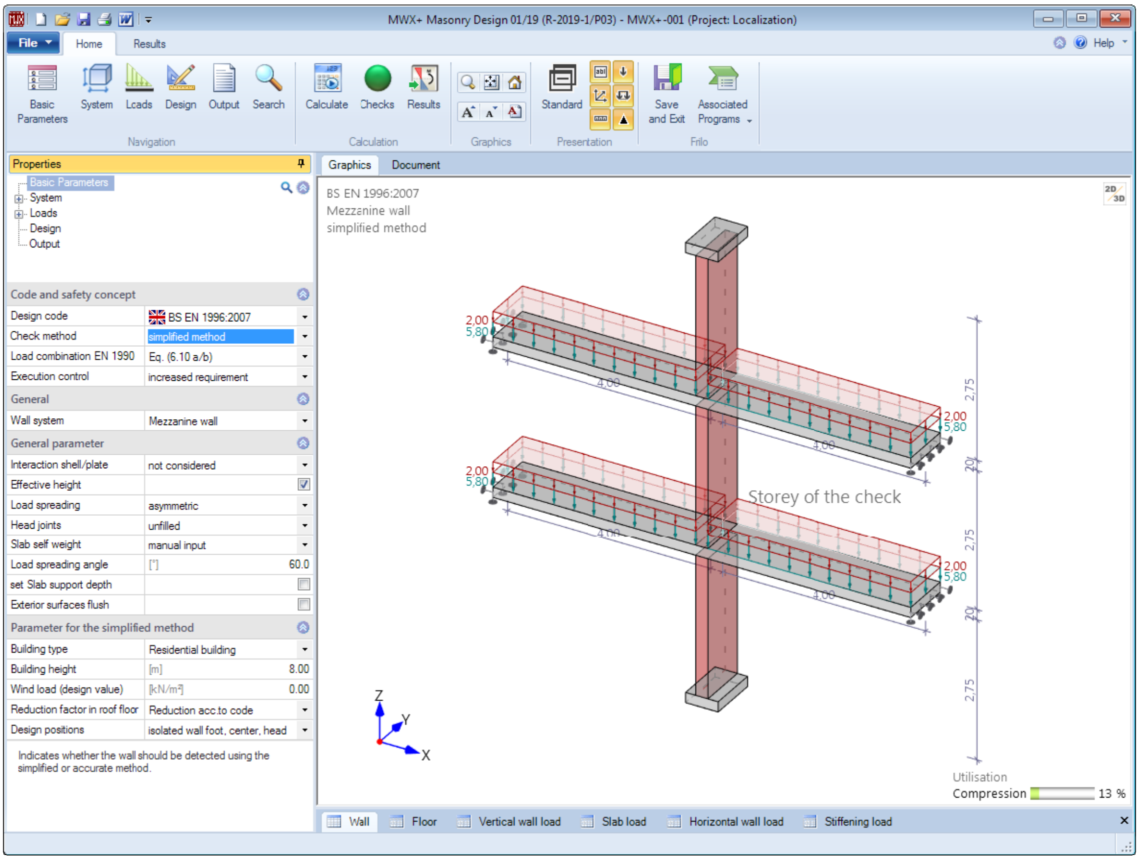


Masonry Application MW+

This manual describes the work with the *MW+* applications. The description is limited to the fundamentals and the available functions for a verification in accordance with EN 1996.

Contents

Basic Documentation – Overview

In addition to the individual program manuals, you will find basic explanations on the operation of the programs on our homepage www.frilo.com ▸ Support ▸ Articles/Information ▸ Basic operating instructions.

Application options

The MW+ applications are general software programs for the verification of walls and piers made of artificial masonry with rectangular cross-sections. For the verification, the following standards are available depending on your licence:

- DIN 1053-1:1996-11 (global safety concept) or
- DIN 1053-100:2007-09 (partial safety concept)
- EN 1996-1-1 and EN 1996-3
  in combination with the National Annexes for
  - Germany
  - Austria
  - United Kingdom
  - Czech Republic
  - Netherlands
  - Belgium
- Seismic verifications as per DIN 4149 and/or EN 1998-1
  (determination of the permissible earthquake zone)

For the verification, either the simplified or the more accurate calculation method can be used. When applying the simplified calculation method, the software checks compliance with the limits of application. If these limits cannot be met, the more accurate calculation method is available as an alternative.

All effects of actions are entered with their characteristic values and can additionally be configured by assigning them to alternative or concurrency groups.

The load cases and load case combinations are automatically generated from the selected effects of actions and the necessary verifications are performed. For each individual verification, the software checks every load case combination that is theoretically possible to decide whether it could become decisive for this verification.

Comprehensive adjustment options allow you to control in detail the calculation and the output of the structural system, the loads and the results.

Additional features are as follows:

- 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 EN 1996 and ÖNORM EN 1996
  - Manufacturer’s database for masonry bricks of Wienerberger Ziegelindustrie GmbH Austria in accordance with ÖNORM B 1996
  - User-defined material
- Load transfer and/or transfer of the structural system to the FRILO foundation applications
- The entire structural system and the loads can be entered via the interactive GUI

MWX+/MWM+/MWK+

The MWX+ application is suitable for the verification of individual walls. The transition of the global structural system is achieved via corresponding border conditions determined by the connected components (bending stiffness of walls underneath and above the considered wall, supporting conditions of floor slabs on the opposite side of the wall). In addition to individual walls, you can perform calculations of structural systems that consist of basement walls, intermediate storey walls and top storey walls.

Moreover, MWX+ allows you to analyse bracing diaphragms loaded by diaphragm-related shear.

MWM+ is a calculation software for structural stability verifications of multi-storey walls. The calculation also includes stability verifications of basement walls and the determination of the lateral earth pressure in standard cases if earth pressure applies.

The MWK+ application is suitable for structural safety analyses of basement walls loaded by lateral earth pressure. A main feature of the software is the comprehensive calculation of lateral earth pressure acting on the basement wall. 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 floor and supports it.

You can define storey floors as being supported either on the left, on the right or on both sides. In addition, cantilevered floor slabs (for balconies) are definable. In this case, it is always assumed that the wall to be verified is covered on its total top surface by a solid floor slab and supports it. Alternatively, you can define a ring beam for bracing purposes.

The masonry wall to be verified can be loaded by vertical effects of actions resulting from

- vertical wall loads from storeys above
- concentrated loads applying at a freely definable height
- floor loads
- line loads on floors

as well as to horizontal effects of actions resulting from

- wall loads perpendicular to the wall plane
- lateral earth pressure perpendicular to the wall plane (MWM+/MWK+)
- bracing loads parallel to the wall plane (MWX+)

MWP+

The MWP+ application is suitable for the verification of masonry piers, i.e. bar-shaped components with a rectangular cross section that are mainly loaded by compression under systematic uniaxial and biaxial bending.

You can apply the simplified calculation method in the analysis of piers under a systematic centric loading. If other loading conditions apply, the analysis must be based on the more accurate calculation method. If applicable, a biaxial eccentricity is taken into consideration for the analysis.

You can select whether the masonry pier should be a

- cantilever column
- hinged column
- restrained column

in the calculation. The supporting conditions are specified separately for the two main axes in this calculation.

The masonry pier to be verified can be loaded by

- centric or eccentric vertical concentrated loads at its top

and/or

- uniformly distributed horizontal loads,
- concentrated horizontal loads or
- horizontal trapezoidal loads.

Basis of calculation

General

The basis of calculation of the MW+ applications is Eurocode 6, specifically his parts EN 1996-1-1 and EN 1996-3. The National Annexes for Germany, Austria, the United Kingdom, the Czech Republic, the Netherlands and Belgium are implemented in the current software version. The availability of National Annexes is determined by the software licence available on the computer on which the software is installed.

We like to draw your attention to our in-house expert documentation dealing with masonry construction that illustrates in detail the general verification procedures in masonry construction as well as the design fundamentals for the MWX software. Therefore, we are not going to deal with questions of design in this chapter but concentrate on the description of the calculation procedures to obtain the design values of the effects of actions.

Recommended of literature (only available in German)

[1] Wagner, Ingo; Hoffmann, Jens: Berechnung von Mauerwerk Vergleich DIN 1053-1/ DIN 1053-100, FRILO-Magazin 2008: Sonderheft Mauerwerk, Friedrich+Lochner GmbH, Stuttgart, 2008.

[2] Wagner, Ingo; Hoffmann, Jens: Berechnung von Mauerwerk nach ÖNORM EN 1996, FRILO-Magazin 2010: Sonderheft Mauerwerk, Friedrich+Lochner GmbH, Stuttgart, 2010.

[3] Wagner, Ingo; Hoffmann, Jens: Berechnung von unbewehrten Mauerwerkspfeilern aus künstlichen Steinen nach DIN 1053 und EN 1996, FRILO-Magazin 2010, Friedrich+Lochner GmbH, Stuttgart, 2010.

The above-mentioned publications are available for download on the FRILO homepage: https://www.frilo.eu/de/service/fachinformationen/frilo-magazin.html.

Load cases for the calculation of the internal forces

The application generates load cases with the loads entered by the user irrespective of the calculation method. The load cases for permanent and transient actions are always generated separately.

For the generation of the load cases, a difference is made between vertical and horizontal actions. Vertical actions include uniformly distributed loads, concentrated loads, line-section loads and trapezoidal loads acting on the wall to be verified. For the horizontal actions, plate-related actions and diaphragm-related actions are distinguished. The classification scheme is illustrated in detail in the table below. The symbols shown in the table are also used in the printout of the load case combinations decisive for the analysis.

Consec. no.	Code	Description
1	G_v	Self-weights of the structures and all permanent portions of the vertical wall and floor loads; basic value
2	G_h	Permanent portions of the horizontal wall loads; only in combination with the more accurate calculation method; basic value
3	G_S	Permanent portions of the bracing loads
4	Q_G	Half the amounts of the variable portions of all vertical floor loads that may be treated as permanent actions in accordance with DIN 1053-1 as well as DIN 1053-100
5	Q_v	Variable portion of each single vertical load
6	Q_h	Variable portion of each single horizontally applying load (plate-related effects)
7	Q_S	Variable portion of each single horizontal bracing load
8	A_h	Accidental portion of horizontal wall loads
9	A_S	Accidental portion of bracing loads

Permanent actions

The permanent actions distinguish themselves from the variable ones among other things by the fact that they are to be considered even when they act favourably.

The load cases of the permanent actions are included either with their lower or their upper partial safety factor. A combination of these values among the permanent load cases will only take place between vertical and horizontal loads. All vertical permanent loads, for instance, are always multiplied with the same partial safety factor.

When using the simplified calculation method, no considerable horizontal loads (plate-related effects, lateral earth pressure) may apply. Therefore, the load cases G_h are only generated in combination with the more accurate calculation method.

Special regulations of DIN EN 1996 - quasi-permanent actions

For variable vertical imposed loads acting on the storey floors, the National Annex to DIN EN 1996-1-11 allows that only half the amounts of the imposed loads are assumed acting permanently. This assumption ensures that the spread angle between the node moments and the support reactions (load eccentricity) is maintained within more realistic limits. This special treatment is not necessary when using the simplified method because the stability verification is performed via load-independent reduction factors and, therefore, eccentricities are not calculated explicitly. Consequently, the load case Q_g is not generated when applying the simplified calculation method.

Even though vertical wall loads can also result from floor loads, the application considers this problem only for storey floor loads. Vertical wall loads are not subject to this regulation.

According to the basic text of EN 1996, you may assume the effect of imposed loads with their full amount on both floor sides simultaneously. You can optionally disable this provision in the software, i.e. the imposed loads on both floor sides are fully considered in the load combinations.

Variable vertical actions

When applying the simplified calculation method, only one single load case Q_v is generated from all vertical linear loads. In addition to this, a separate load case Q_v is generated for each defined concentrated load. This allows the correct dimensioning of the maximum eccentricity in the length direction of the wall when bracing loads act simultaneously.

When using the more accurate calculation method, an individual load case is generated for each variable load that includes the vertical wall load with its full amount and the vertical floor load with half its amount in each case (only with DIN EN 1996).

Variable horizontal actions

The load cases Q_h are only generated in combination with the more accurate calculation method. These load cases include the variable portion of a normal horizontal action each. Accidental horizontal actions are assigned to one load case A_H each.

In the load cases Q_S, variable portions of each bracing load are combined in groups if they result from a normal action, otherwise A_S load cases are generated.

Concurrency and alternative groups

The user can control the internal generation of load cases for bracing loads in MWX+ and horizontal loads in MWP+ via their assignment to concurrency and alternative groups. This way, he/she can define loads that do not comply with the load cases required for the load case combinatorics.

Loads that are assigned to the same concurrency group always act together and must not result from different actions. The variable portions of those concurrent loads are included in one and the same load case.

You can only define concurrency groups with loads of the same load type. The main reason for this resides in the fact that the internal forces caused by vertical and horizontal loads are calculated on different structural systems and treated differently (e.g. moment redistribution) in the design. If vertical and horizontal loads were assigned to the same concurrency group, the internal forces of both load types would have to be calculated on the same structural system. A moment redistribution could not take place in this case because you may only redistribute moments resulting from horizontal loads.

Loads that are assigned to the same alternative group never act simultaneously. Combinations of actions including load cases of the same alternative group are excluded from the analysis. You can assign any type of load to an alternative group.

Loads that the user has assigned to the same concurrency group and the same alternative group are treated as concurrent loads. Concurrency groups have priority in practice. Loads that have been assigned to the same concurrency group and, thus, to the same load case can be assigned to an alternative group in addition. Consequently, the load cases defined this way may exclude each other. Due to this effect, the combination of concurrency groups and alternative groups allows you to define complex loading situations. This option is particularly suitable for the examination of wind loads from different directions or loads resulting from one and the same action, for instance.

Example of the effects of concurrency groups and alternative groups

The following example is intended to demonstrate the effects of concurrency groups and alternative groups:

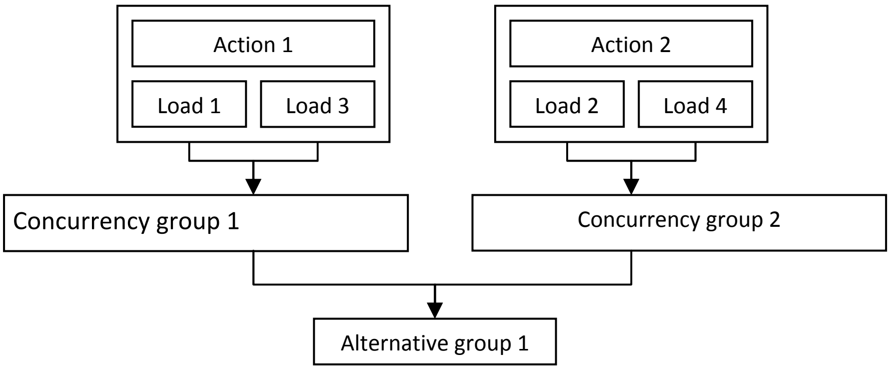


Figure 1: Effects produced by concurrency groups and alternative groups

Load 1 is a horizontal load acting in the x-direction and load 2 acts in the opposite direction. The loads 3 and 4 produce the same situation but in the y-direction. The loads in both directions should apply simultaneously. You cannot include the loads in opposite directions into the same approach. Therefore, the loads 1 and 3 as well as the loads 2 and 4 should apply simultaneously. The loads 1 and 2 should exclude each other as well as the loads 3 and 4. Consequently, two load cases are generated, the first one includes the loads 1 and 3, the second one the loads 2 and 4. Both load cases apply alternatively, however.

