Organizatori

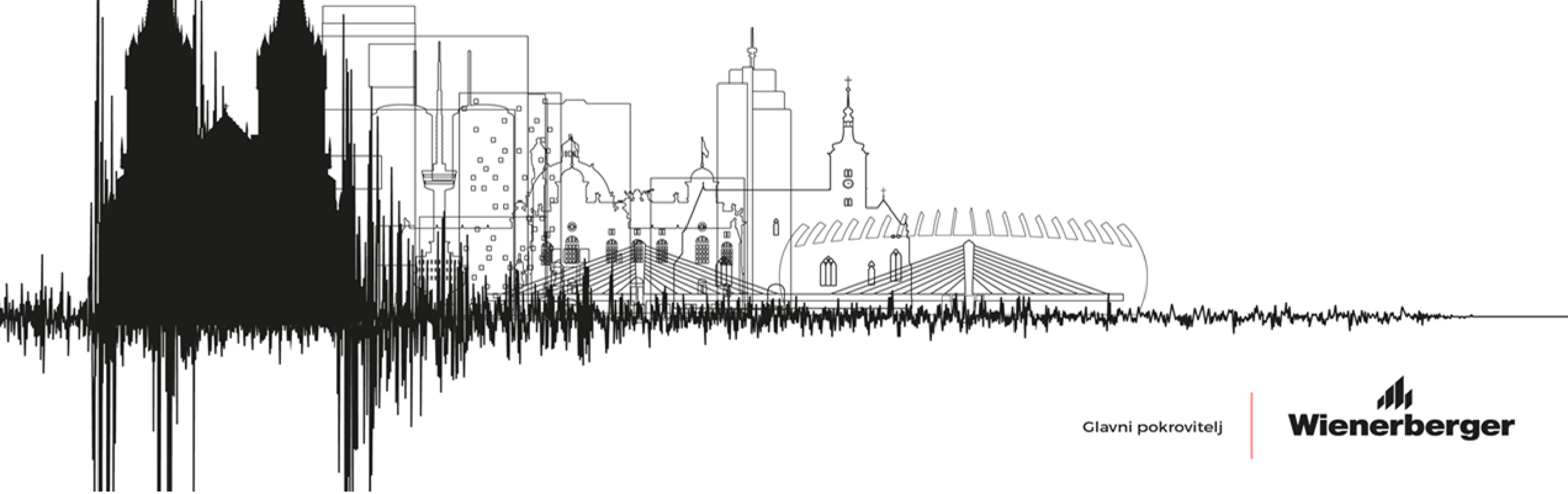
SVEUČILIŠTE U ZAGREBU
GRAĐEVINSKI FAKULTET
UNIVERSITY OF ZAGREB
FACULTY OF CIVIL ENGINEERING

SVEUČILIŠTE U SPLITU
FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE

Hrvatska komora inženjera građevinarstva

WEBINAR

"SAVJETOVANJE 4: OBNOVA ZAGREBA NAKON POTRESA – ZAGREBU OD SPLITA"



Glavni pokrovitelj

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ISKUSTVA I EKSPERIMENTALNA ISTRAŽIVANJA U VEZI SEIZMIČKE SANACIJE ZIDANIH ZGRADA

Prof. dr. sc. Miha Tomaževič
Zavod za gradbeništvo Slovenije,
Oddelek za konstrukcije
Ljubljana, Slovenija

New generation of masonry solutions

Andreas Jäger and Tomislav Franko, Wienerberger

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Agenda

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- Market trends
- Wienberger product- and system development
- Evaluation of new masonry types towards seismic performance
  - Small scale tests
  - Masonry tests
  - Cyclic shear tests
  - Full scale building tests on reaction wall
  - Shaking table tests
- Summary

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Market trends

Main European wide market trends

Urbanization

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- Trend for urbanization continues
- Increasing housing starts for multifamily houses
- Stagnating housing starts for single familiy houses

Main European wide market trends

Lack of skilled labor

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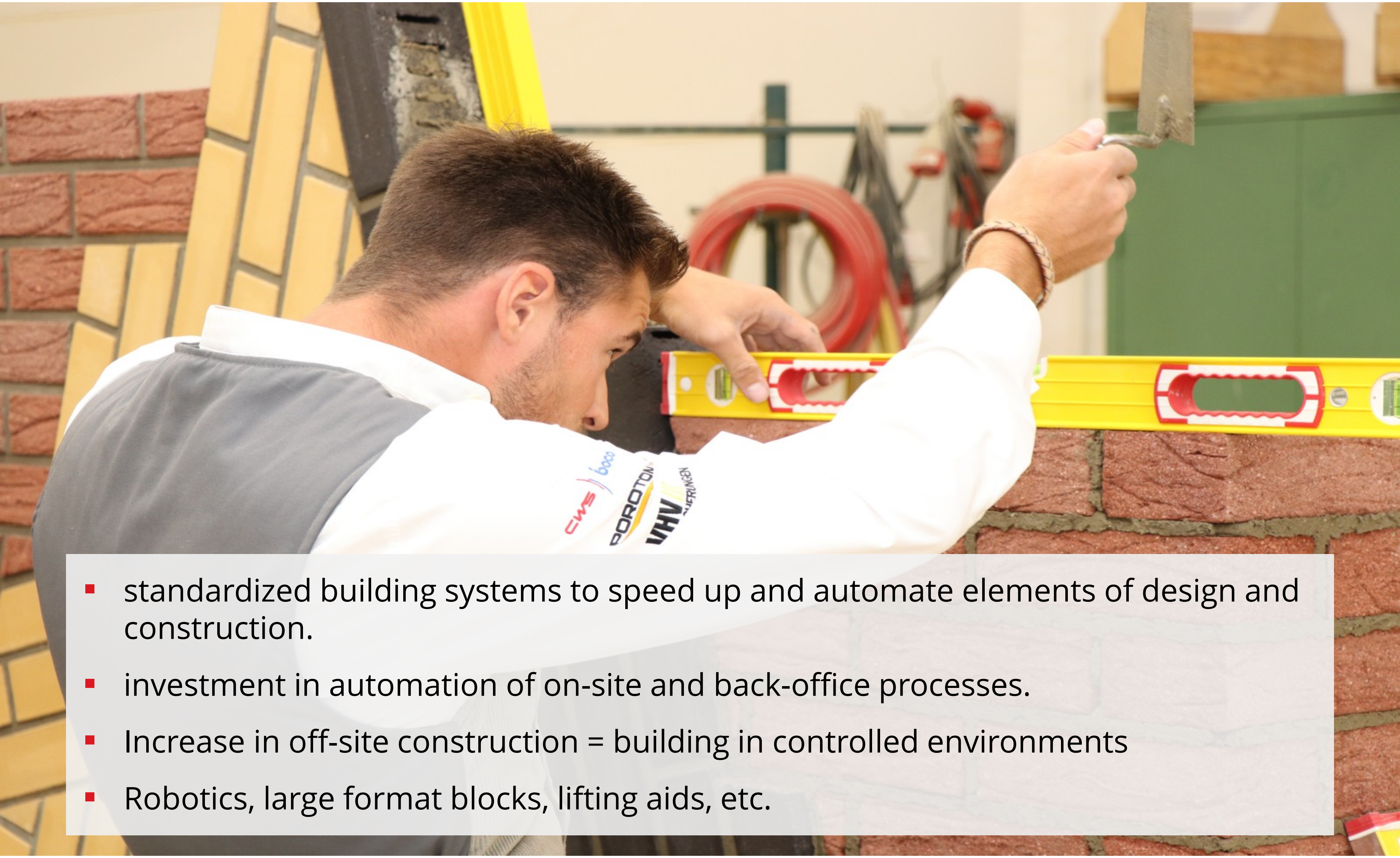

- standardized building systems to speed up and automate elements of design and construction.
- investment in automation of on-site and back-office processes.
- Increase in off-site construction = building in controlled environments
- Robotics, large format blocks, lifting aids, etc.

Main European wide market trends

Sustainability (CO2 emissions, circularity, ...)

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- Climate change
- Significant reduction of ecological footprint, especially CO2 emissions
- Trend to recycled and sustainbale materials
- Circular Economy
- Focus on reuse and renovation/retrofitting

