PRB-PG5F

**PraxisRegelnBau**
Initiative Praxisgerechte Regelwerke im Bauwesen e.V.
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# Improvement of the applicability of building standards by pre-normative work – Part 5: Masonry buildings

**BBSR - research project**
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## FINAL REPORT (Summary – English Version)

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Mai 2013 until Mai 2015

**Research Institute:**
**Deutsche Gesellschaft für Mauerwerks- und Wohnungsbau e.V.**
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|---|---|---|
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*The authors of the chapters are responsible for the contents.*

This report has 21 pages.

## Index

# 0 Overview

The research topics were chosen based on the fact that the four subject areas

- „Material“ Sub-Project 1
- „Buckling“ Sub-Project 2
- „Shear in bracing wall systems“ Sub-Project 3
- „In-plane shear “ Sub-Project 4

have the highest relevance for the construction practice.

The relation of the individual subprojects to various parts of DIN EN 1996 is presented in the Table 0.1 as follows:

Table 0.1: Overview - Reference of the sub-projects (SP) to the Eurocode 6 parts

| Sup-project | Topic | Researcher | Reference to the standards | | |
|---|---|---|---|---|---|
| | | | EC 6-1-1 | EC 6-2 | EC 6-3 |
| SP 1 | “Material Parameters” | Prof. Brameshuber | X | X | |
| SP 2 | “Buckling“ | Prof. Graubner | X | | X |
| SP 3 | “Shear in bracing wall systems” | Prof. Jäger | X | | |
| SP 4 | “In-plane shear” | Prof. Seim | X | | |
| P 5 | “National Annexes“ | Prof. Graubner | X | X | X |

**Sub-Project 1** „ Material“ - Prof. Brameshuber

The sub-project 1 refers to DIN EN 1996-1-1 and EN 1996-2 (see table 0.1) and should demerge the different parts of the standard. This coincides with the PRB-target "Ease of use".

**Sub-Project 2** „Buckling“ - Prof. Graubner

The aim of the project is the verification and revision of the load factors, which are defined in the accurate calculation method in EN 1996-1-1 for the analysis of stability failure and the applicable buckling length. Comparing the different calculation models with a proposal using realistic load-deformation behaviour, a significant increase in load capacity is possible for thin walls. Furthermore, using the developed new proposal the NDPs can be reduced. In addition specialities of buckling analysis for walls with partial support length of the slab were studied to act pre-normatively.

**Sub-Project 3** „Shear in bracing wall systems“ - Prof. Jäger

In subproject 3, the research refers to the building stiffening by masonry walls according to DIN 1996-1-1 (see Table 0.1). Planned target of the subproject 3 is to improve the practicality of the calculation and proof of bracing walls in masonry structures with consideration of the cracked and / or plasticity.

**Sub-Project 4** „In-plane shear“ - Prof. Seim

The sub-project 4 refers to DIN EN 1996-1-1 (see Table 0.1). There are hesitations and confusions to be eliminated in the individual evidence and the definition of geometrical parameters. This corresponds to the PRB targets to increase the clarity in the application and construction practice. A concrete proposal for a simplified shear check will be presented.

**Project 5** „National Annexes“ - Prof. Graubner

The research project 5 "Analysis of different National Annexes of DIN EN 1996" deals with the harmonization of national annexes of Eurocode 6.

# 1 Sub-Project 1 „ Materials " (Prof. Brameshuber)

## 1.1 Reason/ Initial situation

EC6 has been developed in the recent 15 years to achieve a consistent European standard for the execution and design of masonry. The quite different products of masonry units demanded very early a variable uptake of units and mortar in the EC6 and the creation of categories, e. g. referring to the fraction of holes. As a consequence a mixture of design of product specifications and design rules had been generated, which from the view today lead to a lot of complications. The de-emphasis therefore is a necessary step for the administration of EC6. Then the designer would only handle with material parameters which are needed for statics and construction. However, where these parameters come from is not necessarily important and should be standardized in the product standard. Such a separation is suitable for masonry as well. The categories for classification of units according to the European standard is not accepted in Germany until now, because this would lead to a complete re-arrangement of existing unit groups, including the disadvantage of a comprehensive restructuring of common masonry compressive strengths depending on the unit strength classes/kinds of material. Theis in different cases would cause lower values for the masonry strength. This example shows that the global concept of the current EC6 is not applicable to the practical situation.

Additionally the requirements on the initial shear strengths are a second example for the necessity of the de-emphasis of design rules and product properties. These material properties are greatly influenced by the material of the units. The actual equalization of the shear values is not very suitable for some products, and in consequence leads to very conservative values for the design of bending and shear. A consideration of material specifications with respect to the initial shear strengths will not be realized in the EC6 as well as in the national appendix. Regulations concerning the required values for the specified unit/material combination implemented in the product standard would lead to a better responsibility for each single producer.

## 1.2 Object of the research project

A concept has been worked out which inserts a characteristic masonry compressive strength in the design code as material parameter to be used for the calculation.

