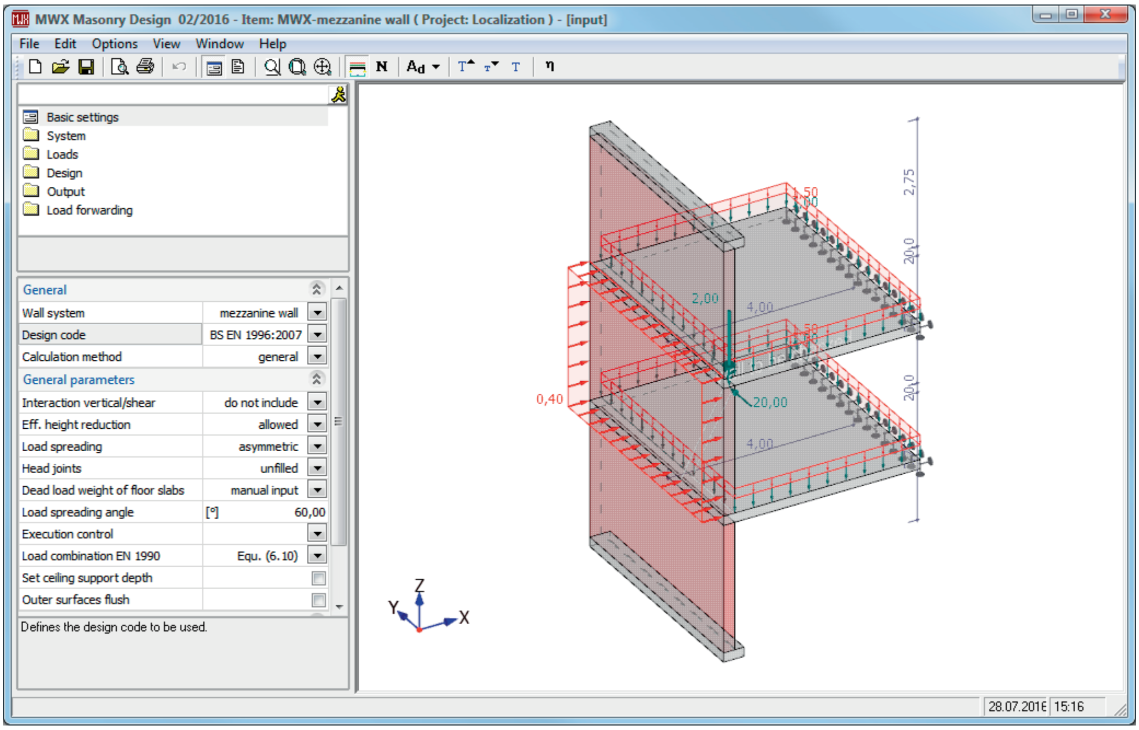
MWX - Masonry Design

FRILO Software GmbH
www.frilo.com
info@frilo.com
As of 28/07/2016



MWX - Masonry Design

Contents

Application options 5
Basis of calculation 6
General notes 6
Design values of the action-effects 6
Load cases for the calculation of the action-effects 7
Load case combinations for the calculation of the action-effects 9
Calculation of the characteristic values of the bar action-effects 10
Action-effects resulting from imposed loads on ceilings 12
Actions-effects resulting from concentrated loads 12
Action-effects resulting from bracing loads 13
Redistribution of moments 13
Calculation of the design values of the action-effects 14
Settings 15
General notes 15
General parameters 16
Parameters for the simplified method 19
Parameters for the general design method 20
System 21
Walls 21
Ceilings 23
Loads 24
Vertical wall loads 24
Horizontal wall loads 27
Ceiling loads 28
Bracing loads 31
Analysis 33
Verification points 33
Analyses in accordance with DIN 1053-1 33
Analyses in accordance with DIN 1053-100 35
Analyses in accordance with EN 1996-1-1 38
Analyses in accordance with EN 1996-3 38
Design situations and load combinations IAW DIN 1053-100 39
Output 40
General options 40
System options 40
Load options 40
Result options 41
Result graphs 41
Load transfer 42
Strip foundation FDS 42

Edge strip foundation FDR 42
Calculation examples IAW DIN 1053 **44**
Exterior wall according to the simplified calculation method 44
System and loading 44
Structural safety analysis IAW DIN 1053-1 and DIN 1053-100 45
Bracing wall plate 48
System and loading 48
Structural safety analysis IAW DIN 1053-1 and DIN 1053-100 49
Calculation examples IAW DIN 1996 **55**
Exterior wall according to the simplified calculation method 55
System and loading 55
Structural safety analysis IAW ÖNorm B-1996-3 and NA to BS EN 1996-3 57
Bracing wall plate 60
System and loading 60
Structural safety analysis IAW ÖNorm B-1996-3 and NA to BS EN 1996-3 61
Frequently asked questions **67**

Application options

MWX is a general design application for the analysis of the structural safety of individual walls with rectangular cross sections that are made of artificial bricks. You can perform the design either in accordance with

- DIN 1053-1:1996-11 (global safety concept)
- DIN 1053-100:2007-09 (partial safety concept)
- DIN EN 1996: 2015
- EN 1996-1-1 (more accurate calculation method)
- EN 1996-3 (simplified calculation method)
- and in combination with the applicable National Annexes, either ÖNORM B 1996-1-1 and ÖNORM B 1996-3 or NA to BS EN 1996-1-1 and NA to BS EN 1996-3.
- Design under earthquake actions according to DIN 4149 and EN 1998-1 resp. (incl. determination of the max. permissible earthquake zone)

You can base your analysis either on a simplified or a more accurate calculation method. When applying the simplified calculation method, MWX checks compliance with the limits of application. If these limits are not adhered to, you can apply the general calculation method.

In addition to individual walls, you can perform calculations for structural systems of basement, intermediate storey and top storey walls. You can define floor slabs to be supported on the left, the right or both sides. Also cantilevering 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 cast concrete slab and supports it.

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

- wind loads from storeys above
- concentrated bearing loads at the wall head
- ceiling loads

and/or horizontal effects resulting from

- wall loads applying perpendicular to the wall plane (e.g. due to wind and earth pressure)
- bracing loads applying parallel to the wall plane (e.g. due to wind or inclination).

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

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

Overview of the features

- General load situation including
  - ceiling loads
  - uniformly distributed and linearly varying wall loads
  - concentrated bearing loads
  - wall loads perpendicular to the wall plane
  - bracing loads parallel to the wall plane
- Analysis of bracing wall plates
- Detailed material definition
  - Material according to the selected design standard
  - Material database for masonry officially approved by the German Institute for Construction Technology DIBT for the design in accordance with DIN 1053-1 and DIN 1053-100
  - User-defined material
- Load transfer to the strip foundations and edge strip foundations.

Basis of calculation

General notes

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

We like to draw your attention to an expert documentation about masonry construction that illustrates in detail the design procedure of masonry structures. The design in the MWX 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 calculation procedures of the design values determined by the effects of actions.

Design values of the action-effects

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

Load cases for the calculation of the action-effects

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

For the generation of the load cases, it is distinguished between vertical and horizontal actions. Vertical actions include uniformly distributed and concentrated loads applying to the wall to be verified; horizontal actions are divided into slab and plate effects of actions. The distinction scheme is illustrated in detail in the table below. The symbols shown in the table are also used in the documentation and the printout of the load case combinations decisive for the analysis.

Consec. no.	Name	Description
1	$G_{v,Inf}$	Dead weights from construction and all permanent portions of the vertical wall and ceiling loads. Basic value (corresponds to $\gamma_G = 1.0$).
2	$G_{v,sup}$	As above, however including the portion exceeding the basic value (for $\gamma_G > 1.0$)
3	$G_{h,inf}$	Permanent portions of the horizontal wall loads, only with the more accurate calculation method. Basic value (corresponds to $\gamma_G = 1.0$).
4	$G_{h,sup}$	As above, however including the portion exceeding the basic value (for $\gamma_G > 1.0$)
5	$G_{S,Inf}$	Permanent portions of the bracing loads. Basic value (corresponds to $\gamma_G = 1.0$).
6	$G_{S,Sup}$	As above, however including the portion exceeding the basic value (for $\gamma_G > 1.0$)
7	Q_G	The half of the variable portions, with respect to amount, of all vertical ceiling 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 (slab load)
10	Q_S	Variable portion of a single horizontal bracing load
11	A_h	Accidental portion of horizontal wall loads
12	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 have to be taken into account even when they act favourably.

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

When using the simplified calculation method, no considerable horizontal loads (slab loads) may be taken into account. Therefore, the load cases $G_{h,inf}$ and $G_{h,sup}$ are only generated in combination with the more accurate calculation method.

Particular regulations according to DIN 1053 - quasi-permanent actions

According to DIN 1053, imposed variable vertical loads applying to ceilings may only be treated as permanent loads when half of their value is included in the calculation. 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 applying the simplified calculation method.

Even though vertical wall loads defined in the MWX application can normally also result from ceiling loads, the application considers this problem only for the ceiling 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. In addition to this, a separate load case Q_v is generated for each defined concentrated load in order to be able to dimension correctly the maximum eccentricity in the length direction of the wall when bracing loads act simultaneously.

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

Variable horizontal actions

The load case Q_h is only used in combination with the more accurate calculation method. 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.

The user cannot define accidental horizontal actions that act perpendicular to the wall plate; 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 action-effects

In masonry construction, a particular number of analyses have to be performed due to the variety of possible system definitions and actions. For each of these analyses, one single decisive load case combination exists. When performing a design applying 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.

Name	DS[1)]	Description
SigmaD	Ed[2)] EdA[3)]	Analysis with compression stress
TauP	Ed EdA	Analysis with slab shear
TauS	Ed EdA	Analysis with plate shear
Epsilon	Ed	Edge strain analysis with plate shear. Only when designing in accordance with DIN 1053.
Ex	Ed EdA	Limitation of the gapping joint through the thickness of the wall (slab effects of action). Only when designing in accordance with DIN 1053.
Ey	Ed EdA	Limitation of the gapping joint through the length of the wall (plate effects of action). 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 bar action-effects

General notes

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

In general, the calculation of action-effects is performed on a plain equivalent system (bar theorem).

Particularities of masonry structures

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

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

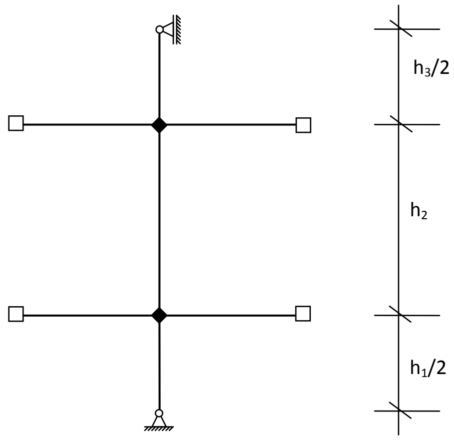
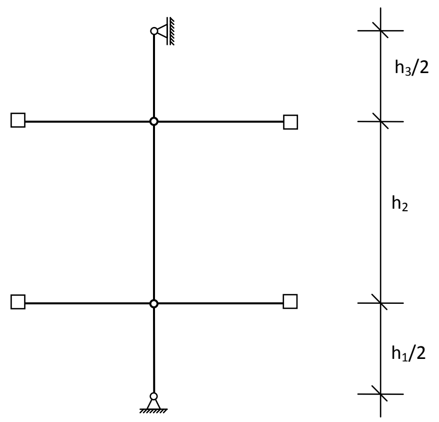
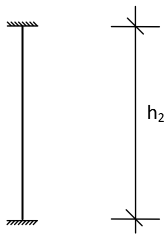
Therefore, the action-effects resulting from the torsion of the ceiling edges and those due to the effects on the slab (horizontal effects of actions) must be calculated via different structural systems. We will explain this in detail below.

Structural systems for the general design method

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

The moments in the wall/ceiling nodes are calculated on equivalent bar systems. The location of the zero points of the moment are assumed normally at half of the wall height of the storeys above and below. The walls (to be verified) of the lowest storey (built on the foundation) constitute an exception. In this case, the full wall height is including assuming a restrained wall foot at the same time.

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

System	Description	System sketch (based on an intermediate storey wall)
System I[1)]	Calculation of the foot and head moments due to ceiling bearing torsion The walls and ceilings are rigidly joined to each other. The walls underneath and above are cut at the half of the wall height and pinned at the section points. The supported ceiling sides are assumed pinned, restrained or freely projecting depending on the user-defined bearing conditions.	
System II	Calculation of the normal wall forces as well as the bending and shear forces resulting from the horizontal wall loads (slab effects of actions) The walls and ceilings are rigidly joined to each other. The walls underneath and above are cut at the half of the wall height and pinned at the section points. The supported ceiling sides are pinned. The axial forces are modified in accordance with the continuity factors entered. The wall moments calculated on this system correspond to the unredistributed values.	
System III	Calculation of the moments of the fully fixed end resulting from horizontal wall loads (slab effect of actions) The nodes at the wall foot and wall head are restrained. This creates a bar that is restrained at two sides. The result of the calculation on this system are the moments of the fully fixed ends, i.e. the maximally redistributable moments at the wall foot and the wall head.	
1)	When performing the design in accordance with DIN 1053, the bending moments and shear forces are reduced to 2/3 of their values (DIN 1053-1, Para. 7.2.2. or DIN 1053-100, Para. 9.2.2). When performing the design in accordance with EN 1996-1-1, the bending moments and shear forces resulting from the ceiling torsion are reduced by the factor km in accordance with equation C.2.	

Structural systems for the simplified analysis

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

Action-effects resulting from imposed loads on ceilings

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

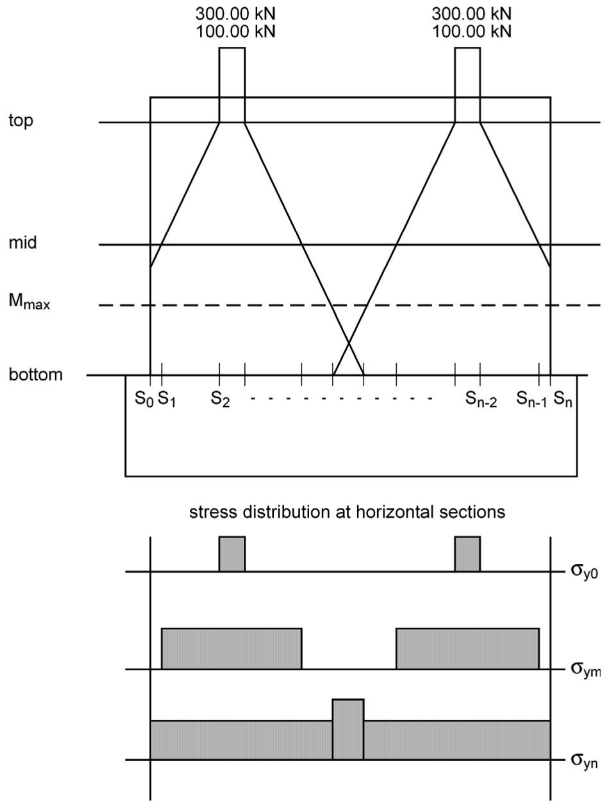
EN 1996-1-1, Annex C defines a reduction factor. The calculation of this factor however opposes to the action-effects calculation via bar models.

