

University  
of Ljubljana

Faculty of *Civil and  
Geodetic Engineering*  
Institute of Structural Engineering,  
Earthquake Engineering and  
Construction IT



# Seismic Stress Test of Building Stock in Slovenia

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Special ambassador session, March 24, 2021

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  - IKPIR
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  - Actions
  - Seismic performance certificate of a building
- **Conclusions**

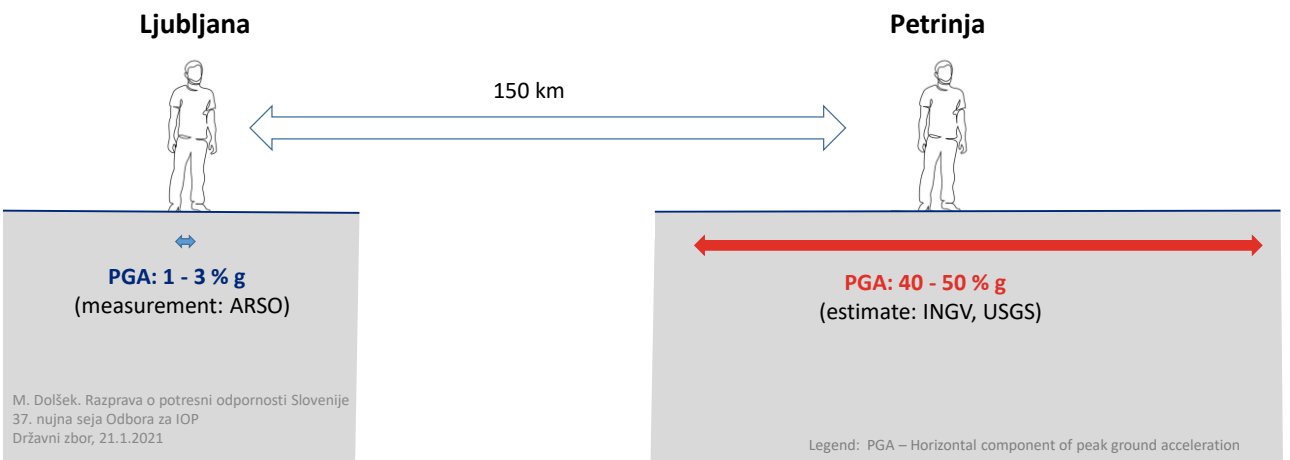
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## Rationale

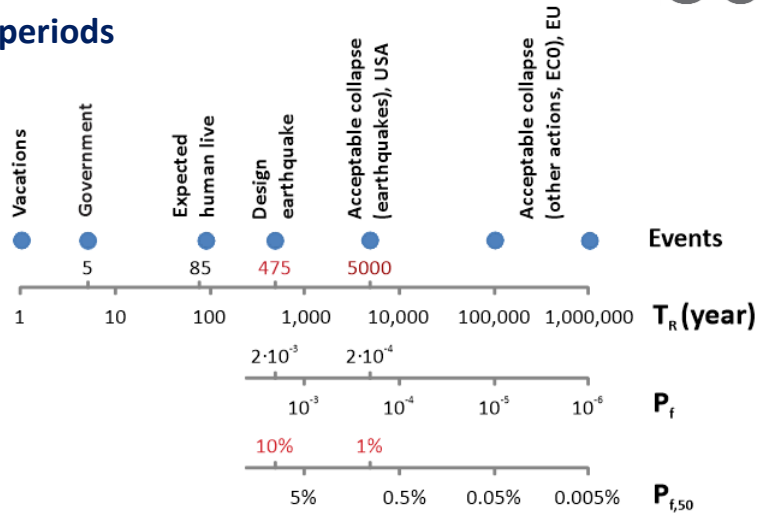
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- Perception of ground motion and seismic risk



# Rationale

- Event & (mean) return periods
- Acceptable risk?