Load case combinations for the calculation of the internal forces

In masonry construction, a specific 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. When performing the design in accordance with the partial safety concept it should be distinguished between the normal (permanent and transient) and the accidental design situation. The table below gives an overview of the assignment of load case combinations to the corresponding verifications.

Verification	**Design situation**	**Description**
Compression	Ed[1)] EdA[2)]	Analysis with compression stress
Plate-related shear	Ed EdA	Analysis with plate-related shear
Diaphragm-related shear	Ed EdA	Analysis with diaphragm-related shear
Border strain	Ed	Border strain analysis with diaphragm-related shear. Only when designing in accordance with DIN EN 1996.
Gaping joint	Ed EdA	Limitation of the gaping joint through the thickness of the wall (plate-related effects) and in the diaphragm direction (bracing loads). Only when designing in accordance with DIN EN 1996.

1) Permanent and transient design situation

2) Accidental design situation

Calculation of the characteristic values of the internal member forces

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

Particularities of masonry structures

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

Whereas only axial wall forces resulting from vertical loads must be calculated on the pinned member in the simplified calculation method, you must define a frame system that allows the estimation of the bearing-load-reducing effect by the total floor torsion above the wall support when applying the more accurate calculation method. Internal forces resulting from horizontal loads may be calculated on the pinned member whereby a redistribution of the wall moment to the top and base moments up to full restraint is permissible when the equilibrium is preserved, and the cracking of cross sections is taken into consideration. (This regulation is based on the model assumption that the assumed solid floor slabs have a considerably higher flexural rigidity than the walls themselves and, therefore, provide for a high degree of decoupling of the walls in the different storeys with respect to the effects of horizontal loads).

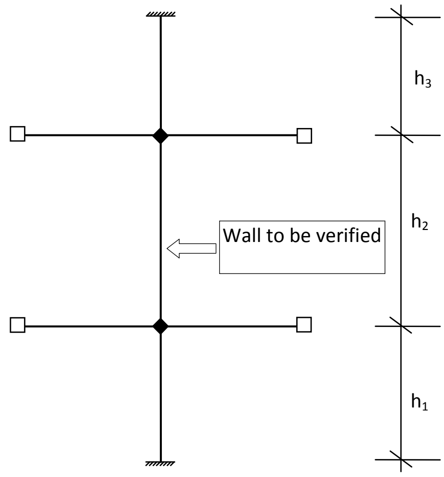
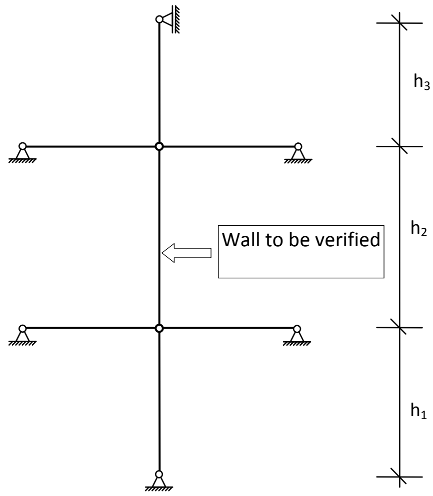
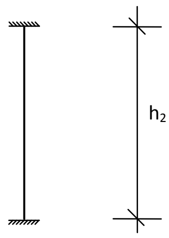
Therefore, the internal forces caused by the total floor torsion and those caused by plate-related effects (horizontal loading) must be calculated on different structural systems. We will explain this in detail below.

Structural systems for the more accurate analysis

The axial forces are calculated on a pinned member. The continuity effect of storey floors can be mapped via continuity factors, via the description of the floor as a two-span girder or via the specification of floor support reactions (e.g. from the FE design of the floor slabs).

The calculation of the moments in the wall-floor nodes is performed on an equivalent member system. The transition to the global system is achieved by assuming that the walls above and/or underneath are fully restrained at the opposite ends. To map a realistic behaviour of the internal forces over the wall height, it is of utmost importance to select the correct installation situation (basement, intermediate storey, top storey) in the software.

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

Structural system	**Description**	**Schematic system diagram (based on an intermediate storey wall)**
System I[1)]	*Calculation of the base and top moments due to floor support torsion.* The walls and floors are rigidly joined to each other. Walls above and underneath are assumed fully restrained at their ends. The opposite floor edges are assumed either pinned, restrained or freely projecting depending on the user-defined supporting conditions.	
System II	*Calculation of the axial wall forces as well as the bending moments and shear forces resulting from the horizontal wall loads (plate-related effects).* The walls and floors are rigidly joined to each other. Walls above and underneath are assumed pinned at their ends. The opposite floor edges are pinned. Axial forces are modified in accordance with the user specifications (continuity factor or pre-defined support reactions). The wall moments calculated on this system correspond to the values that are not redistributed.	
System III	*Calculation of the moments of the fully fixed end resulting from horizontal wall loads (plate-related effects)* All nodes with floor slab connections are restrained. This creates a member that is restrained at two sides. The result of the calculation on this system delivers the moments of the fully fixed ends, i.e. the maximally redistributable moments at the wall base and the wall top. In combination with ring beams, the maximally redistributable moments are obtained from the elastic restraint through the connected walls (corresponds to the continuity effect because the ring beam provides a pinned abutment.)	
1)	In addition, the bending moments and shear forces are reduced because of the total floor torsion by applying the factor k_m in accordance with equation (C.2) of EN 1996-1-1, Annex C.	

Structural systems for the simplified analysis

When applying the simplified calculation method, only axial forces must be calculated on the member system. Therefore, the calculation of the internal forces is limited to the examination of system II defined above.

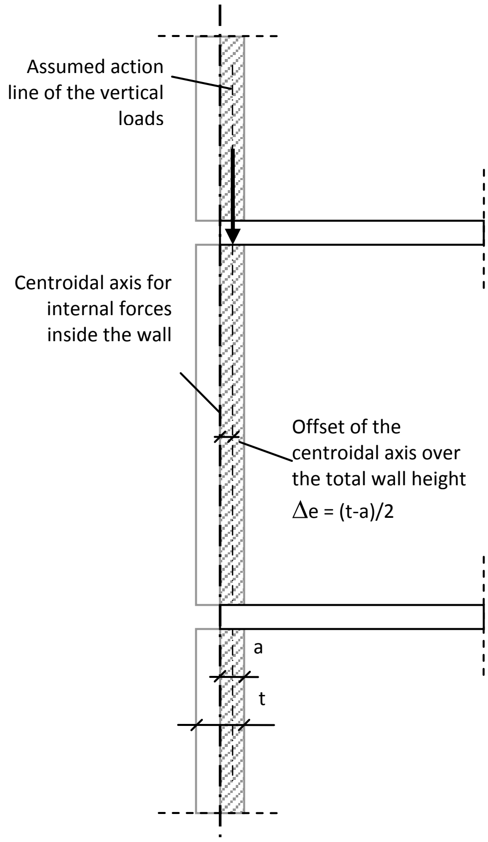
Internal forces resulting from imposed loads on the storey floors

When applying the more accurate method, the bending moments resulting from imposed vertical loads on the storey floors must be calculated. This calculation is performed on system I as described above. The results of this calculation are on the safe side because the cracking of the cross-sections and the accompanying loss of stiffness cannot be considered in the linear calculation of the internal forces applying to the wall-floor node. Therefore, you may reduce the bending moments as per EN 1990-1-1, Annex C. The formula specified in the standard was derived empirically and is limited to reduction degrees in the range of 50 to 100 %.

Calculation of internal forces with partially supported floor slabs

In contrast to all preceding standards, DIN EN 1996-1-1 requires that floors slabs not supported over the entire thickness of the wall (partially supported floor slabs) already be considered in the calculation of the internal forces. As the internal forces are calculated on a plain frame system, this influence cannot be mapped accurately, however. Therefore, the FRILO Masonry software applications implement the simplified method proposed by DIN EN 1996-1-1, Annex C. In this case, the internal forces are determined with a calculated wall thickness, which corresponds to the floor bearing length (or to the average bearing length if the bearing lengths at the wall top and the wall base differ from each other). The bearing-strength verifications are subsequently performed at the wall top and the wall base for the bearing length of the floor slab that corresponds to the calculated wall thickness. On all verification points within the wall height, the verification uses the actual wall thicknesses. However, an offset eccentricity is added, which is determined by the distance of the central wall plane to the central axis of the bearing length.

Figure 2: Model for the consideration of partially supported floor slabs as per DIN EN 1996-1-1, informative Annex C



Under normal conditions, this approach produces conservative results, not least because the mostly favourable influence of possibly existing facing bricks is not considered in this case. You should be careful, however, if wind loads apply perpendicular to the wall plane at the same time. The bearing strength under wind suction can be considerably smaller than under wind pressure because the action line of the vertical loads is generally assumed with an offset against the interior wall face and the fixed-end moments are limited depending on their direction at the same time (compare the illustrative model of the pressure arch in Figure 3). Therefore, we recommend that you always examine both cases.

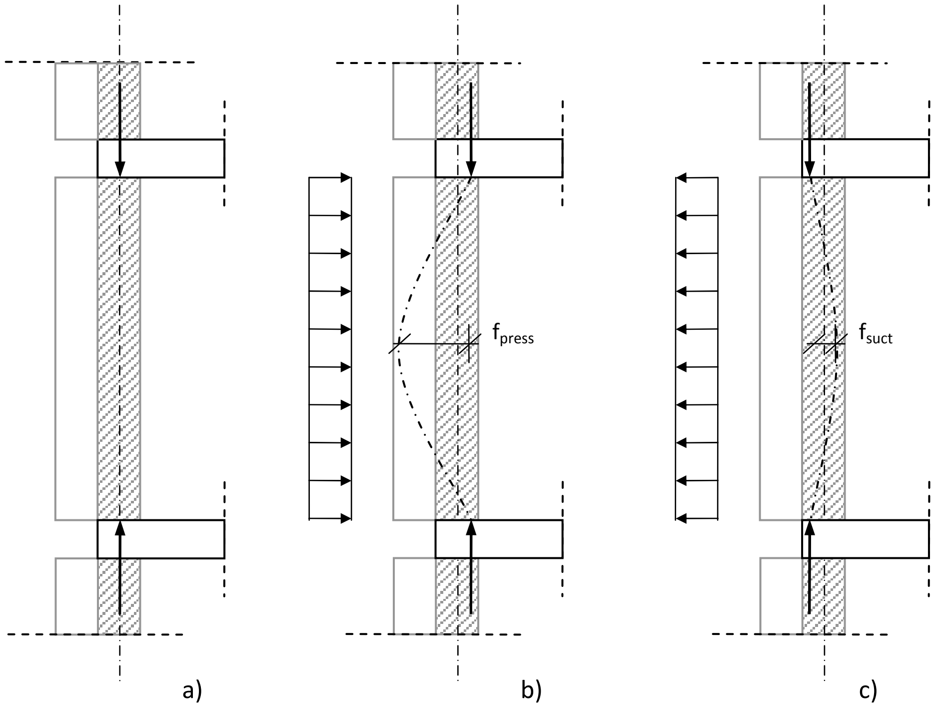


Figure 3: Difference in horizontal load-bearing strength under pressure and suction; a) initial state (total floor torsion is disregarded), max. camber of the pressure arch with wind pressure (b) and with wind suction (c)

In the verification as per DIN EN 1996-3 (simplified verification method) any moment consideration is dispensed with. The influence of partially supported floor slabs is fully considered via the modified equations for the reduction factors of the wall bearing strength at the wall top and the wall base specified by the National Annex. These equations also provide for the risk of buckling failure. For the axial force bearing strength at the wall top and base, the actual or the lowest floor bearing length at the wall top or the actual or lowest wall contact length at the wall base are considered, depending on the selected calculation parameters at the different verification points. The buckling stability verification at half the wall height is always based on the mean value.

Determination of the internal forces when centring bars or soft strip inlays have been defined

If centring bars have been defined for the wall top, a moment hinge is placed at the upper end of the member in system II (moments caused by the total floor torsion) and in system III (fully fixed-end moments caused by horizontal effects of actions). This ensures that the vertical loads apply exactly in the centre at the centring bar.

If soft strip inlays have been defined, the procedure is as with partially supported floor slabs, i.e. the internal forces are determined using a calculated wall thickness that corresponds to the wall thickness minus the width of the soft strip inlay. Moreover, the offset of the centroidal axis between the central wall plane and the central axis of the resulting bearing surface is considered in the same way.

Note: Soft strip inlays are not available in the current version but will be implemented soon.

Internal forces caused by concentrated loads

As a standard, the application assumes an angle of 60° for the distribution of the load. In derogation of expert literature (cf. ref. [4]), you can define a load-propagation angle in the range of $45° \leq \alpha \leq 90°$. $\alpha = 90°$ corresponds to the situation in which no load propagation is assumed (e.g. for masonry without sufficient transversal tensile strength in accordance with the General Approval by the Building Authorities (abZ) or with the European Technical Approval (ETA)).

The concentrated loads produce exclusively axial wall forces. Possible eccentricities of concentrated loads cannot be considered.

If a wall is loaded by concentrated loads, the cross-sections in all supporting points along the wall length axis are calculated. In this case, the supporting points are the intersections of the left and right legs of the load-propagation triangles with the respective level lines. The level lines mark the top, the middle and the base of the wall as well as the point where the maximum bending moment, if any, applies.

