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ANALYSIS OF SEISMIC RESPONSE OF AN RC FRAME STRUCTURE WITH LEAD RUBBER BEARINGS

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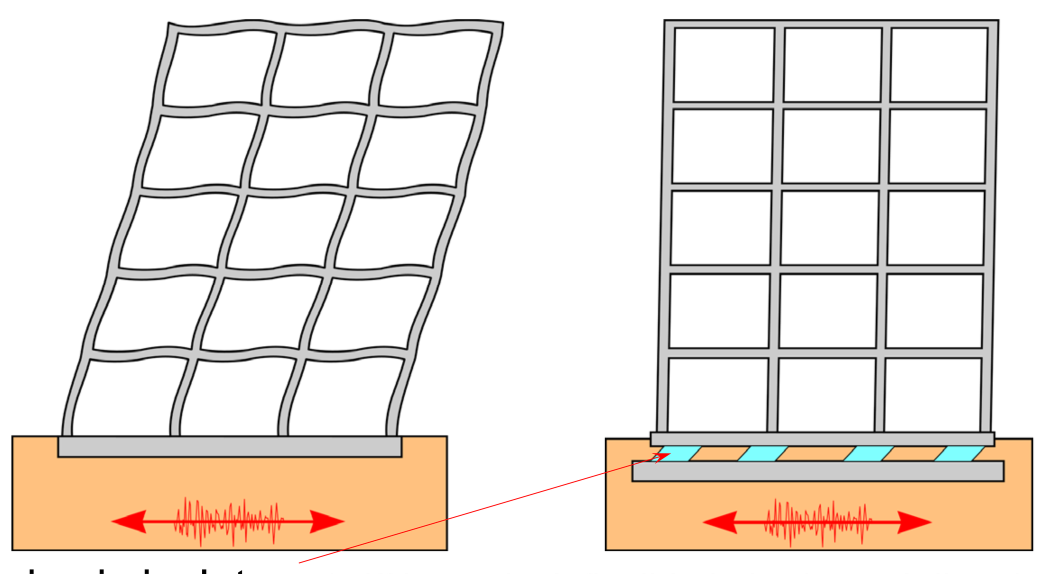
Abstract: Base isolation of buildings is the most efficient way of designing seismically resistant structures. Application of seismic isolators allows mutually independent movements of the ground and the structure during earthquakes. The application of seismic isolators increases the natural period of vibrations, which reduces the seismic forces in the structure. The paper analyzes the influence of the application of lead rubber bearings (LRB) on the response of the structure to the action of the north-south component of the Imperial Valley (El Centro) earthquake. A reinforced concrete frame structure was analyzed both for the case of base isolation and rigid foundation. Based on the comparative analysis of the natural period of vibrations, base shear seismic forces, displacement of the top level of the structure and relative interstorey drift, conclusions were drawn about the efficiency of application of this type of seismic isolators. The base isolation of buildings significantly reduces the required level of ductility of the structure, as well as damage to structural and non-structural elements.

Key words: base isolation, lead rubber bearing, RC frame structure, El Centro, direct dynamic analysis. **References**: 27 relevant references were used for preparation of paper.

Introduction

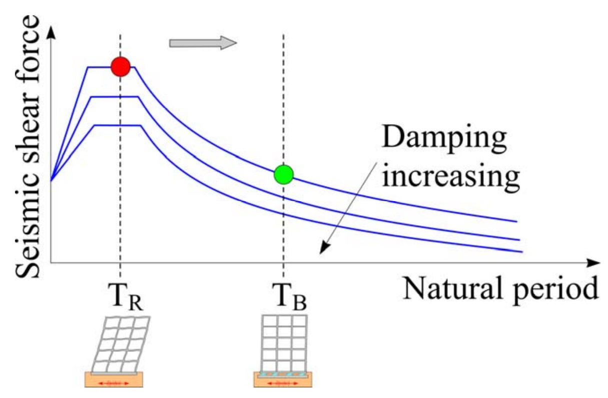
Earthquake → dominant in structural design
damage of the structural elements
collapse of the structure
huge material costs
loss of human lives