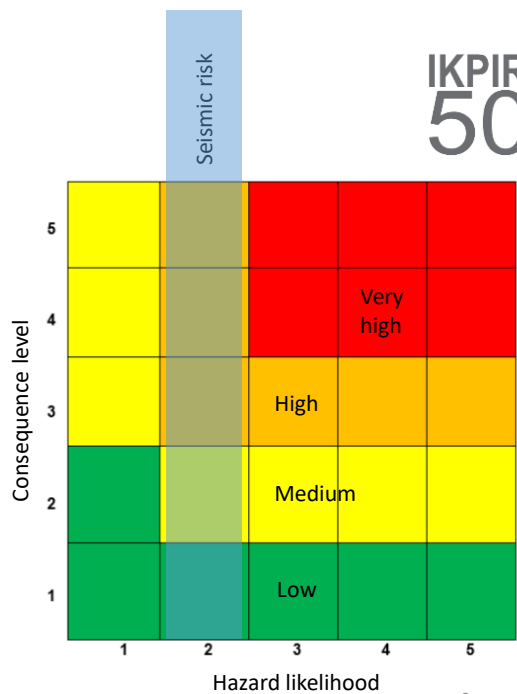


Dolšek, Design of structures in seismic areas: Past, Present and Future  
<http://www.lct-group.com/lecture/design-of-structures-in-seismic-areas-past-present-and-future-4u99.ntm>

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# Rationale

- Governmental (national) risk assessment (Slovenia)
  - Risk Matrix
  - Hazard level 2: app. 200 year return period
  - Consequence level 5: losses > 2.4 % GDP

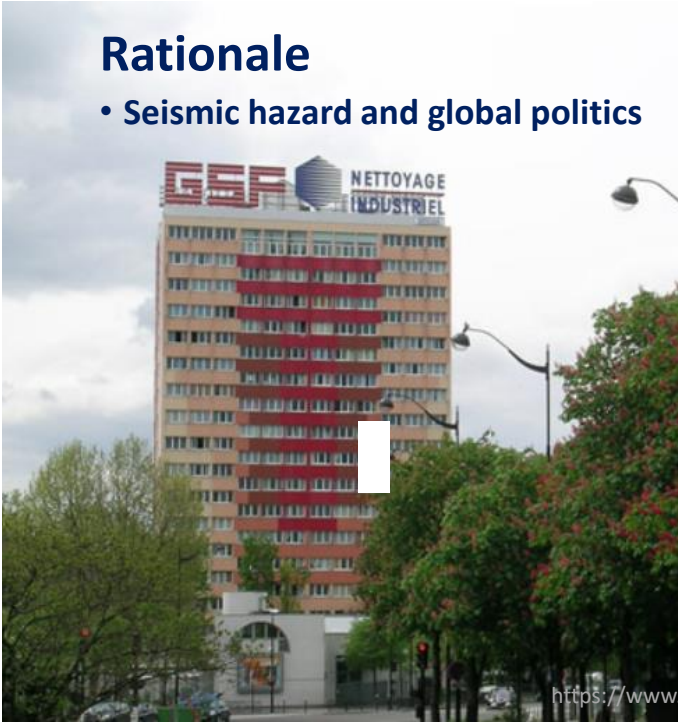


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# Rationale

- Seismic hazard and global politics



<https://www.dezeen.com/>

# Rationale

- Seismic hazard and global politics

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Ljubljana



500 - 750 km



Paris, Berlin



←→

**PGA: 25 % g**

M. Dolšek. Razprava o potresni odpornosti Slovenije  
37. nujna seja Odbora za IOP  
Državni zbor, 21.1.2021

◆

**PGA: 1 % g**

Legend: PGA – Horizontal component of peak ground acceleration

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# Rationale

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## Problem:

- Major seismic events cause human suffering
- False perception of seismic risk causes incorrect decision-making towards community seismic resilience
- Scenario-based risk assessment does not show full picture
- Global politics (e.g. The Paris Agreement) blur the regional issues

## Solution:

- Physics-based simulations of seismic risk
- Disseminate results to society rather than only scientific journals and standards

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# Seismic stress test of building stock in Slovenia

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## • Theoretical background:

- STREST project (EU-funded project, FP7)
- Seismic Stress Test of Built Environment & Research Program Earthquake Engineering (Slovenian Research Agency)