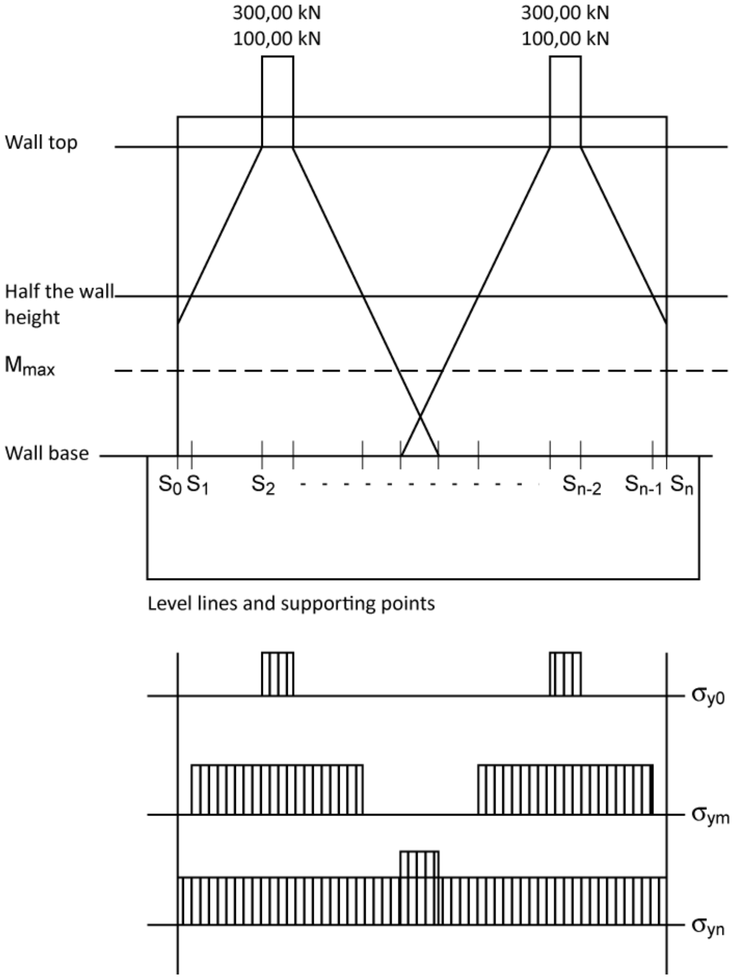


Figure 4: Shape of the assumed load propagation and verification sections through the length of the wall

Internal forces resulting from sectional line loads and trapezoidal loads

The propagation of vertical loads over the wall height is traced in the same way as the load propagation of concentrated loads in accordance with the table below:

Load type	Propagation	Explanation
Uniformly distributed load	No	Uniformly distributed loads act over the total length of a wall. Load propagation is not possible.
Concentrated load	Yes	Is used to map structural loads caused by relatively stiff girders in such a way that a uniform support compression can be assumed in the bearing surface for the verification. If concentrated loads apply, the conventional verification of the compression effects at the wall top is replaced by a load transfer verification (verification of partial area compression).
Line-section load	Yes	Is used to map limited structural wall loads that must be considered in combination with the floor torsion. If line-section loads apply, the conventional verification of compression stress is performed. The verification of the load transfer is dispensed with.
Trapezoidal load	No	Is used to map variable structural wall loads applying over the wall length, e.g. for support reactions due to floor loads from FEM calculations (applies mainly to the simplified verification method). The consideration of the load propagation would produce irrational axial wall force behaviours due to the problem of intersecting load-propagation areas for moving loads based on trapezoidal loads.

If line-section loads or trapezoidal loads apply to a wall, the verifications are performed on several vertical cross-sections along the wall length axis. In this case, the supporting points are in the centre (on the edge with trapezoidal loads) of the segments that result from the intersections of the specific axial wall force with each level line (see Figure 5). The software uses internally at least 14 level cross-sections with consideration of the defined horizontal loads.

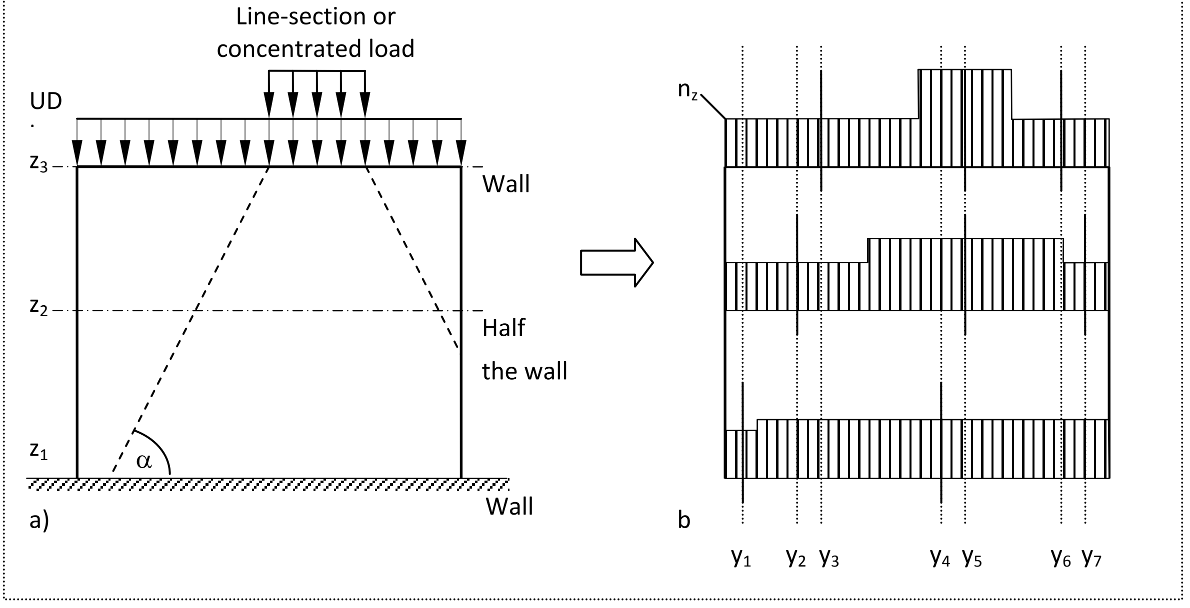


Figure 5: Exemplary representation of the location of the examined vertical sections with only three level sections a) loading situation and level sections, b) axial force distribution in the level sections and location of the vertical sections

Internal forces resulting from bracing loads (MWX+)

Effects of actions resulting from the bracing of the building (diaphragm-related shear) are always defined as a set of internal forces (axial force, shear force in the direction of the diaphragm, bending moment about the strong axis of the wall) applying to the wall top in MWX+. The further behaviour of these internal forces within the storey height is determined on the simple structural model of a cantilever. This approach provides a maximum of flexibility for the calculation of the bracing core (e.g. using the restraining effect of the floor slabs). According to this concept, the internal forces to be defined correspond to the internal forces acting on the bracing wall at the level of the wall top edge. The definable axial force is basically intended to consider bracing walls whose axes do not coincide with the centroidal axis of the bracing core. The global bracing moment (relating to the entire core) is transferred by force couples (or, more generally, by force groups) that act favourably (increase the axial force) or unfavourably (uplift) depending on the direction of action of the bracing load on the individual wall with respect to shear force resistance.

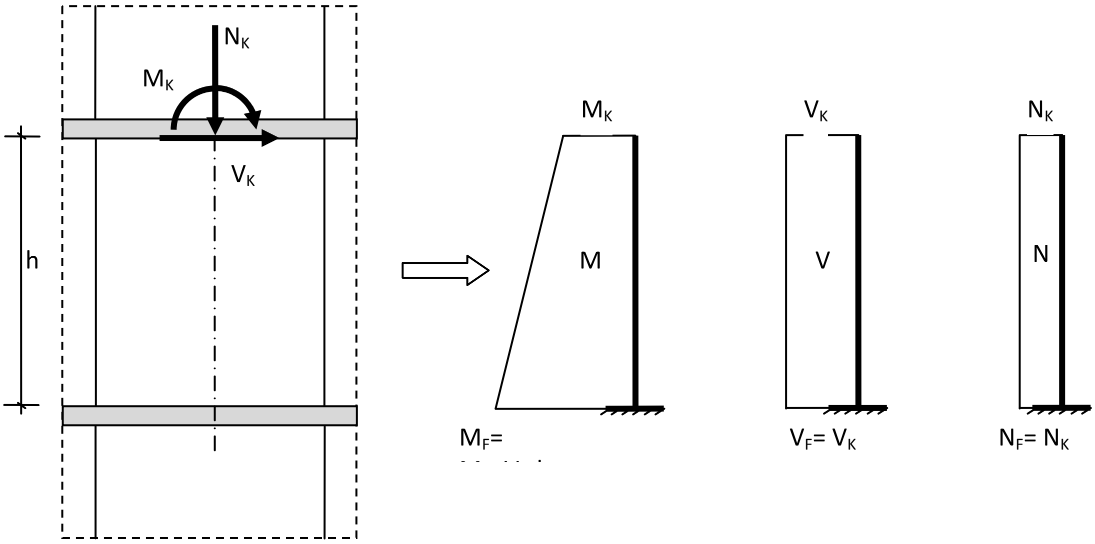


Figure 6 Internal forces behaviour over the wall height for the analysis of diaphragm-related shear at the wall top (cantilever model) caused by the pre-defined internal forces

Relocation rule and redistribution of moments with horizontal effects of actions

In the more accurate verification method, the relocation rule for the resultant force is of great importance and allows the consideration of the actual non-linear load-bearing behaviour and the limitation of load eccentricities caused by node moments, if the condition $e > 0.333 \cdot t$ is complied with (see DIN EN 1996-1-1, Annex C). If e is greater than $0.333 \cdot t$ you cannot assume a rigid joint between the wall and the floor slab any longer. The behaviour of the joint comes close to that of a hinge. This limitation is permissible from a mechanical point of view because the node moments are indirect effects of actions and are not considered for the load transfer. At the same time, a self-centring effect occurs, which is also mentioned in the text of the standard. This matter of fact is sufficiently proven by experiments and numerical analyses.

The note in DIN 1053 allowing the determination of wall moments caused by these loads on an equivalent member system whose degree of restraint at the ends is freely selectable if the equilibrium is preserved (DIN 1053-100, Para. 9.2.5) also takes the non-linear load-bearing behaviour at the wall-floor node into account.

This method is based on the actual load-bearing behaviour of the wall. Therefore, it is also suitable for verifications as per DIN EN 1996-1-1. To apply this method in practice, follow the steps below, see also the figure on the next page:

1. Determine the node moments at both wall-floor nodes of the wall and apply the relocation rule for the resultant force if the prerequisites are met
2. Determine the moments of the fully fixed ends caused by horizontal load
3. Reduce the moments of the fully fixed ends in such a way that the superposition with the moments at the wall-floor node produces load eccentricities that do not exceed the limit value specified by the relocation rule for the resultant force. At the same time, adjust the moment behaviour while preserving the equilibrium (span moment).
4. Superimpose the moment behaviour of both portions

The moment behaviour determined this way corresponds to the basic idea of hinge generation in line with the increasing load eccentricity at the wall-floor node. This approach includes also the simplified verification method known as "arch model" as a limit case. This method disregards the total floor torsion. We like to point out in this connection that higher load eccentricities ($e = 0.45 \cdot t$) must be permitted at the front and rear ends of the wall because the application of the partial safety concept provides for a higher spread angle between the unfavourably acting horizontal load and the favourably acting structural wall load, which should be considered.

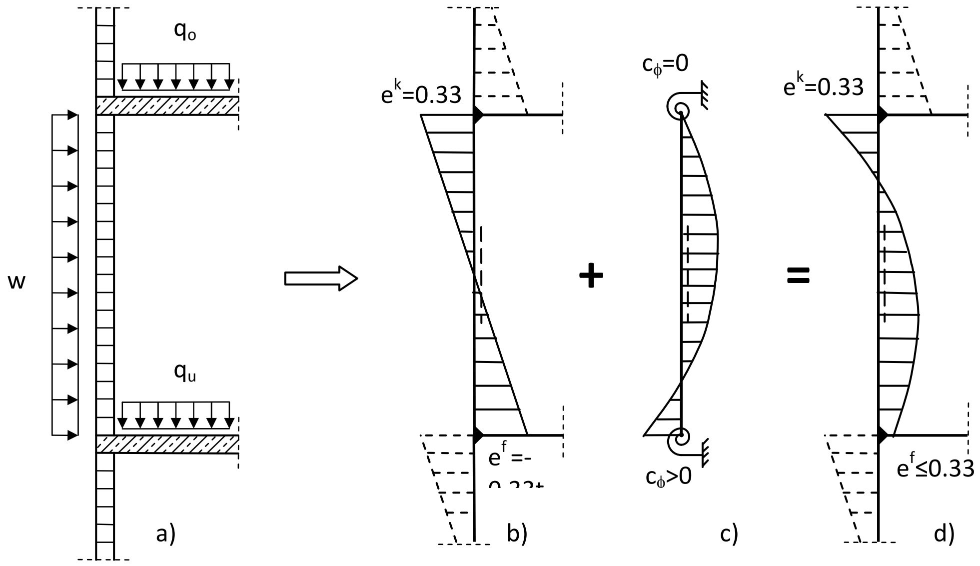


Fig.: Example of the determination of the wall moments caused by the total floor torsion and horizontal load. a) System and loading, b) exemplary moment behaviour due to the total floor torsion, c) compatible equivalent system for horizontal loads, d) superimposed moment behaviour for the verification of the wall

For the verification of masonry piers with MWP+, the same procedure is applied with a combined eccentricity based on the assumption of two axes.

$$e = \sqrt{\left(\frac{e_y}{t_y}\right)^2 + \left(\frac{e_z}{t_z}\right)^2}$$

Calculation of the design values of the internal forces

The internal member forces for the calculated global system are available as characteristic values for the internally generated load cases. They are combined to design values of the internal member forces in accordance with the stipulations of EN 1990 and the applicable National Annex. Special cases, such as "max. bending effects at min. structural load ($1.5 \cdot M_k \oplus 1.0 \cdot N_k$)" are automatically included.

In the ongoing calculation, every theoretically possible load case combination is verified. Only the combinations that are decisive for a specific verification are finally put out, however.

Subsequently, the internal member forces are superimposed with the specific internal forces resulting from the load propagation under concentrated loads and the maximum specific axial force is determined with consideration of the eccentricities through the length of the wall and the gaping joints. The analyses are based on this axial force.

Settings

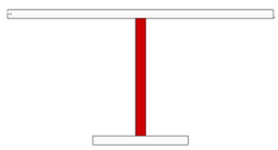
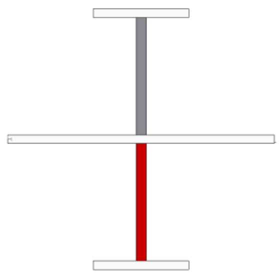
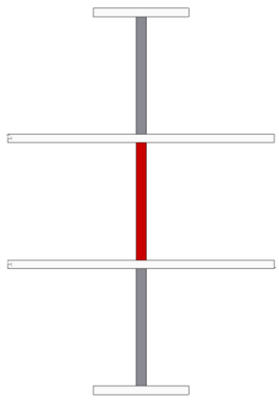
General

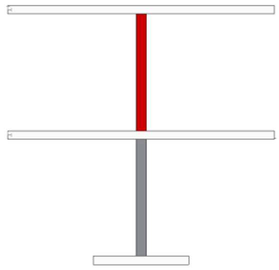
Wall system (MWX+, MWK+)

This option allows you to define the structural system that is used for the verifications of the masonry wall in question in accordance with the following table. To ensure that the verifications are close to reality, it is of utmost importance that you select an appropriate structural system. On the one hand, the deflection of the floor slabs directly underneath the wall to be verified has an influence on the moment behaviour within the wall height. On the other hand, the masonry walls in the storeys above and below have a supporting effect on the wall-floor nodes and contribute to an economic design when applying the more accurate verification method.

Since the reduction factors for the bearing strength of the wall are exclusively derived from the system geometry in the simplified verification method, a transition from the structural system of a single wall to another wall type is only mandatory if the floor slabs above and below the wall to be verified have different spans or properties.

Be careful with exterior walls (floor slabs supported only on one side) in the simplified calculation method: Because the definition of a wall in the storey above is missing, MWX always interprets the structural system of a single wall as being a top storey wall with a considerably reduced load-bearing strength. If this is not the case, you can set the option "Reduction factor in attic" to "As in intermediate storey".

