Bauhaus-Universität Weimar

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Forecast Engineering

SEISMIC ASSESSMENT OF EXISTING BUILDING

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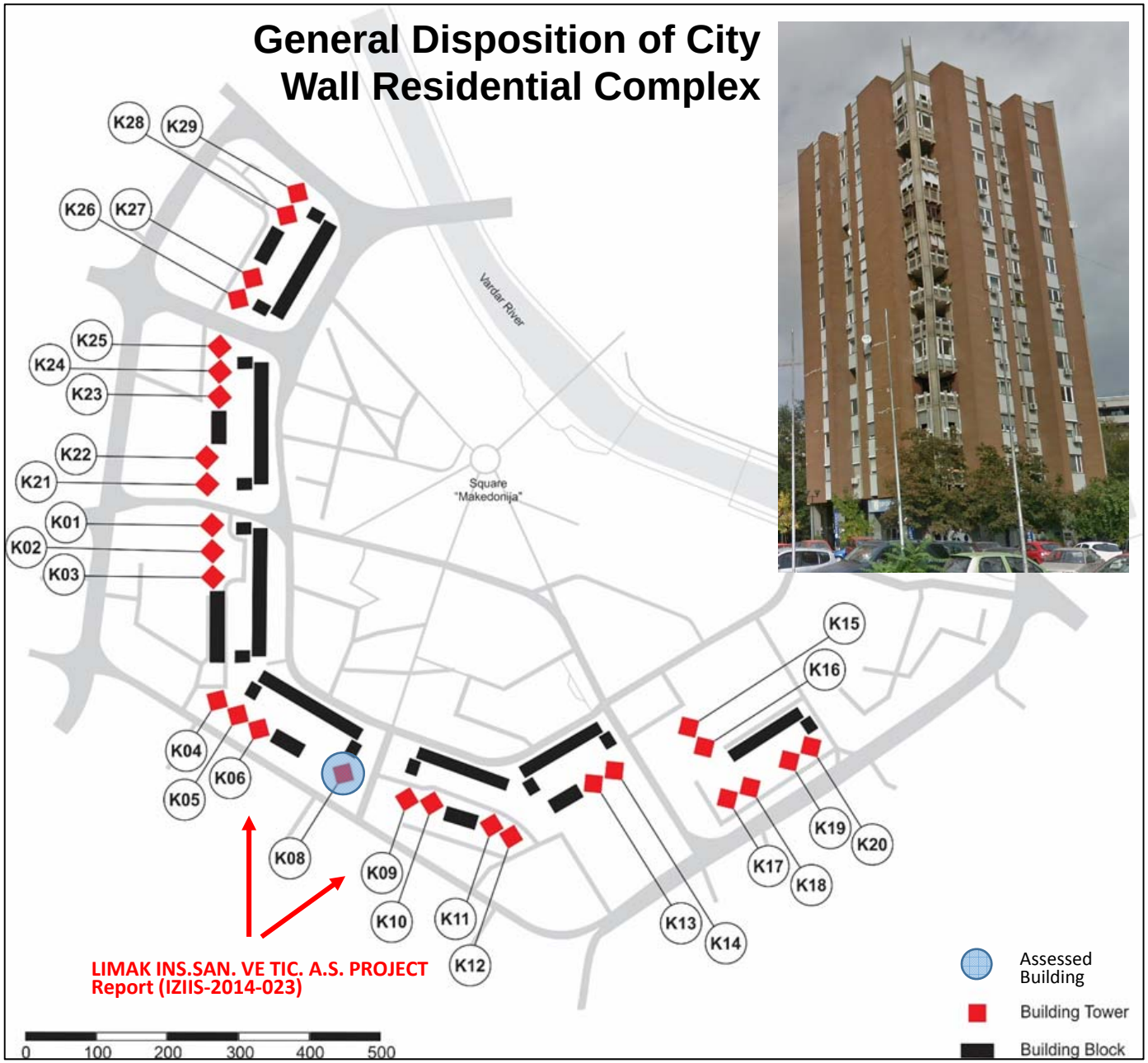
ИЗИИС IZIIS

Introduction



nonlinear static analysis

- for the usual load the structure remains in the linear-elastic field of material work and relationship between load and displacement is simple. In case of earthquake, and depending on his intensity, the individual parts of the structure pass into nonlinear material working area. To be followed behavior by a structure in a nonlinear domain in the conditions of the earthquake, were developed non-linear dynamic and static seismic analysis.

- pushover analysis is combined with the response spectrum, and in Eurocode 8, N2 method is used. The N2 method transforms the response of the multi-degree system (MDOF) into the response of an equivalent system with one degree of freedom (SDOF). This is necessary to make the pushover curve comparable with the demand, which is presented through the demand spectrum corresponding to the SDOF system.

nonlinear static analysis

Regulations and software

EN 1998-3 (2005): Eurocode 8: Design of structures for earthquake resistance – Part 3: Assessment and retrofitting of buildings

Csi- SAP2000 and VcaSlu (free eurocode design software by Prof. P Gelfi from Italy)

