# Detaljna procjena stanja i istražni radovi

**doc.dr.sc. Mislav Stepinac**

# Istražni radovi
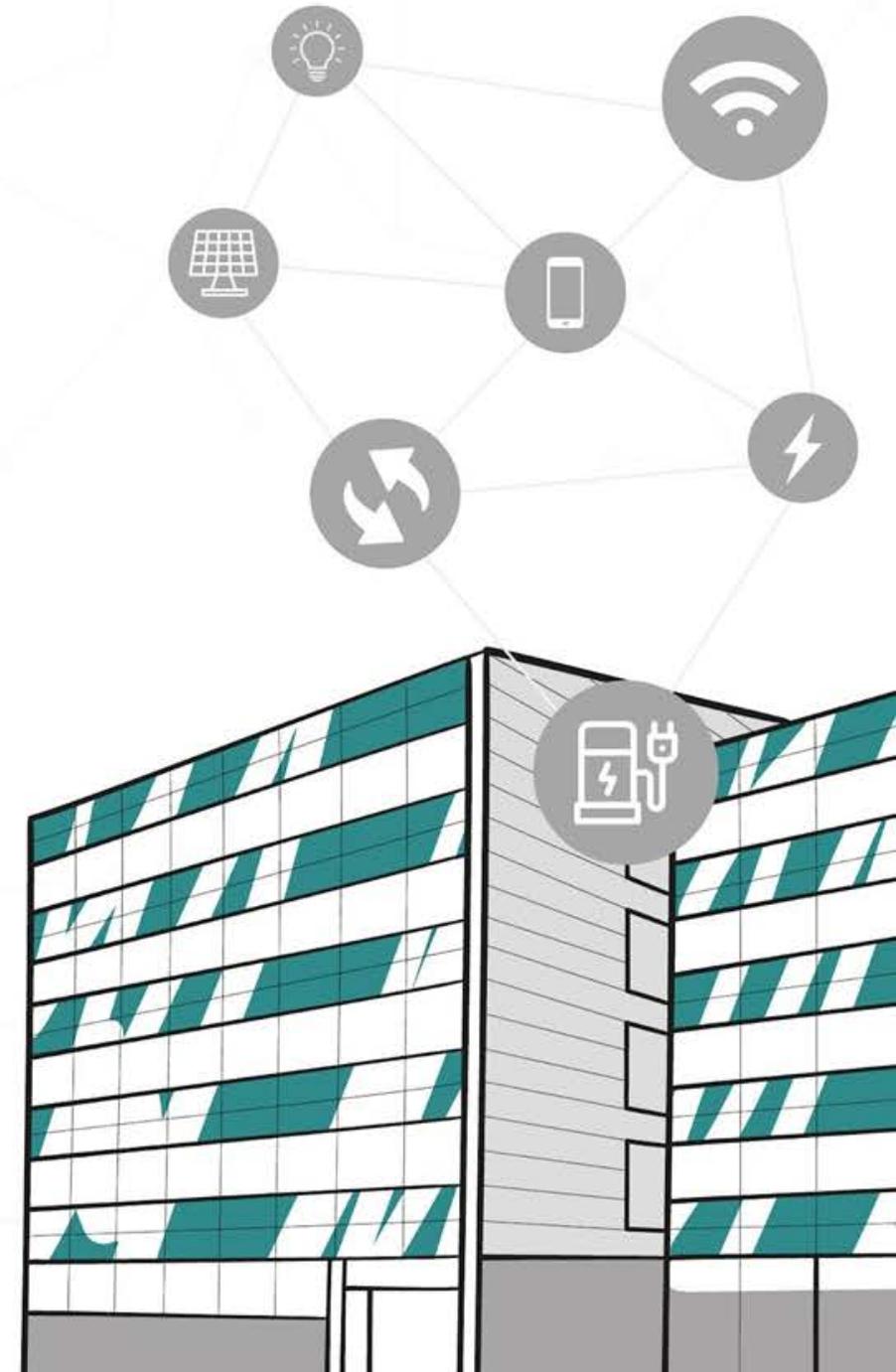
Procjena: Građevinski inženjeri su odgovorni za izgrađenu okolinu. Izuzev projektiranja novih građevina, odgovorni su i za održavanje pouzdanosti postojećih građevina. Procjena stanja uključuje sve aktivnosti vezane uz potvrđivanje pouzdanosti postojećih konstrukcija za buduću uporabu

| Pregled i ispitivanje | Nadogradnja | Verifikacija |
|---|---|---|

Pregled i ispitivanje: ispitivanja građevine na licu mjesta. Prilikom detaljnog pregleda prikupljaju se informacije o građevini, nakon čega se provode i ispitivanja materijala u laboratorijima te se na temelju tih podataka određuje osnova za analizu konstrukcije i potvrdu njezine pouzdanosti.

