SYSTEM3E

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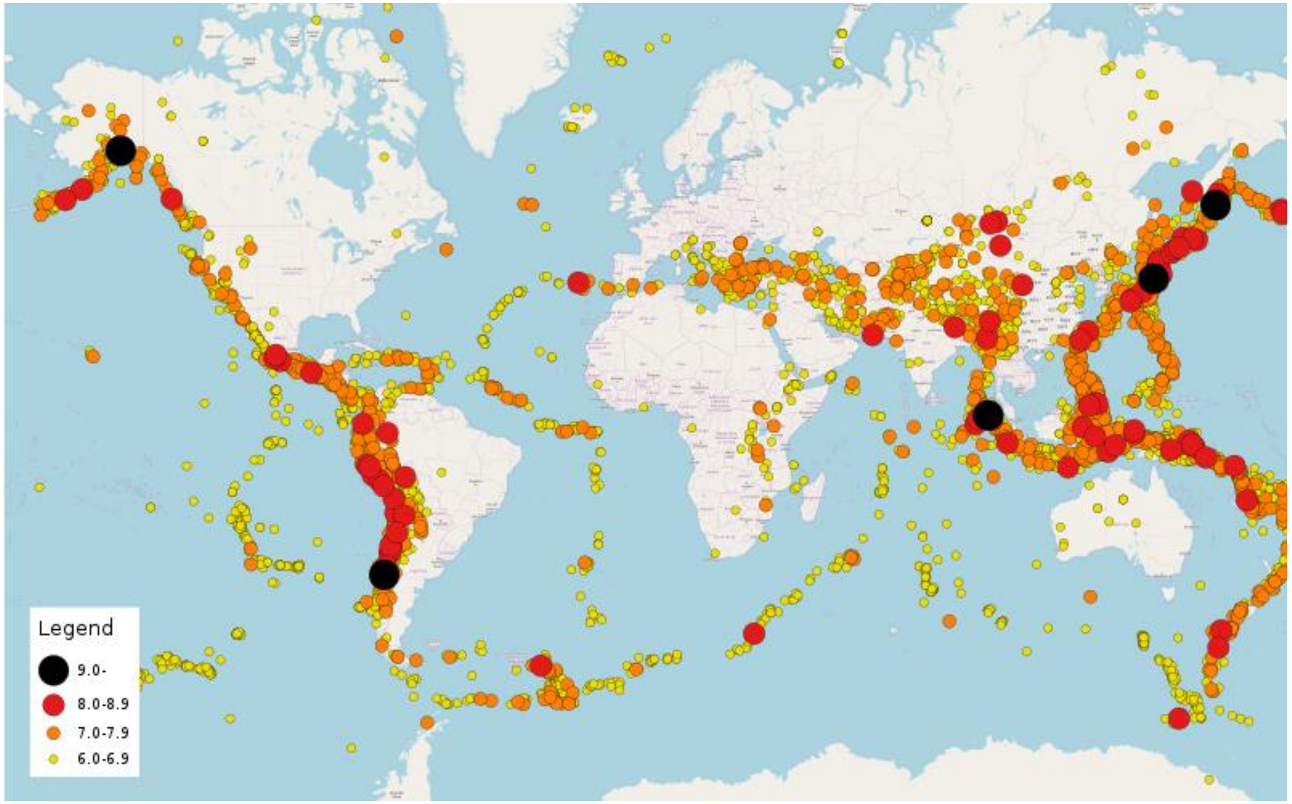
01. Introduction

The aim of the activity is to demonstrate that SYSTEM 3E technology can be freely implemented in seismic prone areas.

In this approach, SYSTEM 3E is considered as load-bearing and self-standing structure with no reinforcing concrete and steel as suggested in International Building Code and Eurocode 8

SYSTEM 3E can deliver its all values (economy, ecology, energy-saving) when is used without supplementary materials and concrete/steel load-bearing structures. Therefore, we aim to demonstrate that S3E is safe to be implemented in seismic prone areas on its own.