The EC6 in connection with the national appendix has been relieved of all specific material descriptions. In a first step all these material parameters will be exemplarily described for one kind of unit in the product standard. The major item of this product standard deals with the definition of production, testing and the determination of characteristic values. Actually it has been not fixed whether the determination of characteristic values will be inserted in each product standard. Depending of the kind of units and the hole pattern it might be a good solution. However, this should be discussed in the next steps.

An important issue of the research project is the discussion with the industry, the authorities and the designing engineers. The conception will therefore be presented in workshops and discussed there. It might be possible that the determination of characteristic values will be dependend on the material to be contemplated.

## 1.3 Conclusion

The major aim of the project is the establishment of a consequent separation of EC6 and product standards. In the case of masonry at least six product standards have to be formed in that way that the designer is able to work with a characteristic value independent of the unit-/mortar combination will be chosen for the execution. Clay-units, Calcium-Silicate-units, concrete and light-weight concrete, aerated autoclaved concrete as well as natural stone, respectively, in combination with different mortars he to be considered.

Within the first half year of the project a concept had been worked out for the separation of the different parts of the standard, and the establishment of a so-called snippet version has been prepared.

Within the second half year this snipped version had been finished. All parts dealing with specific product and execution contents have been removed. The contents referring to executional details have been transferred to the EC6, part 2. Only a small number of contents had to be listed both in part 1-1 and part 2. All contents dealing with specific product details had been transferred in an intermediate standard called ENXXX and ENXXX+NA. Choosing this way of procedure these contents have been saved and can be in a further step integrated in the product standards.

Very important is that the principle of the categories had been saved. For some kinds of units the categories have been graded finer, because looking to the German market some units really do not fit the categories given in the actual EC6. In some cases no assignment is possible. In addition also for units without holes a category has been included. At this stage of work the tables for calculating the characteristic strength fk according to the national appendix have been taken but must be newly arranged according the categories created. This has to be done in the next steps.

In EC6 itself only masonry strength classes are given, initial shear strength values as well as tensile strengths of units. The principle is, that the designer prescribes classes and the executer has to take the correct unit/mortar combination on the basis of the given determination of values in ENXXX and the product standard.

In a last step it is shown the possibility of the extension of the product standard by specific unit properties (initial shear strength, unit tensile strength). The unit producer then would be able to declare material specific values for a better exploitation of the material properties deviating from the conservative characteristic values. Each unit producer should be able, whether he wants to use the conservative standardized values (in this case e. g. the given initial shear strengths), or declares normative but individual values.

A first proposal for the arrangement of Eurocode 6 with comments for a better traceability of the new recommended structure is given in the annex of the final report.

# 2 Sub-Project 2 „Buckling“ (Prof. Graubner)

## 2.1 Reason/ Initial situation

This research project deals with the buckling behaviour of masonry walls. Considering the non-linear material behaviour in case of stability analysis a new simple practical method is developed. Additionally, the applicable buckling length for walls with partially support lengths of the slab is analysed and a corresponding proposal is worked out.

## 2.2 Object of the research project

Due to the stability failure a necessary reduction of the centric load capacity considering slenderness of the wall and load eccentricity is performed with the use of the load factor $\Phi_m$. The current regulation is extensive and only partially suitable for hand calculation. There are many input parameters required for calculation, which may be differently regulated in the individual countries and must be taken from several tables. According to the principles of standardisation work [2] optimized parameters for different stone-mortar combinations should be avoided. This is achieved with the new design proposal which does not depend neither on the $E_0/f_k$-ratio nor to the final creep coefficient $\varphi_\infty$ and limits of slenderness $\lambda_c$. As a result, the load capacity function is applicable for all materials used in masonry. Specific properties of materials are included in the load capacity function. This approach has the advantage that the code is more practical, because less input parameters are required. This leads to a reduction or elimination of National Determined Parameters (NDP). Furthermore, the manual calculations are significant simplified, because the new design proposal uses a simple linearized load capacity function.

In Table 2.1 the currently valid regulation is compared with a new design proposal, which was developed and validated in the research project. In order to simplify the load capacity function of DIN EN 1996-1-1 [3] for stability analysis, extensive comparative calculations were performed. In the Figures 2.1 and 2.2 some results of the new design proposal (red curves) are compared with the currently valid design method of EN 1996-1-1 (blue curves) and precise non-linear design method (black curves) according to [1]. The results are shown exemplary for two often used stone-mortar-combinations and demonstrate the high quality of the simplified design proposal. Also some safety deficiencies of the complex approach according to DIN EN 1996-1-1 Annex G at large regular load eccentricities can be eliminated.

