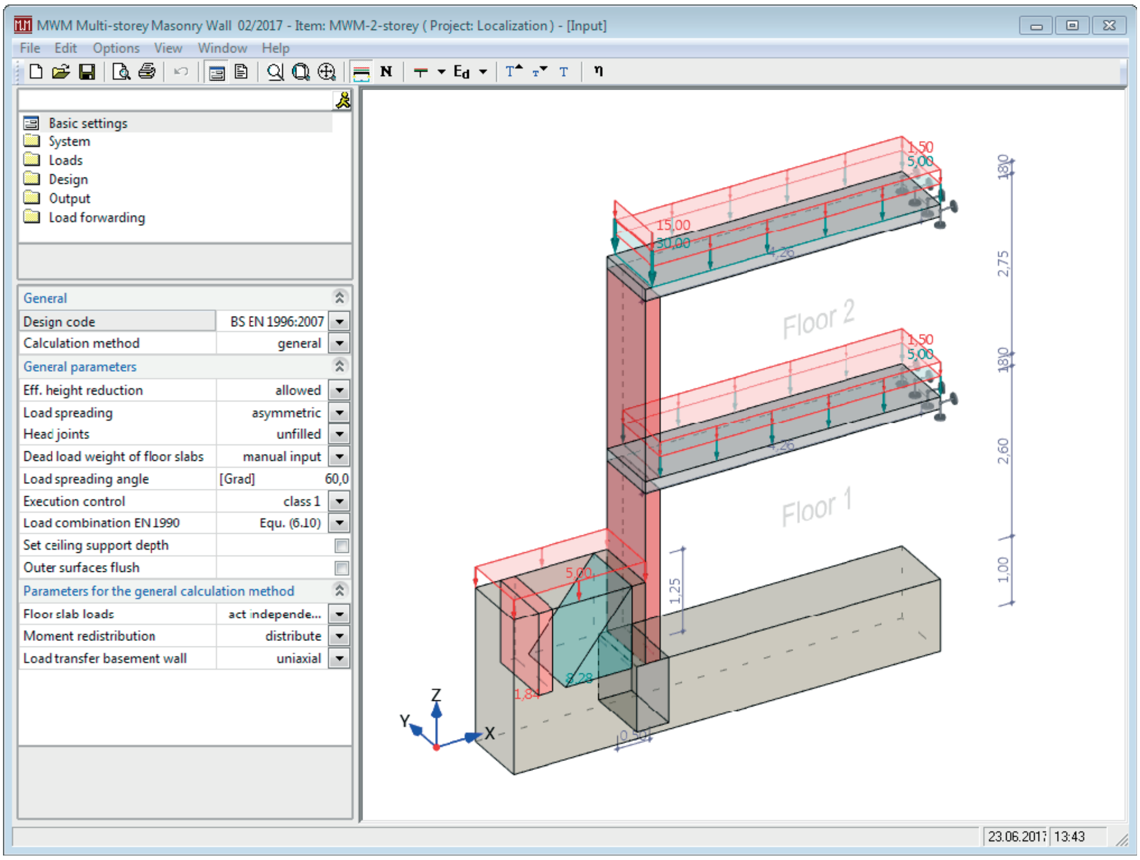
Multi-storey Masonry Wall MWM

FRILO Software GmbH
www.frilo.com
info@frilo.eu

As of 23/06/2017



Multi-storey Masonry Wall MWM

Contents

Further information and descriptions are available in the relevant documentations:

FDC – Basic Operating Instructions	General instructions for the manipulation of the user interface
FDC – Menu items	General description of the typical menu items of Frilo software applications
FDC – Output and printing	Output and printing
FDC - Import and export	Interfaces to other applications (ASCII, RTF, DXF …)
FCC	Frilo.Control.Center - the easy-to-use administration module for projects and items
FDD	Frilo.Document.Designer - document management based on PDF
Frilo.System.Next	Installation, configuration, network, database

Application options

MWM is a general design application for the analysis of the structural safety of multi-storey walls that are made of artificial bricks and have a rectangular cross section. You can optionally perform the design in accordance with

- DIN 1053-100:2007-09 (partial safety concept)
- EN 1996-1-1 (more accurate calculation method)
- EN 1996-3 (simplified calculation method)

in combination with the respective National Annex. The following NAs are available DIN EN 1996-1-1/-3, ÖNORM B 1996-1-1/-3, NA to BS EN 1996-1-1/-3, NEN EN 1996-1-1/NB and prNBN EN 1996-1-1 ANB.

You can perform the verification using either the simplified method or the more accurate method, unless this is excluded by national regulations. When applying the simplified calculation method, MWM checks compliance with the limits of application. If these limits cannot be met, the more accurate calculation method is available as an alternative.

The calculation also includes stability verifications of basement walls and the determination of the lateral earth pressure in standard cases, if earth pressure applies. Storey floors can be supported either on the left, on the right or on both sides. In addition, projecting 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.

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

- wall loads from storeys above
- concentrated support loads at the wall head
- floor loads

and/or horizontal effects resulting from

- wall loads applying perpendicular to the wall plane (e.g. due to wind and earth pressure)
- soil (perpendicular to the wall plane)

MWM generates automatically the appropriate load cases and load case combinations depending on the defined actions and performs the necessary analyses, whereby the decisive load case combination is determined for each storey and for each individual verification.

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

Scope of performance

- General load situation including
  - Floor loads
  - Evenly distributed or linearly variable structural wall loads
  - Concentrated support loads
  - Wall loads perpendicular to the wall plane
  - Soil loads
- Detailed material definition
  - Material according to the selected design standard
  - Material database for masonry officially approved by the German Institute for Construction Technology DIBT for the design in accordance with DIN 1053-1 and DIN 1053-100
  - Manufacturer's database for masonry bricks of Wienerberger Ziegelindustrie GmbH Österreich in accordance with ÖNORM B 1996
  - User-defined material
- Load transfer to the Frilo applications 'Strip Foundation' and 'Reinforced Raft Foundation.'
- The system and the loads can be entered completely via the interactive GUI.

Basis of calculation

General

The standard series DIN 1053 in its current versions (DIN 1053-1; 1996-11 and DIN 1053-100:2007-09) constitutes the basis of calculation in the MWM application. In addition to this, the design can be performed in accordance with Eurocode 6, particularly its parts EN 1996-1-1, EN 1996-1-2 and EN 1996-3. The National Annexes for Austria, UK, Netherlands and Belgium are implemented in the current software version (NEN and NBN only part 1-1, as no National Annexes are available yet for part 3).

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

Recommendations of literature (only available in German)

/1/ Wagner, Ingo, Dipl.-Ing., Dipl.-Wirt.-Ing. (FH), Hoffmann, Jens, MSc: „Berechnung von Mauerwerk - Vergleich DIN 1053-1 / DIN 1053-100“ in FRILO-Magazin 2008, Friedrich+Lochner GmbH: Stuttgart, 2008.

/2/ Wagner, Ingo, Dipl.-Ing., Dipl.-Wirt.-Ing. (FH), Hoffmann, Jens, MSc: Berechnung von Mauerwerk nach ÖNORM EN 1996, in: FRILO-Magazin 2010, special edition Mauerwerk ÖNORM EN 1996, Friedrich+Lochner GmbH: Stuttgart, 2010.

/3/ Wagner, Ingo, Dipl.-Ing., Dipl.-Wirt.-Ing. (FH), Hoffmann, Jens, MSc: Berechnung von unbewehrten Mauerwerkspfeilern aus künstlichen Steinen nach DIN 1053 und EN 1996, in: FRILO-Magazin 2010, Friedrich+Lochner GmbH: Stuttgart, 2010.

