

Raziskave nevarnosti seizmičnih resonančnih učinkov med sedimenti in stavbami v petih slovenskih mestih z metodo mikrotremorjev

Andrej Gosar

ARSO – Urad za seismologijo in geologijo

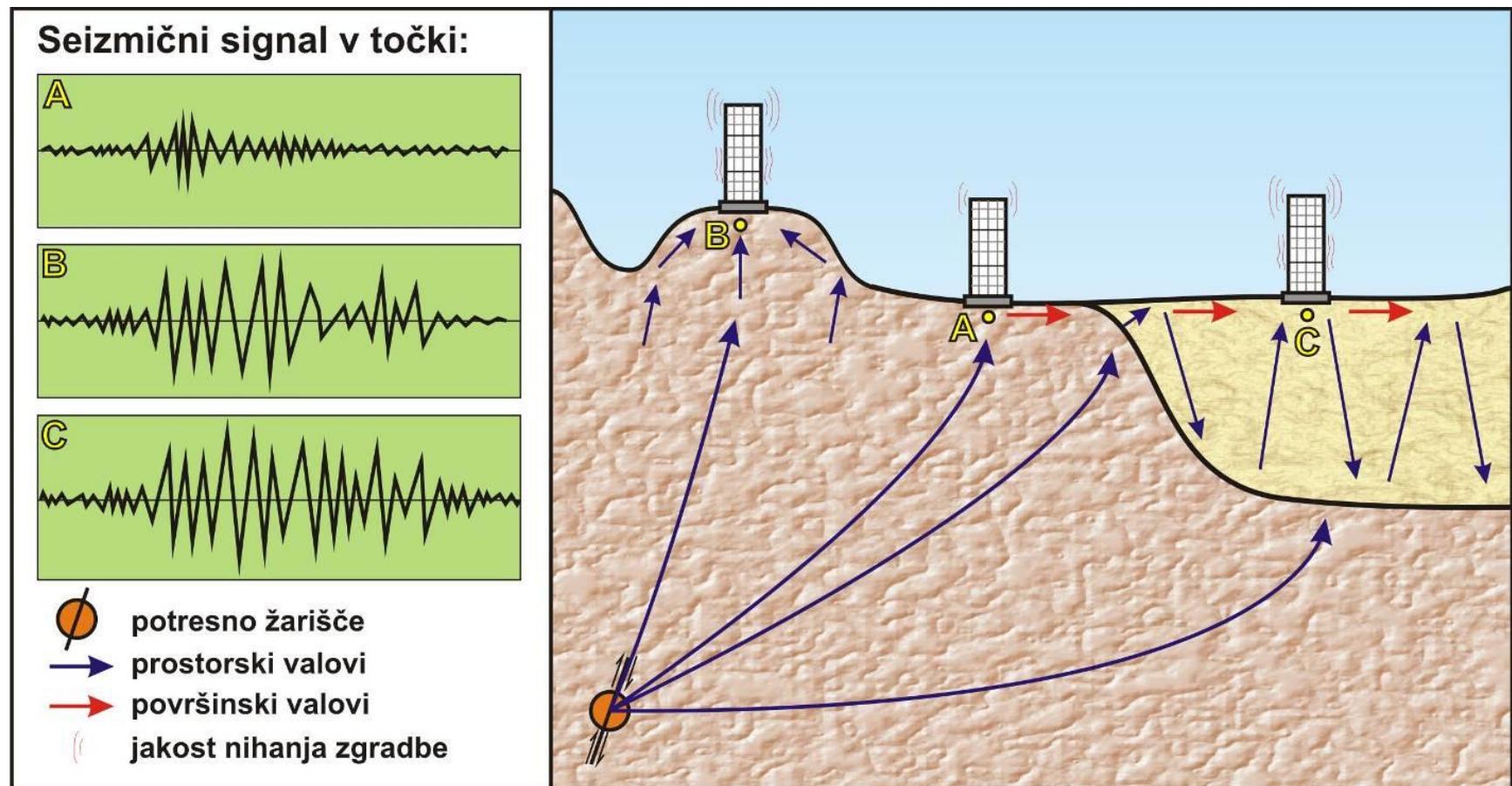
in

UL – Naravoslovno-tehniška fakulteta

Potresno nihanje tal

je odvisno od:

- a) žariščnih lastnosti potresa,
- b) regionalne geološke zgradbe,
- c) vplivov lokalne geološke zgradbe (mehkih sedimentov).



Resonanca med sedimenti in stavbami

- Stavbe pridejo v resonanco s temi, kadar
 - njihova lastna frekvenca nihanja sovpada z lastno frekvenco sedimentov,
 - lastna frekvenca sedimentov je odvisna od njihove debeline in hitrosti strižnega valovanja, $f=Vs/4h$
- Resonanca povzroči:
 - večje amplitude nihanja stavbe,
 - podaljša trajanje močnega nihanja kar rezultira v večjih poškodbah ali celo porušitvi stavbe.



Kalamata, Grčija - 1985

Lastna frekvenca stavb

- stavbe zaradi raznih vplivov nihajo, njihova lastna frekvenca je enaka

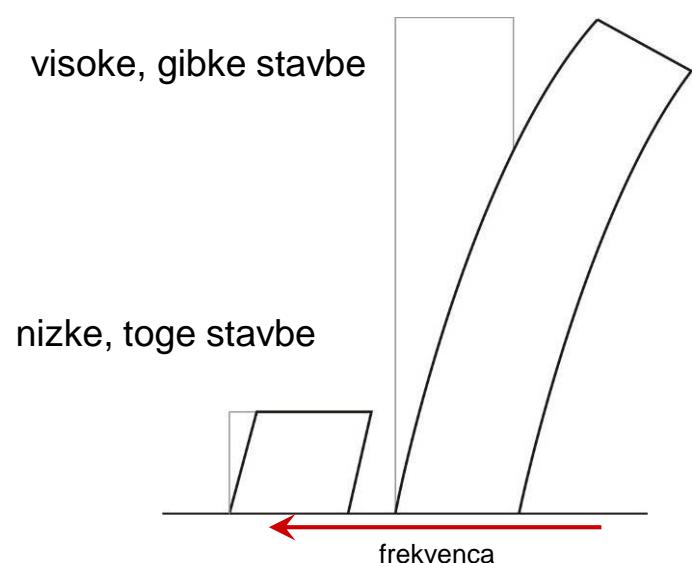
$$f = \frac{1}{2\pi} \sqrt{\frac{k}{m}} ; \quad \begin{matrix} k & \dots \text{tugost} \\ m & \dots \text{masa} \end{matrix}$$

- največji vpliv na tugost stavbe ima njena višina:
 - višje stavbe so bolj gibke (manj toge), torej imajo v primerjavi z nižjimi stavbami tudi nižje lastne frekvence.
- lastne frekvence stavbe ni lahko izračunati ali oceniti!

Značilne osnovne lastne frekvence stavb (Kramer, 1996)

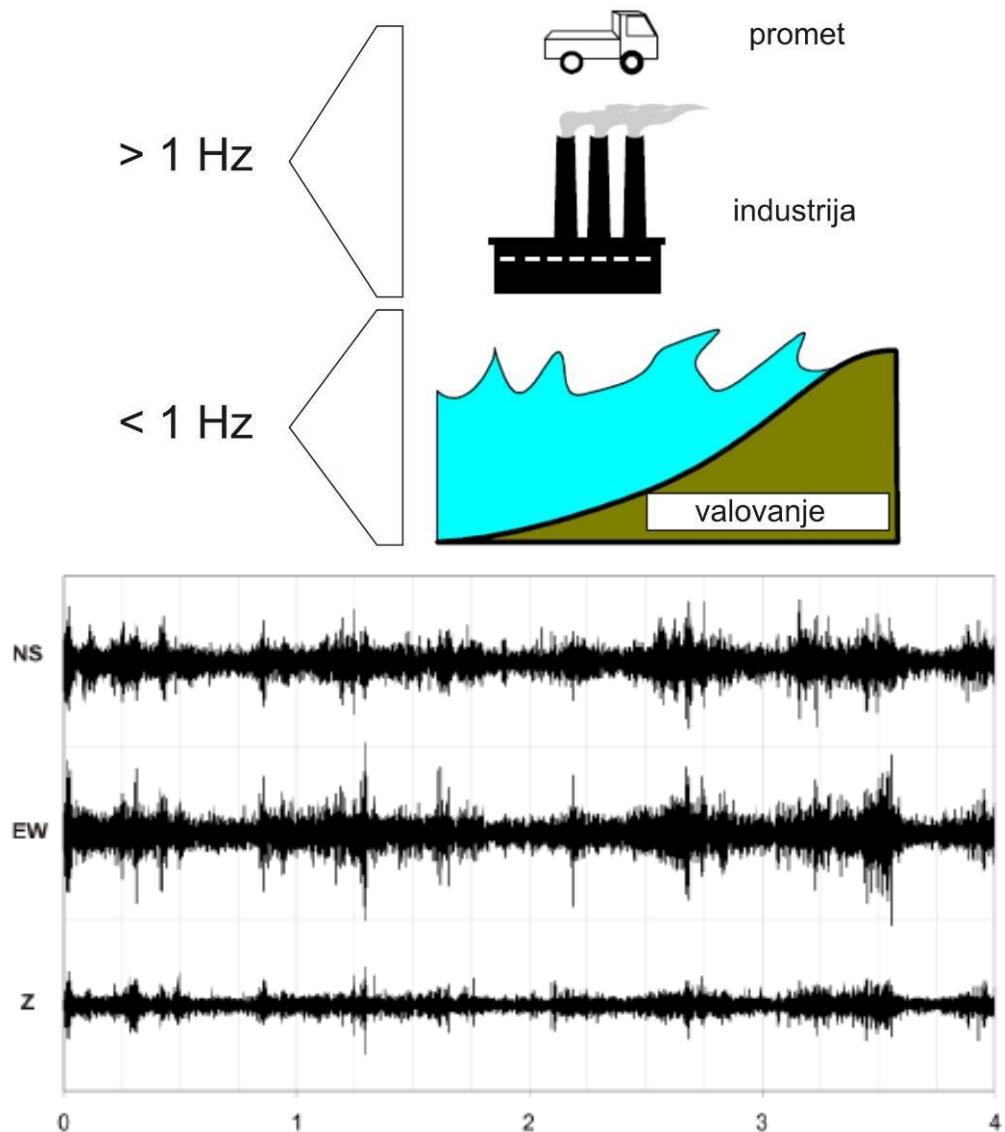
vrsta zgradbe	osnovna frekvenca [Hz]
enonadstropna	10
dvonadstropna	5
3 do 4-nadstropna	2
visoke zgradbe	0,5 – 1,0
zelo visoke zgradbe	0,15 – 0,2

$$f_{stavbe} \approx 10 / n$$



Mikrotremorji

- ambientne vibracije tal,
- neznana prostorska in časovna razporeditev valovnih izvorov,
- naravnega in umetnega izvora,
- predvsem površinsko valovanje, deloma tudi prostorsko,
- frekvenčno območje od 0,01 do nekaj 10 Hz,
- amplitudo od 10^{-4} do 10^{-2} mm (nizkoenergijsko valovno polje).

