Structural behavior of compressed earth blocks stabilized with the mineral-based admixture Oxabrick Loko

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Stabilized compressed earth blocks (CEBs) offer a low-emission alternative to conventional masonry systems. To broaden the range of application of CEB masonry walls, experimental investigations on the load bearing properties are required. This study assesses the structural behavior of masonry made from CEB stabilized with a novel admixture, through a series of mechanical tests for the blocks, the mortar, and the full masonry system.

The tested stabilized CEBs and the earthen mortar are based on excavation soil and are stabilized with the cement-free admixture Oxabrick Loko. It is shown that this earth-based masonry system complies with the minimal requirements set by the Swiss national masonry standard SIA 266. This a significant step towards enabling engineers to design CEB structures according to well established mechanical models they are familiar with.

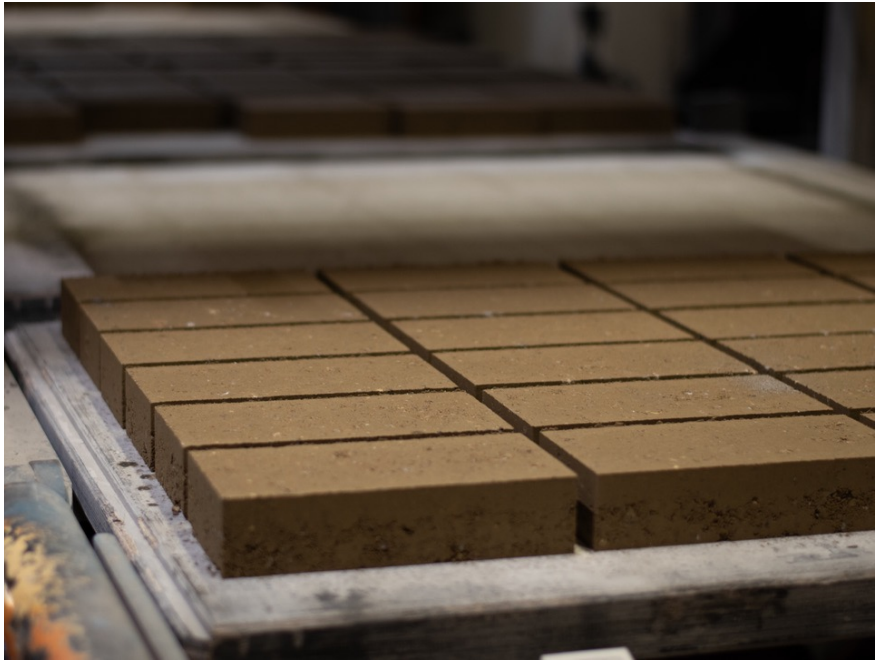
oxara terrabloc

Motivation & Approach

”Declared masonry” according to SIA 266

- Currently in Switzerland there is no standard for earthen construction materials.
- The Swiss structural masonry standard SIA 266 is not limited to predifined masonry material types but allows the use of any masonry system that fulfills a set of minimal mechanical requirements, classified as ”declared masonry”.
- For this study the required mechanical tests according to SIA 266 were conducted for earth-based masonry stabilized with the mineral additive Oxabrick Loko, thereby laying the basis for structural design with the existing standard.

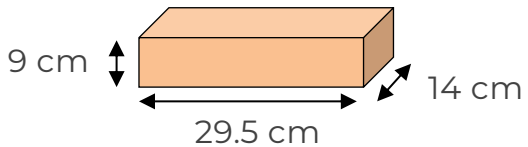
CEB production process



CEB & Mortar Properties

CEB properties

Dimensions:



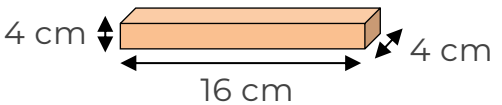
Recipe:
- 98% excavation waste
- 2% Oxabrick Loko

Properties of Oxabrick Loko:
- Powder based on mineral salts and industrial waste
- Reduces mixing water content
- Increases strength and water resistance
- GWP: 0.32 kg CO_2 eq / kg [1)]

1) *Lifecycle assessment data was calculated as part of the ZeroStrat Project, which was conducted in collaboration with ETH Zurich and commissioned by the Swiss Federal Office of Energy (SFOE).*

