Organizatori

SVEUČILIŠTE U ZAGREBU
GRAĐEVINSKI FAKULTET
UNIVERSITY OF ZAGREB
FACULTY OF CIVIL ENGINEERING

SVEUČILIŠTE U SPLITU
FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE

Hrvatska komora inženjera građevinarstva

WEBINAR

"SAVJETOVANJE 4: OBNOVA ZAGREBA NAKON POTRESA – ZAGREBU OD SPLITA"

Glavni pokrovitelj

Wienerberger

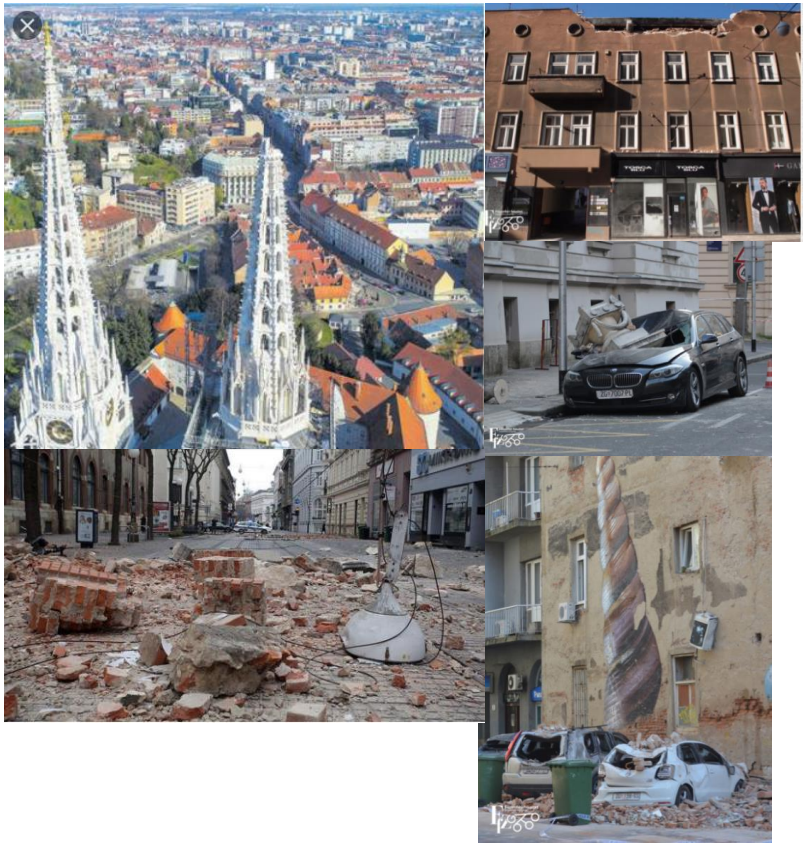
PROCJENA POTRESNE RANJIVOSTI I NOSIVOSTI ZGRADA KAO PREDUVJET SPRJEČAVANJA, UPRAVLJANJA I PREVLADAVANJA POTRESNOG RIZIKA U POVIJESNIM GRADSKIM SREDIŠTIMA

Interreg Italy - Croatia PMO-GATE
European Regional Development Fund
EUROPEAN UNION

Prof. dr. sc. Željana Nikolić
Sveučilište u Splitu, FGAG
Katedra za teoriju konstrukcija
Split, Hrvatska

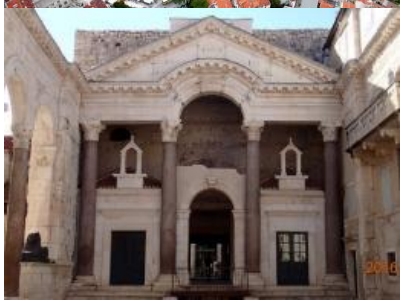
MOTIVACIJA

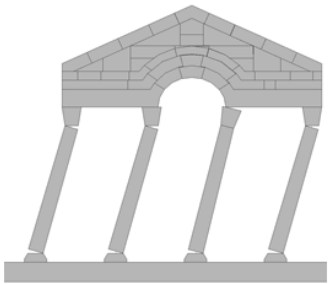
Gradska središta s velikim brojem stanovnika i posjetilaca i zgradama starima po nekoliko stoljeća / desetljeća mogu biti izvor velikih ljudskih i materijalnih gubitaka u slučaju nastanka potresa.



ANALIZA POTRESNE OTPORNOSTI ANTIČKIH GRAĐEVINA

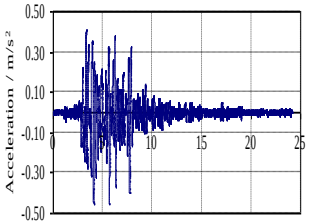
SeismoNuMod: Razvoj numeričkih modela armirano-betonskih i kamenih zidanih konstrukcija izloženih potresnom opterećenju zasnovanih na diskretnim pukotinama



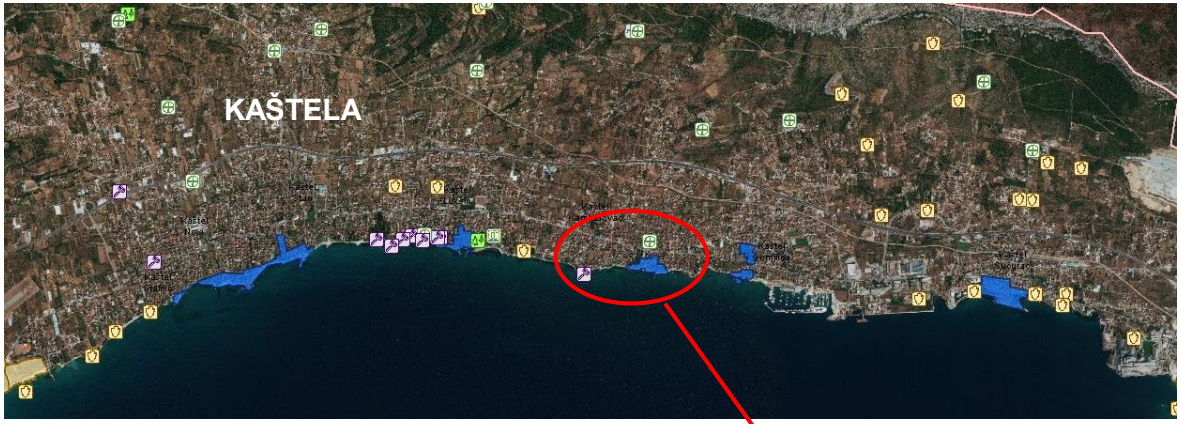


Numeričko modeliranje i ispitivanje kamenih zidanih konstrukcija (model konstrukcije Protiron)