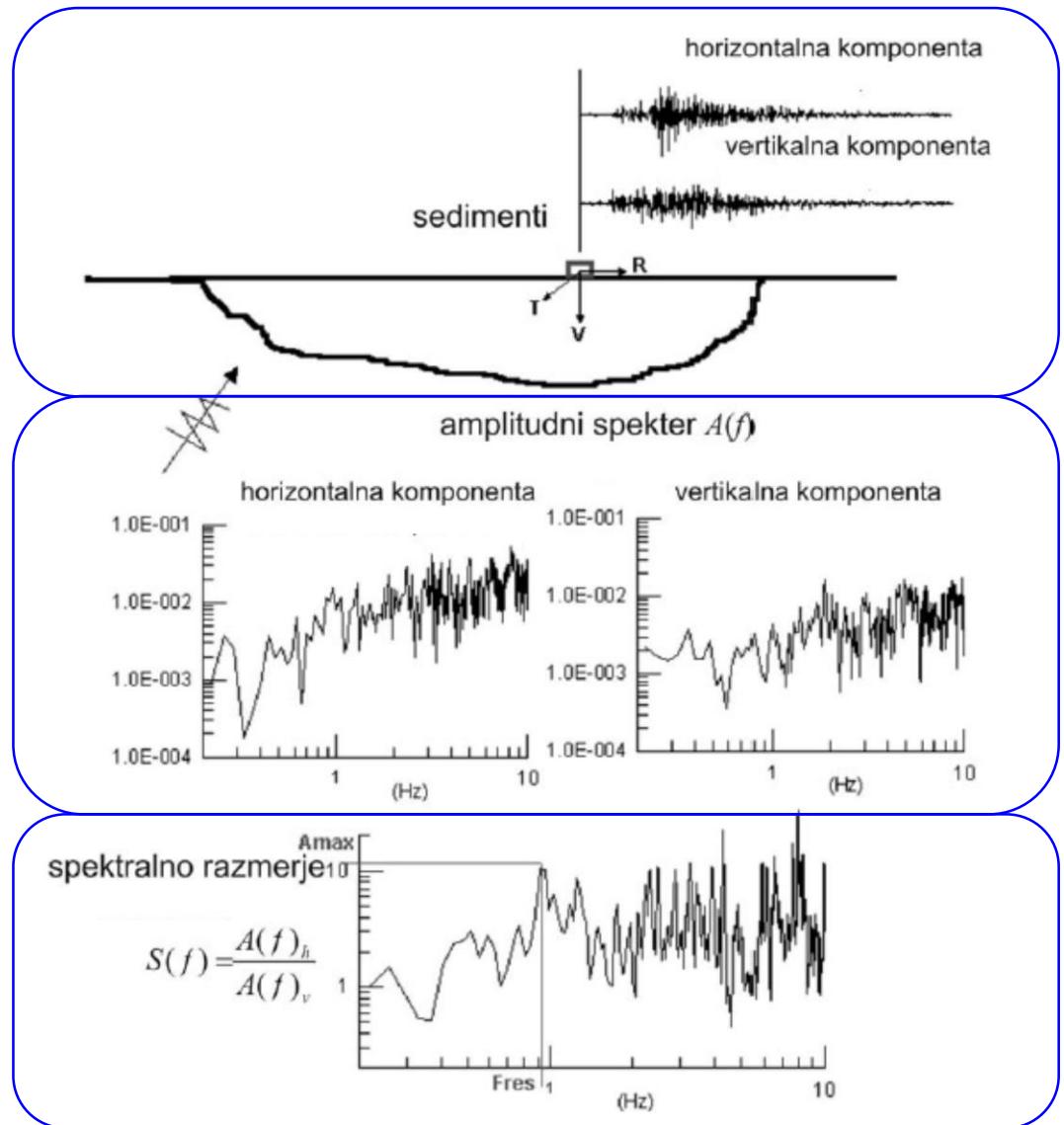


Horizontal to Vertical Spectral Ratio (HVSR)

(Nogoshi in Igarashi, 1971; Nakamura, 1989)

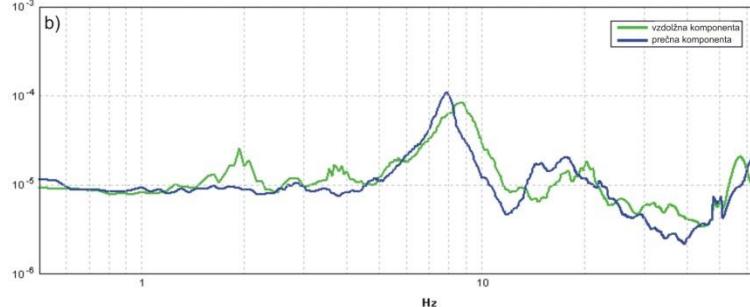
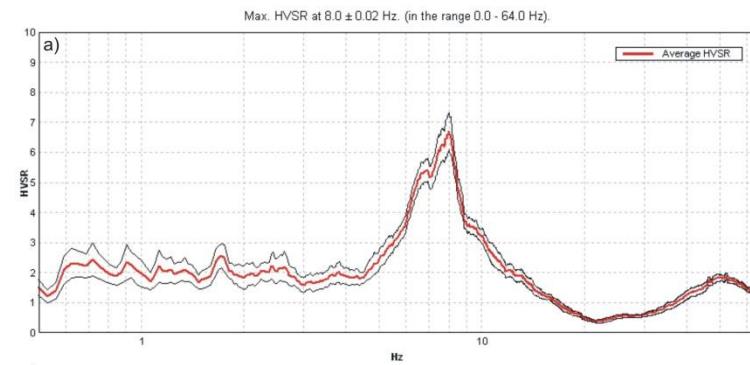
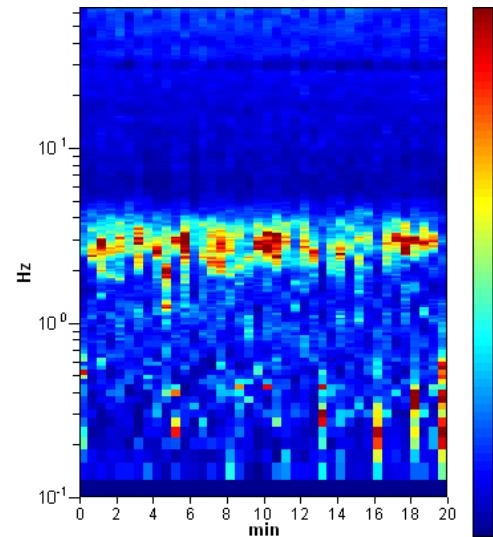
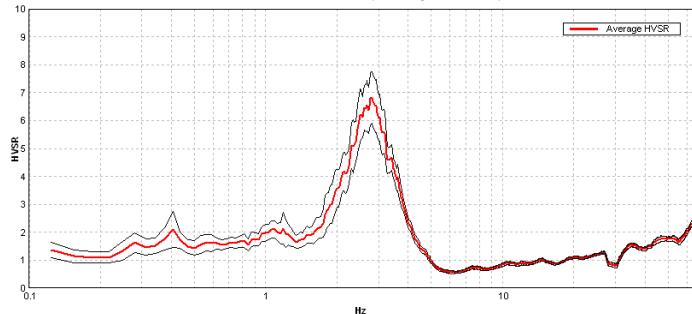
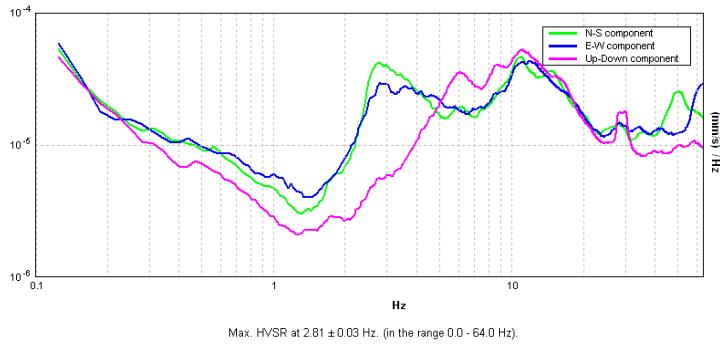
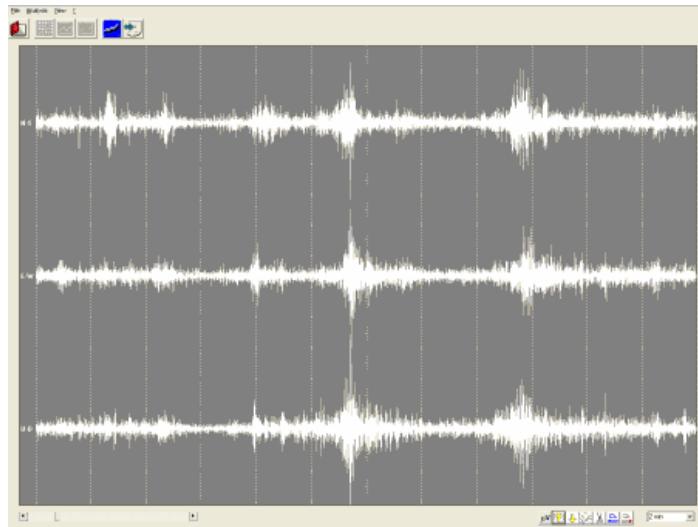
Metoda spektralnega razmerja med zapisom mikrotremorjev na horizontalnih in vertikalni komponenti:

$$HVSR(f) = \frac{\sqrt{H_{NS}(f) \cdot H_{EW}(f)}}{V(f)}$$

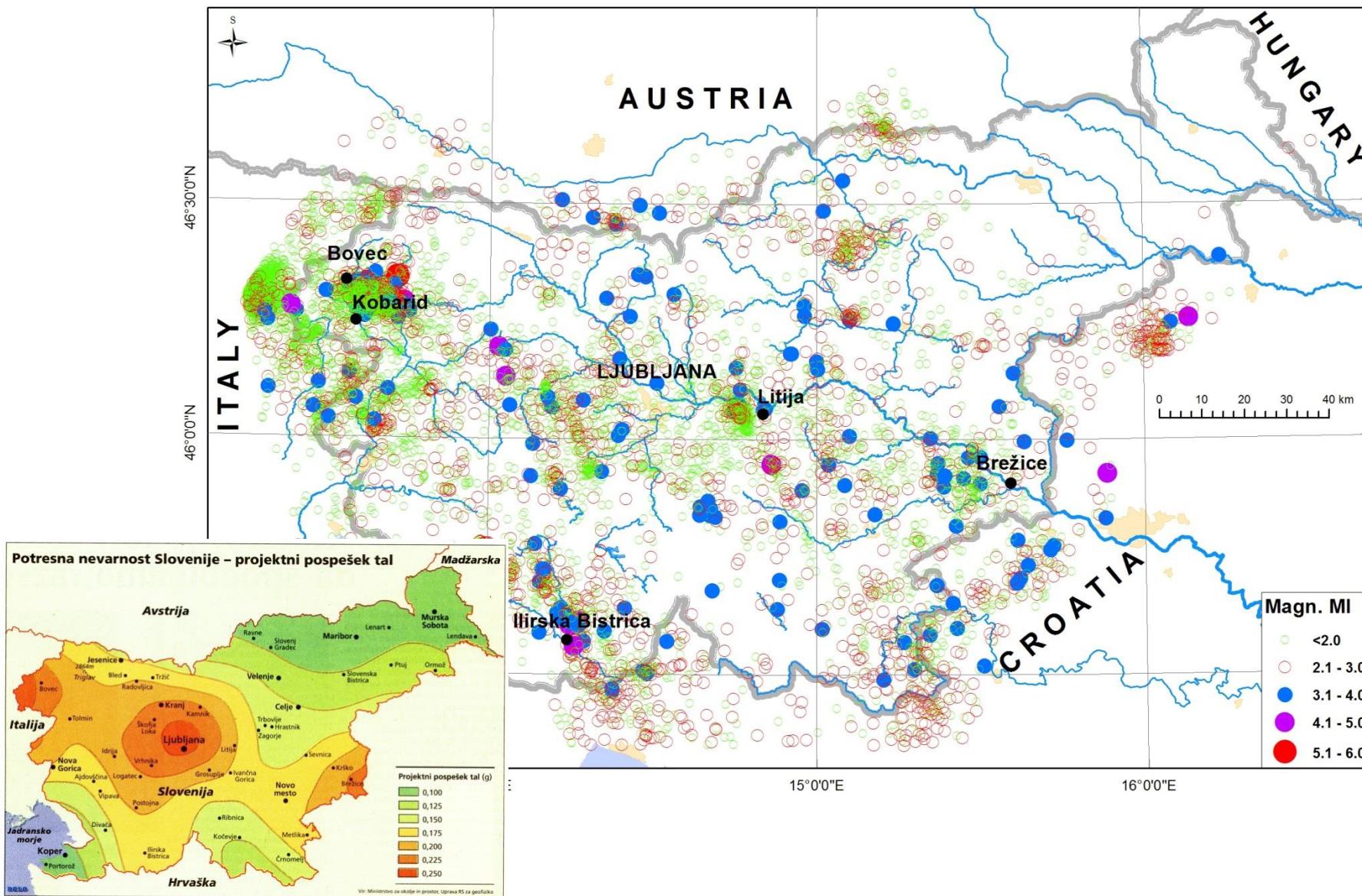


(Pitilakis, 2004)

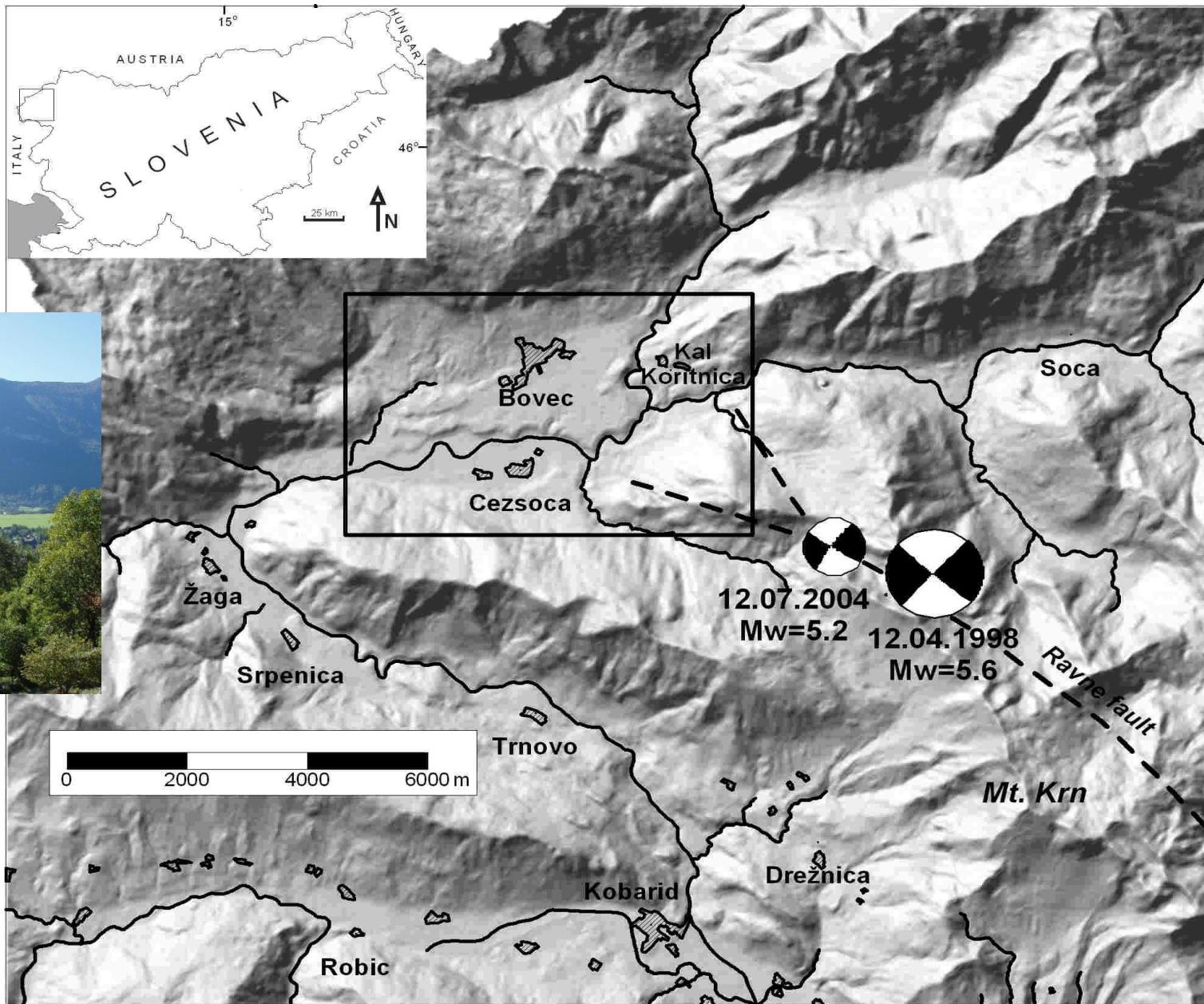
Horizontal to Vertical Spectral Ratio (HVSR)



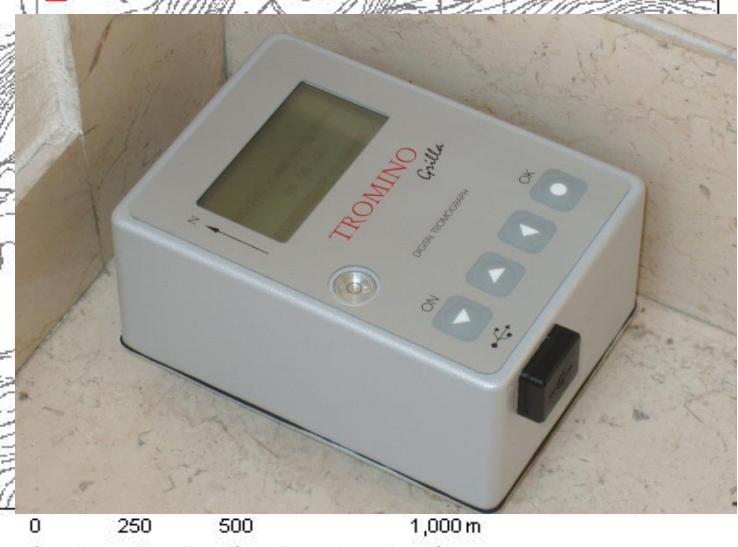
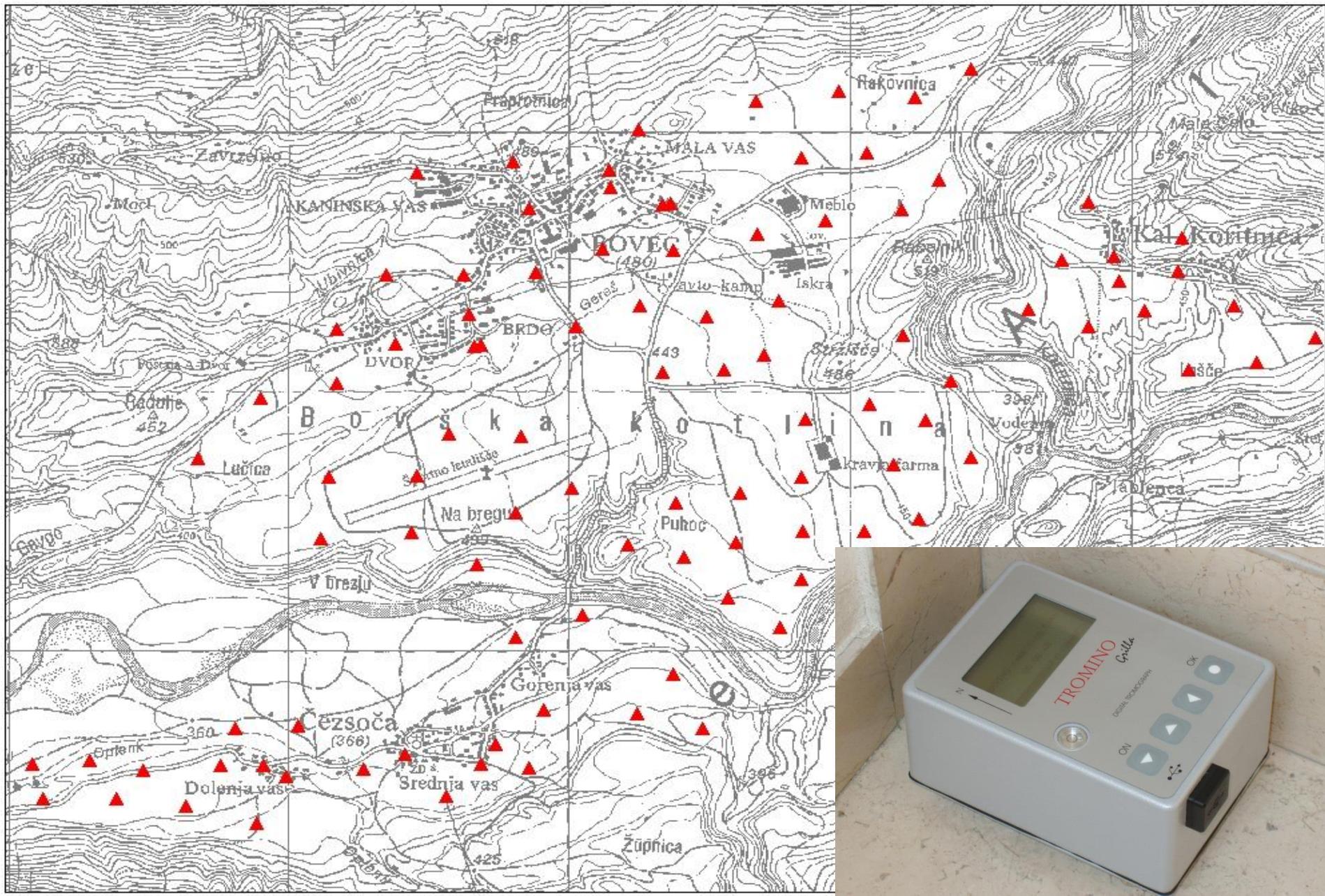
Raziskave nevarnosti resonance med tlemi in objekti v petih slovenskih mestih – opečne stavbe