Mortar properties

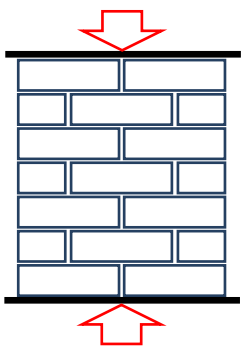
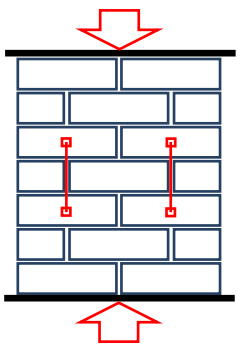
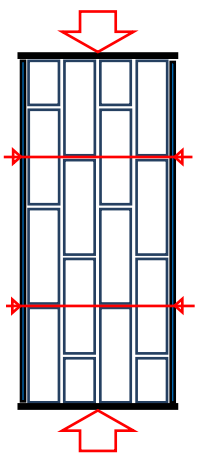
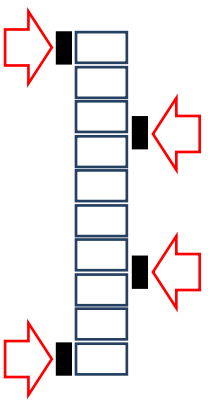
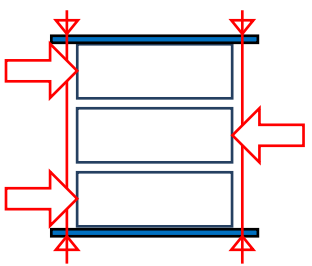
Dimensions:



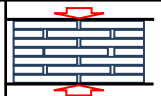
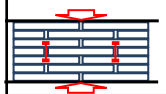
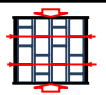
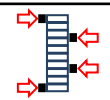
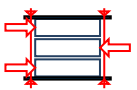
Recipe:
- 55% excavation waste sieved to 0-2 mm
- 40% concrete sand 0-4 mm
- 5% Oxabrick Loko

Fresh state properties:
- Moisture content: 12.5 wt%
- Spread: 14.7 cm

Masonry Testing Plan

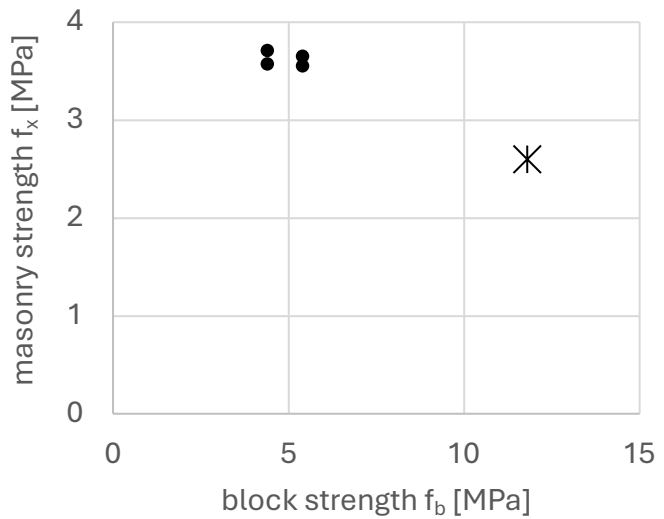
Parameter	Compr. strength	Elastic modulus	Perp. strength	Flexural strength	Initial shear strength
Symbol	f_{xk}	E_{xk}	f_{yk}	f_{fxk}	f_{vk0}
Standard	SN EN 1052-1	SN EN 1052-1	SIA 266/1	SN EN 1052-2	SN EN 1052-3
# Samples	3	3	3	5	3 x 3
Set-Up					

Results

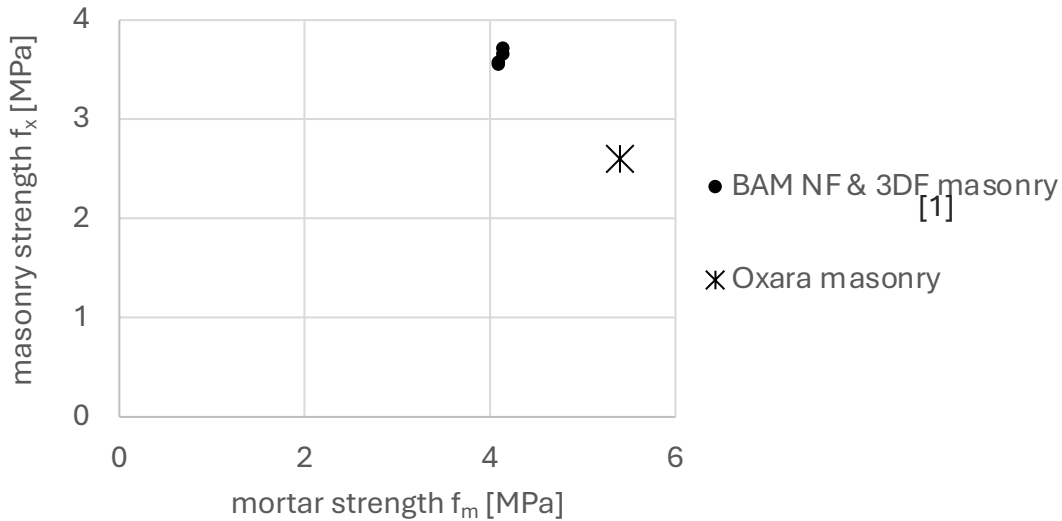
Property	Symbol	Test Set-Up	Result	SIA 266 requirement	Standard
Block compr. strength	f_{bk}		11.8 MPa	>2.5 MPa	SN EN 772-1
Mortar compr. strength	f_{mk}		5.4 MPa	>5 MPa	SN EN 1015-11
Masonry compr. strength	f_{xk}		2.2 MPa	>1.8 MPa	SN EN 1052-1
Masonry elastic modulus	E_{xk}		4.2 GPa	>1.8 GPa	SN EN 1052-1
Masonry perp. strength	f_{yk}		2 MPa	>0.5 MPa	SIA 266/1
Masonry bending strength	f_{fxk}		0.11 MPa	No min. value	SN EN 1052-2
Initial shear strength	f_{vk0}		0.16 MPa	Not requried	SN EN 1052-3