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

Actions-effects resulting from concentrated loads

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

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



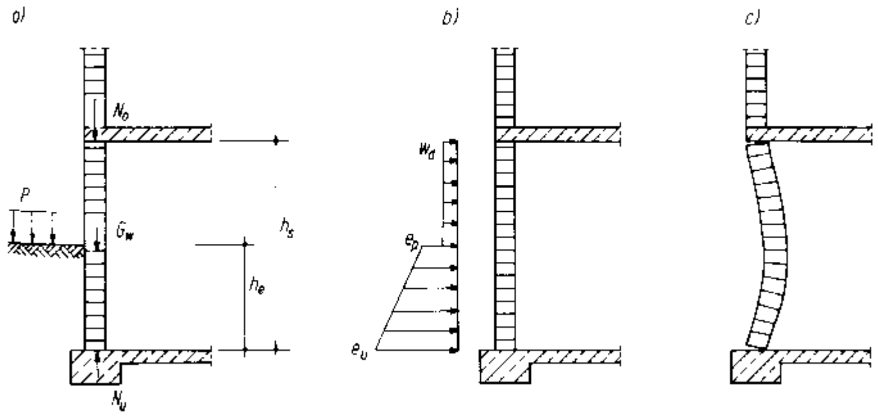
Action-effects resulting from bracing loads

For the calculation of the effect of actions resulting from bracing loads, the considered wall plate is assumed as an idealized cantilever plate. On this system, the effects of actions on the plate are calculated for each load case in the form of an integral and separately from the action-effects on the bar (bending moment M_x and shear force V_y). Elastic restraints created by the supported ceiling slabs are not considered.

Redistribution of moments

Fundamental theoretical considerations

The shear forces from horizontal loads such as earth pressure or wind are calculated on the pinned single-span beam. The subsequent analysis is based on the greatest bending moment.
The design on the basis of the maximum bending moment is surely on the safe side because the favourably acting axial forces are not considered. They result from the fact that a horizontal load causes an inward or outward deflection and there is not free torsion of the wall between the ceilings or between the foundation and the ceiling. Restraint moments occurring at the wall head and foot reduce the bending moment calculated on the single-span beam.



Deflection of basement slab and foundation not shown.

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

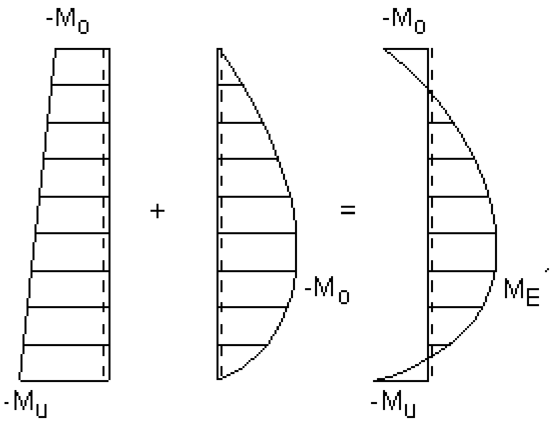
At the wall head: $M_o = -N_o \cdot \frac{d}{3}$

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

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

Due to the action of vertical loads, it is possible that the cross section already present cracks. You should therefore take existing eccentricities at the wall head and foot into consideration.

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



The restraint moments to be considered are calculated as follows:

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

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

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

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

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

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

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

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

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

Simplified method:

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

Calculation of the design values of the action-effects

The bar action-effects of the load cases described in table 5 are available as characteristic values. They are combined to design values of the bar action-effects giving consideration to the stipulations of the applicable design standard.

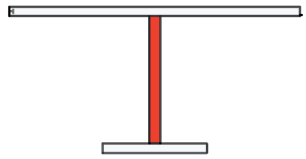
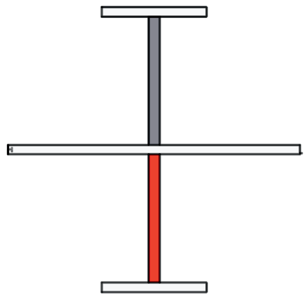
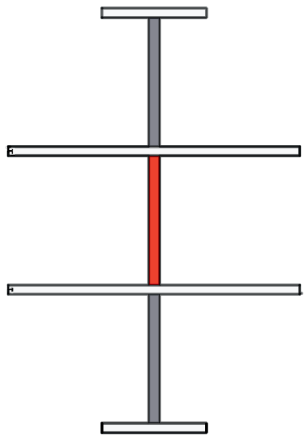
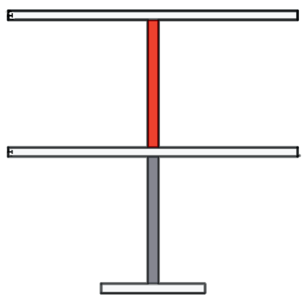
Subsequently, the bar action-effects are superimposed with the related action-effects resulting from load propagation under concentrated loads. The maximum related axial force is determined giving consideration to the eccentricities through the length of the wall and the gapping joints. The analyses are based on this axial force.

Settings

General notes

Wall system

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

Value	Description	System sketch (the wall to be verified is shown in red)
Individual wall	Single-storey masonry structure consisting of a single wall. The wall is built on a foundation or floor slab and supports the ceiling.	
Basement wall	Two- or multi-storey masonry structure comprising two walls. The wall to be verified is built on a foundation or floor slab and supports the ceiling. 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

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

Method of analysis

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

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

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

General parameters

Interaction plate - slab

Specification of the way the superposition of the effects of actions acting on the plate and those acting on the slab is performed for the analysis of the resistance of cross sections to axial loads.

Wall plates could be exposed to eccentric effects of actions through the length of the wall if

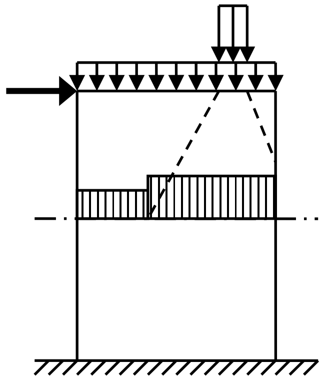
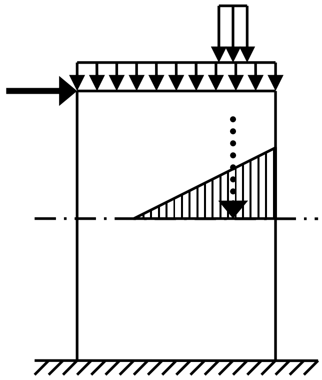
- the concentrated loads apply asymmetrically
- the bracing forces act through the length of the wall (plate shear)
- the axial force behaviour at the wall head varies over the wall length.

The eccentric load produces higher effects of actions at the compressed wall end than the centric load.

It depends on several factors whether it makes sense to consider this increase of effects and you should check it in each case. It might become important where bracing walls are concerned that are relatively short and not retained at the compressed wall ends. The method is not suitable for long walls because the hypothesis that the cross section remains plain is no longer true under normal conditions.

The calculation option "Interaction plate/slab" allows you to select among the following methods for the calculation of the effects of action:

1. Any eccentricity of the resultant of the 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 (giving consideration to gapping cross sectional areas). Subsequent analysis of the maximum value of the axial force (on a strip of 1 m, procedure according to typical engineering practices).

Value	Description	System sketch
Not considered	The analysis of the resistance of cross sections to axial loads is performed without consideration of occurring eccentricities resulting from bracing loads or asymmetrically applying concentrated loads. A sectionwise constant behaviour of the related axial force is assumed. The plate shear analysis and the gapping joint analysis are performed at the most unfavourable vertical section on the basis of the related values of the action-effects.	
Considered	The analysis of the resistance of cross sections to axial loads is based on the maximum value of the related axial force that results when eccentricity resulting from bracing loads or asymmetrically applying concentrated loads is taken into consideration. A variable linear behaviour of the axial force is assumed while taking a gapping joint in the length direction of the wall into consideration. If the analysis without interaction (see above) produces a greater related axial force, the analysis is based on this value. The plate shear analysis and the gapping joint analysis are performed on the basis of the resultant values for the action-effects.	

For an illustration of the calculation procedure including eccentricities along the length of the wall please refer to the worked calculation example "Bracing wall plate".

Reduction of the effective length

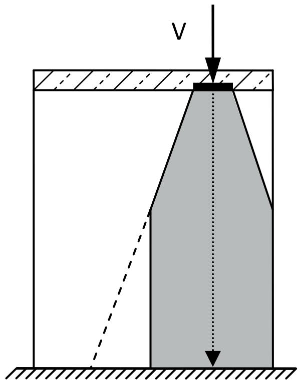
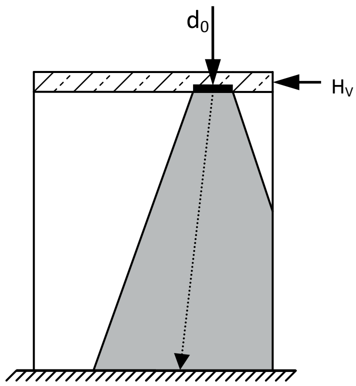
Specification whether a reduction of the effective length of the wall is permissible with regard to the standard limiting conditions.

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

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

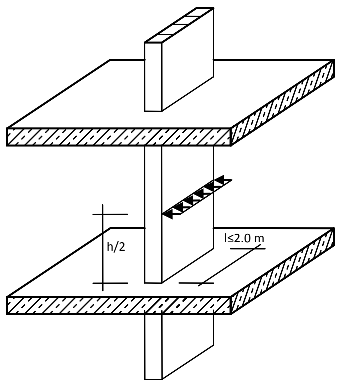
Load propagation

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

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

Head joint filling

Specification whether the head joints of the masonry bond are filled. This option has an effect on the masonry's initial shear resistance value.



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

Specification whether the analysis of a slender wall should be performed including 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).

For walls with a length of less than 2.0 m and a thickness of less than 17.5 cm that are retained at two sides (exception: DIN 1053-1, general design method, no limitation of the wall thickness) a structural safety analysis has to be performed assuming a horizontal load of 0.5 kN applying at half of the wall height 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.

Ceiling dead weight

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

Load propagation angle

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

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

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

Execution supervision (only in combination with BS EN 1996)

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

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 people reside permanently in the building such as in residential buildings 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 wind load (only for EN 1996-3)

Defines the design value of a uniformly distributed wind load acting horizontally on the wall. This value only servers the evaluation of the minimum required wall thickness of walls acting as end support to floors.

Reduction factor

This option specifies how the reduction factor for the ceiling rotation angle at the end bearings in the attic storey should be calculated.

DIN 1053-1 and DIN 1053-100 prescribe this angle for end bearings of ceilings above the highest full storey (DIN 1053-1: $k_3 = 0.5$, DIN 1053-100: $\Phi_3 = 1/3$, EN 1996-3: $\Phi_s = 0.4$)). If a bearing load reduction is however prevented via constructive measures such as centring bars, there is no need to take the reduction factor into account. $k_3 = 1.0$, $\Phi_3 = 1.0$ bzw.
$\Phi_s = 1.0$ is assumed in this case.

Verification points

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

In manual calculation, the compression analysis is usually performed according to the simplified method assuming the maximum value of the axial compressive strain (occurs normally at the wall foot, 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 foot 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.

Analysis	Verification point "Wall foot"	Verification point "Separately considered"
Compression	Max. effects of actions over the total wall height (wall foot, half of the wall height, if required) Analysis with the highest resultant bearing load reduction (slenderness or ceiling torsion at the wall head or foot)	Analysis with bearing load reduction due to ceiling torsion at the wall head and foot Analysis with bearing load reduction due to slenderness at the half of the wall height.
Plate shear	Analysis at the wall foot	Analysis at the wall head and foot
Edge strain	Analysis at the wall foot	Analysis at the wall head and foot
Eccentricity	Analysis at the wall foot	Analysis at the wall head and foot

Parameters for the general design method

DeckenlastenFloor loads (Nur bei Nachweis nach EN 1996-3 only)

Spefication whether the live loads on both sides of a floor slab are to be taken as acting simultaneously (see EN 1996-1-1, para. 2.4.2, note 2) or separately.

Moment redistribution

Specification whether bending moments due to lateral loads can be redistributed between the ends and the span of the wall. In close agreement with reality moment redistribution is done by choosing the moments at the top and the bottom of the wall as large as possible (with the limiting condition being the max. allowable eccentricity or the full fixed end moments – always considering lateral loads and floor deflection together) and subsequently adjusting the moment distribution along the height of the wall under preservation of equilibrium. In case moment redistribution is not wanted, the moment distribution due to lateral loads is based on single hinged beam analysis.

System

Walls

Type

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

In some cases as for the evaluation of the limiting criteria for the application of the simplified method, it is important to know whether the wall is an exterior or interior wall (single- or multi-leaf).