Value	Description	Schematic system diagram (the wall to be verified is shown in red)
Single wall (MWK+: only basement wall)	Single-storey masonry structure consisting of a single wall. The wall is built on a foundation or floor slab and supports a storey floor.	
Basement wall (MWK+: basement wall + ground storey)	Two- or multi-storey masonry structure comprising two walls. The wall to be verified is built on a foundation or floor slab and supports a storey floor. You must define the wall above for the calculation of the node moments.	
Intermediate storey wall	Two- or multi-storey masonry structure comprising three walls. The lower wall is either built on a foundation or floor slab or on top of another wall. You must define the walls above and below for the calculation of the node moments.	

Top storey wall	Two- or multi-storey masonry structure comprising two walls. The lower wall is either built on a foundation or floor slab or on top of another wall. You must define the wall underneath for the calculation of the node moments.	

Standard

Allows you to select the design standard the structural safety analyses should be based on. The NAD includes the corresponding National Annex (i.e. DIN EN 1996 = EN 1996 + NA for Germany).

Verification method

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

The verification as per EN 1996-1-1 ("general verification method") corresponds to the more accurate verification method as per DIN 1053. The simplified method, which is comparable to the method provided by DIN 1053 in its essential parts, is 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 event of non-compliance, a corresponding message is displayed, and no verification is performed. The user must manually switch over to the more accurate method in this case.

You should prefer the simplified verification method if it can be applied. The results of this method are insignificantly more conservative, and the method is easier to apply in a wider range of cases due to the reduced number of parameters to define. The risk of erroneous entries and inappropriate calculations is minimised in this case.

General parameters

Interaction of the diaphragm and the plate (MWX+)

Specification of the way the superposition of the effects of actions resulting from diaphragm-related effects and from plate-related effects is performed in the analysis of the resistance of cross- sections to axial loads.

Wall diaphragms are possibly loaded eccentrically through the length of the wall, if

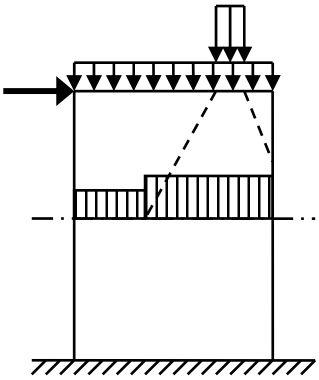
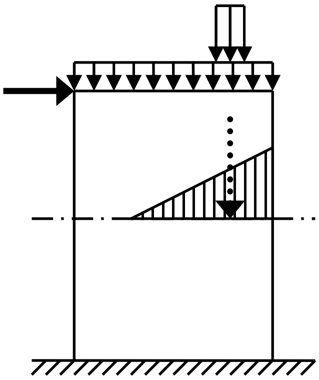
- the concentrated loads apply asymmetrically
- the bracing forces act through the length of the wall (plate-related shear)
- the axial force behaviour at the wall top varies over the wall length.

The eccentric loading produces higher compression effects on the compressed wall end than the centric loading.

It depends on several factors whether considering the increase of effects makes sense and you should check it in each case. It might become important where bracing walls are concerned that are relatively short and not retained on the compressed wall side. The method is not suitable for long walls because a plain cross-section can no longer be assumed in this case. (MWX+ checks internally whether disregarding the interactions is more unfavourable).

The calculation option "Interaction diaphragm/plate" allows you to select one of the three following methods for the calculation of the effects of actions:

1. Any kind of eccentricity of the resultant axial force through the length of the wall is disregarded. The behaviour of the axial force is constant or tiered over the total wall length.
2. Determination of the axial force behaviour over the wall length (with consideration of gaping cross-sectional areas). Subsequent analysis of the maximum value of the axial force (typically at the wall end, procedure in line with customary design practice).
3. As per DIN EN 1996 - in addition to the reduction of the centrical load-bearing strength from eccentricities through the thickness of the wall, an additional reduction is applied for eccentricities through the length of the wall using corresponding reductions factors. DIN EN 1996 requires that this verification is performed exclusively at half the wall height.

Value	Description	Schematic system diagram
Not considered	The analysis of the resistance of cross sections to axial loads is performed without consideration of existing eccentricities caused by bracing loads or asymmetrically applying concentrated loads. A constant behaviour of the specific axial force in each section is assumed. The plate-related shear analysis and the gaping-joint analysis are performed on the most unfavourable vertical section and are based on the specific values of the internal forces.	
Via axial force distribution	The analysis of the resistance of cross-sections to axial loads is based on the maximum value of the specific axial force that results when the eccentricity caused by bracing loads or asymmetrically applying concentrated loads is taken into consideration. A variable linear behaviour of the specific axial force is assumed while taking a gaping joint through the length of the wall into account. If the examination of the system without interaction (see above) produces a greater specific axial force, the verification is based on exactly this value. The verification of plate-related shear and of the gaping joint are based on the resultant values of the internal forces.	
Via reduction factors	The verification of the resistance of cross sections to axial loads is based on the resultant axial force. The reduction factors for the consideration of the eccentricities in both axis directions are superimposed by multiplication.	

Reduction of the effective length

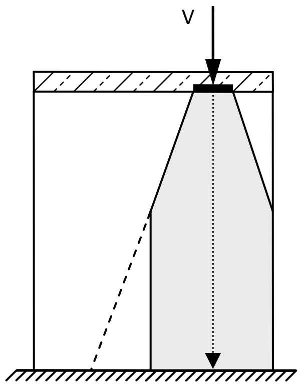
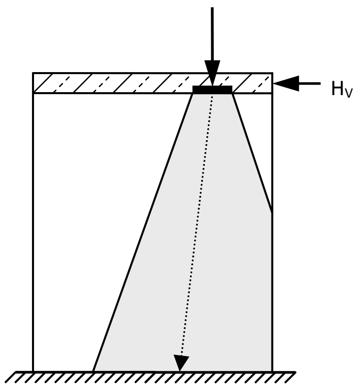
Specification whether a reduction of the effective length of the wall is permissible with respect to the standard border conditions.

Where masonry of simplified design with 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 area under concentrated loads should always be assumed symmetrical or whether it might also be asymmetrical. The selection of the correct option is only relevant when the developing load-propagation area is limited by intersections with the vertical wall ends. If asymmetrical load propagation is permissible, the absorption of the deflection forces generated by the inclination of the load path must be ensured by adjacent bracing diaphragms!

Value	Description	Schematic system diagram
Symmetrical	Only the symmetrical portion of the load-propagation area is included in the calculation of the specific axial force.	
Asymmetrical	The full load-propagation area is considered in the calculation of the specific axial force. It must be ensured that the generated drive force H_V is absorbed by adjacent diaphragms.	

Transversal joint solidification

Specification whether the transversal joints of the masonry bond are solidified. The setting of this option influences the masonry's bond shear resistance as well as the shear strength of the wall (diaphragm-related shear as well as plate-related shear).

Floor self-weight

This option allows you to select whether the construction weight of the supporting layer of the storey floor should automatically be included in the calculation by MWX+ or not. This option is only relevant when the wall loads already include the floor loads.

Load-propagation angle

Defines the load-propagation angle for concentrated loads. Default is 60° in accordance with EN 1996. This value corresponds to an approximative ideal elastic material behaviour (elastic half-plane).

For masonry according to approval, a greater distribution angle might be required. If you select masonry according to approval when defining the material, the value for the load-propagation angle stored in the material database is automatically set.

To suppress the consideration of the load propagation also in combination with masonry of simplified design and user-defined masonry, select a load-propagation angle of 90°.

Execution control (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 factors for resistances depending on the execution control. Currently, only Great Britain profits from this option in the British National Annex. The corresponding class must be selected when this NA is applied.

Parameters for the simplified method

The parameters listed below shall mainly help to evaluate the limiting criteria for the application of the simplified calculation method.

Type of building

This option specifies whether the building is permanently occupied, like a residential building, or whether a subordinate building such as a garage is concerned.

This option is exclusively intended for the evaluation of the limiting criteria for the simplified calculation method.

Building height

The option allows you to specify the building height above ground level.

Where buildings with pitched roofs are concerned, you may assume the mean value of the ridge and eaves heights.

This option is exclusively intended for the evaluation of the limiting criteria for the simplified calculation method.

Design value of the wind load (not for verifications as per DIN EN 1996-3)

Specifies the value of an evenly distributed wind load. This value is used to evaluate whether the minimum wall thickness is to be used as an application criterion.

The application criteria modified by DIN EN 1996 do not make any reference to this value.

Reduction factor in the attic storey

This option specifies how the reduction factor for the floor-rotation angle at the end supports should be calculated in the attic storey.

For end supports of floors above the uppermost full storey, this value is taken from EN 1996-3: $\Phi_s = 0.4$ (DIN EN 1996-3: $\Phi_s = 1/3$).

The option "As intermediate storey" applies the usual reduction based on the floor spans. You should always select this option when a wall in the basement or in an intermediate storey is mapped as a single wall because the structural system of the floor slabs in the individual storeys is completely regular.

If a bearing load reduction is prevented via constructive measures such as centring bars, however, there is no need to take the reduction factor into account. Φ_S is set to 1.0.

Verification points

This option specifies whether the analysis should be performed only at the wall base or separately at the wall top, half the wall height and the wall base.

In manual calculations, the compression analysis is usually performed using the simplified method and assuming the maximum value of the axial compressive strain (occurs normally at the wall base, with concentrated loads also at half the wall height) irrespective of whether the reduction factor assumes its most unfavourable value at the wall top, the wall base or at half the wall height.

According to EN 1996-3, the differentiated consideration of the verification points and of the accompanying coincidence of the point of effect determination with the effective bearing load-reducing impacts is not required. Under normal conditions, this consideration produces more favourable verification results.

Verification	Verification point "Wall base"	Verification point "Separately considered"
Compression	Max. effects of actions over the total wall height (wall base, half the wall height, if required) Analysis with the highest resulting bearing load reduction (slenderness or floor torsion at the wall top or wall base)	Analysis with bearing load reduction due to floor torsion at the wall top and the wall base Analysis with bearing load reduction due to slenderness at half the wall height.
Diaphragm-related shear	Analysis at the wall base	Analysis at the wall top and the wall base
Border strain	Analysis at the wall base	Analysis at the wall top and the wall base
Eccentricity	Analysis at the wall base	Analysis at the wall top and the wall base

Parameters for the more accurate method

Floor loads (only in combination with DIN EN 1996)

This option specifies whether the live loads should be assumed acting all the time simultaneously on both sides of a floor plane for the determination of the node moments (cf. EN 1996-1-1, Para. 2.4.2, Comment 2).

In accordance with DIN EN 1996, always all chequered arrangements of the floor loads are examined in addition.

Redistribution of moments

The option specifies whether a moment redistribution should be performed for horizontal wall loads. For the redistribution of the moments, the degrees of restraint at the wall top and base are defined as great as possible in imitation of the actual supporting behaviour (criteria are the permissible max. eccentricity and/or the fixed-end moments) and the moment behaviour over the wall height is adjusted while preserving the equilibrium. If you deselect the redistribution of moments the moment behaviour is determined over the wall height and the wall top and base are assumed pinned.

Load transfer in a basement wall (MWK+, MWM+)

This option allows you to select whether a reduction of the lateral earth pressure should be applied to basement walls retained on four sides analogously to the simplified method to take a possible bi-axial load transfer into account.

(In the simplified verification method for basement walls retained on four sides, you may reduce the minimum structural load to be verified depending on the relation of the length to the width of the wall. This measure corresponds to a reduction of the lateral earth pressure. There are no specific provisions concerning basement walls in EN 1996-1-1.)

Structural system

Walls

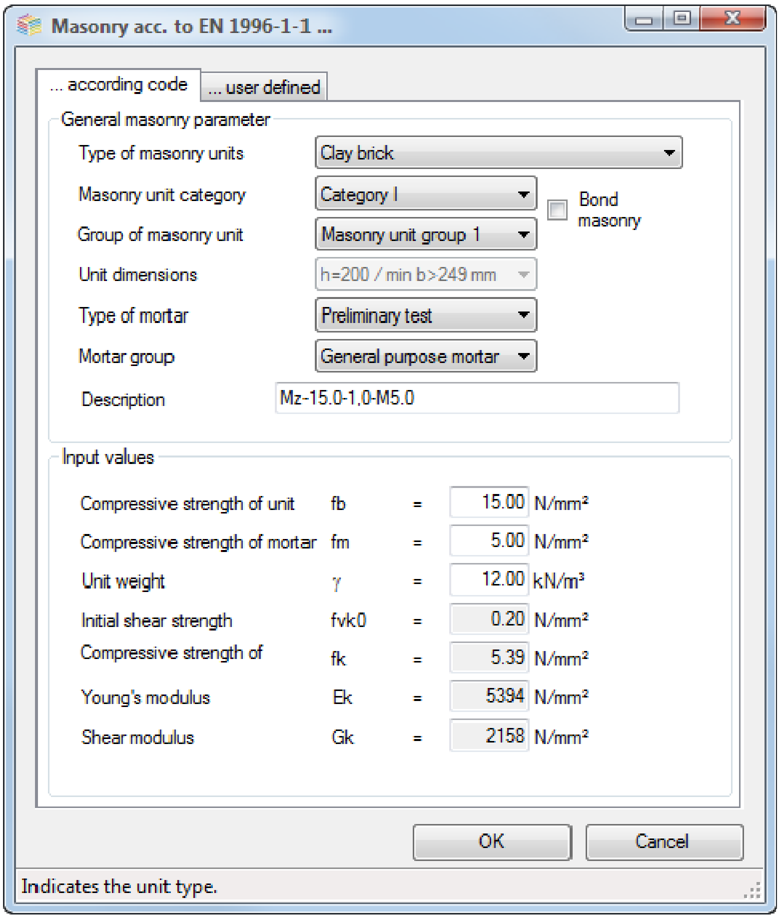
Type

Specification whether the wall is a single-leaf or a multi-leaf wall.

In certain cases, it is important to know whether the wall to be calculated is an interior or exterior wall (single-leaf or multi-leaf). This information is required to check compliance with the limiting criteria for the application of the simplified method, for instance.

Material

The option displays a dialog that allows you to define masonry of simplified design, to select masonry according to approval or to enter a user-defined material.



<u>According to code</u>

Type of masonry unit:

- masonry bricks
- lime-sand bricks
- normal-weight concrete blocks
- lightweight concrete blocks
- aerated concrete blocks

Masonry unit:

Depending on the selected type, suitable masonry units are displayed for selection and the corresponding values are set by default.

You can optionally select 'Masonry bond'.