Nadogradnja (updating): Svi novi podaci vezani uz ponašanje konstrukcije, djelovanja na konstrukciju, uvjete okoliša ili svojstva materijala moraju se koristiti prilikom svake iduće analize konstrukcije kako bi se dobili pouzdani rezultati.

Verifikacija: Na temelju analize provedene na postojećim građevinama potrebna je odgovarajuća potvrda da je konstrukcijsko ponašanje i pouzdanost na zahtijevanoj razini

Popravak, obnova i pojačanje

**Istražni radovi**

**ARES Istraživačka grupa**

**Voditelj + doktorand**

*T1* – Zidane konstrukcije

T. Renić, I. Hafner

Suradnici
doc.dr.sc. C. Bedon
prof. T. Kišiček
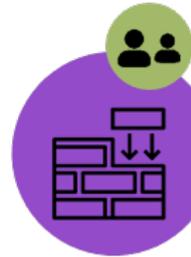
*T2* – Drvene konstrukcije

doc.dr.sc. R. Jockwer
J. Barbalić
N. Perković

Suradnik
prof. V. Rajčić

*T3* – Pouzdanost

doc.dr.sc. R. Jockwer

Suradnici
doc.dr.sc. G. Fink
dr. Daniel Honfi

*Monitoring i eksperimenti*

Janko Košćak

Suradnici
doc.dr.sc. C. Bedon
prof. V. Rajčić
prof. T. Kišiček

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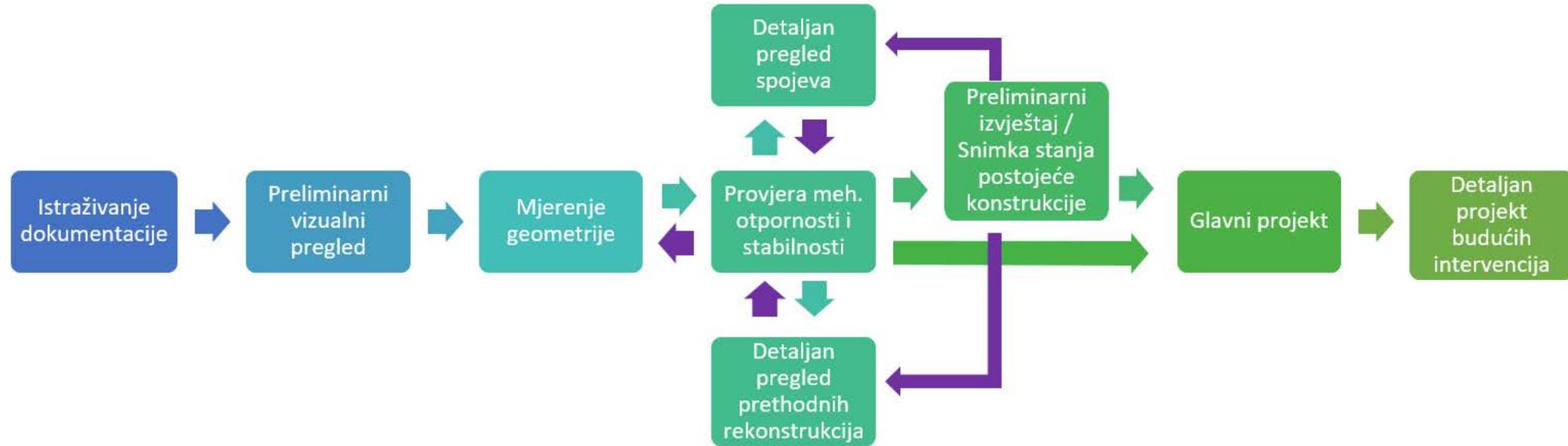
# Procjena stanja

Stepinac, M., Rajčić, V., Barbalić, J.: Inspection and condition assessment of existing timber structures, *GRAĐEVINAR, 69* (2017) 9, pp. 861-873, doi: https://doi.org/10.14256/JCE.1994.2017