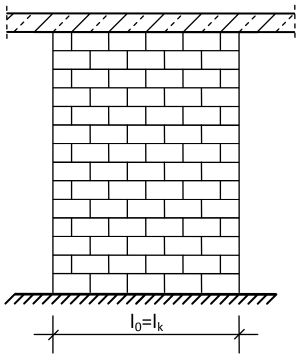
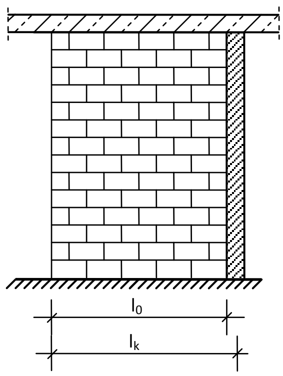
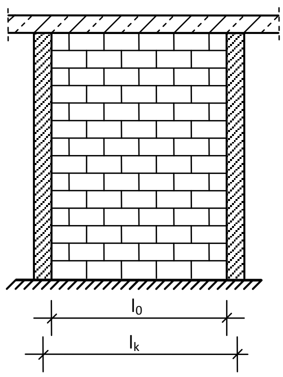
Material

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

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

Support

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

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

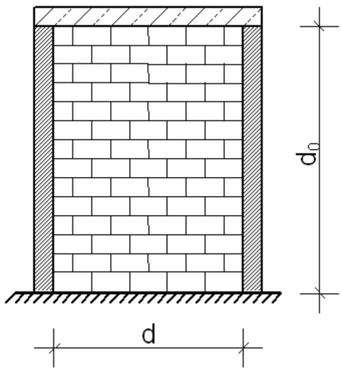
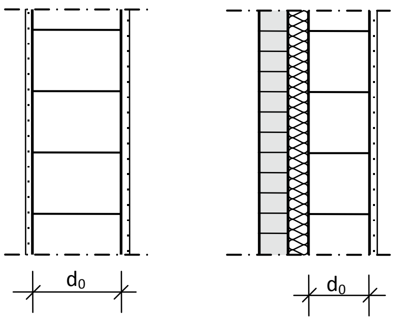
(l_k = arithmetical wall length for the effective length calculation, l_0 = clear wall length for the load distribution/analysis)

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

Based on the number of effective supports the effective wall length l_k as well as the corresponding effective length of the wall are calculated.

Geometry of the wall

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

Value	Description	System sketch
h_0	Clear wall height	
l_0	Clear (=arithmetical) wall length, the load distribution is based on. (Due to the frequent use of butt joints in combination with flat steel anchors for the wall connection, this value is taken into account as effective wall length for the plate shear analysis).	
d_0	Thickness of a single-leaf wall or thickness of the bearing layer of a multi-leaf wall	
HS	Total height of the shear wall. Only referenced in the calculation of the shear stress distribution factor if the shear capacity of the wall is to be checked according to DIN 1053-1 or DIN 1053-100.	

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.

g_z

Dead weight addition for the wall lining, for instance.

Please note: Only the self-weight of the wall to be checked will be included in the analysis. Walls above and underneath the wall to be checked only contribute to the stiffness at the wall-floor-connection in the frame analysis.

Text

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

Ceilings

Type

Specification of the type of ceiling: supported on the left, the right or both sides.

Construction

Specifies the type of construction of the ceiling. Currently, only solid ceilings are supported.

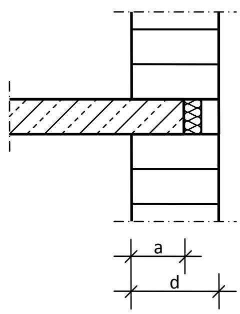
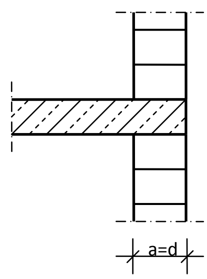
Value	**Description**
Reinforced concrete ceiling	Reinforced concrete ceiling refers to a solid ceiling that is two-dimensionally supported.

Currently, only the calculation based on the assumption of a two-dimensionally supported solid ceiling is supported by application. 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".

Modulus of elasticity

Arithmetical or characteristic value of the modulus of elasticity of the ceiling. Is only relevant for analyses based on the more accurate calculation method (calculation of actions-effects resulting from the torsion of the ceiling bearings).

Geometry of the ceiling

Value	Description	System sketch
Bearing length a le/ri	Bearing length of the left/right ceiling. **Note: Is only relevant for the calculation of the effective length. No local effects resulting from partly supported ceiling slabs are verified!**	
Thickness d le/ri	Thickness of the left/right ceiling. Different thicknesses at the left and the right side are currently not permitted.	
Span l le/ri	span of the left / right ceiling; distance of the left / right wall surface to the supporting node.	
Width b le/ri	Affected width of the left/right ceiling. **Note: The value must at least be equal to the clear wall length!**	
Support Lag le/ri	Supporting conditions of the left/right ceiling: 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 ceiling loads, if applicable).	

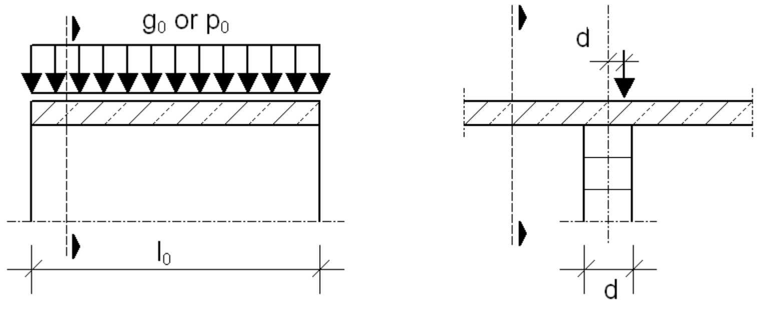
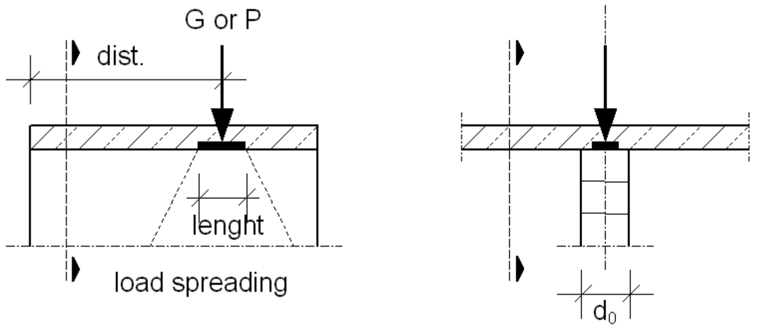
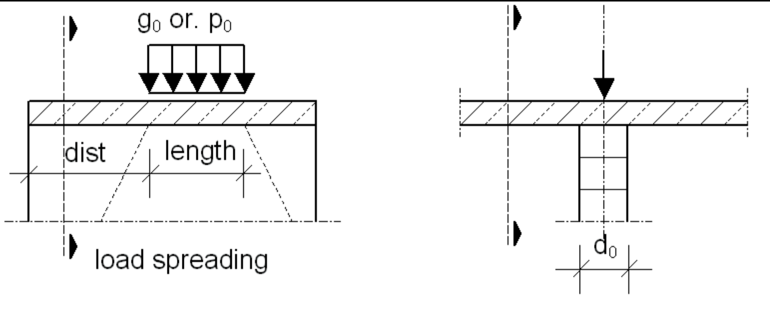
Loads

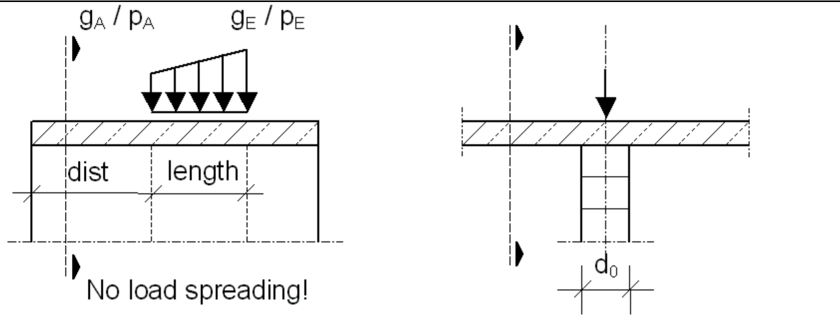
Vertical wall loads

Type

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

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 through the thickness of the wall to uniformly distributed loads.

Uniformly distributed load: Applies always over the total wall length.	
Concentrated load: Overlapping of load contact areas of several concentrated loads is not permissible.	
Block load[1)]: Uniformly distributed load, action over a portion of the total wall length.	

Trapezoidal load[2)]: Equal to block load, but with different load values at beginning and end.	
1)	Block loads are intended to represent support reactions from walls in upper storeys, which carry concentrated loads. These transferred loads do not comply with the standards ideas of concentrated loads. Thus block loads are included in the (global) internal forces at the top of the wall, and the design check underneath concentrated loads is omitted. Note: load spreading is assumed underneath block loads!
2)	Trapezoidal loads are intended to represent support reactions from walls in upper storeys, which are eccentrically loaded (in the direction of the wall length), or slab reactions from preceeding finite element analyses. Note: No load spreading is assumed underneath trapezoidal loads!

Spacing

Distance of the line of action of a concentrated load to the left wall edge or distance form the left end of the wall to the beginning of the block or trapezoidal load respectively.

g_0 / q_0

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

Load-length

Length of the contact area of the concentrated load through the length of the wall or length of the load distribution of a portion of the total length or a trapezoidal load.

e_y

Eccentricity of the impact plane of a distributed load through the thickness of the wall. Only available with uniformly distributed loads over the whole wall lenght.

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

d_1

Length of the contact area of the concentrated load through the thickness of the wall. Note: In the structural analysis it is presumed, that the centreline of the concentrated load coincides with the centre plane of the wall, e.g. no eccentricities are taken into account.

Action

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.

Notes concerning the use of block loads

When using block loads it has to be kept in mind, that load spreading is separately performed for each block load, meaning without interacting with neighbouring block loads. This can lead to unexpected and unrealistic load overlapping along the height of the wall (see following illustration). The definition of stepped loads should therefore not be done by concatenating several block loads but by a pyramid-like stacking of block loads. If load spreading not to be performed, concatenating of trapezoidal loads is suitable.

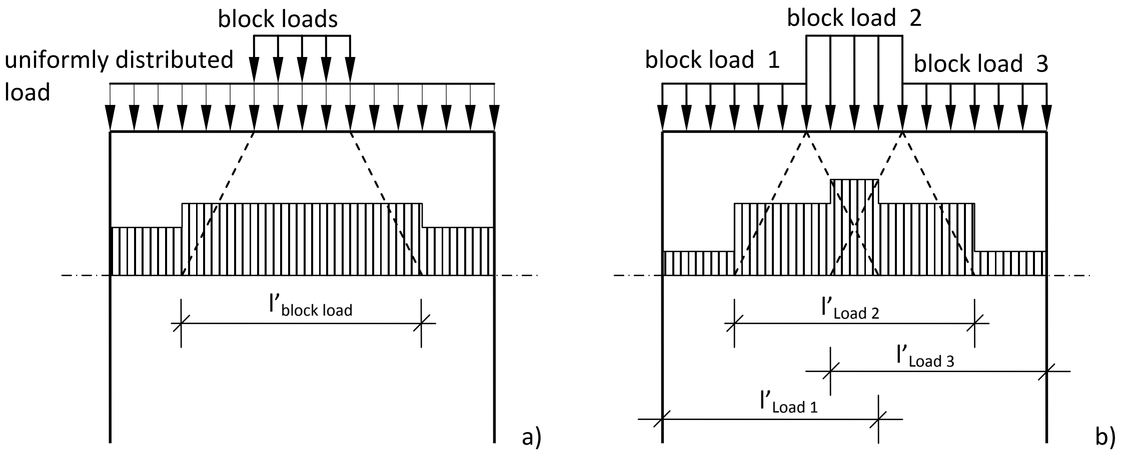


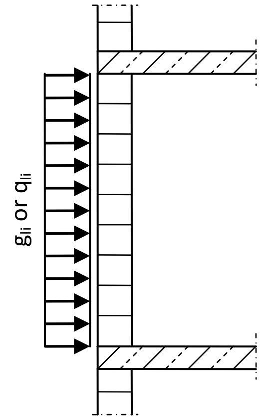
Illustration 1: application of block loads: a) correct load spreading, b) unrealistic crossover of the load spreading cone

Horizontal wall loads

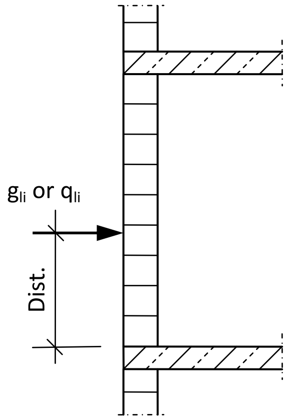
Type

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

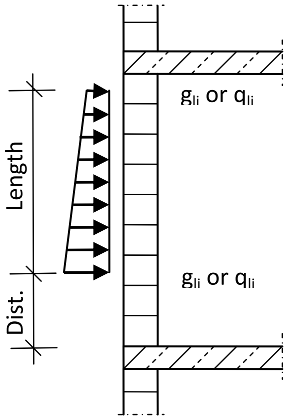
Uniformly distributed load
(constantly distributed load)



Concentrated load
(line load constant over the
wall length)



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



Load values

Value	Description	
g_u / q_u	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]
go / qo	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 foot in [m]
	Trapezoidal load	Distance of the lower end of the load to the wall foot in [m]

Action

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.

Ceiling loads

Type

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

Level

Specification of the consecutive number of the wall that supports the ceiling to which the load applies. The lowest wall has always the number 1. See also "Level of the vertical wall loads".

Action

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.

Load values

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

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 superimposed loads (compressive axial forces) do not necessarily produce a higher loading rate of the wall cross section (resistance against slab stresses). Lower superimposed loads might produce the premature failure of the wall. Therefore, the continuity of the ceiling must be taken into consideration under certain circumstances.

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

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

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

Example 1:

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

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

Example 2:

As example 1, however with end bearing

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

Example 3:

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

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

Example 4:

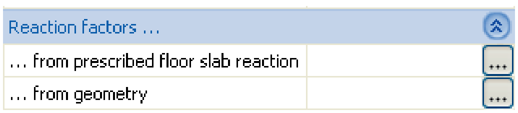
Special case "Continuity needs not be considered", central bearing

$$\text{Fac } q_{le} = \text{Fac } q_{ri} = 0.500$$

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

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

Warning note: *This command has only an effect on the current ceiling load, i.e. you must repeat it for each additional ceiling load.*
Automatically generated continuity factors may be rendered invalid by changing floor or floor load defintions!