Main European wide market trends

Digitalization

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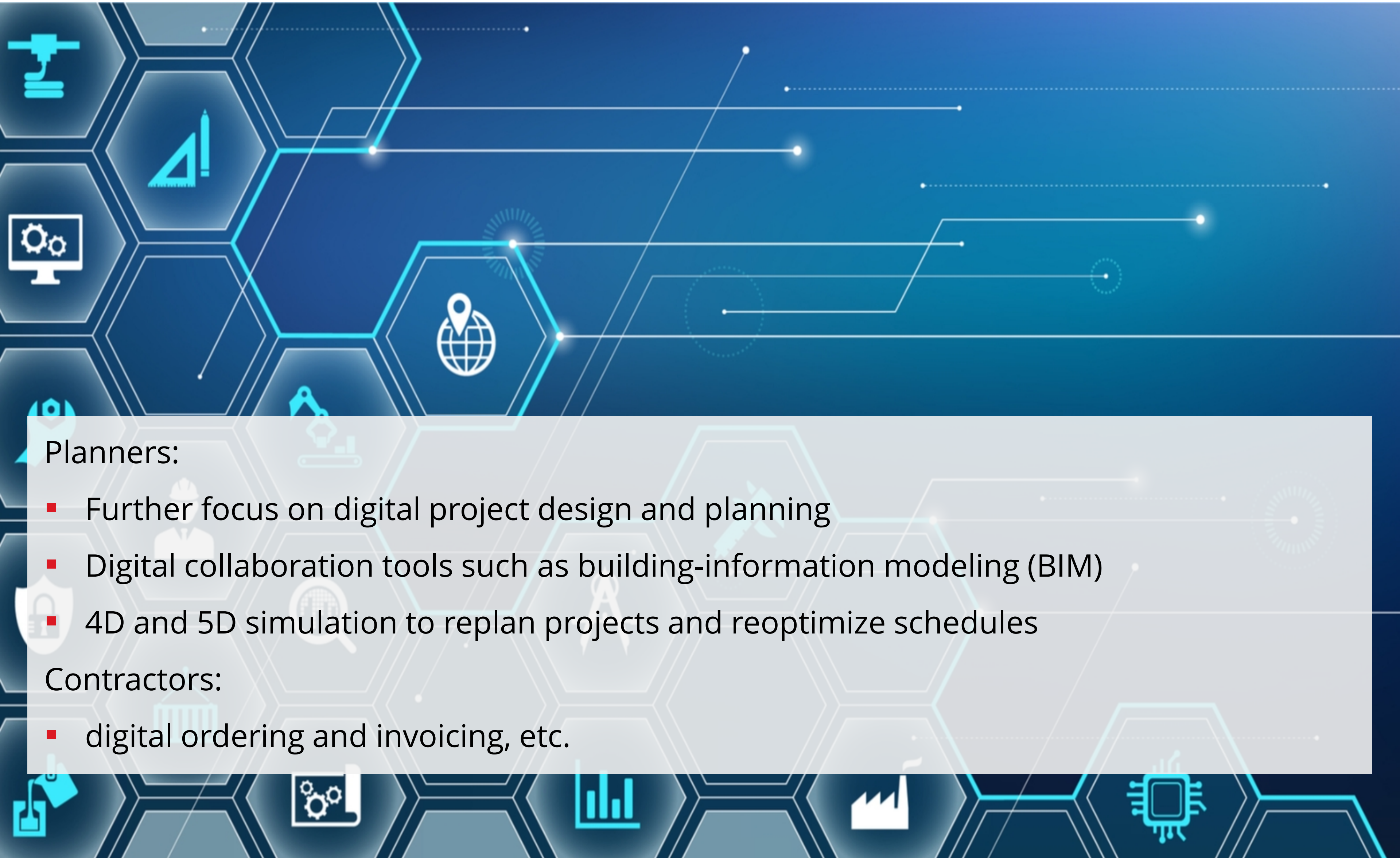

Planners:

- Further focus on digital project design and planning
- Digital collaboration tools such as building-information modeling (BIM)
- 4D and 5D simulation to replan projects and reoptimize schedules

Contractors:

- digital ordering and invoicing, etc.

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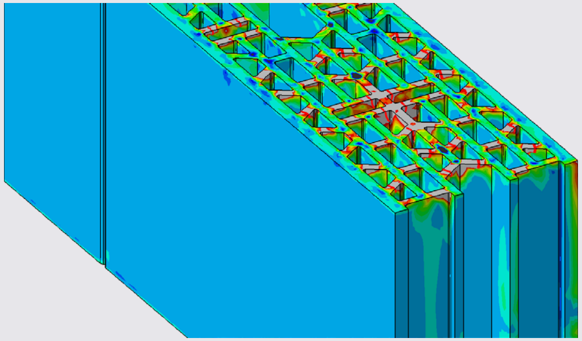
Wienberger product- and system development



Virtual Labs

Innovation fields

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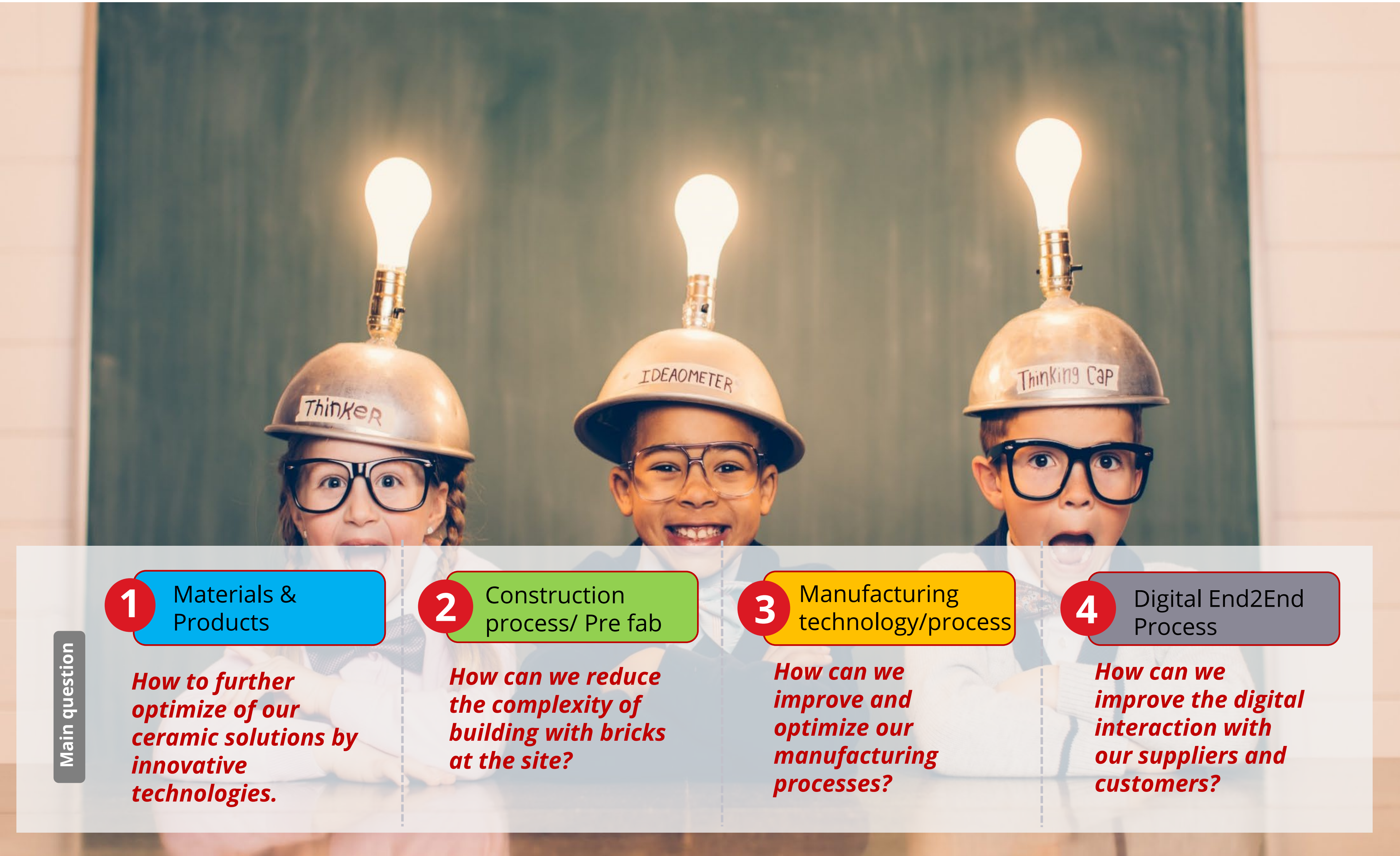

Main question

1 Materials & Products

How to further optimize of our ceramic solutions by innovative technologies.

2 Construction process/ Pre fab

How can we reduce the complexity of building with bricks at the site?

3 Manufacturing technology/process

How can we improve and optimize our manufacturing processes?

4 Digital End2End Process

How can we improve the digital interaction with our suppliers and customers?

Simulation of masonry strength

Simulation of crack formation

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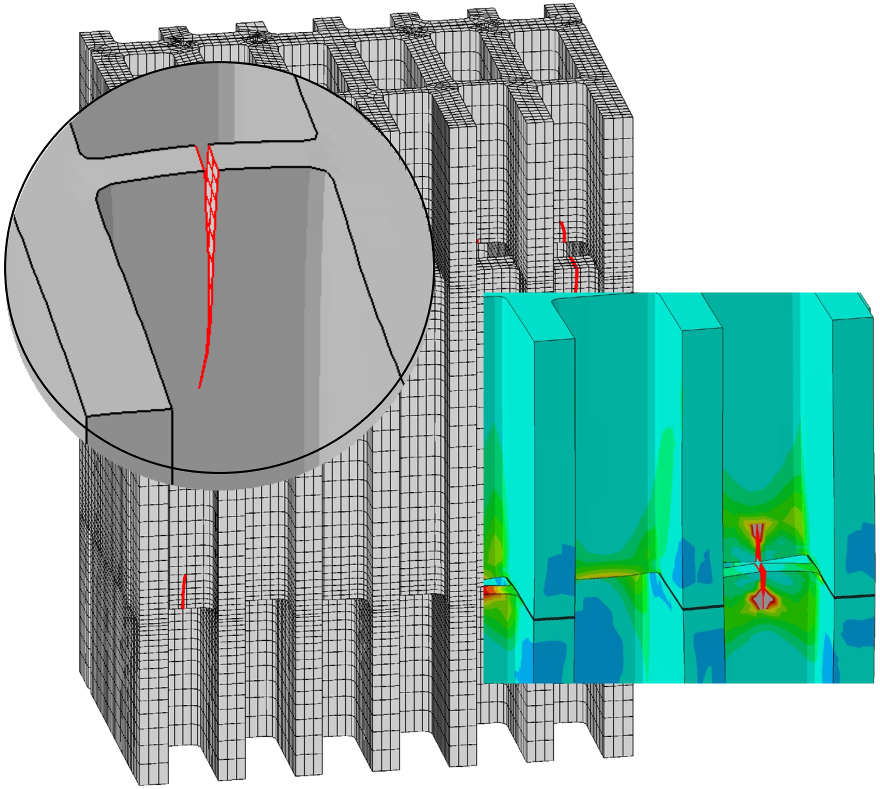
- Simulation of crack formation to cover exact failure mechanisms