Table 2.1: Comparison of the regulations of EN 1996-1-1 with the new design proposal

| **EN 1996-1-1** | **New proposal** |
|---|---|
| **Anhang G (1)**<br>$\Phi_m = A_1 \cdot e^{\frac{-u^2}{2}}$<br>where<br>$A_1 = 1 - 2 \cdot \frac{e_{mk}}{t}$<br>$u = \frac{\lambda - 0,063}{0,73 - 1,17 \frac{e_{mk}}{t}}$<br>with<br>$\lambda = \frac{h_{ef}}{t_{ef}} \cdot \sqrt{\frac{f_k}{E}} = \frac{h_{ef}}{t_{ef}} \cdot \sqrt{K_E}$ | **Anhang G (1)**<br>$\Phi_m = 1,10 \cdot \left(1 - 2 \cdot \frac{e_m}{t}\right) - 0,021 \cdot \lambda$<br>$\leq 1 - 2 \cdot \frac{e_m}{t}$<br>where<br>$\lambda = \frac{h_{ef}}{t_{ef}}$ |
| **6.1.2.2 (1) (ii)**<br>$e_{mk} = e_m + e_k \geq 0,05 \cdot t$<br>where<br>$e_m = \frac{M_{md}}{N_{md}} + e_{hm} + e_{init}$<br>$e_k = 0,002 \cdot \phi_\infty \cdot \frac{h_{ef}}{t_{ef}} \cdot \sqrt{t \cdot e_m}$ | **6.1.2.2 (1) (ii)**<br>$e_m = \frac{M_{md}}{N_{md}} + e_{init} \geq 0,05 \cdot t$<br>($M_{md}$ includes the moments at the middle of the wall due to horizontal loads e.g. wind loads) |

The following equations and parameters can be reduced or eliminated:

- Elimination of Equations (6.6) and (6.8) of EN 1996-1-1
- Reduction of NDP 3.7.4(2) to EN 1996-1-1
- Elimination of NDP 3.7.2(3) and NDP 6.1.2.2(2) to EN 1996-1-1