# Procjena stanja

# Postojeće građevine
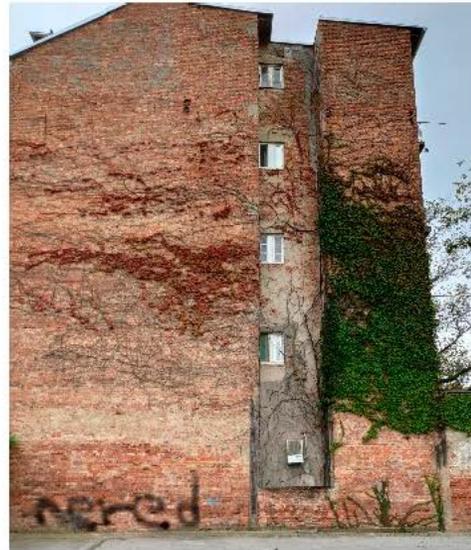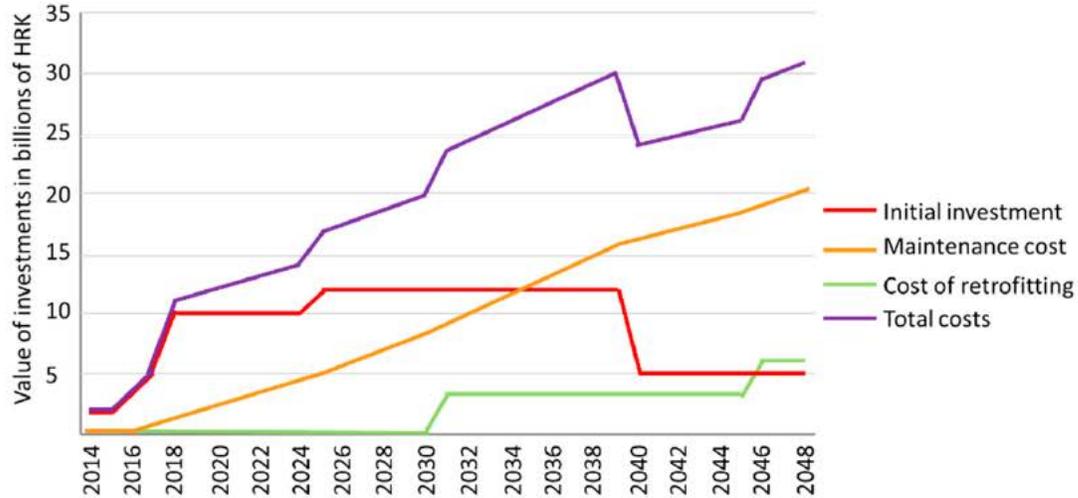
Stepinac, M.; Kisicek, T.; Renić, T.; Hafner, I.; Bedon, C. Methods for the Assessment of Critical Properties in Existing Masonry Structures under Seismic Loads—The ARES Project. *Appl. Sci.* **2020**, *10*, 1576. https://doi.org/10.3390/app10051576
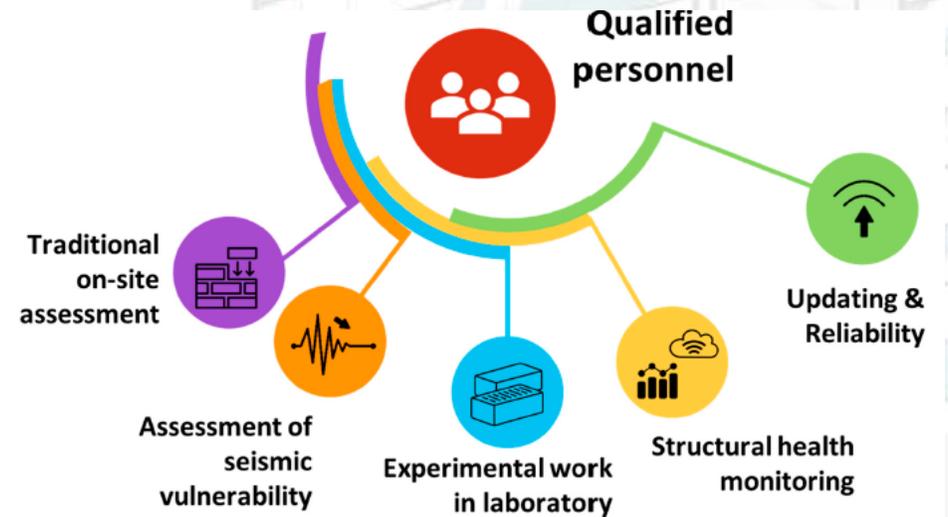
# Brzi pregled

- Temelj je za određivanje stanja zgrade
- Besplatan je, dok je nalaz na teret podnositelja
- Izrađuju ga ovlašteni inženjer građevine ili sudski vještaci.

# HRN EN 1998-3

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# Opći podaci i povijest

Dostupna dokumentacija

**1**

**2**

Propisi i norme

**4**

**3**
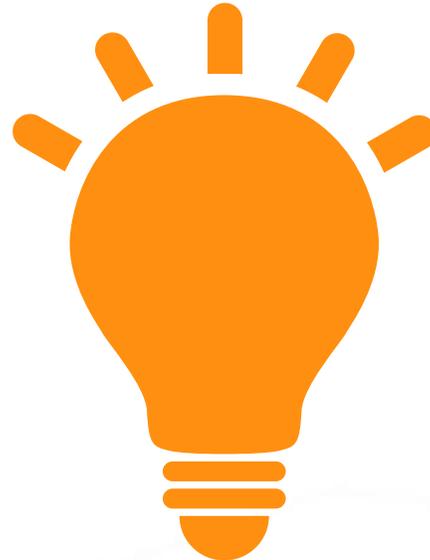
Laboratorijska mjerenja

Terenska ispitivanja

# Zahtijevani ulazni podaci

## KONSTRUKCIJA

Identifikacija konstruktivnog sustava

Razrada detalja (nepravilna?)