Simulation of masonry strength

Optimization of masonry strength

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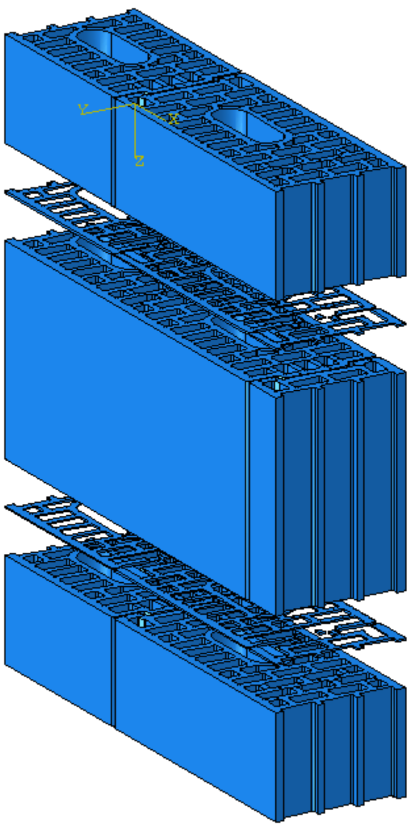
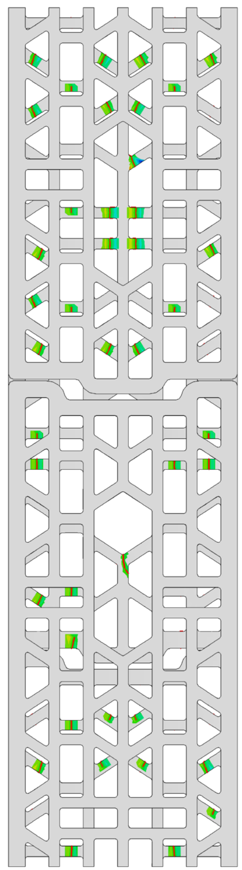
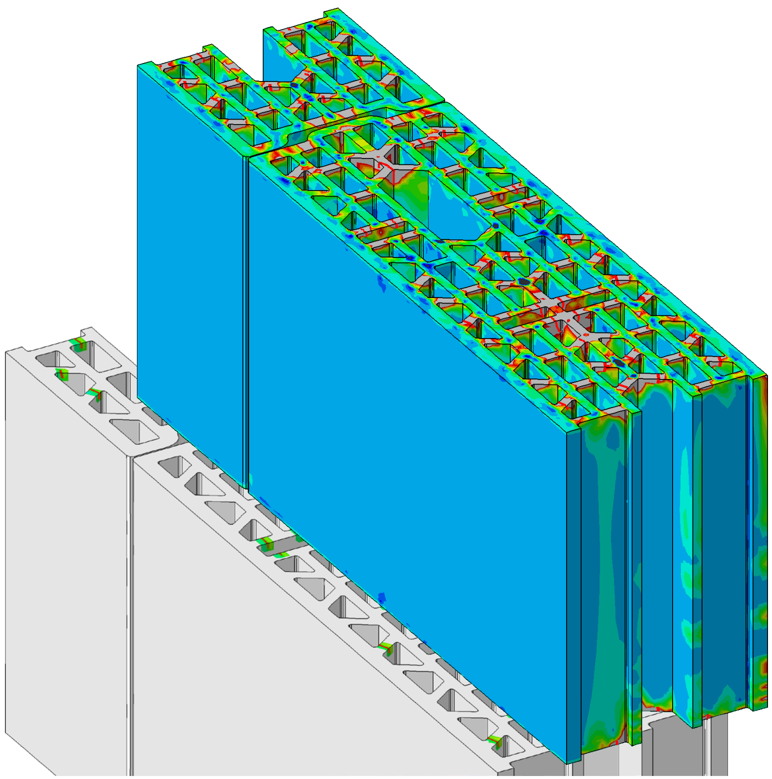
Optimization of block design

- Significant Increase of masonry strength







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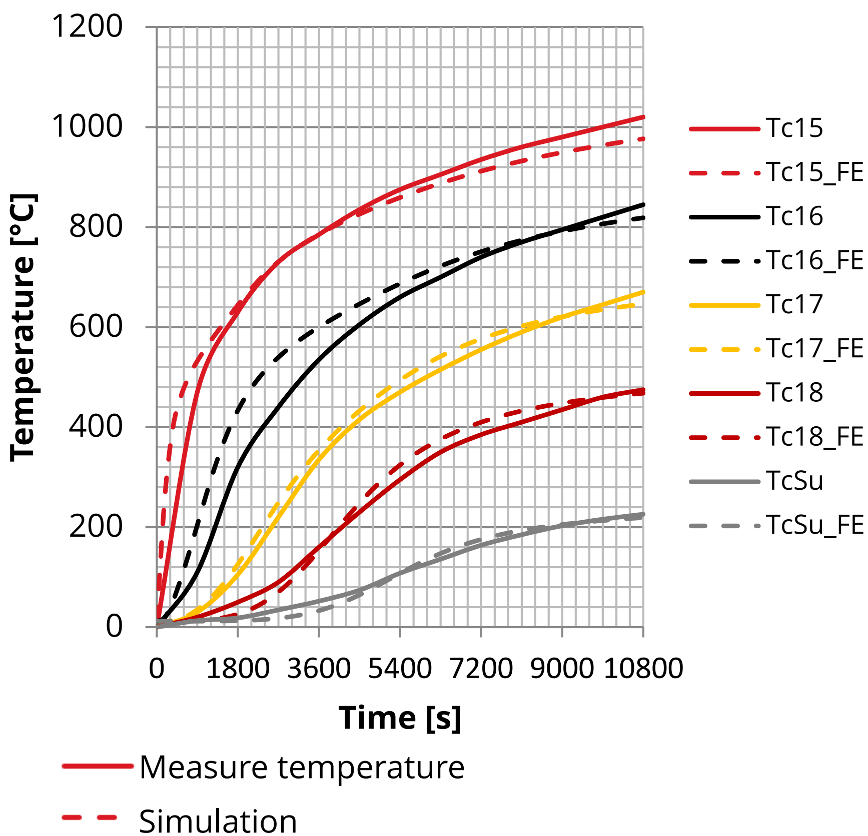
Simulation of masonry strength

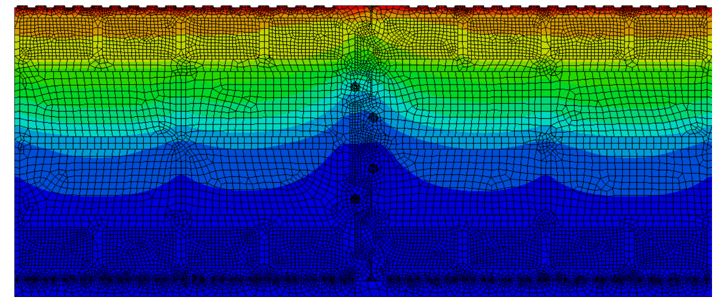
Optimization of fire resistance

Simulation of fire test

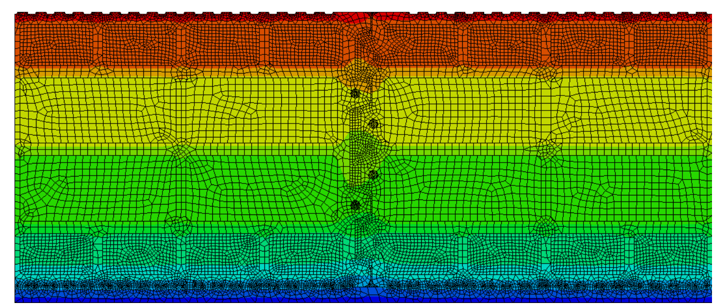
› Non-linear heat flow and temperature dependent material properties considered



Temperature distribution t = 30 min, temperature front due to radiation faster in cavities



Temperature distribution t = 180 min – almost uniform temperature distribution



Our Vision

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Virtual Labs

Virtual Ceram Lab

Virtual Mech Lab

Virtual Prod Lab

Masonry robotics

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Mobile masonry robot

Cooperation with Fast Brick Robotics

Wienerberger commitment to sustainability

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3 column strategy

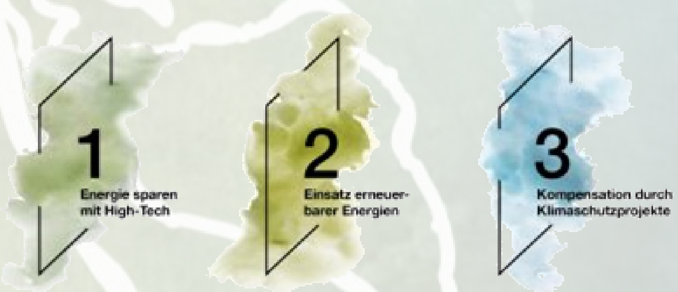
1. Save energy, reduce emissions

   Wienerberger reduced the use of thermal energy by 20% in the last 5 years and is constantly working on reducing CO_2 emissions