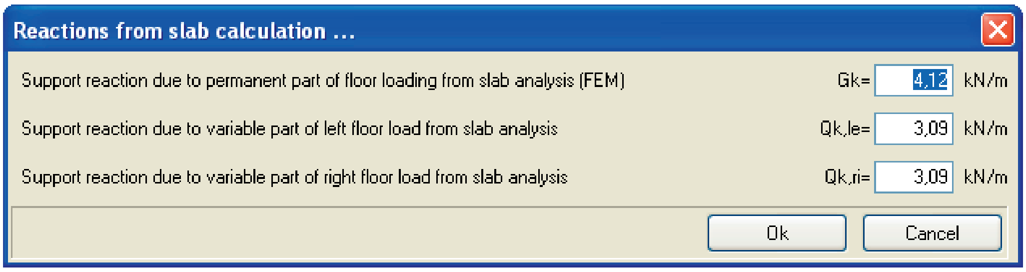


Setting bearing forces resulting from slab calculation by default

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

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

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



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

Continuity factor for the permanent load portion on the left ceiling side $$f_{Gk,le} = 0.5 \cdot \frac{G_k}{g_{k,le} \cdot l_{le}}$$

Continuity factor for the permanent load portion on the right ceiling side $$f_{Gk,lri} = 0.5 \cdot \frac{G_k}{g_{k,ri} \cdot l_{ri}}$$

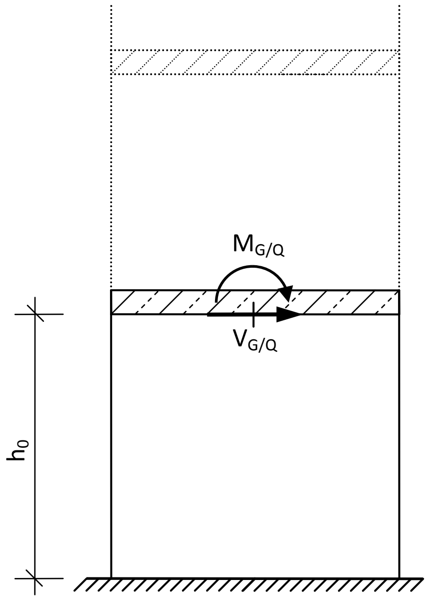
Continuity factor for the variable load portion on the left ceiling side $$f_{Qk,le} = 0.5 \cdot \frac{Q_{kle}}{q_{k,le} \cdot l_{le}}$$

Continuity factor for the variable load portion on the right ceiling side $$f_{Qk,ri} = 0.5 \cdot \frac{Q_{kri}}{q_{k,ri} \cdot l_{ri}}$$

Bracing loads

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 introduction into the wall is not performed, i.e. it is assumed that the bracing loads are introduced continuously (e.g. via the ceilings).



Load values

Bracing loads are defined by their corresponding internal forces, e.g. the transversal force and bending moment, which have to be pre-calculated using an appropriate structural model of the diaphragm (for instance simplified model of more accurate unsing the Frilo Building Model GEO).

Value	Desciption
VG	Permanent part of the transversal force at the top of the wall in [kN]
VQ	Variable part of the transversal force at the top of the wall in [kN]
MG	Permanent part of the bending moment at the top of the wall in [kNm]
MQ	Variable part of the bending moment at the top of the wall in [kNm]

Since no further bracing loads are allowed to act within the height of the wall, the shear forces at the top and the bottom of the wall are identical. The bending moment at the bottom includes the additional part V·h0 , e.g. a cantilever is assumed as structural system for the wall.

Action

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 that include this action, the wall plate is considered to be a wind plate and the shear correction factor α_c is taken into account.

When the analysis is performed in accordance with DIN 1053-1, the assignment of action groups is not applicable. The only distinction to be made is whether the load is a seismic load or not. In the former case the additional specifications of DIN 4149 are included in the design checks.

ConGrp

Number of load group, whose loads are assumed to always act together. Number 0 means the load does not belong to any load group.

AltGrp

Number of load group, whose loads are assumed to never act together. Number 0 means the load does not belong to any load group.

Text

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

Notes: *The total height of the wall plate required for the calculation of the shear stress distribution factor has to be defined by the user (wall definition).*

For the orderly determination of the shear matching factor in accordance with DIN 1053-100, it is important to select the appropriate action group for the variable load portion! Wind plates are only recognized as such when the wind load portion amounts at least to 75% of the total load.

Analysis

Verification points

MWX performs the following analyses 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 foot. In order to verify the bearing capacity of walls exposed to dominant slab stresses correctly (e.g. exterior walls with low superimposed load exposed to wind), MWX checks in addition a horizontal section at the point where the local maximum eccentricity occurs through the thickness of the wall (unless this horizontal section coincides with the half of the wall height. In this case, the result of the buckling analysis is always more favourable).

When bracing wall plates are verified in accordance with DIN 1053-100, it is important to know whether the wall to be verified is a wind plate. In this case, it is permissible to use the shear correction factor α, which has a favourable effect on the result. MWX assumes that the wall to verify is a wind plate 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 DIN 1053-1

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	Analysis	Comment
Wall foot	Axial compressive stran[1)]	Incl. impact of undesired horizontal concentrated load H=0.5 kN, if applicable
	Shear stress due to plate shear	
	Edge strain	With $E = 3000 \cdot \sigma_0$
	Gapping joint through the length of the wall	
Wall head	Bearing stress under concentrated loads	

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

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

Verification point	Analysis	Comment
Wall head	Axial compressive strain	Bearing load reduction due to rotation angle of the supported ceiling
	Shear stress due to plate shear	
	Edge strain	With E = 3000·σ_0
	Gapping joint through the length of the wall	
	Bearing stress under concentrated loads	
Half of the wall height	Axial compressive strain	Bearing force reduction due to effective slenderness, incl. the impact of the undesired horizontal concentrated load H=0.5 kN, if applicable
Wall foot	Axial compressive strain	Bearing load reduction due to rotation angle of the lower ceiling
	Shear stress due to plate shear	
	Edge strain	With E = 3000·σ_0
	Gapping joint through the length of the wall	

Analyses based on the general design method

Verification point	Analysis	Comment
Wall head	Axial compressive strain	
	Shear stress due to plate and slab shear	
	Edge strain	With $E = 3000 \cdot \sigma_0$
	Gapping joint through the length and thickness direction of the wall	
	Bearing stress under concentrated loads	
Half of the wall height	Axial compressive strain	Incl. impact of undesired horizontal concentrated load H=0.5 kN, if applicable
	Gapping joint through the length and thickness direction of the wall	
Max. eccentricity through the thickness of the wall	Axial compressive strain	Without consideration of an undesired eccentricity
	Gapping joint through the length and thickness direction of the wall	
Wall foot	Axial compressive strain	
	Shear stress due to plate and slab shear	
	Edge strain	With $E = 3000\ \sigma_0$
	Gapping joint through the length and thickness direction of the wall	

Analyses in accordance with DIN 1053-100

Analyses based on the simplified calculation method

If 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	Analysis	Comment
Wall foot	Resistance of cross sections to axial loads[1)]	Incl. impact of undesired horizontal concentrated load H=0.5 kN, if applicable
	Shear resistance under plate shear	
	Edge strain	With $E = 1000 \cdot f_k$
	Limitation of the nominal 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 are higher at half of the wall height than at the wall foot, the higher effects are used in the analysis.

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

Verification point	Analysis	Comment
Wall head	Resistance of cross sections to axial loads	Bearing load reduction due to rotation angle of the supported ceiling
	Shear resistance under plate shear	
	Edge strain	With $E = 1000 \cdot f_k$
	Limitation of the nominal eccentricity through the length of the wall	
	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 undesired horizontal concentrated load H=0.5 kN, if applicable
Wall foot	Resistance of cross sections to axial loads	Bearing load reduction due to rotation angle of the lower ceiling
	Shear resistance under plate shear	
	Edge strain	With $E = 1000 \cdot f_k$
	Limitation of the nominal eccentricity through the length of the wall	

Analyses based on the general design method

Verification point	Analysis	Comment
Wall head	Resistance of cross sections to axial loads	
	Shear resistance with plate and slab shear	
	Edge strain	With $E = 1000 \cdot f_k$
	Limitation of the nominal eccentricity through the length and thickness direction of the wall	
	Partial area compression under concentrated loads	
Half of the wall height	Resistance of cross sections to axial loads	Incl. impact of undesired horizontal concentrated load H=0.5 kN, if applicable
	Limitation of the nominal eccentricity through the length and thickness direction 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 nominal eccentricity through the length and thickness direction of the wall	
Wall foot	Resistance of cross sections to axial loads	
	Shear resistance with plate and slab shear	
	Edge strain	With $E = 1000 \cdot f_k$
	Limitation of the nominal eccentricity through the length and thickness direction of the wall	

Analyses in accordance with EN 1996-1-1

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

Verification point	Analysis
Wall head	Resistance of cross sections to axial loads
	Shear resistance with plate and slab shear
	Partial area compression under concentrated loads
Half of the wall height	Resistance of cross sections to axial loads [1)]
Max. eccentricity through the thickness of the wall	Resistance of cross sections to axial loads
Wall foot	Resistance of cross sections to axial loads
	Shear resistance with plate and slab shear

1) the design check at the mid height of the wall (“slenderness”) is based on an assumed value of $E_k/f_k = 700$.

Analyses in accordance with EN 1996-3

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

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	Analysis	Comment
Wall foot	Resistance of cross sections to axial loads[1)]	
	Shear resistance under plate shear	
	Edge strain	With $E = 1000 \cdot f_k$
	Limitation of the nominal 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 foot, the higher effects are used in the analysis.

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

Verification point	Analysis	Comment
Wall head	Resistance of cross sections to axial loads	Bearing load reduction due to rotation angle of the supported ceiling
	Shear resistance under plate 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. impact of undesired horizontal concentrated load H=0.5 kN, if applicable
Wall foot	Resistance of cross sections to axial loads	Bearing load reduction due to rotation angle of the lower ceiling
	Shear resistance under plate shear	

Design situations and load combinations IAW DIN 1053-100

Analysis	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 nominal eccentricity	Characteristic loads (including accidental loads but no earthquake)
Edge strain	Infrequent or frequent combination (excluding accidental loads)

According to DIN 1053-100, you can perform the edge strain analysis alternatively for the frequent design situation as defined by DIN 1055-100 instead of the infrequent situation provided that the initial 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 edge 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 initial shear resistance from the shear resistance analysis. The analysis of the edge strain is based on the frequent design situation.

The accidental combination is always verified 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.

Output

As with all other FRILO applications, the available output media include the monitor display, MS Word and the printer. You can launch the output on the display or the printer via the corresponding menu items in the main tree.

Options	Description
	Output directly to Microsoft Word (must be installed on the local computer)
	Displays the values in a text window on the screen. The result graphics are not shown, you can access them via the toolbar below the menu bar.
	The option starts the output on the printer

The main menu item "Output" allows you to specify in detail the scope of data to be printed. The individual options are shortly described below.

General options

Option	Description
System graph	Output of a graphical representation of the total system
Abbreviated printing	Output of a compact version of the system and the results. When you select abbreviated printing, 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 and legends are described in detail in the output. This option is not available with abbreviated printing.

System options

Option	Description
Comment	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.
Ceilings	Output of the ceilings in the form of a table.

Load options

Option	Description
Comment	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 head. The dead weights and dead weight additions are put out together with the walls.
Ceiling loads	Output of the vertical loads that apply directly on the ceilings.
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.

Result options

Option	Description
Comment	Output of the comments to the calculation results.
Load case combinations	Output of the load case combinations on which the analyses are based.
Action-effects	Output of the design values of the action-effects on which the analyses are based.
Compressive stress	Output of the analysis with compressive stress, is normally always included in the output
Slab shear	Output of the slab shear analysis.
Plate shear	Output of the plate shear analysis.
Edge strain analysis	Output of the border strain analysis with plate shear. Only in combination with DIN 1053.
Gapping joint	Analysis of the gapping joint in wall thickness and length direction. Only in combination with DIN 1053-1 and DIN 1053-100.

Result graphs

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

Load transfer

A feature for the transfer of loads to the analysis applications

- FDS Strip Foundation
- FDR Edge Strip Foundation

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

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

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

Strip foundation FDS

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

1. short walls that are expected to have a rigid kinematics through the length of the wall
2. walls with a constant behaviour of the bearing reactions through the length of the wall (eccentricities through the length of the wall are neither available!)

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

Restraint moments and shear forces resulting from slab 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 around the longitudinal foundation axis should become decisive due to the selected foundation dimensions, the user must manually add the corresponding values to the transferred loads via the input dialog of FDS.

Edge strip foundation FDR

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

If several concentrated loads apply and cause a tiered behaviour of the bearing force over the wall length you do not know 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 MWX, the transferred data are on the safe side due to the assumption that the load propagation areas of all concentrated loads overlap at the wall foot. Overlapping actually occurs when the maximum distance between the two outer concentrated loads does not exceed the 1.2-fold value of the clear wall height (based on a load propagation angle of 60°). Otherwise, the user can delete individual load cases from the automatically generated load combinations in FDR on his own responsibility.

Restraint moments and shear forces resulting from slab 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 effects cannot be taken into account either.

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

Calculation examples IAW DIN 1053

Exterior wall according to the simplified calculation method

System and loading

Construction

- Building height: 8.0 m
- Clear ceiling span: 5.20 m (opposite bearing d=11.5 cm)
- Exterior wall made of masonry, single-leaf
- Clear distance between bracing wall (d=36.5 cm) and wall opening is 1.5 m
- Wall finish: exterior: 20 mm lime-cement plaster; interior: 20 mm lime plaster
- Ceilings: reinforced concrete C30/37

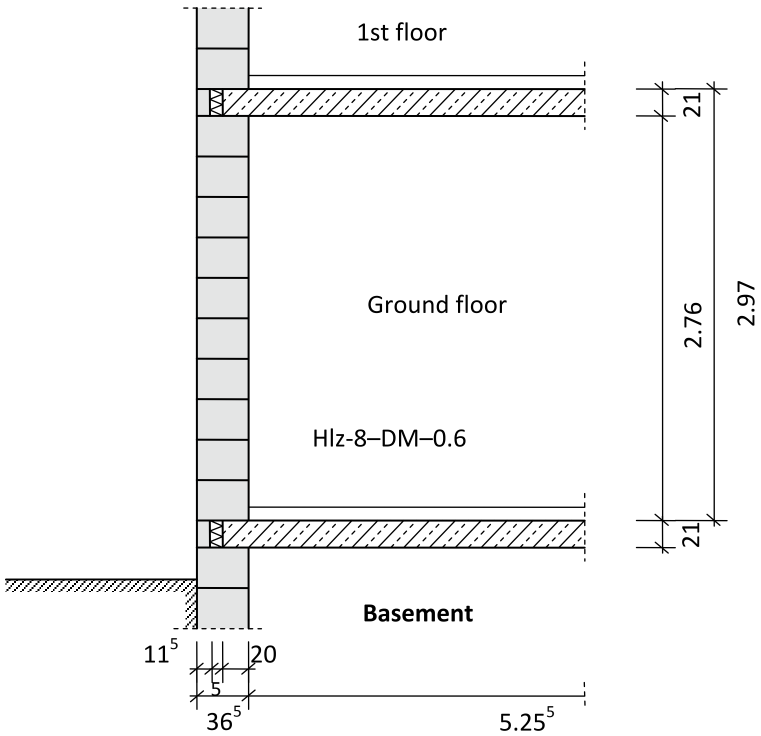


Illustration 2: Example of a supporting exterior wall

Masonry

- Special honeycomb bricks for thin-bed mortar in accordance with DIBt approval (German Institute for Construction Technology in Berlin)
- Brick strength class 8, thin-bed mortar, unfilled head joints
- Bulk density class: 0.6, arithmetical value of the dead weight acc. to DIN 1055-1 g_0=7.0 kN/m³
- Restrictions by the approval of the construction supervision authorities.