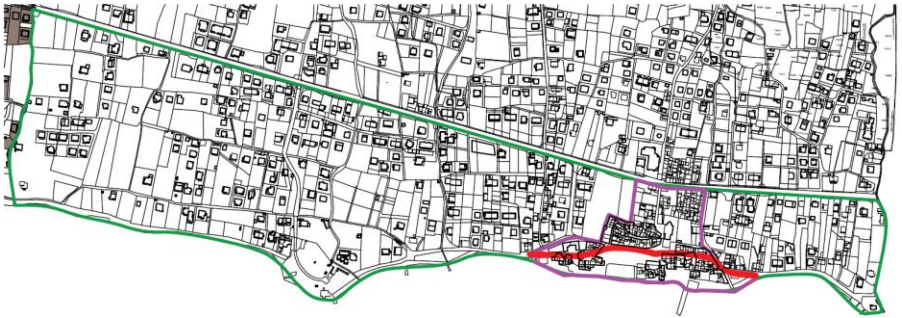
PMO-GATE: Preventing, Managing and Overcoming Natural-Hazards Risks to mitiGATE economic and social impact



ANALIZA PODRUČJA



KAŠTEL KAMBELOVAC



IDENTIFIKACIJA ARHITEKTONSKIH, KONSTRUKCIJSKIH I MATERIJALNIH KARAKTERISTIKA ZGRADA

- Klasifikacija zgrada prema njihovim konstrukcijskim i materijalnim karakteristikama (razdoblje izgradnje)
- Pronalaženje postojeće tehničke dokumentacije u arhivima
- Snimak postojećeg stanja za zgrade bez tehničke dokumentacije: terensko istraživanje, arhitektonski snimak, utvrđivanje karakteristika konstrukcije i svojstava materijala (vizualni pregled, infracrvena termografija, procjena temeljem razdoblja izgradnje)
- Google map, Street view, Snimak područja do 1968. godine
- Formiranje baze podataka o zgradama
- Geodetski snimak područja

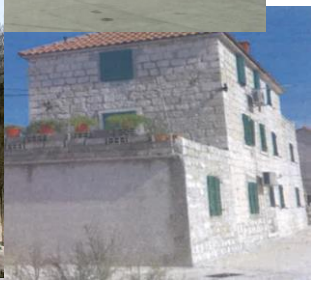
TIPIČNE ZGRADE











OČUVANOST, STANJE OŠTEĆENJA

METODOLOGIJA ZA OCJENU POTRESNE RANJIVOSTI ZGRADA

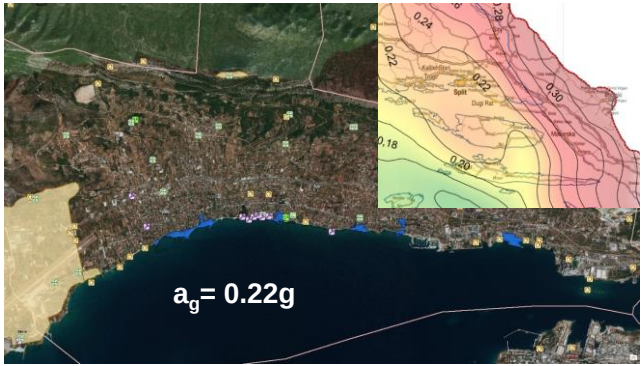
Metoda indeksa ranjivosti za zidane zgrade

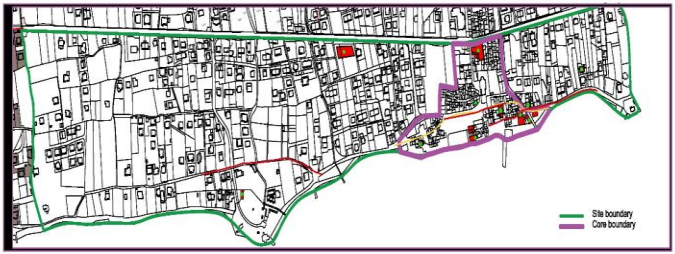
- Benedetti, Petrini, 1983; GNDT 1993 s modifikacijama (SAVE project)
- Utjecaj propisa za protupotresnu gradnju u Hrvatskoj
- Primjena: zgrade građene od nepravilnih i pravilnih kamenih blokova, zidane zgrade od betonskih i glinenih blokova s i bez serklaža

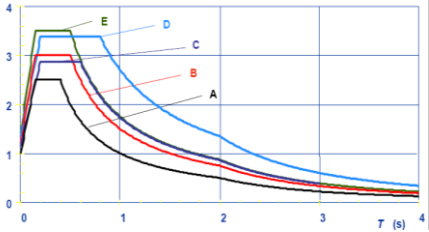
PARAMETAR		BODOVI (P)				TEŽINSKI KOEF.W
		A	B	C	D	
1	VRSTA I ORGANIZACIJA KONSTRUKCIJSKOG SUSTAVA	0	5	20	45	1.50
2	KVALITETA KONSTRUKCIJSKOG SUSTAVA	0	5	25	45	0.25
3	NORMIRANA OTPORNOST	0	5	25	45	1.50
4	POLOŽAJ ZGRADE I TEMELJI	0	5	25	45	0.75
5	STROPNE KONSTRUKCIJE	0	5	15	45	1.00
6	TLOCRTNI OBLIK	0	5	25	45	0.50
7	VISINSKA PRAVILNOST	0	5	25	45	1.00
8	NAJVEĆA UDALJENOST IZMEĐU ZIDOVA	0	5	25	45	0.25
9	KROV	0	15	25	45	0.50
10	NEKONSTRUKTIVNI ELEMENTI	0	0	25	45	0.25
11	STANJE OČUVANOSTI	0	5	25	45	1.00
INDEKS POTRESNE RANJIVOSTI : $I_v = \sum_{i=1}^{11} P_i W_i$						59.0

INDEKSI POTRESNE RANJIVOSTI ZGRADA

POTRESNA OPASNOST NA HR TEST PODRUČJU







Ground type	S	T_B (s)	T_C (s)	T_D (s)
A	1,0	0,15	0,4	2,0
B	1,2	0,15	0,5	2,0
C	1,15	0,20	0,6	2,0
D	1,35	0,20	0,8	2,0
E	1,4	0,15	0,5	2,0