## • Workflow:

- Phase 1: Pre-assessment
  - Step 1: Data Collection
  - Step 2: Definition of risk measures and acceptance criteria
- Phase 2: Assessment
  - Step 3: Risk Assessment
- Phase 3: Decision
  - Step 4: Determination of critical buildings
  - Step 5: Development of risk mitigation guidelines
- Phase 4: Report
  - Step 6: Presentation of results

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## Seismic stress test of building stock in Slovenia

### • Technical part:

- Objective: Physics-based simulations
- IKPIR application for seismic risk assessment (Žižmond, Babič, Dolšek, 2020)

### • Models:

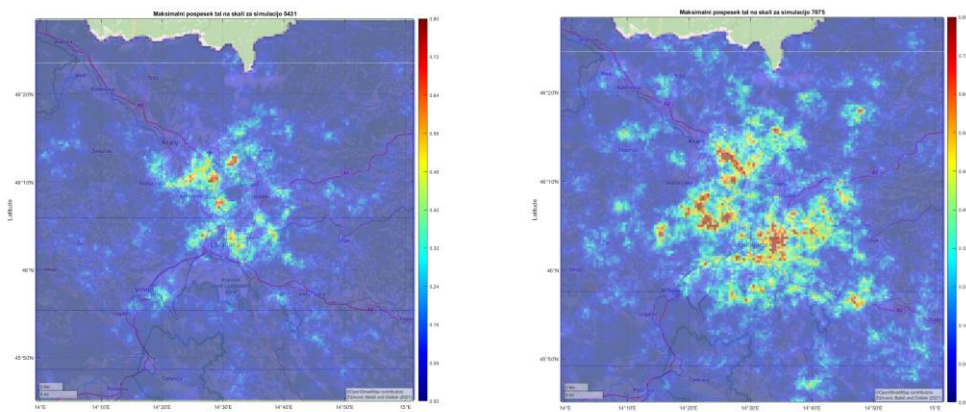
- Seismic hazard model (time-based, scenario-based)
- Exposure model for building stock and people (500,000 building/parts, 97 billion euros)
- Building stock fragility model (20 building classes, 5 discrete damage states)
- Consequence model (time-based, scenario-based)
- Decision model (Long-term vs. short-term risk acceptance, Babič & Dolšek 2019)

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## Seismic stress test of building stock in Slovenia

### • Scenario-based risk assessment (Informative) :

- Earthquake occurs (Mw=6.4, epicentre= 5 km N of Ljubljana)
- **Ground starts shaking (PGA fields using GMM, 500 simulations)**

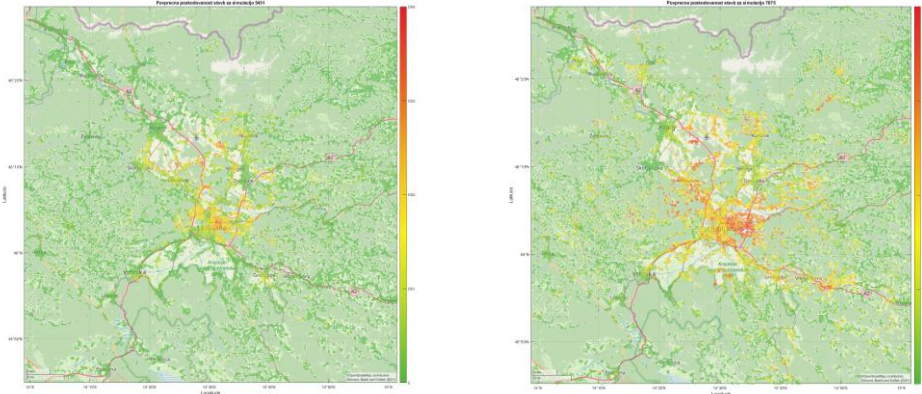


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## Seismic stress test of building stock in Slovenia

### • Scenario-based risk assessment (Informative):

- Shaking causes damage on buildings (none, slight, moderate, extensive, complete)
- Uncertain process ( $500 \times 20 = 10,000$  simulations)



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## Seismic stress test of building stock in Slovenia

