13th International Brick and
Block Masonry Conference
Amsterdam, July 4-7, 2004

NEW SWISS STRUCTURAL MASONRY CODE

N. Mojsilović[1] and P. Marti[2]

Abstract

In 2003 the Swiss Society of Engineers and Architects (SIA) introduced a set of new structural design codes including the masonry code SIA 266. The development of SIA 266 had two main objectives. Firstly, the provisions introduced by Recommendation SIA V177 (1995) had to be simplified and made more user-friendly. Secondly, the new code had to be compatible with its companion codes SIA 260 to 267 as well as with Eurocode 6 (EN 1996), Design of Masonry Structures, though considering specific national requirements. Overall, the new code permits a better utilisation of the potential offered by structural masonry.

Keywords

Codes, design, masonry, structures.

1 Introduction

In 2003 the Swiss Society of Engineers and Architects (SIA) introduced a set of new structural design codes: Basis of Structural Design (SIA 260); Actions on Structures (SIA 261); Concrete Structures (SIA 262); Steel Structures (SIA 263); Composite Steel-concrete Structures (SIA 264); Timber Structures (SIA 265); Structural Masonry (SIA 266); and Geotechnical Design (SIA 267). These codes became effective as of January 1, 2003 and will replace the previous Swiss structural design codes after a coexistence period of 18 months.
The development of SIA 266 (Marti and Mojsilović, 2003) had two main objectives: firstly, the provisions introduced by Recommendation SIA V177 (1995) had to be simplified and made more user-friendly; secondly, the new code had to be compatible with its companion codes SIA 260 to 267 as well as with Eurocode 6 (EN 1996), Design of Masonry Structures, though considering specific national requirements.
In addition to SIA 266, which should be valid for the next 10 to 20 years, a supplementary document, SIA 266/1, was developed which is envisaged to be revised more frequently, depending on EN developments. It contains references to relevant EN

[1] Nebojša Mojsilović, Lecturer, Institute of Structural Engineering, ETH, Zurich, Switzerland, mojsilovic@ibk.baug.ethz.ch.
[2] Peter Marti, Professor, Institute of Structural Engineering, ETH, Zurich, Switzerland, marti@ibk.baug.ethz.ch.

standards, covering product specifications and testing methods. Furthermore, it defines some testing methods that are not covered by the EN standards.

2 Background

2.1 Code Development in Europe

Within the European Committee for Standardisation (CEN), European Standards (EN) for structural design, execution of construction works, construction products and testing have been elaborated since 1989. Most parts of the structural design codes, the Eurocodes, were published as pre-standards (ENVs) between 1992 and 1998. The conversion of these ENVs to ENs started in 1998. Publication of the EN Eurocodes is to take place between 2002 and 2006.

After the date of availability of the approved EN Eurocodes a national calibration period of two years and a subsequent coexistence period of a Eurocode package of three years are foreseen. After this conflicting national standards must have been withdrawn and national provisions must have been adapted to make sure that all parts of the related package can be used without ambiguity.

2.2 Code Development in Switzerland

Harmonised structural design codes issued by the Swiss Society of Engineers and Architects (SIA) have been in use since 1990. They treat basic principles of structural design and actions on structures (SIA 160), steel structures (SIA 161) and concrete structures (SIA 162). A corresponding amendment for masonry structures (SIA V177) followed in 1995. The structural timber code (SIA 164) was formally adapted in 1991. No unified Swiss code was available in the area of geotechnical design.

The EN development is being accompanied by Swiss mirror committees whose chairmen are members of the Structural Standard Committee (KTN) of SIA. The mirror committees are responsible for the maintenance of the existing SIA codes as well as for the preparation of national application documents for the ENs.

In order to simplify the transition to the ENs and to account for the many uncertainties connected with the EN development, the KTN decided in 1998 to completely update the existing Swiss structural design codes. This resulted in the project “Swisscodes”, a concentrated effort which found broad support in the Swiss construction industry and lead to the publication and introduction of the new structural design codes SIA 260 to 267 in 2003.

The new structural design codes were published in German and French. Italian translations are available and English translations are due to appear in 2004.

3 SIA 266

3.1 Terminology

Like its companion codes, SIA 266 provides a comprehensive list of technical terms (in German, French, Italian and English) including definitions. A notation section completes the chapter on terminology.

3.2 Basis of Design

In accordance with SIA 260, the design criteria are expressed by simple and transparent relationships. For example, the design value of an ultimate resistance, R_d, is given by

$$R_d = R\left\{\frac{\eta X_k}{\gamma_M}, f_{cd}, f_{sd}, f_{pd}, a_d\right\} \qquad (1)$$

The resistance factor γ_M is set equal to 2 for masonry. X_k denotes the characteristic value of a masonry property. η is a conversion factor accounting for the construction type (regular, structural bond or dry head joint masonry) and for any concentrated loading of the masonry. a_d represents design values of geometrical properties and f_{cd}, f_{sd} and f_{pd} denote the design values of the concrete compressive strength and the yield strengths of reinforcing and prestressing steel, respectively.