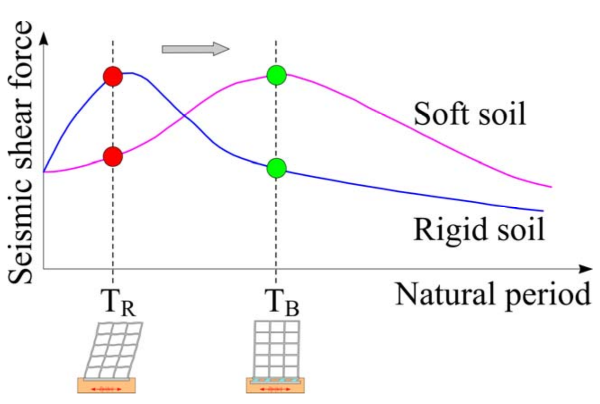
Design of seismically resistant structures
Base isolation (seismic isolators and energy dissipation devices)
Change of structural response during earthquake

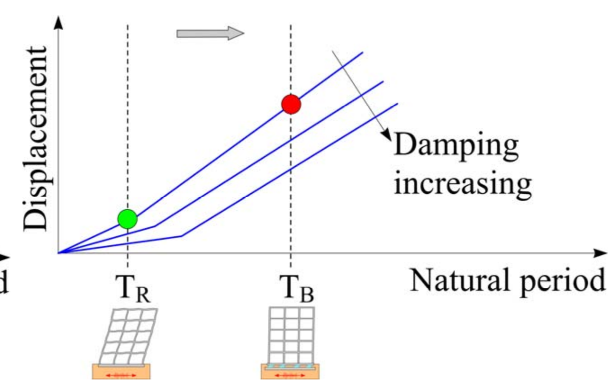


Seismic isolators (stiff in vertical, flexible in horizontal direction)

The natural period of vibration of the isolated structure increases up to several times compared to the rigidly founded structure.



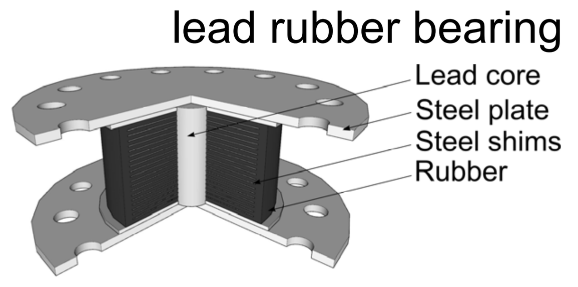




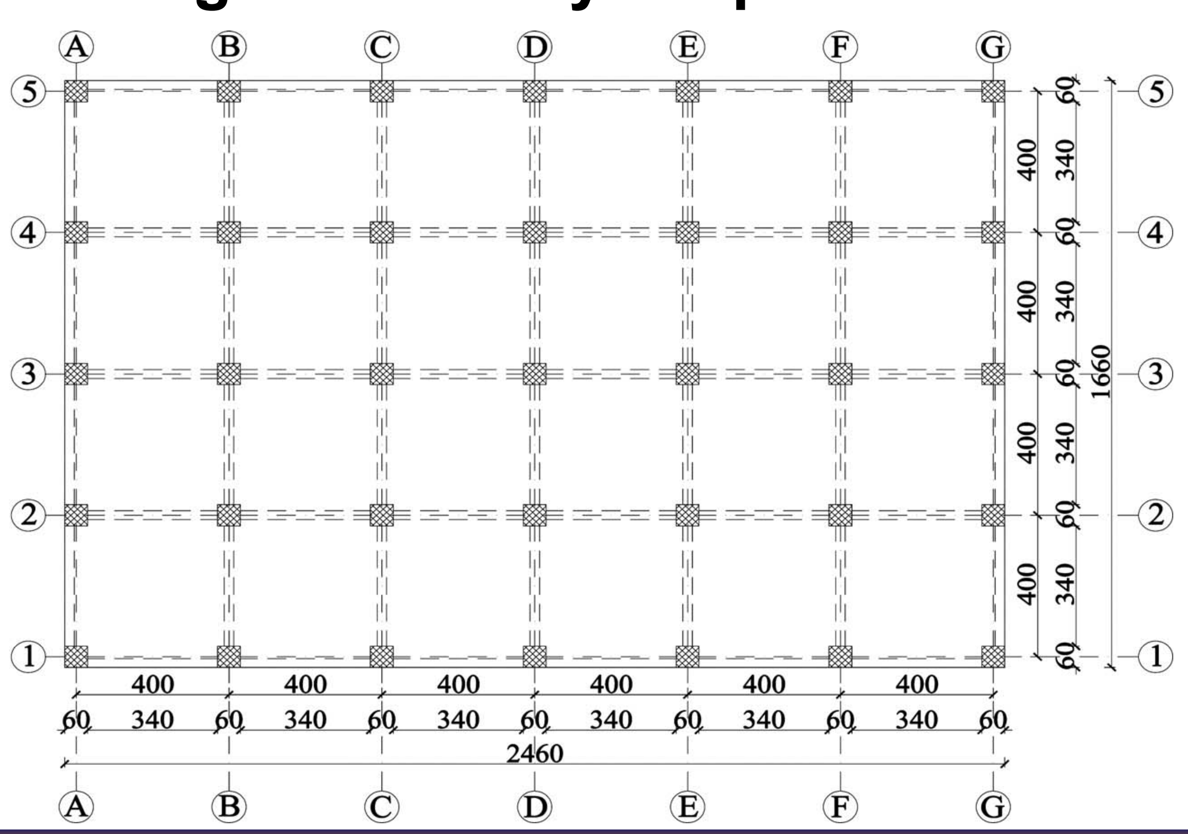
Seismic isolators:
- elastomeric bearings → low damping rubber bearing / lead rubber bearing / high damping rubber bearing
- sliding bearings
- combined bearings

