COMMISSION OF THE EUROPEAN COMMUNITIES
FP7- INFRASTRUCTURES-2008-1
SP4-Capacities

SERIES
SEISMIC ENGINEERING RESEARCH INFRASTRUCTURES
FOR EUROPEAN SYNERGIES

FULL SCALE TESTING OF MODERN UNREINFORCED THERMAL INSULATION CLAY BLOCK MASONRY HOUSES

S. Lu, A. Jäger
Wienerberger AG, Vienna, Austria

L. Mendes, P. Candeias, A. C. Costa, E. Coelho
LNEC, Lisbon, Portugal

H. Degee, C. Mordant
University of Liège, Liège, Belgium

V. Sendova, Z. Rakicevic
IZIIS, Skopje, Macedonia

M. Tomazevic
Slovenian National Building and Civil Engineering Institute, Ljubljana, Slovenia

Outline

- Project Framework
- Wienerberger's Housing Solution
- Experimental Campaign
- Numerical Simulations

Project Framework

- Motivation
  - Clay block masonry housing solutions are conceived for providing **mechanical strength** but also for **thermal insulation** in order to fulfill the strict legal requirements for heating/cooling energy demand

Insulation filled block

Wienerberger e4 Brick-House 2020

Project Framework

- Motivation
  - This solution represents a **very common** construction method in Europe
  - However, most of the experimental results available were carried out on **cyclic shear tests**
  - This type of solution still lacks **seismic vulnerability assessment**

Project Framework

- Research Consortium
  - In the scope of the SERIES project Transnational access, the following research group came together:
    - **Wienerberger AG (AT)** – Leader
      - Developer and manufacturer of the housing solution
    - **University of Liège (BE)**
      - Design tasks and numerical simulations
    - **IZIIS (MK)**
      - Test data analysis
    - **Additional contribution**
      - Dr. Miha Tomazevic as an external advisor
  - Access provider
    - **LNEC (PT)** – 3D Shaking Table

Project Framework

- Objectives
  - Experimental Campaign
    - Assess the dynamic response characteristics and its evolution
    - Identify probable collapse mechanisms
    - Measure ultimate drift values
    - Evaluate ductility and behaviour factors
    - Quantify damping ratios
    - Provide further experience for retrofitting and strengthening
  - Numerical Simulations
    - Develop and calibrate a numerical model to simulate with adequate accuracy the structural behaviour observed in the experiments

Project Framework

- Methodology
  - Perform large-scale seismic tests on prototypes representative of this construction type
  - Extract as much information as possible about the seismic behaviour of the mock-ups
    - Probable collapse mechanisms, ultimate drift values, *etc.*
  - Use numerical models as a complementary tool to the experiments:
    - Preliminary assessment of the mock-up response
    - After calibrated are to be used to extend the structural analysis

Wienerberger's Housing Solution

- Insulation filled clay blocks – the premium products of Wienerberger

  - Novel geometry of blocks allows for filling voids with mineral wool
  - Advantages:
    - Reduction of heat energy demand by 25% → Perfect solution for passive houses
    - Incombustible mineral materials ensure healthy indoor air quality and fire protection
    - Thermal insulation material is protected inside of clay blocks → durable solution with long lifetime

Wienerberger's Housing Solution

- Working with insulation filled blocks

Laying of first course in conventional mortar

Application of thin layer mortar

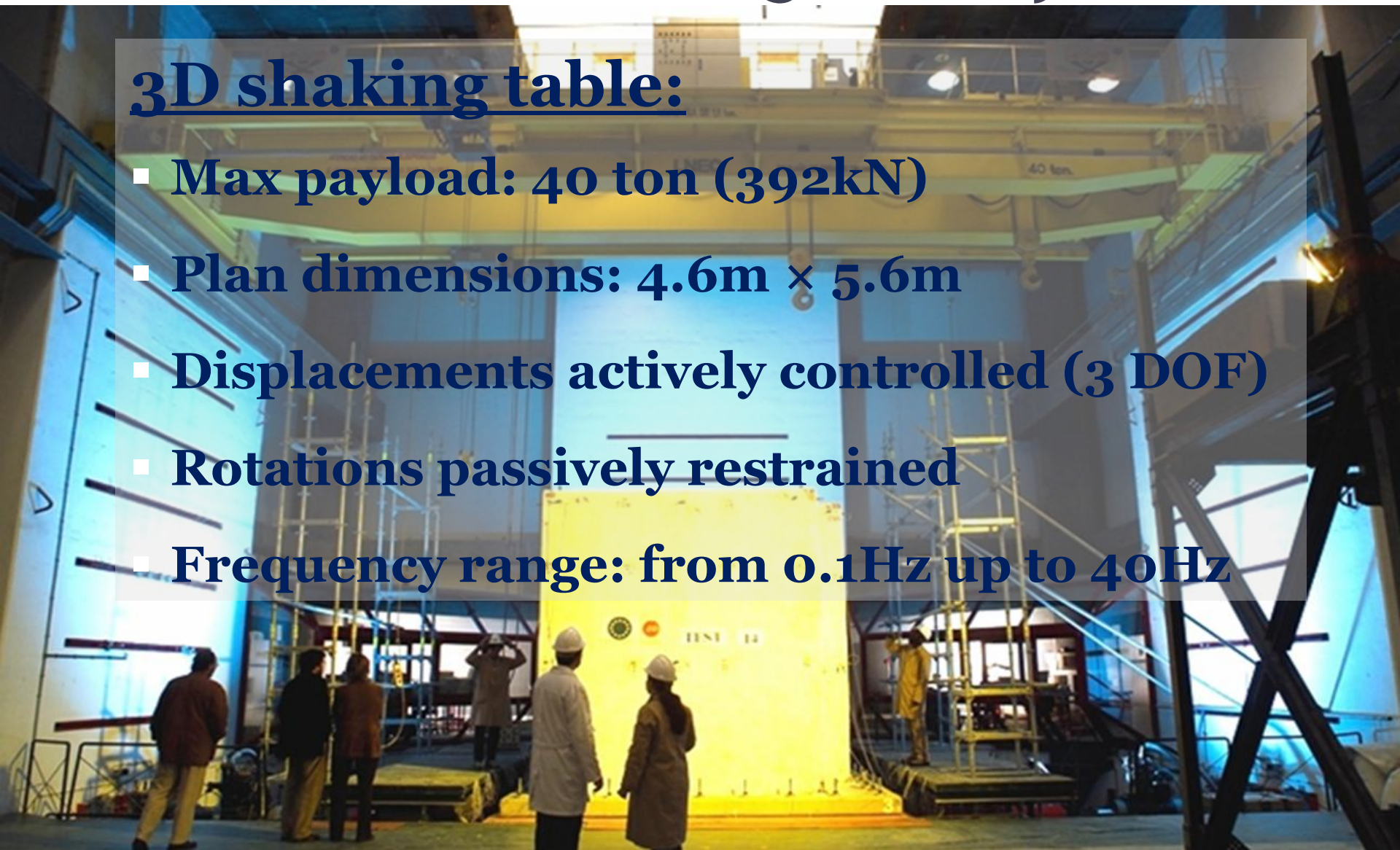
Placing of insulation filled blocks on thin layer mortar

