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SEISMIC RETROFITTING OF THE PARLIAMENT BUILDING OF REPUBLIC OF NORTH MACEDONIA - NECESSITY, SOLUTIONS AND CONSTRUCTION

"Seismic assessment and retrofitting of masonry and preserved structures"
Athens, 13 September 2023

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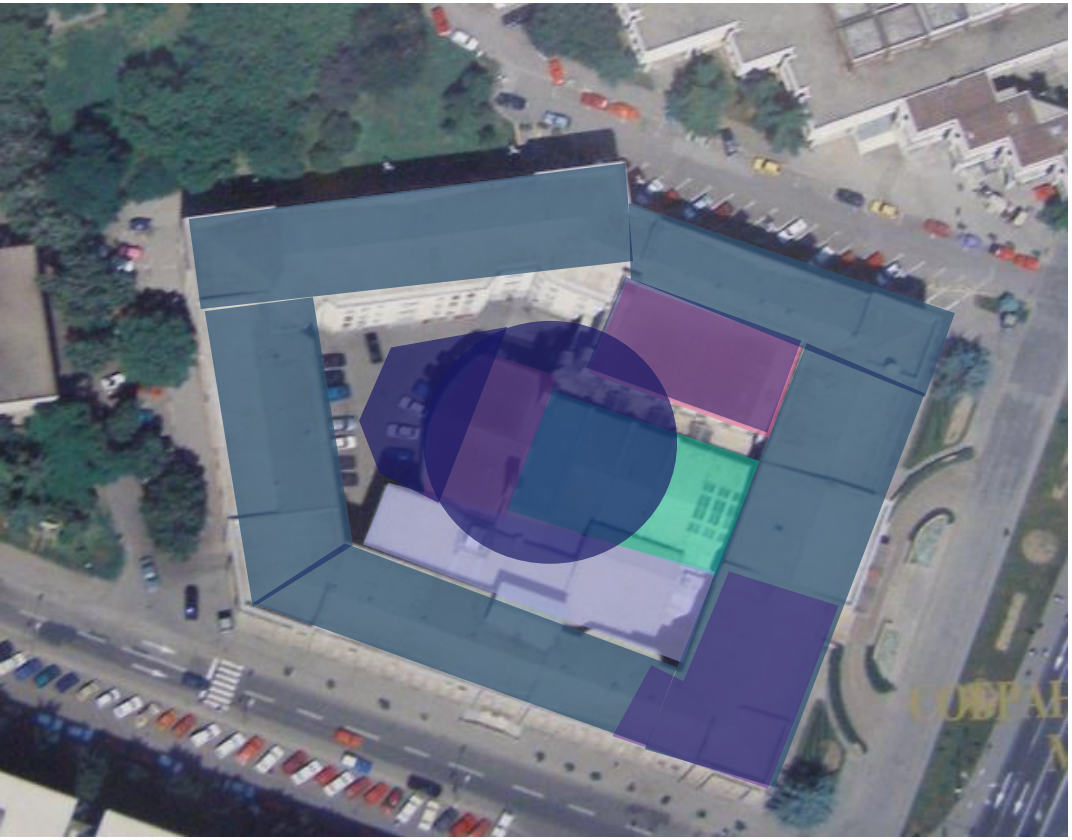
Project for enlargement, building of another storey and adaptation of the Parliament building

- ? definition of possibilities and conditions
- ? estimation of existing stability (complex, specific, responsible task)
- ? strengthening of the main structural system

Knowledge from technical, written and photo documentation



1996 reconstruction – north-east angle
(implementation of RC elements)

2005 Project for enlargement, building of another story over pentagon, adaptation (~3600 m^2)

1936-1939 Original structure-pentagon
(brick masonry walls in both directions)

1936-1939 - Main Hall 1
(reinforced concrete frame structure)

1954 - first enlargement - Hall 2
(reinforced concrete frame structure)

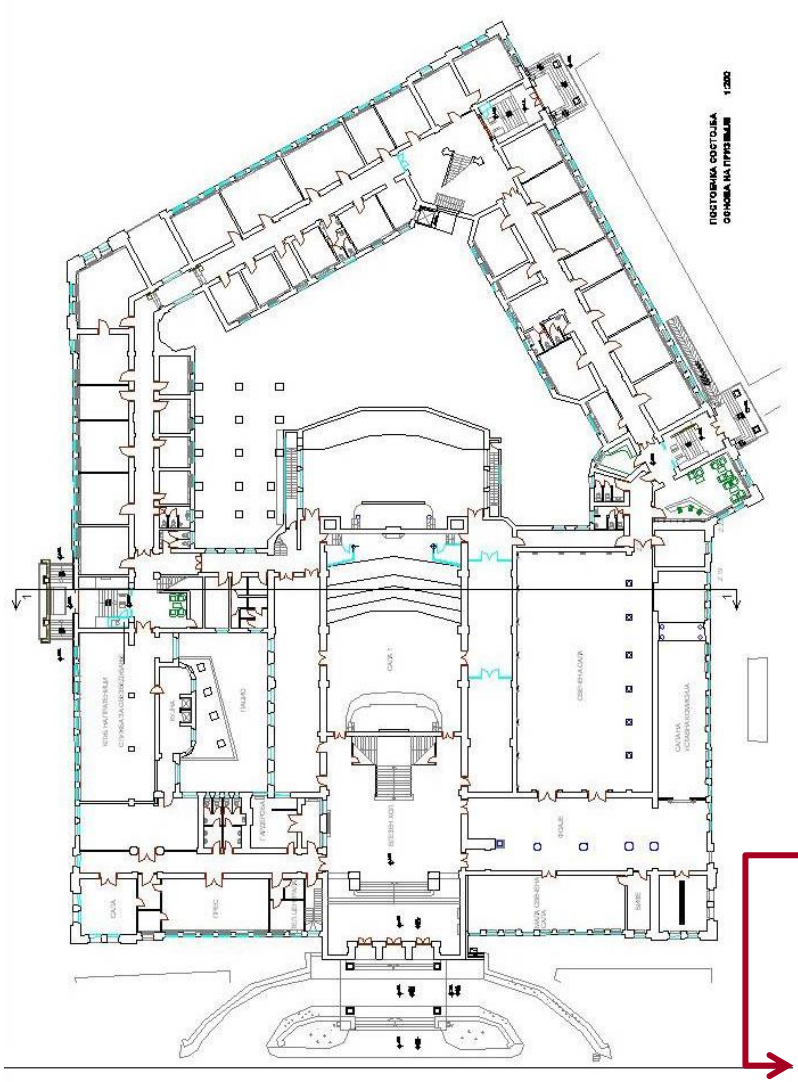
1954 - first adaptation - Crystal Hall
(replacement of existing masonry with RC columns and still beams)

1963 - post earthquake repair
(injection, rebuilding of collapsed part grouting of partition walls, pre-stressing of walls, consolidation of parapets)

1964-1965 – second adaptation - Halls
(strengthening by RC belt courses)

1967 second enlargement – Halls 3,4
(reinforced concrete frame structure)

Knowledge from technical, written and photo documentation



Main structural system of pentagon

- ✓ according to *CONSTRUCTOR -Maribor and ZRMK Ljubljana (1964)*

"…massive brick walls combined with concrete belt courses and columns…."