  $\Rightarrow$ σ_0 = 1.0 N/mm² (f_k = 3.1 N/mm²)

Loading

- Superimposed wall loads (w/o ceiling bearing loads)
  - ⇒ Permanent: 27.3 kN/m
  - ⇒ Variable: 8.1 kN/m

- Ceiling loads
  - ⇒ Flooring and plaster: 1.4 kN/m²
  - ⇒ Imposed load incl. partition wall addition: 2.70 kN/m²
- Ceiling bearing loads
  - ⇒ From permanent loads: 17.8 kN/m
  - ⇒ From variable loads: 7.2 kN/m
- Wall dead weight
  - ⇒ Masonry: 2.56 kN/m²
  - ⇒ Plaster: 0.75 kN/m²

Verification of the limiting criteria

The limiting criteria for the application of the simplified calculation method are identical in DIN 1053-1 and DIN 1053-100.

- The building height above ground level does not exceed 20.0 m.
- The ceiling span is less than 6.0 m.
- The building in question is a residential building, i.e. a building where people reside permanently. The imposed loads applying on top of the ceilings do not exceed the value of 5 kN/m².
- According to Table 24, Line 4, the following applies:

⇒ d > 240 mm $h_0 = 2.76 < 12 \cdot d = 12 \cdot 0{,}365 = 4.38\ \text{m}$

The simplified calculation method is appropriate.

Structural safety analysis IAW DIN 1053-1 and DIN 1053-100

System parameters

The effective length is to be set equal to the clear wall height because d > 250 mm. The effective slenderness is calculated as follows:

$$\Rightarrow \lambda = \frac{h_k}{d} = \frac{276}{36.5} = 7.56$$

Design values of the effects of actions

Under normal conditions, wind loads must not be taken into consideration in combination with the simplified method. Impacts from the torsion of the ceiling are already included in the reduction factors. Therefore, the determination of the action-effects is limited to the calculation of the axial compressive force.

When DIN 1053-1 is applied, the compressive strains have to be calculated from the axial compressive force. When applying DIN 1053-100, the axial forces are directly included in the analysis.

DIN 1053-1	DIN 1053-100
Design value of the axial compressive force at the wall head	
$N = 27.3 + 8.1 + 17.8 + 7.2 = 60.4$ kN/m	$N_{E,d} = 1.35 \cdot (27.3 + 17.8) + 1.5 \cdot (8.1 + 7.2) = 83.8$ kN/m
Design value of the axial compressive force at half of the wall height	
$N = 60.4 + \frac{(0.365 \cdot 7.0 + 0.75) \cdot 2.76}{2} = 65.0$ kN/m	$N_{E,d} = 83.8 + 1.35 \cdot \frac{(0.365 \cdot 7.0 + 0.75) \cdot 2.76}{2} = 90.0$ kN/m
Design value of the axial compressive force at the wall foot	
$N = 60.4 + (0.365 \cdot 7.0 + 0.75) = 69.5$ kN/m	$N_{E,d} = 83.8 + 1.35 \cdot (0.365 \cdot 7.0 + 0.75) \cdot 2.76 = 96.1$ kN/m

Design values of the resistances

DIN 1053-1	DIN 1053-100
Basic value of the permissible compressive strain $\sigma_0 = 1.0$ N/mm²	Characteristic compressive strength $f_k = 3.1$ N/mm²
Reduction factors $l = 0.365/2 + 5.20 + 0.11/2 = 5.44$	
$k_1 = 1.0$ $k_2 = \frac{25 - \lambda}{15} = \frac{25 - 7.56}{15} = 1.162 > 1$ $k_2 = 1.0$	$\Phi_2 = 0.85 - 0.0011 \cdot \lambda^2 = 0.85 - 0.0011 \cdot 7.56^2 = 0.79$
$k_3 = 1.7 - \frac{l}{6} = 1.7 - \frac{5.44}{6} = 0.79 < 1.0$	$\Phi_3 = 1.6 - \frac{l}{6} = 1.6 - \frac{5.44}{6} = 0.69 < 0.9$
Permissible compressive strain at the wall head and foot $\sigma_{perm} = k \cdot \sigma_0 = 0.79 \cdot 1.0 = 0.79$ N/mm²	Design value of the resisting axial force at the wall head and foot $N_{R,d} = \Phi_3 \cdot A \cdot \eta \cdot f_k / \gamma_M = 0.69 \cdot 36.5 \cdot 100 \cdot 0.85 \cdot 0.31/1.5 = 442.4$ kN/m
Permissible compressive strain at half of the wall height $\sigma_{perm} = k \cdot \sigma_0 = 1.0 \cdot 1.0 = 1.0$ N/mm²	Design value of the resisting axial force at half of the wall height $N_{R,d} = \Phi_2 \cdot A \cdot \eta \cdot f_k / \gamma_M = 0.79 \cdot 0.365 \cdot 1.0 \cdot 0.85 \cdot 3.1 \cdot 10^{-3}/1.5 = 506.5$ kN/m

Analysis

DIN 1053-1	DIN 1053-100
$\sigma_{D,exis} \leq \sigma_{D,perm}$ or $\frac{\sigma_{D,exis}}{\sigma_{D,perm}} \leq 1.0$	$N_{E,d} \leq N_{R,d}$ or $\frac{N_{E,d}}{N_{R,d}} \leq 1$
At the wall head	
$\frac{\sigma_{D,exis}}{\sigma_{D,perm}} = \frac{60.4}{0.365 \cdot 1.0 \cdot 0.79 \cdot 1000} = \underline{\underline{0.21 < 1.0}}$	$\frac{N_{E,d}}{N_{R,d}} = \frac{83.8}{442.4} = \underline{\underline{0.19 < 1.0}}$
At half of the wall height	
$\frac{\sigma_{D,exis}}{\sigma_{D,perm}} = \frac{65.0}{0.365 \cdot 1.0 \cdot 1.0 \cdot 1000} = \underline{\underline{0.18 < 1.0}}$	$\frac{N_{E,d}}{N_{R,d}} = \frac{90.0}{506.5} = \underline{\underline{0.18 < 1.0}}$
At the wall foot	
$\frac{\sigma_{D,exis}}{\sigma_{D,perm}} = \frac{69.5}{0.365 \cdot 1.0 \cdot 0.79 \cdot 1000} = \underline{\underline{0.24 < 1.0}}$	$\frac{N_{E,d}}{N_{R,d}} = \frac{96.1}{442.4} = \underline{\underline{0.22 < 1.0}}$

The analysis of the load introduction (partially supported ceiling slab) is dispensed with because the maximum loading rate of the analysis of the resistance of cross sections to axial forces is smaller than the related bearing length of the ceiling slab in per cent (η = 22% < ~55%).

Bracing wall plate

System and loading

Construction

- Building height: H=9.50 m
- Ceiling span l_1=4.10 m
- Exterior wall made of masonry, bracing wall (wind plate)
- Wall finish: Exterior leaf is self-supporting; interior: lime plaster: 20 mm
- Clear distance between bracing wall (d=17.5 cm) and wall opening is 1.75 m
- The ceilings are solid slabs, fully two-dimensionally supported

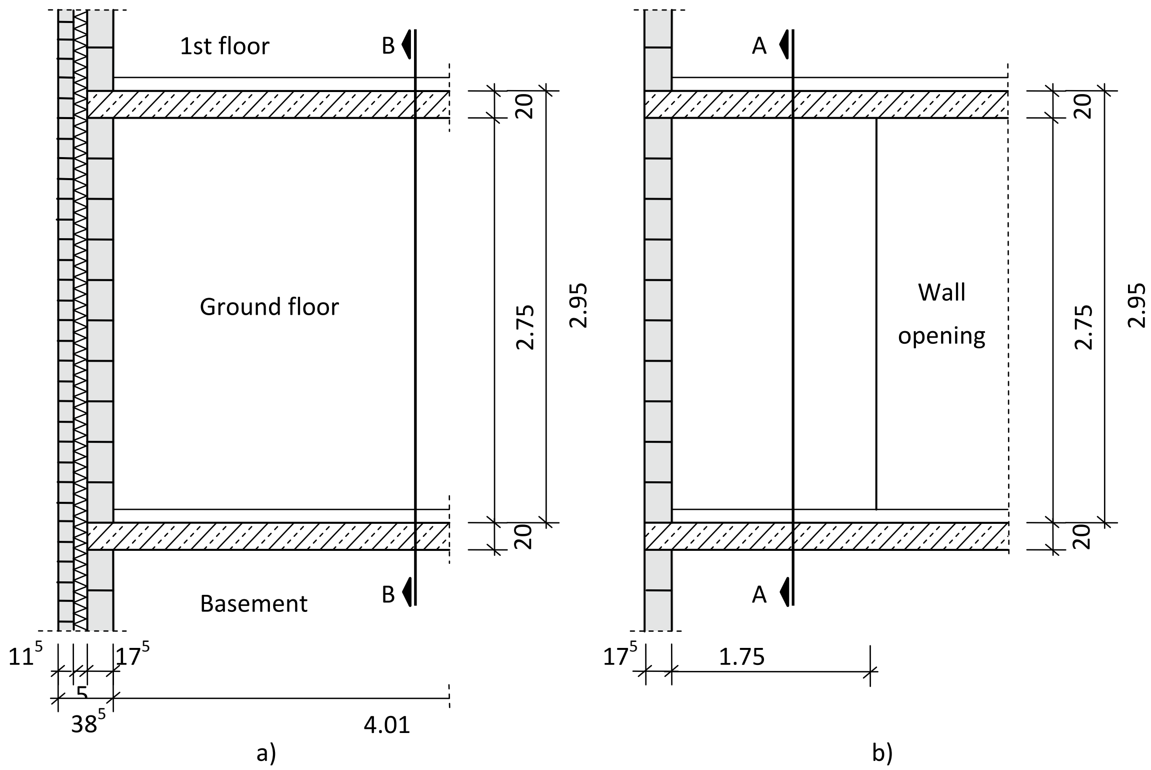


Illustration 3: Bracing wall plate, a) vertical section through the bracing wall (section A-A), b) View of the bracing wall from the interior (section B-B)

Masonry

- Special calcium silicate units for thin-bed mortar (KS-P), brick strength class: 20
- Bulk density class: 1.6, arithmetical value of the dead weight acc. to DIN 1055-1 g_0=17 kN/m³
- Format 12DF, unfilled head joints

Loading

- Superimposed wall loads
  - ⇒ Permanent: 43.1 kN/m
  - ⇒ Variable: 18.7 kN/m

- Ceiling bearing loads (from separate slab calculation, p = 4.7 kN/m²)
  - ⇒ From permanent loads: 17.5 kN/m
  - ⇒ From variable loads: 14.8 kN/m
- From wind and building inclination
  - ⇒ Horizontally acting in the ceiling plane: 14.5 kN
- Wall dead weight
  - ⇒ Masonry: 2.98 kN/m²
  - ⇒ Plaster: 0.35 kN/m²

Verification of the limiting criteria

The limiting criteria for the application of the simplified calculation method are identical in DIN 1053-1 and DIN 1053-100.

- The building height above ground level does not exceed 20.0 m.
- The ceiling span is less than 6.0 m.
- The building in question is a residential building, i.e. a building where people reside permanently. The live loads applying on top of the ceilings do not exceed the value of 5 kN/m².
- The following applies to the clear wall height:

$$115\ \text{mm} \leq d < 240\ \text{mm} \qquad 2.75\ \text{m} = h_0 \leq 2.75\ \text{m}$$

The simplified calculation method is appropriate.

Structural safety analysis IAW DIN 1053-1 and DIN 1053-100

General notes

The length of the present wall plate is very low in view of the fact that it is a bracing wall plate. Consequently, the bending that occurs through the length of the wall can produce an important portion of the compressive stress on the masonry and should therefore be taken into consideration in the analysis of the resistance of cross sections to axial forces.

In connection with the simplified analysis method, two load combinations should be examined:

1. the maximum superimposed load and bracing load
2. the minimum superimposed load and bracing load

You cannot predict with certainty which of the two load combinations will become decisive for the analysis of the resistance of cross sections to axial forces. Therefore, the analysis is performed for both load combinations. The shear resistance analysis, however, normally produces a more unfavourable result with the second load combination.

System parameters

The preconditions for the reduction of the effective length are complied with because d = 175 mm. Consequently, the reduction factor for a wall retained at two sides is applied $\beta = 0.75$.

Because $l = b' = 1.75 + 0.175/2 = 1.84 < 15 \cdot 0.175 = 2.63\ \text{m}$ the wall is assumed to have restraints at three sides. (This approach to the wall length assumes a connection to the transversal wall at the wall end that complies with the bond. If flat steel anchors are used, the clear wall length should be included instead.)

Effective length of the wall restraint at three sides $h_k = \dfrac{1}{1+\left(\dfrac{0.75 \cdot 2.75}{3 \cdot 1.84}\right)^2} \cdot 0.75 \cdot 2.75 = 1.81\ \text{m}$

Effective slenderness of the wall $\lambda = \dfrac{181}{17.5} = 10.3$

Calculation for the 1st load combination (max. superimposed load and bracing load)

The analysis in accordance with DIN 1053-1 should provide evidence that the maximum edge strain is smaller than the permissible strain. Possibly occurring gapping joints (also through the length of the wall) must be taken into account. In the analysis in accordance with DIN 1053-100, the maximum axial force at the compressed wall end related to the cross section thickness is determined. To be on the safe side, the structural analysis of the bracing wall is based on the clear wall length, i. e. the wall could be connected also via head joints on site.