2. Use renewable energy

   Local plants use renewable energy and produces with Bio-electricity

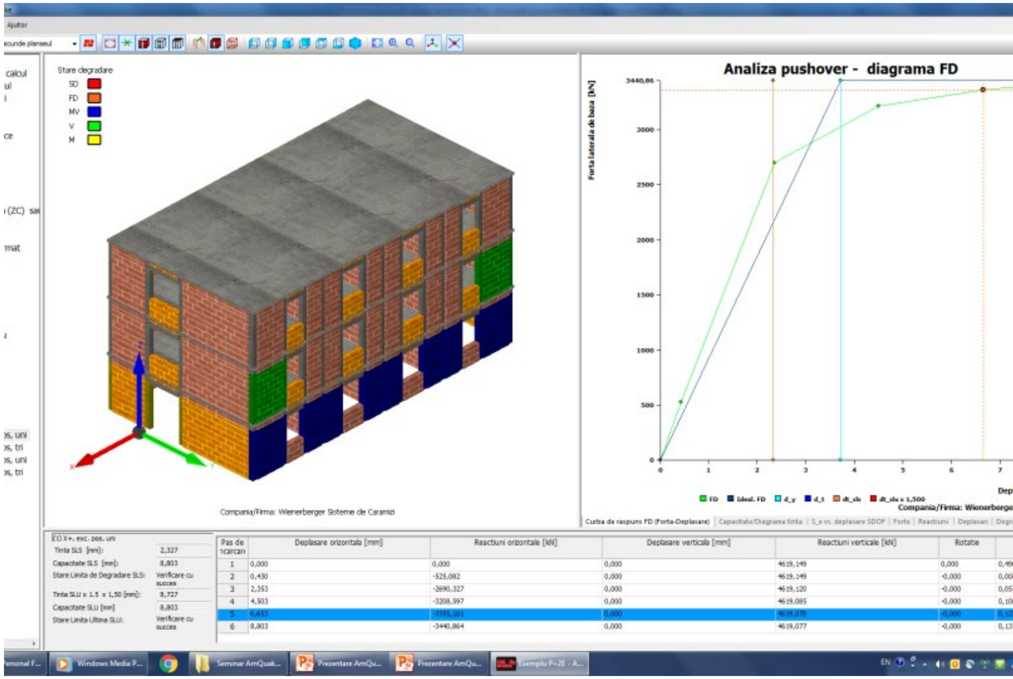
3. Invest in climate protection projects



AmQuake Software

AmQuake is a calculation software used for the structural design of masonry buildings:

- safe to seismic action;
- designed according to the most recent European and national design codes EC6 & EC8
- designed using the most modern methods of seismic calculation

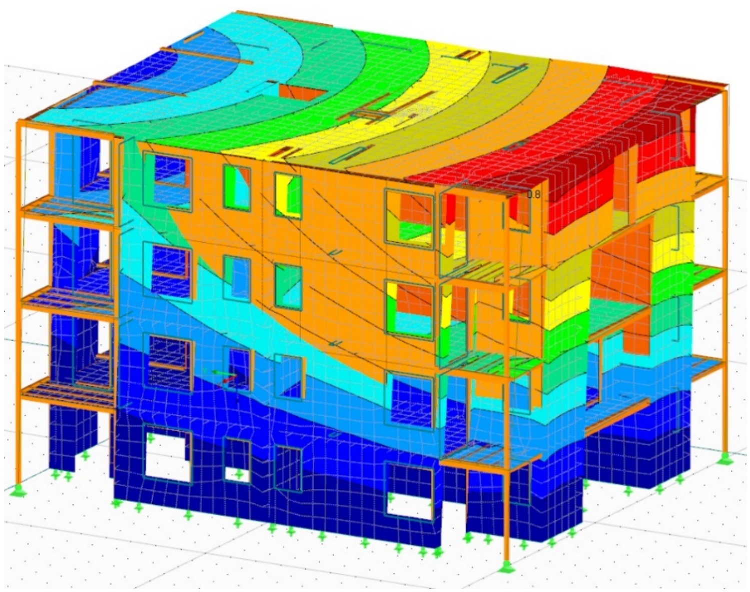


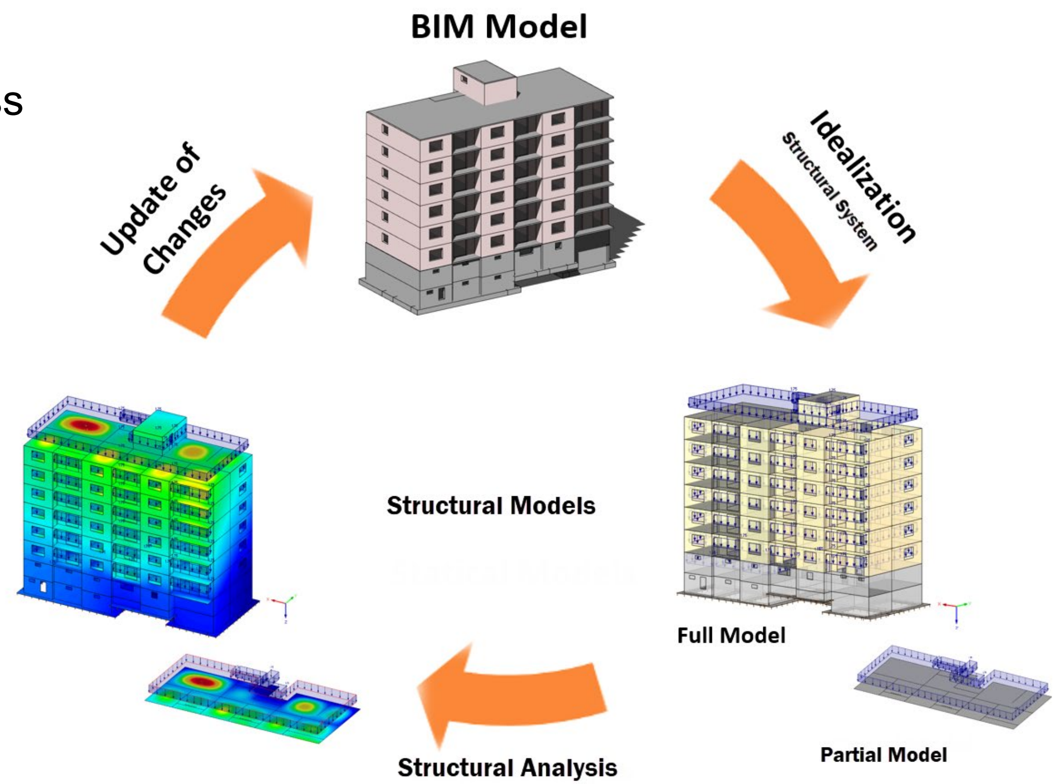
AmQuake is based on the **PUSH-OVER analysis** of the structure and on the **Frame by Macro Elements – FME Modelling Method**.

3D design module for FEM calculations

Development of engineering design software with Dlubal

- Development of stable masonry module for RFEM
- Robust calculation for engineering practice
- Feasible calculation time
- Full integration in BIM planning process





Wienerberger provides full system solutions

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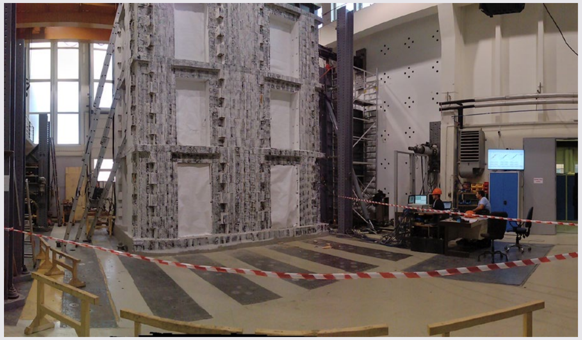
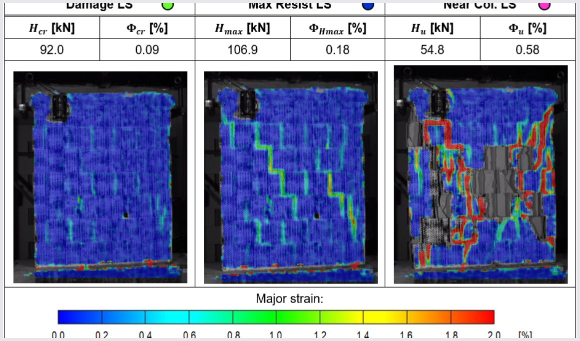
Porotherm Zubehör

Evaluation of new masonry types towards seismic performance





Materials and products

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Porotherm IZO Profi

Porotherm Dryfix extra masonry glue

Evaluation of seismic performance

Overview on test program at ZAG Lubljana

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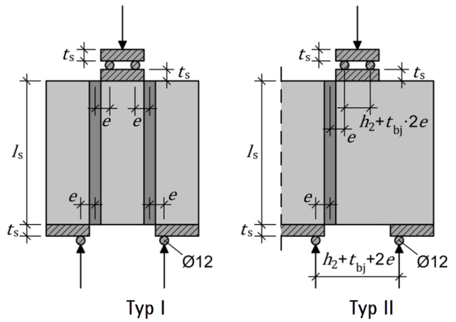
Shear strength acc. EN 1052-3

Abbildung 5-26: Scherversuche nach EN 1052-3 [203]



Cyclic shear tests on walls

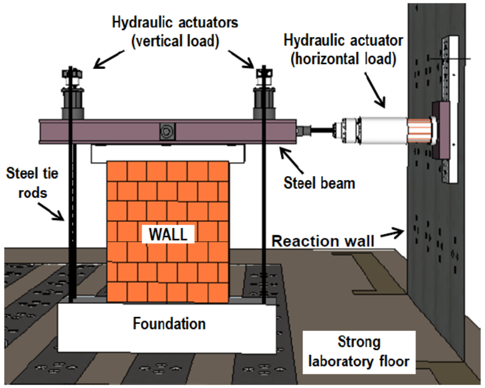


Figure 29: View of the test setup for cyclic shear tests.