02. Building Codes for Seismic Assessment

The seismic assessment of new structures is governed by building codes and standards that vary by region and country.

These codes are designed to ensure that buildings can withstand seismic forces and minimize damage during earthquakes.

Local building authorities enforce these codes to ensure that structures are safe and resilient against seismic forces.

Here are some general principles and aspects typically covered in seismic assessment regulations:

1. International Building Codes (IBC):
In the United States, the International Building Code (IBC) provides guidelines for seismic design. The seismic provisions of the IBC are based on the seismic hazard of the specific location.

2. Eurocode 8 (EC8):
In Europe, Eurocode 8 (EC8) is commonly used for seismic design. It provides regulations for the seismic assessment and design of structures, taking into account different seismic zones.

3. Seismic Zones:
Building codes classify regions into seismic zones based on historical earthquake data. The seismic zone determines the level of seismic activity, and building requirements are adjusted accordingly.

4. Seismic Load Calculation:
Regulations provide methods for calculating seismic loads that structures must be designed to resist. These loads are influenced by factors such as the building's mass, stiffness, and the seismicity of the region.

5. Structural Performance Categories:
Codes often define different structural performance categories based on the importance of the structure. Higher importance structures, like hospitals or emergency response facilities, may have more stringent seismic design requirements.

6. Ductility and Redundancy:
The codes may specify requirements for ductility and redundancy in structural systems, allowing buildings to deform in a controlled manner during an earthquake.

7. Materials and Construction Standards:
Specifications for some construction materials and construction practices are outlined to ensure that the completed structure meets seismic resilience requirements.

8. Seismic Retrofitting:
In some cases, regulations may include provisions for the seismic retrofitting of existing structures to improve their seismic performance.

03. Seismic Hazard Assessment

It is common to perform a seismic hazard assessment for a specific location and specific masonry structure, especially to determine the level of seismic forces the structure may experience and to evaluate potential seismic risk and the likely performance of structures during earthquakes. Compliance with seismic building codes is crucial for ensuring that new masonry structures are designed and constructed to withstand seismic forces. These codes incorporate seismic hazard considerations.

01 **Probabilistic Seismic Hazard Assessment (PSHA)** to determine probability of earthquakes of different magnitudes occurring at a specific location.

02 **Deterministic Seismic Hazard Assessment (DSHA)** determining the impact of specific earthquake scenarios on masonry structures. It considers a single earthquake event or a set of scenarios to assess potential ground shaking, fault rupture, and other seismic hazards.

03 **Site-Specific Analysis** including detailed studies of soil types, local fault lines, and other site-specific factors that can influence seismic hazard.

04 **Ground Motion Prediction Equations (GMPEs)** that estimates of ground motions at specific locations, considering factors such as distance from seismic sources and local soil conditions.

05 **Hazard Zonation** considering the regional seismicity, geological features, and the potential for ground shaking.

06 **Nonlinear Dynamic Analysis** involving modelling the response of masonry structures under earthquake loading, considering the nonlinear behaviour of materials and structural elements. This method provides insights into the potential damage and failure modes.

07 **Vulnerability and Fragility Assessments** involving evaluating their susceptibility to seismic forces and estimating the likelihood of different damage states.

08 **Experimental Testing** of masonry components and structures under simulated earthquake conditions provides valuable data for understanding their seismic behaviour.

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04. Safety assessment of SYSTEM 3E Technology in seismic regions

Scope:
Safety assessment of SYSTEM 3E structures in seismic regions using linear and non-linear finite element analysis.

Research Approach:
The focus of the planned project is to increase understating of SYSTEM 3E structural behaviour in seismic events that allow their appropriate assessment and future application.

Challenge:
The challenge is to perform a linear and non-linear analysis for modelled macro structures made of SYSTEM 3E EKO+ elements and validate it in real environment.

In the first stage, Finite Element Modelling (FEM) is planned to be used in modelling the static and dynamic structural behaviour under static and seismic loadings.