Load cases for the calculation of the internal forces

The application generates load cases with the loads entered by the user irrespective of the selected standard and calculation method. The selected standard and calculation method are taken into consideration through the configuration of the structural system (which varies for the simplified and the more accurate calculation method) on the one hand, and through the calculation of superposition factors that are included in the calculation together with the load cases (partial safety factors and combination coefficients for actions) on the other. 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 on the wall to be verified. Horizontal actions have the effect of plate-related loading on the wall. 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.
3	G_h	Permanent portions of the horizontal wall loads, only in combination with the more accurate calculation method.
7	Q_G	The half of the variable portions, with respect to amount, of all vertical floor loads that may be handled as permanent actions in accordance with DIN 1053-1 as well as DIN 1053-100. This does not apply to the design in accordance with EN 1996.
8	Q_v	Variable portion of a single vertical load.
9	Q_h	Variable portion of a single horizontally applying load (plate-related loading)
10	Q_S	Variable portion of each single horizontal bracing load
11	A_h	Accidental portion of horizontal wall loads

Special regulations by DIN 1053 - quasi-permanent actions

According to DIN 1053, imposed variable vertical loads applying to floors may only be included with half of their value in the calculation if they should be treated as permanent loads. This special treatment helps to keep the splay angle of the node moments within realistic limits and can be dispensed with in the simplified method because the analysis of stability is performed via load-independent reduction factors. Therefore, eccentricities are not calculated explicitly. Consequently, the load case Q_g is not generated when using the simplified calculation method.

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

Variable vertical actions

When applying the simplified calculation method, only a single load case Q_v is generated from all vertical live loads acting over the total length of the wall. 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 of its amount in each case.

Variable horizontal actions

The load cases Q_h are only generated in combination with the more accurate calculation method.
The user cannot define accidental horizontal actions that act perpendicular to the diaphragm, application-internal calculation processes require however in some cases two appropriate A_h load cases for the analysis of particularly slender walls in accordance with DIN 1053-1, Para. 6.9.1 or 7.9.2 and DIN 1053-100, Para. 8.9.1.4 or 9.9.1.4.

Load case combinations for the calculation of the internal forces

In masonry construction, quite a 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. If the design is performed in accordance with DIN 1053-1, this distinction can be dispensed with. The table below gives an overview of the assignment of load case combinations to the corresponding analyses.

DS[1)]	**Description**
Ed[2)] EdA[3)]	Analysis with compression stress
Ed EdA	Analysis with plate-related shear
Ed EdA	Limitation of the gaping joint through the thickness of the wall (plate-related loading). Only when designing in accordance with DIN 1053.

1) *Design situation, distinction only when the analysis is based on the partial safety concept*

2) *Permanent and transient design situation*

3) *Accidental design situation*

Calculation of the characteristic values of the internal member forces

General

The characteristic values of the internal actions are calculated separately for each load case. To do this, different structural systems are used depending on the internal forces to be verified.

In general, the calculation of the internal forces is performed on a plain equivalent system (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 torsion of the floor supports 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 head and base moments up to full restraint is permissible when the balance is preserved and the cracking of cross sections is taken into consideration.

Therefore, the internal forces resulting from the torsion of the floor edges and those due to the plate-related loading (horizontal loading) must be calculated on different structural systems. We will explain this in detail below.

Structural systems for the more accurate analysis

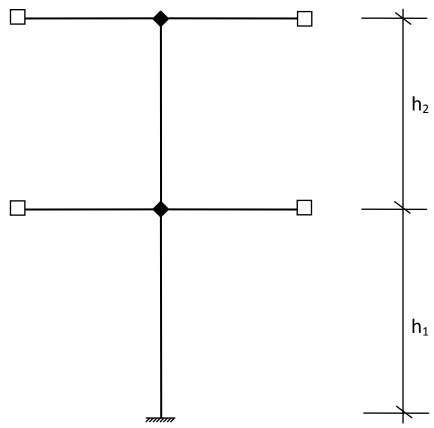
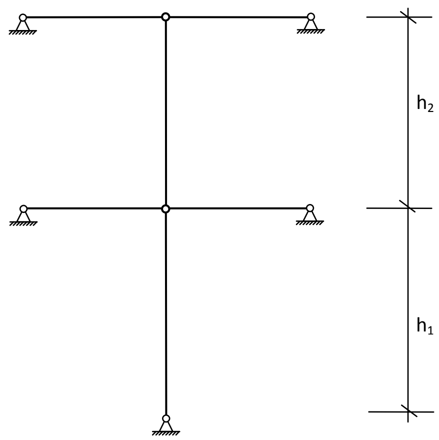
The axial forces are calculated on a pinned member. In MWM, you can take the continuity effect of the intermediate floors into account via

- the structural system of the intermediate floor (single-span or two-span system)
- the definition of continuity factors (Winkler coefficients for each load case)
- the definition of the support reactions of the floor slab transferred to the wall

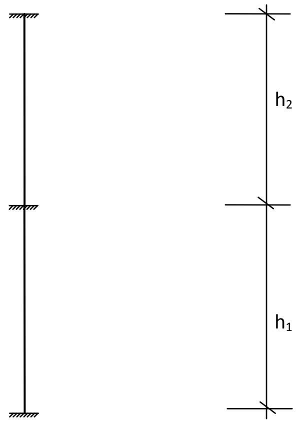
By using the first or second method mentioned above, the axial force transfer can be decoupled from the node moments – this is important if the floor support reactions have been determined beforehand in a FE plate-related calculation, for instance.

The calculation of the moments in the wall-floor nodes is performed on an equivalent member system in accordance with the geometric dimensions of the walls and the intermediate floors defined by the user as well as the support conditions at the opposite ends. A rigid restraint in the foundation structure is assumed at the base of the lowest wall.

Under these border conditions, up to three structural systems are generated depending on the load situation. 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 diagram (example: interior wall over two storeys)
System I[1)]	Calculation of the base and head moments due to floor support torsion. The walls and floors are rigidly joined to each other. The supported floor edges are assumed either pinned, restrained or freely projecting depending on the user-defined supporting conditions. The base of the lowest wall is restrained.	
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 floor are rigidly joined to each other. The supported floor edges are pinned. Axial forces are modified in accordance with the continuity factors entered by the user, the specified support reactions and/or the defined structural system of the intermediate floor. The wall moments calculated on this system correspond to the values that have not been redistributed.	

<table>
<tr><td>System III</td><td>Calculation of the moments of the fully fixed end resulting from horizontal wall loads (plate-related effects)

The nodes at the wall base and wall head are restrained. Consequently, members that are restrained on both sides are generated for each storey. The result of the calculation on this system are the moments of the fully fixed ends, i.e. the maximally redistributable moments at the wall base and the wall head.</td><td></td></tr>
<tr><td>1)</td><td colspan="2">When performing the design in accordance with DIN 1053, the bending moments and shear forces are reduced to 2/3 of their amount (DIN 1053-1, Para. 7.2.2. or DIN 1053-100, Para. 9.2.2). This method is also applied in combination with ÖNORM B 1996-1-1 because the Austrian standard is very close to DIN 1053.

When performing the design in accordance with EN 1996-1-1, the bending moments and shear forces resulting from the floor torsion are reduced by the factor km in accordance with equation (C.2).</td></tr>
</table>

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 intermediate floors

When applying the more accurate method, the bending moments resulting from imposed vertical loads applying to the intermediate floors must be calculated. The calculation is based on system I. The node moments are always calculated using the values of the defined floor loads (area loads).