3.3 Construction Materials

The third code chapter deals with requirements concerning the material properties of masonry, masonry units, mortar, concrete infill, reinforcement, prestressing systems and ancillary components.

SIA 266 distinguishes between standard and supplier-certified masonry. For standard masonry, minimum values of the mechanical properties are stipulated by the code. Standard masonry can be made of clay bricks or blocks, calcium-silicate blocks, concrete blocks and aerated concrete blocks, with both normal and low density of the brick or block material. The mechanical properties of supplier-certified masonry must be declared by the manufacturer. Provided that certain requirements for the mechanical properties of masonry, masonry units and mortar are met, any type of masonry is permissible. This allows to better deal with the numerous masonry products available on the market and facilitates the use of the code in view of future developments. It should be noted that supplier-certified masonry, contrary to standard masonry, requires a considerable amount of testing since the declaration of mechanical properties must be supported by comprehensive experimental data.

SIA 266 also contains provisions for special-purpose masonry, such as veneer masonry, reinforced masonry, prestressed masonry, prefabricated masonry, exterior and interior facing masonry, fire-resistant masonry, sound and thermal insulating masonry and ductile masonry.

Ductile masonry, a newly introduced term, denotes reinforced masonry with high ductility. Such masonry is intended to be used in certain types of buildings such as hospitals in parts of Switzerland with higher seismic risk. Ductile masonry, together with its components, must satisfy additional requirements, must be executed with filled head joints and has to be orthogonally reinforced with reinforcement that is properly anchored in the adjoining structural members. Ductile masonry is an answer to the higher seismic requirements introduced by the Eurocodes and adopted by the new Swiss codes.

The ratio between the characteristic values of the modulus of elasticity, E_{xk}, and the masonry compressive strength perpendicular to the bed joints, f_{xk}, is set equal to 1000 for standard masonry. The characteristic value of the shear modulus, G_k, is set equal to 0.4 E_{xk} for all types of masonry.

3.4 Structural Analysis and Dimensioning

3.4.1 General

The fourth and main chapter of the code covers the structural analysis and dimensioning of structural masonry. Detailed provisions are provided for unreinforced masonry subjected to eccentric axial loads as well as shear loads. Corresponding design charts are given for both ultimate and serviceability limit states. Furthermore, provisions for reinforced masonry, fire resistance, and seismic loading are included.

3.4.2 Ultimate Limit States

The design value of the axial load, N_{xd}, acting on a wall must satisfy

$$N_{xd} \leq k_N l_w t_w f_{xd} \tag{2}$$

where l_w and t_w denote the length and the thickness of the wall, respectively, and f_{xd} is the design value of the masonry compressive strength perpendicular to the bed joints. The coefficient k_N has to be determined from a design chart such as that in Figure 1. Design charts are provided for different boundary conditions including given eccentricities of the axial force at the supports and imposed rotations due to floor slab deformations. The design charts have been obtained from column-deflection-curves based on an appropriate non-linear eccentricity-curvature relationship for masonry. In Figure 1, ϑ_d denotes the design value of the imposed rotation and $h_{Ed} = \pi\sqrt{E_{xd} l_w t_w^3 / (12 N_{xd})}$.