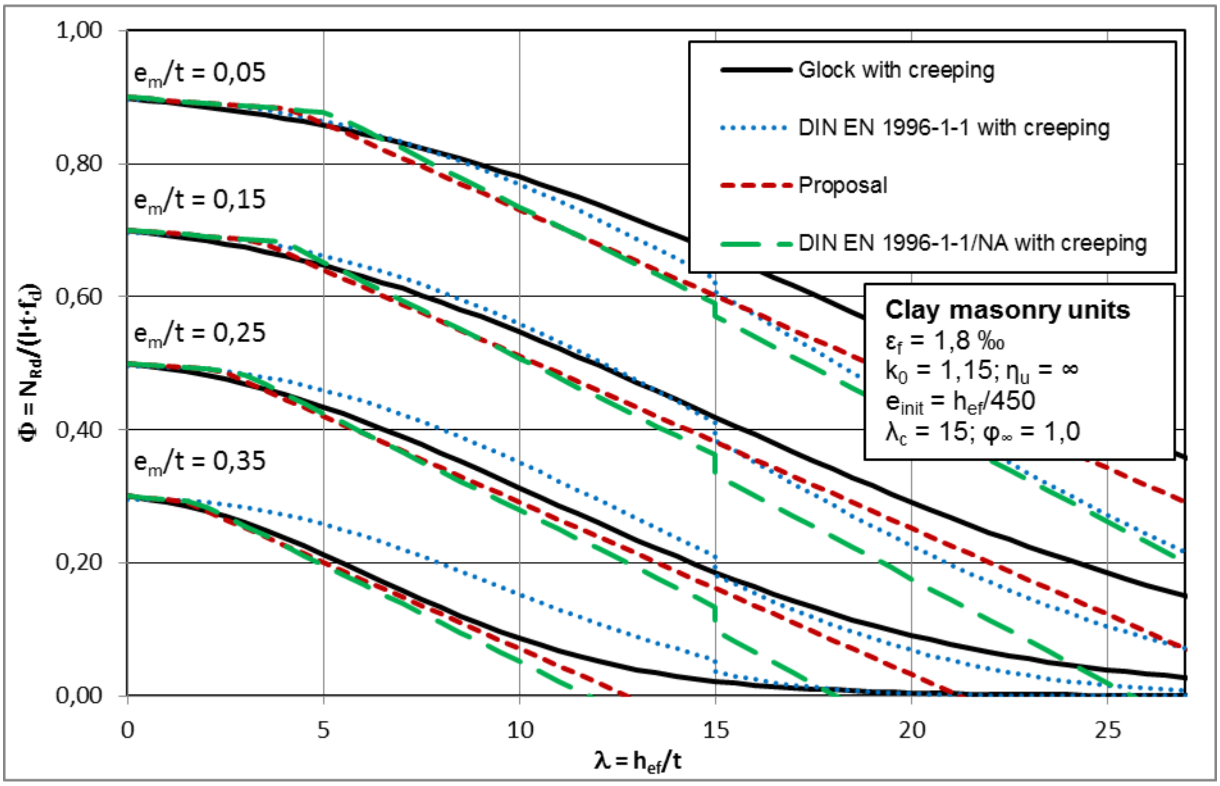


Figure 2.1: Comparison of load capacity function for masonry of clay units

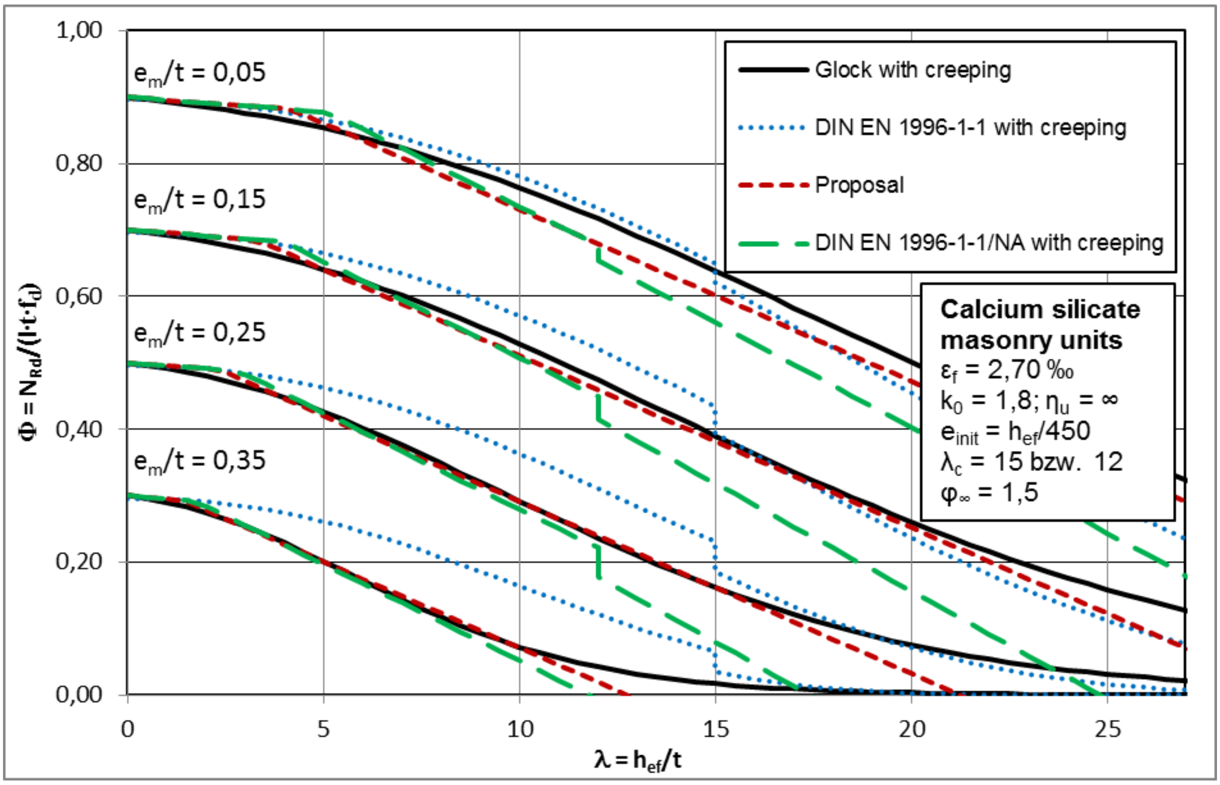


Figure 2.2: Comparison of load capacity function for masonry of calcium silicate units

From Denmark there was an objection regarding the load capacity factors according to annex G of DIN EN 1996-1-1. It is shown in the research project, that in case of large wall slenderness ($\lambda > 20$) with the design method in annex G for certain stone-mortar-combinations (low ratio $E_0/f_k$) the calculated load capacity with increasing compressive strength of the material decreases. However this “defect” is not relevant for most practice cases. Furthermore, it was proven by extensive studies with realistic modelling of the load-deformation behaviour, that the load bearing capacities calculated with the developed proposal are always conservative. With the new design method a possible complication of the current regulation due to a correction of the described “defect” can be eliminated.

In Europe the extension of EN 1996-3 [4] for masonry walls with only partial support lengths of reinforced concrete slabs has high priority. To avoid complicated rules and to establish the simplified design method in Europe by pre-normative acting the buckling behaviour in such loading situations was analysed. Determining the effective buckling length of walls with non-centric loading from the slabs two opposing mechanism can be detected. Firstly, by the design of walls with only partly supported slabs according to DIN EN 1996-1-1 the thickness of the wall is reduced and therefor the stiffness of the wall decreases. This results for statically indeterminate systems in a reduction of clamping moments of the slabs at the top and the base of the wall and thus a lower load eccentricity due to first-order theory. In the case of the buckling failure the resulting load due to the deformations according to second-order theory simultaneously moves in the direction of the cross-section edge and generates turn-back moments. This changes the turning point of the deformation curve of the wall and may allow a reduction of the buckling length. On the other side due to the only partial supported slab at the top and base of the wall not the entire wall thickness can participate to the buckling failure. Approximately this can be represented by a member with varying cross-sections along the member length. However such an approach shows a much lower critical buckling load.