Wienerberger's Housing Solution

First story walls being constructed

Experimental Campaign

LNEC seismic testing facility

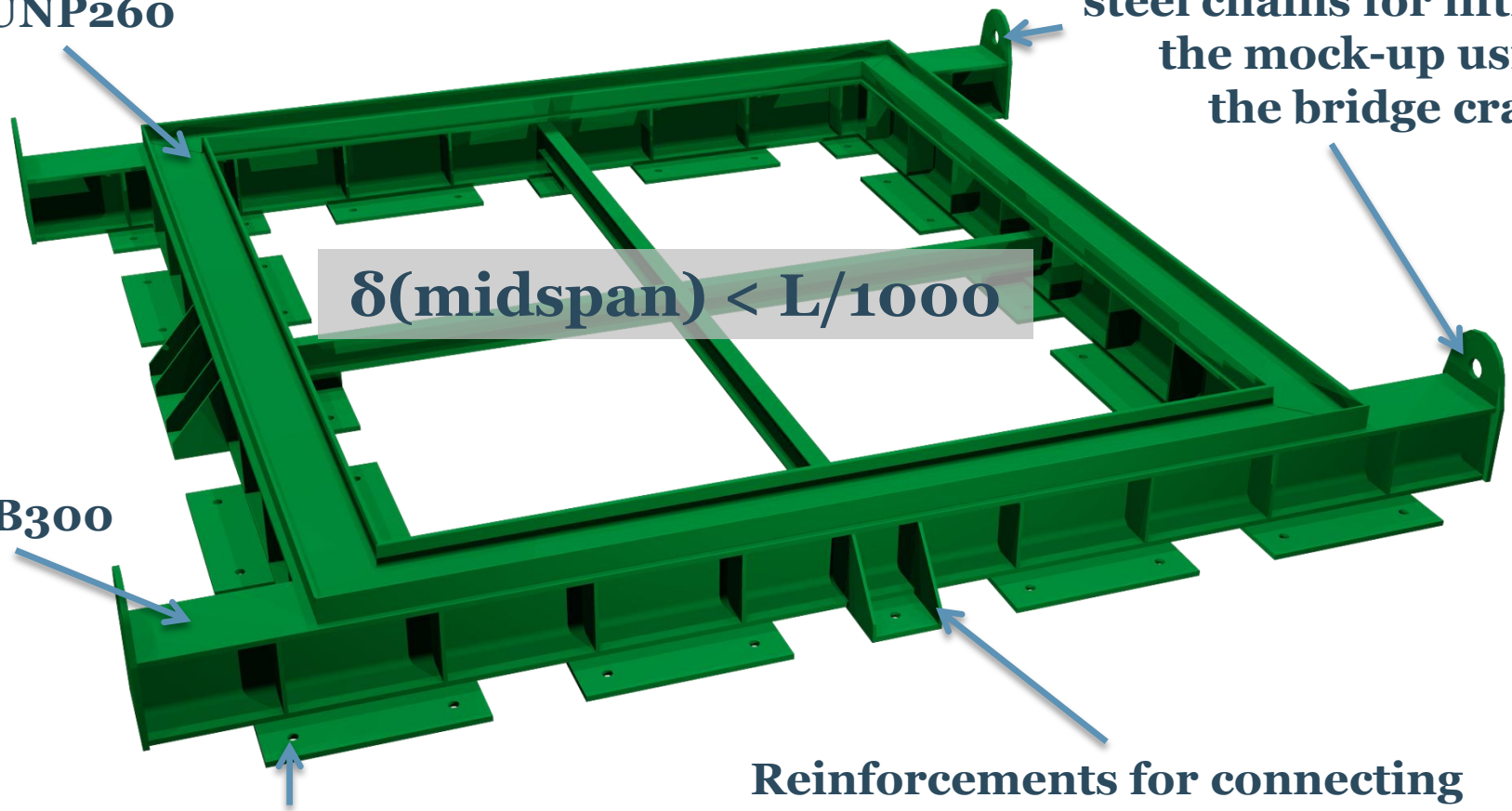


3D shaking table:

- **Max payload: 40 ton (392kN)**
- **Plan dimensions: 4.6m × 5.6m**
- **Displacements actively controlled (3 DOF)**
- **Rotations passively restrained**
- **Frequency range: from 0.1Hz up to 40Hz**

Experimental Campaign

Steel Foundations

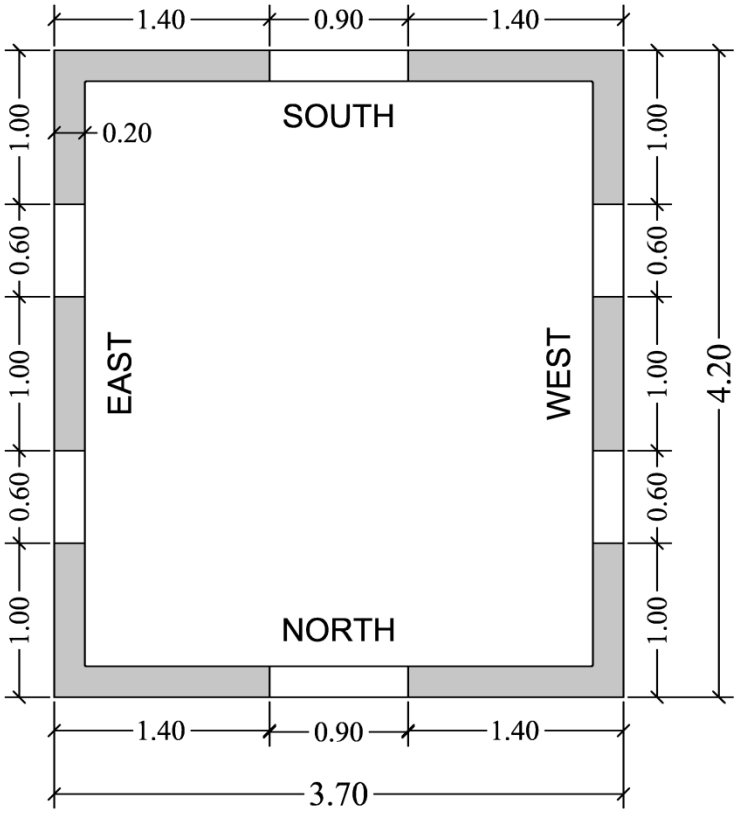


Experimental Campaign
Steel Foundations

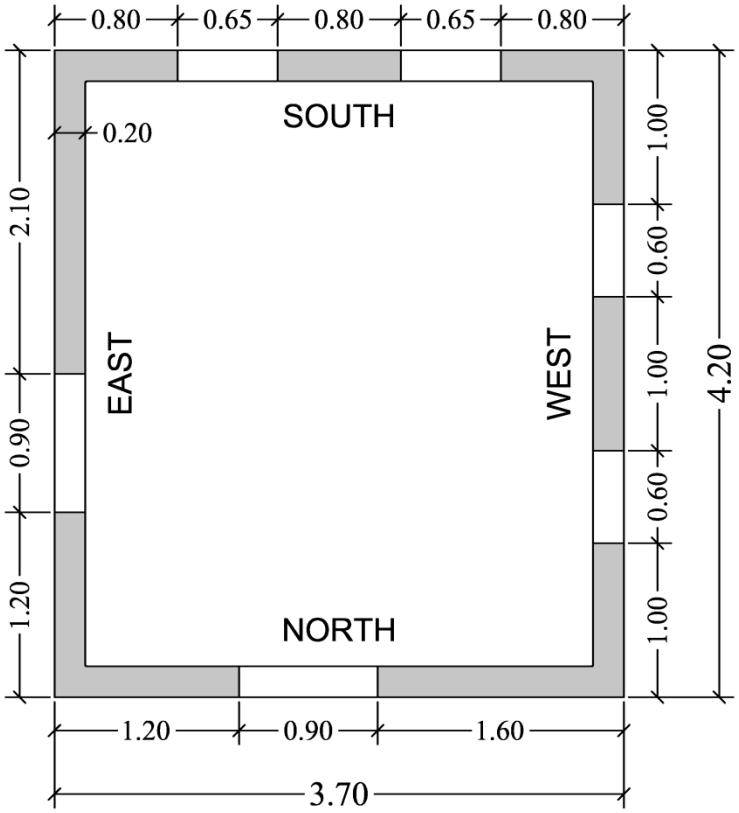
Steel foundation and conventional mortar bed