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04. Safety assessment of SYSTEM 3E Technology in selected seismic scenarios

Tasks and deliveries

Milestone 1.1 Demonstration of SYSTEM 3E EKO+ technology safety to seismic static loads on simplified macro model (linear static analysis)
Milestone 1.2 Demonstration of SYSTEM 3E EKO+ technology safety to seismic dynamic loads on simplified structural model (linear dynamic analysis)
Milestone 1.3 Demonstration of SYSTEM 3E EKO+ technology safety to seismic loads on complex macro-mechanical structural model
Milestone 1.4 Demonstration of SYSTEM 3E safety by experimental testing of model structures (simple and complex micromodel)
Milestone 1.5 Determining dynamic response of SYSTEM 3E EKO+ structures
Milestone 1.6 Evaluating damage states in SYSTEM 3E EKO+ model structures

	Initiative	Deadline
Task 1	Define design criteria and testing conditions	2024
Task 2	Creating a simplified structural model of SYSTEM 3E wall and its safety assessment using linear static and dynamic analysis	2024
Task 3	Creating a complex structural model of SYSTEM 3E construction and safety assessment using linear static and dynamic analysis	2024
Task 4	Demonstration of SYSTEM 3E safety by experimental testing of model structures in sine-beat mode (simple macro-model)	2024
Task 5	Demonstration of SYSTEM 3E safety by experimental testing of model structures in sine-beat mode (complex macro-model)	2024
Task 6	Demonstration of SYSTEM 3E safety by experimental testing of model structures in time-history mode (complex macro-model)	2024
Task 7	Determining dynamic response of SYSTEM 3E EKO+ structures and evaluating damage states	2024
Task 8	Structural design boundary conditions identification	2024

4.1 SYSTEM 3E material characteristics

In-plane response of SYSTEM 3E EKO+ and is assessed using Finite Element Analysis for a simple marco-model. Technical parameters of tested technology are listed in the table and take into account dimensions, density, strength etc.

Mechanical properties of considered technologies

		SYSTEM 3E EKO+
1	Dimensions of a single unit	352x300x704
2	Density [kg/m^3]	d = 310
3	Characteristic unit compressive mechanical strength (⊥ to the surface) [N/mm^2]	f_b = 2
4	Characteristic compressive strength of masonry [N/mm^2]	f_k = 1,02
5	Poisson's ratio	v_{mn} = 0,35
6	Average modulus of elasticity of masonry [N/mm^2]	E_{mn} = 193
7	Characteristic value of the tensile strength (when the upper edge is restrained) at bending in the case of failure in the perpendicular plane [N/mm^2]	$F_{xk^}$ = 0,11
8	Characteristic value of the tensile strength (when the upper edge is restrained) at bending in the case of failure in the parallel plane [N/mm^2]	$F_{xk\|\|}$ = 0,31
9	Characteristic shear strength of masonry in the parallel plane [N/mm^2]	F_{vk} = 0,068

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4.3 Static linear analysis test procedure

To forecast seismic response of SYSTEM 3E structures, in-plane response to static loadings of SYSTEM 3E EKO+ and other competitive technologies made of AAC blocks and ceramics are assessed using Finite Element Analysis is performed first.

Test specimen model:

Three macro models of a wall specimen with 3520 length and x 3000 in height with thickness of a single base element are developed and include the following researched systems.