*"…approximate analysis of repaired building shows that **global safety coefficient is 2,** (for Ks=0.12)…."*

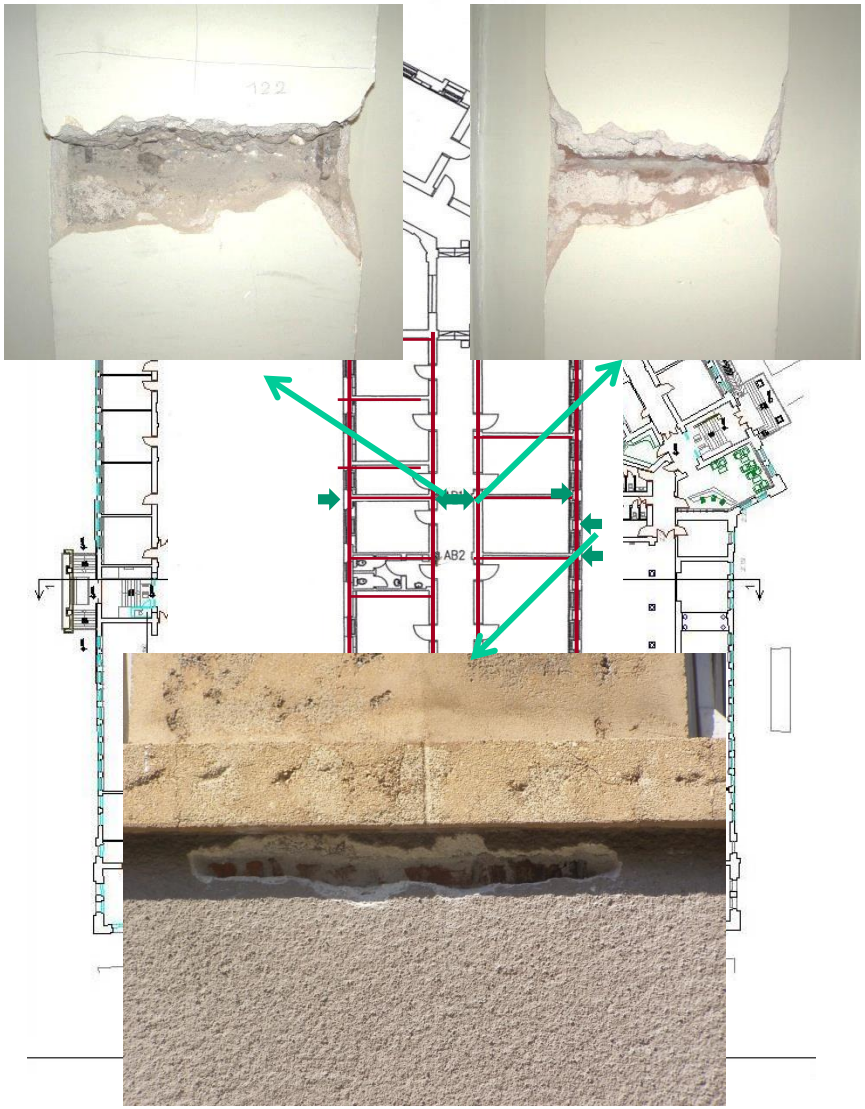
- ✓ according to *Technical conditions for building of another story (1996)*

*"…massive brick walls framed with RC horizontal and vertical belt courses, system known as **confined masonry**…."*

*"…**there is a possibility** for building another story with low live loads, but after additional investigation…."*

Project for enlargement, building of another story & adaptation (2005)

Performed Technical Investigation

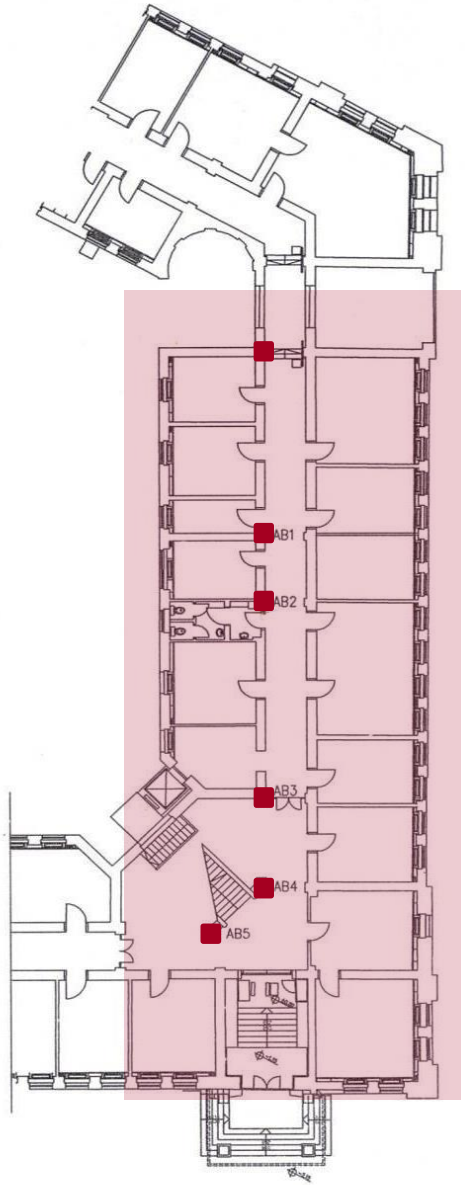


Main reason:

- Precise definition of the main structural system since there is **crucial difference** between **“plain”** and **“confined”** masonry;
- **Identification of RC vertical belt courses** and compare with the code requirements for “confined masonry”;

Methodology:

- Selection of **southwest unit as representative** structural unit;
- **Detail nondestructive testing** of south-west unit using Proceq Profometer 5;
- Confirmation of findings by **minimum number of destructive testing**.



Conclusions for structural system of the pentagon shaped building

- Identified RC vertical elements in selected structural unit

Intensity, placement and quality of built-in materials **are not sufficient** for "confined masonry" according to the requirements in valid technical regulations:

- all corners and intersection of walls
- all free ends of walls with d>19cm
- at max distance of 5m

Global seismic safety:

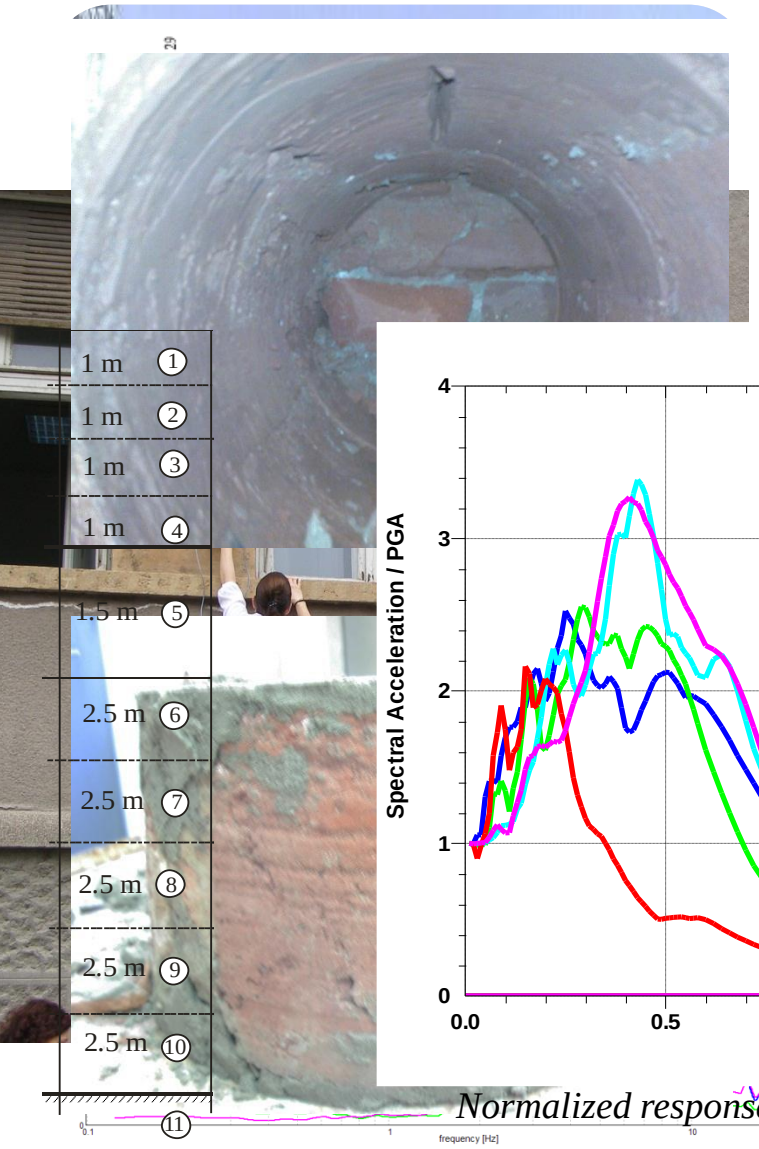
- **~2** according *1965 Code* for **Ks=0.12**
- **less than 1** according *1981 Code* for **Ks=0.30**

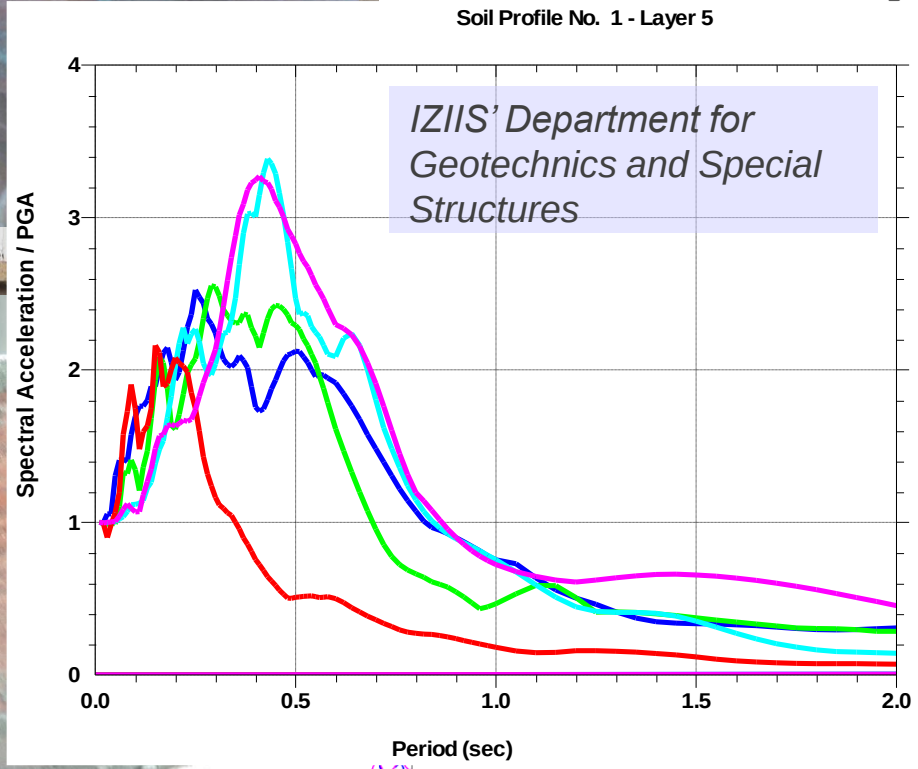
Existing structural system has **unknown** bearing and deformability capacity

Conditions for building of another story:

1. Detail analysis of seismic stability
2. Structural strengthening (allowed number of stories)
3. Dynamic analysis for expected earthquakes (as structure of first category)
4. Additional necessary investigation

Seismic Strengthening of Existing Structure





Normalized response spectra for the level of foundation

Performed additional investigation:

- Definition of geotechnical and geodynamical models of the site;
- Definition of seismic parameters for evaluation of seismic stability of existing structure;

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;

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to its limit

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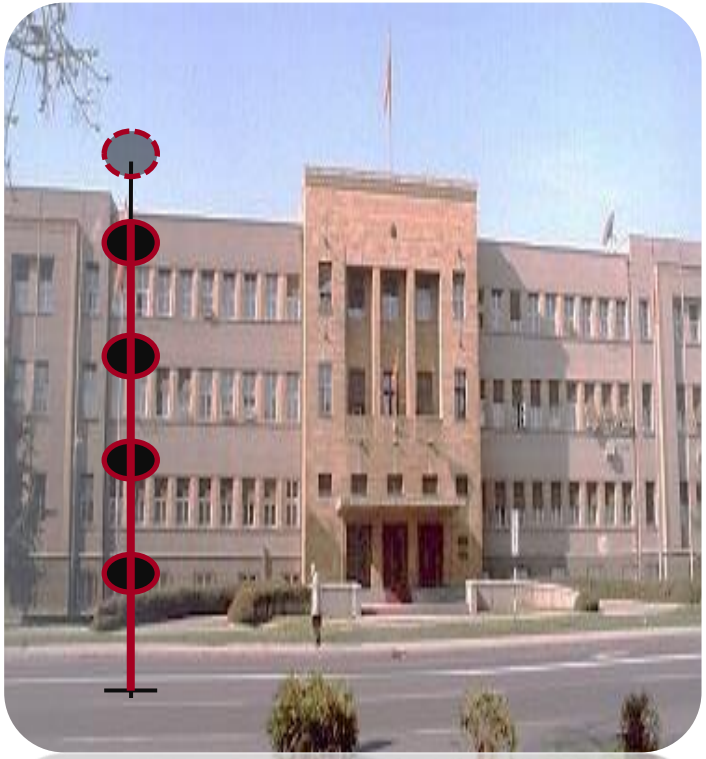
defined

- Analysis of variant solutions from the aspect of stability, economy and possibility for construction

Seismic Strengthening of Existing Structure



1. Existing
2. With additional story
3. Strengthened

Definition of safety criteria:

Level I – elastic behavior, beginning of nonlinearity

$\mu<1.5$, for tp=100 years, $a_{max}=0.27g$

Level II – nonlinear behavior

$1.5<\mu<2.5$, for tp=475 years, $a_{max}=0.38g$

Level III – deep nonlinearity, but non-disturbed stability

$2.5<\mu<3.5$, for tp=950 years, $a_{max}=0.42g$

Bearing and Deformability Capacity:

Bearing Capacity = ultimative story transversal force **Qu**, which compared with the equivalent seismic force gives the safety factor against failure, $F_u=Q_{ul}/S_i$

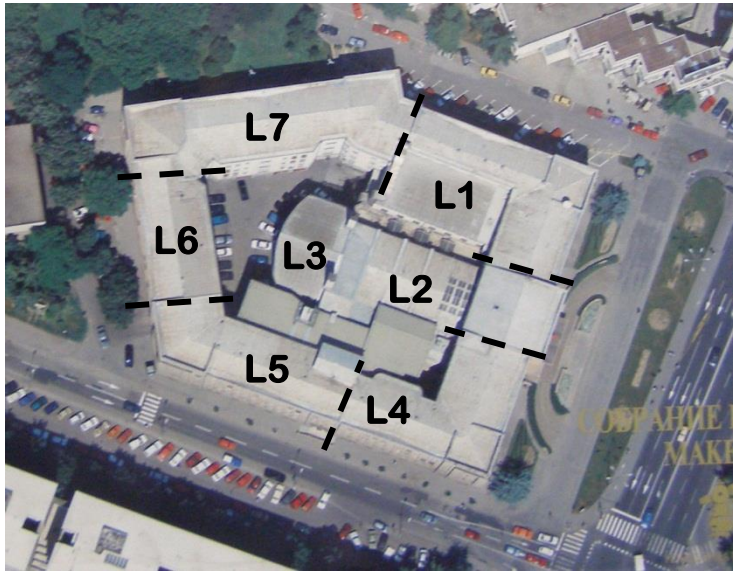
Deformability Capacity = max ductility as relationship between maximal deformation and deformation at yield point, $\mu_{max} = \delta_{max}/\delta_y$

Nonlinear Dynamic Analysis:

Masses - concentrated at floor levels

Hysteretic models - by summing of elasto-plastic characteristics of separate walls

1. Analysis of Existing State



INPUT:

Shear base K = 0.30 (30% G)

Masonry:

E = 800000 kPa;

fc = 1200–2200 kPa; ft = 120–220 kPa;

γ_{brick} = 18.5 kN/m^3

Concrete:

MB 16-23 MPa, GA 240/360

OUTPUT:

Bearing Capacity for L1-L7: 6-18% G, required one - 30%G

Ductility Capacity for L1-L7: 1.4 – 2.1, required one - up to 3.5

The necessity for structural strengthening is analytically approved!

2. Analysis of Existing State with additional story

3 types of modeling: **SW** - separate walls - as merittory
AW - adjoining walls - as control
P - pentagon - without dilatations

Structural Unit	Required bearing capacity (% of weight)	Bearing capacity (% of weight)		Required ductility (maximal)		Ductility capacity (maximal)	
		x-x	y-y	x-x	y-y	x-x	y-y
Existing state – separate walls SW							
L1	30	14.95	14.39	3.72	2.93	2.05	1.42
L2		16.75	22.18	3.58	4.00	2.42	2.30
L4		12.34	10.34	2.90	2.77	1.71	1.92
L5		11.54	12.50	3.33	2.81	1.63	1.72
L6		18.68	7.09	2.21	3.60	1.53	1.97
L7		13.08	13.13	3.10	3.20	1.71	1.65
Existing state with adjoining walls, AW							
L1	30	20.20	16.10	2.10	2.57	1.42	1.56
L2		17.70	27.30	2.53	4.30	2.37	3.60
L4		18.00	15.80	2.10	2.10	1.52	1.92
L5		20.40	13.10	1.75	2.90	1.46	1.48
L6		30.80	6.70	1.77	3.00	1.27	1.24
L7		21.10	17.80	1.99	1.50	1.55	1.47
Existing state without dilatation P							
P	**30**	**17.8**	**17.00**	**2.50**	**2.55**	**1.62**	**1.63**

Technical Solution for Structural Strengthening

based on:

- required additional strength and deformability (demand - existing)
- requirements in technical regulation
- minimum intervention for optimal results

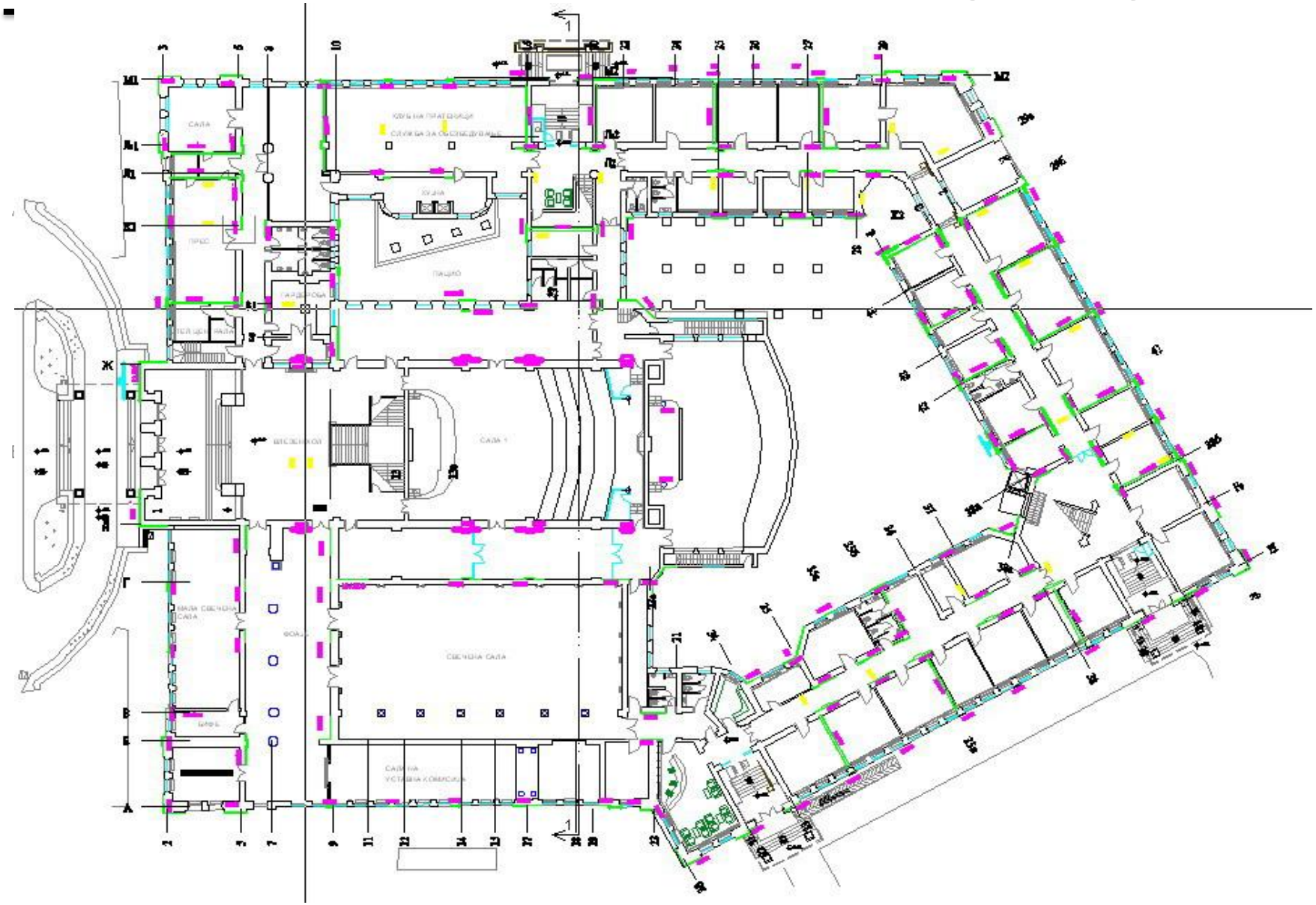
additional limitations:

- requirements as historical building under protection by the Law for cultural heritage
- possibilities for implementation of new RC elements
- avoiding interventions in areas appointed by investor (specific areas, expensive interior with high value or significance…)
- continuous functioning of Parliament during realization of strengthening

concept for strengthening:

- Variant solutions from the aspect of stability, economy and possibility for construction
- Selection of most appropriate solution using classical methods and elements using the same building materials as the existing ones

Technical Solution for Structural Strengthening



3. Analysis of Strengthened State

- modeling: **SW** - separate walls,
- redefined masses
- redefined mechanical characteristics

INPUT:

Shear base K = 0.24 (24% G)

new RC elements:

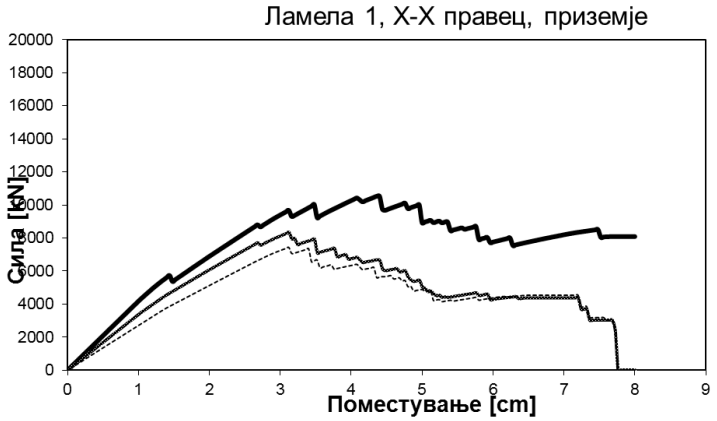
MB 30 MPa, RA 400/500

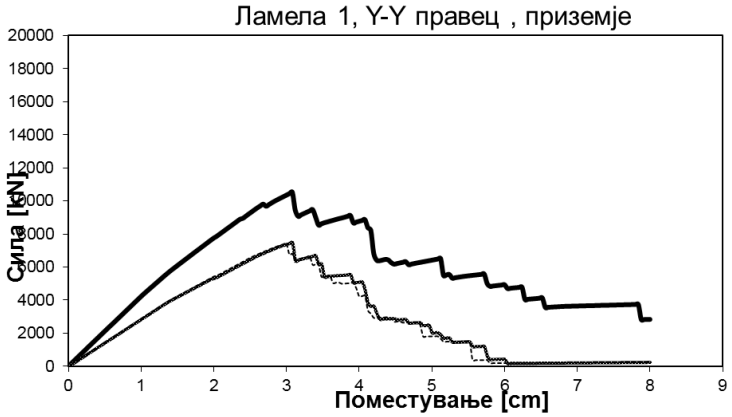
Structural unit	required bearing capacity (% of weight)	Bearing capacity (% of weight)		Required Ductility (max)		Ductility Capacity (max)	
		x-x	y-y	x-x	y-y	x-x	y-y
Separated walls **SW**							
L1	24	24.8	23.7	2.10	2.40	2.80	2.75
L2		27.8	24.0	1.60	3.70	3.09	4.82
L4		22.1	21.9	2.30	2.10	2.54	2.22
L5		23.1	23.7	1.80	2.20	2.74	2.75
L6		31.2	34.0	1.60	1.10	1.95	2.33
L7		24.5	23.2	2.00	2.60	2.23	2.71

Effectiveness of Strengthened State

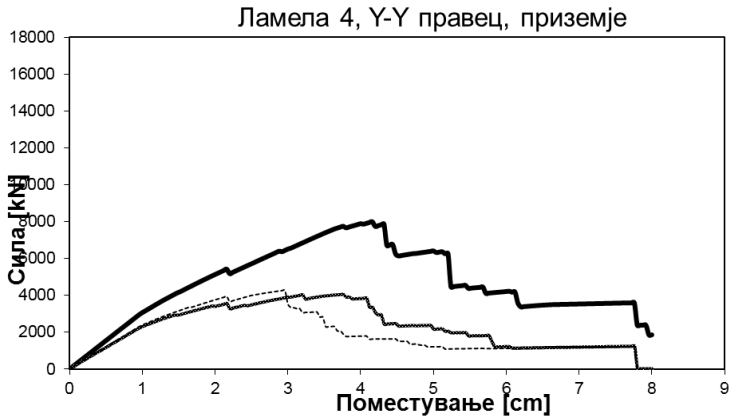
- Comparison of **story diagrams** strength – deformability
- Comparison of **energy dissipation capacity**