Experimental Campaign

Mock-ups



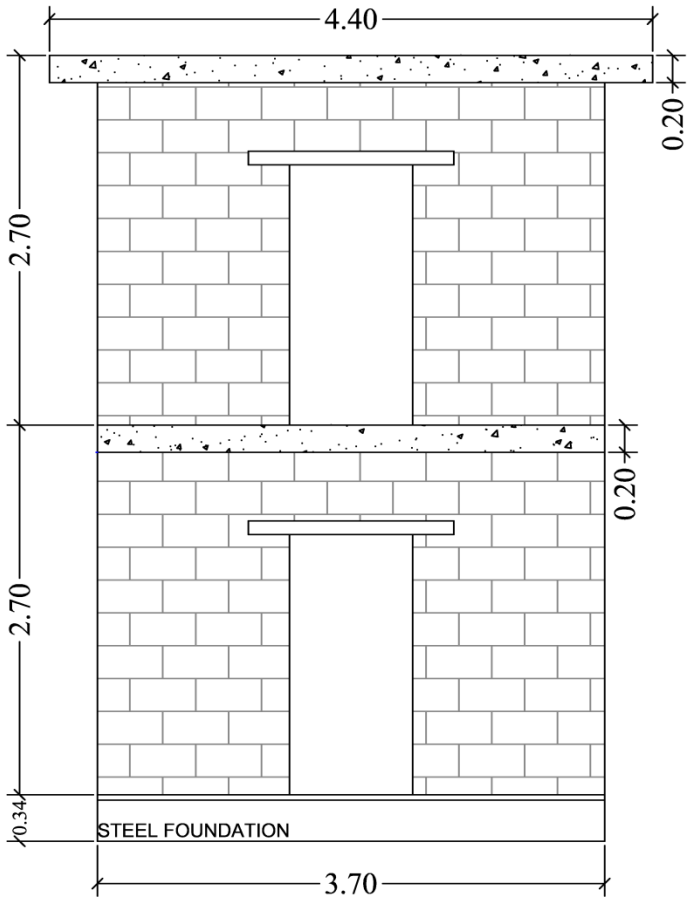
Mock-up A - Symmetric



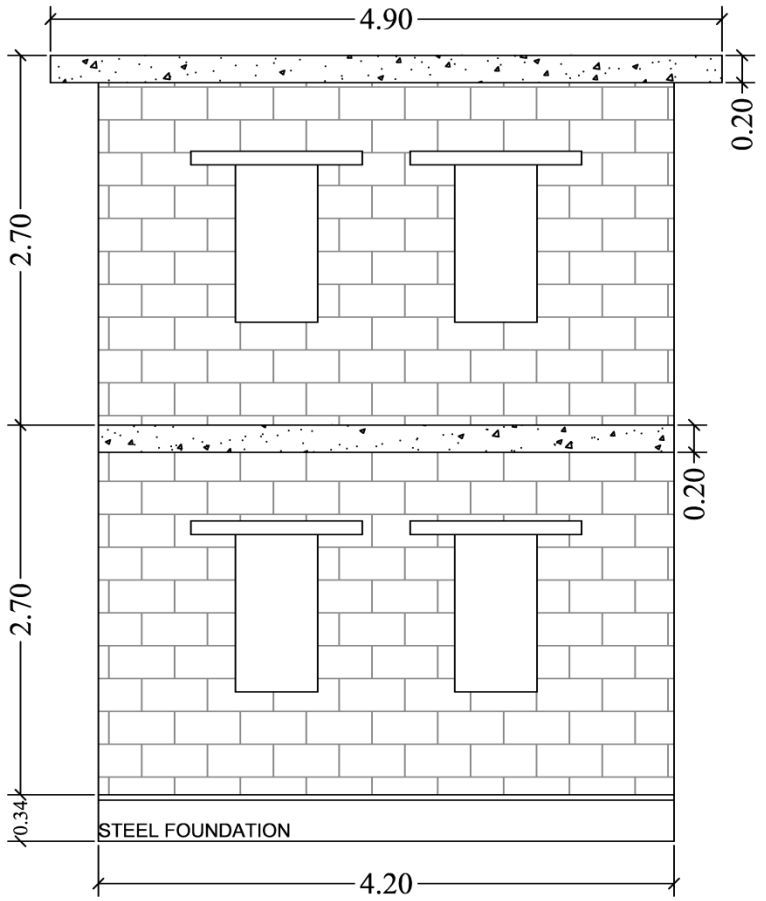
Mock-up B - Asymmetric

Experimental Campaign

Mock-ups



NORTH/SOUTH FAÇADE

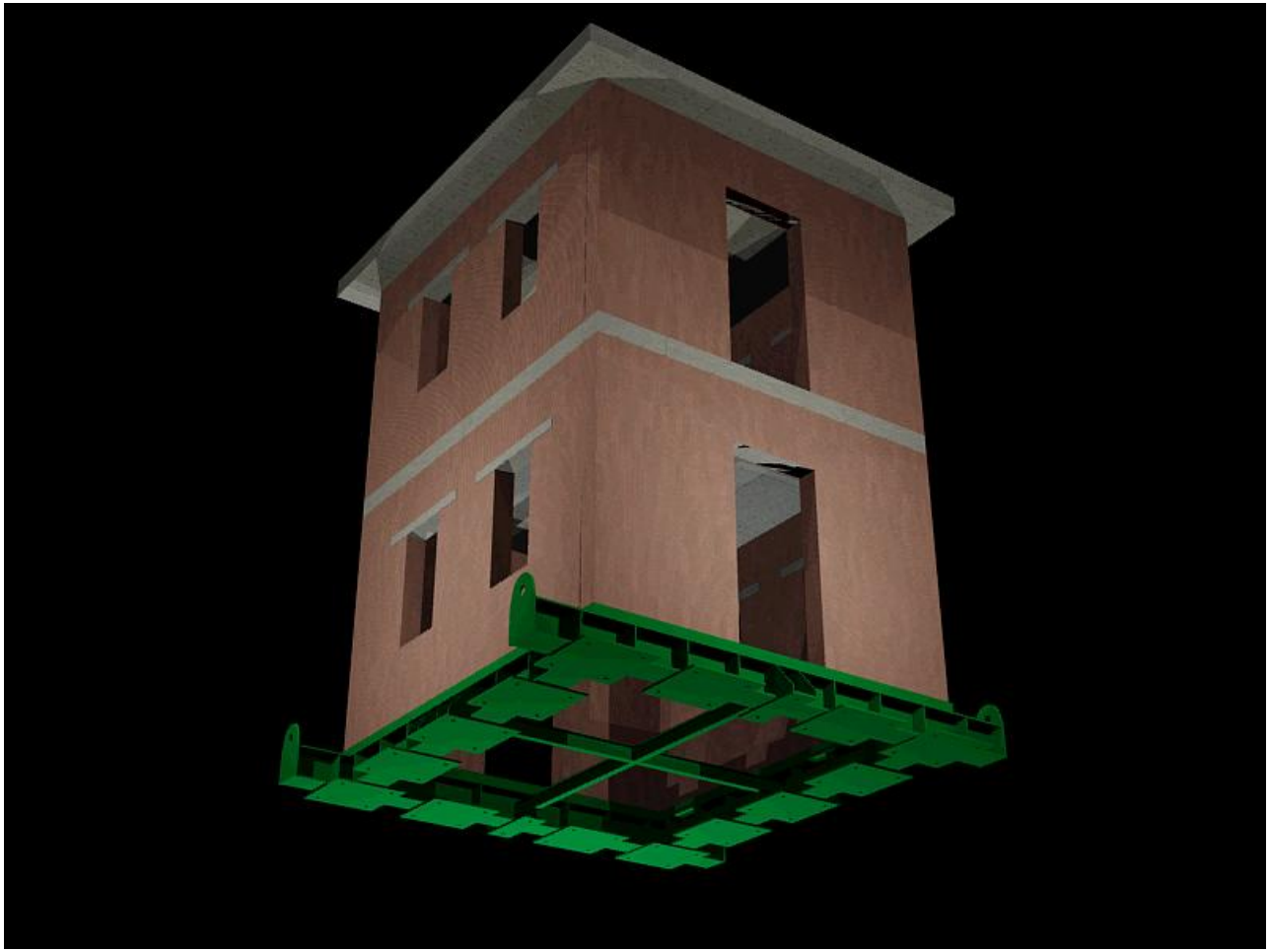


WEST/EAST FAÇADE

Mock-up A - Symmetric

Experimental Campaign

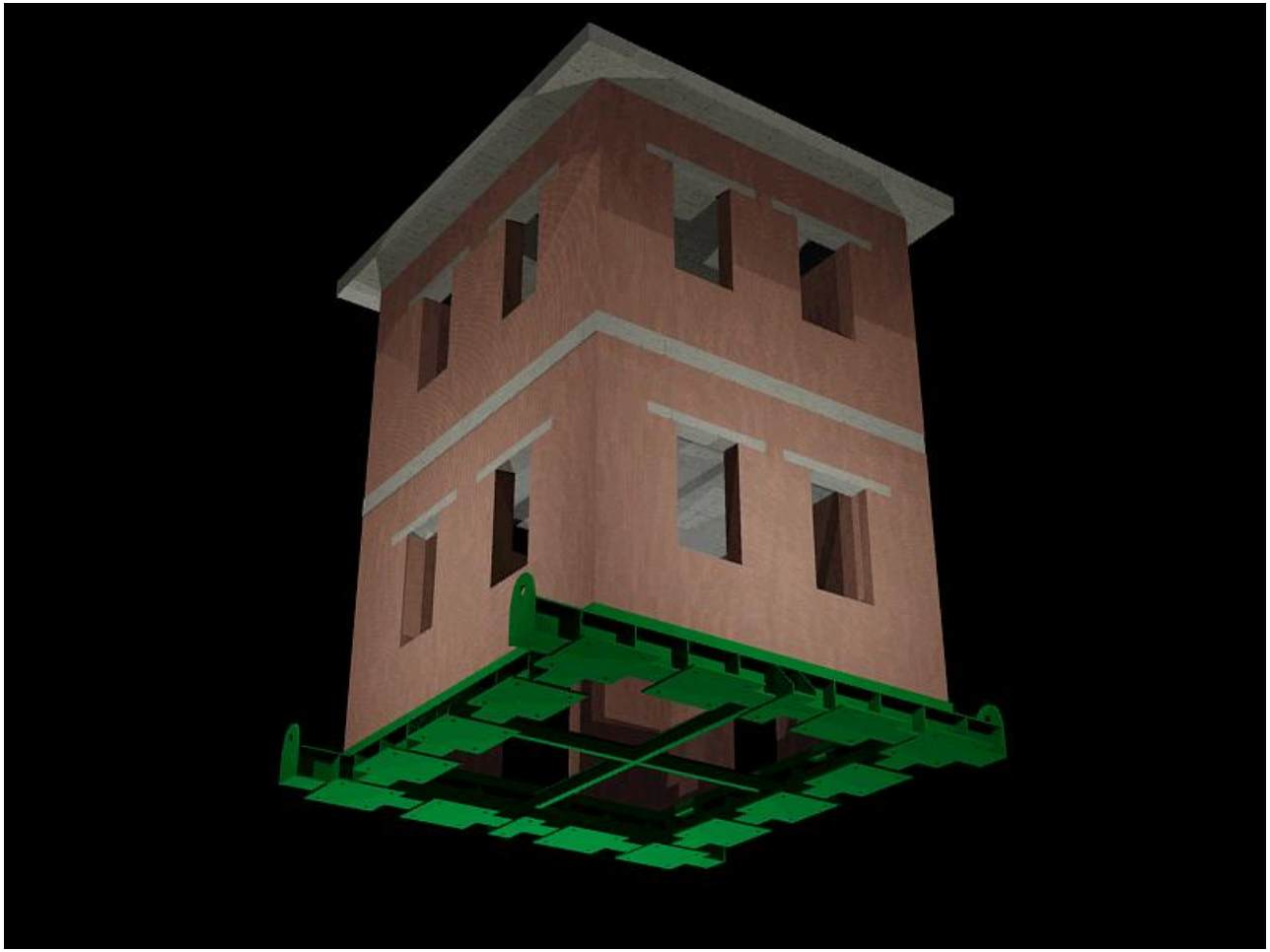
Mock-ups



Mock-up A - Symmetric