Raziskave v Bovški kotlini po potresih 1998 in 2004



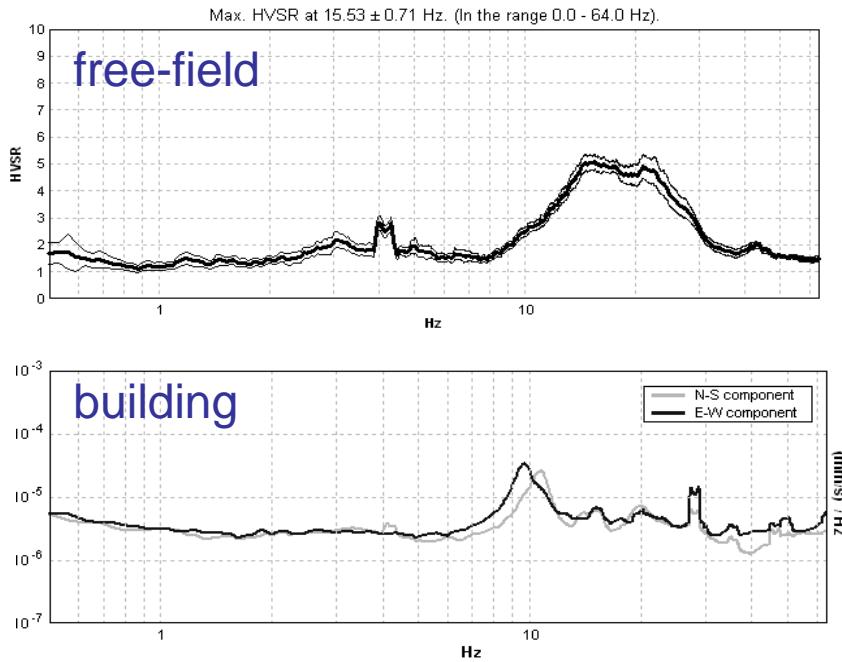
Raziskave z mikrotremorji (prosto površje)



Analiza resonance – Brdo (ne)

1998: slight damage (gr. 1)
2004: slight damage (gr. 1)

H3

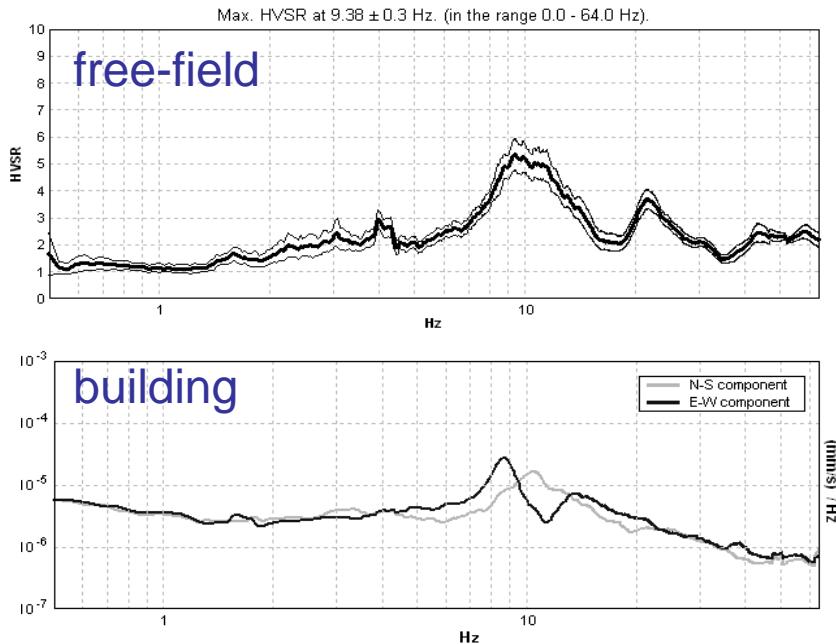


Analiza rezonance – Brdo (da)

1998: moderate damage (gr. 2)

2004: moderate damage (gr. 2)

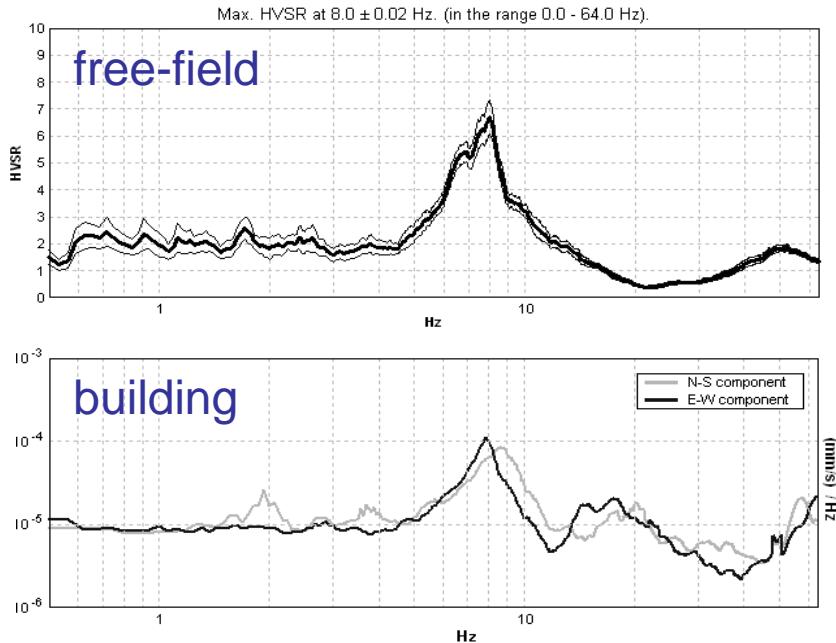
H2



Analiza rezonančnosti – Mala vas (da)

1998: very heavy damage (gr. 5)
new building constructed
2004: moderate damage (gr. 2)

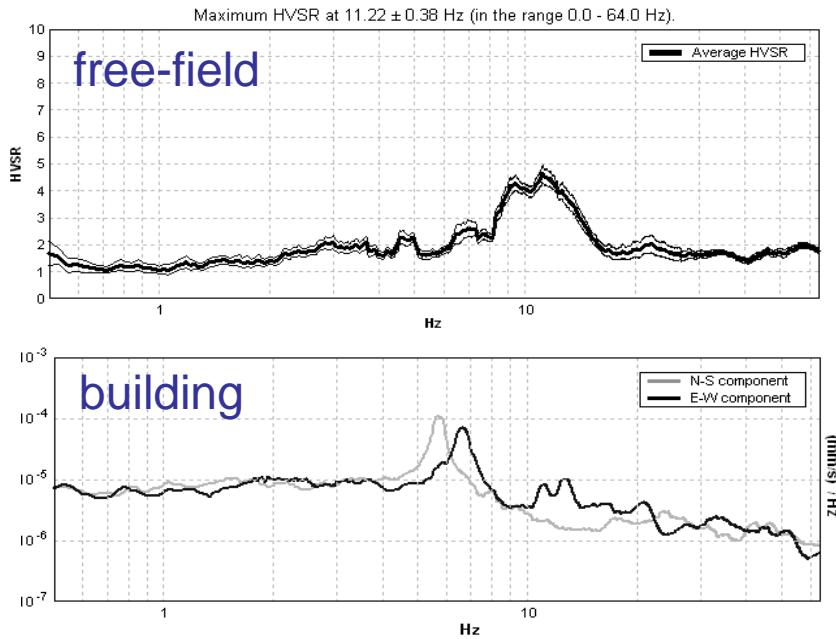
H1



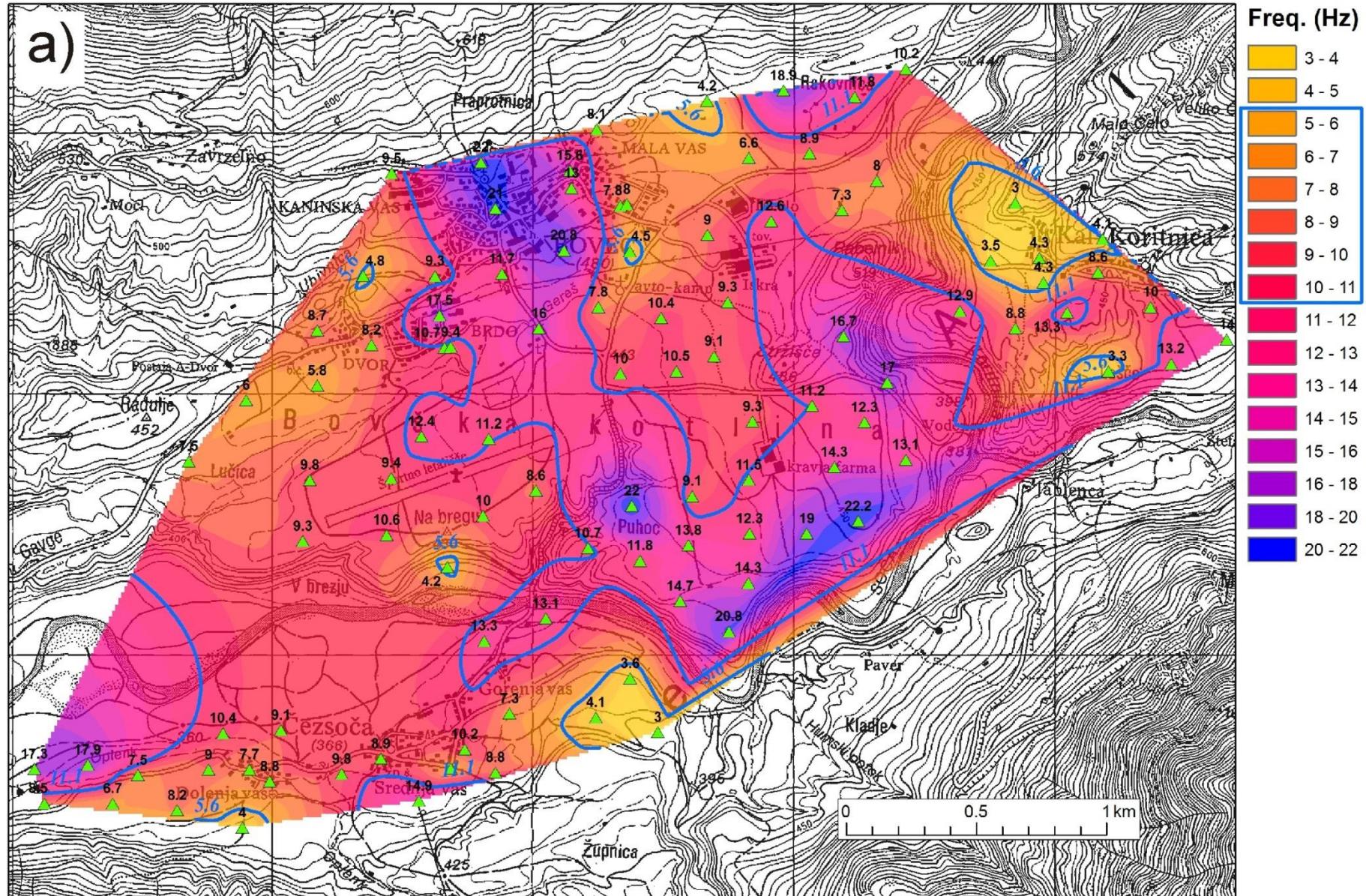
Analiza rezonance – Brdo (ne)