Plastic Hinges – manual defined

informations for structural assessment

Definition of Knowledge Level

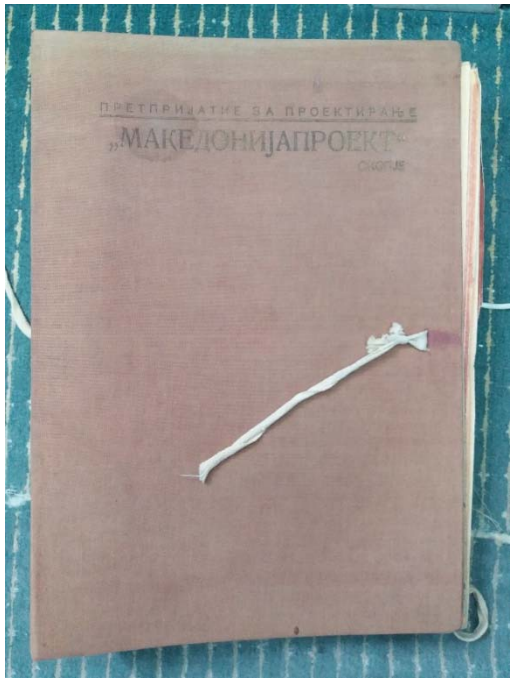
For this analysis, we obtain knowledge level 3 (KL3, Full knowledge) which corresponds with following state of knowledge of geometry, details and materials. The confidence factor value of this building is CF=1.

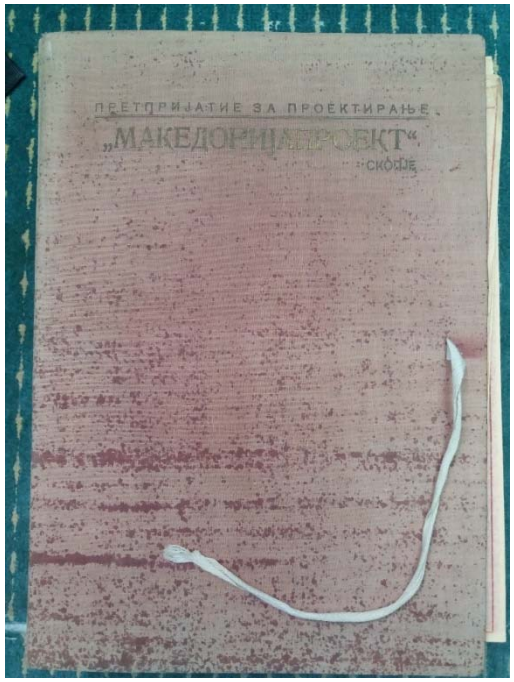
Lateral Loads for Pushover

The analysis is performed using two planar models, one for each main horizontal direction of the building. Two vertical distributions of lateral loads are applied:

- Uniform pattern, based on lateral load that are proportional to mass regardless of elevation
- Modal pattern, proportional to lateral load consistent with the lateral modal displacements of building

Original design documentation





Z. Talevski, P. Gavrilovic, D. Jurukovski. CITY WALL - Building 8, Tech. num. 1164, Makedonija Proekt from VII.1967

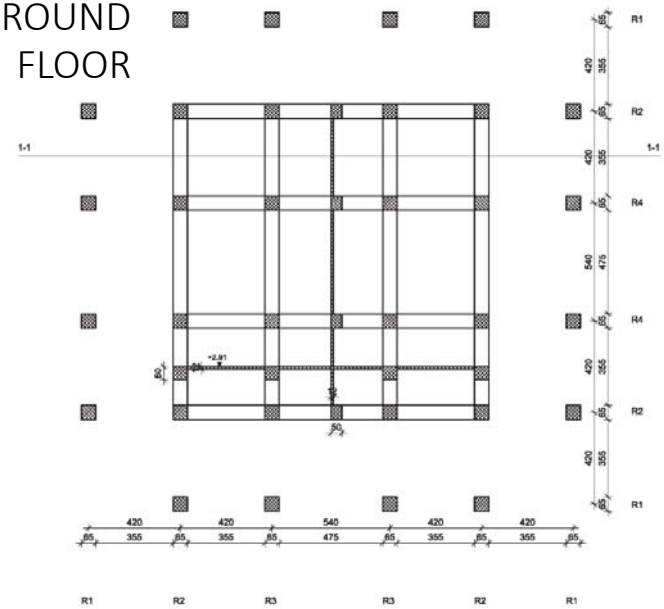
Design Technical regulation

Provisional Technical Regulations for Construction in Seismic Regions. Official Gazette of SFRY, No. 39 of 30.09.1964

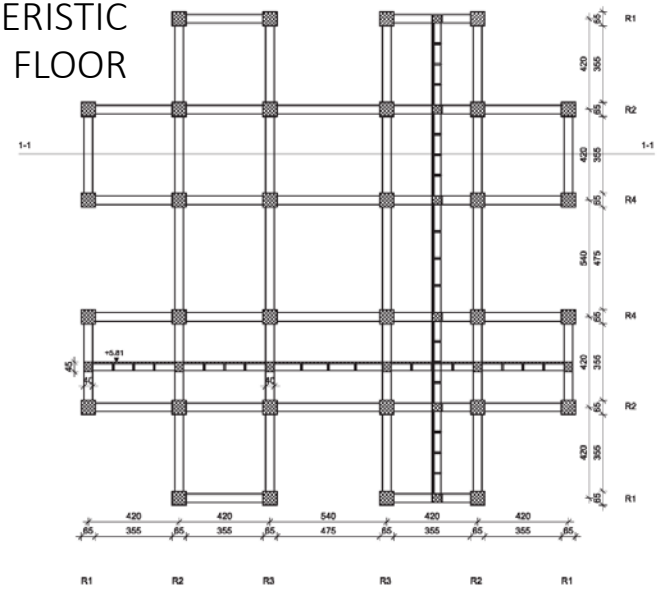
Provisional Technical Regulations for concrete and reinforced concrete, Official Gazette of FNRY, No. 46 of 03.06.1947