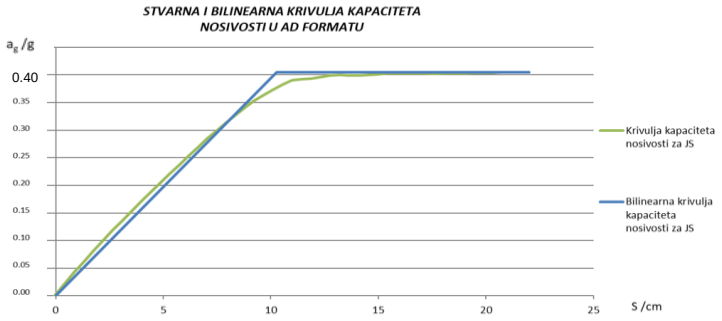
Geofizičko istraživanje - Nacionalni institut za oceanografiju i eksperimentalnu geofiziku, OGS Trieste

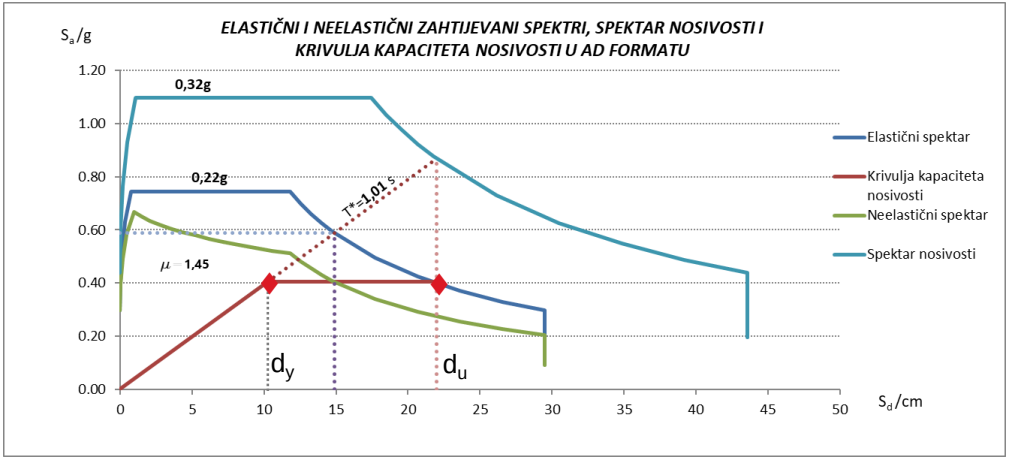
HRN EN 1998-3 – Projektiranje potresne otpornosti konstrukcija – 3. dio: Ocjenjivanje i obnova zgrada

NELINEARNE METODE PRORAČUNA

- Nelinearni statički proračun
- Nelinearni proračun primjenom vremenskog zapisa

NELINEARNI STATIČKI PRORAČUN



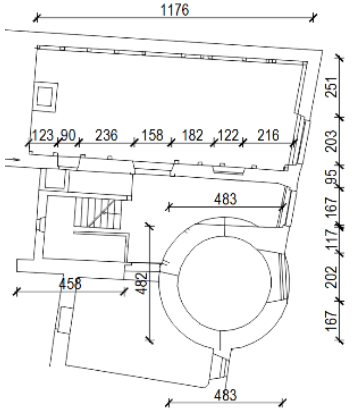


Kula Cambi

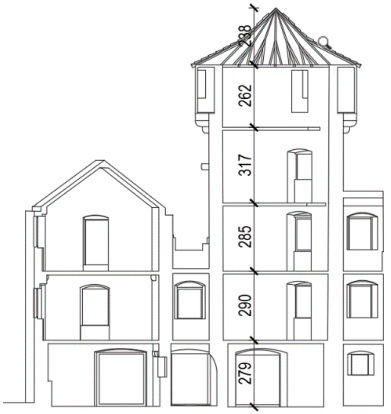
Building name:	Cambi tower
Building type:	Public
Structure type:	stone walls, wooden floors, wooden roof
Construction period:	XV century
Changes of the structure:	Residential part on the north side added in the XVIII century
Period of changes:	XVIII
Data collection methods:	Visual inspection, architectural measurments, standards at the time of construction, iphotos, google maps, geoportal.dgu
Location:	c.p. *32; c.m. Kaštel Kambelovac

*TREMURI software, S.T.A.DATA, Professional version, Torino, 2019.

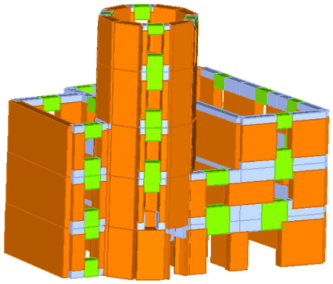
Ground floor plan:



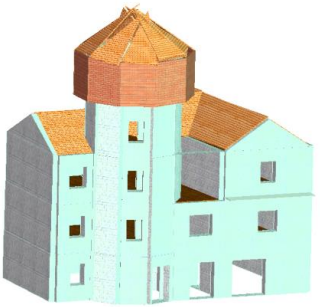
Section cut:



Structural model



Rendered model:



REZULTATI ZA JEDNOLIKU, LINEARNU I MODALNU RASPODJELU

No.	Insert in report	Seism dir.	Seismic load	Eccentricity [cm]	dt NC [cm]	dm NC [cm]	dt SD [cm]	dm SD [cm]	d*y DL [cm]	a NC	a SD	a DL	dm/dt NC
1	☑	+X	Uniform	0,00	1,68	8,80	1,68	6,60	0,27	4,068	3,120	1,059	5,238
2	☑	+X	Static forces	0,00	2,81	8,55	2,81	6,41	0,19	2,882	2,181	0,428	3,043
3	☑	-X	Uniform	0,00	1,79	8,55	1,79	6,41	0,18	4,007	3,057	0,764	4,777
4	☑	-X	Static forces	0,00	2,86	8,45	2,86	6,34	0,14	2,841	2,146	0,319	2,955
5	☑	+Y	Uniform	0,00	4,38	14,45	4,38	10,84	0,66	3,227	2,428	0,722	3,299
6	☑	+Y	Static forces	0,00	5,35	1,95	5,35	1,46	0,86	0,365	0,273	0,726	0,364
7	☑	-Y	Uniform	0,00	2,46	1,45	2,46	1,09	0,47	0,672	0,555	1,092	0,589
8	☑	-Y	Static forces	0,00	3,45	1,25	3,45	0,94	0,36	0,408	0,324	0,580	0,362
9	☑	+X	Uniform	75,90	1,76	8,90	1,76	6,67	0,29	3,955	3,034	1,074	5,057
10	☑	+X	Uniform	-75,90	1,60	8,90	1,60	6,67	0,28	4,173	3,206	1,155	5,563
11	☑	+X	Static forces	75,90	2,96	8,65	2,96	6,49	0,20	2,781	2,104	0,417	2,922
12	☑	+X	Static forces	-75,90	2,71	8,55	2,71	6,41	0,18	2,969	2,248	0,446	3,155
13	☑	-X	Uniform	75,90	1,94	8,55	1,94	6,41	0,16	3,828	2,913	0,648	4,407
14	☑	-X	Uniform	-75,90	1,47	8,55	1,47	6,41	0,17	4,534	3,467	0,899	5,816
15	☑	-X	Static forces	75,90	3,04	8,45	3,04	6,34	0,13	2,700	2,037	0,271	2,780
16	☑	-X	Static forces	-75,90	2,44	8,40	2,44	6,30	0,12	3,239	2,450	0,376	3,443
17	☑	+Y	Uniform	62,43	5,05	16,06	5,05	12,04	0,77	3,177	2,383	0,684	3,180
18	☑	+Y	Uniform	-62,43	3,74	4,80	3,74	3,60	0,61	1,263	0,966	0,836	1,283
19	☑	+Y	Static forces	62,43	5,88	2,10	5,88	1,58	0,93	0,357	0,268	0,711	0,357
20	☑	+Y	Static forces	-62,43	4,03	1,45	4,03	1,09	0,64	0,360	0,270	0,716	0,360
21	☑	-Y	Uniform	62,43	2,61	1,45	2,61	1,09	0,45	0,635	0,521	0,998	0,556
22	☑	-Y	Uniform	-62,43	2,05	1,55	2,05	1,16	0,48	0,825	0,689	1,317	0,756
23	☑	-Y	Static forces	62,43	3,57	1,15	3,57	0,86	0,32	0,360	0,285	0,493	0,322
24	☑	-Y	Static forces	-62,43	3,05	1,05	3,05	0,79	0,34	0,411	0,334	0,657	0,344

Display analysis details

Insert all analysis in report

Delete analysis

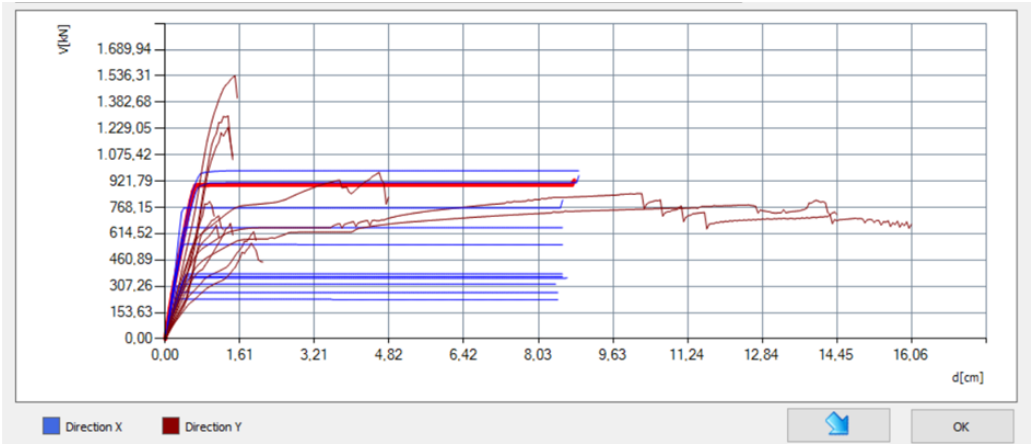
Colour legend

- Satisfied
- Not satisfied
- Failure to decay
- Self weight not converging
- Most significative analysis

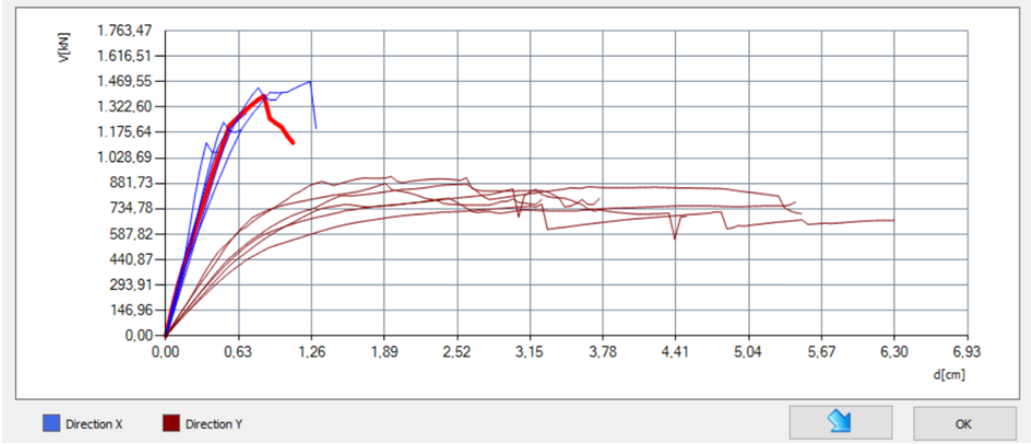
No.	Insert in report	Seism dir.	Seismic load	Eccentricity [cm]	dt NC [cm]	dm NC [cm]	dt SD [cm]	dm SD [cm]	d*y DL [cm]	a NC	a SD	a DL	dm/dt NC
2	☑	+X	Modal distribution	0,00	1,01	1,10	1,01	0,82	0,25	1,045	0,900	1,511	1,089
4	☑	-X	Modal distribution	0,00	0,99	0,65	0,99	0,49	0,20	0,804	0,712	1,365	0,657
6	☑	+Y	Modal distribution	0,00	3,61	4,50	3,61	3,38	0,50	1,228	0,940	0,727	1,247
8	☑	-Y	Modal distribution	0,00	3,48	5,50	3,48	4,12	0,52	1,526	1,167	0,794	1,580
11	☑	+X	Modal distribution	75,90	1,08	1,30	1,08	0,97	0,33	1,108	0,951	1,670	1,204
12	☑	+X	Modal distribution	-75,90	0,97	0,70	0,97	0,52	0,23	0,851	0,754	1,477	0,722
15	☑	-X	Modal distribution	75,90	1,02	1,00	1,02	0,75	0,28	0,992	0,863	1,581	0,980
16	☑	-X	Modal distribution	-75,90	0,86	0,45	0,86	0,34	0,14	0,725	0,650	1,258	0,523
19	☑	+Y	Modal distribution	62,43	4,23	6,30	4,23	4,73	0,56	1,471	1,113	0,651	1,489
20	☑	+Y	Modal distribution	-62,43	2,86	3,25	2,86	2,44	0,36	1,118	0,870	0,754	1,136
23	☑	-Y	Modal distribution	62,43	3,67	5,45	3,67	4,09	0,50	1,450	1,105	0,710	1,485
24	☑	-Y	Modal distribution	-62,43	2,97	3,75	2,97	2,81	0,43	1,230	0,955	0,822	1,263