Dr Robinson invented lead rubber bearing in late 1970's

Basic parts of lead rubber bearing



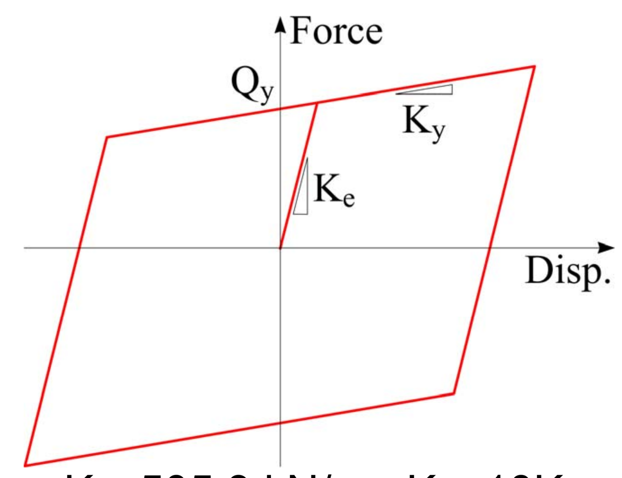
Setting of the analysed problem



RC frame structure:
- Gr+13St (storey high 3 m)
- columns 60/60 cm
- beams 25/50 cm
- slabs 20 cm
- dead load 2.0 kN/m^2
- live load 3.0 kN/m^2

Lead rubber bearing:
- diameter 650 mm
- 20 layers of 12 mm rubber
- steel shims 3 mm
- lead core 150 mm

Bilinear hysteretic behaviour of LRB



K_y=505.3 kN/m; K_e=10Ky; Q_y=100 kN; K_v=700 000 kN/m;

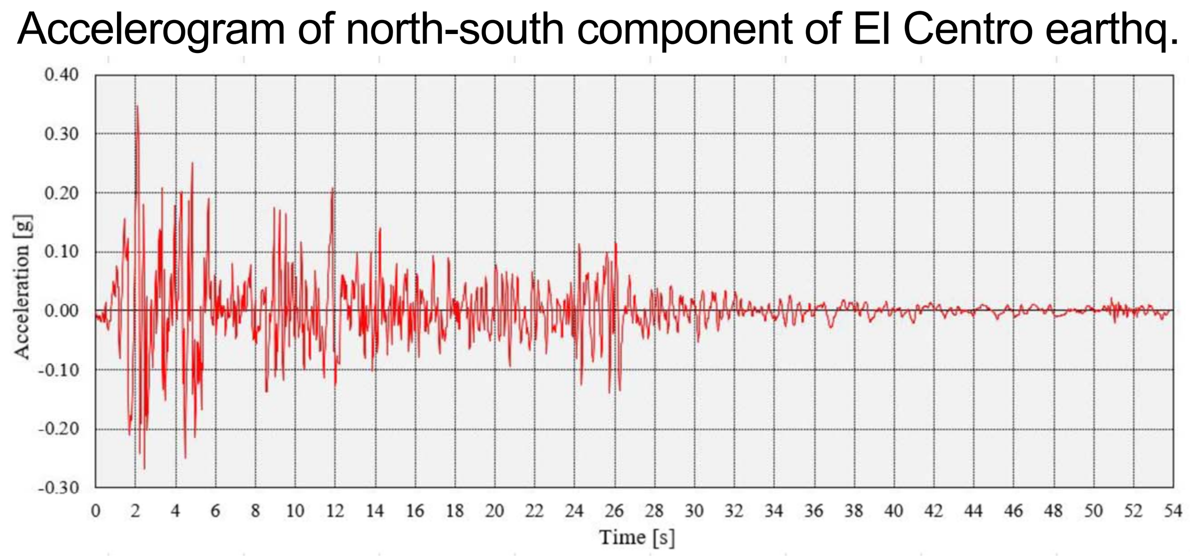
Numerical analysis of the seismic response of the RC frame structure