Nekonstruktivni dijelovi

## GEOMETRIJA I ARHITEKTURA

Dimenzije

Presjeci

Vrijednost zgrade

Baština + umjetnine

## MATERIJAL

Identifikacija materijala

Nedostaci materijala

Mehanička svojstva

## IZVORNI PRORAČUN

Izvorni kriteriji proračuna

Q faktor ako je moguće

## UPORABA

Opis uporabe

Ponovna identifikacija uporabnih opterećenja

## OŠTEĆENJA

Podaci o oštećenjima i prošlim popravcima

Prošli potresi i ponašanje zgrade

# Razina znanja

OGRANIČENO RZ1

UOBIČAJENO RZ2

POTPUNO RZ3

GEOMETRIJA 1

DETALJI 2

MATERIJALI 3

# RZ 1

**OGRANIČENO RZ1**

Lokalne provjere
Linearni modeli dopušteni

**GEOMETRIJA** 1
- Iz jednostavnog snimka ili arhivskih nacrta
- Ako postoje odstupanja potrebno detaljno provjeriti geometriju

**DETALJI** 2
- Konstrukcijski detalji nisu poznati iz nacrta
- Detalji se pretpostavljaju prema stilu i vremenu gradnje

**MATERIJALI** 3
- Ne postoje saznanja o mehaničkim karakteristikama materijala
- Karakteristike se pretpostavljaju prema stilu i vremenu gradnje

**RZ 2**

nZEB
TRENING CENTAR

**UOBIČAJENO RZ2**

Provjera konstrukcije

Linearni i nelinearni modeli

**GEOMETRIJA** 1

Iz opsežnog snimka ili arhivskih nacrta

Ako postoje odstupanja potrebno detaljno provjeriti geometriju

**DETALJI** 2

Konstrukcijski detalji su poznati iz opsežnog in-situ pregleda

Provesti ograničen pregled kritičnih detalja

**MATERIJALI** 3

In-situ ispitivanja mehaničkih karakteristika materijala

Ograničen broj ispitivanja

EIHP
Energetski institut Hrvoje Požar

Iceland
Liechtenstein
Norway grants

Sveučilište u Zagrebu
Građevinski fakultet

13

**RZ 3**

**POTPUNO RZ3**

Provjera konstrukcije
Linearni i nelinearni modeli

**GEOMETRIJA** 1

Iz sveobuhvatnog snimka i arhivskih nacrta
Ako postoje odstupanja potrebno detaljno provjeriti geometriju

**DETALJI** 2

Konstrukcijski detalji su poznati iz sveobuhvatnog in-situ pregleda
Provesti ograničen pregled kritičnih detalja

**MATERIJALI** 3

In-situ sveobuhvatnih ispitivanja mehaničkih karakteristika materijala
Ograničen broj ispitivanja

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# Razine znanja

Materijalni podaci:

Vizualni snimak, potpuni snimak, detalji, ograničeni, opsežni i sveobuhvatni pregledi in-situ

Tlačna, posmična i vlačna čvrstoća te moduli elastičnosti i posmika.

Preporučeni najmanji zahtjevi za različite razine pregleda i ispitivanja

| | Pregled (detalja) | Ispitivanje (materijala) |
|---|---|---|
| | Za svaki tip primarnih elemenata (greda, stup, zid) | |
| Razina pregleda i ispitivanja | Postotak elemenata za kontrolu detalja | Uzorci materijala po katu |
| Ograničena | 20 | 1 |
| Opsežna | 50 | 2 |
| Sveobuhvatna | 80 | 3 |

Materijalni podaci:
**SREDNJE VRIJEDNOSTI MATERIJALA** dobivene in-situ ispitivanjem dijele se s **FAKTOROM POVJERENJA (FP)**