A detailed analysis of both mechanisms could not be carried out within this research project because there is a lack of reliable information for the determination of the node moments as well as a scientific based approach for the turn-back moments. Without further extensive investigations it is therefore recommended, that the already existing simple rules for the determination of the buckling length from Germany should be taken as a proposal for the European standardization also in case of partial support length of the slabs. This has been successfully proven over the years in Germany.

## 2.3 Conclusion

The aim of the research project is to simplify the load capacity function of EN 1996-1-1 and the analysis of the buckling length. The new proposal for the determination of the load capacity factors simplifies the design, because it is independent from the material properties and eases the use also for hand calculations. Several national determined parameters can be eliminated or reduced. The analysis of the buckling length for walls with partial support length of the slabs shows the deficits of the European regulations. An appropriate proposal to calculate the buckling length in this case is submitted.

## References

[1] Glock, C.: Traglast unbewehrter Beton- und Mauerwerkswände; Dissertation am Fachbereich Bauingenieurwesen und Geodäsie der Technischen Universität Darmstadt; 2004

[2] Initiative Praxisgerechte Regelwerke im Bauwesen e. V. (i. G.): Grundsätze bei der Normungsarbeit nach einem Beschluss des PRB-Lenkungsausschusses vom 6. April 2011. PRB-LA_0030. Berlin.

[3] EN 1996-1-1:2010-12 Eurocode 6: Bemessung und Konstruktion von Mauerwerksbauten. Teil 1-1: Allgemeine Regeln für bewehrtes und unbewehrtes Mauerwerk. Berlin: Beuth-Verlag.

[4] EN 1996-3:2010-12: Eurocode 6: Bemessung und Konstruktion von Mauerwerksbauten. Teil 3: Vereinfachte Berechnungsmethoden für unbewehrte Mauerwerksbauten. Berlin: Beuth-Verlag.

[5] CEN/TC 250/SC 6 N 490; Dokument zur Sitzung des Ausschusses CEN/TC 250/SC 6 am 04.05.2012 in Paris.

# 3 Sub-Project 3 „Shear in bracing wall systems“ (Prof. Jäger)

## 3.1 Reason/ Initial situation

The distribution of the horizontal forces on the bracing elements of a shear wall system is based on an elastic (uncracked and non-plastic) state. The consideration of the cracked and / or plastic state should be carried out in future by using a deformation based approach instead of the previously used stiffness based approach. A frame formula has been derived and implemented for the linear and cracked state.

## 3.2 Object of the research project

*Description and evaluation of the existing approach:*

It is usually common to distribute the horizontal forces on the bracing elements of a skeleton or shear wall system via the bending stiffness of the stiffening parts in the uncracked state. It is assumed that the floor slabs are infinitely rigid and do not deform. The cracked state could be safely represented using reduced stiffness values, however, only very inaccurately. In this way, nonlinear effects and redistribution of the forces could not be covered or taken into account.

The transition to the semi-probabilistic design concept has led to significant problems for masonry, because the combination rules for actions lead for example in case of wind to a relatively large spread of favorable and unfavorable once. Considerable efforts are being made in the last decade in order to compensate this theoretical defect, e.g. by exploitation reserve load capacity. The design method is based on the ultimate limit state, in which the load bearing capacity will be determined in the state of failure - strictly speaking for the whole building. However, this state is not reached in masonry structure by the appearance of the first cracks. This way of thinking, i.e. verifying against cracks, leads to an underestimation of the carrying capacity and thus to uneconomic constructions. Nonlinear material effects and the overall behavior are usually ignored.

In the DIN EN 1996-3 / NA: 2012-01 it is under NDP to 4.1 (1) P "on a mathematical proof of the bracing may be dispensed with if ... in longitudinal and transverse direction of the building obviously a sufficient number of enough long shear walls exist ... ". Quantification of the load carrying capacity of the bracing systems of these buildings can counteract doubts to this rule at the European level.

*Description of deformation-based approach:*

In earthquake engineering, a method of assessment of the structural behavior has been established, which has become known as the Capacity Spectrum Method. It shows the behavior of the structure under the influence of earthquake forces and combines deformation and strength as criteria. This method assumes a push-over curve describing the load-deformation behavior of the structure under consideration of load redistribution, plastic hinges, plastic zones, etc.. Here, the horizontal force is increased incrementally on the structure and the deformation of one or more clearly defined points of the structure are observed, until a specific limit is reached or even until the failure of components or the entire system. The aim of this research project was to implement the deformation-based approach taking into account structural and material nonlinearities on the structural analysis of masonry structures, with stiff reinforced concrete floor slabs, so in future it is possible to perform the design with a more realistic load distribution.

*Description of the frame solution (based on deformation method):*
In the idealization as frame system, it is assumed that the wall panels are connected to the ceiling each side, via joints, whereby the transmission of moments from the ceiling perpendicular to the wall plane is excluded. Parallel to wall panels the connection is assumed to be fixed-fixed or fixed-hinged supported, see Figure 1.