Experimental Campaign

Mock-ups



Mock-up B - Asymmetric

Experimental Campaign

Mock-up Construction

Connection between the masonry walls and the RC slabs

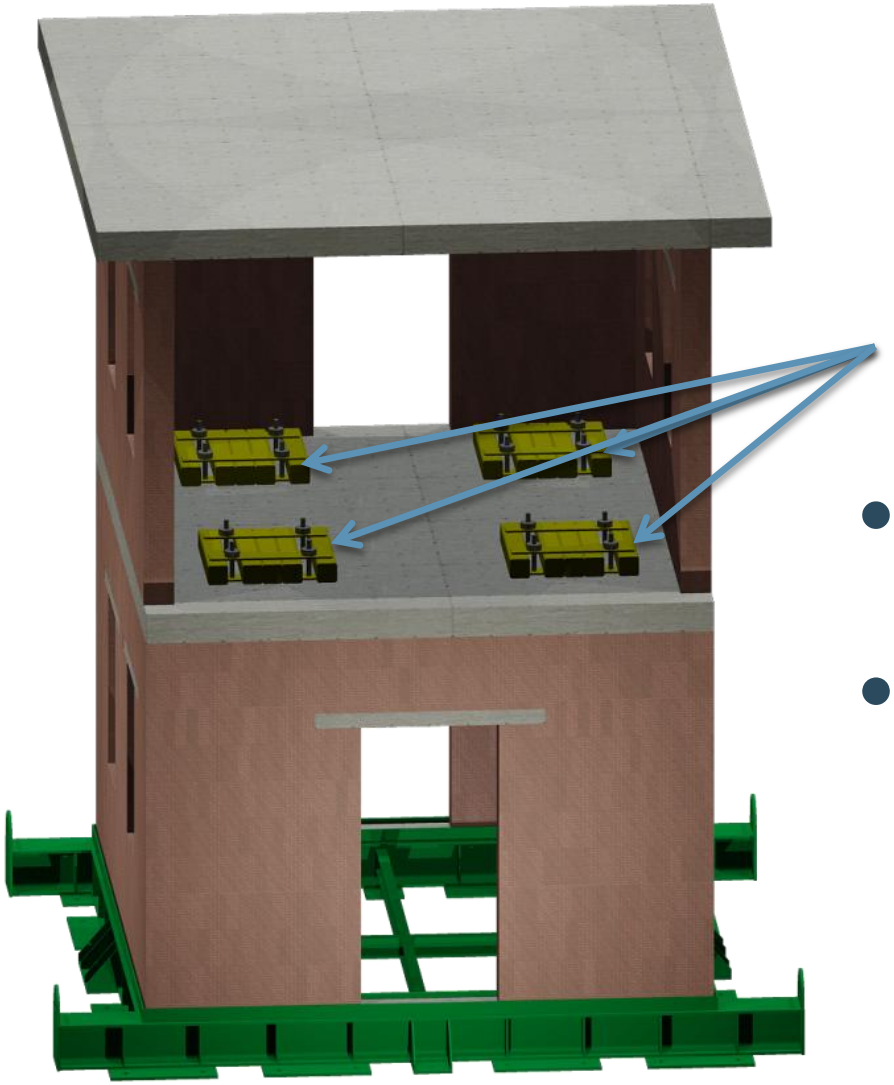
Experimental Campaign

Mock-up Construction

Mock-up construction is completed

Experimental Campaign

Additional Masses

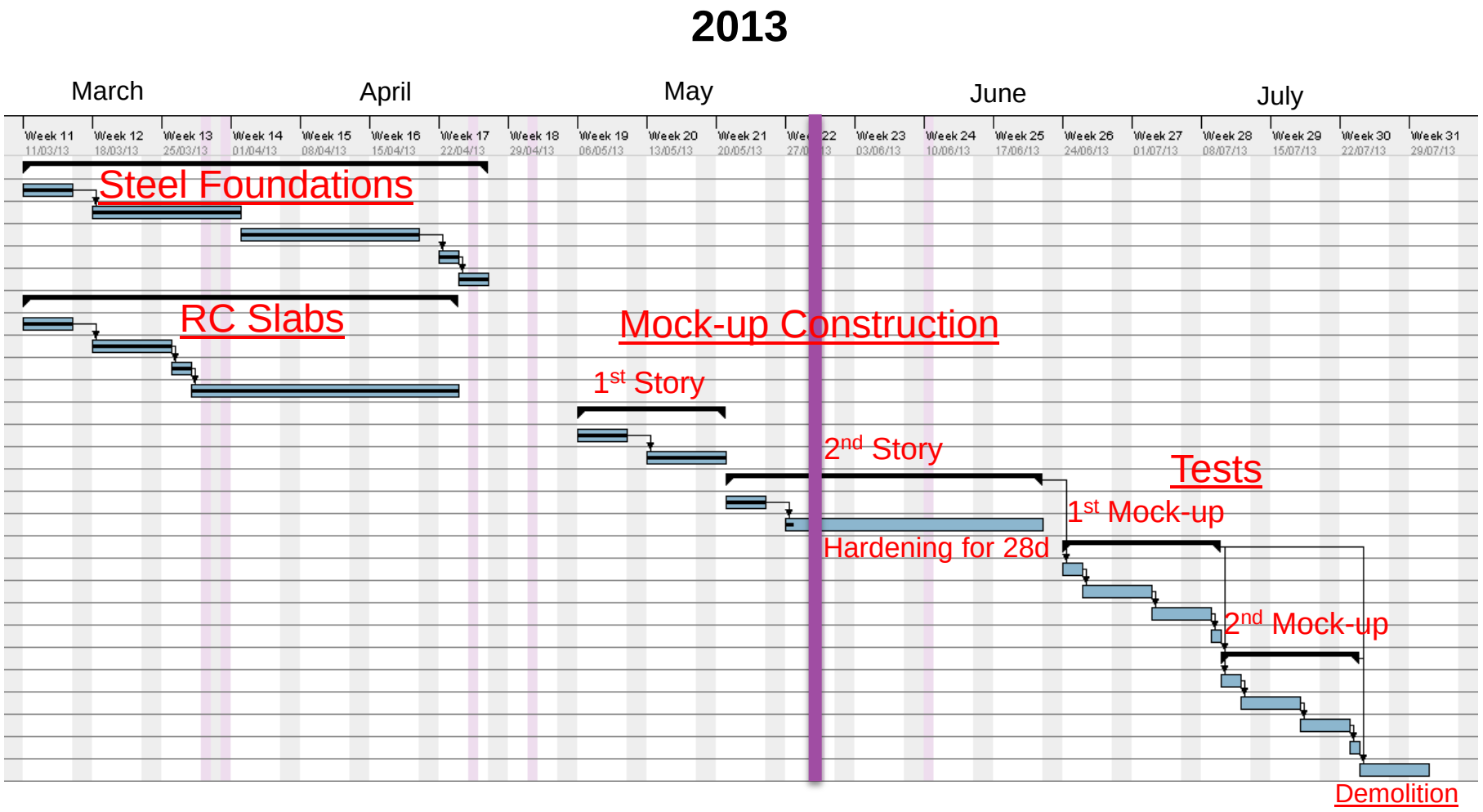


4 masses of 6kN

- For considering a live load of 2kN/m²