<u>According to approval (DIN EN / ÖNORM EN)</u>

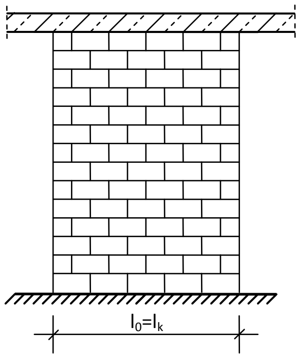
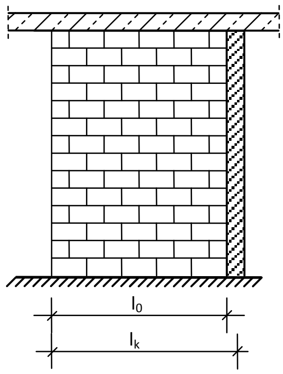
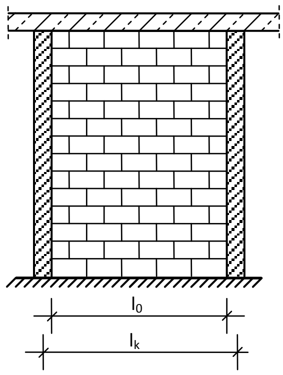
You can select material made by Wienerberger or Schlagmann.

<u>User-defined</u>

You can freely define material parameters and assign a user-defined name. The option "Set standard values" allows you to set defaults of a standard material and adjust them subsequently.

Support

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

Value	Description	Schematic system diagram
On two sides	The wall is retained at the head and the base to prevent lateral shift	
On three sides	The wall is retained at the head, the base and one vertical side to prevent lateral shift.	
On four sides	The wall is retained at the head, the base and both vertical sides to prevent lateral shift.	

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

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

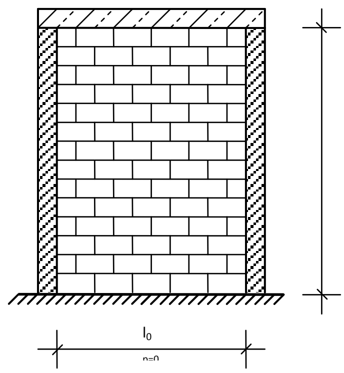
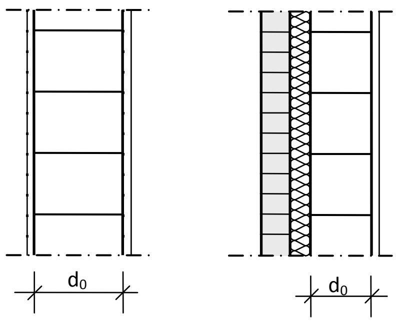
Based on the number of effective restraints, the effective wall length l_k is calculated.

Centring bar

Allows you to select whether a centring bar in the centroidal axis of the wall should be considered in the calculation at the wall top. A centrical load application is enforced and no fixed-end moments caused by horizontal loads are enabled.

Geometry of the wall (not in MWP+)

The option allows you to define the decisive dimensions of masonry walls. For more details, see the table below.

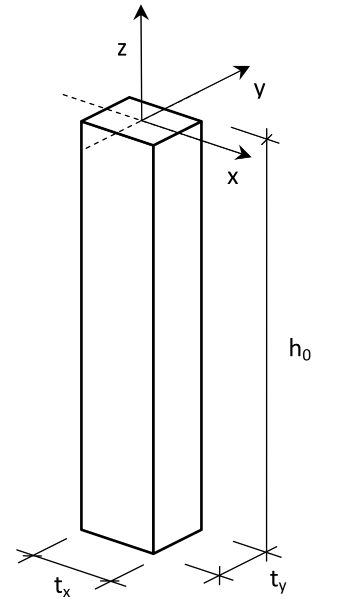
Value	Description	Schematic system diagram
h_0	Clear wall height	
l_0	Clear (=calculated) wall length, which is the basis of the load transfer. (Due to the frequent use of butt joints in combination with flat steel anchors for the wall connection, this value is considered for the effective wall length in the plate-related shear analysis).	
d_0	Thickness of a single-leaf wall or thickness of the bearing layer of a multi-leaf wall	

Spacing of the transversal bracing walls (not in MWP+)

Value	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

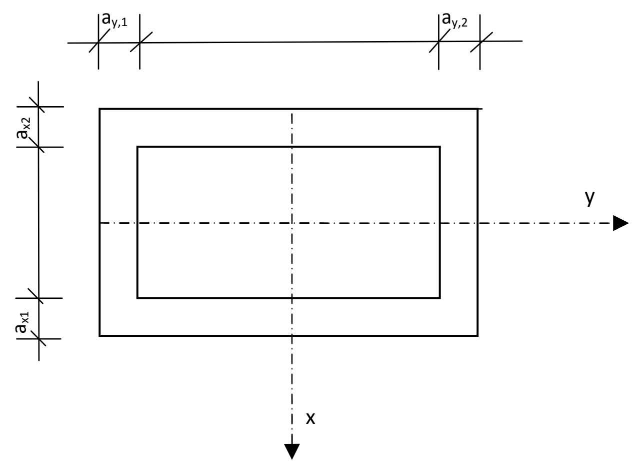
Pier dimensions (MW+)

The option allows you to define the decisive dimensions of masonry walls. For more details, see the table below.

Value	Description	Schematic system diagram
h0	Clear height of the pier	
tx	Thickness of the pier in the x-direction	
ty	Thickness of the pier in the y-direction	

Load application at the pier top (MWP+)

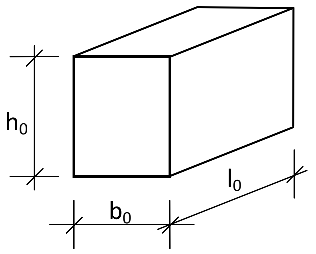
The load is applied at the pier top either over the total cross-sectional area (normally in combination with reinforced concrete beams) or over a partial area that is defined by specifying the distances to the edges in each cross-sectional axis.

Value	Description	Schematic system diagram
Distance to the edge in the x-direction	ax1	
	ax2	
Distance to the edge in the y-direction	ay1	
	ay2	

If a beam is fully supported, all distances to the edges must be set to zero. If a beam projects over the edge of the pier, the edge distance in this direction must be set to zero.

Foundation (MWP+)

You can pre-define an isolated foundation for the foundation structure in the MWP application. This definition serves the purpose of representing the foundation graphically and setting default geometric values for the export to the FRILO foundation applications. MWP+ does not provide for the design of the foundation.

Value	Description	Schematic system diagram
Foundation height	h_0	
Foundation width	b_0	
Foundation length	l_0	

g_z

Self-weight addition for the wall surfacing as weight force per m² wall surface. The weight addition defined this way is included with its simple value, i.e. it must correspond to the sum of the area weight of the plaster on both wall faces (interior and exterior).

Note: *(MWX+, MWK+) Only the self-weight of the wall to be verified is considered! The walls above and/or below are only used to determine the node stiffness in the respective equivalent structural system.*

Projection over foundation (MWX+)

You can enter a projection of the lowest wall over the foundation edge. The calculation is analogous to the partial support of floor slabs.

Text

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

Storey floors

Type

Allows you to specify the type of storey floor: supported on the left/right side or on both sides.

Type

Specifies the type of construction of the storey floor. Currently, only solid slabs are supported.

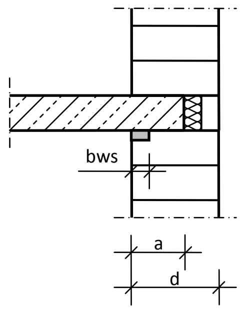
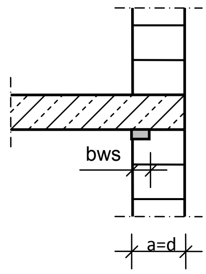
Value	Description
Reinforced concrete floor	Reinforced concrete floor refers to a solid floor slab that is two-dimensionally supported.

Currently, only the calculation based on the assumption of a two-dimensionally supported solid floor slab is supported by the software. You can simulate the conditions under joist floors by entering concentrated loads or via distributed eccentrically applying vertical wall loads, see also the chapter "Frequently asked questions".

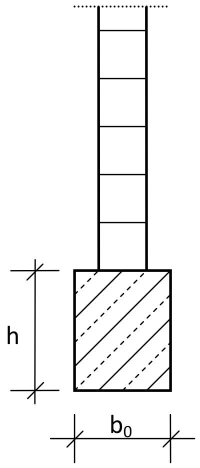
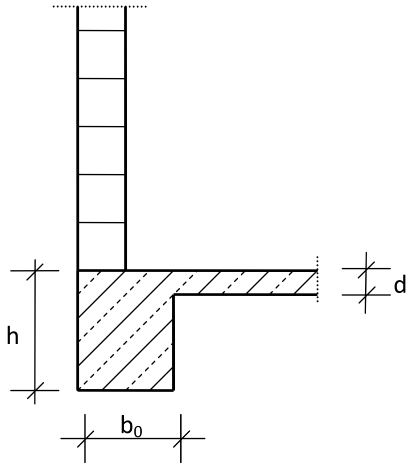
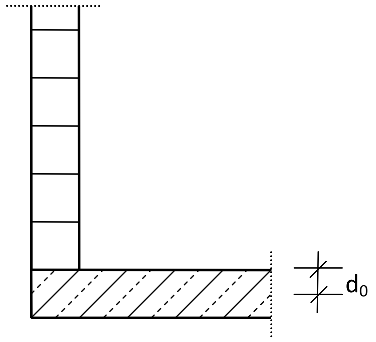
Modulus of elasticity

Calculated or characteristic value of the modulus of elasticity of the storey floor slab. It is only relevant for analyses based on the more accurate calculation method (calculation of internal forces resulting from the torsion of the floor supports). However, this value has a decisive influence on the node moments and, therefore, on the moment behaviour over the wall height.

Geometry of the storey floor slab

Value	Description	Schematic system diagram
Bearing length a le/ri	Bearing length of the left/right storey floor.	
Width of soft strip bws le/ri (implementation planned, not available yet)	Width of a soft strip inlay that provides a centring aid and prevents plaster spalling. The defined floor bearing depth minus the width of the soft strip inlay on both wall sides (net bearing length) must not fall below the minimum bearing length prescribed by DIN EN 1996!	
Thickness d le/ri	Thickness of the left/right storey floor. Different floor thicknesses at the left and the right side are currently not permissible.	
Span l le/ri	Span of the left/right intermediate floor slab; distance of the left/right wall surface to the supporting node.	
Width b le/ri	Affected width of the left/right intermediate floor. **Note: The value must at least be equal to the clear wall length!** **If the wall length is smaller than the floor width, an even distribution of the floor bearing load over the wall length is assumed!**	
Support Sup le/ri	Supporting conditions of the left/right storey floor: projecting, pinned or restrained (defines an equivalent structural system for the calculation of the node moments and for the automatic calculation of the continuity factors of floor loads, if applicable).	

Foundation (MWM+, MWK+)

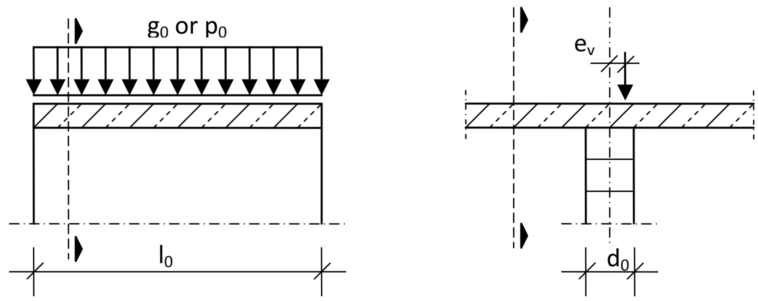
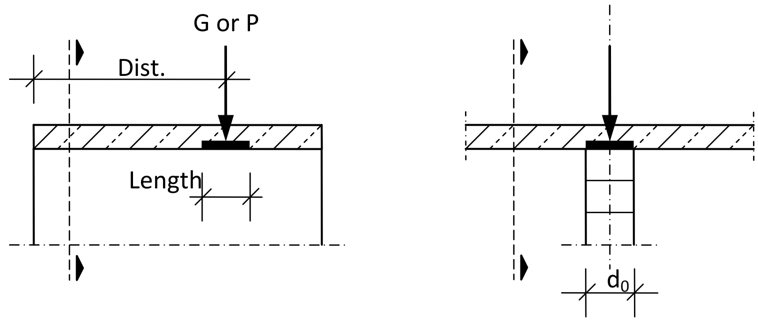
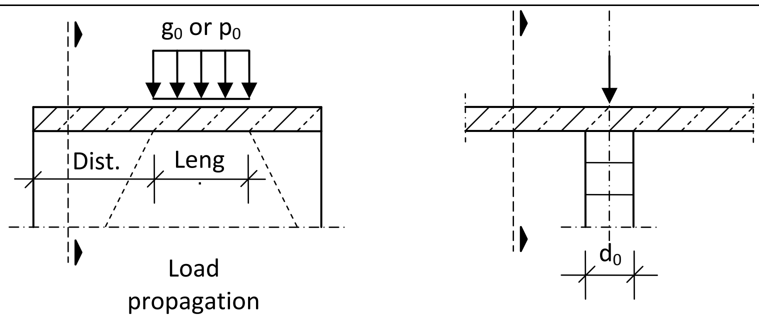
Type	Geometry
Strip foundation	
Boundary strip foundation	
Floor slab	

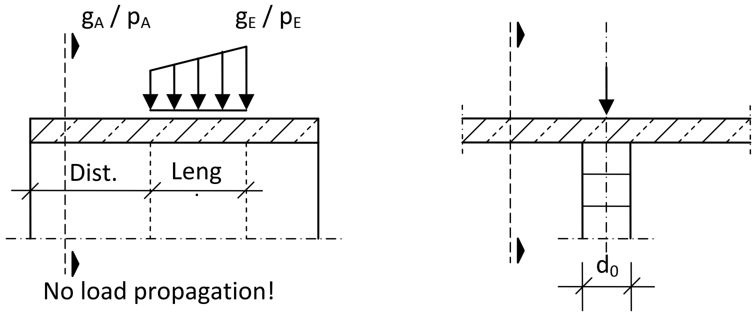
Loads

Vertical wall loads

Type

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

Uniformly distributed load: applies always over the total wall length	
Concentrated load: overlapping of load contact areas of several concentrated loads is not permissible.	
Line-section load[1)] constant linear load distributed over a part of the wall length.	

Trapezoidal load[2]: corresponds to a line-section load with variable load coordinates	
1)	The definition of a line-section load is a mean to map support reactions from walls above to which concentrated loads could apply. According to the standard, a line-section load is not identical to partial area compression caused by the load application. 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 top. Note: Load propagation is assumed when line-section loads apply.
2)	Like the line-section load, the trapezoidal load is a mean to map support reactions that are linearly variable in each section, however, such as support reactions from FE plate calculations that are caused by vertical and horizontal loads or by eccentrically arranged walls above (e.g. short bracing walls etc.). Note: No load propagation is assumed when trapezoidal loads apply.

Distance

Distance of the line of action of a concentrated load from the left wall end 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-propagation 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 floor, otherwise to $d_0/2$. The optional specification of an eccentricity is particularly relevant for the definition of partly supported floor slabs with a very low bearing length.

d_1

Length of the contact area of the concentrated load through the thickness of the wall. For the verification, it is always assumed that the line of action of the concentrated load runs in the middle plane of the wall, i.e. that an existing eccentricity has no impact on the load-bearing capacity of the wall.

ActGrp

Action of the variable load portion. The permanent load portion is always assigned to the permanent action.