Geometry and Materials

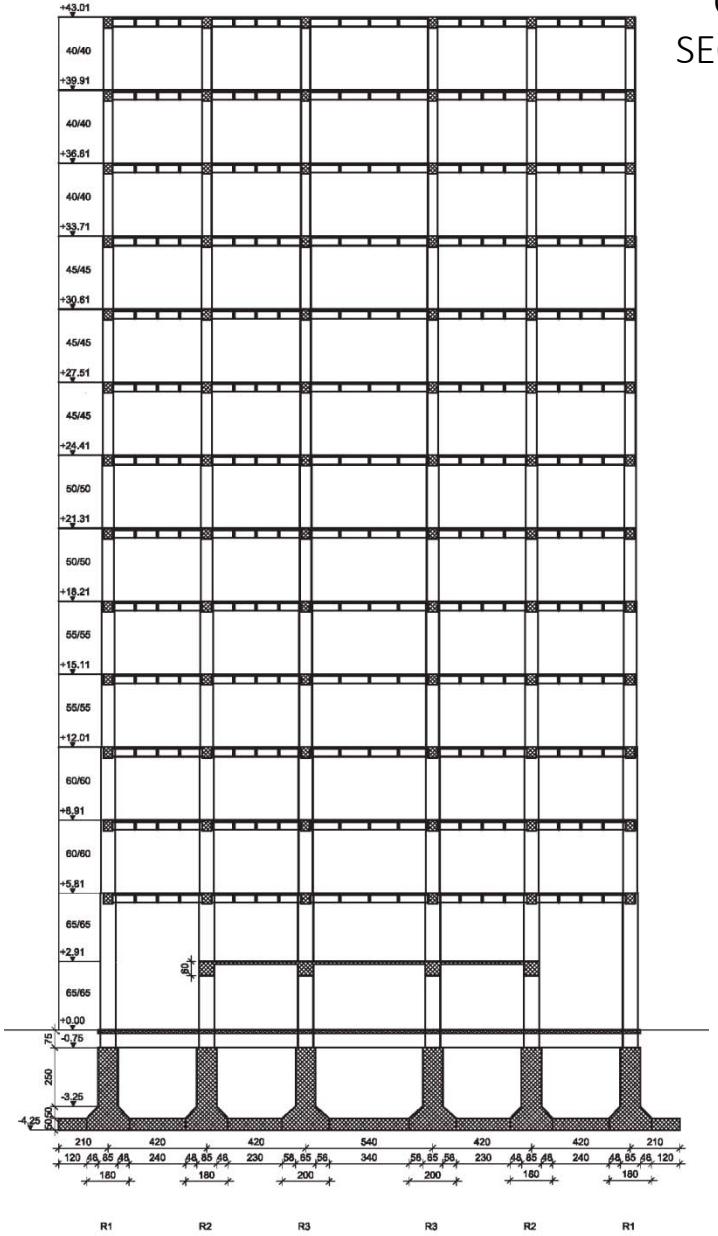
GROUND FLOOR



CHARACTERISTIC FLOOR



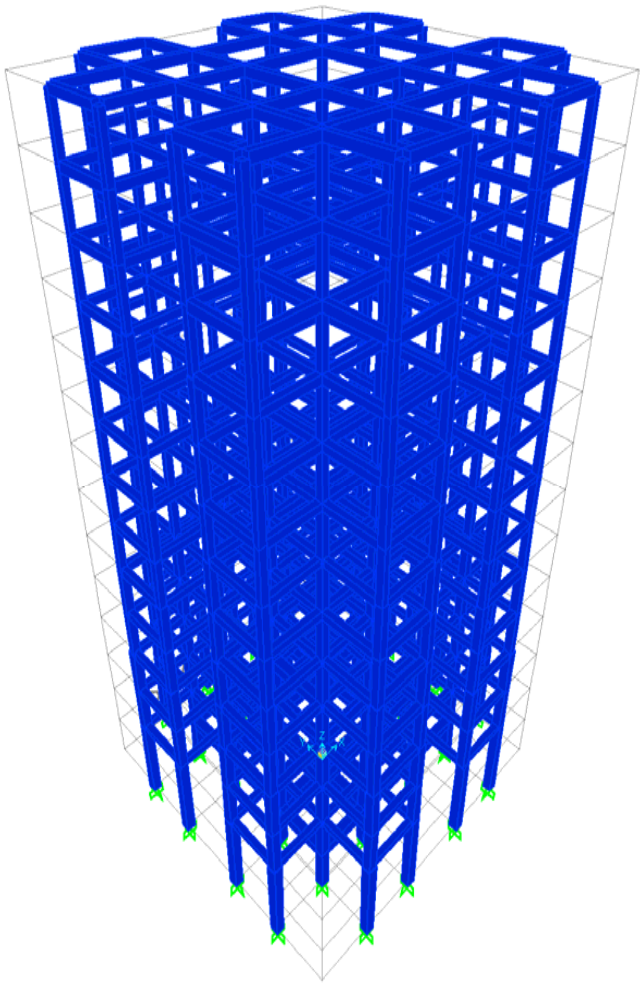
CROSS SECTION

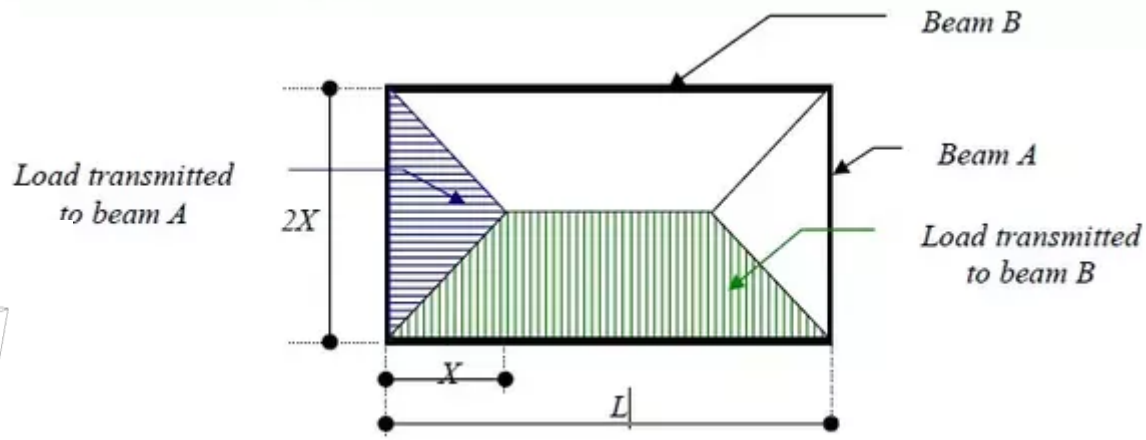


Reinforcement
GA 240/360

Concrete
MB30–C25/30

Modeling



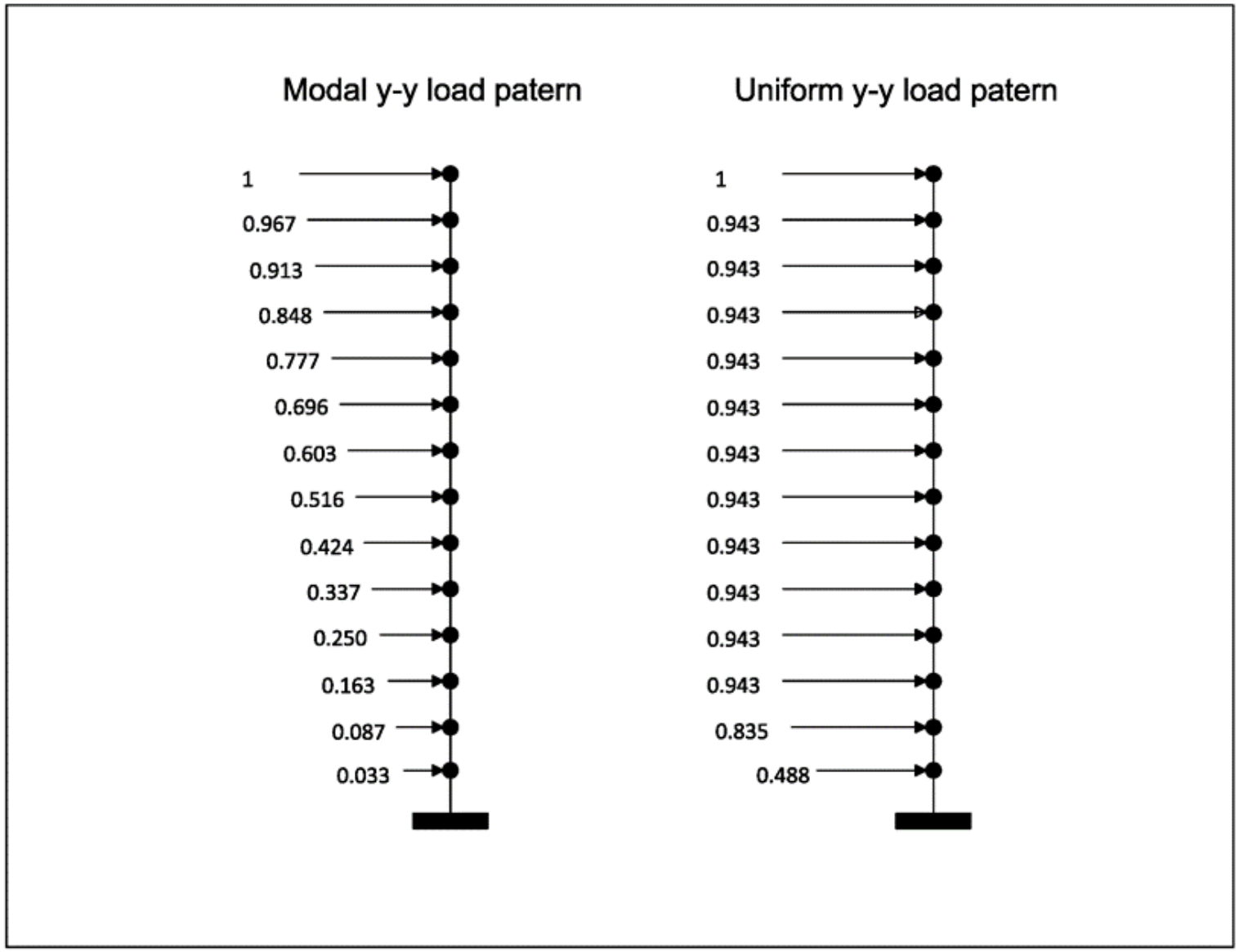


$$q_x = \frac{l_y^4}{l_x^4 + l_y^4} * q$$

$$q_y = \frac{l_x^4}{l_x^4 + l_y^4} * q$$

q – distributed load on the floor slab
q_x – distributed load on the RC beam in x direction