$$FP_{RZ1} = 1,35$$

$$FP_{RZ2} = 1,20$$

$$FP_{RZ3} = 1,00.$$

| NDT Method | Devices/Test | What Is Measured? | How Is It Measured? | References |
|---|---|---|---|---|
| Visual inspection | / | Quality of masonry (mechanical parameters, dimension, shape), mortar and wall connections | Without a device, using a base/set of rules (i.e., Masonry quality index-MQI) | Borri et al. [27] |
| Measurement of masonry unit hardness | Rebound hammer (Schmidt hammer) | Compressive strength of masonry units, mortars and built masonry | A predefined number of tests is conducted in both horizontal and vertical direction (with a calibration needed) | Breysse and Martínez-Fernández [28], Sýkora et al. [29] |
| Measurement of reinforcement location | Ground Penetrating Radar (GPR) | Location (depth) of reinforcement | The device is placed on the measured surface and moved along a linear axis (with a calibration needed), transmitting radio wave signals into a structure and detecting echoes | Agred, Klysz and Balayssac [30] |
| Stress wave transmission | Ultrasonic Pulse Velocity test (UPV) test/Resonant frequency test (RF) | Compressive strength of concrete or masonry | UPV-two transducers are placed on two sides of the specimen after which the time of wave travel is measured RF-a piezometric sensor is used with different attachment techniques to obtain resonant frequency | Sajid et al. [31] |
| Ultrasonic velocity testing | Impact hammer and accelerometer | Characterization of masonry wall homogeneity and variability | On opposite sides of the wall, an impact hammer and an accelerometer are placed. The mechanical impulse is generated by the hammer striking the material and the signal is then received by the accelerometer. | Mesquita et al. [32] |
| Sonic velocity testing | Impact hammer and accelerometer | Location of heterogeneities, voids or inclusions of other materials in masonry elements | On opposite sides of the wall, an impact hammer and an accelerometer are placed, after which the mechanical impulse is generated by the hammer striking the material and the signal is then received by the accelerometer | Martini et al. [33] Valluzzi et al. [34] |
| Surface penetrating radar | Ground Penetrating Radar (GPR) | Location (depth) of reinforcement, thickness of elements, position of voids and moisture content | The device is placed on the measured surface and moved along a linear axis (with a calibration needed) transmitting radio wave signals into a structure and detecting echoes | Martini et al. [33] Wai-Lok Lai, Dérobert and Annan [35] |

## Methods for the Assessment of Critical Properties in Existing Masonry Structures under Seismic Loads—The ARES Project

Mislav Stepinac [1,*], Tomislav Kisicek [1], Tvrtko Renić [1], Ivan Hafner [1] and Chiara Bedon [2]

1 Faculty of Civil Engineering, University of Zagreb, 10000 Zagreb, Croatia; tomislav.kisicek@grad.unizg.hr (T.K.); tvrtko.renic@grad.unizg.hr (T.R.); ivan.hafner@grad.unizg.hr (I.H.)
2 Department of Engineering and Architecture, University of Trieste, 34127 Trieste, Italy; chiara.bedon@dia.units.it
* Correspondence: mislav.stepinac@grad.unizg.hr

Abstract: Masonry structures are notoriously vulnerable to horizontal actions caused by earthquakes. Given the high seismicity of the European region, and that the European building stock comprises a lot of masonry buildings, knowledge about their structural response to seismic excitation is particularly important, but at the same time difficult to determine, due to the heterogenous nature of materials and/or constructional techniques in use. An additional issue is represented by the current methods for mechanical properties assessment, that do not provide a reliable framework for accurate structural estimations of existing buildings characterized by different typological properties. Every structure, in other words, should be separately inspected in regard to its mechanical behaviour, based on dedicated approaches able to capture potential critical issues. In this review paper, an insight on the Croatian ARES project is presented (Assessment and Rehabilitation of Existing Structures), including a state-of-the-art of the actual building stock and giving evidence of major difficulties concerning the assessment of existing structures. The most commonly used techniques and tools are compared, with a focus on their basic features and field of application. A brief overview of prevailing structural behaviours and Finite Element numerical modelling issues are also mentioned. As shown, the general tendency is to ensure "sustainable" and energy-efficient building systems. The latter, however, seem in disagreement with basic principles of structural maintenance and renovation. The aim of the ongoing ARES project, in this context, is to improve the current knowledge regarding the assessment and strengthening of structures, with a focus on a more reliable design and maintenance process for existing masonry buildings.

Keywords: structural assessment; masonry buildings; earthquakes; seismic loads; existing structures; reliability; rehabilitation; risk

# Vizualni pregled

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# Sklerometar za mort

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# Sonična ispitivanja
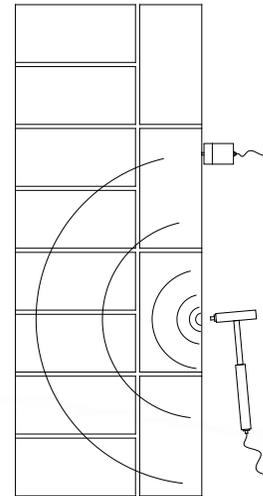