Reaction wall tests

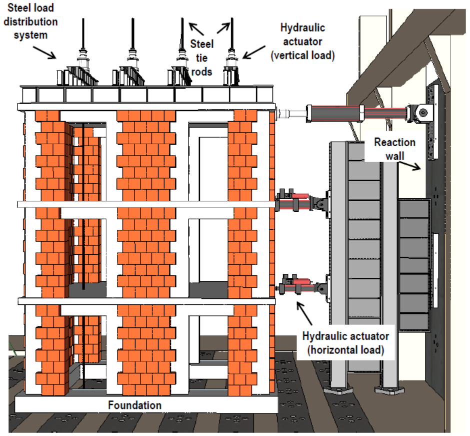


Figure 32: Multistorey model in the test setup.

Shaking table tests (LNEC Lisbon)

Cyclic shear tests

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Test setup

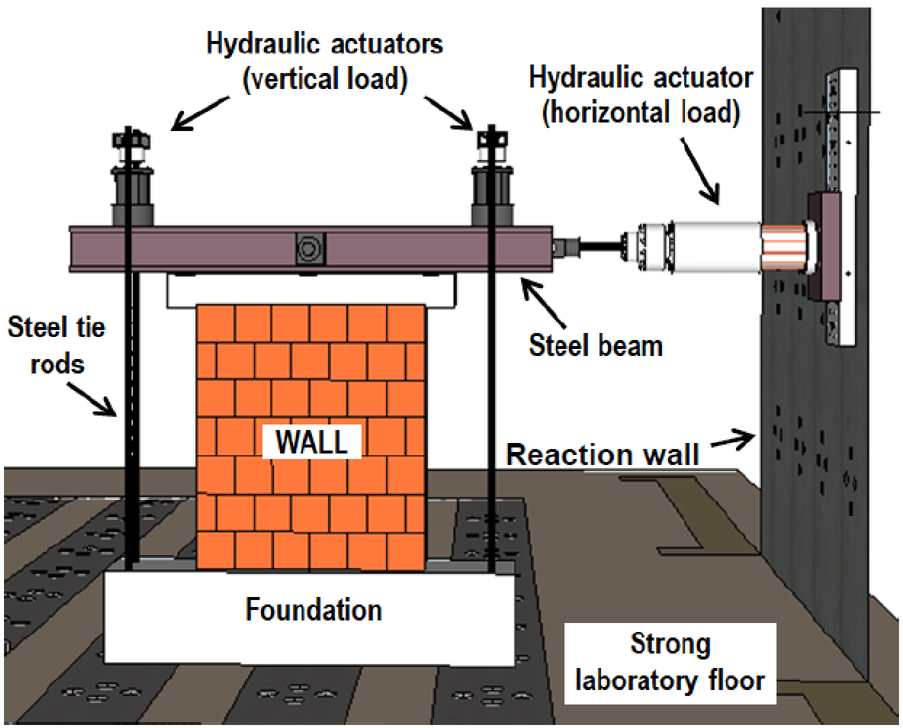

Figure 29: View of the test setup for cyclic shear tests.

Cyclic loading

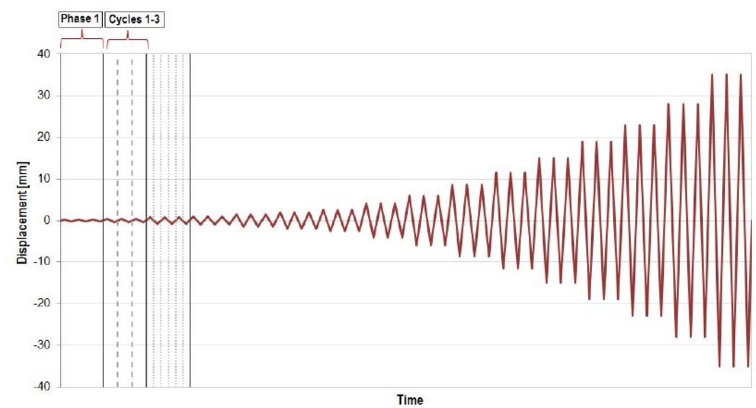

Figure 31: Program of horizontal loading for wall W8.

Cyclic shear tests

Test results

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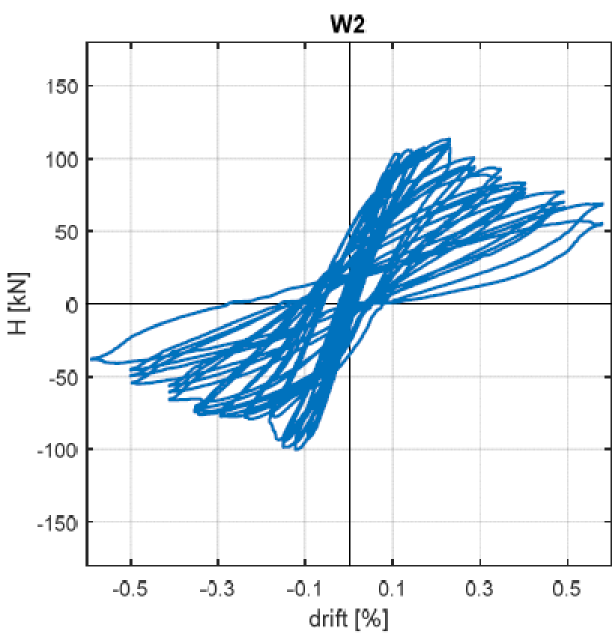
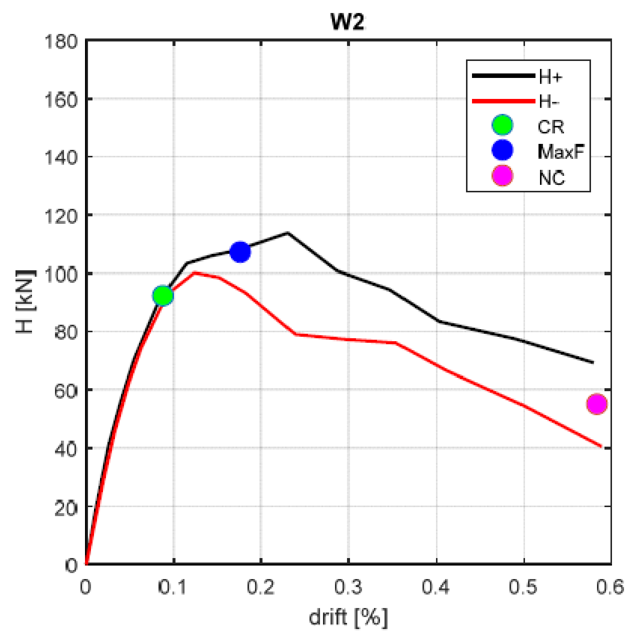
Test results serve as input for push-over calculations:

- Load – displacement curveLast- Verschiebungs-Kurve
- Maximum shear resistance
- Maximum drift capacity





Results unreinforced masonry

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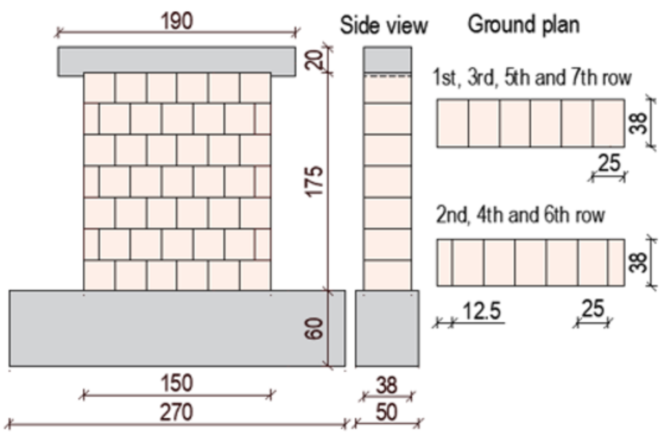
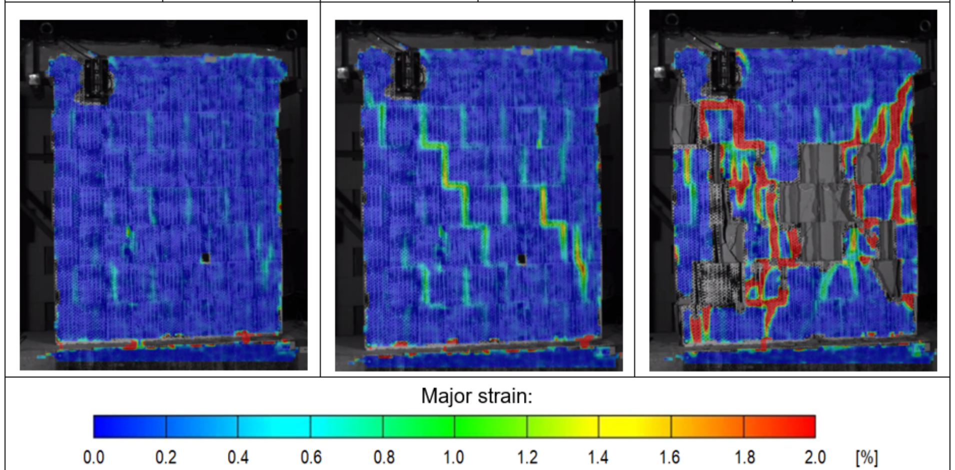
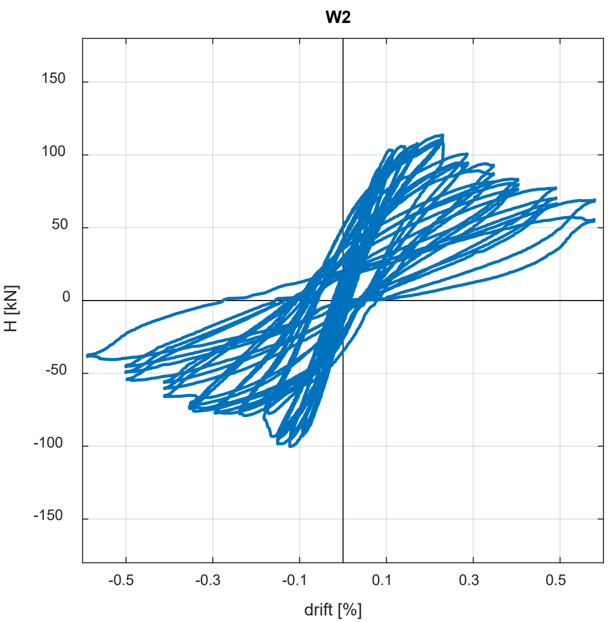