q_y – distributed load on the RC beam in y direction

load patern


Modal y-y load patern
1
0.967
0.913
0.848
0.777
0.696
0.603
0.516
0.424
0.337
0.250
0.163
0.087
0.033
Uniform y-y load patern
1
0.943
0.943
0.943
0.943
0.943
0.943
0.943
0.943
0.943
0.943
0.943
0.835
0.488

load cases

Pushover load case number:

- 1 load case for gravity load (Gk+ψQk) – Nonlinear Static;
- 8 load cases for Uniform lateral loads;
- 8 load cases for Modal lateral loads;

1. +X_+ecc;
2. +X_-ecc;
3. -X_+ecc;
4. -X_-ecc;
5. +Y_+ecc;
6. +Y_-ecc;
7. -Y_+ecc;
8. -Y_-ecc;

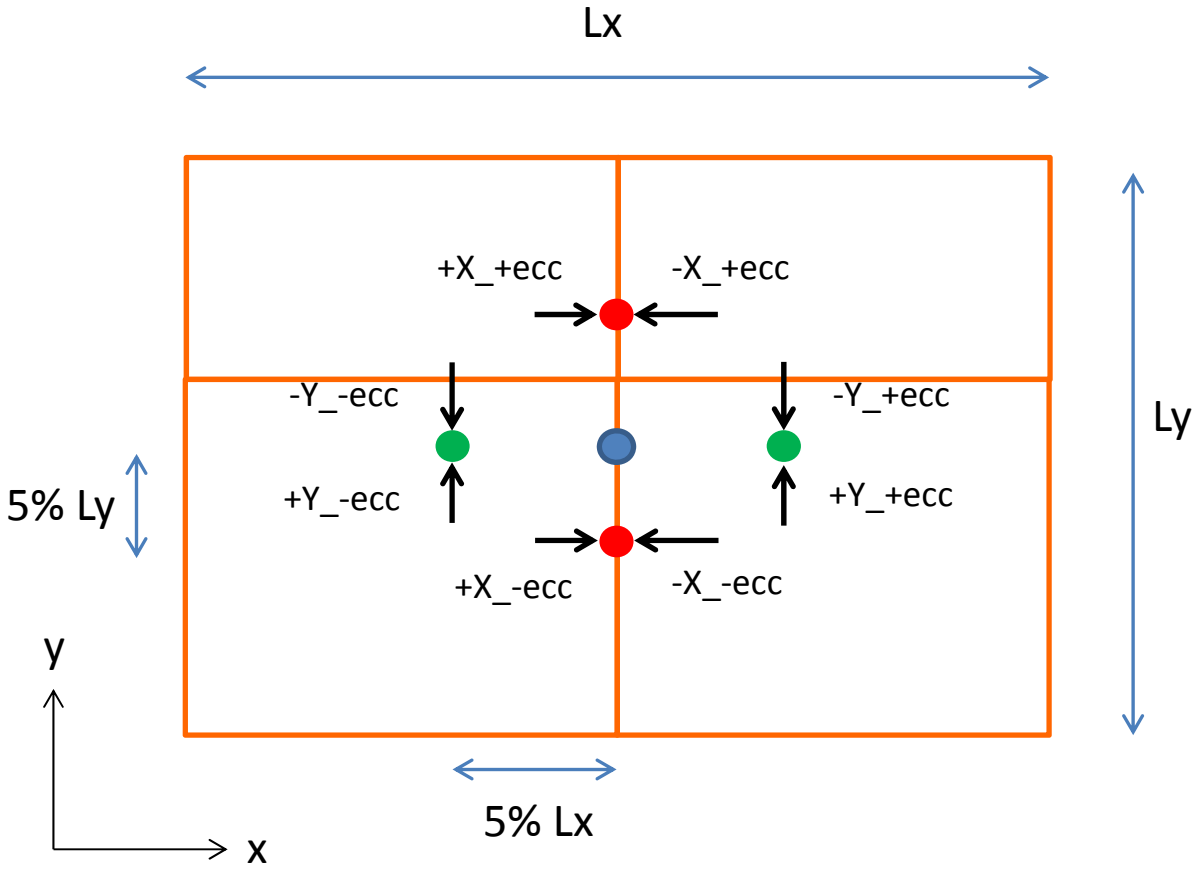
X2

→ Lateral force

● Eccentricity along X direction

● Eccentricity along Y direction

● Center of mass



Plastic hinge deginition

$$\theta_{cr} = \frac{M_{cr} * L_v}{3EI}$$

$$M_{cr} = \left(\frac{N}{A} + f_{ctm}\right) * \frac{b * h^2}{6}$$

$$\theta_y = \phi_y * \frac{L_v + \alpha_v * z}{3} + 0.0014 * \left(1 + 1.5 * \frac{h}{L_v}\right) + \phi_y * \frac{d_{bl} * f_y}{8 * \sqrt{f_c}}$$