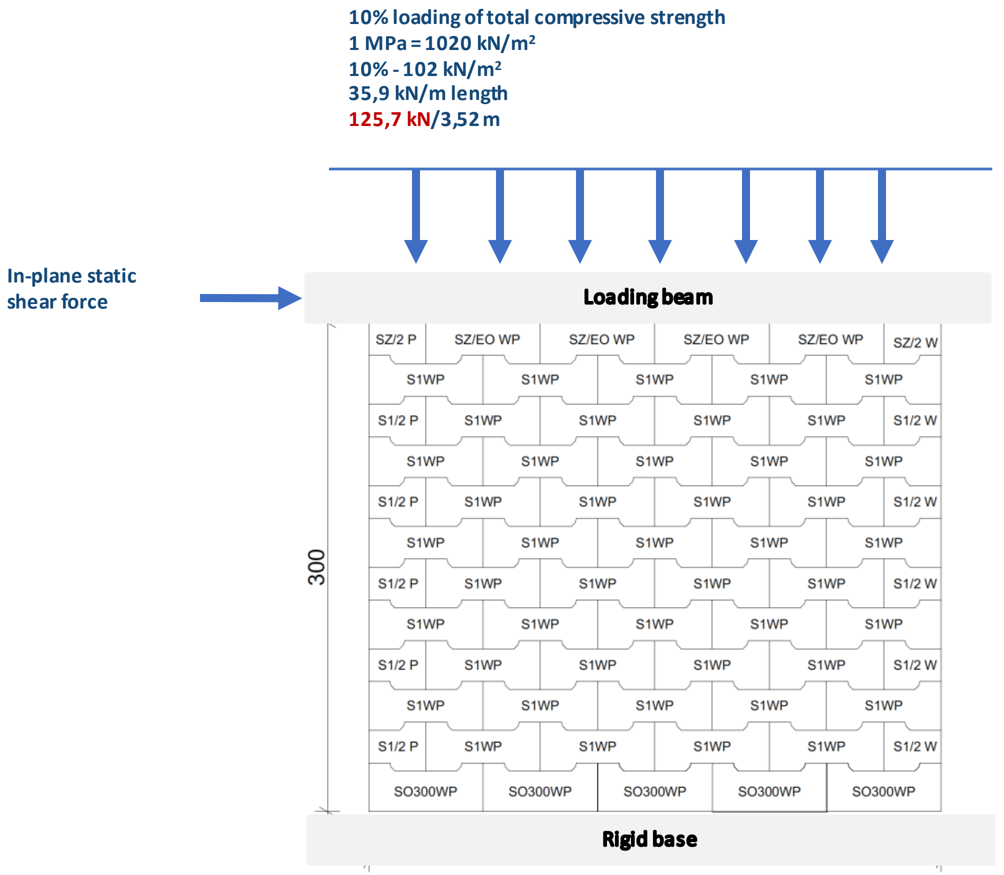
Test scenario:

1. **Preloading of the walling system at minimal of 10 % of its loading capacity**

(10% of 1,02 MPa = 0,1 x 1020 kN/m^2 = 102 kN/m^2), at the wall with length of 3,52 m there is 0,352m x 102 kN/m^2 x 3,52 = 125,7 kN/sample

2. Shear static displacement determination
Static loading of the walling SYSTEM to achieve the target drift and determine whether the shear strength is not exceeded.

Information expected?
At what drift the walling system reached its maximum shear strength?



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Information expected?

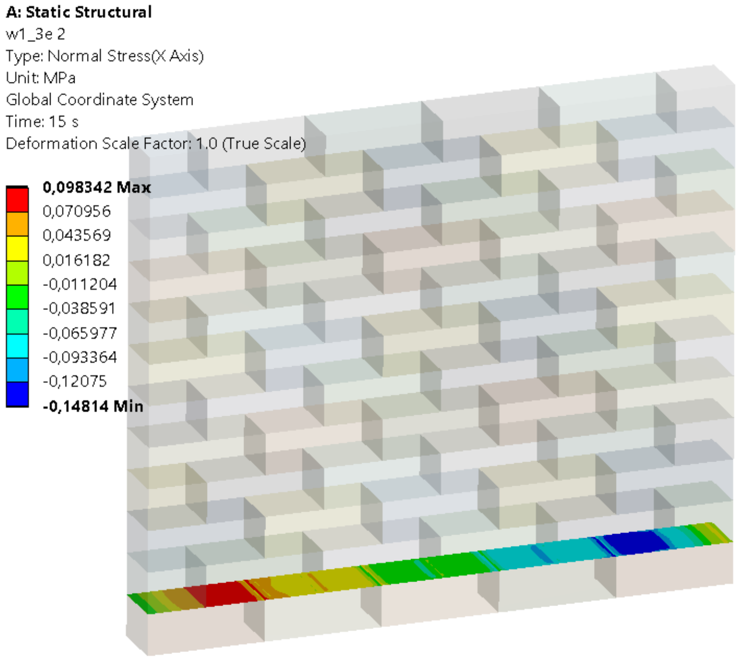
At what drift the walling system reached its maximum shear strength?