$$V_p = \sqrt{\frac{E_d}{\rho} \frac{1-\nu}{(1+\nu)(1-2\nu)}}$$

Prazna reška

$\sigma_0$

$A_g$
$A_d$

$H_u$

$\sigma_0$

# Flat jack

Construction and Building Materials
Volume 384, 27 June 2023, 131407
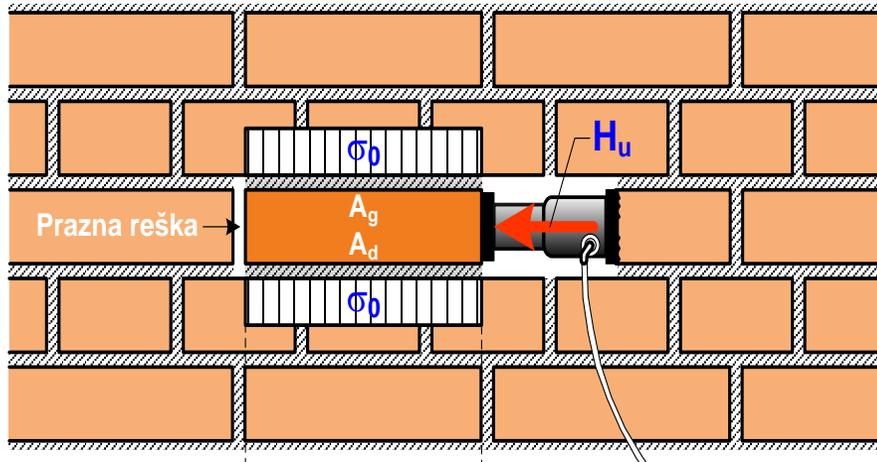
Review

Review of the flat-jack method and lessons from extensive post-earthquake research campaign in Croatia

Luka Lulić [a], Mislav Stepinac [a], Marko Bartolac [a], Paulo B. Lourenço [b]

1. Štemerica
2. Ekscentrična kružna pila
3. Plosnata preša
4. Hidraulična pumpa
5. Hidraulično crijevo
6. Komparator
7. Cilindrična preša+ hidraulična pumpa
8. Laptop
9. Metalni diskovi
10. Ljepilo
11. Ulje
12. Induktivni senzor
13. Sustav za prikupljanje podataka
14. Shema za test
15. Doza
16. Zaštitni limovi
17. Voda
18. Industrijski usisavač
19. Laserski skener
20. Produžni kabel
21. Električni generator