The results of this calculation are on the safe side because the calculated restraint of the wall/floor node cannot be achieved due to the cracking of the cross sections and the resulting loss of stiffness. Therefore, the bending moments must not be reduced. In accordance with DIN 1053, the bending moments and shear forces are reduced in a general manner using the factor 2/3. EN 1996-1-1, Annex C prescribes an empirically derived reduction factor $0.5 \leq \eta \leq 1.0$, based on the overall stiffness of the wall-floor node. Due to the strong affinity of German and Austrian masonry structures, the verification in accordance with ÖNORM B 1996-1-1 is based on the reduction factor stated by DIN 1053.

Internal forces resulting from concentrated loads, sectional line loads and trapezoidal loads

In the MWM application, the propagation of vertical loads over the wall height is traced as shown in the table below.

Load type	Propagation	Explanation
Uniformly distributed load	No	Uniformly distributed loads act over the total length of a wall. 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 supporting area for the verification. If concentrated loads apply, the conventional verification of the compression effects at the wall head 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 of 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 load trains from trapezoidal loads.

As a standard, a load propagation angle of 60° in relation to the horizontal axis is assumed for the distribution of the load. Alternatively, you can define a load propagation angle in the range of $0° < \alpha \leq 90°$ (α=90° is the limit angle at which load propagation does not take place any longer; the neglection of the load propagation is often required by approvals of the construction authorities where large-format masonry elements are concerned).

The concentrated loads produce exclusively axial wall forces. Possible eccentricities are not relevant for the determination of the internal forces as defined in the standard (concentrated loads resulting from supported girders)

If concentrated loads, line-section loads or trapezoidal loads apply to a wall, the verifications are performed on several vertical cuts along the wall length axis. In this case, the supporting points lie in the centre (on the edge with trapezoidal loads) of the segments that result from the intersection with each level line of the referenced axial wall force (see Figure 1). The software uses internally at least 14 level cross sections with consideration of the defined horizontal loads.

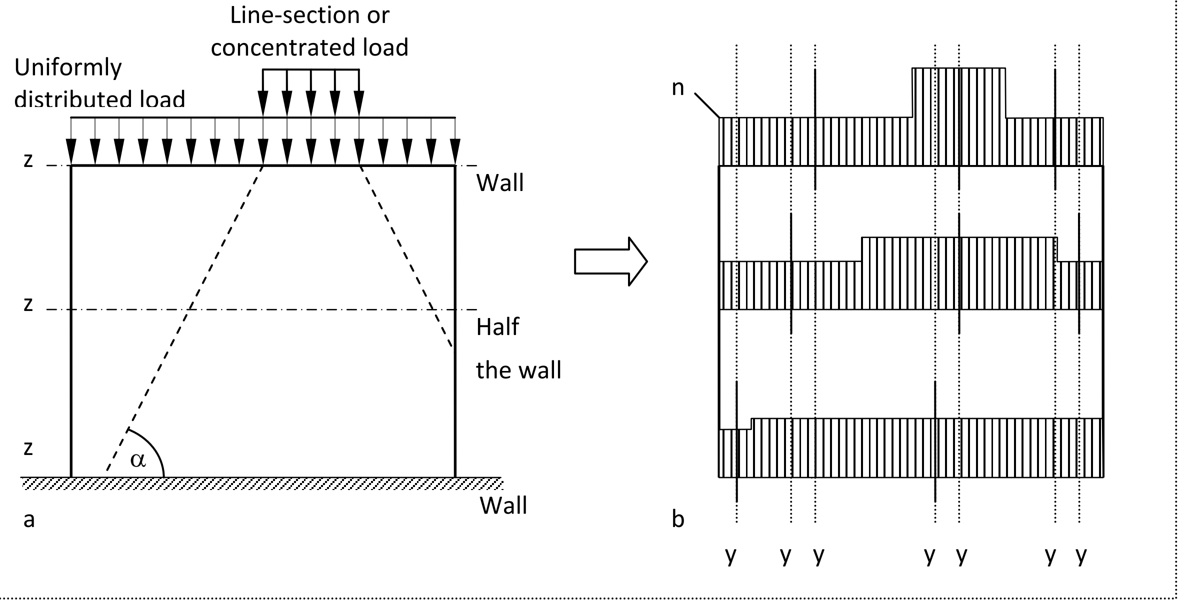


Figure 1 Exemplary presentation of the location of the examined vertical sections with only three level sections a) Loading situation and level sections, b) Axial force distribution in the level sections and location of the vertical sections

Redistribution of moments

Fundamental theoretical considerations

The internal forces resulting from horizontal loads, such as earth pressure or wind, are calculated on the pinned single-span beam. The subsequent analysis is based on the greatest bending moment.
The design based on the maximum bending moment is far on the safe side because the favourably acting eccentricities of the axial forces are not considered. They result from the fact that a horizontal load causes an inward or outward deflection and that the wall cannot wrench or twist freely between the intermediate floors or between the foundation and the next floor. Restraint moments occurring at the wall head and base reduce the bending moment calculated on the single-span beam.

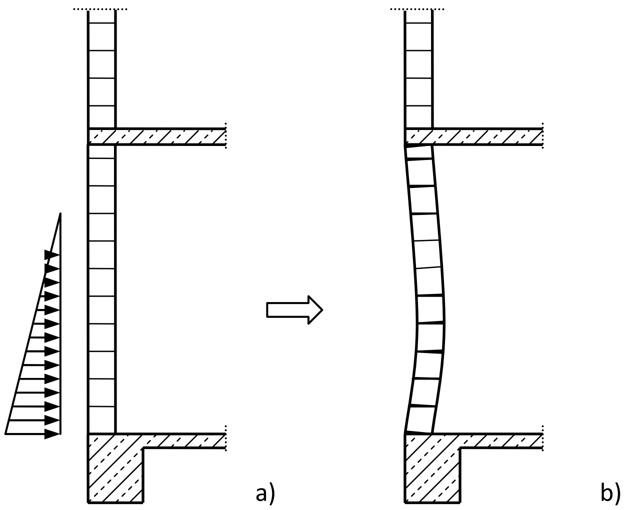


Figure 2: Loading situation on basement wall (a) und deformed structural system with gaping joints (b)

The maximum value of the fixed-end moment is determined by the permissible maximum eccentricity of the axial force through the thickness of the wall |max e| (depending on the selected standard). Therefore, the following fixed-end moments can be considered:

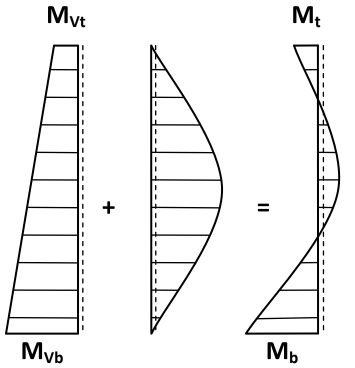
At the wall head $M_t = -N_t \cdot |\max e|$

At the wall base $M_b = -N_b \cdot |\max e|$

N_t axial force at the wall head
N_b axial force at the wall base
|max e| value of the permissible max. eccentricity

Due to the torsion of the floor, some of the cross sections may present already cracks. You should therefore take existing eccentricities at the wall head and base into consideration.

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



The fixed-end moments to be considered are calculated as follows:

$M_t = \pm N_t \cdot (|\max e| \pm e_t)$

$M_b = \pm N_b \cdot (|\max e| \pm e_b)$

whereby e_t and e_b are the controlled eccentricities resulting from vertical loads.