The derivation of the stiffness matrices of individual wall panels is based on the derivation of the stiffness matrix for a plane frame with a constant rectangular cross-section taking into account the shear deformation (beam theory according to Timoshenko). This formulation has been extended to cracked and plasticized wall regions. A calculation of the exemplarily system shown in Figure 3 with 2 storeys with or without the redistribution of the forces shows load capacity reserves of up to 115% by redistribution of the forces in the cracked state.

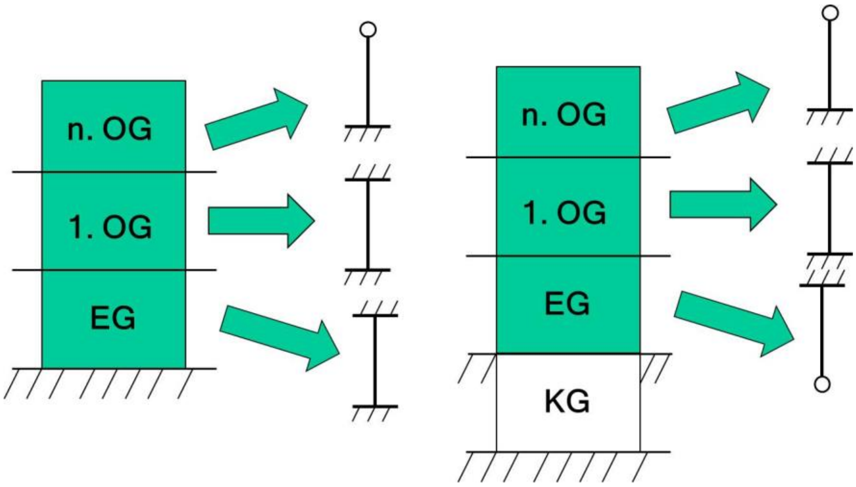


Figure 3.1 Idealization as a beam system for the wall panels

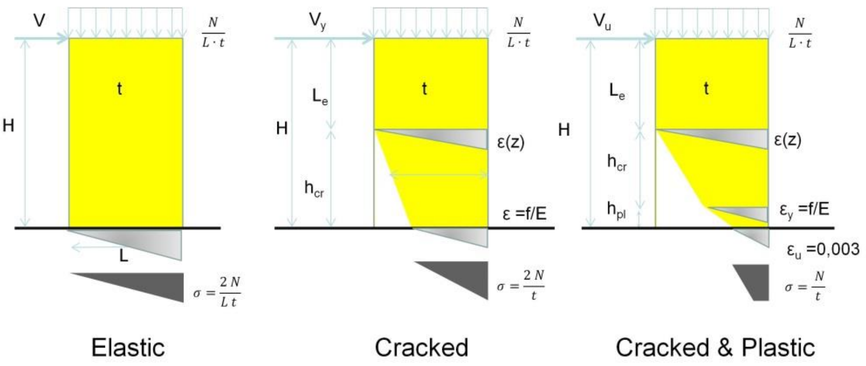


Figure 3.1: Wall panels: elastic, cracked, cracked & plastic

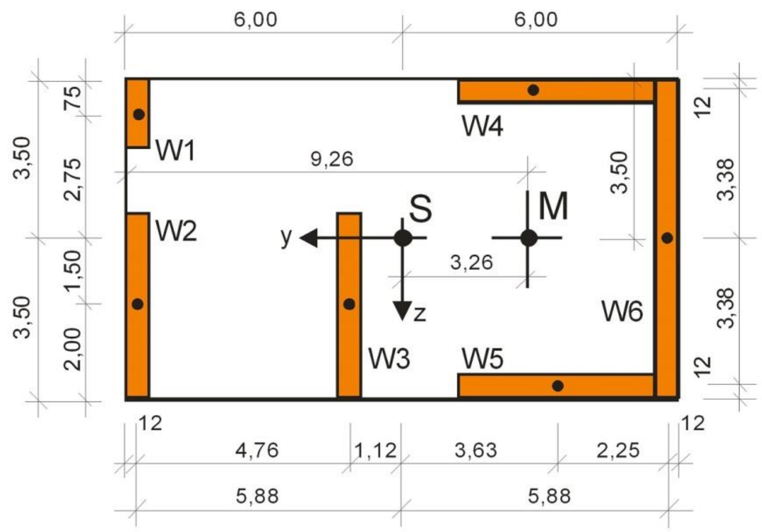


Figure 3.3 Example: Floor plan

## 3.3 Conclusion

Planned targets:

Improving the practical feasibility of building standards by considering the cracked and / or plastic state of the bracing elements.