1998: slight damage (gr. 1)
2004: slight damage (gr. 2)

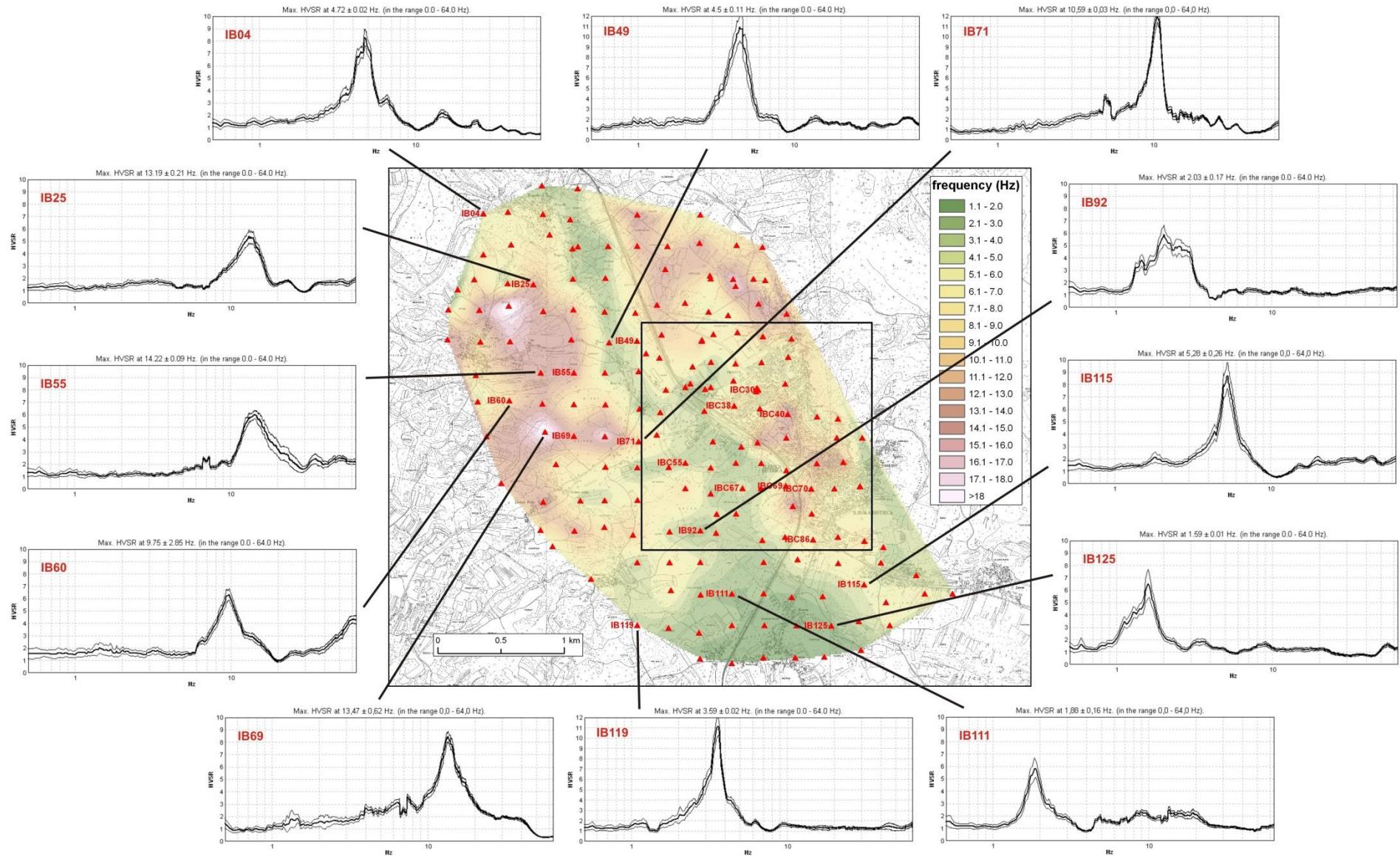
H6



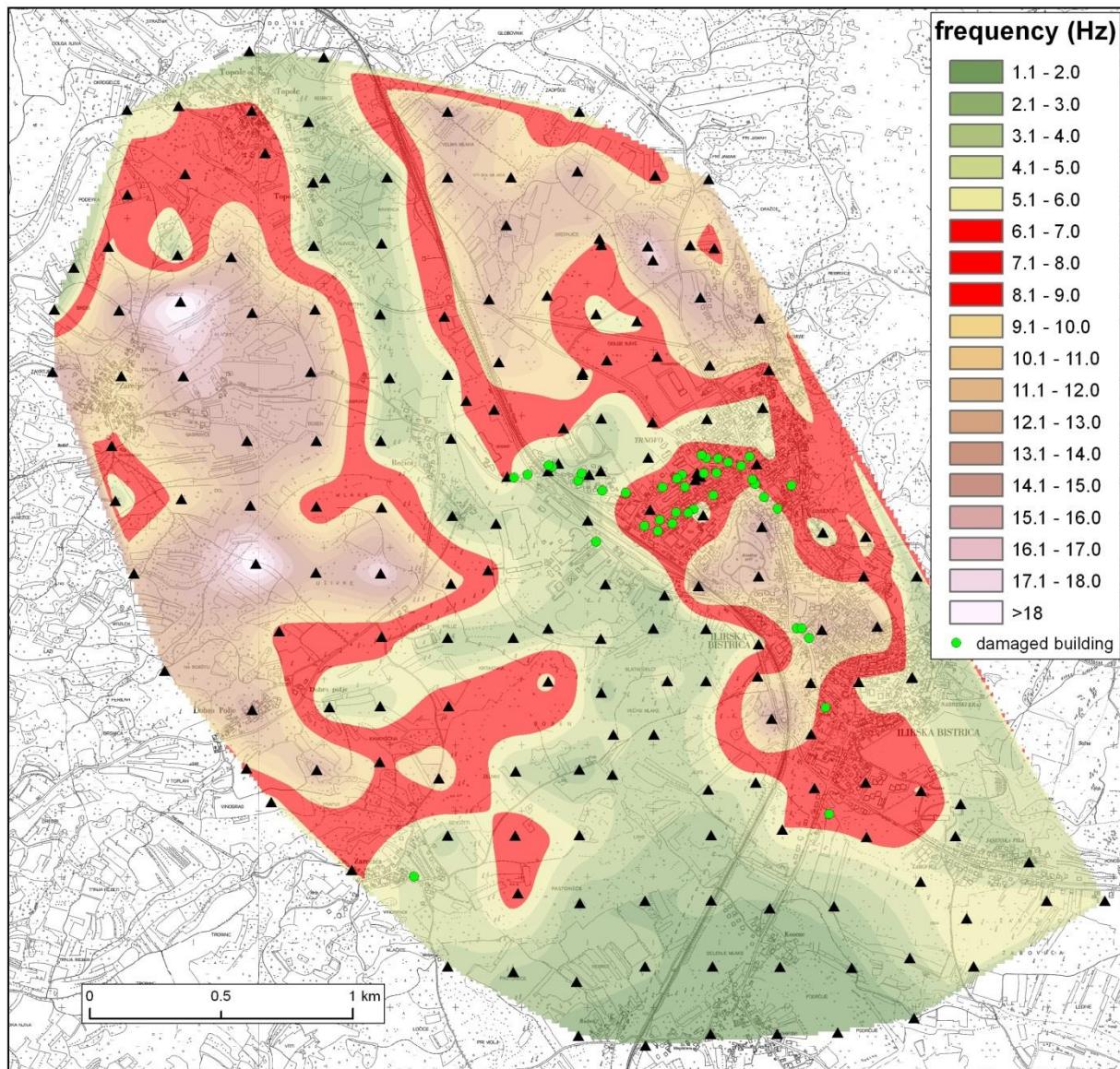
Karta lastne frekvence sedimentov – nevarnost resonance (5-11 Hz)