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

$M_t = \max[-N_t \cdot (|\max e| - e_t), M_{vt}]$

$M_b = \max[-N_b \cdot (|\max e| - e_b), M_{vb}]$

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

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

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

Simplified method

When applying the simplified method, you cannot take horizontal loads into account. Therefore, a moment redistribution is not relevant.

Calculation of the design values of the internal forces

The internal member forces for the internally generated load cases are available as characteristic values. They are combined to design values of the internal member forces with consideration of the stipulations of the applicable design standard.

Subsequently, the internal member forces are superimposed with the related internal forces resulting from the load propagation under concentrated loads. If required, the maximum related 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.

Note: *The number of possible load combinations increases exponentially with the growing number of loads. To minimize computing time and/or to ensure that systems with several storeys and complex loading situations are computable, loads of the same kind and resulting from the same action should always be combined (e.g. floor self-weight and floor superstructure should be combined to a single floor load).*

Verification process

Verification points

MWM performs the following verifications provided that the user has defined loads producing corresponding effects of actions.

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

Analyses in accordance with DIN 1053-100

Analyses based on the simplified calculation method

When you set the parameter "Verification points" to the value "Maximum axial force" in the Basic parameters section, the following analyses are performed using the simplified calculation method:

Verification point	Verifications	Comment
Wall base	Resistance of cross sections to axial loads[1)]	incl. impact of an undesired horizontal concentrated load H=0.5 kN, if applicable
Wall head	Partial area compression under concentrated loads	

[1)] If the effects of actions resulting from load propagation under concentrated loads at half of 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 head" in the Basic parameters section, the following analyses are performed using the simplified calculation method:

Verification point	Verifications	Comment
Wall head	Resistance of cross sections to axial loads	Bearing load reduction due to rotation angle of the supported floor plane
	Bearing stress under concentrated loads	
Half of the wall height	Resistance of cross sections to axial loads	Bearing force reduction due to effective slenderness, incl. impact of the undesired horizontal concentrated load H=0.5 kN, if applicable
Wall base	Resistance of cross sections to axial loads	Bearing force reduction due to the rotation angle of the lower floor plane

Analyses based on the more accurate calculation method

Verification point	Verifications	Comment
Wall head	Resistance of cross sections to axial loads	
	Shear resistance under plate-related shear	
	Partial area compression under concentrated loads	
Half of the wall height	Resistance of cross sections to axial loads	incl. the impact of the undesired horizontal concentrated load H=0.5 kN, if applicable
	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 plate-related shear	

Analyses in accordance with EN 1996-1-1

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

Verification point	Verifications
Wall head	Resistance of cross sections to axial loads
	Shear resistance with diaphragm-related and plate-related shear
	Partial area compression under concentrated loads
Half of the wall height	Resistance of cross sections to axial loads 1)
Max. eccentricity through the thickness of the wall	Resistance of cross sections to axial loads
Wall base	Resistance of cross sections to axial loads
	Shear resistance under diaphragm-related and plate-related shear

1) The verification of the axial-force resistance at half of the wall height ("buckling stability verification") is based on the relation Ek/fk = 700.

Analyses in accordance with EN 1996-3

The analysis in accordance with EN 1996-3 is based on the simplified calculation method. The following verifications are performed:

Analyses based on the simplified calculation method

When you set the parameter "Verification points" to the value "Maximum axial force" in the Basic parameters section, the following analyses are performed using the simplified calculation method:

Verification point	Verifications	Comment
Wall base	Resistance of cross sections to axial loads[1)]	
	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 head	Partial area compression under concentrated loads	

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

When you set the parameter "Verification points" to the value "Separately for wall base, wall middle and wall head" in the Basic parameters section, the following analyses are performed using the simplified calculation method:

Verification point	Verifications	Comment
Wall head	Resistance of cross sections to axial loads	Bearing load reduction due to rotation angle of the supported floor plane
	Shear resistance under diaphragm-related shear	
	Bearing stress under concentrated loads	
Half of the wall height	Resistance of cross sections to axial loads	Bearing force reduction due to effective slenderness, incl. the impact of the undesired horizontal concentrated load H=0.5 kN, if applicable
Wall base	Resistance of cross sections to axial loads	Bearing force reduction due to the rotation angle of the lower floor plane
	Shear resistance under diaphragm-related shear	

Design situations and load combinations IAW DIN 1053-100

Verifications	Design situation/load combination
Resistance of cross sections to axial loads	Permanent/transient or accidental situation
Shear resistance	Permanent/transient or accidental situation
Limitation of the controlled eccentricity	Characteristic loads (include accidental loads but no seismic loads)

The accidental combination is always examined when either the user has assigned bracing loads to the accidental loads or the accidental horizontal loads H=0.5 kN must be included in the analysis of the resistance of cross sections to axial loads and these horizontal loads are assumed to be distributed over the total wall length (is done automatically). In each case, the analysis in the permanent/transient design situation is performed before.

Basic parameters

General

Standard

Allows you to select the design standard that constitutes the basis of the structural safety analysis.

Verification method

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

Both, DIN 1053-1 and DIN 1053-100 describe a simplified and a more accurate calculation method for the analysis of masonry walls. The design in accordance with EN 1996-1-1 is based on the more accurate method. A simplified procedure that is comparable to that of DIN 1053 in its essential parts is included in EN 1996-3.

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

General parameters

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.

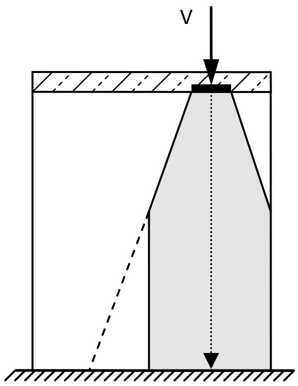
The user must inform himself/herself about existing approvals and their contents and make the corresponding adjustments.

Load propagation

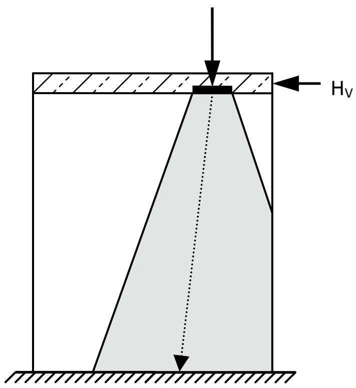
Specification whether the load propagation area under concentrated loads should always be assumed as being symmetrical or might also be asymmetrical. The selection of the correct option is only relevant when the load propagation area is limited by the intersection with the vertical wall ends. If asymmetrical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

Value | **Description** | **Schematic diagram**

Symmetrical — Only the symmetrical portion of the load propagation area is included in the calculation of the related axial force.



Asymmetrical — The load propagation area is fully considered in the calculation of the related axial force. The absorption of the generated drive force H_V must be ensured by adjacent diaphragms.



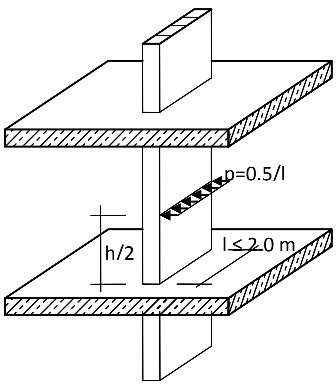
Transversal joint solidification

Specification whether the transversal joints of the masonry bond are solidified. This option influences the magnitude of the bond shear resistance of the masonry.

Analysis of slender walls (only in combination with DIN 1053)

Specification whether the analysis of a slender wall should take a horizontal load of 0.5 kN (equally distributed over the total wall length as per DIN 1053-1, Para. 6.9.1 or 7.9.2 and DIN 1053-100, Para. 8.9.1.4 or 9.9.1.4) into account.