Attention: *According to EN 1991-1-1, imposed loads of the categories A to D are not considered as independent variable loads. Therefore, instead of assigning the imposed loads to their actual category specified by EN 1990, they must be assigned to the most unfavourable of all categories!*

Load values (MWP+)

Value	Description
G	permanent portion of the concentrated vertical load
Q	variable portion of the concentrated vertical load
e_x	eccentricity of the load application point in the x-direction
e_y	eccentricity of the load application point in the y-direction

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 figure). You should therefore define the moving loads rather in the form of a ‘pyramid’ than segment by segment. The pyramid-type definition considers that only the load difference propagates in direction of the neighbour load. If load propagation should completely be dispensed with, load sections can be assembled using trapezoidal loads.

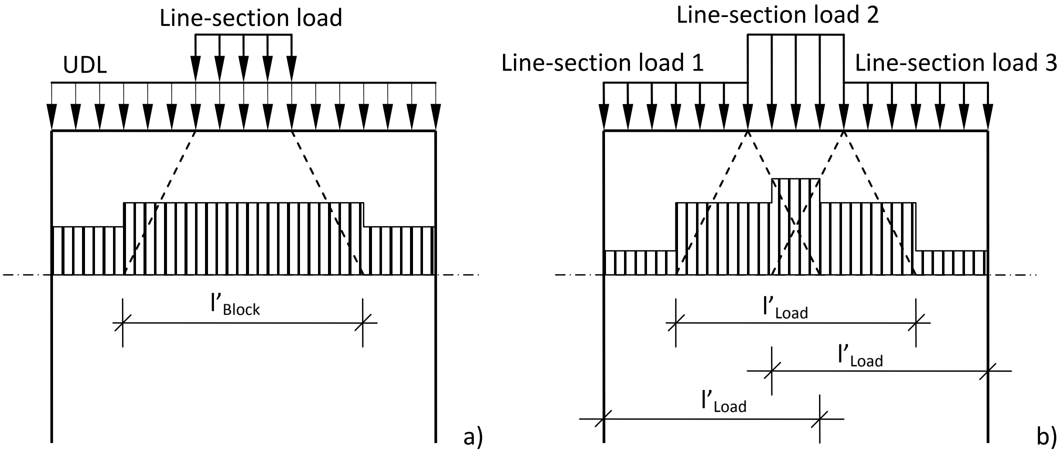


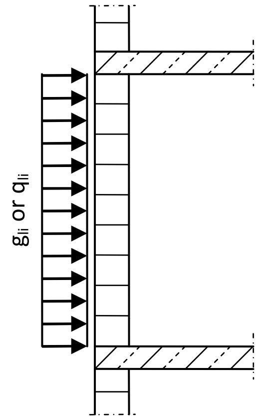
Figure: Use of line-section loads: a) correct load propagation in compliance with design practices b) unrealistic overlapping of the load-propagation cones

Horizontal wall loads

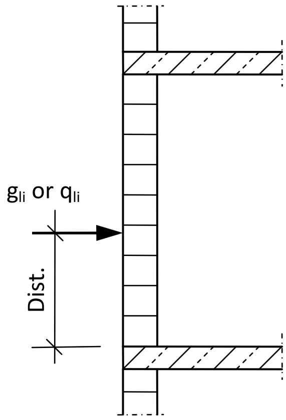
Type

Specification whether the load in question is a uniformly distributed load (constant area load), a concentrated load (line load constant over the wall length) or a trapezoidal load (linearly variable load over the wall height).

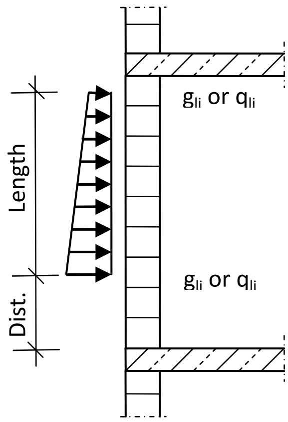
Uniformly distributed load (constant area load)



Concentrated load (line load constant over the wall length)



Trapezoidal load (area load, linearly variable over the wall height)



Load values

Value	Description	
	Uniformly distributed load	Permanent or variable load portion in [kN/m²] at the lower edge of the wall
g_b / q_b	Concentrated load	Permanent or variable load portion in [kN/m]
	Trapezoidal load	Permanent or variable load portion in [kN/m²] at the lower end of the load
g_t / q_t	Uniformly distributed load	Permanent or variable load portion in [kN/m²] at the upper edge of the wall
	Concentrated load	Not applicable
	Trapezoidal load	Permanent or variable load portion in [kN/m²] at the upper end of the load
Length	Trapezoidal load	Load extension over the wall height in [m]
Dist.	Uniformly distributed load	Not applicable
	Concentrated load	Distance in [m] of the line of action of the load from the wall base
	Trapezoidal load	Distance in [m] of the lower end of the load to the wall base

Note: *If the affected width of the load is greater than the wall length (e.g. with adjacent wall openings), you should increase the load value manually based on the relation of the affected width and the wall length.*

ActGrp

Action of the variable load portion. The permanent load portion is always assigned to the permanent action.

Text

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

Floor loads

Type

Specification of the load type. You can select constant area loads or line loads parallel to the wall.

Level

Specification of the consecutive number of the wall that supports the storey floor to which the load applies. The lowest wall is always number 1. See also the level of the vertical wall loads.

ActGrp

Number of the action of the variable load portion. The permanent load portion is always assigned to the permanent action.

Attention: *According to EN 1991-1-1, imposed loads of the categories A to D are not considered as independent variable loads. Therefore, instead of assigning the imposed loads to their actual category specified by EN 1990, they must be assigned to the most unfavourable of all categories!*

Continuity effect

The bearing strength of the masonry wall is mainly determined by the magnitude of the existing axial force and the wall moment caused by floor torsion at the wall support. The FRILO Masonry applications always calculate the wall moments from the floor loads on an equivalent structural system as per EN 1996-1-1, Annex C with consideration of the defined floor spans and their support conditions.

This option allows you to select the default that should be used to quantify the continuity effect of the floor slab (to which the floor loads apply), i.e. to calculate the floor support reaction caused by the floor load.

Value	**Description**
Continuity factor	Continuity factor (Winkler coefficient), separately for permanent and the variable load portions on the left/right side of the floor
Floor geometry	The floor support reaction is determined with consideration of the defined supporting conditions at the end of the floor spans on a single-span or two-span beam.
User-def. support reaction	The user enters a value for the floor support reaction, if this value is known from a FE plate calculation, for instance.

Text

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

Load values

Value	**Description**
g le/ri	Permanent load portion in [kN/m²] on the left/right side of the floor
q le/ri	Variable load portion in [kN/m²] on the left/right side of the floor

Continuity factors

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 structural loads (compressive axial forces) do not necessarily produce a higher utilization of the wall cross-section (resistance against plate-related effects of actions). Lower structural loads might cause the premature failure of the wall. Therefore, the continuity effect of the floors must be taken into consideration under certain circumstances.

DIN EN 1996 provides simplified regulations stating the conditions that allow disregarding the continuity of floor slabs. To transfer this concept in a general manner to the design procedure, so-called continuity factors are included in the definition of floors in MWX+. The continuity factor is defined as follows:

f = relation of the support reaction at the top of the wall (resulting from the load) to the amount of the loading (resultant force).

Value	**Description**
Fac g le/ri	Continuity factor (Winkler coefficient) for the permanent load portion on the left/right side of the floor
Fac q le/ri	Continuity factor (Winkler coefficient) for the variable load portion on the left/right side of the floor

<u>Example 1:</u>

The floor system is a two-span beam with equal spans l under a uniformly distributed load q, with a central support

$\text{Fac } q_{le} = \text{Fac } q_{ri} = 1.250/2 \cdot q \cdot l/(q \cdot l) = 0.625$

<u>Example 2:</u>

As example 1, however with end support

$\text{Fac } q_{le} = \text{Fac } q_{ri} = 0.438/2 \cdot q \cdot l/(q \cdot l) = 0.438$

<u>Example 3:</u>

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

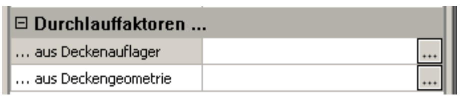
$\text{Fac } q_{le} = \text{Fac } q_{ri} = 1.000/2 \cdot q \cdot l/(q \cdot l) = 0.500$

<u>Example 4:</u>

Special case "Continuity needs not be considered", central support

$\text{Fac } q_{li} = \text{Fac } q_{re} = 0.500$

Note: Under normal conditions, the continuity factors for distributed loads applying to cantilevered spans are > 1.0.



If the equivalent frame system is also suitable for the determination of the floor support reactions, the switch "Continuity factors ... from floor geometry" provides for the automatic generation of the continuity factors from the geometry and the supporting conditions of the defined storey floors.

Attention: *This command only refers to the currently active floor load, i.e. you must repeat it for each additional floor load.*

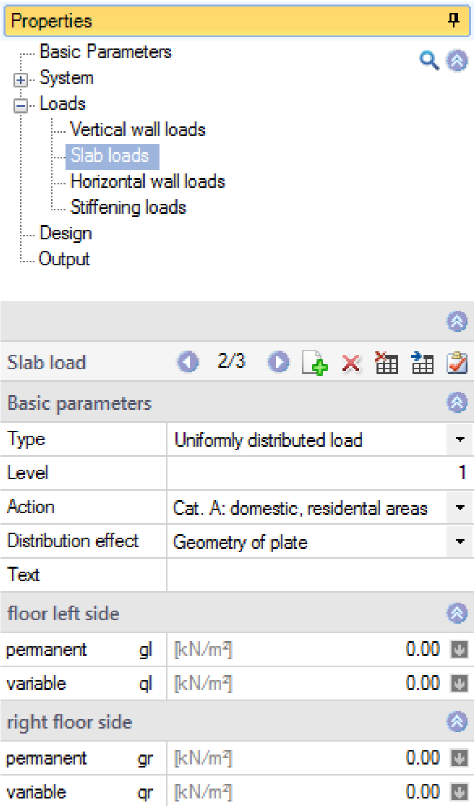
All automatically generated continuity factors become invalid if you change the floor definition or the floor loads on the respective floor level subsequently!

Pre-setting of support reactions resulting from a plate-related calculation

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

In many cases, the floor support reactions are not calculated on the equivalent system but in the floor design via FEM, however. When the limiting criteria for the application of the simplified calculation method are met, these support reactions could be used directly in the design of the wall (they are entered in MWX+ as vertical wall loads).

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



In the displayed dialog, the support reactions in [kN/m] resulting from the floor calculation are entered separately for load portions resulting from permanent loads and those resulting from imposed loads for the left and right side of the floor. The software calculates the equivalent continuity factors from these support reactions and the specified loads on the left and right side of the floor as follows:

Continuity factor for the permanent load portion on the left floor side
$$f_{Gk,li} = 0,5 \cdot \frac{G_k}{g_{k,li} \cdot l_{li}}$$

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

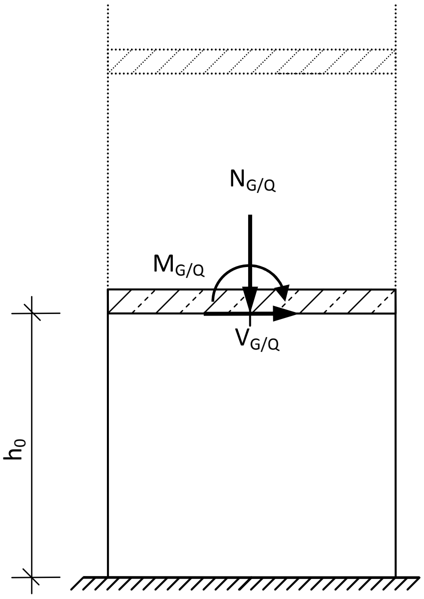
Continuity factor for the variable load portion on the left floor side
$$f_{Qk,li} = 0,5 \cdot \frac{Q_{kli}}{q_{k,li} \cdot l_{li}}$$

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

Bracing loads (MWX+)

Type

The option displays an insert row for the list of bracing loads. You can define any number of bracing loads. An analysis of the load transfer into the wall is not performed, i.e. it is assumed that the bracing loads are transferred continuously (e.g. via the floor levels).



Load values

The bracing loads are defined as characteristic values of the applying internal forces, i.e. axial force, shear force and bending moment, which must be determined beforehand with a suitable model (e.g. simplified equivalent model for the bracing wall or more accurate calculation in the FRILO Building Model GEO).

(Axial forces apply if diaphragms are arranged eccentrically in the floor plan.)

Value	Description
N_G	permanent portion of the axial force in [kN] applying at the wall top
N_Q	variable portion of the axial force in [kN] applying at the wall top
V_G	permanent portion of the shear force in [kN] applying at the wall top
V_Q	variable portion of the shear force in [kN] applying at the wall top
M_G	permanent portion of the bending moment in [kNm] applying at the wall top
M_Q	variable portion of the bending moment in [kNm] applying at the wall top

As no other bracing loads apply over the wall height, the shear forces at the wall top and the wall base are identical. The moments at the wall base differ from those at the wall top by the portion $V*h_0$, i.e. any restraining effect at the wall top is disregarded.

ActGrp

Number of the action of the variable load portion. The permanent load portion is always assigned to the permanent action. If a shear load is defined as an accidental load (except with earthquakes), the application assumes that it is a wind load. In the combinations of actions including this action, the diaphragm is deemed a wind diaphragm and the shear correction factor α_c is considered.

When the analysis is performed in accordance with DIN 1053-1, the assignment of action groups can be dispensed with. You simply must select whether a bracing load should be treated as seismic effect. In this case, the additional provisions of DIN 4149 are applied to each load case combination that includes this load.

ConGrp

Specifies the number of the load case group including the load cases that are assumed always acting simultaneously. If you assign the number '0', this means that this load will not be assigned to any concurrency group.

AltGrp

Specifies the number of the load case group including the load cases that are assumed never acting simultaneously. If you assign the number '0', this means that this load will not be assigned to any alternative group.

Text

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

Note: *You must enter the total height of the diaphragm when defining the wall because this value is required to calculate the shear stress distribution factor.*

For the orderly determination of the shear adjustment factor in accordance with DIN EN 1996-1-1, it is important to select the appropriate action group for the variable load portion! Wind diaphragms are only recognized as such when the wind load portion amounts at least to 75 % of the total load.

Lateral earth pressure (MWM+)

Simplified method

Height of earthfill

Specification of the filling height of the backfill material, measured from the wall base.

Specific weight

Specification of the specific weight of the filling material.

Note: When a filling height > 0 is defined, MWM+ considers the lowest wall as basement wall and performs the required verifications based on the simplified regulations for basement walls (without calculation of the lateral earth pressure). If the filling height is very low and the vertical structural loads are very high at the same time, the results of the verification can be far on the safe side.

More accurate method

When a filling height > 0 is defined, the lateral earth pressure is calculated internally in accordance with DIN 4085 or EN 1997 (separately for the soil self-weight and the live load on the ground surface). The calculated lateral earth pressure is considered as an exterior load in the determination of the internal forces and the subsequent verifications.