SAP2000 FEM model:
- columns and beams 1D beam FE
- slabs 2D shell FE
- FE mesh 1x1 m
- geom. (P-Δ) nonlinearity
- modal and direct dynamic analysis

Concrete model:
- Mander's stress-strain curve
- pivot hysteretic model
- plastic hinges acc. FEMA-356

Reinforcement model:
- kinematic hardening

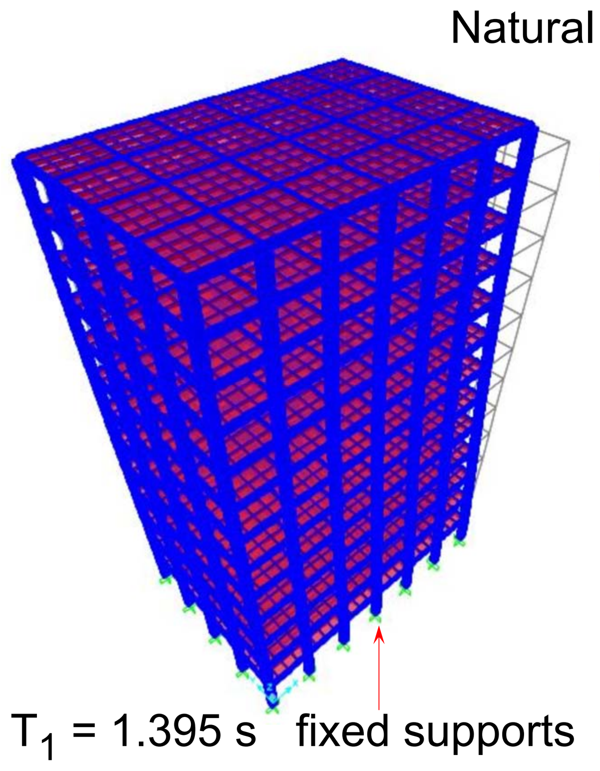
Accelerogram of north-south component of El Centro earthq.