For walls with a length of less than 2.0 m and a thickness of less than 17.5 cm that are retained on two sides (exception: DIN 1053-1, more accurate method, no limitation of the wall thickness) a structural safety analysis assuming a horizontal load of 0.5 kN that applies at half of the wall height must be performed if the effective slenderness h_k/d is greater than 12. According to the partial safety concept, this load case should be classified as accidental.



If the calculation is performed for a wall with a length of more than 2 m assuming a 1-m-strip, you can dispense with this analysis by switching off this option.

Floor self-weight

This option allows the user to select whether the construction weight of the supporting layer of the intermediate floor should automatically be included in the calculation by MWM or not. The continuity factor is calculated from the floor geometry and the supporting conditions in this case.

Load propagation angle

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

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

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

Execution control (only if required by the selected National Annex)

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

Consequence class (only if required by the selected National Annex)

Defines the consequence class in accordance with EN 1990. The consequence class provides the basis for the determination of the partial safety factors to be applied to the actions.

Load combinations as per EN 1990 (only if required by the selected National Annex)

Specifies which of the two combination rules (eq. 6.10 or eq. 6.10a/b) shall be applied if the selected National Annex allows a selection.

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

It 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 (only for a verification as per EN 1996-3)

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

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.

This factor is specified by the selected design standard (DIN 1053-100: $\Phi_3 = 1/3$, EN 1996-3: $\Phi_s = 0.4$) for end supports of floors above the topmost full storey. 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. The following applies: $\Phi_3 = 1.0$ or $\Phi_s = 1.0$.

Verification points

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

In manual calculation, 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 of the wall height) irrespective of whether the reduction factor assumes its most unfavourable value at the wall head, the wall base or at half of the wall height.

Neither DIN 1053 nor EN 1996-3 require a separate consideration of the verification points and the accompanying coincidence of the point of the effect calculation and the effective bearing load-reducing impacts for the design. Under normal conditions, this consideration produces more favourable analysis results.

Verifications	Verification point "Wall base"	Verification point "Separately considered"
Compression	Max. effects of actions over the total wall height (wall base, half of the wall height, if required) Analysis with the highest resultant bearing load reduction (slenderness or floor torsion at the wall head or base).	Analysis with bearing load reduction due to floor torsion at the wall head and base Analysis with bearing load reduction due to slenderness at half of the wall height.

Parameters for the more accurate method

Floor loads (only in combination with 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).

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 head and the wall 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 with consideration of balance preservation. If you deselect the redistribution of moments the moment behaviour is determined over the wall height and the wall head and base are assumed pinned.

Structural system

Walls

Type

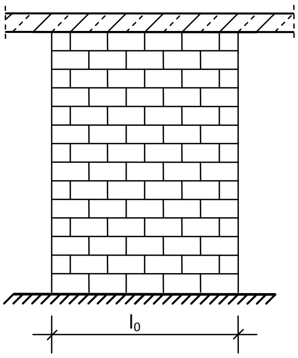
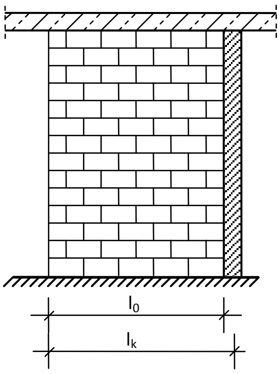
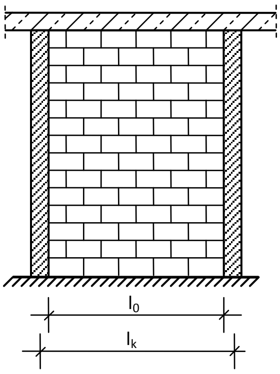
Specification whether the wall is a single-leaf or a multi-leaf wall. In certain cases, it is important to know whether the wall to be calculated is an interior or exterior wall (single-leaf or multi-leaf). This information is required to check compliance with the limiting criteria for the application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

Support

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

Value	Description	Schematic 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)

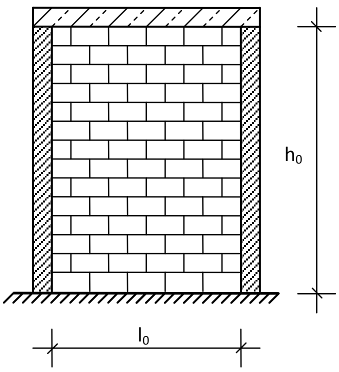
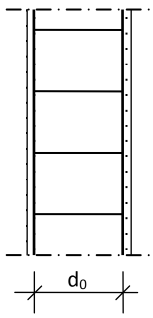
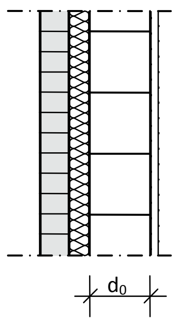
In addition to the number of retained sides, also the thicknesses of the retaining diaphragms must be entered. The application checks internally whether the wall thicknesses are relevant regarding the selected design standard.

The minimum lengths of these walls stipulated by DIN 1053-1 and DIN 1053-100 or EN 1996-1-1 are not checked. The user must do this manually!

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

Geometry of the wall - height / thickness / length

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

Value	Description	Schematic 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 as effective wall length for the diaphragm-related shear analysis).	
d_0	Thickness of a single-leaf wall or thickness of the bearing layer of a multi-leaf wall	 

Spacing of transversal bracing walls

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.

SW addition

Self-weight addition, e.g. for the wall lining (total of exterior and interior plaster layer).

Foundation projection

For a verification as per DIN EN 1996, you can define a wall projection beyond the edge of a slab foundation or reinforced raft foundation. This projection is considered in the calculation and in the verification in the same way as partly supported floor slabs.

Text

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

Intermediate floors

Type

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

Type

Specifies the type of construction of the floor. Currently, only solid floors 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. The conditions under joist ceilings can be simulated by the user by entering concentrated loads or via distributed eccentrically applying vertical wall loads, see also the chapter "Frequently asked questions".

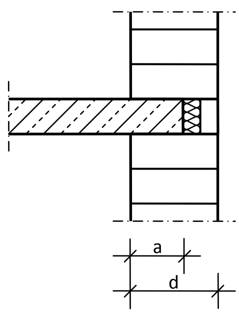
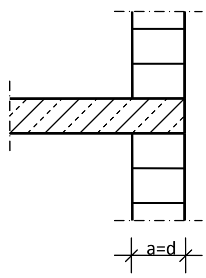
Thickness

Thickness of carcass floor. It applies to both sides of the floor. Different thicknesses at the left and the right side are currently not allowed.

Modulus of elasticity

Calculated or characteristic value of the modulus of elasticity of the floor slab. Is only relevant for analyses based on the more accurate calculation method (calculation of internal forces resulting from the torsion of the floor supports).

Geometry of the floor

Value	Description	Schematic diagram
Support length a le/ri	Support length of the left/right intermediate floor. ***Note: Is only relevant for the calculation of the effective length. No local effects resulting from partly supported floor slabs are verified!***	 
Span l le/ri	Span of the left / right intermediate floor; 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!***	
Support Sup le/ri	Supporting conditions at the opposite end of the left/right floor slab: projecting, pinned or restrained (defines an equivalent structural system for the calculation of the node moments and the automatic calculation of the continuity factors of floor loads, if applicable).	

Foundation

The MWM software allows the specification of the geometric dimensions of different foundation types. These specifications are only used for the graphical representation of the structural system and for the load transfer to the corresponding foundation software applications.

The load-bearing capacity of the foundation structure is not verified!

Type of foundation

Specification of the type of foundation: foundation slab, strip foundation or reinforced raft foundation.