Achieved results:

- Detailed description of the deformation-based approach, including program flow charts.
- Derivation of the beam stiffness matrices for frames with partially cracked and / or plastic section, taking into account the shear deformations according to Timoshenko
- Programming in Matlab & Fortran
- Through redistribution of internal forces due to the consideration the cracked condition, reserve load capacity of up to 115% could be achieved
- These reserve load capacity warrant waiving a proof of bracing justification in apparently stiffened buildings in DIN EN 1996-3 / NA: 2012-01

# 4 Sub-Project 4 „In-plane shear“ (Prof. Seim)

## 4.1 Reason/ Initial situation

The subproject 4 was focused on the calculation of shear resistance on the subsystem level. In this context subsystems are masonry walls under vertical and horizontal in-plane loading. Masonry in Germany is predominantly unreinforced masonry. Therefore the load-bearing capacity is ruled by the interaction of vertical and horizontal loading essentially.

The starting position for the subproject can be described as follows:

- The existing rules contain inconsistencies connected to the application of the basics of engineering mechanics and in terms of the definition of geometrical parameters.
- The design rules as introduced on the European level are completely doubled by design rules in the national annex in Germany.
- Within the design rules for shear resistance force level and stress level are mixed unsystematically.

Actually the principles of ease-to-use are violated due to inconsistencies and doubling of rules by the national annex.

## 4.2 Object of the research project

Based on the principles „Grundsätze bei der Normungsarbeit“ [1] the following aims can be defined for subproject 4:

- Shear resistance should be determined based on well known principles of engineering mechanics. A mix of different principles and a mix of different reference values in terms of forces and stresses should be avoided.
- The application of design rules should be improved by unified equations an graphical design tools.
- The number of different combinations of actions should be limited to two.
- All basic procedures and definitions for the design of masonry structures should meet the basic definitions as taken for other structural materials.
- The outcome of the subproject is aimed to abandon national definitions in Germany to EC6 in the future.

As a first step (anamnesis) the differences between European and national German design rules are documented. Inconsistencies connected to the application of mechanical principles are traced. The consequences different design rules have on the load bearing capacity of masonry shear walls are specified. Therefore a direct comparison of shear strength according to European rules and German rules is presented.

The following proposals are derived:

All design equations considering different failure criteria are unified to a force based level. This leads to an integrated approach, which is always based on the main principles of engineering mechanics. Actions can be calculated using stress fields or strut-and-tie models. Thus the load flow always remains clear and traceable, without mixing theory of plasticity and leveltheory of elasticity during calculations.

The definition of a prefactor $k_v$ helps to merge different correction factors which were introduced within the German national annex. By the definition of this prefactor, the design equations become much clearer. A prefactor $k_v$ involves the option of specific definition of just one factor on a national level, if no common European solution will be achieved.
The principle of interaction diagrams [2] are taken aiming for simplified check of different failure criteria. Equations for interaction diagrams are derived in a general form for European design rules and for German design rules as well. The application of basic equations is illustrated with several examples for specific masonry materials. Interaction diagrams can be directly used for structural design; moreover interaction diagrams are a very illustrative tool to compare different design equations directly.

### 4.3 Conclusion

The calculation of the load-bearing capacity of in-plane-loaded masonry walls is not trivial due to anisotropic characteristics of the material. Thus the volume and the complexity of existing EC6 rules seem to be adequate. Within the subproject the focus was laid on the improvement of transparency and intelligibility of the existing rules, always aiming on ease-of-use.

### References

[1] Grundsätze bei der Normungsarbeit, PRB-LA_00030, 2011.
[2] SIA 266; Schweizer Norm Mauerwerk. Schweizerischer Architekten- und Ingenieurverein. 2003.

# 5 Additional project: Analysis of different National Annexes of Eurocode 6 (Prof. Graubner)

## 5.1 Occasion and inital situation

The Eurocodes allow for the European countries various national opening clauses. These so-called NDPs (Nationally determined parameters), take into account national characteristics. With the NDPs important existing regulations are updated. These regulations are resulting from the building tradition and the safety level. Furthermore NCIs (Non-Conflicting Information) are possible. Thereby rules are updated which were valid previously in each European country and which are not contradictory to the new Eurocode regulations.

To enforce the German position in Europe it is important to understand the different interests of other European countries. Therefor an analysis of the annexes to Eurocode 6 was undertaken. The choice of the regarded countries refers to the neighbouring states of Germany and some other countries with important interest in masonry (Britain and Italy):

- Germany (DE)
- Austria (AT)
- Belgium (BE)
- Czech Republic (CZ)
- Denmark (DK)
- England(GB)
- France (FR)
- Italy (IT)
- Netherlands (NL)
- Poland (PL)
- Switzerland (CH)

The parts 1-1; 2 and 3 of EN 1996 were examined.

Subsequently, the number of NDPs of the different parts of the code are listed:

- EN 1996-1-1 20 NDPs
- EN 1996-2 5 NDPs
- EN 1996-3 8 NDPs

At the beginning of the research project the different national attachments from the different countries (31 documents) had to be procured. The most national annexes are only in the local language available. Specifically in standards the exact wording is of great importance. This situation makes the investigation tremendously difficult.