$$\theta_u = \frac{1}{\gamma_{el}}\left(\theta_y + (\phi_u - \phi_y) * L_{pl} * \left(1 - \frac{0.5 * L_{pl}}{L_v}\right)\right)$$

$$L_{pl} = 0.1 * L_v + 0.17 * h + 0.24 * \frac{d_{bl} * f_y(MPa)}{\sqrt{f_c(MPa)}}$$

θ_{cr} – is the chord rotation at cracking
θ_y – is the chord rotation at yielding
θ_u – ultimate chord rotation capacity
ϕ_y – is the yield curvature at the end section
ϕ_u – is the ultimate curvature at the end section

capacity curve

- The relation of transformation of multi degree of freedom system (MDOF) to the single degree of freedom system (SDOF) system is called <u>modal transformation factor</u> for which the following equation applies:

$$\Gamma = \frac{\sum m_i * \phi_i}{\sum m_i * \phi_i^2}$$

The mass of equivalent SDOF system m^* is determined as:

$$m^* = \sum m_i * \phi_i$$

The force F^* and displacement d^* of the equivalent SDOF system are computed as:

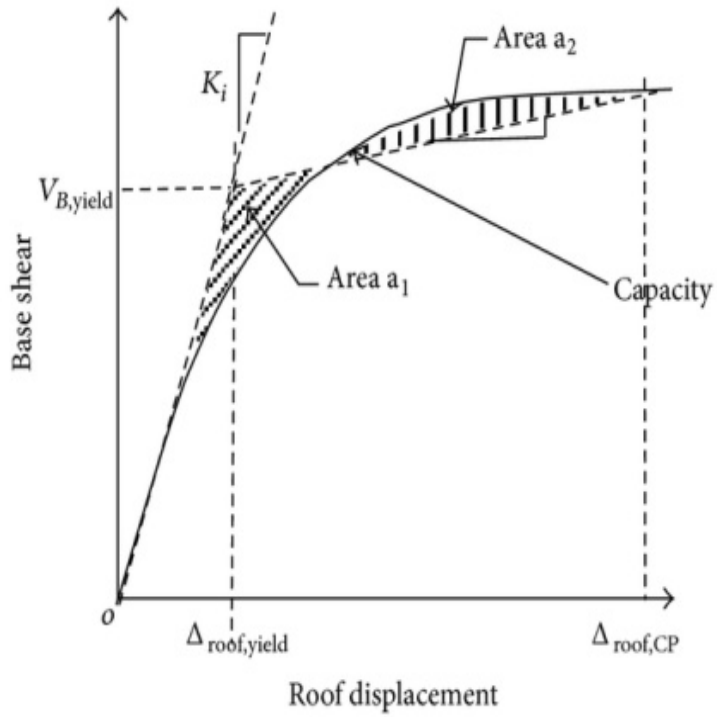
$$F^* = \frac{F_b}{\Gamma}$$

$$d^* = \frac{d_n}{\Gamma}$$

Where F_b and d_n are, respectively, the base shear force and the control node displacement of the MDOF system.

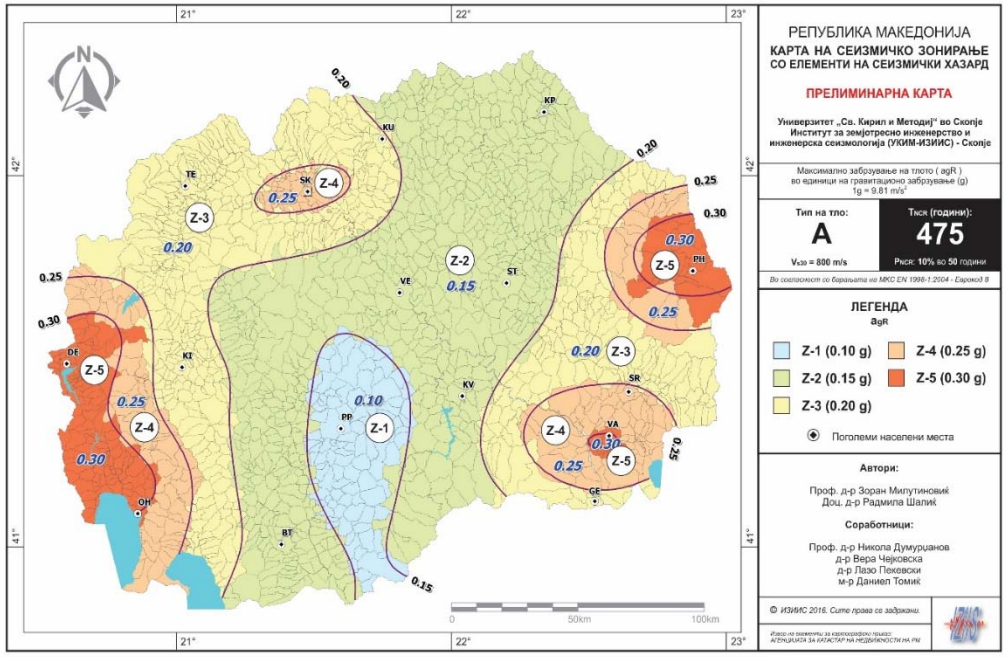
capacity curve

- Bilinear model of the SDOF pushover curve, as an elastic perfectly plastic idealization was determined by an area equivalent method. Area under SDOF capacity curve and area up capacity curve must be the same.



