MOTT MACDONALD

Seismic Risk Assessment of Large Panel Buildings in Bulgaria

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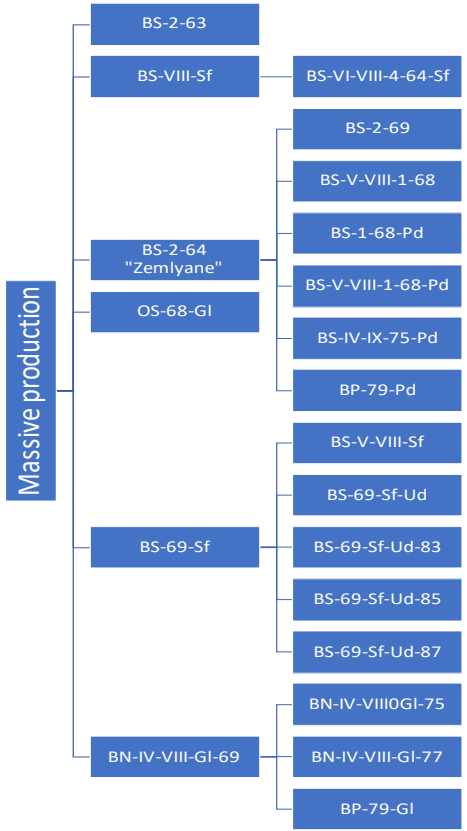
THE WORLD BANK

GFDRR
Global Facility for Disaster Reduction and Recovery

24/09/2018

1960 construction in Bulgaria 1990 home of 1.7M people today



13,000+ large panel buildings
(20% of all multifamily buildings)

≈ 700,000 units in large panel buildings
(20% of total 40% of these in towns and cities)

≈ 1,750,000 people in large panel buildings
(24% of all; 33% of all urban population)

Energy Efficiency of Multi-Family Residential Buildings National Programme (EENP)

€250m

Credit line from CEDB and KFW

€600m

Spent by end of 2017

752

Buildings renovated by Oct 2017

612

Buildings under renovation by Oct 2017 (completed design)

€60m

Estimated annual savings of energy consumption by 2022 when the buildings are completed

100k

People living in renovated buildings as of the end of 2017

628

Buildings about to start renovation by Oct 2017 (completed TA)

2022

Buildings approved for renovation and with signed contracts

Basic rules of EENP

Eligible buildings

- 2016 onwards: Buildings built before 1999 with over 3 floors and over 6 units
- 2015-2016: Industrially constructed buildings with over 36 units

Eligible activities and reference costs

- **Technical Audit: €2.5 /sq.m (€6.5 /sq.m. before end of 2016 *)**
- Design: €2.5 /sq.m. (€7.5 /sq.m *)
- Design review & approval: €0.4 /sq.m (€1 /sq.m. *)
- Construction works and materials: €57.5 - 65/sq.m (€125 /sq.m. *)
- Construction supervision: €0.8/sq.m (€3.5 /sq.m.*)
- Investment control: €0.4/sq.m (€2 /sq.m.*)

Key questions

Is the current seismic assessment process under EENP effective and are large panel buildings safe in earthquakes?

What would be the socio-economic impact of a strong earthquake?

Can the seismic safety be improved as part of EENP?

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Project: Probabilistic seismic risk assessment and seismic safety improvement recommendations for pre-1990 multi-family housing structures in Bulgaria and broader Europe Central Asia region

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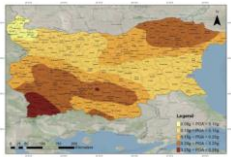
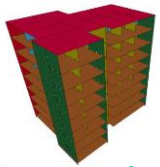
EQE