Design values of the effects of actions

DIN 1053-1	DIN 1053-100
Resultant force applying to the wall foot	
$N = (17.5 + 14.8 + 3.33 \cdot 2.75 + 43.1 + 18.7) \cdot 1.75 = 180.7\ \text{kN}$	$N_{Ed} = (1.35 \cdot (3.33 \cdot 2.75 + 43.1 + 17.5) + 1.5 \cdot (18.7 + 14.8)) \cdot 1.75 = 252.7\ \text{kN}$
Eccentricity of the resultant at the wall foot (through the length of the wall due to the effect of the bracing load).	
$e = 14.5 \cdot 2.75 / 180.7 = 0.22\ \text{m}$	$e = 1.5 \cdot 14.5 \cdot 2.75 / 252.7 = 0.24\ \text{m}$
Limitation of the nominal eccentricity	
$e = e_k = \underline{\underline{0.22\ \text{m} < 0.58\ \text{m}}} = \dfrac{1}{3} \cdot 1.75$	
(The cross section is completely compressed under service loads)	
Maximum edge strain or related axial force and compressed length	
$\sigma_R = \dfrac{180.7 \cdot 10^{-3}}{0.175 \cdot 1.75}\left(1 + \dfrac{6 \cdot 0.22}{1.75}\right) = 1.04\ \text{N/mm}^2$	$N_{Ed,R} = \dfrac{252.7}{1.75}\left(1 + \dfrac{6 \cdot 0.24}{1.75}\right) = 263.2\ \text{kN/m}$
$l_c = l = 1.75\ \text{m}$	$l_c = l = 1.75\ \text{m}$

Analysis of the axial force effects

DIN 1053-1	DIN 1053-100
Basic value of the permissible compressive strain $\sigma_0 = 3.2$ N/mm²	Characteristic compressive strength $f_k = 10.0$ N/mm²
Reduction factors	
$k_2 = \frac{25 - \lambda}{15} = \frac{25 - 10.3}{15} = 0.98$	$\Phi_2 = 0.85 - 0.0011 \cdot \lambda^2 = 0.85 - 0.0011 \cdot 10.3^2 = 0.73$
$k_3 = 1.0$ da $l = 4.19\text{ m} < 4.20\text{ m}$	$\Phi_3 = 0.9$ da $l = 4.19\text{ m} < 4.20\text{ m}$
Analysis	
Permissible compressive strain $\sigma_{perm} = k \cdot \sigma_0 = 0.98 \cdot 3.2 = 3.14$ N/mm²	Design value of the resisting axial force $\gamma_M = k \cdot 1.5 = 1.0 \cdot 1.5 = 1.5$ $N_{Rd} = \Phi \cdot A \cdot f_d = \eta \cdot \Phi \cdot d \cdot l \cdot f_k / \gamma_M = 0.85 \cdot 0.73 \cdot 0.175 \cdot 1.0 \cdot 10.0 / 1.5 \cdot 1000 = 723.9\text{ kN}$
$\frac{\sigma_R}{\sigma_{perm}} = \frac{1.04}{3.14} = \underline{\underline{0.33 < 1}}$	$\frac{N_{Ed,R}}{N_{Rd}} = \frac{263.2}{723.9} = \underline{\underline{0.36 < 1}}$

Calculation for the 2ne load combination (min. superimposed load and bracing load)

Design values of the effects of actions

DIN 1053-1	DIN 1053-100
Design value of the resultant axial force at the wall foot	
$N = (17.5 + 3.33 \cdot 2.75 + 43.1) \cdot 1.75$ $= 122.1$ kN	$N_{Ed} = 1.0 \cdot (17.5 + 3.33 \cdot 2.75 + 43.1) \cdot 1.75$ $= 122.1$ kN
Eccentricity of the resultant at the wall foot (through the length of the wall due to the effect of the bracing load).	
$e = 14.5 \cdot 2.75 / 122.1$ $= 0.33$ m	$e = 1.5 \cdot 14.5 \cdot 2.75 / 122.1$ $= 0.49$ m

Limitation of the nominal eccentricity

$$e = e_k = 0.33 \text{ m} \begin{cases} < 0.58 \text{ m} = 1.75/3 \\ > 0.29 \text{ m} = 1.75/6 \end{cases}$$

(The cross section is partly compressed under service loads)

Maximum edge strain or related axial force and compressed length

DIN 1053-1	DIN 1053-100
$l_c = 3 \cdot (1.75/2 - 0.33) = 1.64$ m $\sigma_R = \frac{2 \cdot 122.1 \cdot 10^{-3}}{1.64 \cdot 0.175}$ $= 0.85$ N/mm²	$l_c = 3 \cdot (1.75/2 - 0.49) = 1.16$ m $N_{Ed,R} = \frac{2 \cdot 122.1}{1.16}$ $= 210.5$ kN/m

Analysis of the axial force effects

DIN 1053-1	DIN 1053-100
Basic value of the permissible compressive strain	Characteristic compressive strength
$\sigma_0 = 3.2$ N/mm²	$f_k = 10.0$ N/mm²
Reduction factors	
$k_1 = 1.0$	
$k_2 = \frac{25 - \lambda}{15} = \frac{25 - 10.3}{15}$ $= 0.98$	$\Phi_2 = 0.85 - 0.0011 \cdot \lambda^2 = 0.85 - 0.0011 \cdot 10.3^2$ $= 0.73$
$k_3 = 1.0$ da $l = 4.19 \text{ m} < 4.20 \text{ m}$	$\Phi_3 = 0.9$ da $l = 4.19 \text{ m} < 4.20 \text{ m}$
Analysis	
Permissible compressive strain	Design value of the resisting axial force
$\sigma_{perm} = k \cdot \sigma_0 = 0.98 \cdot 3.2 = 3.14$ N/mm²	$\gamma_M = k \cdot 1.5 = 1.0 \cdot 1.5 = 1.5$ $N_{Rd} = \eta \cdot \Phi \cdot d \cdot l \cdot f_k / \gamma_M$ $= 0.85 \cdot 0.73 \cdot 0.175 \cdot 1.0 \cdot 10.0 / 1.5 \cdot 1000$ $= 723.9$ kN
$\frac{\sigma_R}{\sigma_{perm}} = \frac{0.85}{3.14} = 0.27 < 1$	$\frac{N_{Ed,R}}{N_{Rd}} = \frac{210.5}{723.9} = 0.29 < 1$

Analysis of the shear force effects

DIN 1053-1	DIN 1053-100
Shear stress distribution factor	
$\frac{h}{l}=\frac{2.75}{1.75}=1.57\begin{cases}<2.0\\>1.0\end{cases}\rightarrow\alpha\text{ or }c=1.29$	
Existing shear stress	Design value of the shear force
$\tau=1.29\cdot\frac{14.5\cdot10^{-3}}{0.175\cdot1.64}=0.065\text{ N/mm²}$	$V_{Ed}=1.5\cdot14.5=21.8\text{ kN}$
Initial shear strength (unfilled head joints)	
$\sigma_{0HS}=0.11/2=0.055\text{ N/mm²}$	$f_{vk0}=0.22/2=0.11\text{ N/mm²}$
Maximum value of the shear strength	
$\max\tau=0.014\cdot20=0.28\text{ N/mm²}$	$\max f_{vk}=0.020\cdot20=0.40\text{ N/mm²}$
Corresponding average compressive strain	
$\sigma_{Dm}=\frac{122.1\cdot10^{-3}}{1.64\cdot0.175}=0.43\text{ N/mm²}$	$\sigma_{Dd}=\frac{122.1\cdot10^{-3}}{1.16\cdot0.175}=0.60\text{ N/mm²}$
Permissible shear stress / shear resistance	
$\text{perm}\tau=\min\begin{cases}0.055+0.20\cdot0.43=\underline{0.14\text{ N/mm²}}\\0.28\text{ N/mm²}\end{cases}$	$f_{vk}=\min\begin{cases}0.11+0.40\cdot0.60=\underline{0.35\text{ N/mm²}}\\0.40\text{ N/mm²}\end{cases}$
	Shear resistance coefficient
	$\alpha_s=\min\begin{cases}1.125\cdot1.75=1.97\text{ m}\\1.333\cdot1.16=\underline{1.55\text{ m}}\end{cases}$
	Design value of the resisting shear force
	$V_{Rd}=\alpha_s\cdot\frac{f_{vk}}{\gamma_M}\cdot\frac{d}{c}=1.55\cdot\frac{0.35\cdot1000}{1.5}\cdot\frac{0.175}{1.25}=50.6\text{ kN}$
Analysis	
$\frac{\tau}{\text{perm}\tau}=\frac{0.065}{0.14}=\underline{\underline{0.46<1}}$	$\frac{V_{Ed}}{V_{Rd}}=\frac{21.8}{50.6}=\underline{\underline{0.43<1}}$

Edge strain analysis

DIN 1053-1	DIN 1053-100
Modulus of elasticity of the masonry	
$E = 3000 \cdot \sigma_0 = 3000 \cdot 3.2 = 9600$ N/mm²	$E = 1000 \cdot f_k = 1000 \cdot 10.0 = 10000$ N/mm²
Strain at the compressed plate edge	
$\varepsilon_D = \frac{\sigma_R}{E} = \frac{0.85}{9600} = 0.89 \cdot 10^{-4}$	$\varepsilon_D = \frac{\sigma_{Rd}}{E} = \frac{0.85}{10000} = 0.85 \cdot 10^{-4}$
Edge strain at the plate edge under tension	
$\varepsilon_R = \varepsilon_D \left(\frac{l}{l_c} - 1\right) = 0.89 \cdot 10^{-4} \left(\frac{1.75}{1.64} - 1\right) = 0.6 \cdot 10^{-5}$	$\varepsilon_R = \varepsilon_D \left(\frac{l}{l_c} - 1\right) = 0.85 \cdot 10^{-4} \left(\frac{1.75}{1.64} - 1\right) = 0.57 \cdot 10^{-5}$
Analysis	
$\frac{\varepsilon_R}{1 \cdot 10^{-4}} = \frac{0.6 \cdot 10^{-5}}{1 \cdot 10^{-4}} = \underline{\underline{0.06 < 1}}$	$\frac{\varepsilon_R}{1 \cdot 10^{-4}} = \frac{0.57 \cdot 10^{-5}}{1 \cdot 10^{-4}} = \underline{\underline{0.06 < 1}}$

Decisive loading rates calculated with MWX

DIN 1053-1	DIN 1053-100
Resistance of cross sections to axial loads	
$\frac{\sigma_R}{\sigma_{perm}} = \frac{1.04}{3.13} = \underline{\underline{0.33 < 1.0}}$	$\frac{N_{Ed,R}}{N_{Rd}} = \frac{246.5^{(*)}}{892.5} = \underline{\underline{0.28 < 1.0}}$
Shear resistance	
$\frac{\tau_{exis}}{\tau_{perm}} = \frac{0.065}{0.140} = \underline{\underline{0.46 < 1.0}}$	$\frac{V_{Ed}}{V_{Rd}} = \frac{21.8}{49.1} = \underline{\underline{0.44 < 1.0}}$
Edge strain	
$\frac{\varepsilon_{R,exis}}{\varepsilon_{R,perm}} = \frac{0.06 \cdot 10^{-4}}{1 \cdot 10^{-4}} = \underline{\underline{0.06 < 1.0}}$	$\frac{\varepsilon_{R,exis}}{\varepsilon_{R,perm}} = \frac{0.06 \cdot 10^{-4}}{1 \cdot 10^{-4}} = \underline{\underline{0.06 < 1.0}}$
Limitation of the nominal eccentricity through the length of the wall (due to bracing load)	
$\frac{e_{exis}}{e_{perm}} = \frac{0.33}{0.58} = \underline{\underline{0.57 < 1.0}}$	$\frac{e_{exis}}{e_{perm}} = \frac{0.33}{0.58} = \underline{\underline{0.57 < 1.0}}$

(*) Application-internal inclusion of the combination coefficient ψ=0.7 to provide for the coincidence of the imposed load and the bracing load (wind load = leading action).

Calculation examples IAW DIN 1996

Exterior wall according to the simplified calculation method

System and loading

Construction

- Building height: 8.0 m
- Clear ceiling span: 5.20 m (opposite bearing t=11.5 cm)
- Exterior wall made of masonry, single-leaf
- Clear distance between bracing wall (d=36.5 cm) and wall opening is 1.5 m
- Wall finish: exterior: 20 mm lime-cement plaster; interior: 20 mm lime plaster
- Ceilings: reinforced concrete C30/37
- characteristic value of wind load q_k=0,40 kN/m^2

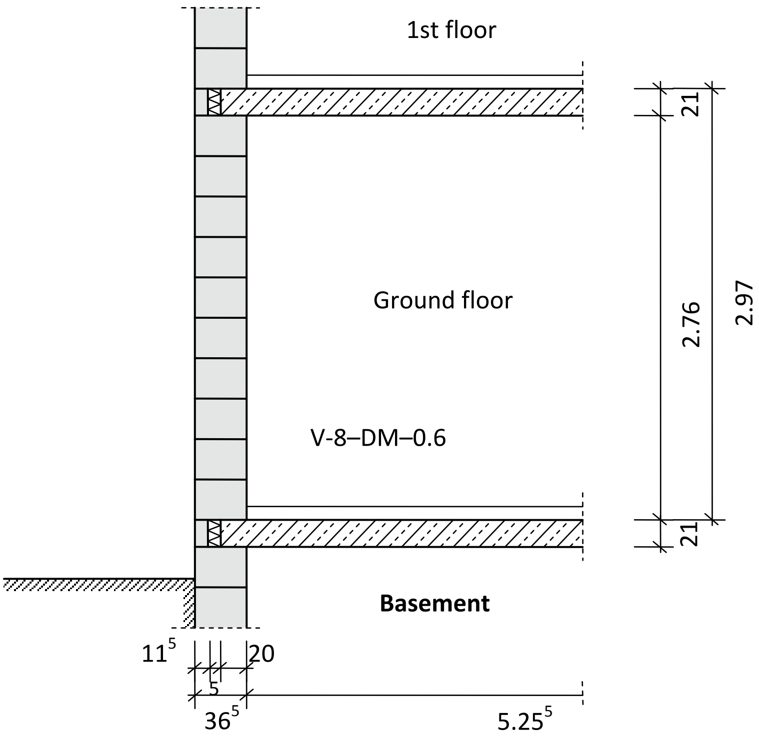


Illustration 4: Example of a supporting exterior wall

Masonry

- Solid lightweight concrete unit
- Brick strength class 8, thin-bed mortar, unfilled head joints
- Bulk density class: 0.6; arithmetical value of the dead weight: g_0=7.0 kN/m³
- f_b = 10.0 N/mm²

Loading

- Superimposed wall loads (w/o ceiling bearing loads)
  - ⇒ Permanent: 27.3 kN/m
  - ⇒ Variable: 8.1 kN/m
- Ceiling loads
  - ⇒ Flooring and plaster: 1.4 kN/m²
  - ⇒ Imposed load incl. partition wall addition: 2.70 kN/m²

- Ceiling bearing loads
  - ⇒ From permanent loads: 17.8 kN/m
  - ⇒ From variable loads: 7.2 kN/m
- Wall dead weight
  - ⇒ Masonry: 2.56 kN/m²
  - ⇒ Plaster: 0.75 kN/m²

Verification of the limiting criteria

The limiting criteria for the application of the simplified calculation specified by ÖNNORM B 1996-3 are identical to those stipulated by NA to BS EN 1996-3 with exception of the maximum building height.