Raziskave v Ilirske Bistrici

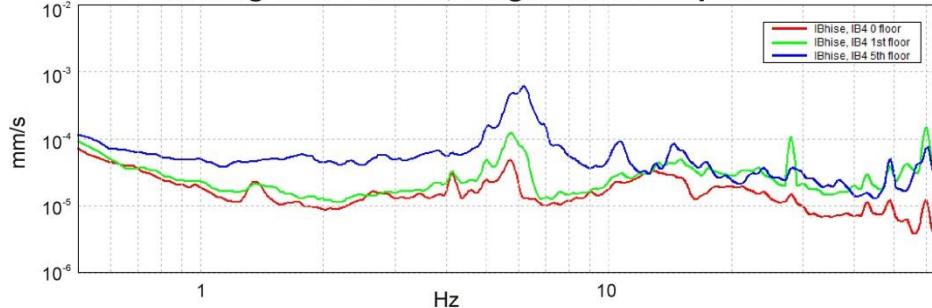


Ilirska Bistrica

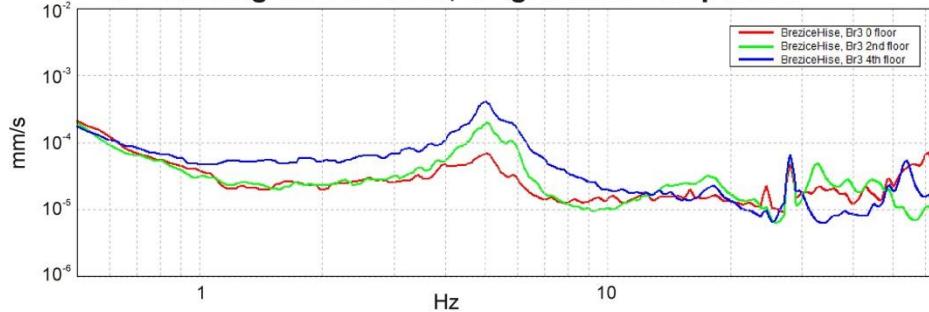


Meritve mikrotremorjev v 58 opečnih stavbah

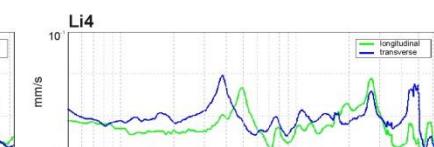
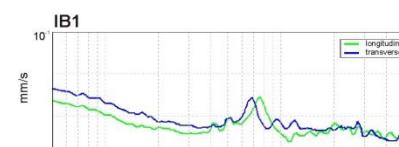
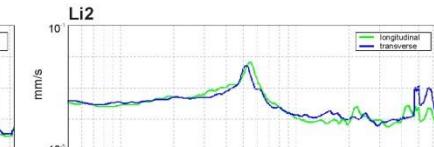
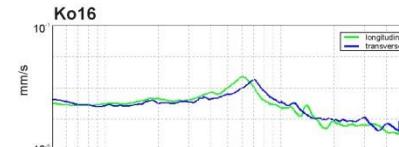
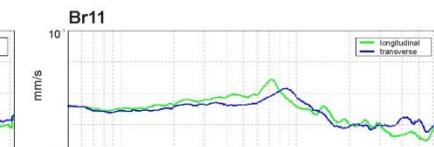
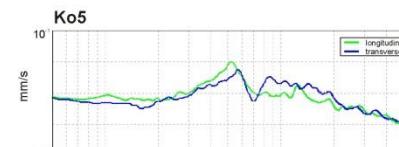
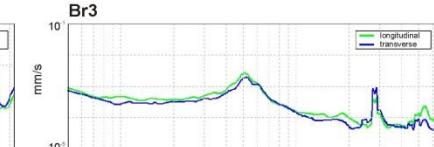
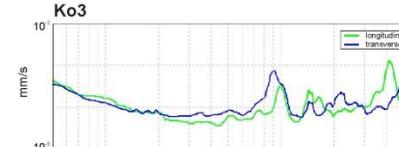
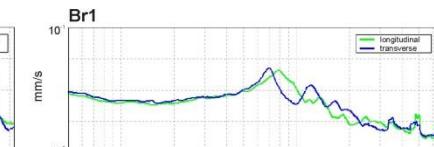
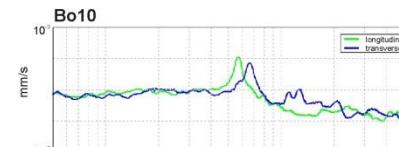
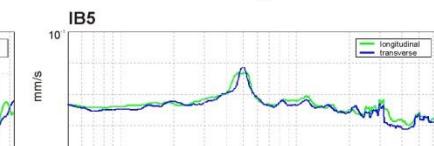
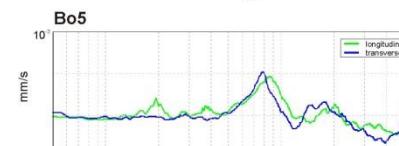
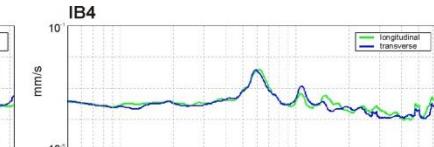
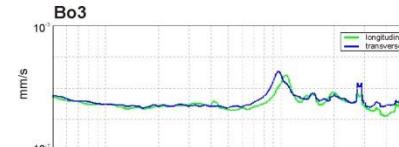
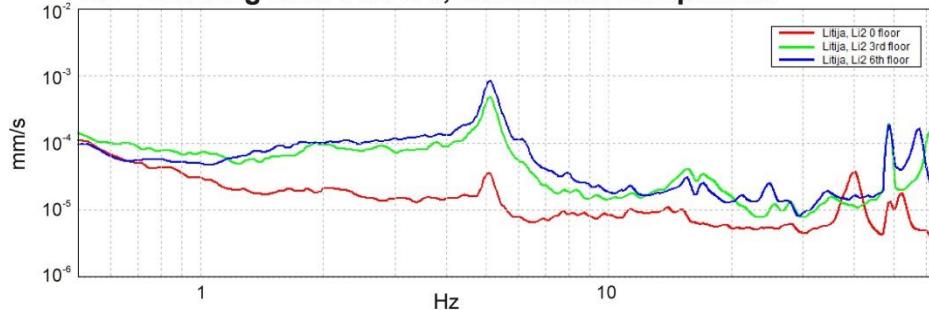
IB4 - building with 6 floors, longitudinal component



Br3 - building with 5 floors, longitudinal component



Li2 - building with 6 floors, transverse component

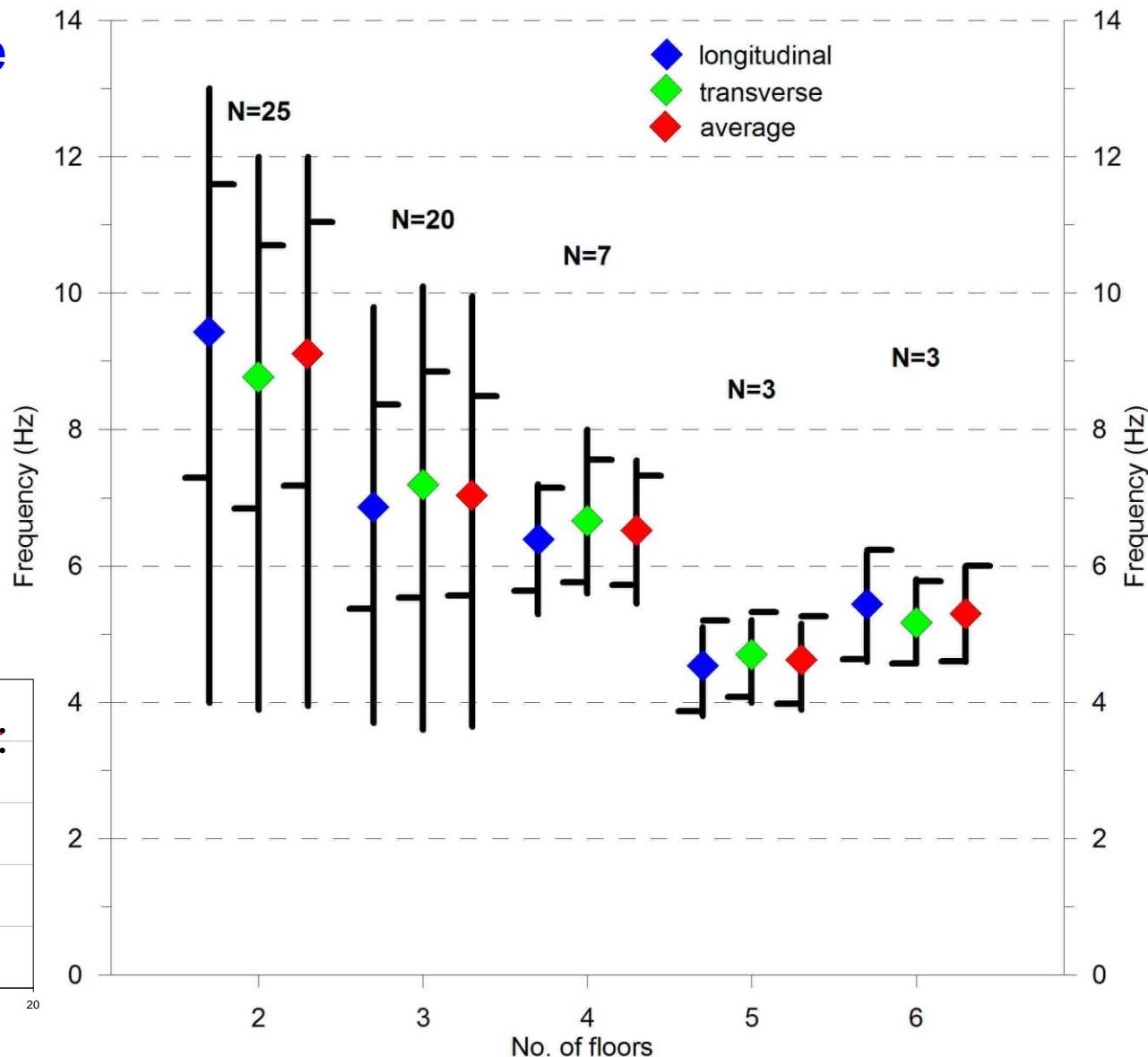
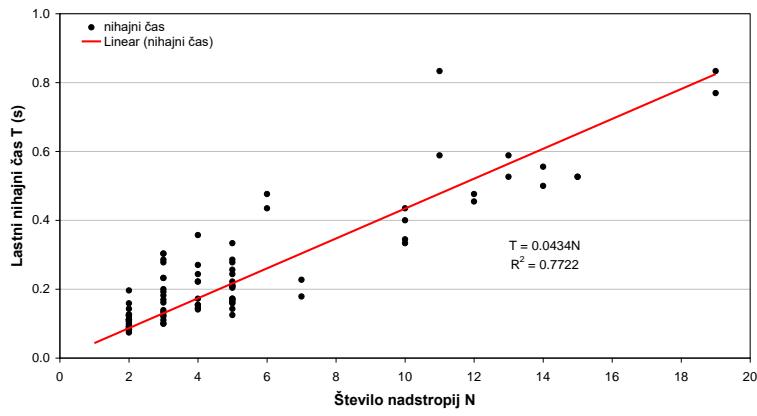


Vzdolžne, prečne in povprečne osnovne frekvence prevladujejo 2-3 etažne hiše; 5,6 – 11,1 Hz