Foundation height h_0

Vertical extension of the foundation.

Foundation width b_0 (not for foundation slabs)

Extension of the foundation in the direction of the span (through the thickness of the wall). Only in combination with a strip foundation and the strip portion of a reinforced raft foundation

Foundation length l_0

Extension of the foundation through the length of the wall. It must at least be equal to the length of the lowest wall.

Slab thickness d_p (not with strip foundations)

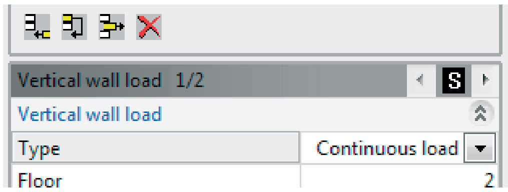
Thickness of the foundation slab for spread foundations.

Comments

You can enter descriptive texts for the system that appear in the output.

Loads

Select loads



Select/enable the desired loads by activating the "S" button or the arrow keys left/right ( ). The values/data-entry fields for the selected load are displayed.

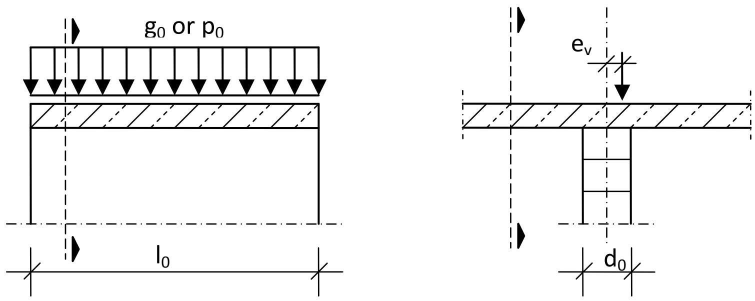
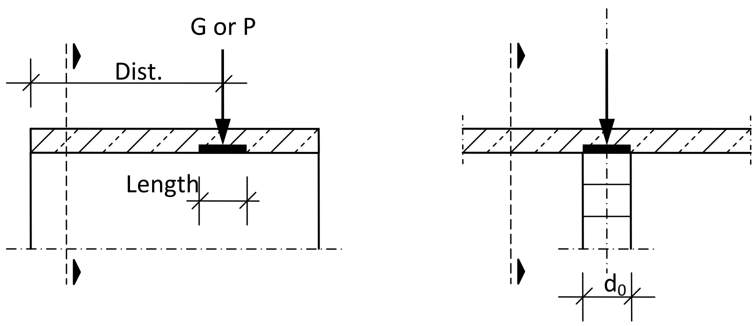
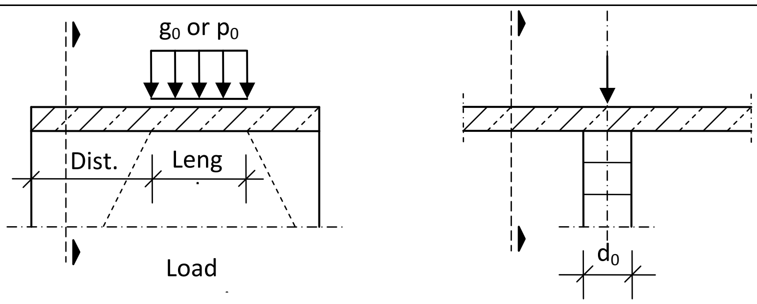
The toolbar above the data-entry section allows you to insert, copy or delete loads. The functions of the individual buttons are described in the displayed "tooltips".

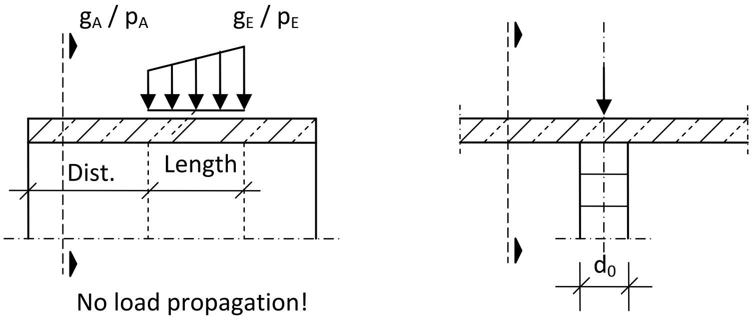
Vertical wall loads

Type

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

Concentrated loads are always assumed acting centrically through the thickness of the wall. You can assign an eccentricity to uniformly distributed loads through the thickness of the wall.

Uniformly distributed load: *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 section of the wall length.*	

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

Distance

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

G / Q or g_0 / q_0

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

Load length

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

e (only for the more accurate method)

Eccentricity of the action plane of a force through the thickness of the wall. This option is only available in combination with uniform linear loads acting over the entire wall length.

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 possibility to define an eccentricity has been implemented in the first place to map partially supported floor slabs with a low supporting depth, i.e. the relocation rule is possibly applied to the resulting eccentricity moments. **Therefore, this option is not suitable to map applying external moments (from brackets or similar structures, for instance).**

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.

Act. Grp.

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.

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 load train rather in the form of a 'pyramid' than segment by segment. The pyramid-type definition takes account of the fact 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.

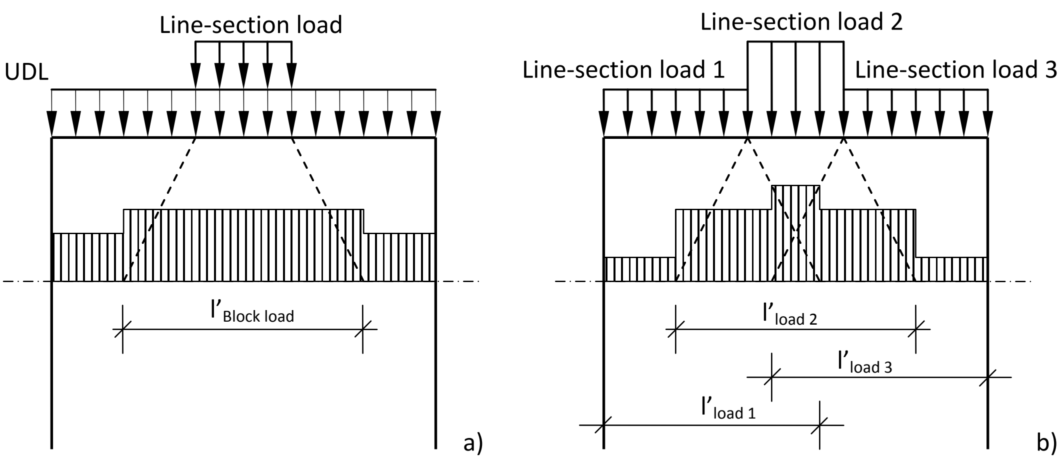


Figure 1: Use of line-section loads: a) correct load propagation in compliance with design practices b) unrealistic overlapping of the load propagation cones

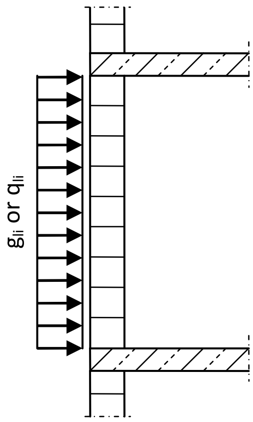
Horizontal wall loads

Note: *The effect of horizontal loads is considered individually for each wall in the design according to best practices, i.e. the influence of a horizontal load is limited to the wall to which it applies. In literature, this method is justified with the restraining effect of the concrete floor slabs, which normally have a considerable greater stiffness than the walls with gaping joints. If such a restraining effect is not given, e.g. where wood joist ceilings or scaffolds for temporary stabilisation of the facade are concerned, the examination must be based on a continuous beam. The MWM application is not suitable for this type of examination.*

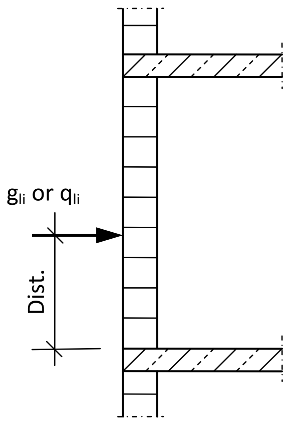
Type

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 distributed over the wall height).