24
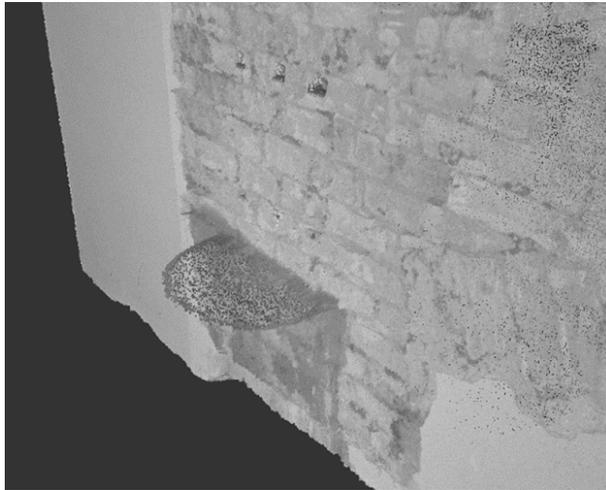
# Eksperimentalna modalna analiza
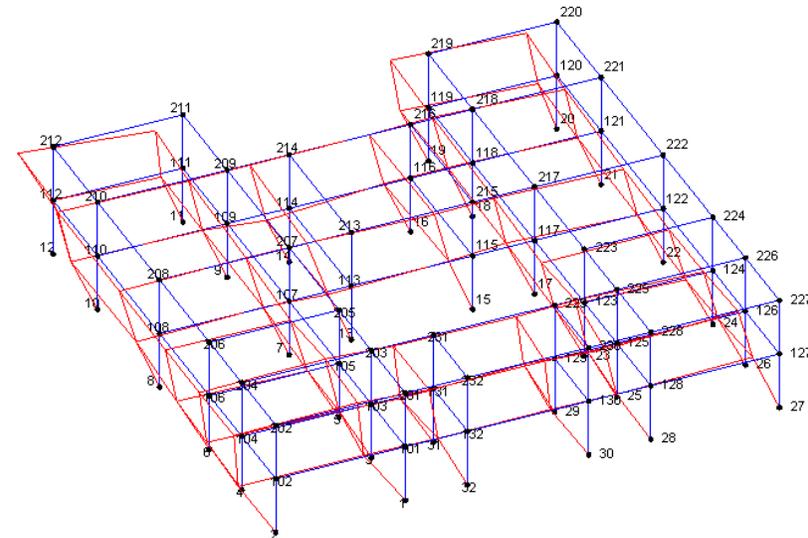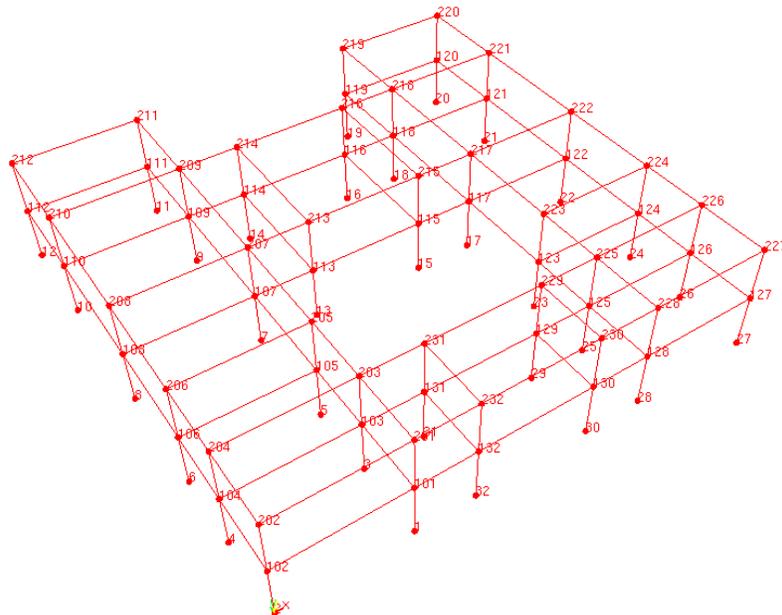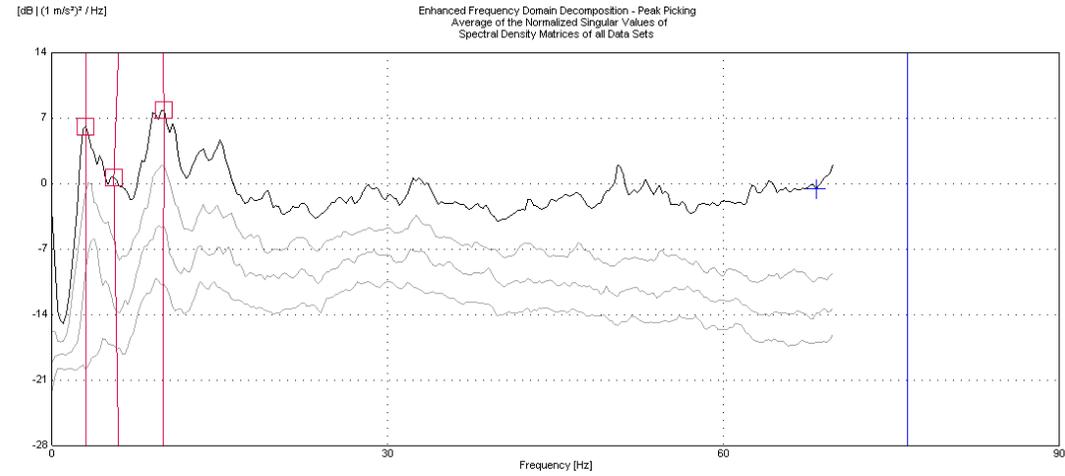