- Positioned to have similar inertial properties to the distributed load

Experimental Campaign

Remaining tasks



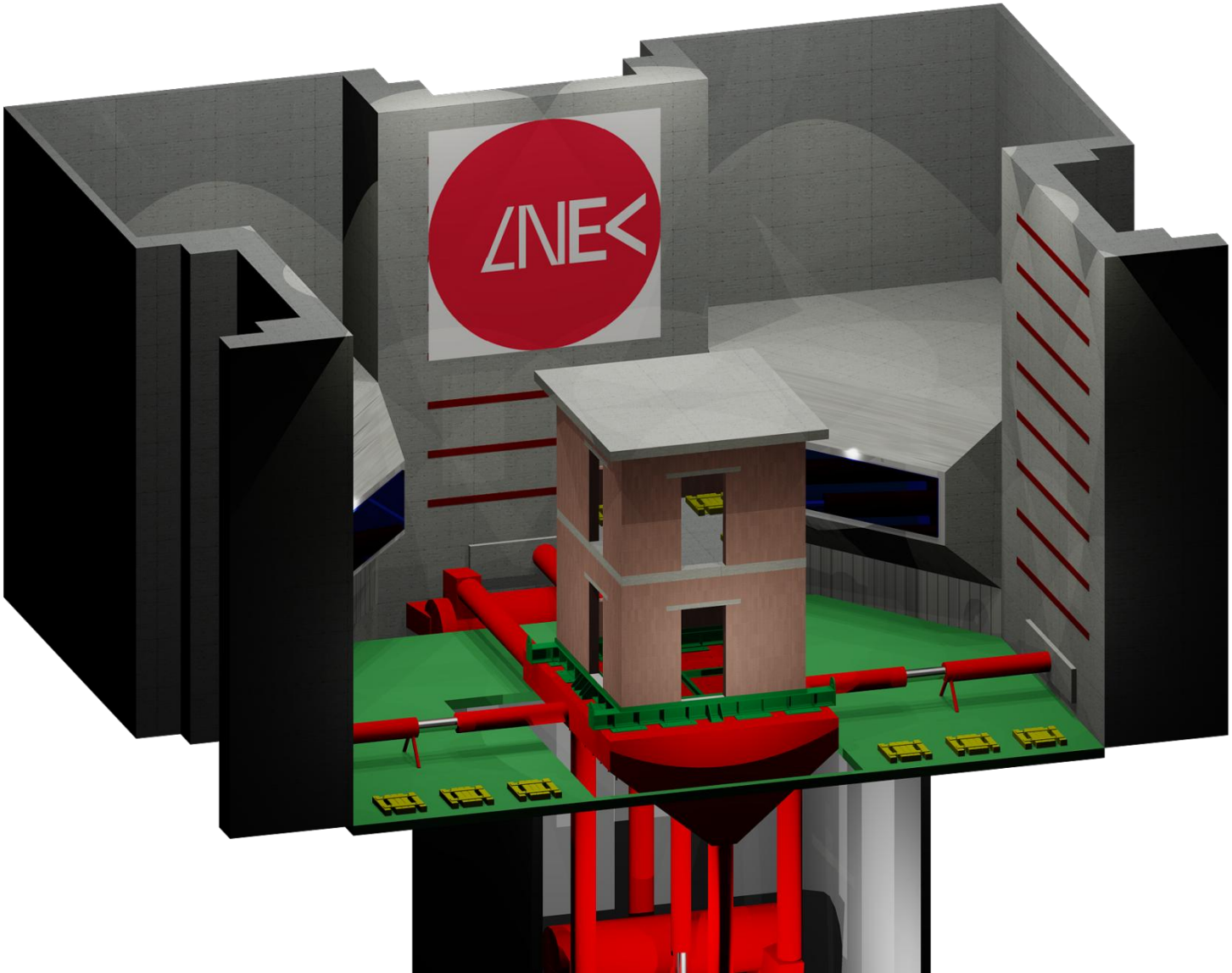
Experimental Campaign

Transportation

Steel ties will be used

- Mitigate mock-up cracking during transportation
- Reduce base deformation and create a favorable compression state
- Load cells will be used to measure the axial force installed in the steel ties