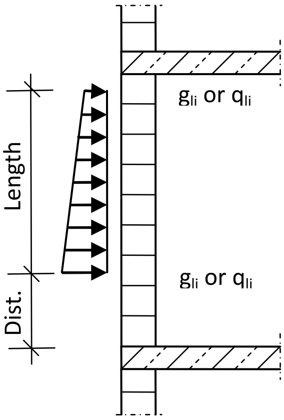
Uniformly distributed load *(constant area load)*



Concentrated load *(line load constant over the wall length)*



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



Load values

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

Act. Grp.

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.

Floor loads

Type

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

Plane

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

Act. Grp.

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.

Continuity effect

Selection whether the calculation of the support reactions of the floor shall be based on user-defined continuity factors (Winkler coefficients for each load portion), on the structural system of the floor (defined floor dimensions + supporting conditions on opposite side) or on pre-set support reactions of the floor (for each load portion).

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 on the left / right side of the floor in [kN/m²]
q le/ri	Variable load portion on the left / right side of the floor in [kN/m²]

Continuity factors (only if the continuity effect is defined accordingly)

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 loading rate of the wall cross-section (resistance against plate-related loading). Lower structural loads might cause the premature failure of the wall. Therefore, the continuity of the floor above must be taken into consideration under certain circumstances.

The masonry standards provide simplified regulations stating the conditions that allow a neglection of the continuity of floor slabs. To implement this concept in a general manner, so-called continuity factors can be included in the definition of floors in MWM. 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).

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

Example 1:

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

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

Example 2:

As example 1, however with end support

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

Example 3:

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

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

Example 4:

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 area loads applying to projecting floor spans are > 1.0.*

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

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

In many cases, the floor support reactions are not calculated on the equivalent system but during the floor design via FEM, however. If the limiting criteria for the application of the simplified calculation method are met, these support reactions can be used directly in the design of the wall (input in MWM 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 floors is decisive for the determination of the moments at the wall/floor nodes as well as the axial forces. However, these axial forces are hardly identical to the calculated support reactions. To be able to solve this problem, the MWM application allows the specification of the desired floor support reactions, which are converted internally into the corresponding continuity factors.
In this case, the nominal values of the floor loads must be specified!

Lateral earth pressure

Simplified method

Height of earthfill

Specification of the height of the backfilled 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 height of backfilled 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 basement 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 via the classes typically used in foundation 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 considered, if required.

Earth pressure equation

Specification of the factor for the calculation of the stress condition under increased active earth pressure. The equation is as follows: $E'_a = E_a \mu_{?} + E0 \quad (1-?)$. The following is true for the active earth pressure: $\mu = 1$, for earth pressure at rest: $\mu = 0$ and for increased active earth pressure: μ between 0 and 1.

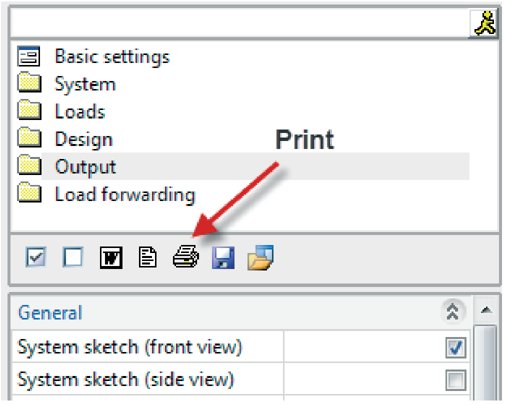
Live load

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.

Output



The available output media are the screen, MS Word and the printer. Printing or display on the screen can be launched via the corresponding icons.

Word	output directly in Microsoft Word (the editor must be installed on the local computer)
Screen	displays the data in a text window on the screen The result graphics are not shown, you can access them via the tool bar below the menu bar.
Print	starts the output on the printer

The main menu item “Output” allows you to configure the scope of the output in a detailed manner. The individual options are briefly described below.

You can display a preview of the documents to be printed in PDF format via the menu options ▸ File ▸ Page view.

General

System graph	output of a graphical representation of the total structural system
Scale	allows you to specify the desired scale for the printing of graphics. If the graphical representations cannot be printed in the specified scale, a suitable scale is selected automatically.
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

Comments	output of user-defined 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.
Intermediate floors	output of the intermediate floors in the form of a table.

Loads

Comments	output of user-defined 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 head. 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 intermediate 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

Comments	output of user-defined comments on the results (design).
Load case combinations	output of the load case combinations on which the analyses are based.
Internal forces	output of the design values of the internal forces on which the analyses are based.
Compressive stress	output of the compressive stress analysis. Always included under normal conditions.
Plate-related shear	output of the plate-related shear analysis.
Gaping joint	analysis of the gaping joint through the thickness and the length of the wall. Only in combination with DIN 1053-100.

Result graphs

Internal forces diagrams	output of the internal forces diagrams for each analysis in the ultimate limit state.
Scale	allows you to specify the desired scale for the printing of the internal forces diagrams. If the graphical representations cannot be printed in the specified scale, a suitable scale is selected automatically.

Load transfer

A feature for the transfer of loads to the analysis applications

- FDS and FDS+ Strip Foundation
- FDR and FDR+ Reinforced Raft Foundation
- MWK Basement Wall of Masonry
- MWX Masonry design

is implemented in MWM. This function allows the user to use the support reactions of walls for the verification of the components underneath and/or perform a refined analysis of individual walls in the masonry software applications suitable for this purpose.

After selection of the appropriate software, the corresponding application is launched automatically and the loading is generated in the form of the concentrated loads or load cases used in MWM. The user must simply add the component-specific details and check the transferred load values.

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 support reactions resulting from axial forces, or more precisely, the resultant 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, the user must manually add the corresponding values to the transferred loads via the input dialog of FDS.

Reinforced Raft Foundation FDR

The foundation application FDR performs the design on a strip of 1 m width, i. e. variable load behaviour over the foundation length is disregarded. The design of the foundation must take place at the point 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 by MWM, 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.

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

Masonry Design MWX (transfer)

This feature creates a new MWX item in a new program window with the selected wall. All calculation parameters as well as the geometry of the walls immediately above and below are taken over.

Basement Wall of Masonry MWK

This function allows an in-depth examination of the lowest wall in the MWK Basement Wall application. You can define very complex soil and ground topology conditions including different types of compaction in this software.

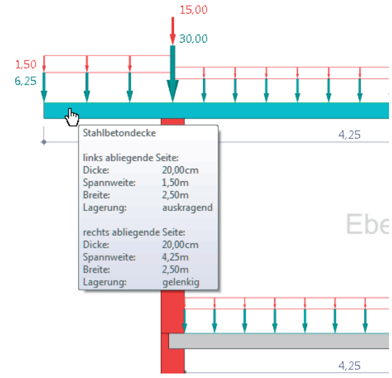
Manipulation of the GUI

The MWM application is fitted with a 3-d graphical user interface, which allows easy navigation from an object to the corresponding menu item and easy adjustment of load and component values directly on the graphic screen.