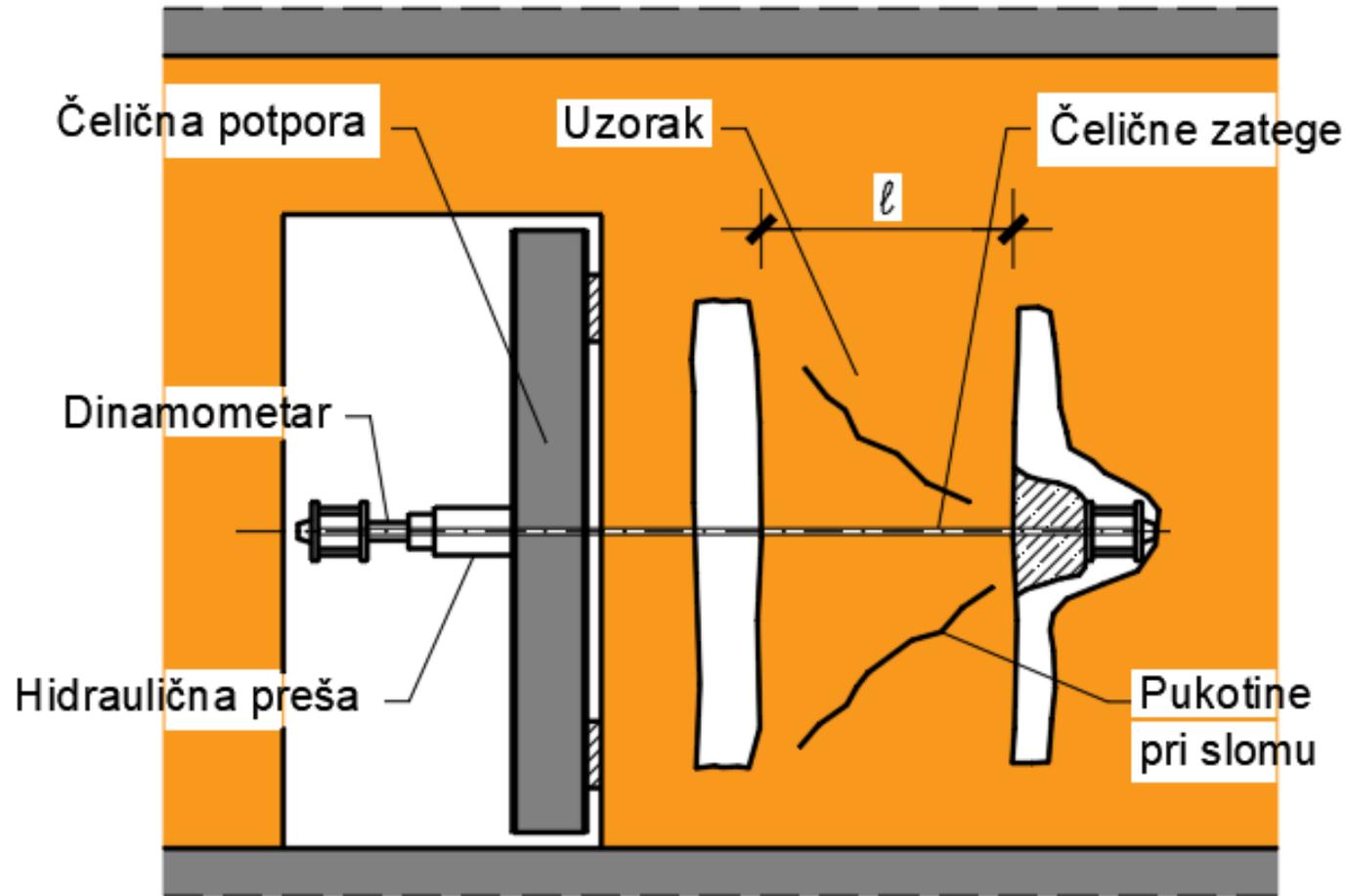
# Vlačna čvrstoća zida
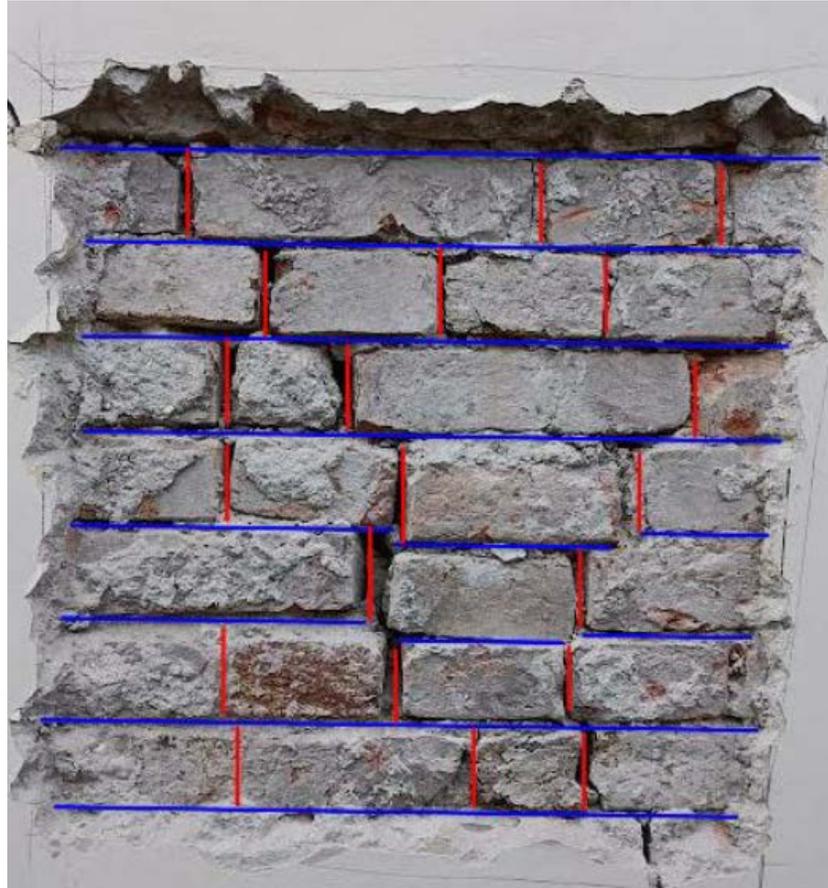
22 cm

78 cm

48 cm

# Hvala na pozornosti!

🏪 Mislav Stepinac, [mstepinac@grad.hr](mailto:mstepinac@grad.hr)