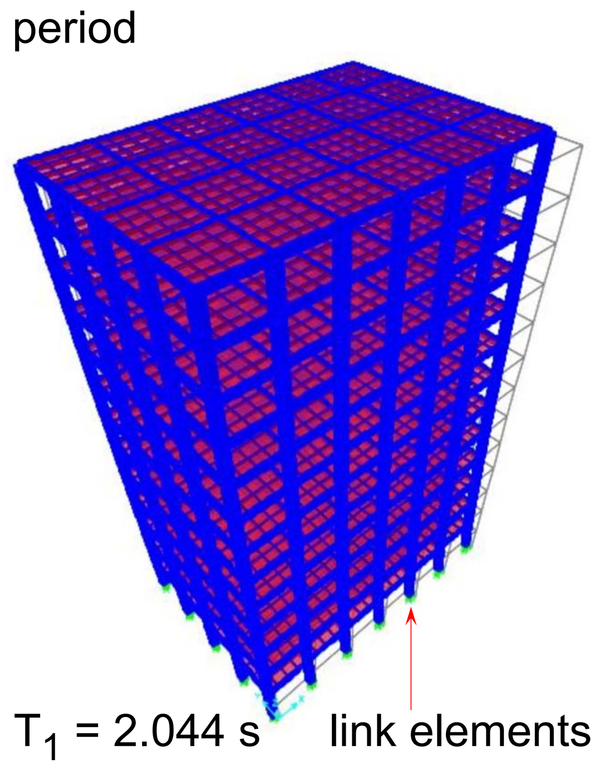
Results of analysis and discussion

Rigid foundation | Base isolation

Natural period

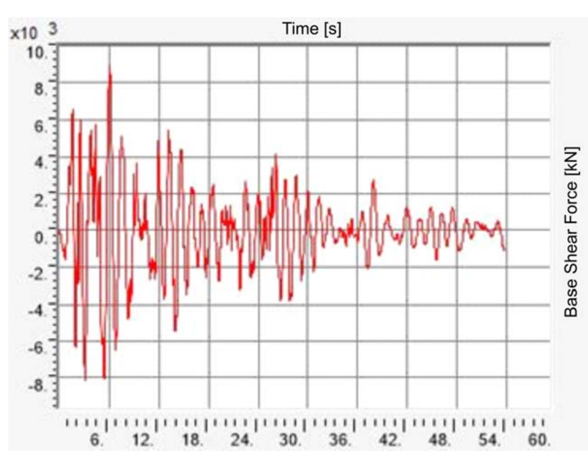


T_1 = 1.395 s fixed supports

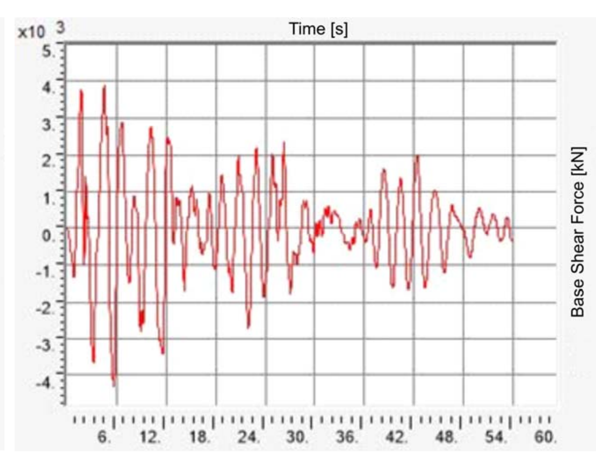


T_1 = 2.044 s link elements

Base shear force



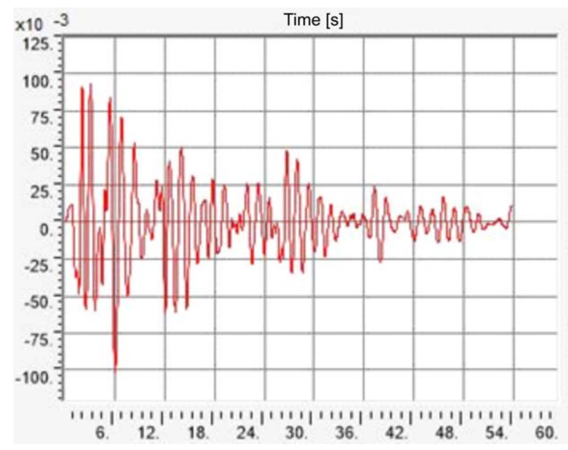
F_{max} = 8 909 kN at t = 6.00 s



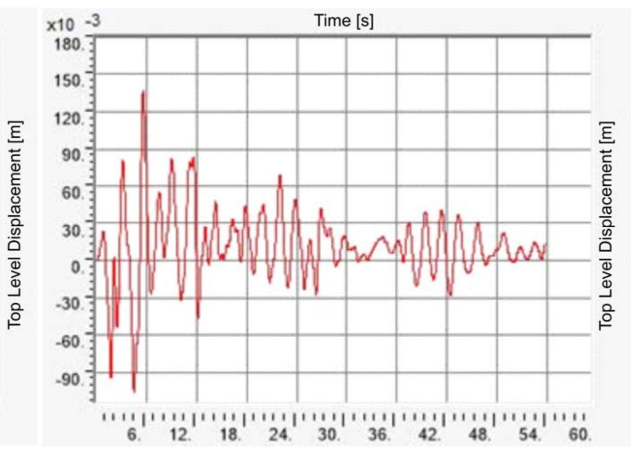
F_{max} = 4 303 kN at t = 5.68 s

Rigid foundation | Base isolation

Horizontal displacement of top level of structure

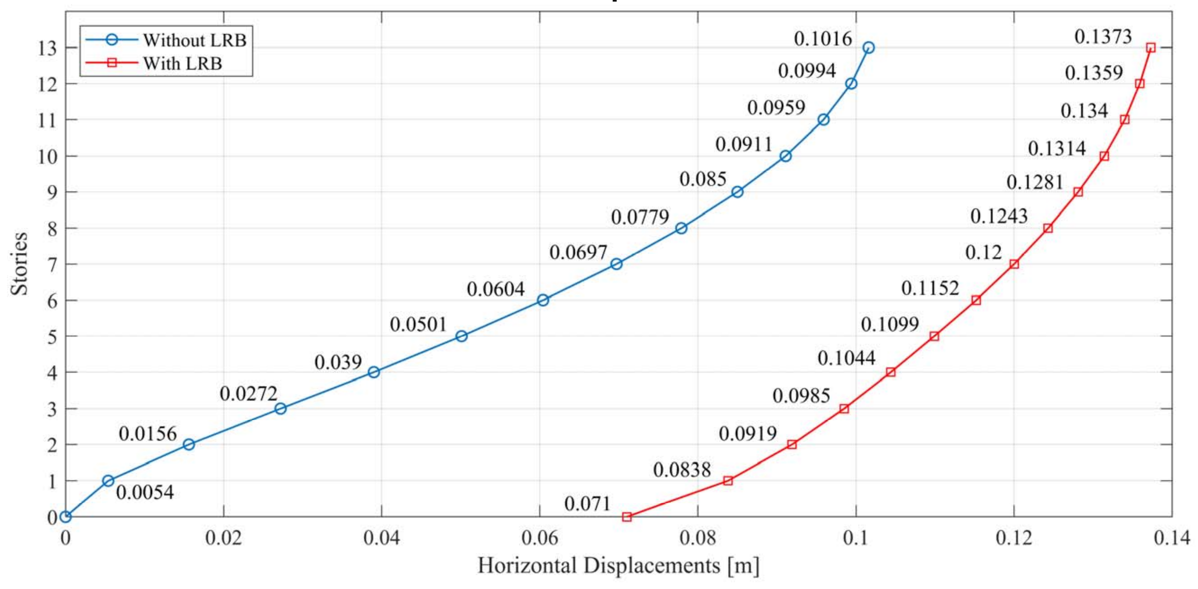