Height of earthfill

Specification of the filling height of the backfill material, measured from the wall base. When using the simplified calculation method, the maximum filling height is limited to the clear height of the basement. In the more accurate method, the filling height can exceed the level of the ground floor. In this case, the horizontal load caused by lateral earth pressure is also considered for the respective walls above.

Angle of wall friction

Defines the roughness of the wall surface to be used in the calculation of the lateral earth pressure. The available classes are typical in civil engineering: smooth, less rough, rough and interlocked.

Specific weight

Specification of the specific weight of the filling material.

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. If the cohesion values > 0 the minimum lateral earth pressure is automatically considered, if necessary.

Earth pressure equation

Specification of the factor for the calculation of the stress condition under increased active earth pressure. The equation is as follows: $E'_a=E_a*\mu+E_0*(1- \mu)$. The following is true for active earth pressure: $\mu = 1$, for earth pressure at rest: $\mu = 0$ and for increased active earth pressure: μ between 0 and 1.

Live load

Specification of a uniformly distributed live load on the ground surface, which is assumed to extend infinitely.

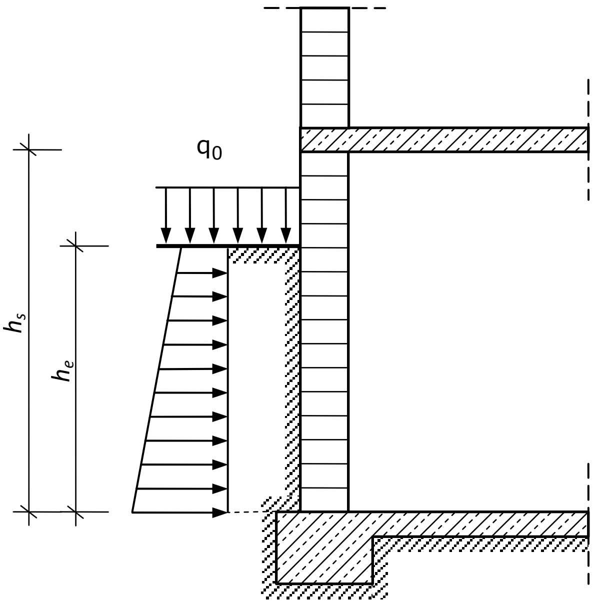
Actions

Specification of the action of the defined live load.

Lateral earth pressure (MWK+)

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

Calculated 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 = Ea*mu+ E0*(1-mu). The following is true for active earth pressure: μ = 1, for earth pressure at rest: μ = 0 and for increased active earth pressure: 0 smaller than μ smaller than 1.

Earth pressure pattern

Specification whether the earth pressure pattern is considered 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">Comments</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 line 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 oscillating load and results to z_t = 0.35 m for oscillating loads ≤ 1.2 kN, otherwise to z_t = 0.60 m.</td></tr>
<tr><td>Oscillating load < 1.2 kN</td><td></td></tr>
<tr><td>Oscillating 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 10531-1 and DIN 1053-100 or with 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.

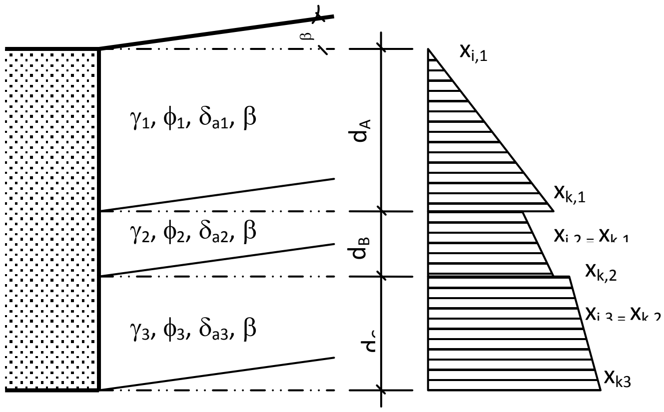
Soil layers

Name

Designation of the soil layer.

xi / xk

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



Gamma/Gamma’

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

phi’

Effective inner friction angle of the soil layer.

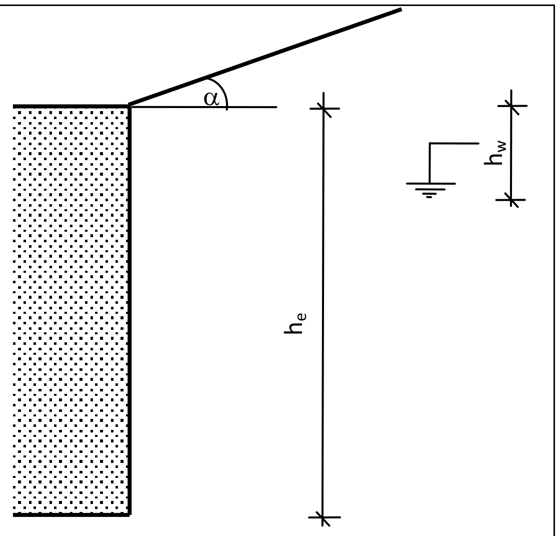
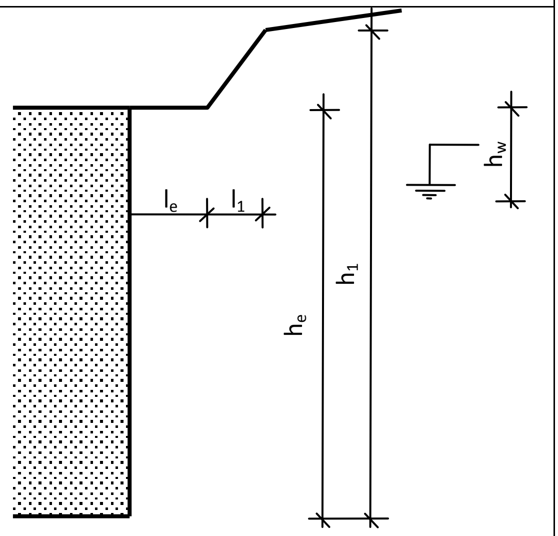
c’

Effective cohesion of the soil layer.

Water and slope (MWK+)

Type of slope

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

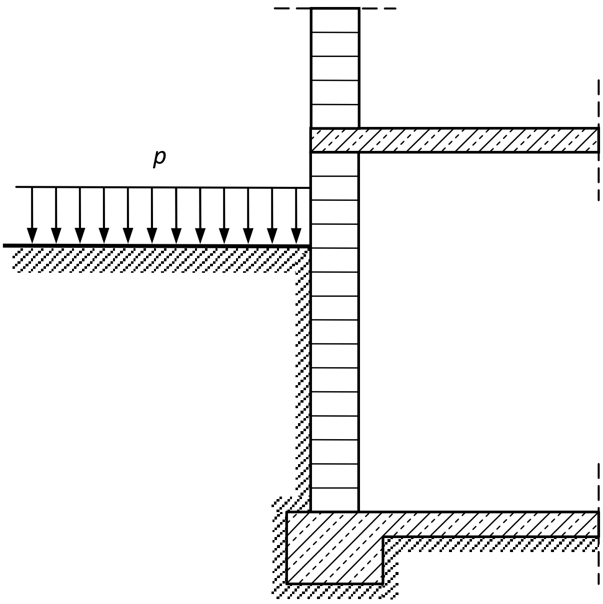
Continuous	
Discontinuous	

Loads on the ground surface (MWK+)

Live load evenly distributed over the ground 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 action groups can be dispensed with.

Line load or concentrated load on the ground surface (MWK+)

Type

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

Load values

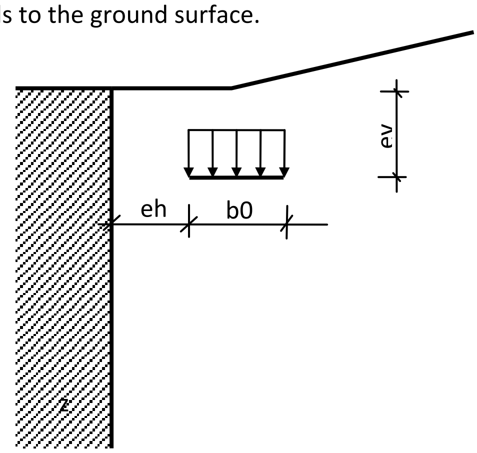
Value	Description
G / g_0	Permanent load portion in [kN] or [kN/m²]
Q_0	Variable load portion in [kN] or [kN/m²]

b0

Width of the line load.

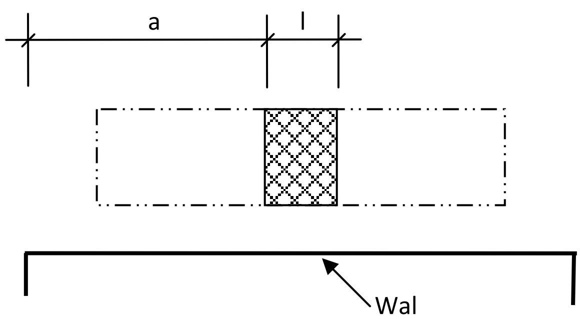
eh / ev

Horizontal distance of the line load 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 concentrated load [l]. Distance of the concentrated load to the left wall edge {a].



ActGrp

Number of the action 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 action groups can be dispensed with.

Text

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

Verification process

Verification points

The following verifications are performed, provided that the user has defined loads producing corresponding effects of actions.

The analyses are performed at the decisive points being the wall top, half the wall height and the wall base. To correctly verify the bearing strength of walls under dominant plate-related effects of actions (e.g. exterior walls with low structural load under wind action), a horizontal section at the point where the local maximum eccentricity occurs through the thickness of the wall is examined in addition. (If this horizontal section does not coincide with half the wall height. The lateral buckling analysis at half the wall height always produces less favourable results in this case).

When bracing diaphragms are verified, it is important to know whether the wall to be verified is a wind diaphragm. In this case, it is permissible to use the shear correction factor α, which has a favourable effect on the result. It is assumed that the wall to verified is a wind diaphragm when only the following bracing loads have been defined:

- Permanent loads (usually the permanent portion resulting from the inclination of the building, not dominant!)
- Wind loads
- Other loads (usually the variable portion resulting from the building inclination)
- Accidental loads (usually wind loads that may be considered as accidental loads)

Analyses in accordance with EN 1996-1-1

Analyses based on the simplified calculation method

When you set the parameter "Verification points" to the value "Maximum axial force" the following analyses are performed in combination with the simplified calculation method:

Verification point	Verifications	Comment
Wall base	Resistance of cross sections to axial loads1)	
	Shear resistance under diaphragm-related shear	
	Border strain	With $E = 1000 \cdot f_k$
	Limitation of the controlled eccentricity through the length of the wall	
Wall top	Partial area compression under concentrated loads	

1) If the effects of actions resulting from load propagation under concentrated loads at half the wall height are higher than at the wall base, the higher effects are used in the analysis.

When you set the parameter "Verification points" to the value "Separately for wall base, wall middle and wall top", the following analyses are performed in combination with the simplified calculation method:

Verification point	Verifications	Comment
Wall top	Resistance of cross sections to axial loads	Bearing load reduction due to rotation angle of the supported floor
	Shear resistance under diaphragm-related shear	
	Border strain	With $E = 1000 \cdot f_k$
	Limitation of the controlled eccentricity through the length of the wall	
	Bearing pressure under concentrated loads	
Half the wall height	Resistance of cross sections to axial loads	Bearing load reduction due to effective slenderness
Wall base	Resistance of cross sections to axial loads	Bearing load reduction due to rotation angle of the lower floor plane
	Shear resistance under diaphragm-related shear	
	Border strain	With $E = 1000 \cdot f_k$
	Limitation of the controlled eccentricity through the length of the wall	

Analyses based on the more accurate calculation method

Verification point	Verifications	Comment
Wall top	Resistance of cross sections to axial loads	
	Shear resistance under diaphragm-related and plate-related shear	
	Border strain	With $E = 1000 \cdot f_k$
	Limitation of the controlled eccentricity through the length and the thickness of the wall	
	Partial area compression under concentrated loads	
Half the wall height	Resistance of cross sections to axial loads	
	Limitation of the controlled eccentricity through the length and the thickness of the wall	
Max. eccentricity through the thickness of the wall	Resistance of cross sections to axial loads	Without consideration of an undesired eccentricity
	Limitation of the controlled eccentricity through the length and the thickness of the wall	
Wall base	Resistance of cross sections to axial loads	
	Shear resistance under diaphragm-related and plate-related shear	
	Border strain	With $E = 1000 \cdot f_k$
	Limitation of the controlled eccentricity through the length and the thickness of the wall	

Design situations and load combinations

Verification	Design situation/load combination
Resistance of cross sections to axial loads	Permanent/transient or accidental situation (incl. earthquake)
Shear resistance	Permanent/transient or accidental situation (incl. earthquake)
Limitation of the controlled eccentricity	Characteristic loads (incl. accidental loads, but no seismic loads)
Border strain	Infrequent or frequent combination (excl. accidental loads)

According to DIN EN 1996-1-1, you can perform the border strain analysis alternatively for the frequent design situation as defined by DIN EN 1990 instead of the infrequent situation provided that the bond shear resistance is not included in the shear resistance analysis.

In compliance with this requirement, MWX+ performs first the analysis of the wall for the infrequent design situation. If the border strain analysis does not come out and the shear resistance analysis still holds some reserves, the entire analysis of this wall is repeated while excluding the bond shear resistance from the shear resistance analysis. The analysis of the border strain is based on the frequent design situation.

Output

General

Option	Description
System graph	Output of a graphical representation of the total structural system.
Brief output	Output of a compact version of the system and the results. When you select brief output, the program determines automatically the output scope. The user has only a limited influence on the contents of the texts that are put out.
Legends	When you select this option, all tables are described in detail via legends in the output. This option is not available when you activate "brief output."

Structural system

Option	Description
Comments	Output of the comments to the system.
Material parameters	Output of detailed material parameters in the form of a table.
Walls	Output of the masonry walls in the form of a table.
Storey floors	Output of the storey floors in the form of a table.

Loads

Option	Description
Comments	Output of the comments to the system.
Actions	Output of the actions including their partial safety factors and combination coefficients.
Wall loads	Output of the vertical loads that apply directly to the wall top. The self-weights and self-weight additions are put out together with the walls.
Floor loads	Output of the vertical loads that act directly on the storey floors.
Horizontal loads	Output of the horizontal loads applying to the wall to be designed.
Bracing loads	Output of the bracing loads applying to the wall to be designed.

Results

Option	Description
Comments	Output of the comments to the calculation results.
Load case combinations	Output of the load case combinations on which the analyses are based.
Internal forces	Output of the design values of the action-effects on which the analyses are based.
Compression effects	Output of the analysis of the compression effects; always included under normal conditions.
Plate-related shear	Output of the plate-related shear analysis.
Diaphragm-related shear	Output of the diaphragm-related shear analysis.
Border strain analysis	Output of the border strain analysis with diaphragm-related shear. only in combination with DIN 1053.
Gaping joint	Analysis of the gaping joint through the thickness and the length of the wall; only in the design as per DIN 1053-1 and DIN 1053-100.

Result graphs

Option	Description
Internal forces diagrams	Output of the internal forces diagrams for each analysis in the ultimate limit state.