--- existing, —— another story, —— strengthened





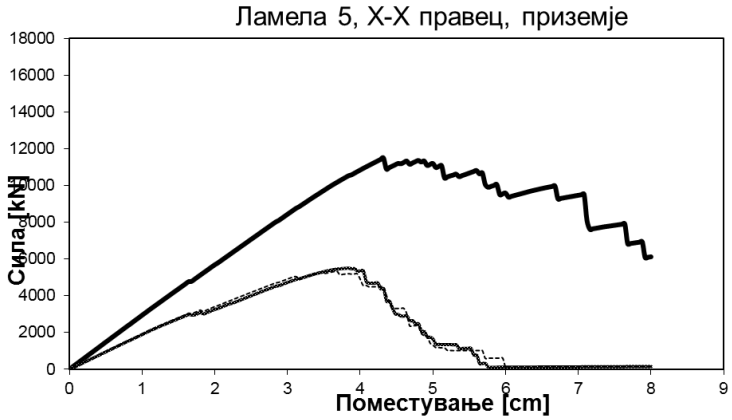
L1

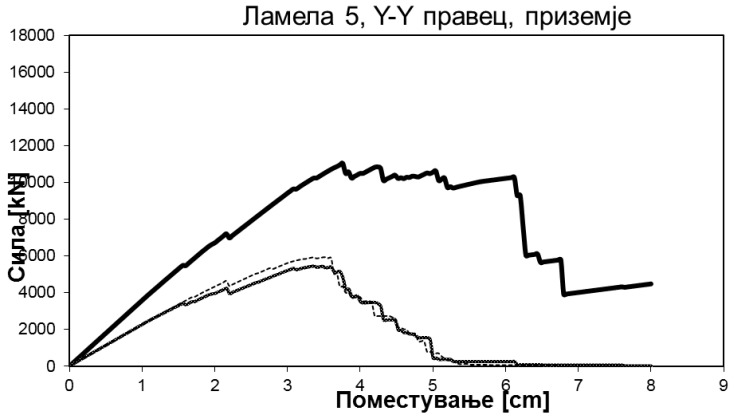


L2

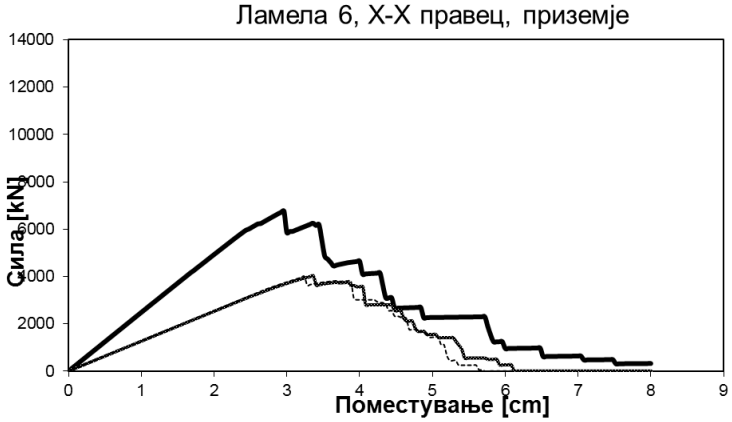
Effectiveness of Strengthened State

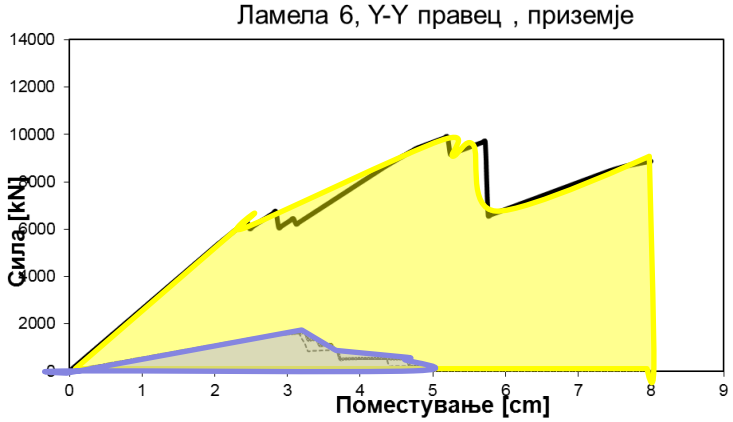
existing, another story, strengthened





L5

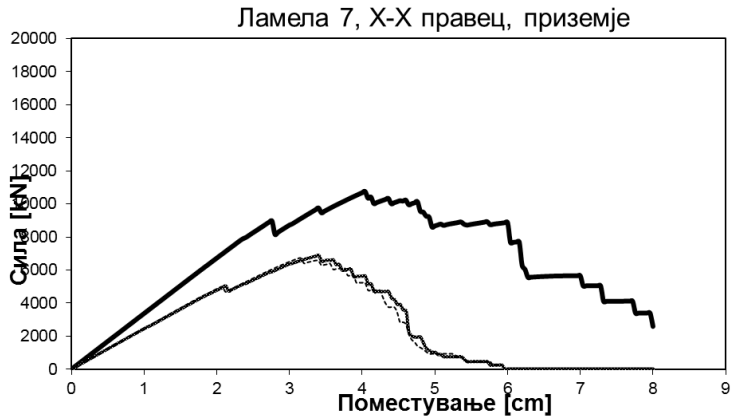


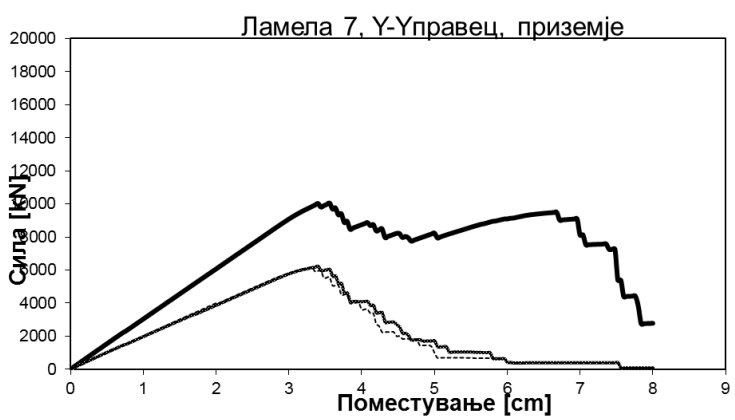


L6

Effectiveness of Strengthened State

existing, another story, strengthened

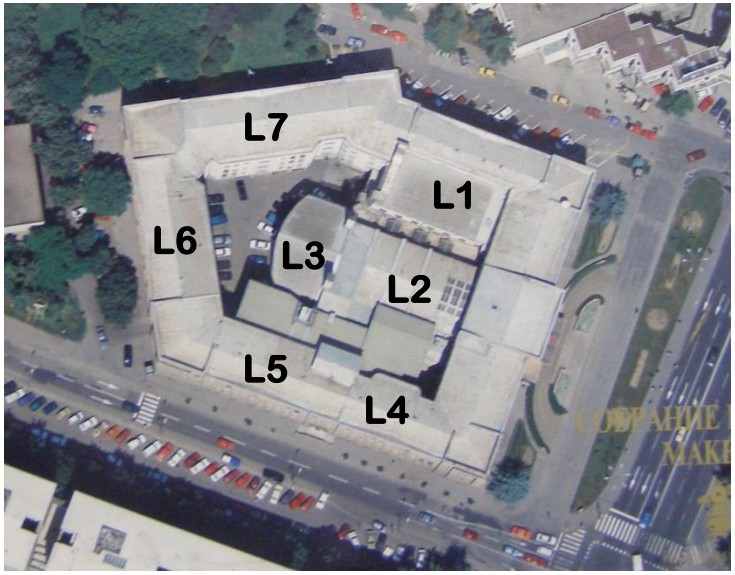




L7

- ✓ **Optimization** of strength, bearing and deformability capacity
- ✓ **Improved structural stability** for expected seismic effects