demand spectra

- Type 1, with referent ground acceleration of 0.25 g (EC8 SpT1)
- Ground category C

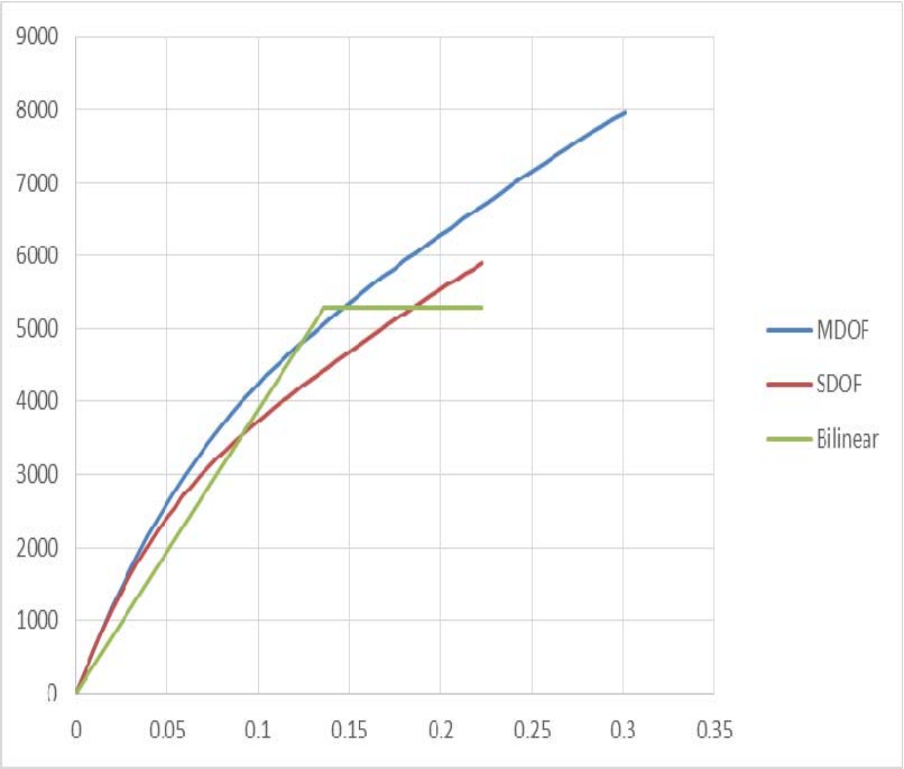


Acceleration displacement response spectrum (ADRS) combines accelerations and displacement on one plot. This representation is especially suitable for combining with SDOF bilinear pushover curve.