- The max. building height above ground level is
  - ⇒ ÖNORM: h_m = 20 m
  - ⇒ BS: h_m = 12 m
- The height of the ground storey must not exceed 3.2 m. It the total height of the building is 7.0 m, the ground storey may have a height of up to 4.0 m.
- The ceiling span is less than 7.0 m.
- The ceiling bearing length amounts at least to 40 % of the wall thickness.
- The building in question is a residential building, i.e. a building where people reside permanently. The imposed loads applying on top of the ceilings do not exceed the value of 5 kN/m².
- The final creep coefficient Φ_m does not exceed 2.0.

The simplified calculation method is appropriate in both cases.

Structural safety analysis IAW ÖNorm B-1996-3 and NA to BS EN 1996-3

System parameters

It is permissible to equate the effective length h_{ef} to the clear wall height because the wall in question acts as end bearing of a ceiling. For single leaf walls, the effective wall thickness t_{ef} is equated to the real wall thickness *t*. The effective slenderness is calculated as follows:

$$\Rightarrow \lambda = \frac{h_k}{d} = \frac{276}{36.5} = 7.56$$

For walls which act as end supports to floors and are additionally loaded with wind loads the minimum required wall thickness is:

$$\Rightarrow \quad t \geq \frac{c_1 \cdot q_{Ewd} \cdot b \cdot h^2}{N_{Ed}} + c_2 \cdot h$$

where	N_{Ed}	smallest design value of the vertical load at the top of the wall
	q_{Ewd}	design value of the wind load in kN/m²
	h	free wall height
	b	width of the wall
	c_1, c_2	constants acc. to table 4.1 in EN1996-3
	t	effective thickness of the wall, used as end bearing

ÖNORM B 1996-3	NA to BS EN 1996-3
$\alpha \geq \frac{N_{Ed}}{t \cdot b \cdot f_d} = \frac{83{,}83}{0{,}365 \cdot 1 \cdot 2{,}66} = 0{,}087$	$\alpha \geq \frac{N_{Ed}}{t \cdot b \cdot f_d} = \frac{83{,}83}{0{,}365 \cdot 1 \cdot 2{,}46} = 0{,}093$
$t \geq \frac{0{,}12 \cdot 0{,}4 \cdot 1{,}5 \cdot (2{,}76)^2}{83{,}83} + 0{,}018 \cdot 2{,}76$ $= 0{,}056 \text{ m} = 5{,}6 \text{ cm}$	$t \geq \frac{0{,}12 \cdot 0{,}4 \cdot 1{,}5 \cdot (2{,}76)^2}{83{,}83} + 0{,}019 \cdot 2{,}76$ $= 0{,}059 \text{ m} = 5{,}9 \text{ cm}$

Design values of the effects of actions

Under normal conditions, wind loads must not be taken into consideration in combination with the simplified method. Impacts from the torsion of the ceiling are already included in the reduction factors. Therefore, the determination of the action-effects is limited to the calculation of the axial compressive force.

ÖNorm B 1996-3	NA to BS EN 1996-3
Design value of the axial compressive force at the wall head	
$N_{E,d} = 1.35 \cdot (27.3 + 17.8) + 1.5 \cdot (8.1 + 7.2) = 83.84 \text{ kN/m}$	
Design value of the axial compressive force at half of the wall height	
$N_{E,d} = 83.8 + 1.35 \cdot \frac{(0.365 \cdot 7.0 + 0.75) \cdot 2.76}{2} = 89.99 \text{ kN/m}$	
Design value of the axial compressive force at the wall foot	
$N_{E,d} = 83.8 + 1.35 \cdot (0.365 \cdot 7.0 + 0.75) \cdot 2.76 = 96.15 \text{ kN/m}$	

Design values of the resistances

ÖNorm B 1996-3	NA to BS EN 1996-3
Characteristic compressive strength	
$f_k = K \cdot f_b^{\alpha} \cdot f_m^{\beta}$	
$K = 0.7$ $\alpha = 0.85$ $f_k = 0.75 \cdot 10^{0.85} = 5.31$ N/mm²	$K = 0.8$ $\alpha = 0.85$ $f_k = 0.80 \cdot 10^{0.85} = 5.66$ N/mm²
Effective length	
$\rho_n = 1.0$ $h_{ef} = h_{clear} \cdot \rho_n = 2.76$ m	
Effective wall thickness	
$t_{ef} = t = 0.365$ m	
Effective span	
$l_{ef} = 5.25 \text{ m} + 0.175 = 5.425$ m	
$\lambda = h_{ef}/t_{ef} = 7.56$	
Reduction factor at half of the wall height	
$\Phi_{s,m} = 0.85 - 0.0011 \cdot \lambda^2 = 0.85 - 0.0011 \cdot (7.56)^2 = 0.787$	
Reduction factor at wall head/foot	
$\Phi_s = 1.3 - \frac{l_{f,ef}}{8} = 1.3 - \frac{5.425}{8} = 0.622$	

Analysis

ÖNorm B 1996-3	NA to BS EN 1996-3
Design value of the resisting normal force At the wall head and foot	
$N_{R,d} = \Phi_s \cdot A \cdot f_k / \gamma_M$ $= 0.622 \cdot 36.5 \cdot 100 \cdot 5.31 / 2.0$ $= 601.69$ kN/m	$N_{R,d} = \Phi_s \cdot A \cdot f_k / \gamma_M$ $= 0.622 \cdot 36.5 \cdot 100 \cdot 5.66 / 2.3$ $= 558.93$ kN/m
Design value of the resisting axial force at half of the wall height	
$N_{R,d} = \Phi_{s,m} \cdot A \cdot f_k / \gamma_M$ $= 0.787 \cdot 36.5 \cdot 100 \cdot 5.31 / 2.0$ $= 762.70$ kN/m	$N_{R,d} = \Phi_{s,m} \cdot A \cdot f_k / \gamma_M$ $= 0.787 \cdot 36.5 \cdot 100 \cdot 5.66 / 2.3$ $= 707.44$ kN/m
Analysis	
$N_{E,d} \leq 1$ or $\frac{N_{E,d}}{N_{R,d}} \leq 1$	
At the wall head	
$\frac{N_{E,d}}{N_{R,d}} = \frac{83.84}{601.69} = 0.14 < 1.0$	$\frac{N_{E,d}}{N_{R,d}} = \frac{83.84}{558.93} = 0.15 < 1.0$
At half of the wall height	
$\frac{N_{E,d}}{N_{R,d}} = \frac{89.99}{762.70} = 0.12 < 1.0$	$\frac{N_{E,d}}{N_{R,d}} = \frac{89.99}{707.44} = 0.13 < 1.0$
At the wall foot	
$\frac{N_{E,d}}{N_{R,d}} = \frac{96.15}{601.69} = 0.16 < 1.0$	$\frac{N_{E,d}}{N_{R,d}} = \frac{96.15}{558.93} = 0.17 < 1.0$

The analysis of the load introduction (partially supported ceiling slab) is dispensed with because the maximum loading rate is smaller than the bearing length of the ceiling slab in per cent.

Decisive loading rates calculated with MWX

ÖNorm B 1996-3	NA to BS EN 1996-3
Resistance of cross sections to axial loads	
At the wall head	
$\frac{N_{E,d}}{N_{R,d}} = \frac{83.84}{600.48} = 0.14 < 1.0$	$\frac{N_{E,d}}{N_{R,d}} = \frac{83.84}{556.96} = 0.15 < 1.0$
At half of the wall height	
$\frac{N_{E,d}}{N_{R,d}} = \frac{89.99}{762.70} = 0.12 < 1.0$	$\frac{N_{E,d}}{N_{R,d}} = \frac{89.99}{707.44} = 0.13 < 1.0$
At the wall foot	
$\frac{N_{E,d}}{N_{R,d}} = \frac{96.15}{600.48} = 0.16 < 1.0$	$\frac{N_{E,d}}{N_{R,d}} = \frac{96.15}{556.96} = 0.17 < 1.0$

Bracing wall plate

System and loading

Construction

- Building height: H=9.50 m
- Ceiling span l_1=4.10 m
- Exterior wall made of masonry, bracing wall (wind plate)
- Wall finish: Exterior leaf is self-supporting; interior: lime plaster: 20 mm
- Clear distance of bracing wall (d=17.5 cm) to wall opening is 1.75 m
- The ceilings are solid slabs, fully two-dimensionally supported
- charakteristische Bemessungswert der Windlast q_k=0,40 kN/m^2

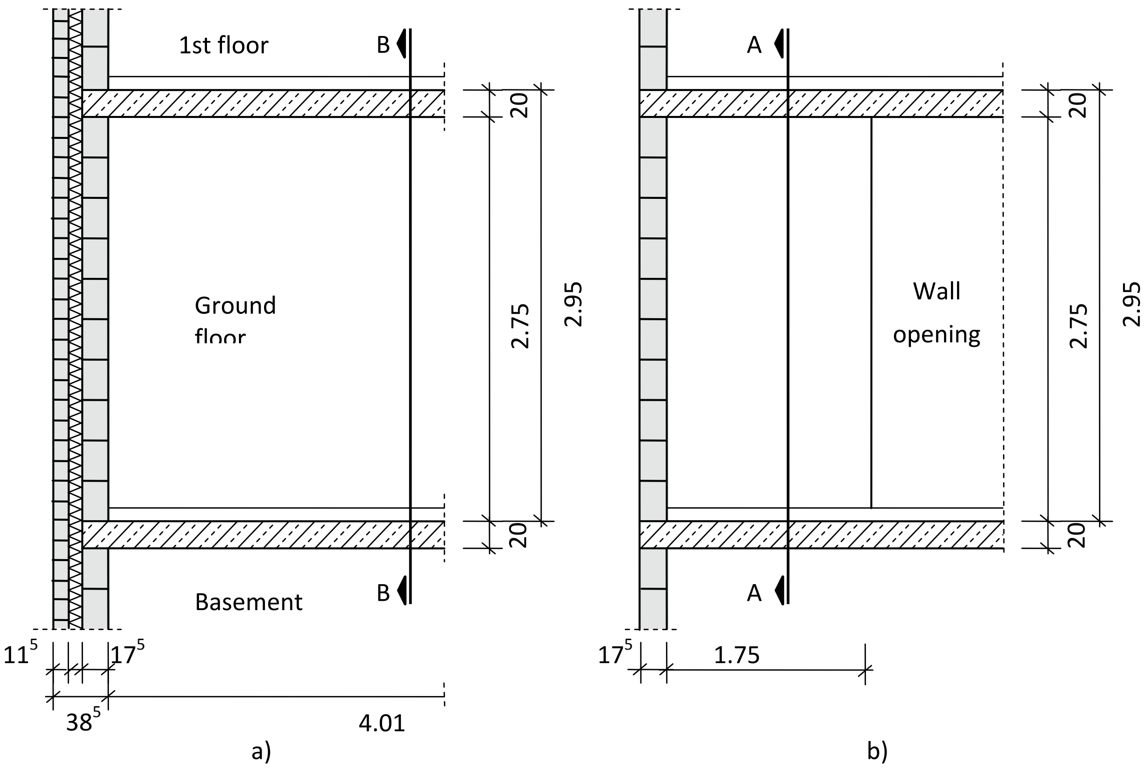


Illustration 5: Bracing wall plate, a) vertical section through the bracing wall (section A-A), b) View of the bracing wall from the interior (section B-B)

Masonry

- Solid lightweight concrete unit (V), brick strength class 8
- Bulk density class: 1.6; arithmetical value of the dead weight: g_0=17 kN/m^3
- Unfilled head joints
- f_b = 10 N/mm²

Loading

- Superimposed wall loads
  - ⇒ Permanent: 43.1 kN/m
  - ⇒ Variable: 18.7 kN/m
- Ceiling bearing loads (from separate slab calculation, p = 4.7 kN/m²)
  - ⇒ From permanent loads: 17.5 kN/m
  - ⇒ From variable loads: 14.8 kN/m
- From wind and building inclination
  - ⇒ Horizontally acting in the ceiling plane: 14.5 kN
- Wall dead weight
  - ⇒ Masonry 2.98 kN/m²
  - ⇒ Plaster: 0.35 kN/m²

Verification of the limiting criteria

The limiting criteria for the application of the simplified calculation specified by ÖNorm B 1996-3 are identical to those stipulated by NA to BS EN 1996-3 with exception of the maximum building height.

- The max. building height above ground level is
  - ⇒ ÖNorm: h_m = 20 m
  - ⇒ BS: h_m = 12 m
- The height of the ground storey must not exceed 3.2 m. It the total height of the building is 7.0 m, the ground storey may have a height of up to 4.0 m.
- The ceiling span is less than 7.0 m.
- The ceiling bearing length amounts at least to 40 % of the wall thickness.
- The building in question is a residential building, i.e. a building where people reside permanently. The imposed loads applying on top of the ceilings do not exceed the value of 5 kN/m².
- The final creep coefficient Φ_m does not exceed 2.0.

The simplified calculation method is appropriate in both cases.

Structural safety analysis IAW ÖNorm B-1996-3 and NA to BS EN 1996-3

General notes

The present wall plate has a very low length for a bracing wall plate. Consequently, bending that occurs through the length of the wall can produce an important portion of the compressive stress on the masonry and should therefore be taken into consideration in the analysis of the resistance of cross sections to axial forces.

In connection with the simplified analysis method, two load combinations should be examined:

3. the maximum superimposed load and bracing load
4. the minimum superimposed load and bracing load

You cannot predict with certainty which of the two load combinations will become decisive for the analysis of the resistance of cross sections to axial forces. Therefore, the analysis is performed for both load combinations. The shear resistance analysis, however, normally produces a more unfavourable result with the second load combination.

System parameters

As the wall serves as a single-side end bearing of the ceiling, the reduction factor for walls retained at two sides $\rho = 1.0$ applies. A restraint on three sides is not permissible.