Experimental Campaign



Experimental Campaign

Seismic Input

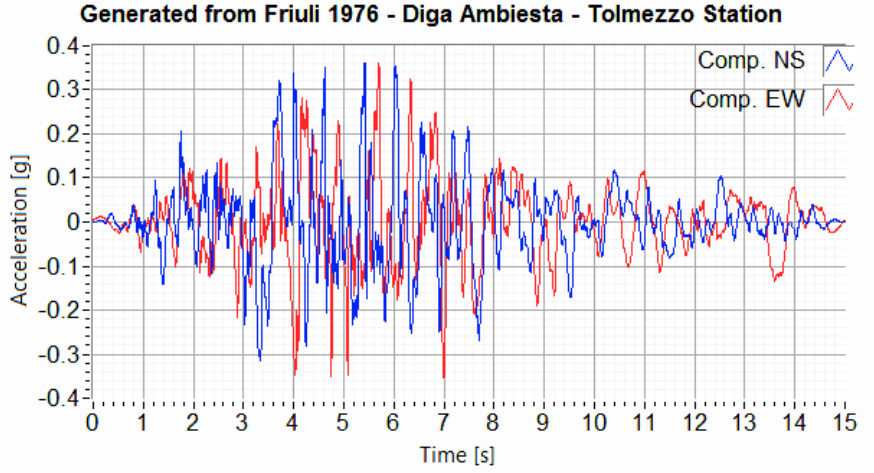
- Reference signal (REF):
  - Semi-artificial earthquake based on a central European record (Friuli 1976 – Tolmezzo Station) and fitted to a EC8 elastic response spectrum
- Test Stages:
  - Target motions will be created from the REF signal
    - LOW – Tuning and verification
    - MED – Service earthquake / short return period earthquake
    - REF – Reference seismic stage / long return period earthquake
    - HIG1 – PGA: REF + 25%

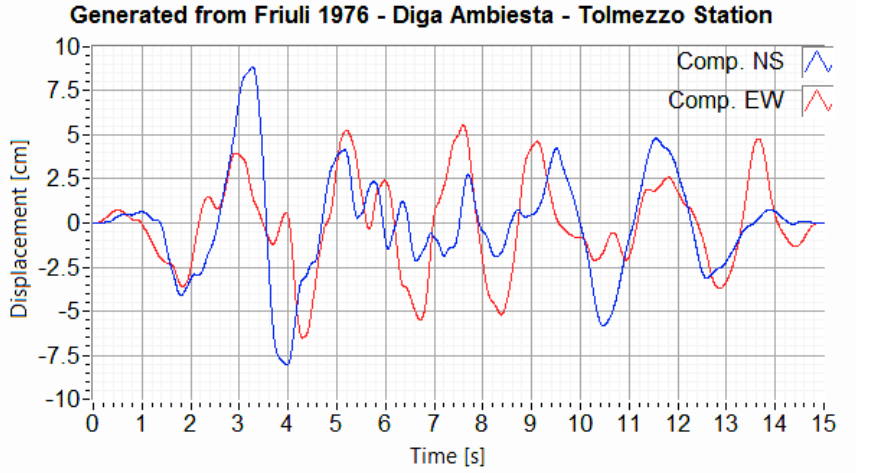
      ….
    - HIGn – PGA: REF + n × 25% (until pre-collapse).

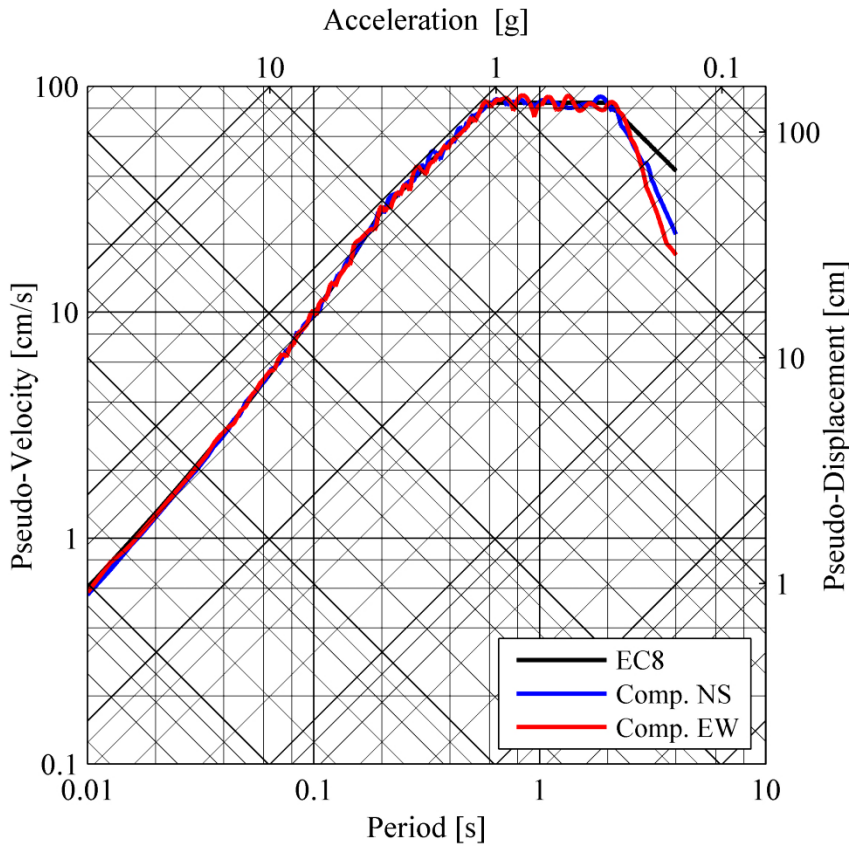
Experimental Campaign

Seismic Input

REF Signal → PGA = 0.36g







Experimental Campaign

Testing Layout

- Before the tests (mock-up on the lab floor)
  - Dynamic characterization using operational modal analysis (ambient excitation)
- During the tests (mock-up on the shake table), each test stage comprises:
  - Dynamic characterization with random excitation
  - Seismic stages