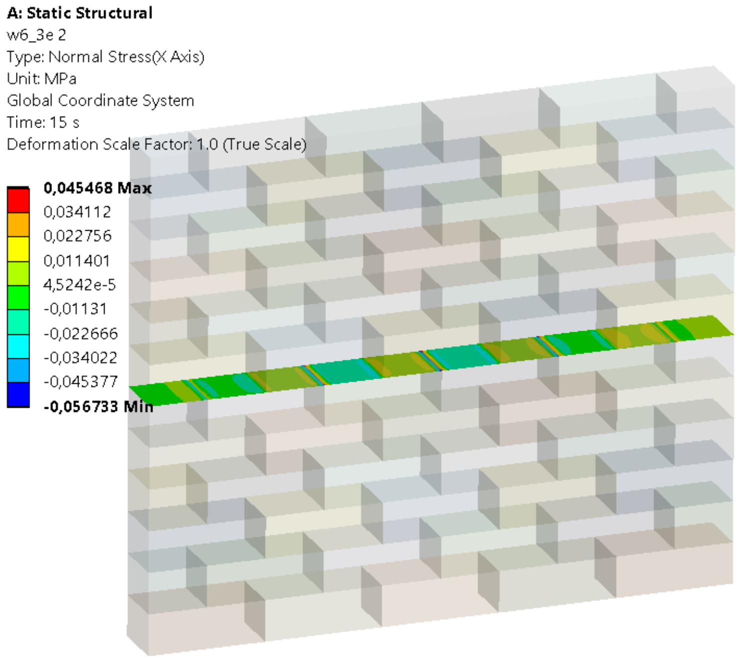
	Test specimen	1.1		1.2
1.	**Target Drift (displacement/height)**	0,5%		1.0%
2.	**Height**	3 m		
3.	**Displacement**	1,5 mm		3 mm
4.	**Load necessary to create the displacement**			
4.1	**SYSTEM 3E EKO+** **Preloading of 125,7 kN/sample**		?	?

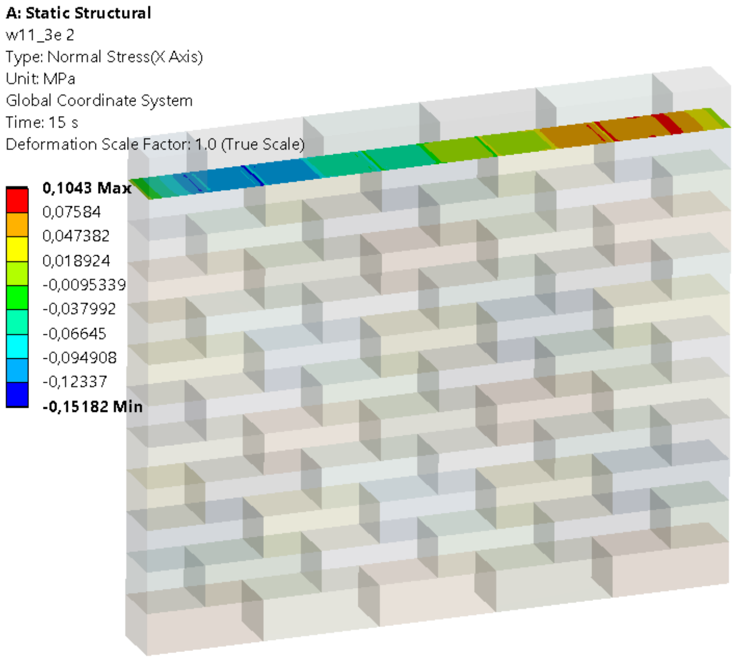
4.3 Static linear analysis – test results at displacement at 0.5% drift

Stress concentration maps at the top, bottom and in the middle of test specimen during static shear loading.