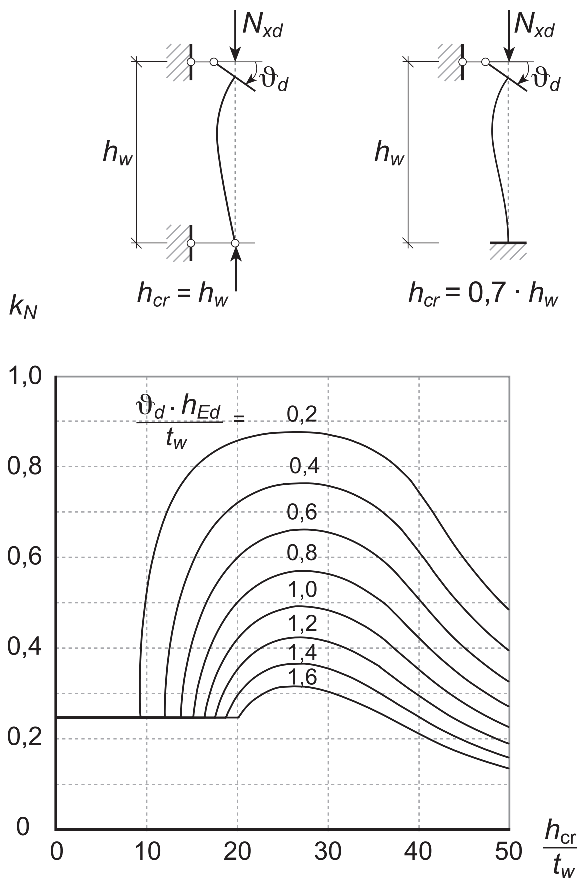
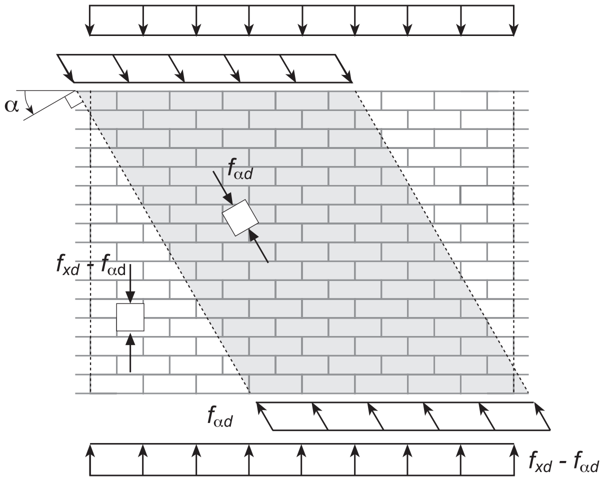


Figure 1 Design Chart: Axial Load and Imposed Rotation

The design charts for shear walls are based on the lower-bound theorem of the theory of plasticity. The corresponding failure criterion is illustrated in Figure 2. The uniaxial compressive strength, $f_{\alpha d}$, depends on the angle of inclination of the assumed inclined compressive stress field, α. By combining the inclined stress field with a vertical stress field subjected to $f_{xd} - f_{\alpha d}$ and varying α, the best lower bound for the ultimate shear force can be determined. In Figure 2, f_{yd} denotes the design value of the masonry compressive strength perpendicular to the head joints; furthermore, $\mu_d = 0.6$.



α	$f_{\alpha d}$
0°	f_{xd}
$0 < \alpha \leq \arctan \mu_d$	f_{yd}
$\arctan \mu_d < \alpha < 90°$	0
90°	f_{yd}

Figure 2 Stress Fields and Masonry Strength $f_{\alpha d}$

The design value of the shear load, V_d, must satisfy

$$V_d \leq k_V l_1 t_w f_{yd} \tag{3}$$

where $l_1 = l_w - 2M_{z1d}/N_{xd}$ denotes the upper length of the stress field. The coefficient k_V has to be determined from a design chart such as that in Figure 3. Design charts are provided for different ratios, f_{yd}/f_{xd}, of the design values of the masonry compressive strengths parallel and perpendicular to the bed joints.

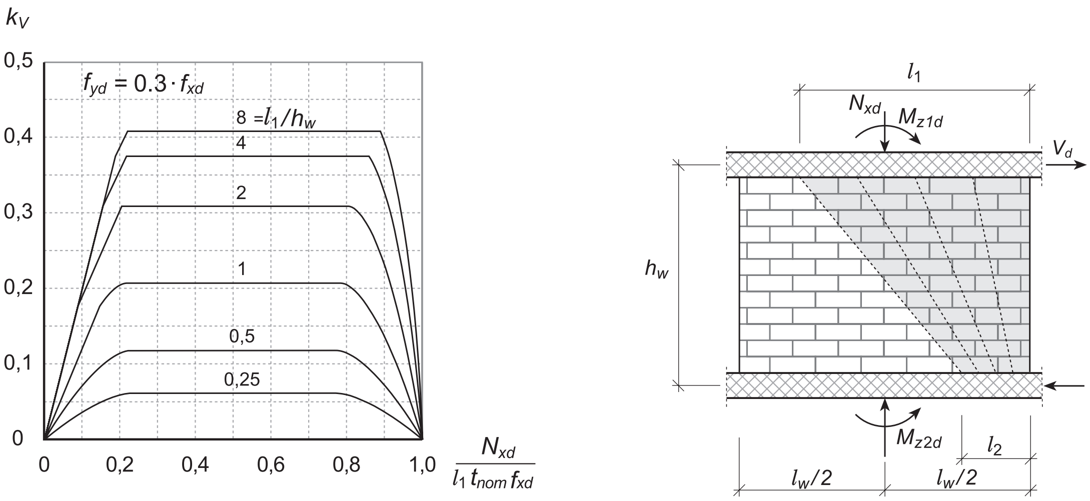


Figure 3 Design Chart: Shear Load

Masonry subjected to combined eccentric axial load and shear can be designed using the same charts with correspondingly modified geometrical data in (2) and (3).
Generally, the tensile strength of masonry must be neglected. Consequently, transverse loads must be assumed to be carried by arching action. Correspondingly, the head joints must be filled. For some special applications it is permissible to take a minimum bending resistance into account.
Concerning fire resistance, tabular values are given for the minimum thicknesses of masonry walls and pillars.