### • Scenario-based risk assessment (Informative) :

- Losses (euros, fatalities)
- Uncertain results

|  | 5. percentile | <b>Median</b> | 95. percentile |
|--|---------------|---------------|----------------|
| <b>No. buildings / parts of buildings exceeding the total damage state</b> | 1,638         | <b>8,404</b>  | 22,982         |
| <b>Fatalities ("annual" population model)</b>                              | 99            | <b>568</b>    | 1.662          |
| <b>Loss (billion euros)</b>  | 3.6           | <b>10.5</b>   | 21.8           |

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### • Time-based risk assessment (Normative) :

- More difficult to explain
- Simple explanation:
  - Seismic events are simulated for a long period and results are averaged over a specified time window (1 year, 50 years)
- Risk is not measured directly by consequences of an earthquake event. Risk measures:
  - Expected annual losses
  - Probability of complete damage over 50 years
  - Number of buildings in risk classes

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### • Time-based risk assessment (Normative) :

- Seismic performance certificate of building stock (high-level summary of SST)

| Risk classes | Number of buildings or parts of buildings × 10 <sup>3</sup> |                             |                             |
|--------------|---|-----------------------------|-----------------------------|
|              | 5 <sup>th</sup> percentile                                  | 50 <sup>th</sup> percentile | 95 <sup>th</sup> percentile |
| A            | 182.4   | <b>229.0</b>                | 268.7                       |
| B            | 173.4   | <b>192.7</b>                | 212.9                       |
| C            | 48.1  | <b>64.4</b>                 | 83.6                        |
| D            | 6.8   | <b>10.6</b>                 | 15.5                        |
| E            | 8.2   | <b>13.5</b>                 | 21.6                        |
| F            | 5.4   | <b>10.0</b>                 | 18.5                        |
| G            | 0   | <b>0</b>                    | 0                           |

Acceptable

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### • Time-based risk assessment (Normative) :

- Seismic performance certificate of building stock
- Median

Long-term acceptable risk for building stock of ordinary importance

~ 100,000 buildings / buildings' parts  
400,000 people  
18 billion euros



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### ▪ Decision:

- Seismic stress test is negative

### ▪ Actions (2020-2050)

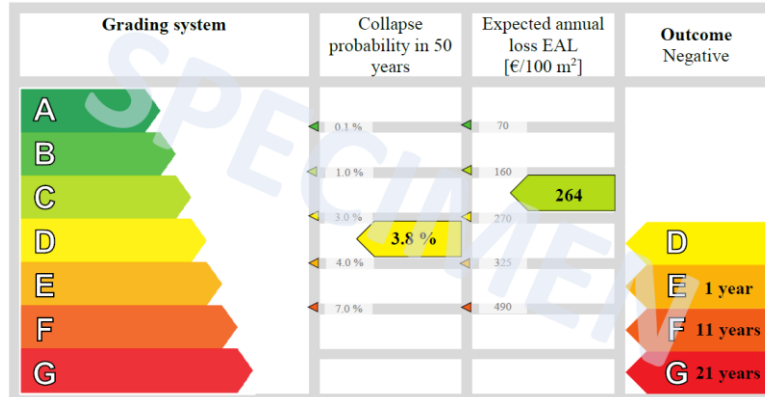
- Strengthen the building stock
- Reduce uncertainty in the seismic risk estimation
- Improve public awareness of seismic risk
- Provide financial incentives for enhancing seismic safety

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- **Seismic performance certificate (label) of a building:**
  - Improves public awareness, reduces uncertainty in risk estimates, can be basis for financial incentives



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## Conclusions

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- **False perception of seismic risk**
  - Partly caused by global goals
  - Causes incorrect decision-making regionally
  - Human actions caused high seismic risk
- **Seismic stress test of building stock in Slovenia:**
  - Version 0
  - Level of details: 0, 1, 2, 3
  - 1-year experience: Physics-based simulation helps, but...
- **Seismic performance certificates**
  - Currently mixed feelings in community (Slovenia)
- **Acknowledgements**
  - Ministry of Education, Science and Sport of Republic of Slovenia
  - Ministry of the Environment and Spatial Planning of Republic of Slovenia

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**Thank you for the invitation  
and attention**