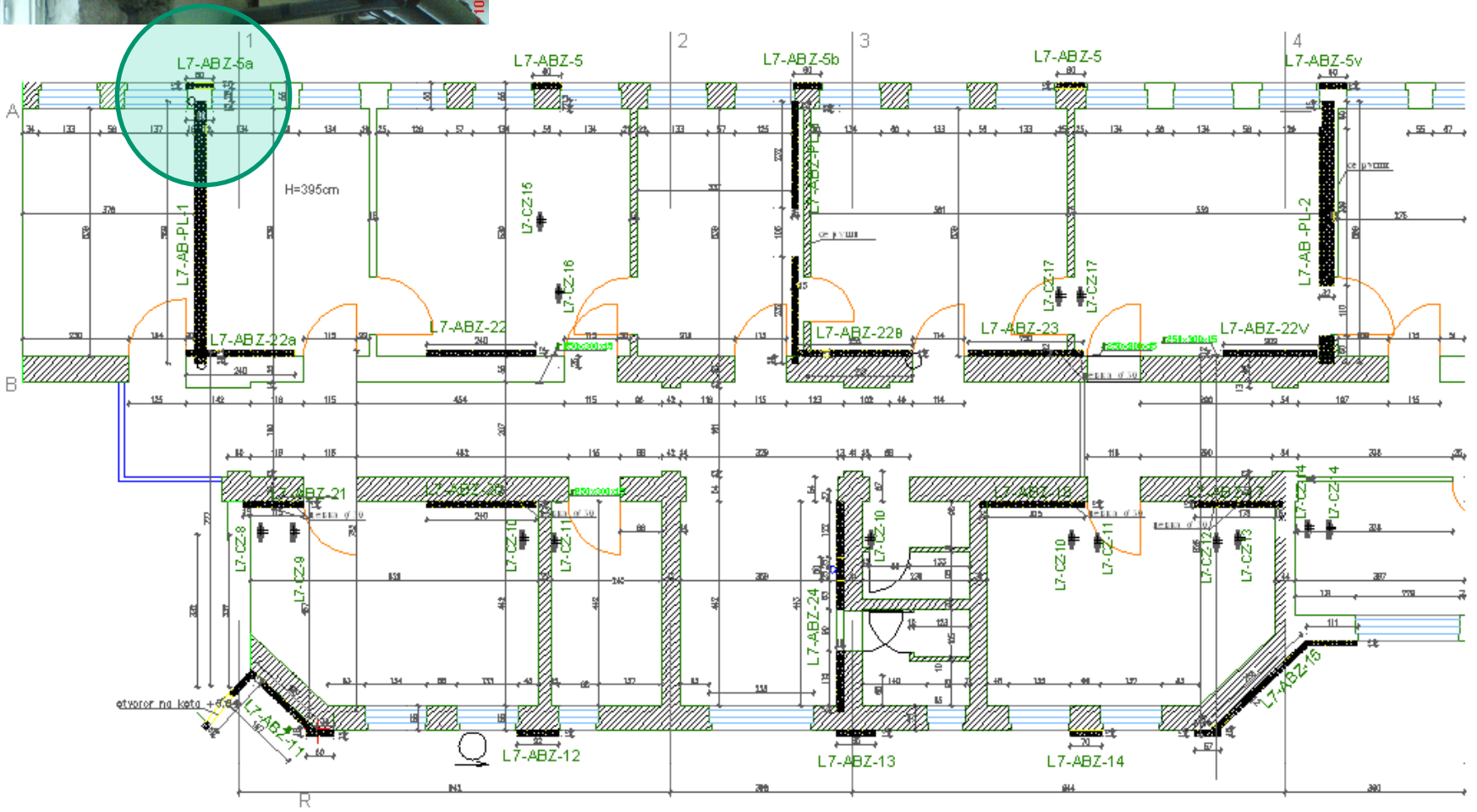
Realization of the strengthening process



- **Starts in April 2010 with L7**
- Continuous functioning of the Parliament
- Continuous supervising by IZIIS' team that encompass:
  - Detailed inspection of the geometry of individual units
  - Direction of activities and prescribing of order, regime and technology of incorporation of strengthening;
  - Elaboration of variant solutions for modification of individual elements due to newly created and limiting conditions of performance of the works on field;
  - Definition of final solutions based on control computations and engineering knowledge harmonized with the possibilities of the contractor and the conditions for performance of the works;
  - Definition of technical solution for strengthening of new positions that arose from the necessity for structural interventions (L3, L1) after the beginning of the works

- **L1, L2, L3, L7 , part of L6 finished until September 2011**

Realization of the strengthening process



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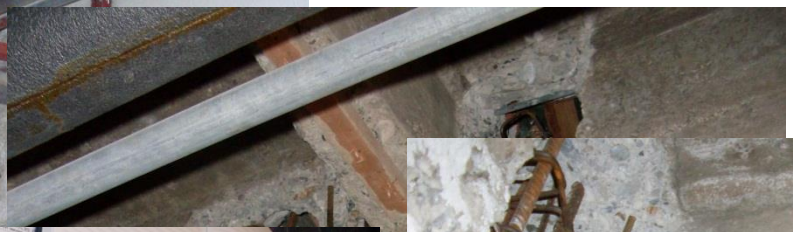

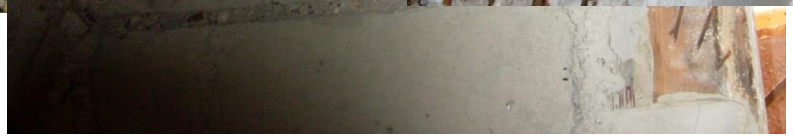

Realization of the strengthening process

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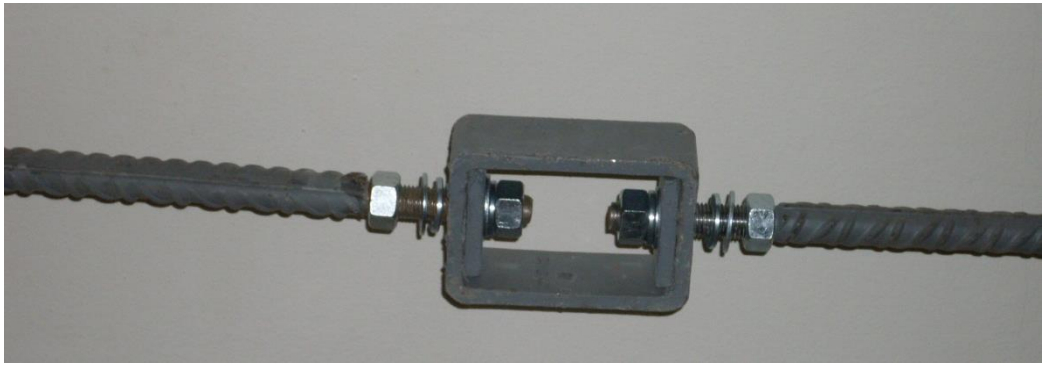
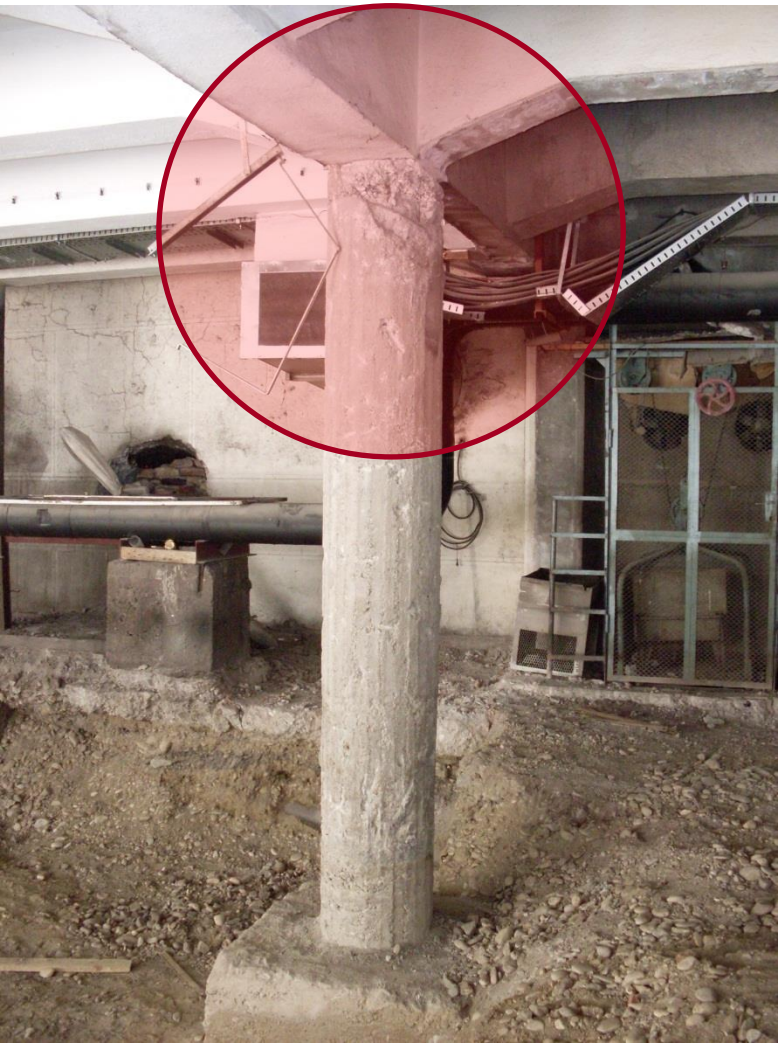