NELINEARNE V-d KRIVULJE

Jednolika i linearna raspodjela



Modalna raspodjela



Smjer x – br.16, modalna raspodjela

Result details

NC

dt 0,86 [cm] > dm 0,45 [cm]

qu = 1,58 dm/dt = 0,52

Not satisfied verification

SD

dt 0,86 [cm] > dm 0,34 [cm]

Not satisfied verification

DL

Sd 0,11 [cm] <= d*y 0,14 [cm]

Satisfied verification

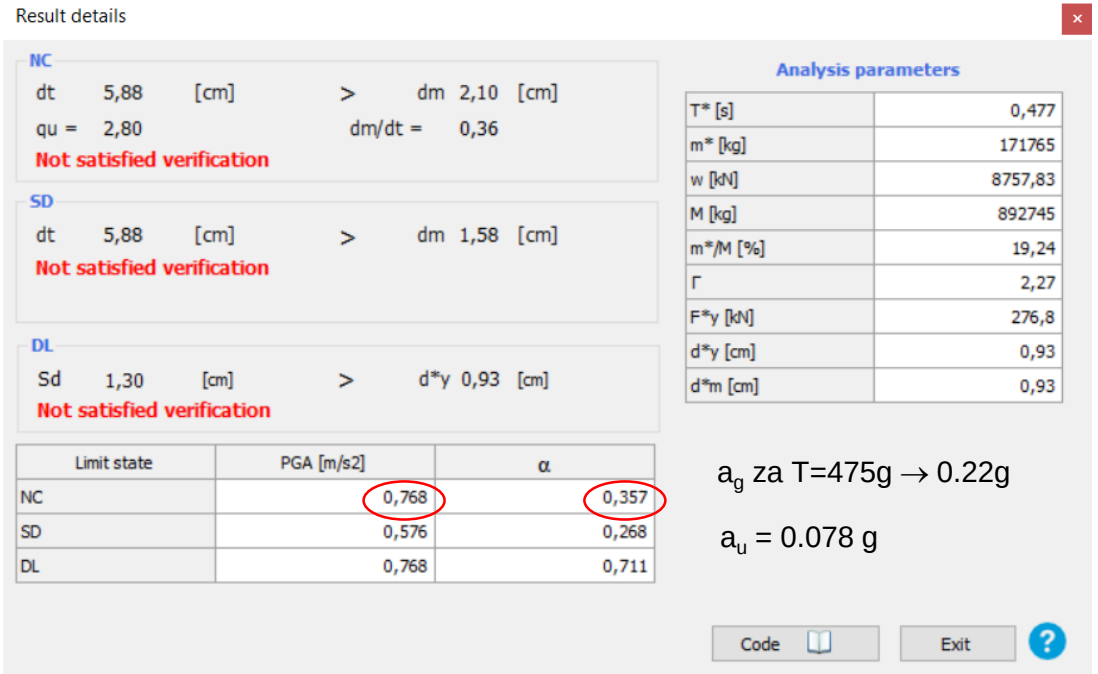
Limit state	PGA [m/s2]	α
NC	1,559	0,725
SD	1,396	0,650
DL	1,358	1,258

Analysis parameters

T* [s]	0,132
m* [kg]	141600
w [kN]	8757,83
M [kg]	892745
m*/M [%]	15,861
Γ	2,22
F*y [kN]	446,8
d*y [cm]	0,14
d*m [cm]	0,2

Code Exit

Smjer y – br.19, linearna raspodjela

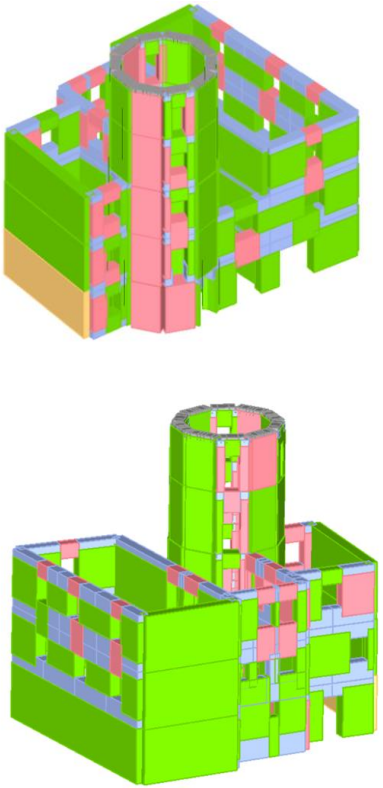


a_g za T=475g → 0.22g

a_u = 0.078 g

STATUS OŠTEĆENJA

Smjer x

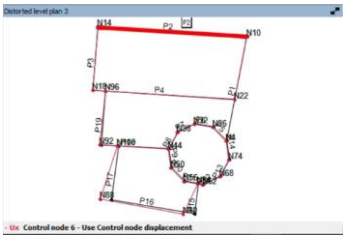


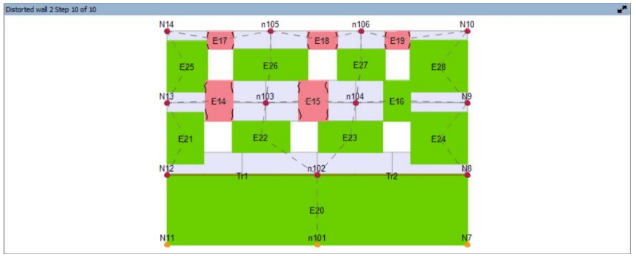
Legend

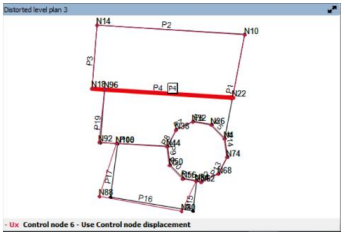
Masonry
Undamaged
Shear damage
Shear failure
Bending damage
Bending failure
Compression failure
Tension failure
Failure during elastic phase