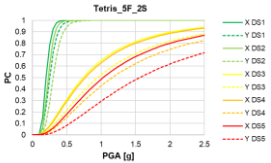
EQE BULGARIA

Seismic Hazard



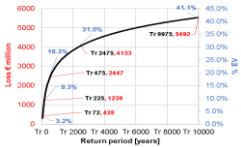
Exposure and Vulnerability

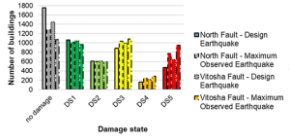




Improvement of Technical Audits

Seismic Risk



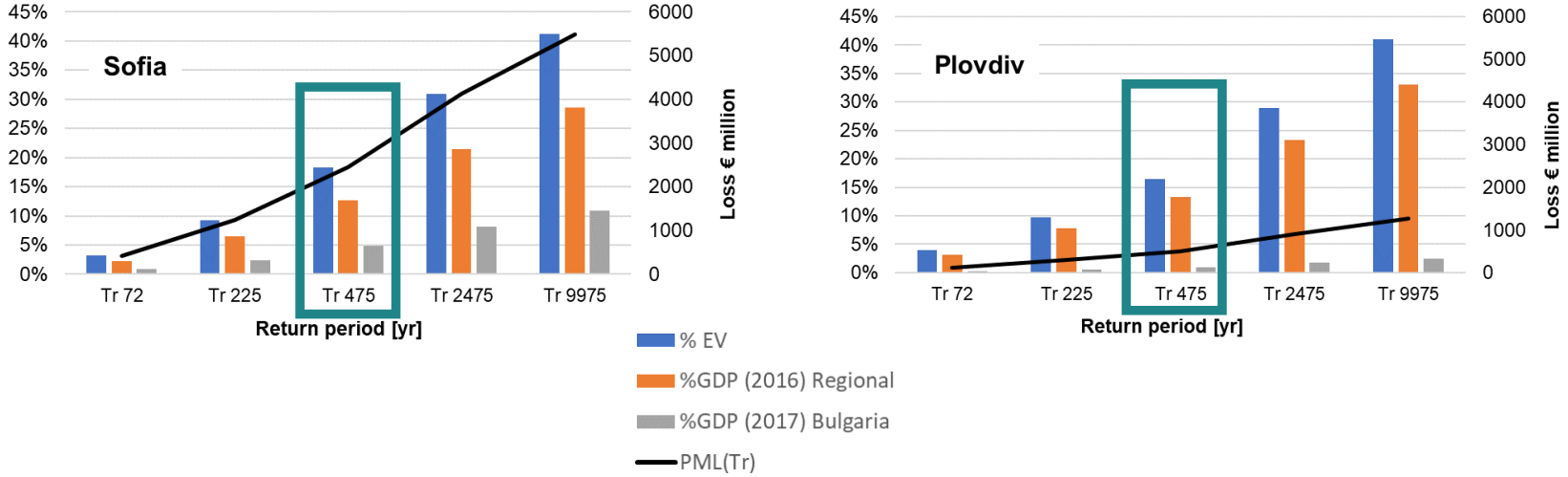


Risk Reduction

Seismic Risk Analysis (Sofia and Plovdiv)

Preliminary results

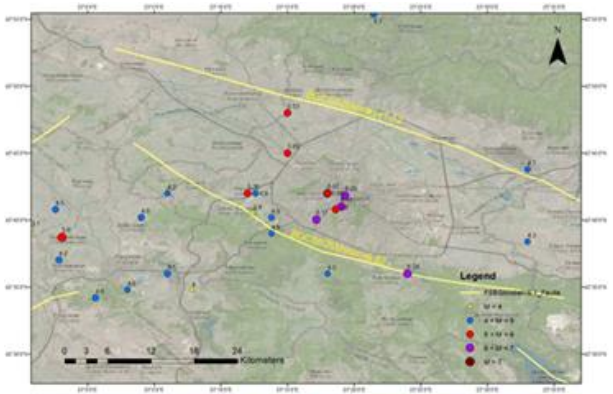
City	Number of exposed units	Exposed value € million	Average Structural loss (50yrs)		Structural damage											
					no damage		DS1		DS2		DS3		DS4		DS5	
			€ million	% EV	N	%	N	%	N	%	N	%	N	%	N	%
Sofia	177473	13349	839	6%	1507	30%	1260	25%	1531	31%	478	10%	45	1%	124	3%
Plovdiv	55558	3114	197	6%	519	28%	386	21%	786	42%	114	6%	16	1%	34	2%