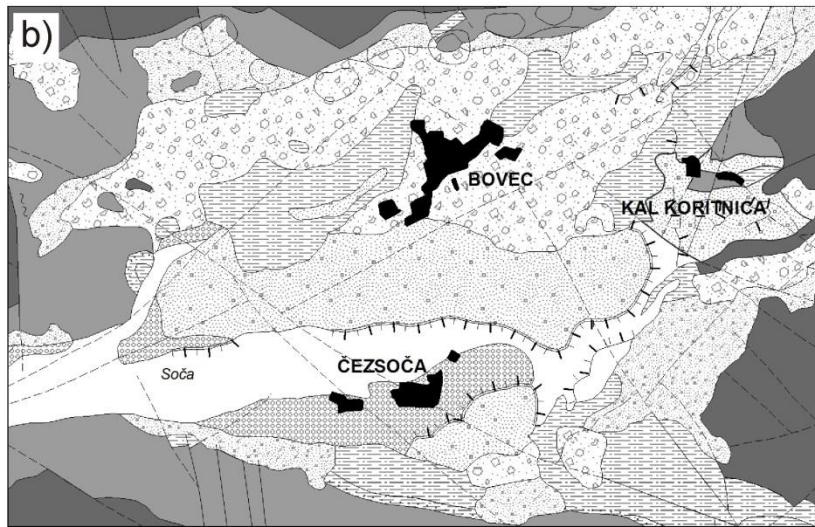
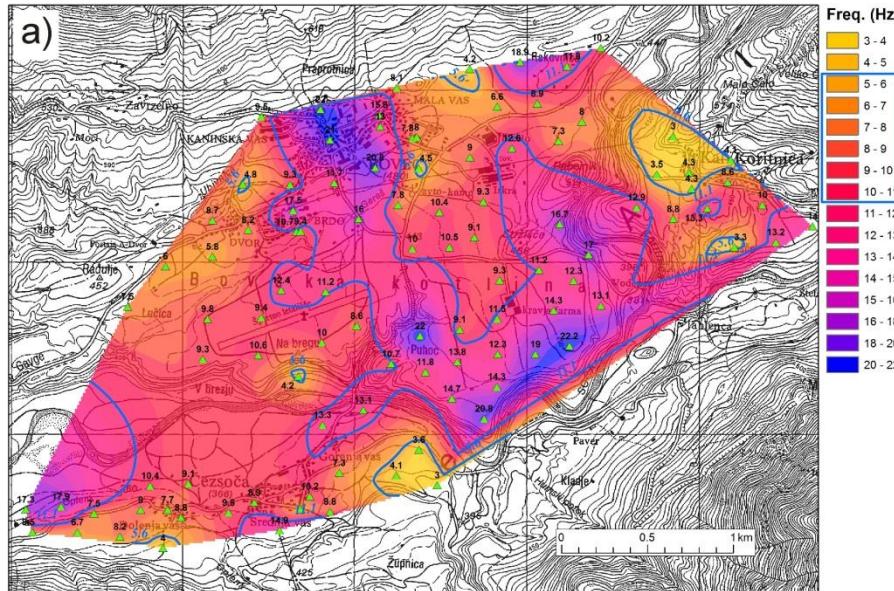
Opečne stavbe

Izpeljava regresijske enačbe za armirano-betonske stavbe:

$$T[s] = 0,0434s N[]$$



Bovška kotlina - 59 %



recent fluvial sediments - Q

scree, slope debris - Q

younger sand, gravel, conglomerate - Q

older sand, gravel, conglomerate (Bovec terrace) - Q

till and tillite - Q

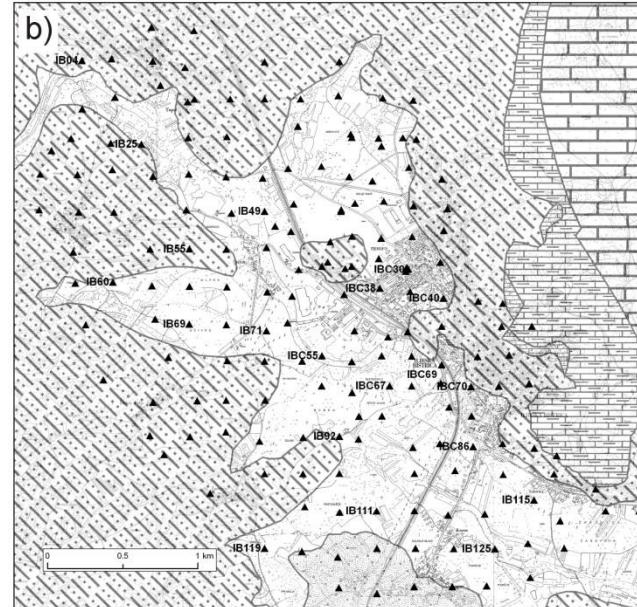
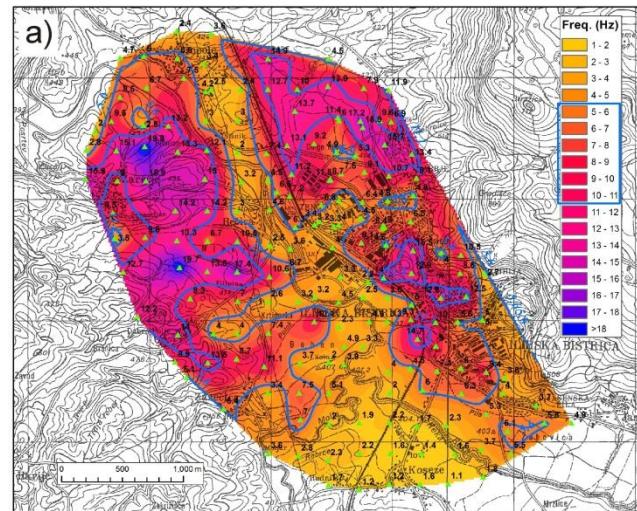
flysch - K

limestone - J

limestone - T

0 0.5 1 km

Ilirska Bistrica - 41 %



alluvium - Q

clay, sand, gravel - PI

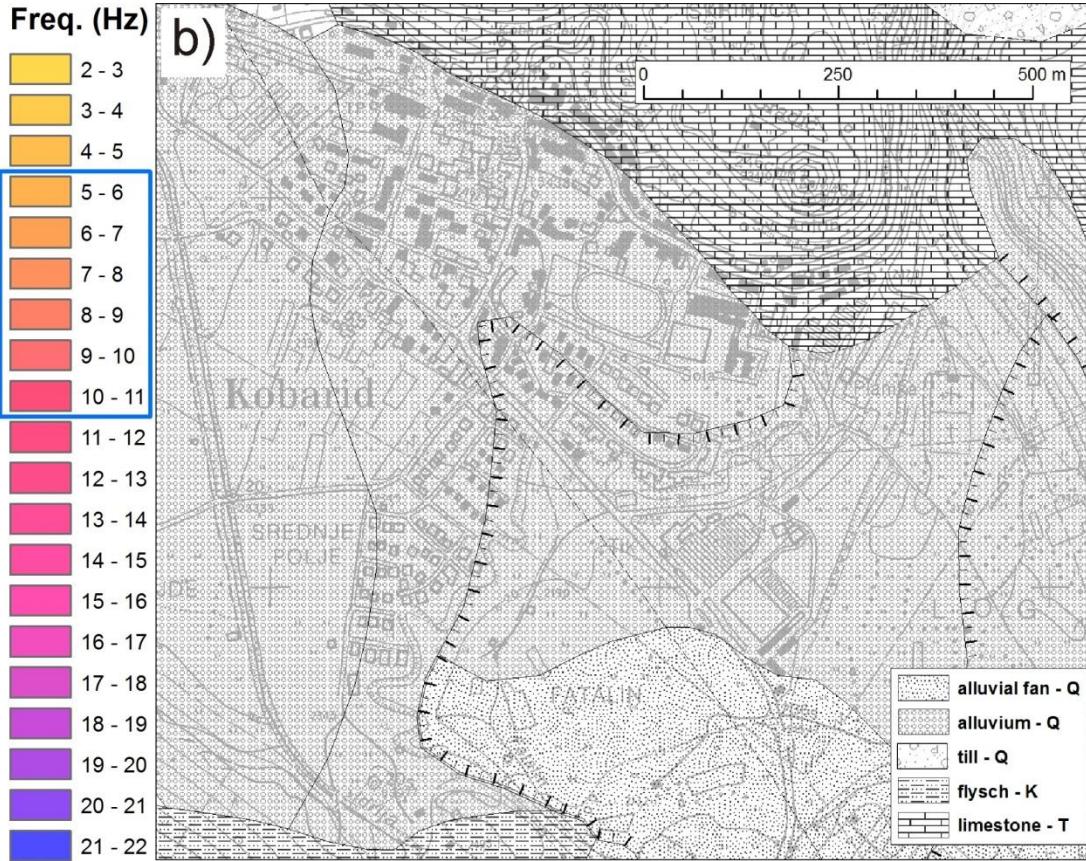
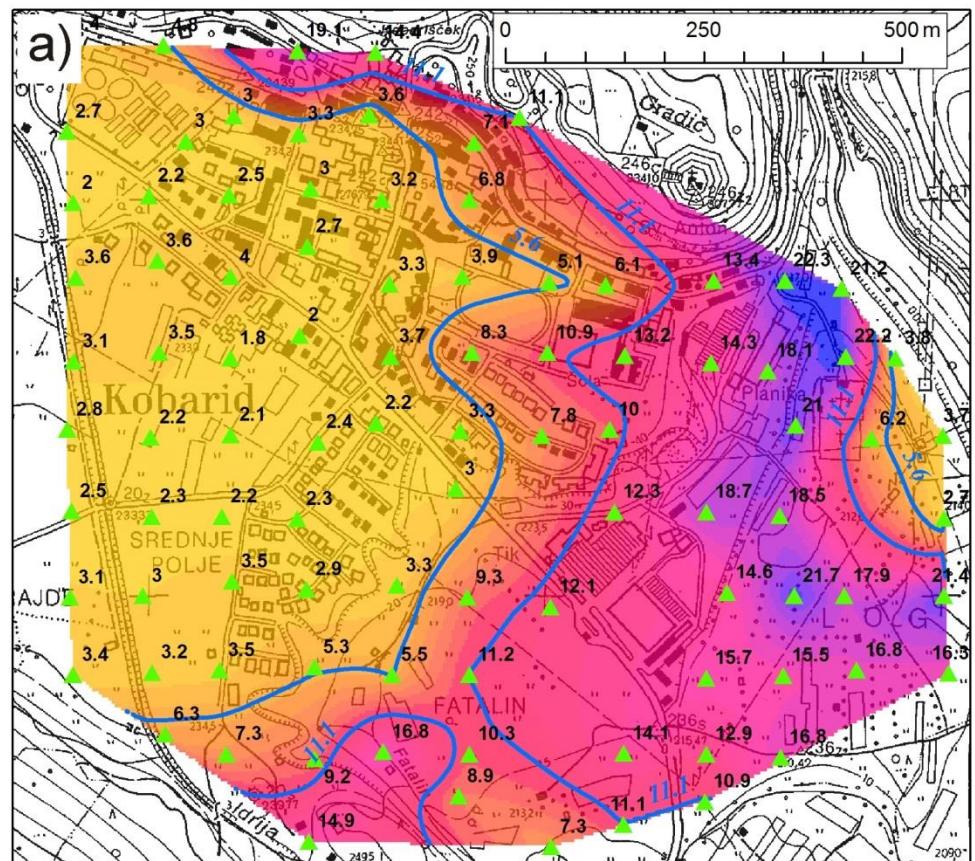
flysch - 2E