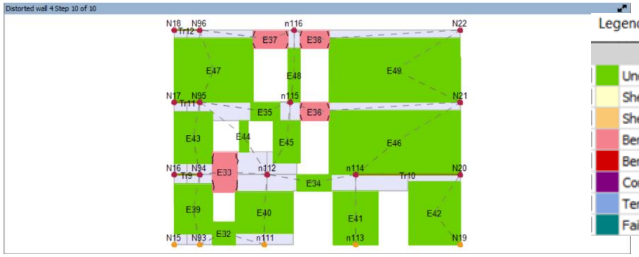
STATUS OŠTEĆENJA

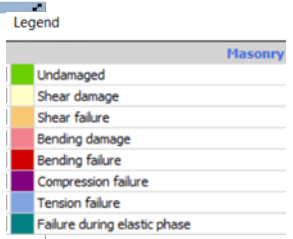
Smjer x

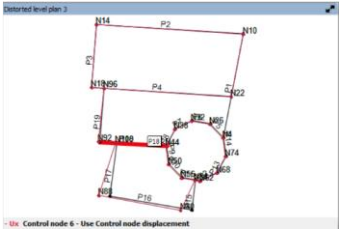






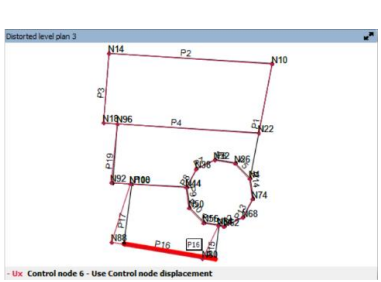


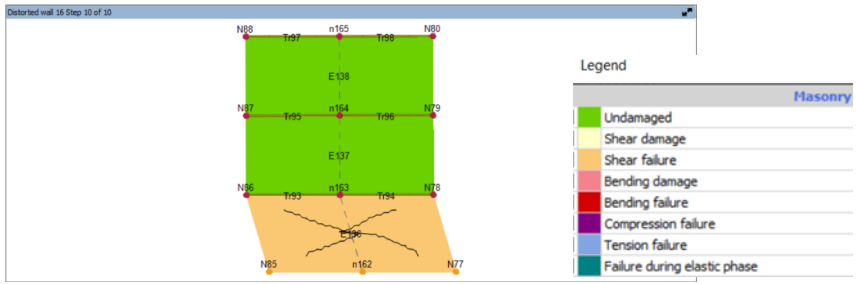


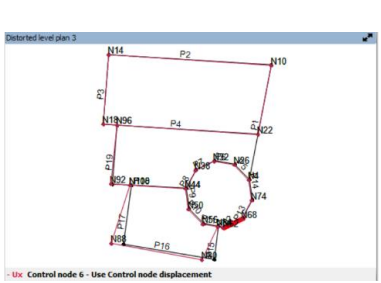


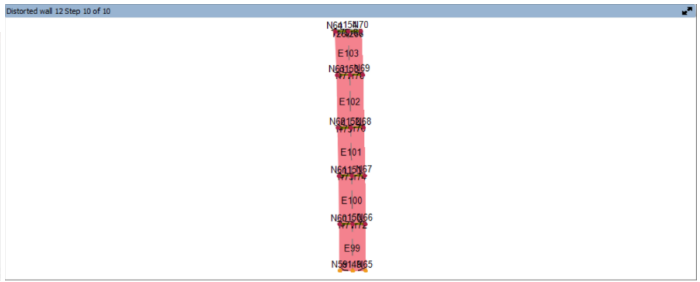
STATUS OŠTEĆENJA

Smjer x



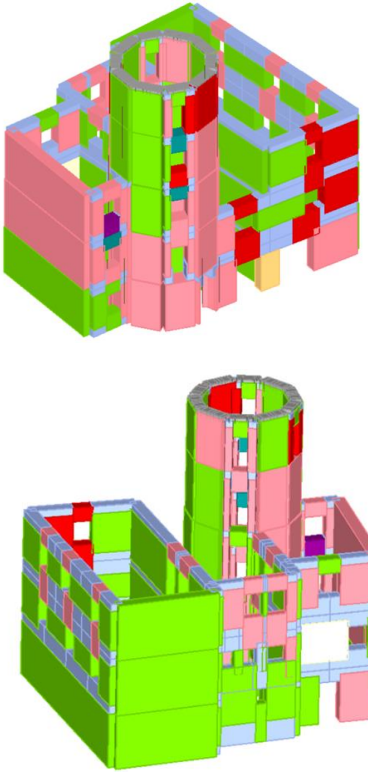


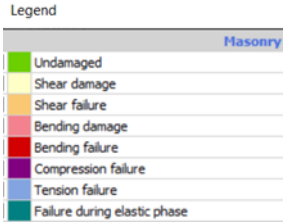




STATUS OŠTEĆENJA

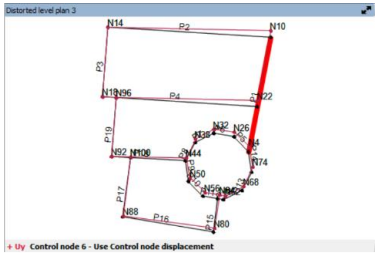
Smjer y

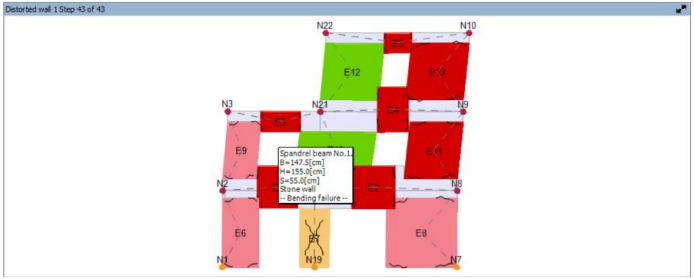


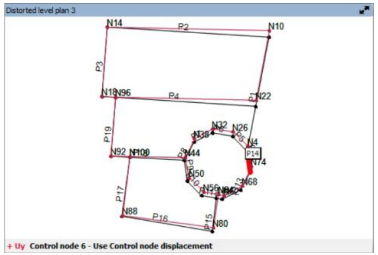


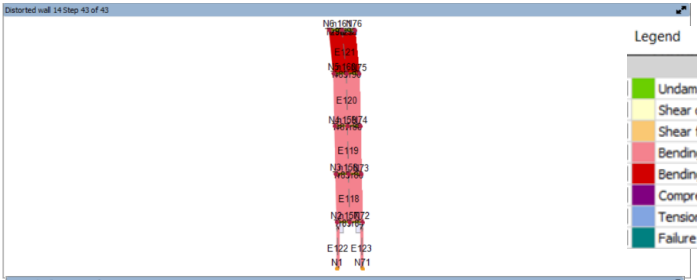
STATUS OŠTEĆENJA

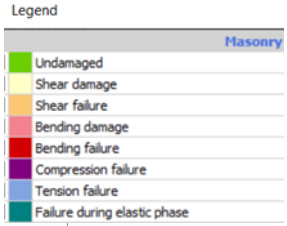
Smjer y

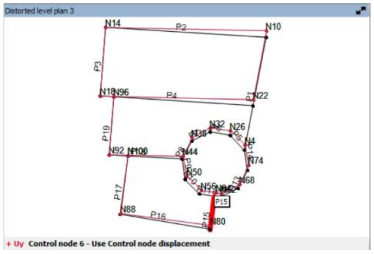


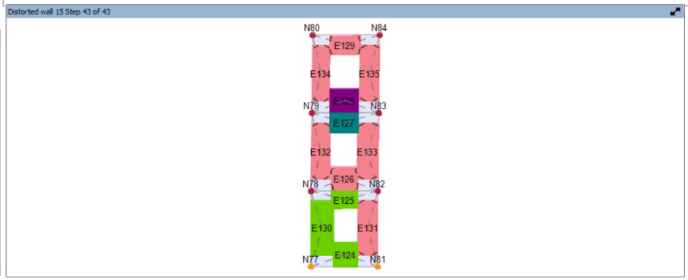








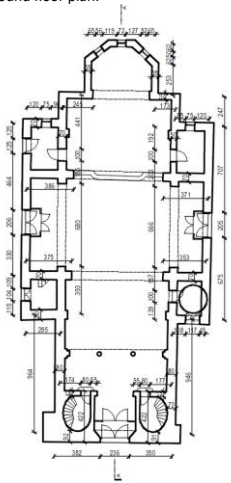




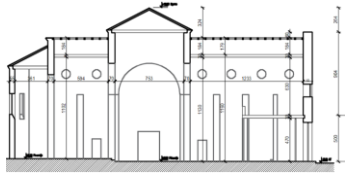
NELINEARNI STATIČKI PRORAČUN – Crkva Sv. Mihovila

Building name:	Saint Mihovil church
Building type:	Public
Structure type:	stone walls, timber floors, timber roof
Construction period:	XVI century
Changes of the structure:	
Period of changes:	
Data collection methods:	Visual inspection, architectural measurments, standards at the time of construction, iphotos, google maps, geoportal.dgu