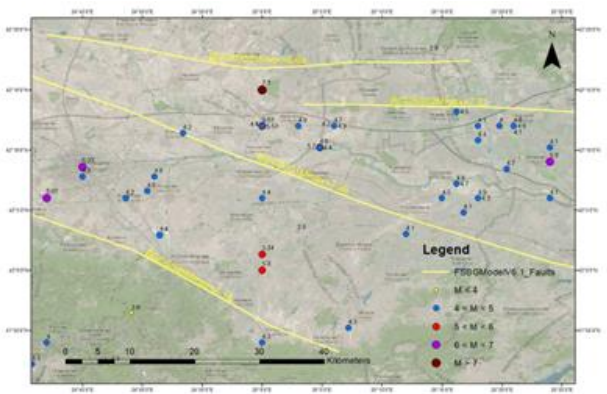
Scenario Seismic Risk Assessment (Sofia and Plovdiv)

Preliminary results

23 April 1818 M6.5 Sofia Earthquake



28 April 1928 M7.1 Plovdiv earthquake



	Total loss € million	% Exp. Value	% Repl. cost	% GDP Regional (2016)	% GDP Bulgaria (2017)	Average loss per unit €	% of average annual salary	% of collapsed buildings
23 April 1818 M6.5 Sofia Earthquake	3584	27%	45%	19%	**7%**	20200	**252%**	15%
28 April 1928 M7.1 Plovdiv Earthquake	417	13%	22%	11%	**1%**	7505	**148%**	6%

Do the numbers make sense?

1 Are these results consistent with past earthquakes?

2 How the large panel buildings are expected to perform compared with other multifamily residential buildings?

3 Where is the risk and how to address it in line with the EENP?

M 6.8 Spitak, Armenia Earthquake, December 7, 1988

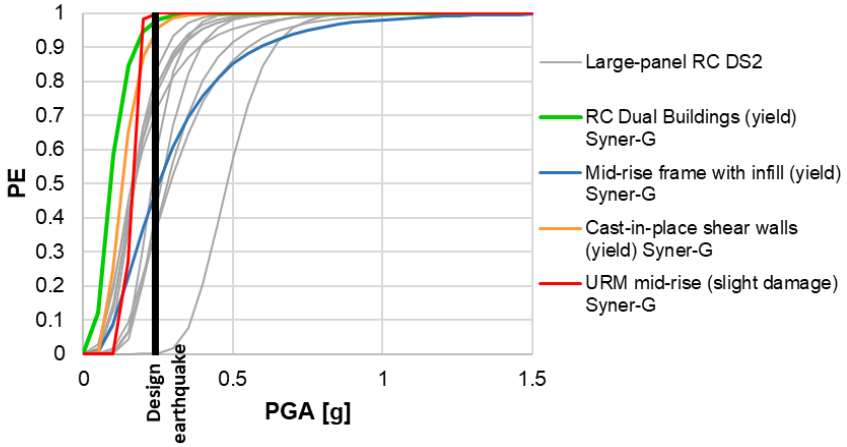
M 7.2 Vrancea, Romania Earthquake, March 4, 1977

M 7.0 17 April 1976 and 19 March 1984 Uzbekistan Earthquake

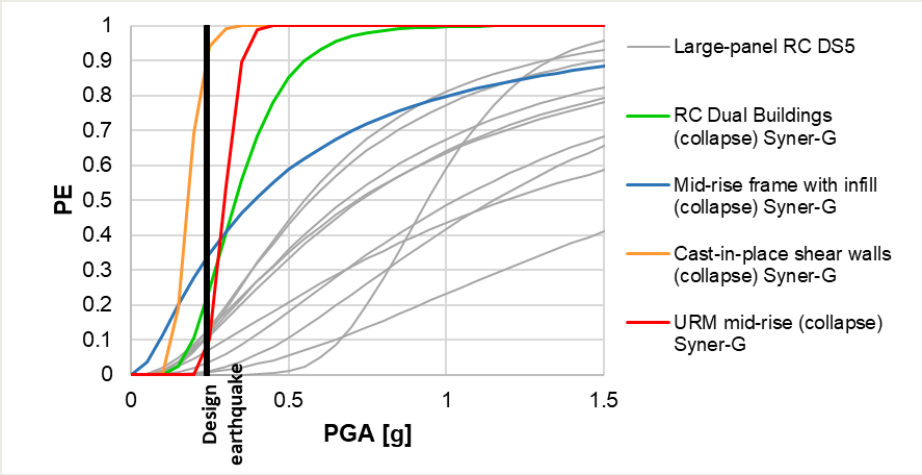
M 5.6, Pernik, Bulgaria Earthquake, 22 May 2013