limestone - K, Pg

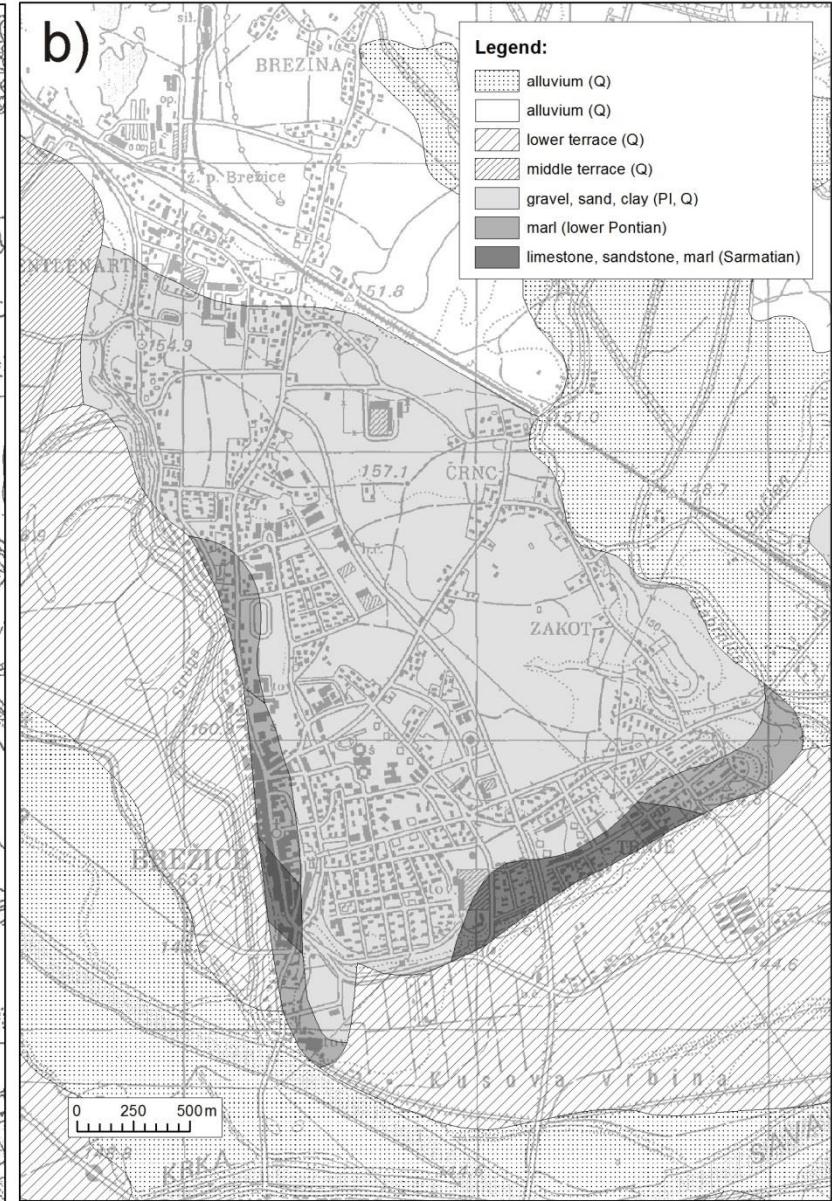
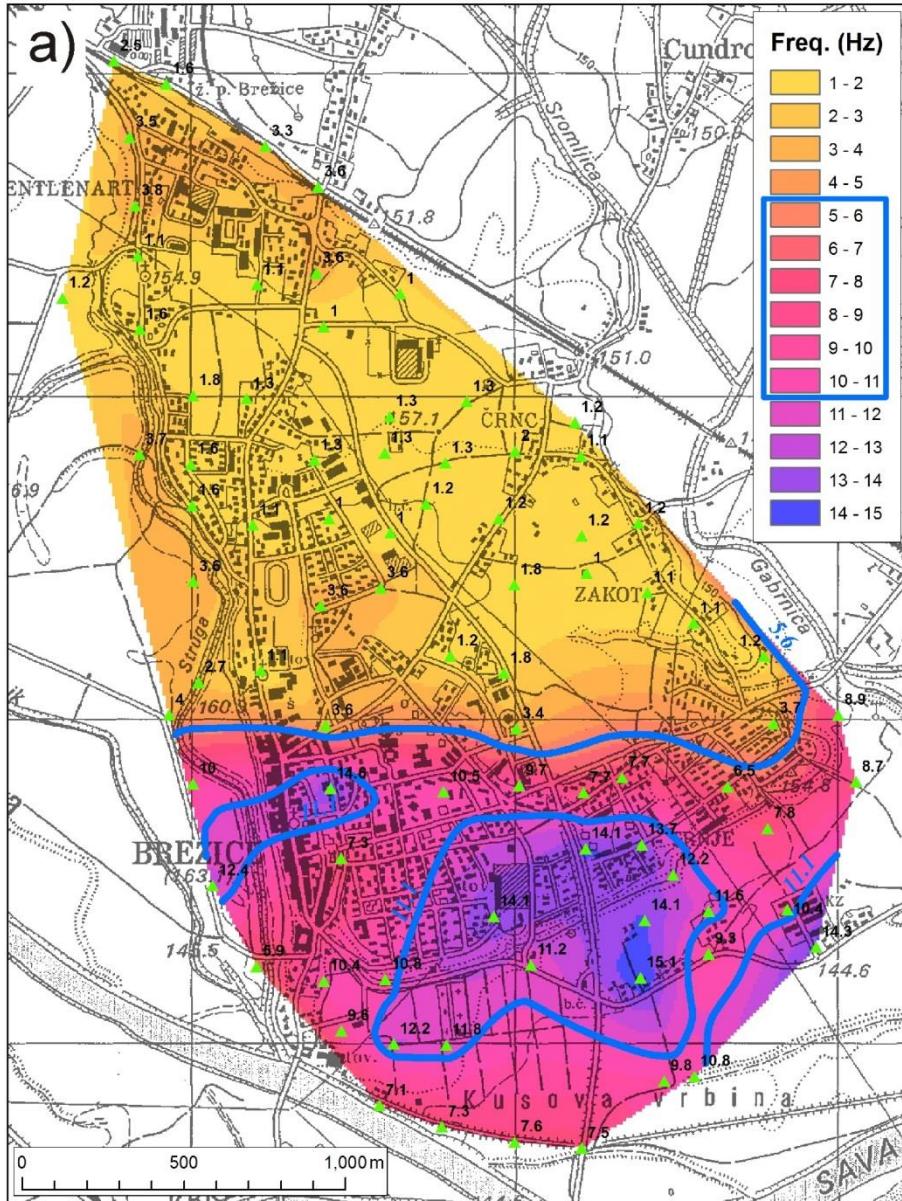
limestone - K^{2,3}

limestone - K_{1,2}

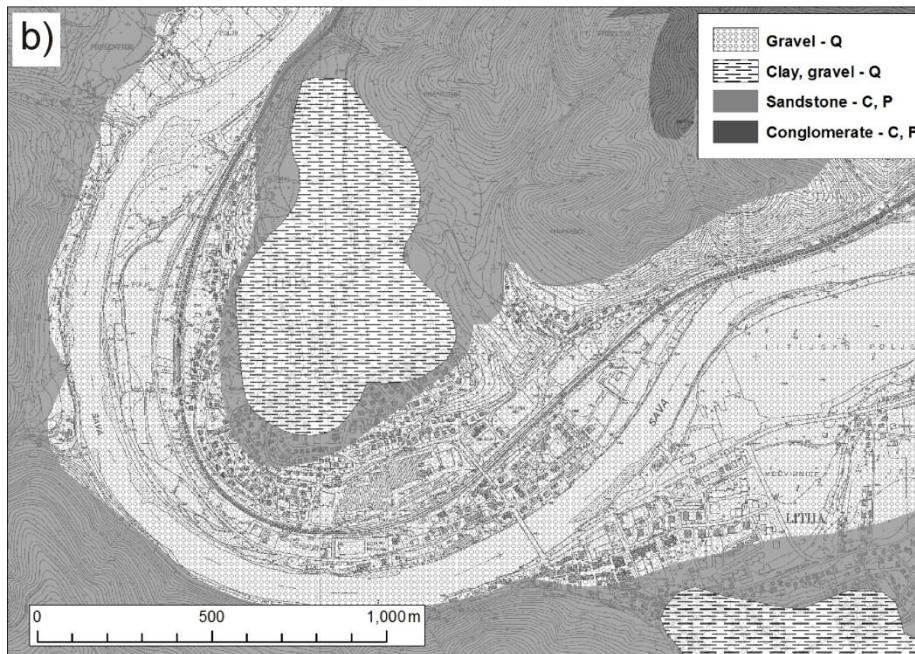
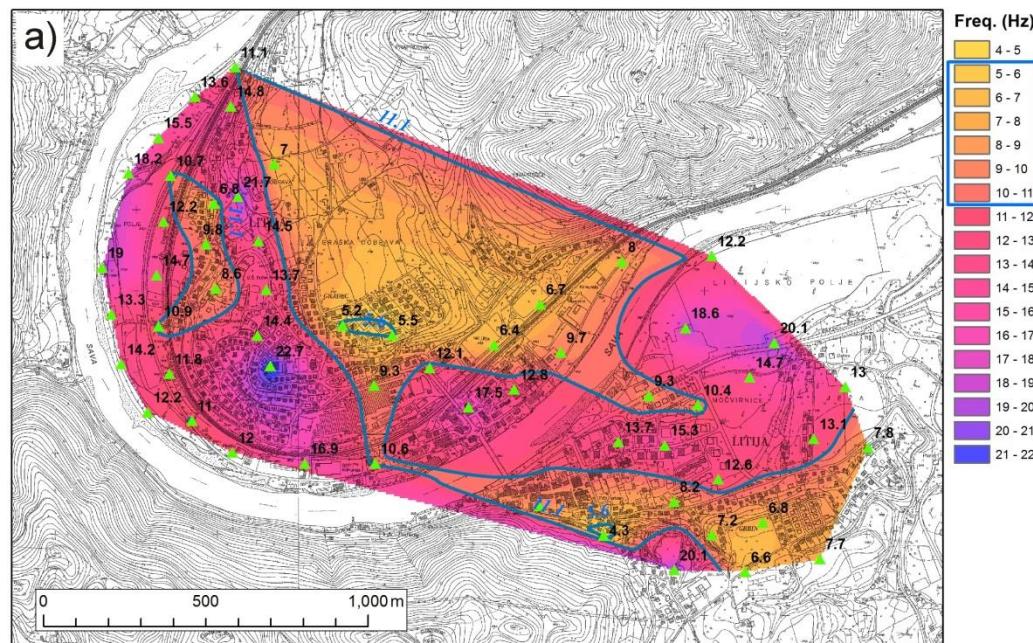
Kobarid - 22%



Brežice - 26 %



Litija - 49 %



Sprememba lastne frekvence zaradi strukturnih poškodb