Effective length with restraint at three sides $h_{ef} = h_{clear} \cdot \rho_3 = 2.75 \cdot 1.0 = 2.75 \text{ m}$

Effective slenderness of the wall $\lambda = \frac{275}{17.5} = 15.7$

For walls which act as end supports to floors and are additionally loaded with wind loads the minimum required wall thickness is:

$$\Rightarrow \quad t \geq \frac{c_1 \cdot q_{Ewd} \cdot b \cdot h^2}{N_{Ed}} + c_2 \cdot h$$

where	N_{Ed}	smallest design value of the vertical load at the top of the wall
	q_{Ewd}	design value of the wind load in kN/m²
	h	free wall height
	b	width of the wall
	c_1, c_2	constants acc. to table 4.1 in EN1996-3
	t	effective thickness of the wall, used as end bearing

ÖNORM B 1996-3	**NA to BS EN 1996-3**
$\alpha \geq \frac{N_{Ed}}{t \cdot b \cdot f_d} = \frac{83,83}{0,365 \cdot 1 \cdot 2,66} = 0,087$	$\alpha \geq \frac{N_{Ed}}{t \cdot b \cdot f_d} = \frac{83,83}{0,365 \cdot 1 \cdot 2,46} = 0,093$
$t \geq \frac{0,12 \cdot 0,4 \cdot 1,5 \cdot (2,76)^2}{83,83} + 0,018 \cdot 2,76 = 0,056$	$t \geq \frac{0,12 \cdot 0,4 \cdot 1,5 \cdot (2,76)^2}{83,83} + 0,019 \cdot 2,76 = 0,059$

Calculation for the 1st load combination (max. superimposed load and bracing load)

The effect of the bracing load produces a linearly variable behaviour the related axial force over the wall length. Correspondingly, the maximum related axial force at the compressed wall end is determined in the analysis. To be on the safe side, the structural analysis of the bracing wall is based on the clear wall length, i. e. the wall could be connected also via head joints on site.

Design values of the effects of actions

ÖNorm B 1996-3	NA to BS EN 1996-3
Resultant force applying to the wall foot	
$N_{Ed} = (1.35 \cdot (3.33 \cdot 2.75 + 43.1 + 17.5) + 1.5 \cdot (18.7 + 14.8)) \cdot 1.75 = 252.7\ \text{kN}$	
Eccentricity of the resultant at the wall foot (through the length of the wall due to the effect of the bracing load).	
$e = 1.5 \cdot 14.5 \cdot 2.75 / 252.7 = 0.24\ \text{m}$	
Maximum related axial force and compressed length	
$N_{Ed,R} = \frac{252.7}{1.75}\left(1 + \frac{6 \cdot 0.24}{1.75}\right) = 263.2\ \text{kN/m}$; $l_c = l = 1.75\ \text{m}$	

Analysis of the axial force effects

ÖNorm B 1996-3	NA to BS EN 1996-3
Characteristic compressive strength	
$f_k = K \cdot f_b^{\alpha} \cdot f_m^{\beta}$	
$f_k = 0.75 \cdot 10_b^{0.85} = 5.31\ \text{N/mm}^2$	$f_k = 0.80 \cdot 10_b^{0.85} = 5.66\ \text{N/mm}^2$
Effective length	
$\rho_n = 1{,}0$ $h_{ef} = h_{clear} \cdot \rho_n = 2.75\ \text{m}$	
Effective wall thickness	
$t_{ef} = t = 0.175\ \text{m}$	
Effective span	
$l_{ef} = 4.01\ \text{m} + 0.175/2 = 4.098\ \text{m}$	
$\lambda = h_{ef} / t_{ef} = 15.7\ \text{m}$	
Reduction factors at half of the wall height	
$\Phi_{s,m} = 0.85 - 0.0011 \cdot \lambda^2 = 0.85 - 0.0011 \cdot 15.7^2 = 0.578$	
Reduction factors at wall head/foot	
$\Phi_s = 1.3 - \frac{l_{f,ef}}{8} = 1.3 - \frac{4.098}{8} = 0.788$	
Analysis	
Design value of the resisting axial force at half of the wall height	
$N_{Rd} = \Phi_{s,m} \cdot A \cdot f_k / \gamma_M = 0.578 \cdot 0.175 \cdot 5.31/2.0 \cdot 1000 = 268.70\ \text{kN/m}$ $\frac{N_{Ed,R}}{N_{Rd}} = \frac{242.1}{268.7} = 0.90 < 1$	$N_{Rd} = \Phi_{s,m} \cdot A \cdot f_k / \gamma_M = 0.578 \cdot 0.175 \cdot 5.66/2.3 \cdot 1000 = 249.23\ \text{kN/m}$ $\frac{N_{Ed,R}}{N_{Rd}} = \frac{242.1}{249.23} = 0.97 < 1$
Design value of the resisting axial force at the wall head/foot	
$N_{Rd} = \Phi_s \cdot A \cdot f_k / \gamma_M = 0.788 \cdot 0.175 \cdot 5.31/2.0 \cdot 1000 = 366.01\ \text{kN/m}$ $\frac{N_{Ed,R}}{N_{Rd}} = \frac{231.3}{366.01} = 0.63 < 1$ $\frac{N_{Ed,R}}{N_{Rd}} = \frac{252.7}{366.01} = 0.69 < 1$	$N_{Rd} = \Phi_s \cdot A \cdot f_k / \gamma_M = 0.788 \cdot 0.175 \cdot 5.66/2.3 \cdot 1000 = 339.49\ \text{kN/m}$ $\frac{N_{Ed,R}}{N_{Rd}} = \frac{231.3}{339.49} = 0.68 < 1$ $\frac{N_{Ed,R}}{N_{Rd}} = \frac{252.7}{339.49} = 0.74 < 1$

Calculation for the 2nd load combination (min. superimposed load and bracing load)

Design values of the effects of actions

ÖNorm B 1996-3	NA to BS EN 1996-3
Design value of the resultant axial force at the wall foot	
$N_{Ed} = 1.0 \cdot (175 + 3.33 \cdot 2.75 + 43.1) \cdot 1.75 = 122.1\ kN$	
Eccentricity of the resultant at the wall foot (through the length of the wall due to the effect of the bracing load).	
$e = 1.5 \cdot 14.5 \cdot 2.75/122.1 = 0.49\ m$	
Maximum related axial force and compressed length	
$l_c = 1.5 \cdot (1.75/2 - 0.49) = 0.578\ m$; $N_{Ed,R} = \frac{2 \cdot 122.1}{0.578} = 422.49\ kN/m$	

Analysis of the axial force effects

ÖNorm B 1996-3	NA to BS EN 1996-3
Characteristic compressive strength	
$f_k = K \cdot f_b^{\alpha} \cdot f_m^{\beta}$	
$f_k = 0.75 \cdot 10_b^{0.85} = 5.31\ N/mm²$	$f_k = 0.80 \cdot 10_b^{0.85} = 5.66\ N/mm²$
Reduction factors at half of the wall height	
$\Phi_{s,m} = 0.85 - 0.0011 \cdot \lambda^2 = 0.85 - 0.0011 \cdot 15.7^2 = 0.578$	
Reduction factors at the wall head/foot	
$\Phi_s = 1.3 - \frac{l_{f,ef}}{8} = 1.3 - \frac{4.098}{8} = 0.788$	
Analysis	
Design value of the resisting axial force at half of the wall height	
$N_{Rd} = \Phi_{s,m} \cdot A \cdot f_k / \gamma_M = 0.578 \cdot 0.175 \cdot 5.31/2.0 \cdot 1000 = 268.70\ kN/m$; $\frac{N_{Ed,R}}{N_{Rd}} = \frac{114.1}{268.7} = 0.42 < 1$	$N_{Rd} = \Phi_{s,m} \cdot A \cdot f_k / \gamma_M = 0.578 \cdot 0.175 \cdot 5.66/2.3 \cdot 1000 = 249.23\ kN/m$; $\frac{N_{Ed,R}}{N_{Rd}} = \frac{114.1}{249.23} = 0.46 < 1$
Design value of the resisting axial force at the wall head/foot	
$N_{Rd} = \Phi_s \cdot A \cdot f_k / \gamma_M = 0.788 \cdot 0.175 \cdot 5.31/2.0 \cdot 1000 = 366.01\ kN/m$; $\frac{N_{Ed,R}}{N_{Rd}} = \frac{106.12}{366.01} = 0.29 < 1$; $\frac{N_{Ed,R}}{N_{Rd}} = \frac{122.1}{366.01} = 0.33 < 1$	$N_{Rd} = \Phi_s \cdot A \cdot f_k / \gamma_M = 0.788 \cdot 0.175 \cdot 5.66/2.3 \cdot 1000 = 339.49\ kN/m$; $\frac{N_{Ed,R}}{N_{Rd}} = \frac{106.12}{339.49} = 0.31 < 1$; $\frac{N_{Ed,R}}{N_{Rd}} = \frac{122.1}{339.49} = 0.36 < 1$

Analysis of the shear force effects

ÖNorm B 1996-3	NA to BS EN 1996-3
Design value of the shear force	
$V_{Ed} = 1.5 \cdot 14.5 = 21.8$ kN	
Initial shear strength	
$f_{vko} = 0.30$ N/mm²	
Maximum value of the shear strength (unfilled head joints)	
$f_{vku} = 0.045 \cdot f_b = 0.045 \cdot 10 = 0.45$ N/mm²	
Design value of the resisting shear force	
$V_{Rd} = c_v \cdot (l/2 - e_{Ed}) \cdot t \cdot f_{vko} / \gamma_M + 0.4 \cdot N_{Ed} / \gamma_M$ $= 1.5 \cdot (1.75/2 - 0.49) \cdot 0.175 \cdot 0.3/2.0 +$ $0.4 \cdot 122.1/2.0$ $= 39.58$ kN $< 3 \cdot (l/2 - e_{Ed}) \cdot t \cdot f_{vku} / \gamma_M$ $< 3 \cdot (1.75/2 - 0.49) \cdot 0.175 \cdot 0.45/2.0$ $= 45.50$ kN	$V_{Rd} = c_v \cdot (l/2 - e_{Ed}) \cdot t \cdot f_{vko} / \gamma_M + 0.4 \cdot N_{Ed} / \gamma_M$ $= 1.5 \cdot (1.75/2 - 0.49) \cdot 0.175 \cdot 0.3/2.3 +$ $0.4 \cdot 122.1/2.3$ $= 34.62$ kN $< 3 \cdot (l/2 - e_{Ed}) \cdot t \cdot f_{vku} / \gamma_M$ $< 3 \cdot (1.75/2 - 0.49) \cdot 0.175 \cdot 0.45/2.3$ $= 39.56$ kN
Analysis	
$\frac{V_{Ed}}{V_{Rd}} = \frac{21.75}{39.58} = \underline{\underline{0.55 < 1}}$	$\frac{V_{Ed}}{V_{Rd}} = \frac{21.75}{34.62} = \underline{\underline{0.63 > 1}}$

Decisive loading rates calculated with MWX

(*) Application-internal inclusion of the combination coefficient ψ=0.7 to provide for the coincidence of the imposed load and the bracing load (wind load = leading action).

ÖNorm B 1996-3	NA to BS EN 1996-3
Resistance of cross sections to axial loads	
Dezimaltrennzeichen Punkt	$\frac{N_{Ed,R}}{N_{Rd}} = \frac{252.7}{339.49} = \underline{\underline{0.74 < 1}}$
Shear resistance	
$\frac{V_{Ed}}{V_{Rd}} = \frac{21.75}{39.58} = \underline{\underline{0.55 < 1}}$	$\frac{V_{Ed}}{V_{Rd}} = \frac{21.75}{34.62} = \underline{\underline{0.63 > 1}}$

Frequently asked questions

Can I also perform an analysis of walls over several storeys in MWX?

No. The application is intended for the analysis of individual walls exclusively. You can use the tried and tested Frilo analysis application MW for the analysis of storey walls.

Why can MWX not perform an analysis of isolated walls?

The MWX application is intended for the analysis of masonry walls in building construction, i. e. the equivalent system used in the application is based on plain frames. In addition, the most analysis approaches assume unshiftable restraints at the wall head and foot. Therefore, isolated walls constitute a special case that is difficult to map adequately using general analysis algorithms.

Why does MWX use a cantilever as an equivalent structural system (within the height of the design wall) for the calculation of action-effects resulting from bracing loads?

The cantilever constitutes a conservative idealisation of the real conditions at bracing plates. More favourable effects of ceiling slabs (such as deflection impediments among others) 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 perform analyses of basement walls in MWX?

Yes, with certain restrictions. MWX examines exclusively the vertical distribution of horizontal loads, i.e. a feature equivalent to the reduction of the required minimum superimposed load with short walls (e.g. from the well-known analysis of basement walls without consideration of the earth pressure) is not implemented.

What do I have to consider in connection with partially supported ceiling slabs?

When performing the structural safety analysis in accordance with DIN 1053-1 or DIN 1053-100, you should be aware of the fact that both standards assume fully supported ceiling plates for the analysis. Partial supports are however not excluded. Therefore, you should observe the following conditions when performing an analysis of partially supported ceiling slabs:

1. If the bearing length is low, an effective restraint of the ceiling slab in the wall is no longer given. You should therefore take the ceiling in the form of an eccentrically applying vertical wall load into account.
2. MWX always assumes full support in the cross section analysis. An analysis of the local effects on the ceiling bearing is not performed. Due to the strong influence of the bearing shape, it is left to the user to perform this analysis.

The structural safety analysis in accordance with EN 1996-1 includes an analysis for partially supported ceiling slabs.

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

As a rule, MWX allows only the calculation of masonry walls exposed to effects by solid and two-dimensionally supported ceiling slabs. 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 identical analyses at least with the simplified method.

With the general design method, the problem arises however that you cannot calculate the bending moments resulting from the ceiling rotation angle using the conventional equivalent systems that are implemented in MWX because you must not assume restraints with joist ceilings. Therefore, the greatest problem is the determination of the eccentricity caused by the ceiling 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 superimposed wall load variable over the wall length with a series of concentrated loads?

No. In the general design method, concentrated loads are not combined with the moments resulting from the rotation angle of the ceiling bearing 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 effect behaviour over the wall length could be produced by the overlapping of the load propagation cones.

Note: *In contrast to concentrated loads block loads are included in the global design checks at the top of the wall. Due to overlapping issues of load spreading regions stepped vertical wall loadings should be modelled using trapezoidal loads instead, which are not subjected to load spreading.*

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

The current version of the application does not provide for a user-defined input of the 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 bearing compression.