Large panel buildings compared to other mid-rise buildings

Fragility functions for Light Damage



Fragility functions for Collapse

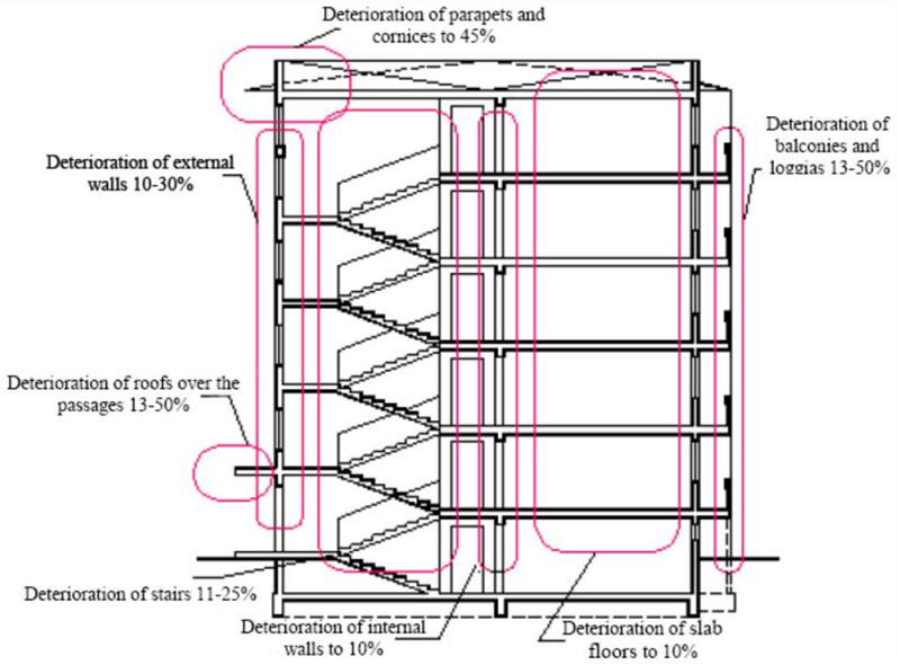


In terms of collapse probability, the large panel buildings are among the lesser vulnerable pre-1990 buildings in Bulgaria

… but …

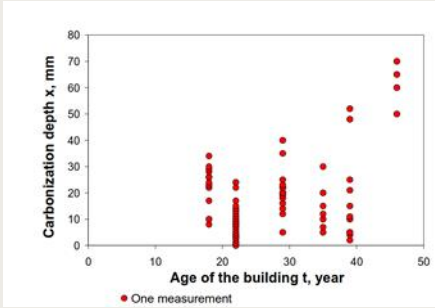
Deterioration

External envelope exposed to the elements

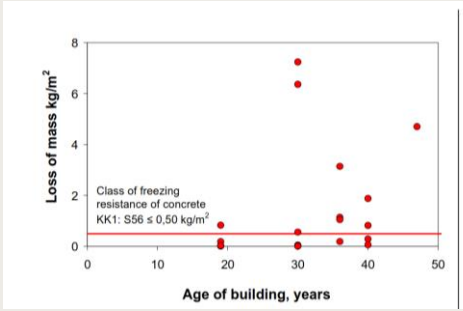


Ignatavicius C. et al., 2000, Modernization of Large Panel Houses in Vilnius

Carbonisation (left) and corrosion (right) of the reinforcement of the façade panels



Loss of concrete mass of the façade panel during frost resistance tests (left) and decay of the façade due to low frost resistance (right)



Kalamees T. et al., 2011, Technical Condition of Prefabricated Concrete Large Panel Apartment Buildings in Estonia

Modification of structural walls

Remodelling of internal spaces

Increasing the size of a door opening

Partial removal of walls for space planning optimisation

Partial removal of façade panel to utilise the balcony and increase usable space and increasing of a door opening /a new door (right)

So, where is the risk?