Realization of the



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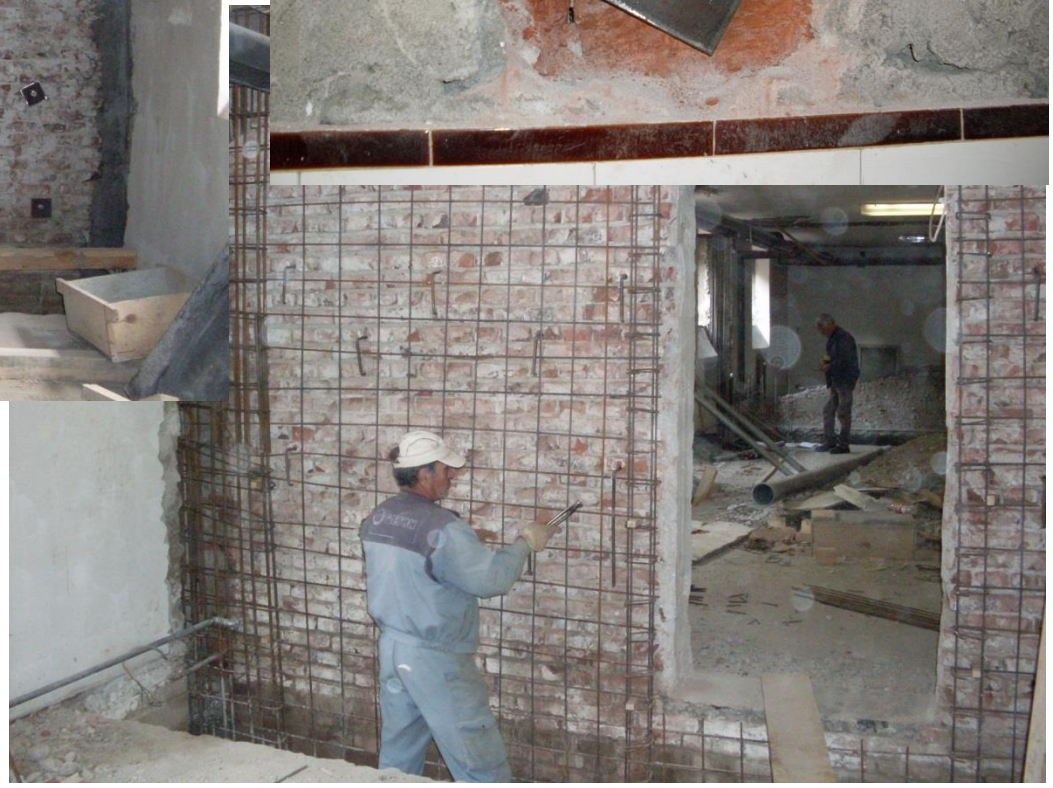
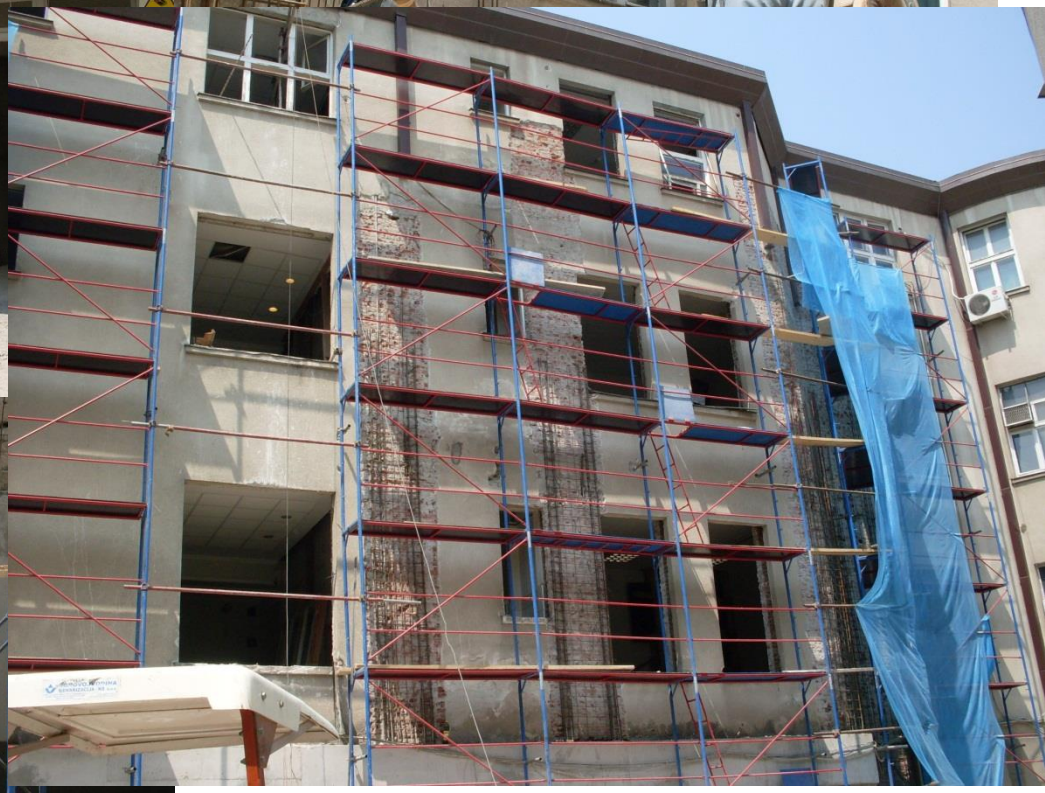


Realization of the strengthening process



North Macedonia Parliament (2014)

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THANK YOU

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