Comparison to Existing CEB Masonry Studies

Masonry strength f_x vs. block strength f_b



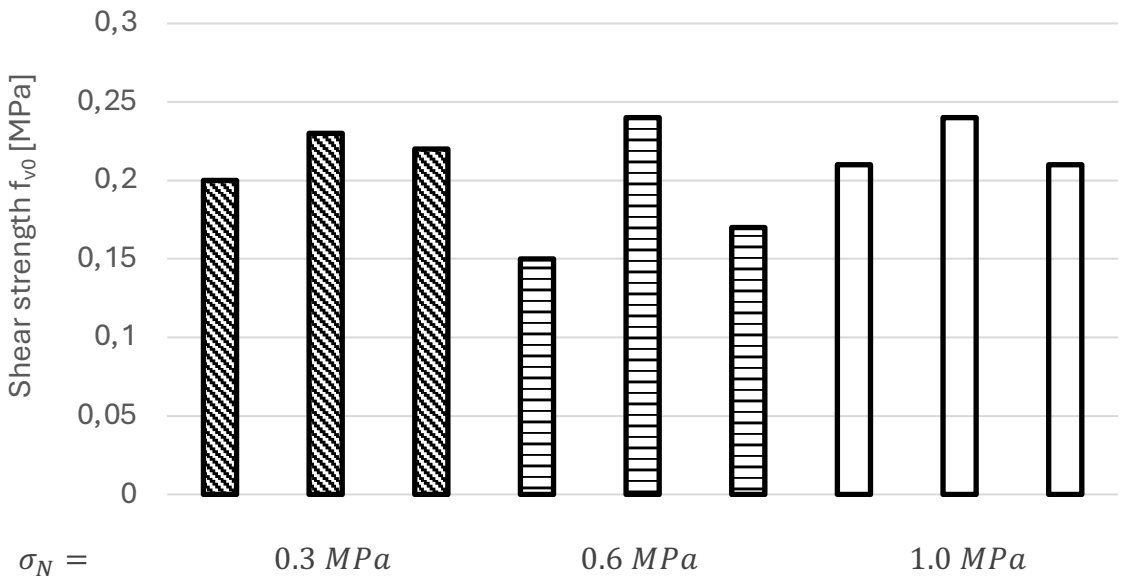
Masonry strength f_x vs. mortar strength f_m



1. Wiehle. P, Brinkmann, M. Material behaviour of unstabilised earth block masonry and its components under compression at varying relative humidity. In: Case Studies in Construction Materials, vol. 17, Elsevier (2022)

Initial Shear Strength

Shear strength results per tested specimen



Shear failure at block-mortar interface

Image from pf expert

Conclusion & Outlook

- All minimal requirements for declared masonry set by SIA 266 were fulfilled for the CEB masonry system stabilized with Oxabrick Loko.
- Considering the relatively high compressive strength of the block ($f_{bk} = 11.8\ MPa$) and of the mortar ($f_{mk} = 5.4\ MPa$) the masonry wall strength ($f_{xk} = 2.2\ MPa$) is low.
- The behavior in shear (f_y) is subject to further investigations as (i) the tested blocks are non-hollow contrary to the assumption by SIA 266 and (ii) the shear strength f_{v0} unexpectedly remained constant as the normal load was increased.
- Further investigations on the block-mortar interface will be conducted on small scale three-stone specimens.

Three-stone testing of mortar-block compatibility

Image from pf expert

$$f_x \approx 0.72 \cdot f_{3x}$$