Experimental Campaign

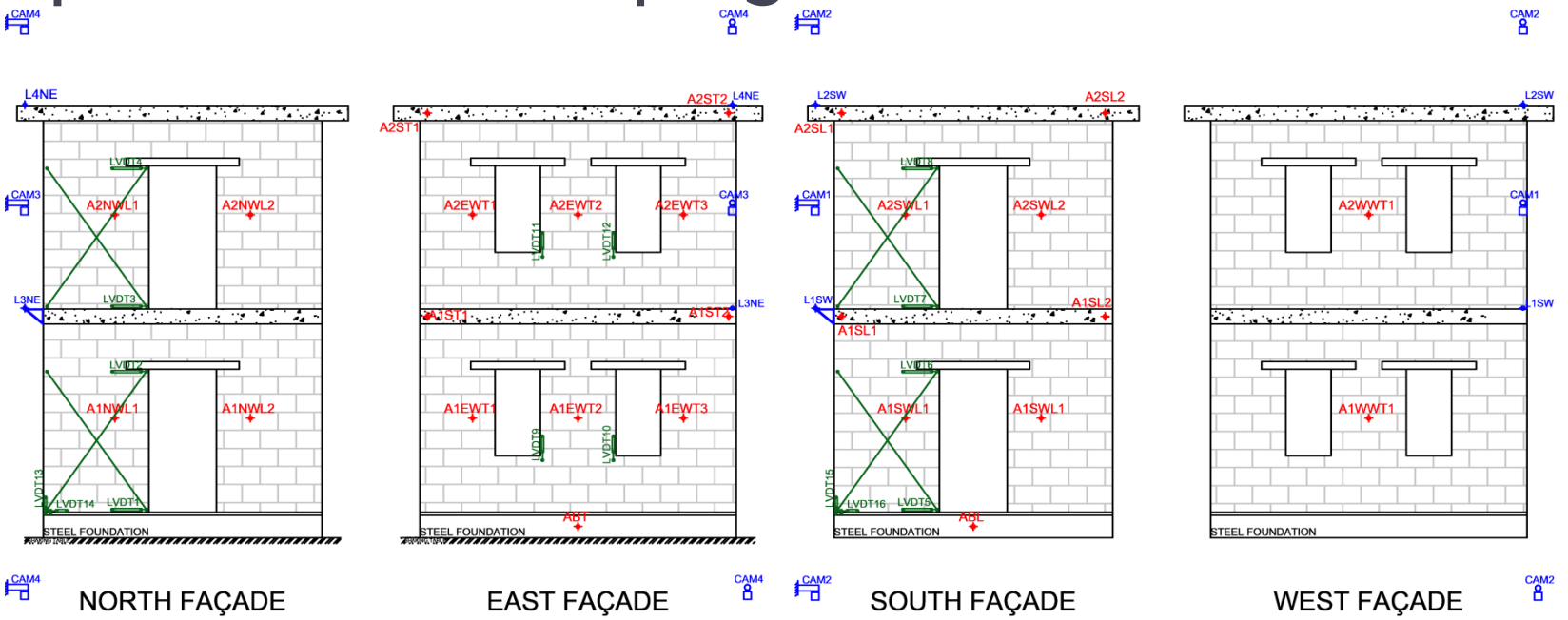
Test Safety

- The mock-ups may develop a sudden and brittle collapse
- For people and equipment safety the following measures will be taken:
  - The RC slabs will be connected to the bridge crane using cables.
  - These cables are to be loose for the expected test displacements and will hold the slabs for larger displacements (*e.g.* collapse or intense sliding of the slabs)

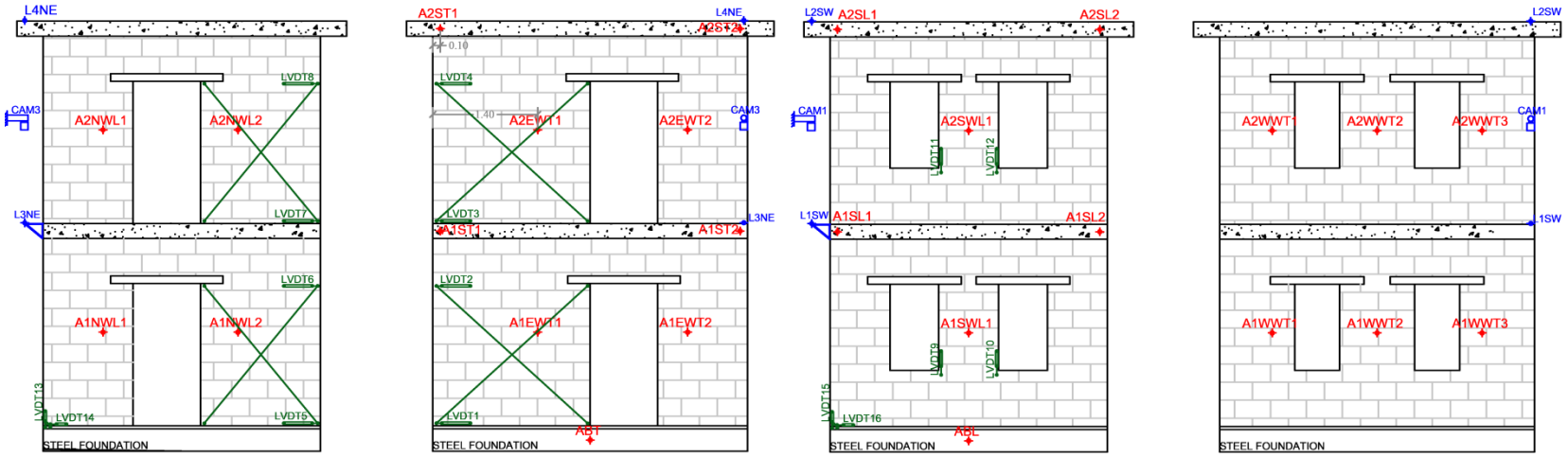
Experimental Campaign

Experimental Campaign - Instrumentation

Mock-up A



Mock-up B



Numerical Simulations

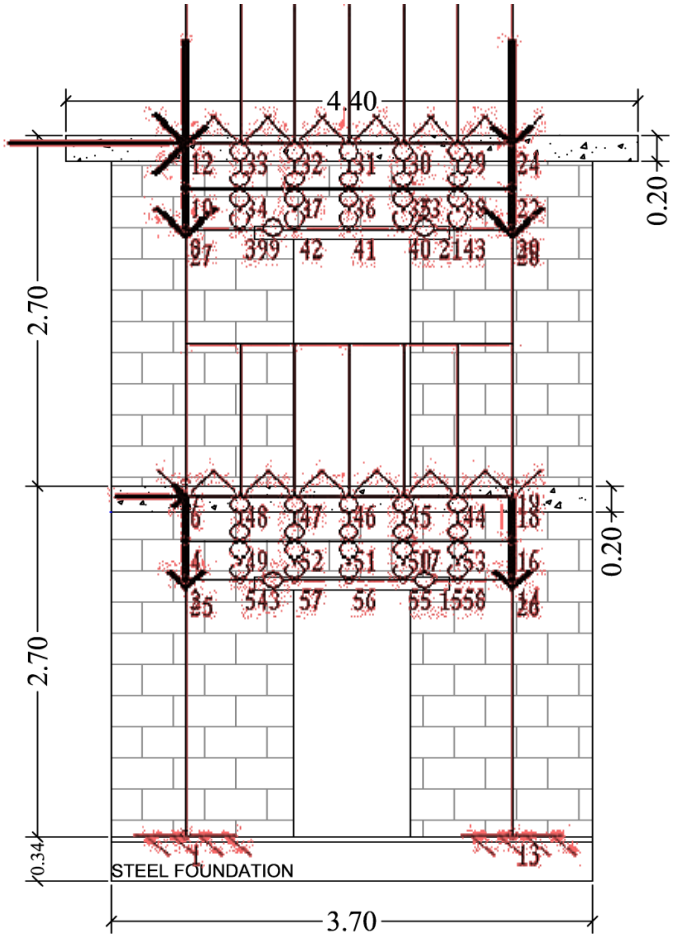
Objectives

- Preliminary assessment of the mock-up response
  - Frequency range
  - Estimation of the maximum sustainable acceleration
  - Expected failure mechanism

  → Equivalent frame model (with EC6 strength verifications) used for
    - modal analysis
    - conventional lateral force method analysis
    - response spectrum analysis
    - pushover analysis