Target displacement of 0,5% (15 mm), loading necessary to create the displacement of 300 kN.



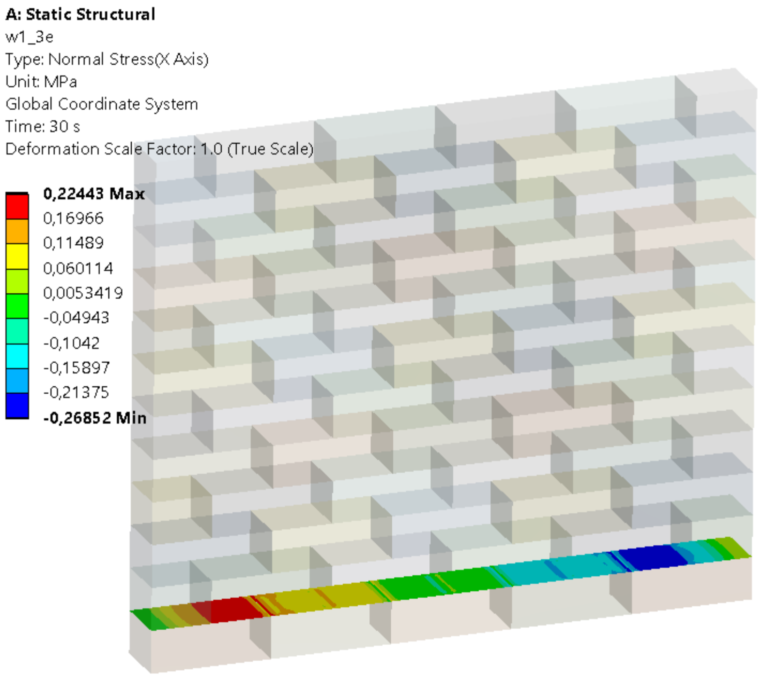


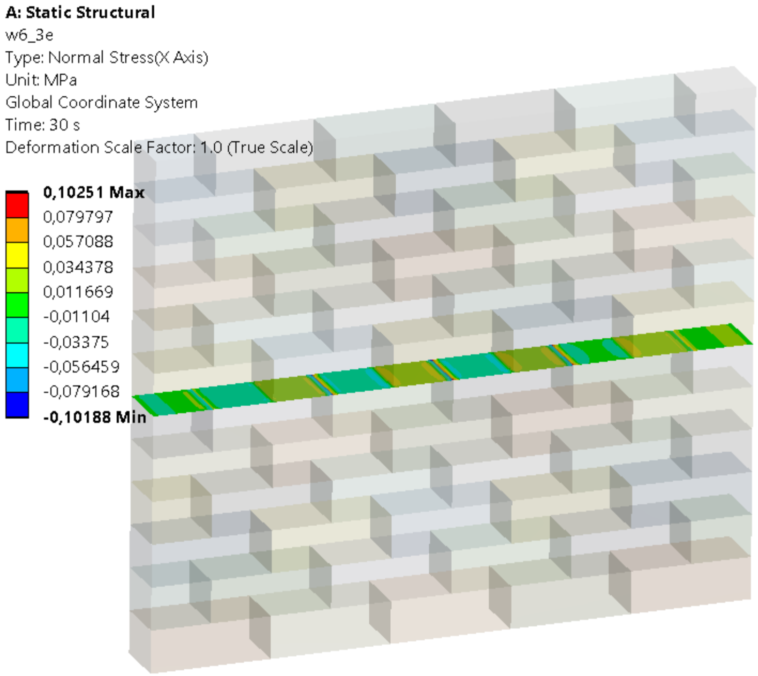


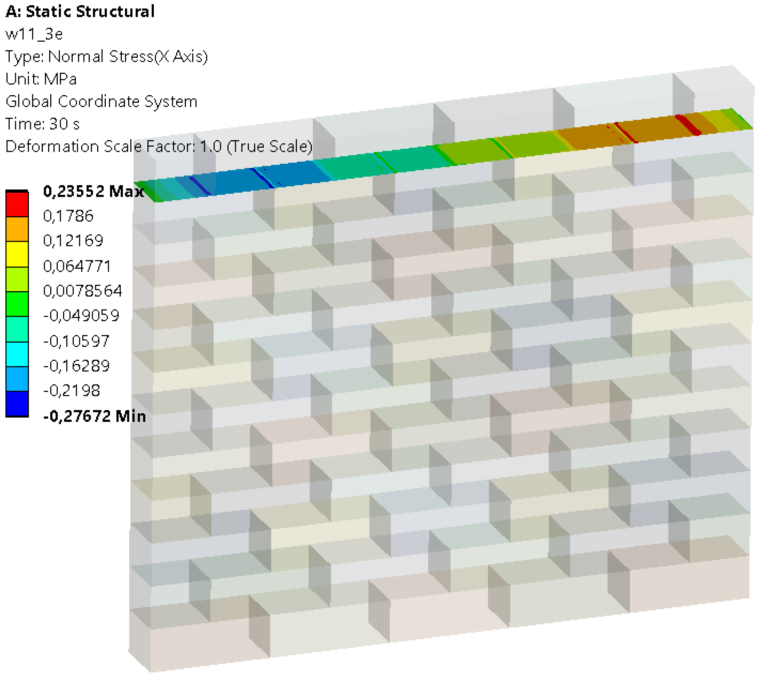
4.3 Static linear analysis – test results at displacement at 1.0% drift

Stress concentration maps at the top, bottom and in the middle of test specimen during static shear loading.

Target displacement of 1.0% (30 mm), loading necessary to create the displacement of 600 kN.







4.4 Static analysis test results interpretation and further work

Test results interpretation:

1. **SYSTEM 3E EKO+ provides structural stability during the static in-plane loading of 0,05; 0,1; 02; 0,3; 0,4; 0,6; 0,8; 1,0; 2,0; 3,0g in a two-floor house scenario.**
2. **In case of seismic event with the above magnitude, the shear stress concentrated within the object is lower than characteristic shear strength of SYSTEM 3E EKO+ construction.**

Further works to complete Task 1.

1. Makro model refinement consider (shape of SYSTEM 3E elements in discrete analysis)
2. In-plane static analysis of refined simple macro-model
3. Characterization of the structural dynamic response of refined model
4. Further development to complex micromodel and laboratory testing

Seismic hazard	Low		Moderate				High and heavy			
PGA	0,05g	0,1g	0,2g	0,3g	0,4g	0,6g	0,8g	1,0g	2.0g	3.0g