Overview of the GUI

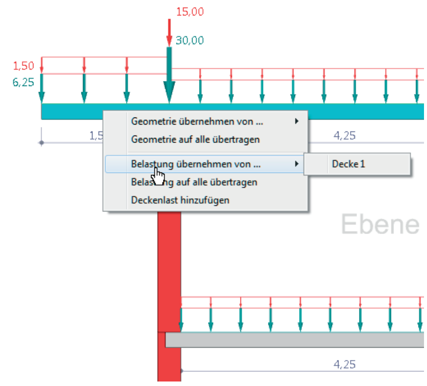
The following features are available in the GUI:

Tooltips



When hovering with the mouse cursor over loads, walls, floors etc. a summary of the decisive parameters such as load values, dimensions etc. is displayed below the cursor. At the same time, the object under the mouse cursor is highlighted in a different colour.
Note: To use this functionality, the focus must be on GUI. To achieve this, click left anywhere in the GUI.

Left-click

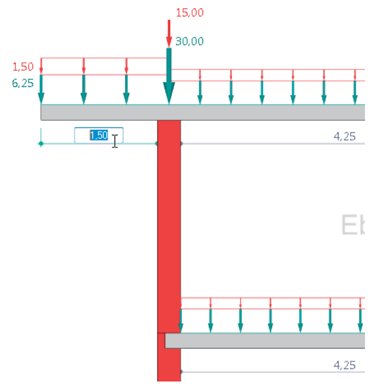


Click with the left mouse button on a graphical object (e.g. loads, walls, floors, foundation, soil, support) to display the corresponding data sheet in the data-entry area. You can edit the properties as desired.

Context menus

Right-clicking on a graphical object (e.g. loads, walls, floors, foundation, soil, supports) displays below the mouse cursor a context menu with helpful options to add or delete walls or to copy floor loads etc..
Using the context menu accelerates the creation of items considerably.

Editable load values and dimensions



The load values and dimensions on dimension chains can be edited by double-clicking on them. The usual way to change these data (via the menu) takes much more time - keyword: efficient, time-saving workflow).

Zoom, rotation and pre-defined views

Right-clicking in a free area of the GUI displays a context menu with additional auxiliary functions for the system definition (e.g. Add soil, Mirror system) and options to select pre-defined views as well as functions allowing to zoom, rotate and displace the views.

Context menus of the individual graphical objects

Walls

Add wall	adds a new wall in the standard dimensions inclusive the floor above to the structural system.
Delete wall	removes the selected wall inclusive the floor above from the system.
Inherit geometry from…	the dimensions and the type of the selected wall are applied to the currently active wall. This avoids entering the parameters several times for walls of the same kind.
Apply geometry to all	the dimensions and the type of the currently active wall are applied to all walls in the system.
Inherit material from …	the material definition of the selected wall is applied to the currently active wall.
Apply material to all	the material parameters of the currently active wall are applied to all walls in the system.
Add vertical load	adds a new vertical load with standard values at the wall head of the selected wall (uniformly distributed load over the total wall length).
Inherit vertical load from …	the vertical loads of the selected wall are applied to the currently active wall.
Add horizontal load	adds a new horizontal load with standard values (uniformly distributed load over the total wall height) to the system. The load applies to the currently active wall.
Inherit horizontal load from …	the horizontal loads of the selected wall are applied to the currently active wall.
Apply horizontal loads to all	the horizontal loads of the currently active wall are applied to all walls in the system. This option allows you to define wind loads over several storeys quickly and easily.

Floors

Inherit geometry from…	the dimensions and the support conditions of the selected floor are applied to the currently active floor.
Apply geometry to all	the dimensions and the support conditions of the currently active floor are applied to all floors in the system.
Inherit loading from…	the loads of the selected floor are applied to the currently active floor.
Apply loading to all	the loads acting on the currently active floor are applied to all floors in the system.
Add floor load	adds a new floor load with standard values to the currently selected floor level.

Floor loads

Delete floor load	removes the selected floor load from the structural system.
Delete all floor loads	removes all floor loads from the structural system.

Horizontal loads

Delete horizontal load	removes the selected horizontal load from the structural system.
Delete all horizontal loads	removes all horizontal loads from the structural system.

Vertical loads

Delete vertical load	removes the selected vertical load from the structural system.
Delete all vertical loads	removes all vertical loads from the structural system.

Floor supports

Change support conditions…	allows you to change the type of support at the opposite floor side.

Soil

Remove soil	removes the soil from the structural system.

General options (right-click in a free area without graphical objects)

View	displays a menu to configure the graphic view etc.
Add soil	adds soil with standard values to the structural system.
Mirror wall-floor system	interchanges the two sides of the defined system, e.g. to change the direction of action of the soil.

Recommended workflow when defining the structural system

Using templates

The 'Edit' menu in the horizontal menu bar on top of the screen offers templates of structural systems with interior and exterior walls and one to four storeys and templates for two-storey wall systems with soil. The standard systems generated this way can be adjusted to the desired system via the GUI in an efficient manner. Edit first a single wall, floor or load and transfer the changes subsequently to other floors and walls via the respective context menu options.

Adding a wind load that acts over all storeys

Via the context menu of any wall you can add a new horizontal load applying to this wall. Edit this load as desired (do not forget to define the action!). Apply this load subsequently to all other walls using the corresponding context menu option.

Navigating to the data-entry section of walls, floors and loads

Just click with the left mouse button on the corresponding object.

Frequently asked questions

Why can MWM not perform analyses of isolated walls?

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

What do I have to consider when using partially supported floor slabs?

When performing the structural safety analysis in accordance with DIN 1053-100 and EN 1996, you should keep in mind that both standards assume fully supported floor slabs for the analysis. Partially supported slabs are not excluded, however. Therefore, you should observe the following conditions when performing an analysis of partially supported floor slabs:

1. If the supporting length is low, an effective restraint of the floor slab in the wall is no longer given. Therefore, we recommend considering the floor as eccentrically applying vertical wall load (do not allow effective length reduction and moment redistribution at the same time!).
2. MWM always assumes full support in the cross-section analysis. An analysis of the local effects on the floor support is not performed. Because the configuration of support has a strong influence, it is left to the user to perform this analysis.

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

As a rule, MWM allows only the calculation of masonry walls loaded by solid slabs that are supported by the entire wall top surface. All structural safety analyses in accordance with DIN 1053 and EN 1996 are based on this assumption.

The provision of structurally proven ring beams or ring anchors for the lateral restraint at the wall head allows the user to perform the analyses identically at least with the simplified method.

With the more accurate method, however, the problem arises that you cannot calculate the bending moments resulting from the floor rotation angle using the conventional equivalent systems that are implemented in MWM because you must not assume restraints with joist floors. Therefore, the greatest problem is the determination of the eccentricity caused by the floor rotation angle. 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 rotation angle of the floor support but are assumed to apply at half of the wall height. Therefore, the bearing capacity at the wall head would be overestimated in the simulation process. 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 head 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.*

How can I take concentrated loads into account that do not apply directly at the wall head?

The current version of the software does not support a user-defined application height of concentrated loads (vertical wall loads). You can simulate the load propagation within narrow limits via the specification of an equivalent contact length of the concentrated load (> 0!). At the same time, you must however manually correct the loading rate in the analysis of the support compression.

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 head 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 DIN 1053 and EN 1996-1-1. WMW allows you to export every single wall to the applications MMX and MWK via the Load Transfer functions.