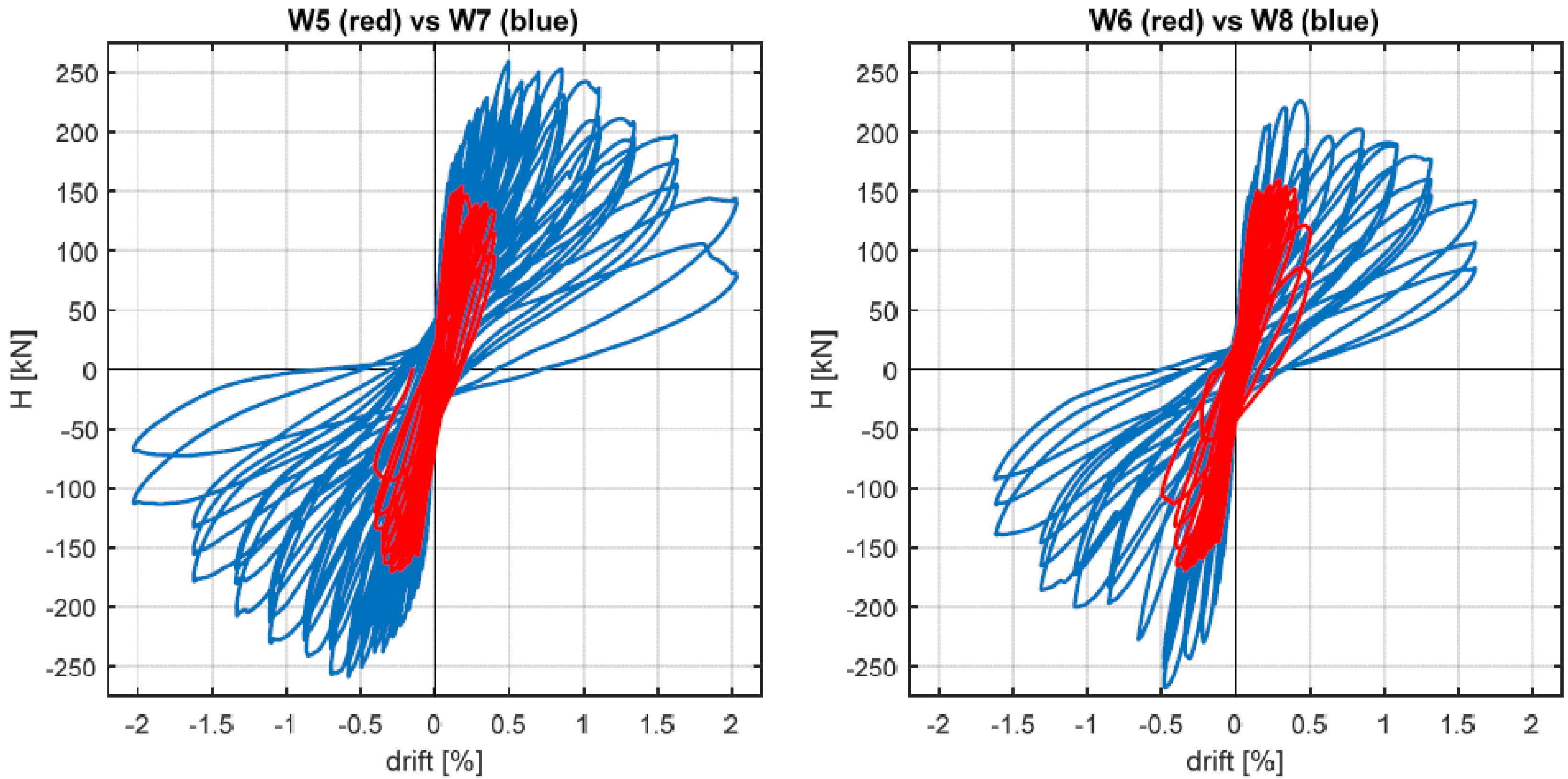
Damage LS		Max Resist LS		Near Col. LS	
H_{cr} [kN]	Φ_{cr} [%]	H_{max} [kN]	Φ_{Hmax} [%]	H_u [kN]	Φ_u [%]
92.0	0.09	106.9	0.18	54.8	0.58





Cyclic shear tests

Effect of confinement



Confined masonry (blue) shows higher ductility than unreinforced masonry (red)

Full scale tests on 3 story building

Type of construction

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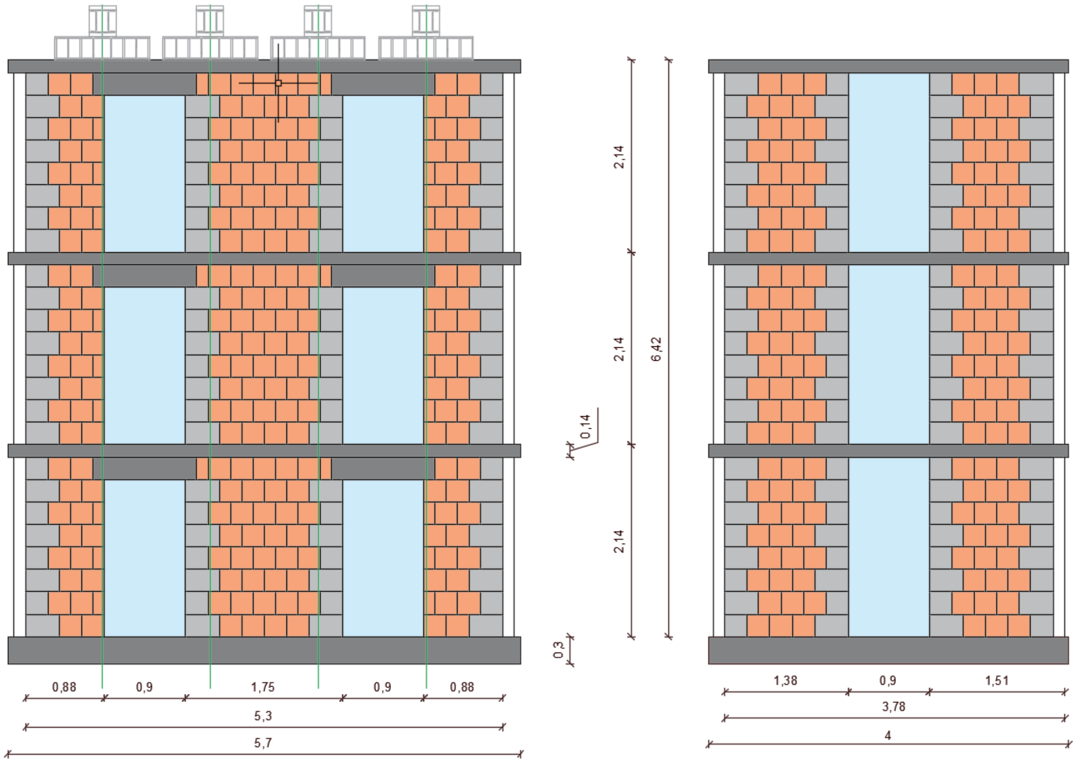
- Part of typical five storey residential structure
- Dimensions 6 x 4 meters in plan and about 7 m high
- Tie columns placed according EC8 rules