Structural stability assessment of a two-floor house exposed to in plane loading

SYSTEM 3E EKO+ **Preloading of 125,7 kN/sample**	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Peak ground acceleration can be expressed in fractions of *g* (the standard acceleration due to Earth's gravity, equivalent to g-force) as either a decimal or percentage; in m/s^2 (1 *g* = 9.81 m/s^2); or in multiples of Gal, where 1 Gal is equal to 0.01 m/s^2 (1 *g* = 981 Gal).

Specific Design Criteria

Seismic hazard accelerations are typically expressed in terms of peak ground acceleration (PGA) and are categorized into different levels of seismic hazards based on the intensity of ground shaking. These categories are often defined as follows:

1.Low Seismic Hazard:

1. PGA: 0 to 0.1 g (gravity)
2. Generally considered low risk, and structures designed for low seismic hazards may experience minimal ground shaking.

2.Moderate Seismic Hazard:

1. PGA: 0.1 to 0.4 g (gravity)
2. Represents a moderate level of seismic risk. Buildings and structures in regions with moderate seismic hazard may experience more significant ground shaking but are designed to withstand these forces.

3.High/Heavy Seismic Hazard:

1. PGA: 0.4 g and above (gravity)
2. Indicates a high or heavy seismic risk. Areas with high seismic hazard levels may experience strong ground shaking during anearthquake, requiring structures to be designed for greater seismic resistance.