Location:	c.p. *83; c.m. Kaštel Kambelovac

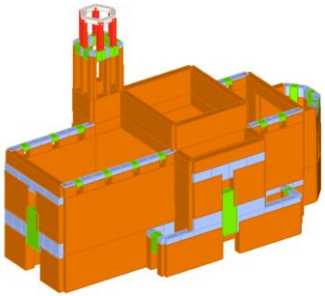
Ground floor plan:



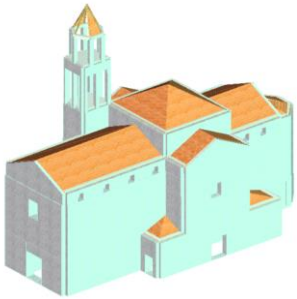
Section cut:



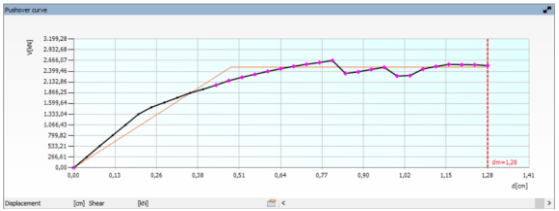
Structural model:



Rendered model:



Smjer x



Result details

NC
dt 1,23 [cm] > dm 0,40 [cm]
qu = 3,03 dm/dt = 0,33
Not satisfied verification

SD
dt 1,23 [cm] > dm 0,30 [cm]
Not satisfied verification

DL
Sd 0,29 [cm] > d*y 0,19 [cm]
Not satisfied verification

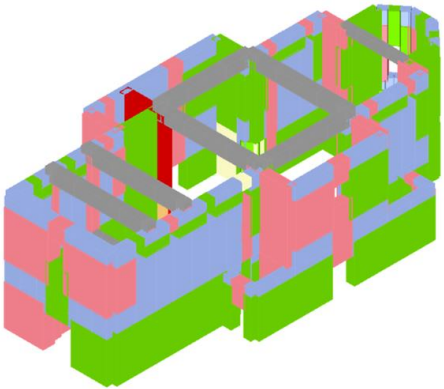
Limit state	PGA [m/s2]	α
NC	0,953	0,443
SD	0,808	0,376
DL	0,709	0,656

Analysis parameters

T* [s]	0,188
m* [kg]	1582630
w [kN]	24631,98
M [kg]	2510913
m*/M [%]	63,03
Γ	1,21
F*y [kN]	3364,86
d*y [cm]	0,19
d*m [cm]	0,33

Code Exit

a_u = 0.097 g

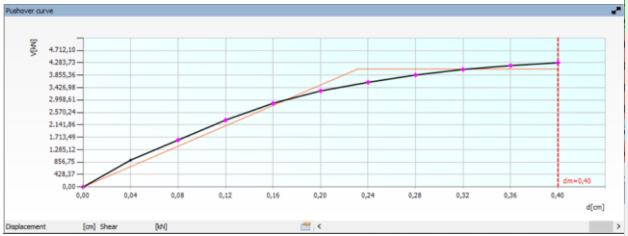


Legend

Masonry
Undamaged
Shear damage
Shear failure
Bending damage
Bending failure
Compression failure
Tension failure
Failure during elastic phase

… NELINEARNI STATIČKI PRORAČUN – Crkva Sv. Mihovila

Smjer y



Result details

NC

dt 1,23 [cm] > dm 0,40 [cm]

qu = 3,03 dm/dt = 0,33

Not satisfied verification

SD

dt 1,23 [cm] > dm 0,30 [cm]