Full scale tests on 3 story building

Test setup and loading

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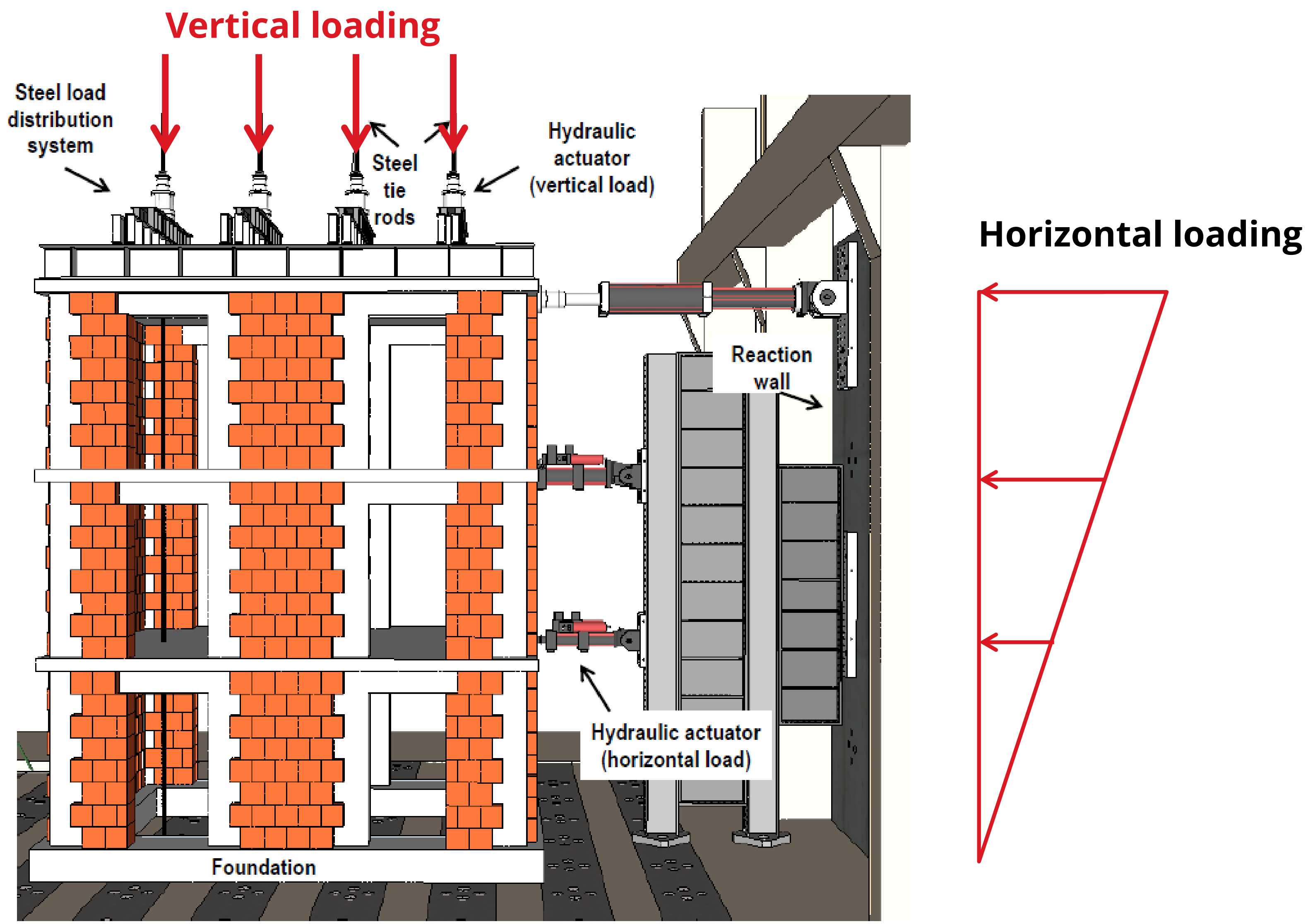

Full scale tests on 3 story building

Test setup and loading

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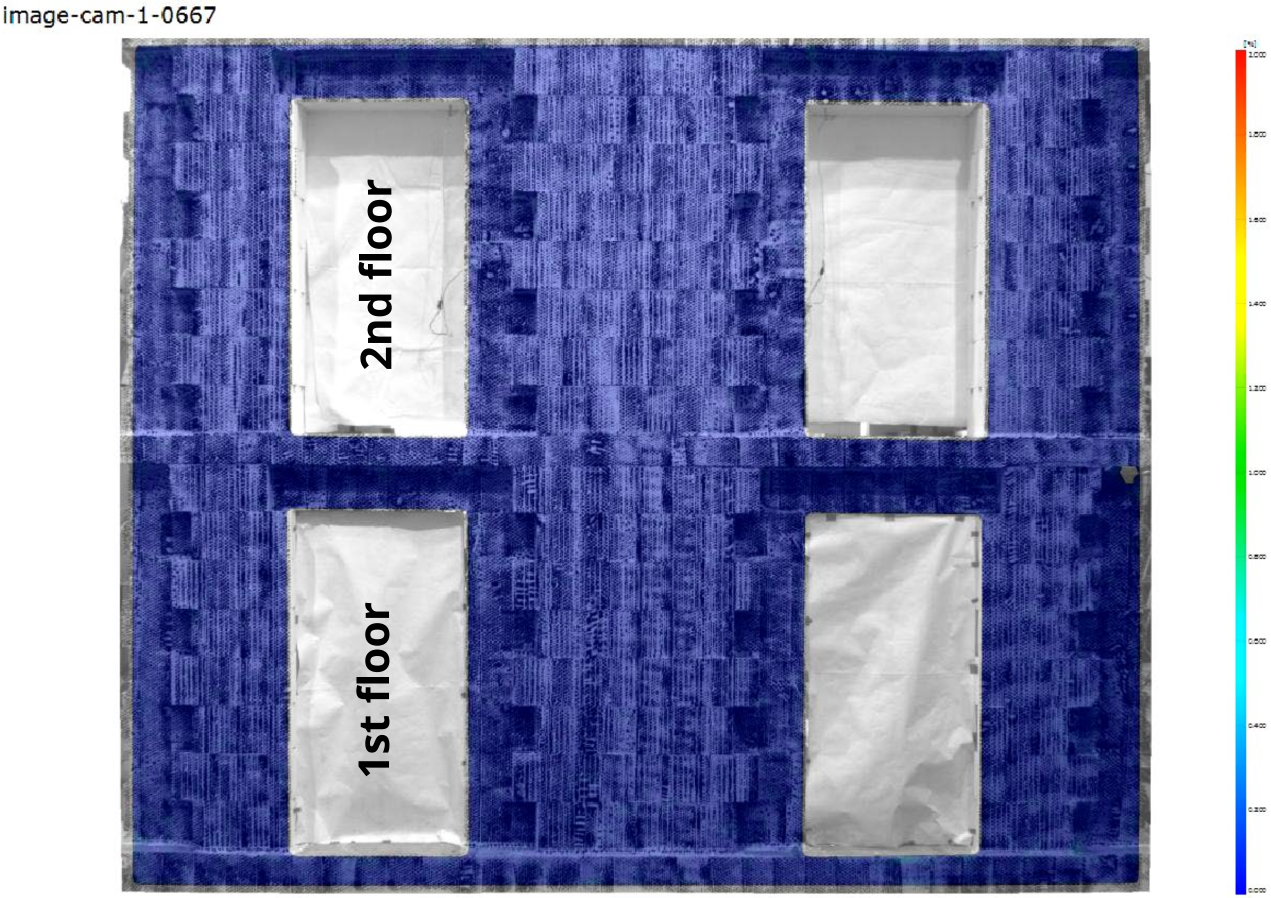

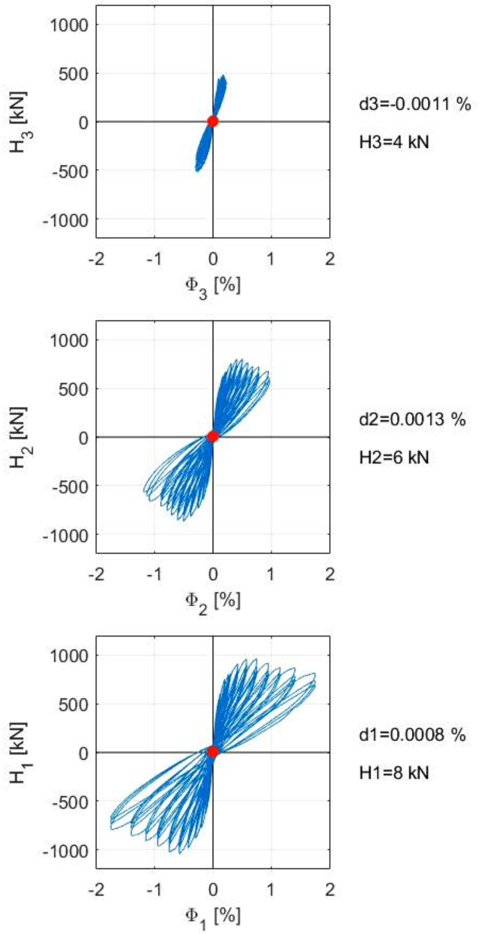

Full scale tests on 3 story building

Test results – cyclic behavior

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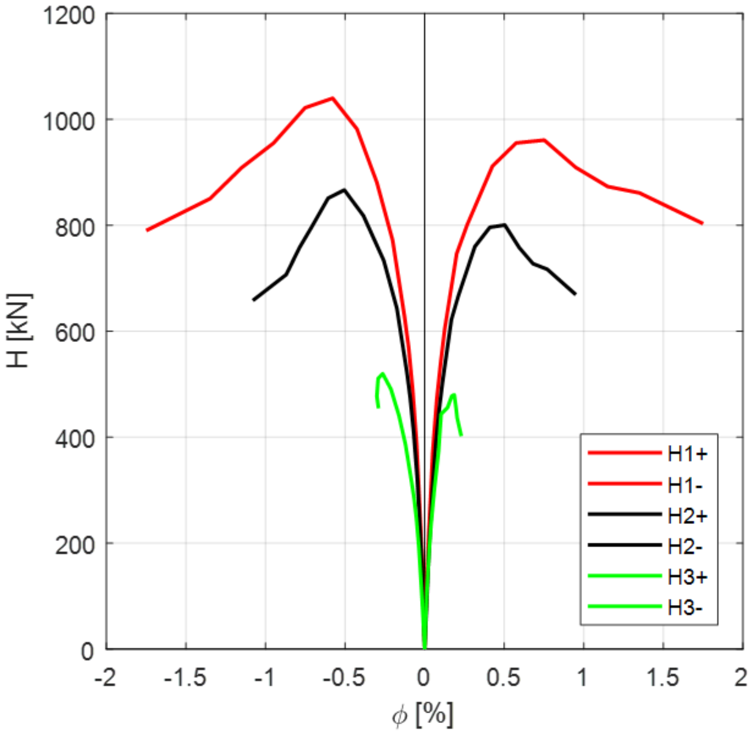
- Envelope of hysteretic curves
- Corresponding limit states
- Max. loads and drift limits