δ_{max} = 0.1016 m at t = 6.04 s

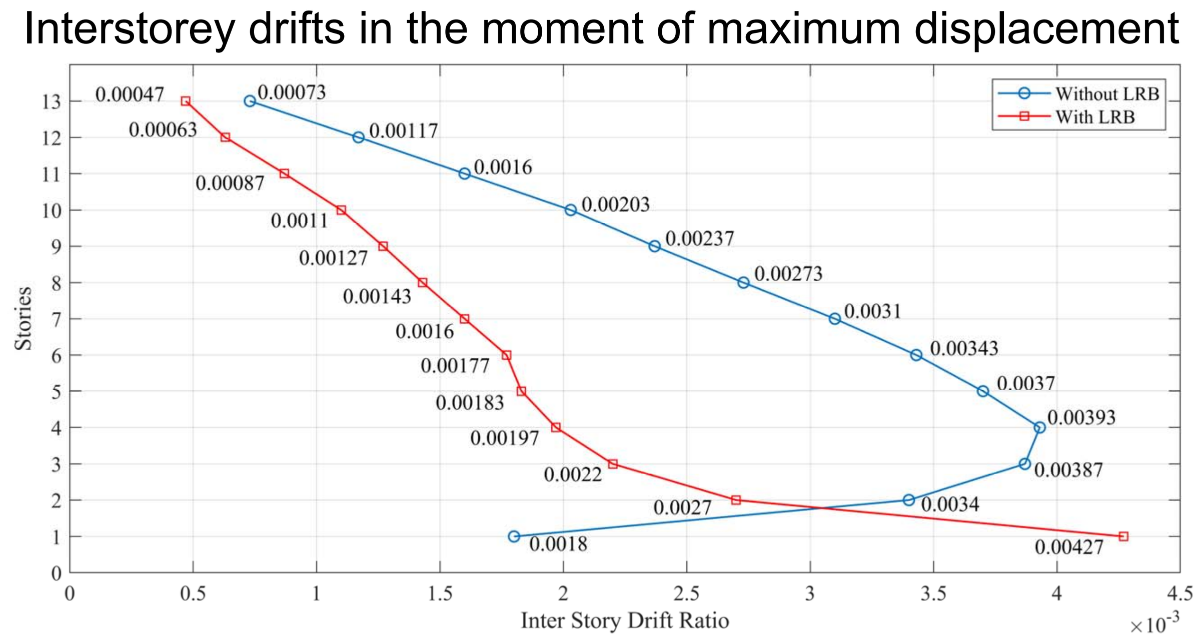


δ_{max} = 0.1373 m at t = 5.60 s

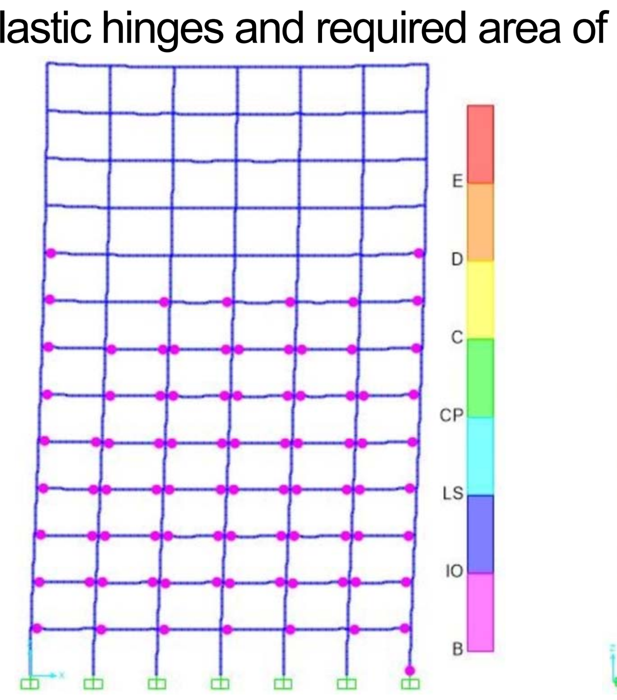
Maximum horizontal displacement of the floors



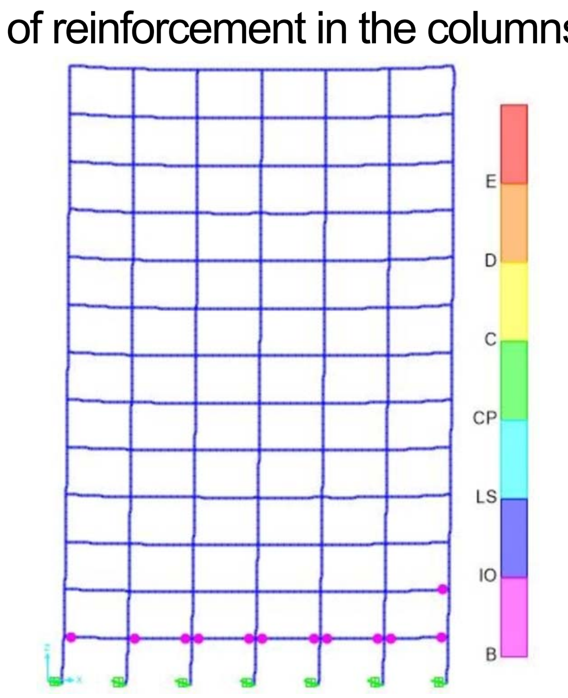
Interstorey drifts in the moment of maximum displacement



Plastic hinges and required area of reinforcement in the columns



A_{req} = 70.5 cm^2



A_{req} = 44.9 cm^2

Conclusion

Application of the lead rubber bearings leads to:

- increase of the natural periods of vibration of the analyzed structure for approximately 45%,
- improvemet of the dynamic response of structure reflected in a reduction of seismic forces, displacement of the top level of the structure and relative interstorey drifts compared to the rigidly founded structure,
- reduction of development of plastic hinges in beams and columns compared to the rigidly founded structure,
- reduction of the influences in the structural elements, which results in the reduction of the required area of reinforcement in the RC columns.

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