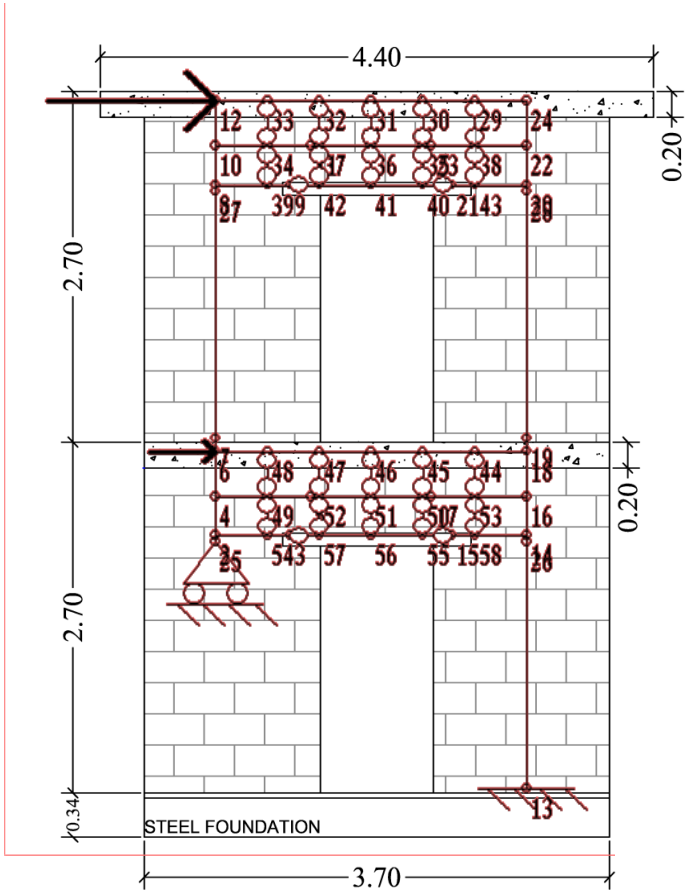
Numerical Simulations

Equivalent frame model



NORTH/SOUTH FAÇADE

Stage 1

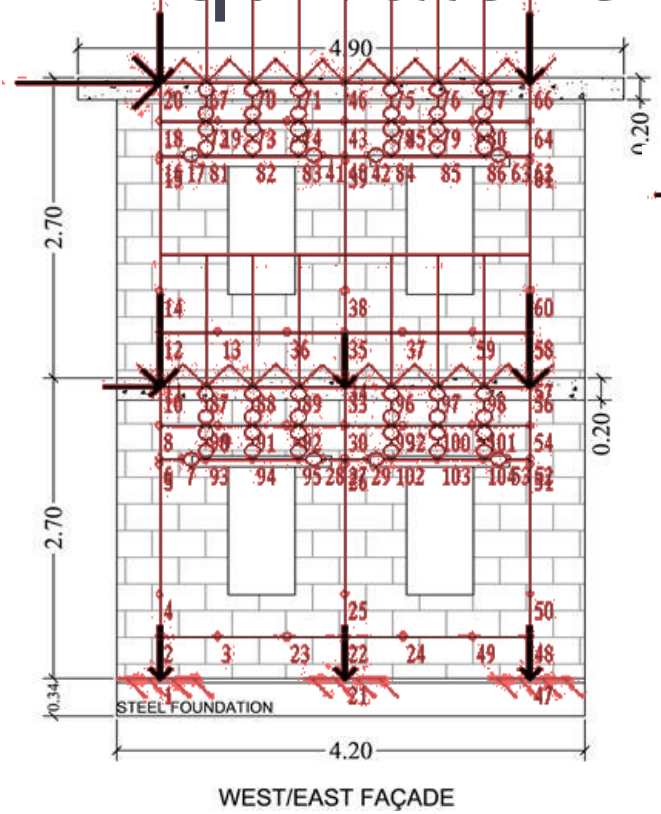


NORTH/SOUTH FAÇADE

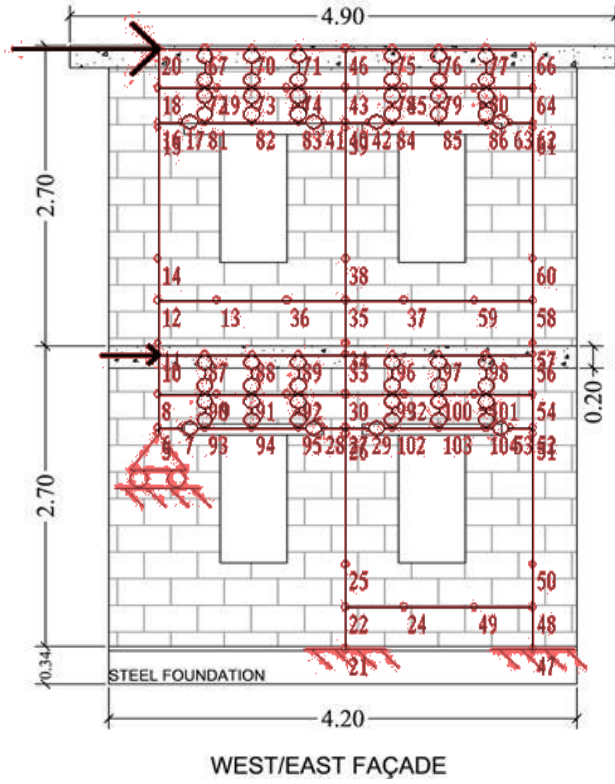
Stage 2 (after failure of wall 1)

Numerical Simulations

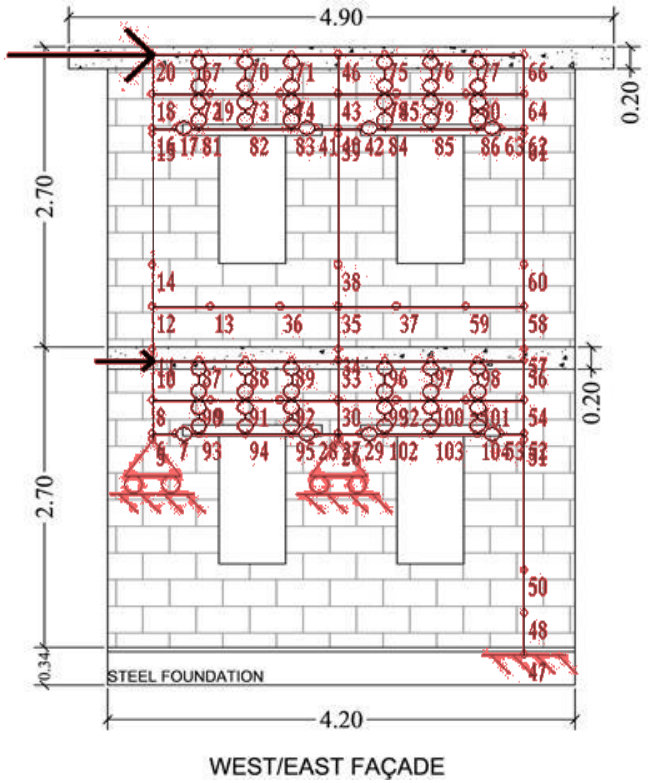
Equivalent frame model



Stage 1



Stage 2
(after failure of wall 1)



Stage 3
(after failure of wall 2)

Numerical Simulations

Remaining tasks

- After the shaking table tests:
  - Re-calibration of the numerical model:
    - Material properties
    - Damage pattern
    - Deformation capacity
    - …
  - Extension of the results to full size buildings
  - Parameter studies in the perspective of the revision of EC8 chapter 9

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