	Damage LS		Max Resist LS		Near Col. LS	
Floor	H_{cr} [kN]	Φ_{cr} [%]	H_{max} [kN]	Φ_{Hmax} [%]	H_u [kN]	Φ_u [%]
3	307	0.07	-	-	-	-
2	401	0.07	833	0.50	-	-
1*	482	0.08	1000	0.66	797	1.75

* limit state of the (model) building

Full scale tests on 3 story building

Test results – evaluation of q- values

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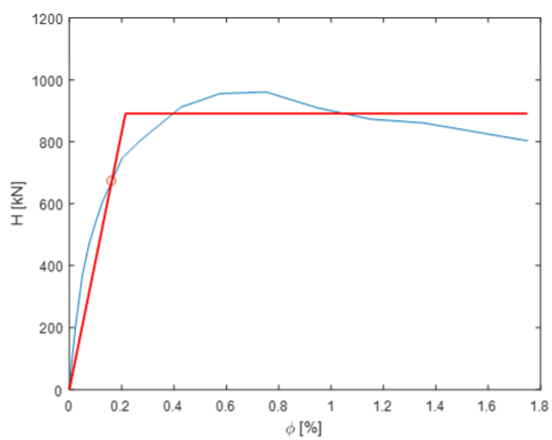
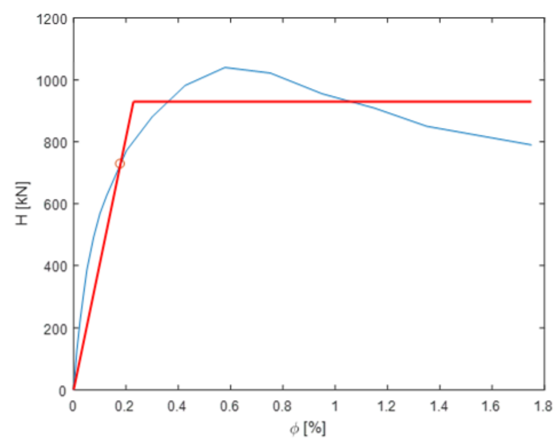
› Bilinearization of envelope

<table>
<tr><th>Floor</th><th>Positive direction</th><th>Negative direction</th></tr>
<tr><td>1</td><td>
</td><td>
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Numerical results of bilinear idealization and **q factor** values

Floor	k [kN/%]	F_{id} [kN]	Φ_{el} [%]	Φ_{ult} [%]	$\mu = u_{ult}/u_{el}$	q [ ]
1. +	4151	891	0.21	1.75	8.15	3.9
1. -	4068	930	0.23	1.75	7.66	3.8
avg.	**4110**	**911**	**0.22**	**1.75**	**7.91**	**3.9**

Full scale tests on 3 story building

Test results – comparison with wall tests

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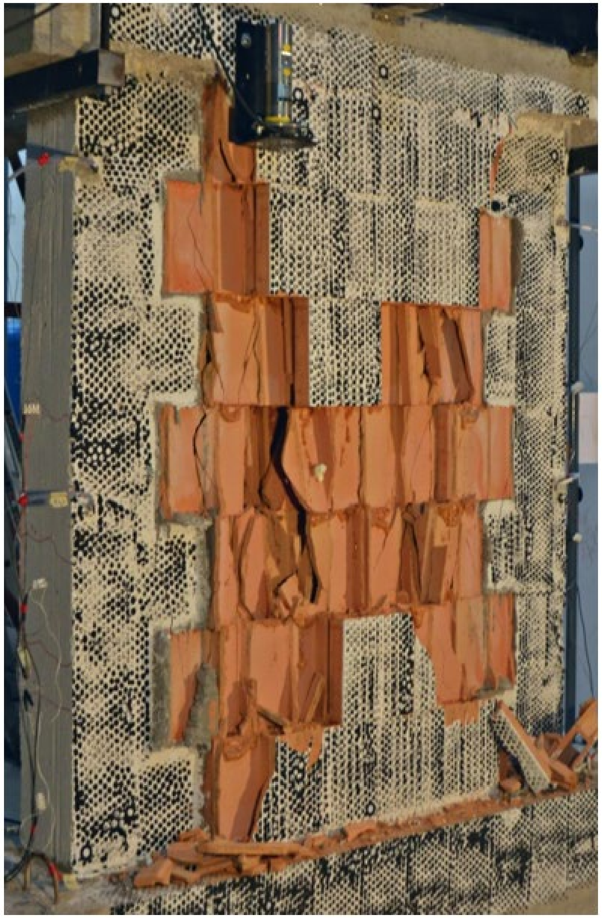
- Strong similarity between failure in wall tests and building model:

Failure of the pier in the building model

Failure of the wall



Full scale tests on 3 story building

Conclusions

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Summary of results

- Mode of response was storey mechanism
- Shear damage of walls in first floor
- High ductility of confined IZO Profi masonry

Conculsions from test institute:

- “Tests and analysis of the results show that buildings built in the above described technology respond adequately to seismic loads”
- “… the tests showed that the ductility and energy dissipation were not severely affected by the level of compressive stress …”
- The behaviour factor q was assessed based on the measured and observed response of the structure and amounted to $\boldsymbol{q = 3.9}$.
  This indicates that in the design the highest value from the interval of recommended values in the Eurocode 8, i.e. $q = 3.0$, can be used.

Shaking table tests

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Shaking table tests

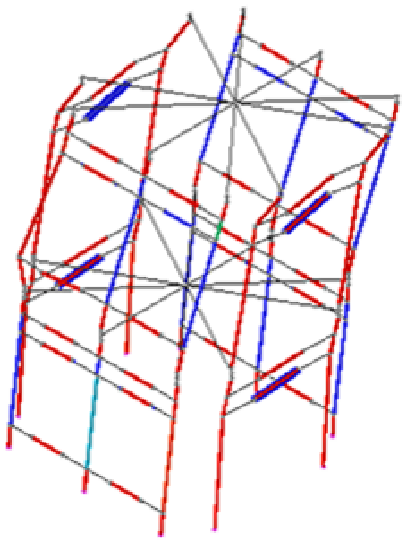
Test at acceleration of 0,30 g

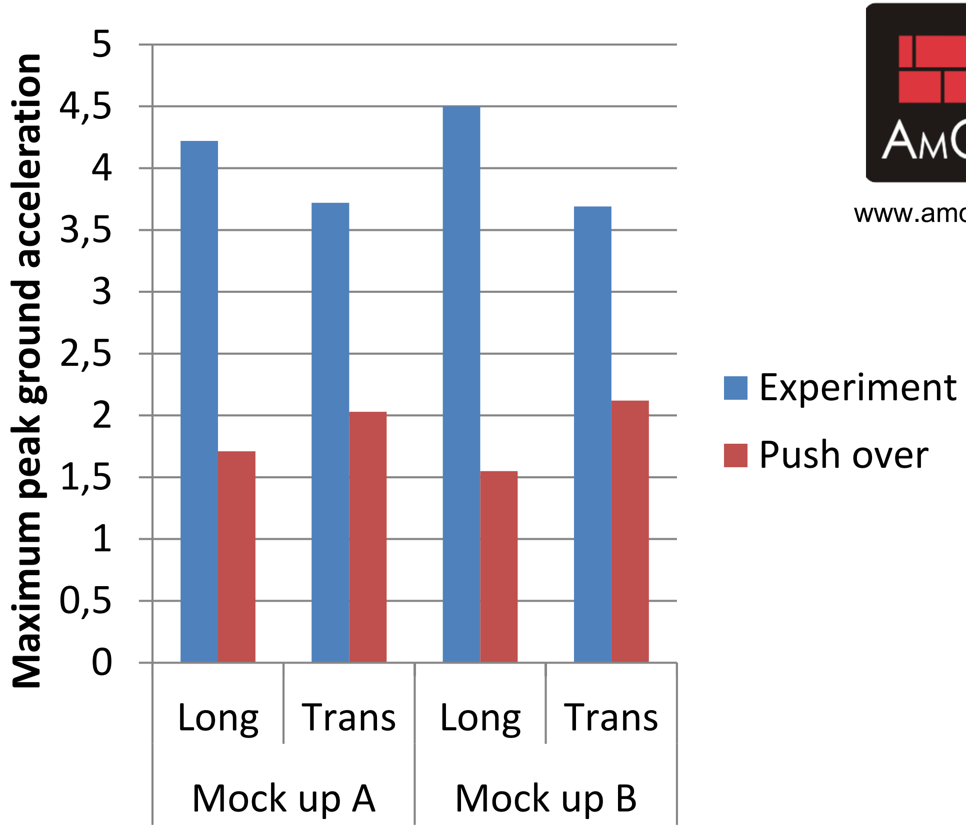
Shaking table tests

Evaluation via numerical analysis

› Nummerical simulations using software **AmQuake**

Equivalent frame model:





www.amquake.eu

› **Big safety margin between experiment and non-linear calculation**

New generation of masonry solutions

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Wienerberger is a trustworthy business partner for the building industry

- We develop our products with sophisticated methods
- We test our solutions in cooperation with local experts
- Our ambition is to develop the **"New generation of masonry solutions"**

Dr. Andreas Jäger, Wienerberger AG, Wienerbergerplatz 1, 1100 Vienna, Austria

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Hvala Vam na pažnji!

Thank you for your attention!