Interfaced software applications

In the masonry applications, the load transfer to the following foundation applications is implemented and linked to the button "Interfaced applications" in the ribbon bar on top of the screen:

- FD+ Single Foundation (only in MWP+)
- FDS+ Strip Foundation (not in MWP+)
- FDR+ Reinforced Raft Foundation (not in MWP+)

The load transfer to other masonry application is implemented as well.

The load transfer feature allows you to convert a wall in MWX+ directly into an item in MWK+ (the system designation, the geometry and the loads are transferred without changes) or a new item can be created below the wall to be examined (designation 'load').

The feature allows you to use the support reactions of walls in the lowest storey or piers for the analysis of the foundations immediately underneath.

After selection of the appropriate foundation software, the corresponding application it is launched automatically, and the loading is generated in the form of the individual load cases used in the masonry application. The user must simply add the foundation-specific details and check the transferred load values.

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

Strip foundation FDS+

The FDS+ application processes only internal member forces (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 support reactions through the length of the wall. (Eccentricities through the length of the wall are neither available!)

Therefore, only the resulting axial forces of the support reactions, or more precisely, the resultant force of the axial force and of 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 plate-related effects 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 about the longitudinal foundation axis should become decisive due to the selected foundation dimensions, you must manually add the corresponding values to the transferred loads via the data-entry dialog of FDS+.

Reinforced Raft Foundation FDR+

The foundation application FDR+ performs the design on a strip of one metre width, i. e. variable load behaviour over the foundation length is disregarded. The design of the foundation must be performed at the point where the highest and/or decisive loads apply.

If several concentrated loads apply and cause a tiered behaviour of the support reaction over the wall length you do not know in advance, 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, 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 base. It is obvious that overlapping 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 plate-related effects 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-related effects cannot be considered either.

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

Frequently asked questions

Should I always use the more accurate verification method because the software handles all laborious calculations anyway?

No! You should prefer the simplified verification method, wherever it can be applied. The results of this method are insignificantly more conservative, and the method is easier to apply in a wider range of cases due to the reduced number of parameters to define. The risk of erroneous entries and inappropriate calculations is minimized in this case.

In general, the verification based on the more accurate method requires a much deeper knowledge of the fundamentals of the bearing behaviour of masonry structures and of how they are to be considered in a verification than the application of the simplified method!

Can I also verify multi-storey walls in MWX+?

No. The application MWX+ is intended for the analysis of individual walls exclusively. The strong point of this application is the isolated verification of individual walls whose integration into the global load-bearing structure can be mapped approximately via the walls below and above and the corresponding supporting conditions. The MWM+ application is suitable for the verification of multi-storey walls.

The software offers a parameter called 'floor support distance', how is this term defined?

The floor support distance that is to be defined in the software applications refers to the clear distance between the wall surface and the axis of the floor support on the opposite side. The input value plus half the wall thickness is directly considered in all verifications.

Bi-axial load transfer is not automatically considered via a reduced floor support distance. In this case, you must specify the effective value of the floor support distance in such a way that the total floor torsion in the plain equivalent system (= beam) corresponds to the total torsion of the slab.

Where can I optionally select whether imposed loads are considered dependent or independent?

All variable loads are always considered as independent loads. According to EN 1991-1-1, imposed loads of the categories A to D are not considered as independent variable loads. Therefore, instead of assigning the imposed loads to their actual category specified by EN 1990, they must be assigned to the most unfavourable of all categories!

Why can isolated walls not be verified in MWX+, MWM+ and MWK+?

The applications are intended for the analysis of masonry walls in building construction, i. e. the structural equivalent systems used in these software applications are based on plain frames. In addition, most analyses assume non-sway restraints of the wall at its top and base. Therefore, isolated walls constitute a special case that is difficult to map adequately using general analysis algorithms.

MWP+ is available for the verification of isolated walls because the defined vertical loads can be entered directly with their assumed max. eccentricities in the software. In this case, you should select the structural system of a cantilever in MWP+.

Why is a cantilever used as equivalent structural system for the calculation of the internal forces caused by bracing loads (within the wall to be verified)?

The cantilever constitutes a conservative idealisation of the real conditions at bracing diaphragms. Favourable effects of floor slabs (such as torsion impediments) are well known among experts, a generally acknowledged method for the reliable quantification of these effects does however not exist to date.

Can I also verify basement walls in MWX+?

Yes, with certain restrictions. MWX+ examines exclusively the vertical transfer of horizontal loads, i.e. a feature corresponding to the reduction of the required minimum structural load with short walls (e.g. as known from the analysis of basement walls without consideration of the earth pressure) is not implemented.

What should I consider in connection with partially supported floor slabs?

The calculation of systems with partially supported floor slabs is based on the easily comprehensible approach described in DIN EN 1996-1-1, Annex C. In this approach, it is first assumed that the calculated wall thickness corresponds to the floor bearing length. All verifications at the wall top and the wall base are performed with this wall thickness. For the buckling analysis at half the wall height, this approach would be too inefficient. Therefore, the total wall thickness and an additional eccentricity equal to the offset of the centroidal axis between the floor bearing length and the wall middle axis is considered.

Inverting this method would also produce identical verification results at the wall top and base, i.e. performing the verifications with the total wall thickness and increasing the existing eccentricities by the existing offset of the centroidal axis.

Why does MWX+ only allow the definition of solid floors and not of joisted floors? How can I perform an analysis of the wall in the second case?

As a rule, MWX+ allows only the calculation of masonry walls loaded by solid and two-dimensionally supported floor slabs. All structural safety analyses in accordance with DIN 1053 and EN 1996 are based on this assumption.

The provision of code-checked ring beams or ring anchors for the lateral restraint at the wall top allows the user to perform the analyses identically, at least when applying the simplified method.

The application of the more accurate method involves the problem, however, that you cannot calculate the bending moments resulting from the torsional angle of the floor using the conventional equivalent systems that are implemented in MWX+ because you must not assume restraints with joisted floors. Therefore, the greatest problem is the determination of the eccentricity caused by the torsional angle of the floor. A remedy to this problem is the consideration of the relocation rule for the resultant force when assuming an eccentricity at the tension block. You can project this eccentricity directly to the wall as vertical wall load using distributed concentrated loads. Concentrated loads with an eccentricity through the wall thickness are not available.

Is it reasonable to simulate a structural wall load variable over the wall length with a series of concentrated loads?

No. In the more accurate method, concentrated loads are not combined with the moments resulting from the torsional angle of the floor support but are assumed to apply at half the wall height. Therefore, the bearing capacity at the wall top would be overestimated in this simulation. In addition, an unexpected/unrealistic behaviour of the effects of actions over the wall length could be produced by the overlapping load-propagation cones.

Note: *In contrast to concentrated loads, line-section loads are also considered at the wall top in the verification. To avoid the problem of overlapping load-propagation areas, you should use trapezoidal loads to map a tiered loading behaviour over the wall length, because load propagation does not occur in his case.*

What should I pay attention to when verifying items imported from the FRILO Building Model GEO?

The GEO software tries to set a maximum of values when exporting a file. The transition from the building model to a masonry-specific equivalent structural system requires in many cases competent judgement of the structural design. Currently, you need to check the following values and modify or supplement them when importing the data in MWX+:

- all basic parameters and among them, the wall system and the setting of the consideration of the self-weight of the floor to 'manual specification' in particular
- the buckling restraints of the wall as well as all material parameters (in the current software version)
- the decisive floor support distances with the corresponding supporting conditions at the opposite floor support
- the floor loads and among them, the extension by load values that cannot be entered directly in the load definition in MWX+ (e.g. effect of partial area loads on the floor slabs) in particular
- horizontal loads (e.g. wind acting on exterior walls)

In connection with the transferred loads, you should check the following conditions:

- Floor loads are transferred as vertical wall loads. To be able to determine the bending moments at the wall-floor nodes correctly, corresponding floor loads based on the area loads defined in the GEO are set up at the same time. The continuity factor is set to "0" to exclude a contribution of these loads to the axial wall force.
- Bracing loads do not apply at the wall top under normal conditions. The lever arm of the bracing loads is adjusted in such a manner that the correct bending moment resulting from the load-bearing effect of the building model is obtained at the wall base instead.

Why do the masonry applications only allow the definition of solid floors and not of joisted floors? How can I perform an analysis of the wall in the second case?

As a rule, the masonry applications allow only the calculation of masonry walls loaded by solid and two-dimensionally supported floor slabs. All structural safety analyses in EN 1996 are based on this assumption.

The provision of code-checked ring beams or ring anchors for the lateral restraint at the wall top allows the user to perform the analyses identically, at least when applying the simplified method.

With the more accurate method, the problem arises, however, that you cannot calculate the bending moments resulting from the torsional angle of the floor using the conventional equivalent systems because you must not assume restraints with joisted floors. Therefore, the greatest problem is the determination of the eccentricity caused by the torsional angle of the floor. A remedy to this problem is the consideration of the relocation rule for the resultant force when assuming an eccentricity at the tension block. You can project this eccentricity directly to the wall as vertical wall load using distributed concentrated loads (= linear load). Concentrated loads with an eccentricity through the wall thickness are not available.

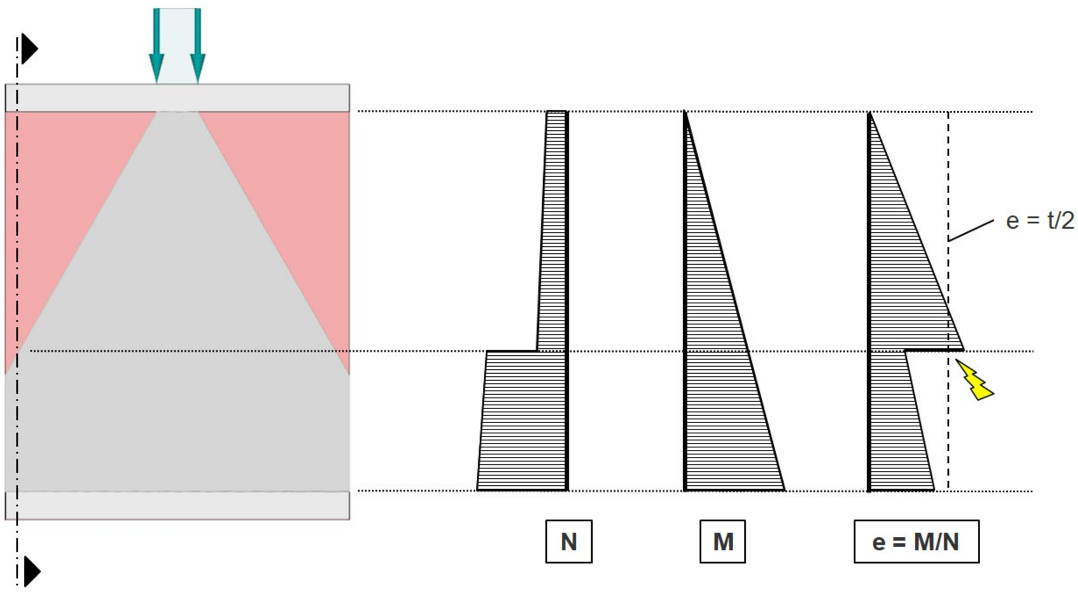
Can I also analyse individual walls in MWM+?

If a verification with the simplified method is sufficient, you can examine also individual walls (i.e. walls separated from the global structural system) in MWM+, because you need not take interactions with the walls immediately above or below into account in this case. Please do not forget to specify in the parameters for the simplified method how the reduction factor for the load-bearing capacity at the wall top should be determined, because the software assumes an individual wall always in the uppermost full storey and, therefore, load-bearing reserves might be disregarded unintentionally.

If a verification in accordance with the more accurate method is required, you should use the software for masonry design MWX+ (or MWK+ for basement walls) because, depending on the place of the wall in the system, its connection to the total system is considered in the structural systems provided by EN 1996-1-1. MWM+ allows you to export every single wall to the applications MMX+ and MWK+ via the Load Transfer functions.

Why does the verification of some walls fail with the more accurate method when a concentrated load or a line-section load was defined at the wall top in addition?

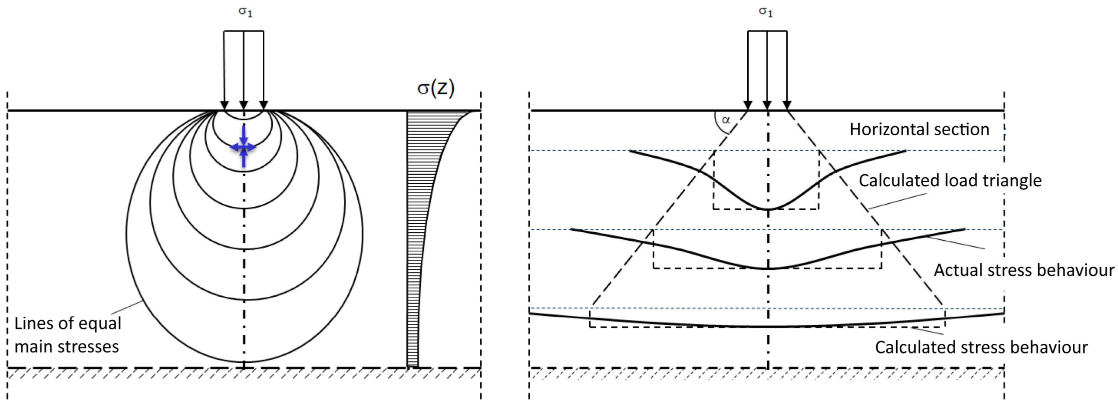
The problem occurs because of the processing of the load propagation underneath the concentrated loads in accordance with design practices. The assumption of the load propagation cones produces axial force offsets in some vertical verification cross-sections (not immediately below the concentrated load) as a side effect, whereas the moment behaviour remains unchanged. The load eccentricity, which is the basis of all pressure analyses in masonry construction, presents also an offset within the wall height that cannot be corrected with the relocation rule for the resultant force as this is the case at the wall top and base. If the resulting axial force runs outside the wall cross-section, this is an impossible state from a mechanical point of view. The wall 'punches through'.



Why are load propagation cones only considered as auxiliaries of customary design procedures?

The concept of the load propagation angle is very well suited for the approximation of the stress distribution immediately underneath a concentrated load over an elastic half-space. The known value α = 60° for the load-propagation angle is based on the evaluation of the stress amplitudes at different distances underneath the concentrated load. Conversely, the stress values result at any depth if you divide the value of the concentrated load by its propagated contact length.

In line with customary design practice, the propagation angle is also used to approximate the stress amplitudes next to the line of action of the concentrated load. Due to the block-shaped mapping of the vertical stress, the calculation becomes more and more unrealistic when the lateral distance increases. The calculated overlapping of the propagation cones of several adjacent concentrated loads can assume an unrealistic state very quickly. A more accurate mapping by means of a diaphragm-related calculation would provide remedy. This is however very laborious and would create additional problems in view of stress irregularities, for instance.



Action Groups - be careful with imposed loads of the categories A to D

According to EN 1991-1-1, imposed loads of the categories A to D are not considered as independent variable loads. Therefore, instead of assigning the imposed loads to their actual category specified by EN 1990, they must be assigned to the most unfavourable of all categories!