For masonry subjected to seismic loads, appropriate response factors for ductile (2.5) and non-ductile (1.5) behaviour are provided and detailed requirements for the reinforcement of ductile masonry are given.
Reinforced masonry and prestressed masonry must be designed according to the structural concrete design code SIA 262 whereby the flexural compression zone depth must not exceed 25% of the wall thickness.

3.4.3 Serviceability Limit States

Similar to the ultimate limit state considerations, crack widths, *r*, of masonry walls subjected to eccentric axial load can be determined using design charts such as that in Figure 4, i.e.

$$r = k_r \frac{N_x h_0}{E_{xk} l_w t_w} \tag{4}$$

where h_0 denotes the masonry layer height.

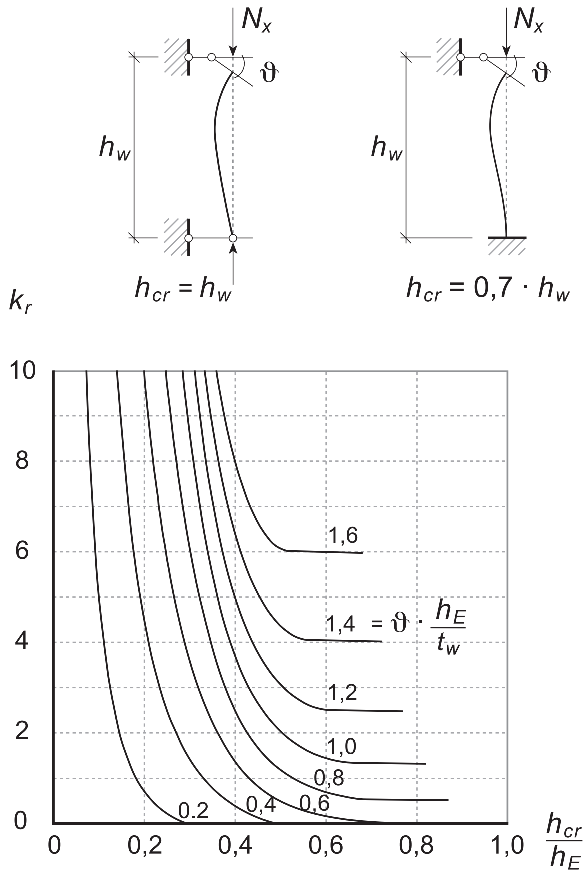


Figure 4 Design Chart: Axial Load and Imposed Rotation

Horizontal displacements at the top, and tensile strains at the bottom, of shear walls can be determined according to the theory of elastic bending, treating the shear wall as a cantilever.

3.5 Detailing and Execution

The last two chapters of the code provide recommendations for the detailing and the execution of masonry. Special emphasis is placed on ancillary components such as wall ties, straps and lintels.

4 Concluding Remarks

In line with the Swiss code tradition, SIA 266 is a very concise document. Users are required to have sufficient theoretical training and practical experience in design and construction to be able to apply the code as responsible professional engineers.

SIA 266 and its companion codes SIA 260 to 267 have created interest among practitioners for the ongoing European standardisation process. The new Swiss codes combine the latest European developments with the Swiss code tradition and provide a good basis for structural design for the years to come.

References

Marti, P., and Mojsilović, N., 2003, SIA 266 Masonry (in German), tec dossier "Swisscodes – die neuen Tragwerksnormen des SIA", Special Publication of tec21, Swiss Society of Engineers and Architects (SIA), Zurich, Nr. 29-30, pp. 24-25.

SIA 266, 2003, Masonry (in German), Swiss Standard, Swiss Society of Engineers and Architects (SIA), Zurich, 44 pp.

SIA 266/1, 2003, Masonry – Supplementary Specifications (in German), Swiss Standard, Swiss Society of Engineers and Architects (SIA), Zurich, 12 pp.

SIA V177, 1995, Masonry (in German), Swiss Standard, Swiss Society of Engineers and Architects (SIA), Zurich, 52 pp.

prEN 1996-1-1:2002, 2003, Eurocode 6: Design of Masonry Structures – Part 1-1: Common rules for reinforced and unreinforced masonry structures, European Committee for Standardisation, Brussels, 131 pp.