Not satisfied verification

DL

Sd 0,29 [cm] > d*y 0,19 [cm]

Not satisfied verification

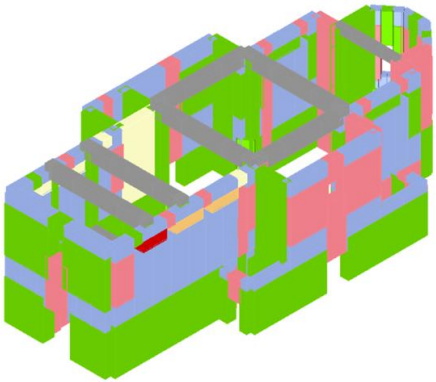
Limit state	PGA [m/s2]	α
NC	0,953	0,443
SD	0,808	0,376
DL	0,709	0,656

Analysis parameters

T* [s]	0,188
m* [kg]	1582630
w [kN]	24631,98
M [kg]	2510913
m*/M [%]	63,03
Γ	1,21
F*y [kN]	3364,86
d*y [cm]	0,19
d*m [cm]	0,33

a_u = 0.091 g

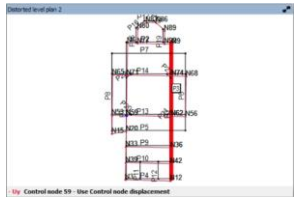
Code Exit

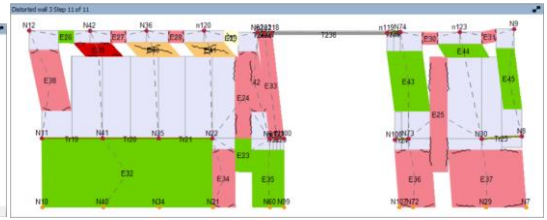


Legend

Masonry

- Undamaged
- Shear damage
- Shear failure
- Bending damage
- Bending failure
- Compression failure
- Tension failure
- Failure during elastic phase





Veslački klub

Building name:	Rowing club
Building type:	Public
Structure type:	stone walls, concrete floors, timber roof
Construction period:	XX century
Changes of the structure:	Part added on the east, concrete walls, concrete slab
Period of changes:	XX century
Data collection methods:	Visual inspection, architectural measurments, standards at the time of construction, iphotos, google maps, geoportal.dgu
Location:	c.p. *330; c.m. Kaštel Kambelovac

a_u = 0.141 g

Vrtić

Building name:	Kindergarten
Building type:	Public
Structure type:	stone walls, timber floors, timber roof
Construction period:	XIX century
Changes of the structure:	Strenghtening floors with concrete slab
Period of changes:	
Data collection methods:	Visual inspection, architectural measurments, standards at the time of construction, iphotos, google maps, geoportal.dgu
Location:	c.p. 232, c.m. Kaštel Kambelovac

$a_u = 0.092$ g

Knjižnica

Building name:	Library
Building type:	Public
Structure type:	stone walls, timber floors, timber roof
Construction period:	XIX century
Changes of the structure:	Part added on the south
Period of changes:	XX century
Data collection methods:	Visual inspection, architectural measurments, standards at the time of construction, iphotos, google maps, geoportal.dgu
Location:	c.p. *48; c.m. Kaštel Kambelovac

$a_u = 0.080$ g

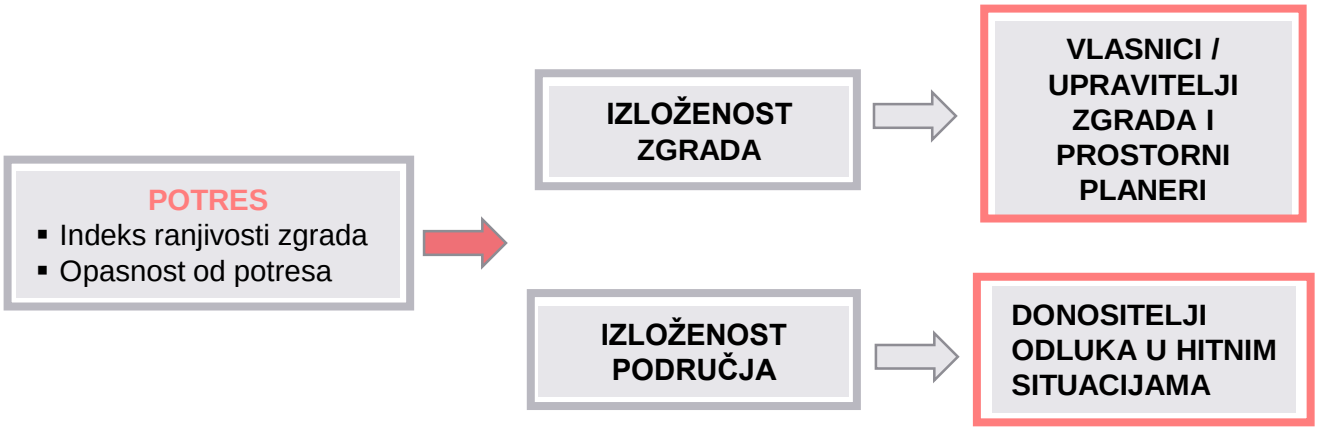
Baletna škola

Building name:	Balet school, Don Frane Bege 1
Building type:	Residential
Structure type:	stone walls, concrete floors, lightwieight concrete ribbed roof
Construction period:	XIX century
Changes of the structure:	
Period of changes:	
Data collection methods:	Visual inspection, architectural measurments, standards at the time of construction, iphotos, google maps, geoportal.dgu
Location:	c.p. *244; c.m. Kaštel Kambelovac

$a_u = 0.183$ g

VAŽNOST METODOLOGIJA ZA PROCJENU IZLOŽENOSTI OPASNOSTIMA

- Metodologija za procjenu potresne ranjivosti može se koristiti za definiranje mapa potresne ranjivosti zgrada koje mogu pomoći pri definiranju prioriteta u sanaciji
- Daljni postupak: nelinearni proračuni, eksperimentalna ispitivanja, projektiranje rekonstrukcijskih zahvata



Hvala na pažnji!

Prof. dr. sc. Željana Nikolić
Sveučilište u Splitu, Fakultet građevinarstva, arhitekture i geodezije
E-mail: zeljana.nikolic@gradst.hr

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