Where is the risk?

Condition of the façade panel connections is a significant contributor

Façade panel fallen onto a parked car in Stara Zagora (corroded connections)

Roof parapet panel fallen during the 22 May Pernik M5.6 earthquake (believed to be due to corrosion of the connection details)

Roof façade panel fallen onto the terrace below (believed to be due to corrosion of the connection details)

How to reduce the risk?

1

Strengthening the Technical Audit process and extracting the TA from the design & construction package

2

Development of a RVS procedure for quick and cost effective assessment of the seismic safety of buildings applying for EENP funding

3

Development of a standard specifying the minimum requirements for inspections of a large panel buildings that apply for EENP funding

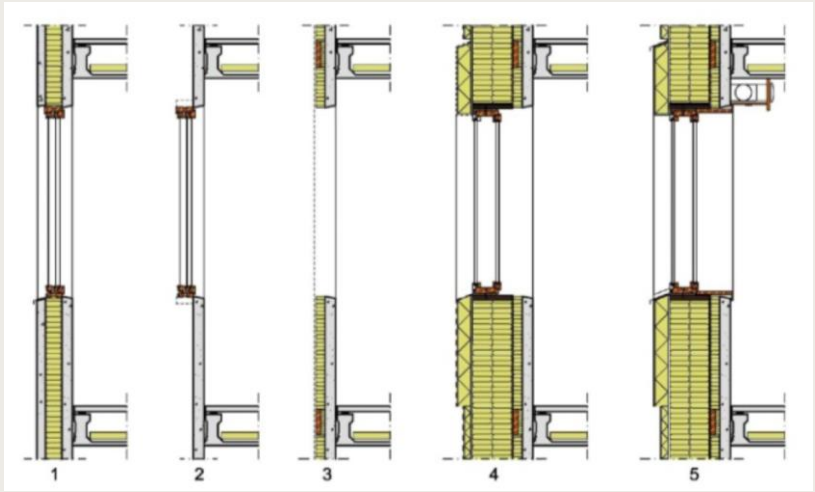
Obligatory strengthening (under EENP) of façade panel connections that have been assessed in pure conditions or if condition is unidentified

Can the seismic risk be reduced as part of EENP?

Current

Is the current retrofit approach the most suitable in long term?

Future?



Replacement of the external layer of the panel with new light and efficient panel (reduced seismic mass of façade panels in seismic regions)

https://mycourses.aalto.fi/pluginfile.php/148391/mod_resource/content/1/20151016_leRoux.pdf

$?

Potential source of funding?

one of the potenctials: unused roofs

RS | Roeleveld-Sikkes Architects

Den Haag / Budapest

Figure 52. Two additional floors

Source:http://townplanner.livejournal.com/4042.html

Figure 53. Five additional floors

Source: http://realty.rbc.ru/articles/22/08/2013/562949988618502.shtml.

M. Šutavičius et al., Mass-Housing: Tendencies and Modernization, 2014

Key messages

Current Technical Audit cannot identify seismically vulnerable buildings

Technical Audit needs strengthening:

- Assessment to be based on current seismic code
- TA to be procured and funded separately
- RVS procedure to speed up and reduce cost of structural assessment
- Standardised practice for structural inspection (of large panel buildings)

Strong earthquake can be devastating for the financial stability of the affected households

Risk awareness and preparedness need improvement:

- Communication campaign to improve understanding of risk
- New legislation and taxation models
- Innovative insurance products
- Social protection for vulnerable groups

Seismic safety can be improved as part of EENP

Seismic safety needs to be incorporated into the EE rehabilitation:

- Seismic retrofit guidelines with approved solutions to speed up design and reduce cost
- Simplified administrative approval process for seismic retrofits
- Technical and financial innovations and new policies for self-funded seismic retrofit

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Thank you

Q&A