## 5.2 Exemplary presentation of an analysis of a NDP

For example the regulations of the different countries for NDP 3.7.2 (2) are compared

Table 5.1: NDP 3.7.2 (2) Ratios to determine the elastic modules ($E = K_E \cdot f_k$)

| | $K_E$ | | | | |
|---|---|---|---|---|---|
| | **Clay masonry units** | **Calcium silicate masonry units** | **Lightweight concrete units** | **Aggregate concrete units** | **Autoclaved aerated concrete units** |
| **DE** | 1.100 | 950 | 950 | 2.400 | 550 |
| **AT** | 1.000 | | | | |
| **BE** | 1.000 | | | | |
| **CZ** | 1.000 | | 700 | 1.000 | 700 |
| **DK** | for clay unit masonry and/or calcium silicate unit masonry made with lime mortar with no cement content:<br>$150 \cdot f_m$<br>for clay unit masonry and/or calcium silicate unit masonry made with mortar using other binder materials:<br>$\min(20 \cdot f_b; 400 \cdot f_m; 1.000)$ | | 1.000 | - | 450 |
| **GB** | 1.000 | | | | |
| **FR** | 1.000 | | | | |
| **IT** | 1.000 | | | | |
| **NL** | 700 | | | | |
| **PL** | if $f_m \geq$ 5,0 N/mm²: 1.000 (expect autoclaved aerated concrete units)<br>if $f_m < 5$ N/mm²: 600 | | | | |
| **CH** | 1.000 | | | | |

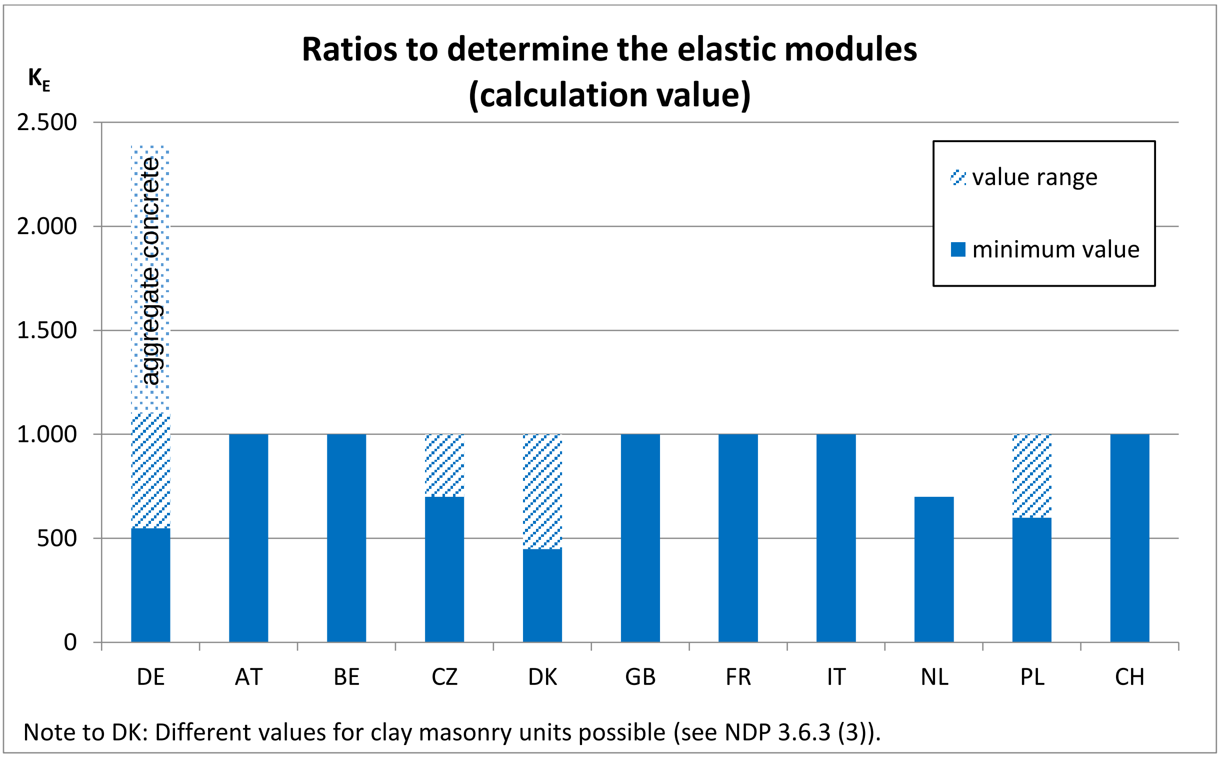


Figure 5.1: Ratios to determine the elastic modules

<u>Preliminary conclusion:</u>

While a strong variety of indicators is provided for Young's modulus in Germany, uniform stone-independent ratios are used in many other countries.

The classification is as mean harmonization potential.

### 5.3 Conclusion

The entire analysis and evaluation of all NDP of DIN EN 1996 Part 1-1; 2 and 3 is undertaken analogous to the illustrated example. In addition, the single parts of the code and the corresponding NDPs are analysed regarding their harmonization potential and presented transparently. The direct comparison of the NDPs of the various countries makes the different interests very clear. This will substantially support Germany´s activities concerning the future European standardization.