$$S_d = \frac{S_e * g * T^2}{4 * \pi^2}$$

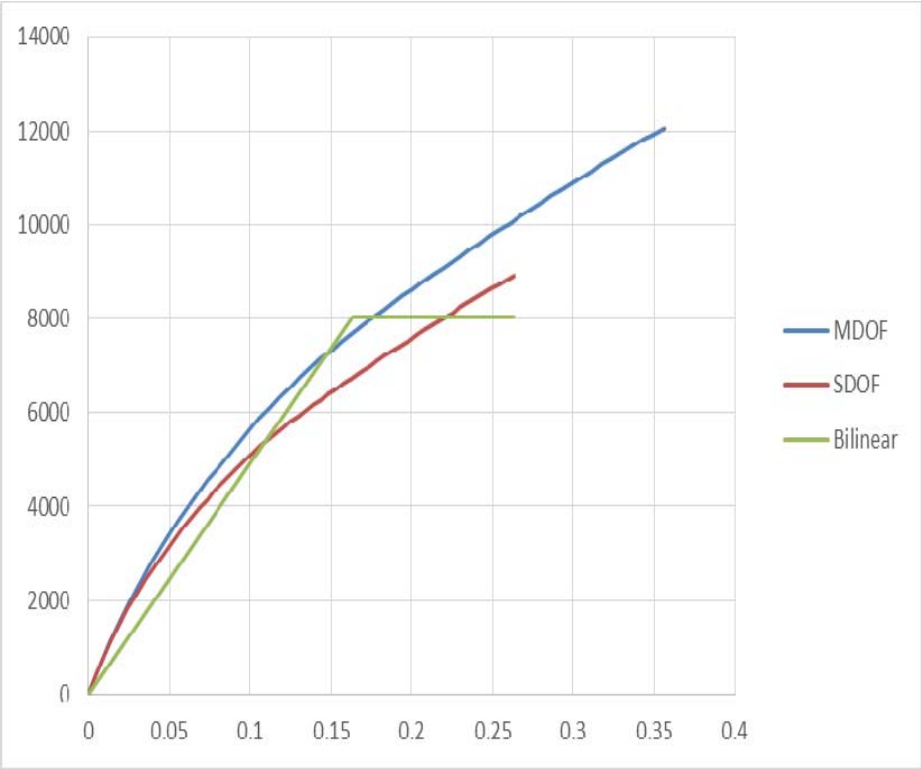
Flexure Capacity

Capacity Curve



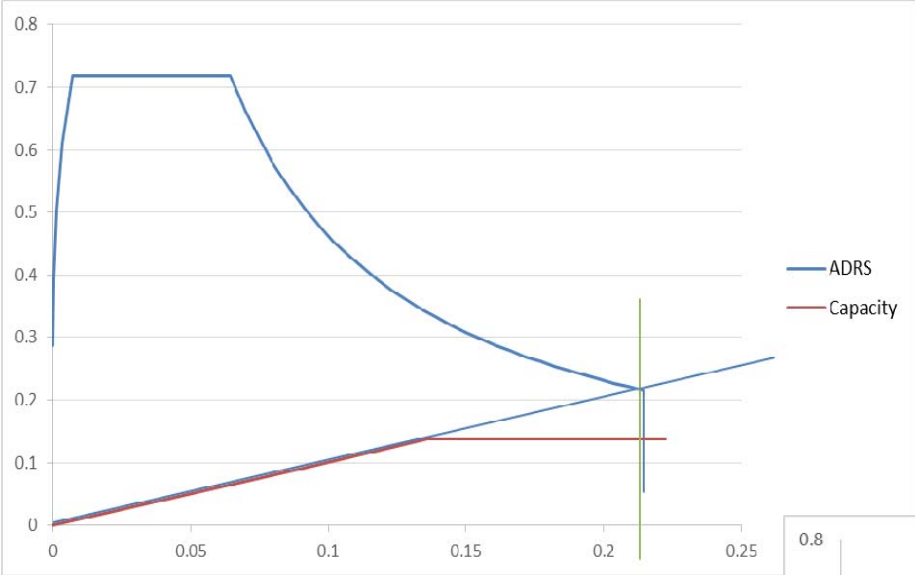
Modal y-y load pattern pushover curves

Uniform y-y load pattern pushover curves



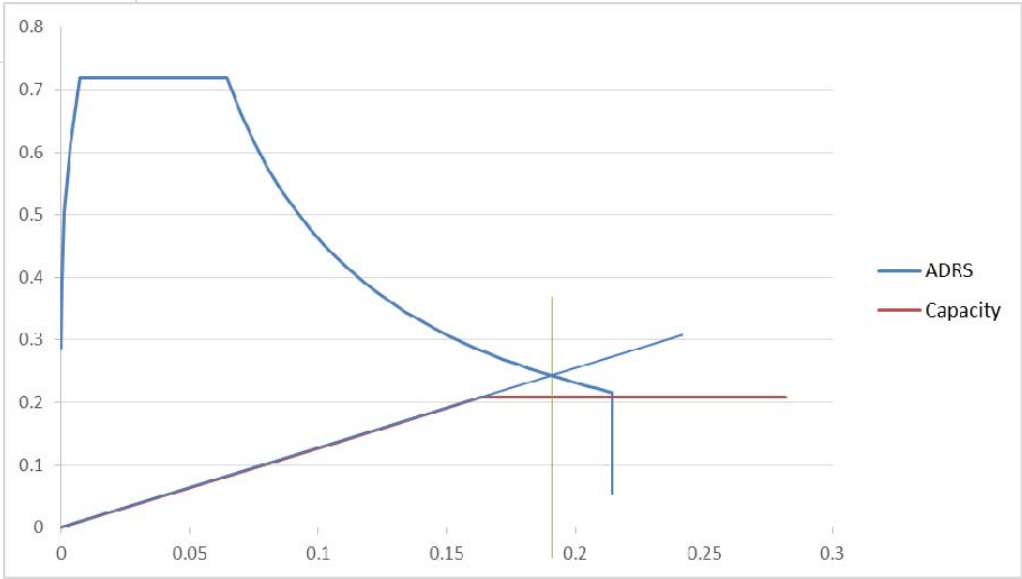
Demand and Flexure Capacity

Capacity Curve



Modal y-y Bilinear SDOF Capacity Curve and Demand

Uniform y-y Bilinear SDOF Capacity Curve and Demand



Demand and Flexure Capacity

Capacity Curve

TABLE : **Demand and Flexure Capacity**

Load case	Demand displacement (m)	Capacity displacement (m)
Modal y-y	0.289	0.301
Uniform y-y	0.259	0.381

Shear Capacity

Shear Capacity

$$V_R = \frac{1}{\gamma_{el}} * \left[\frac{h-x}{2 * L_v} * \min(N; 0.55 * A_c * f_c) + (1 - 0.05 * \min(5; \mu_\Delta^{pl}) * 0.16 * \max(0.5; 100\rho_{tot}) * \left(1 - 0.16 * \min\left(5; \frac{L_V}{h}\right)\right) * \sqrt{f_c} * A_c + \rho_w * b_w * z * f_{yw}\right]$$

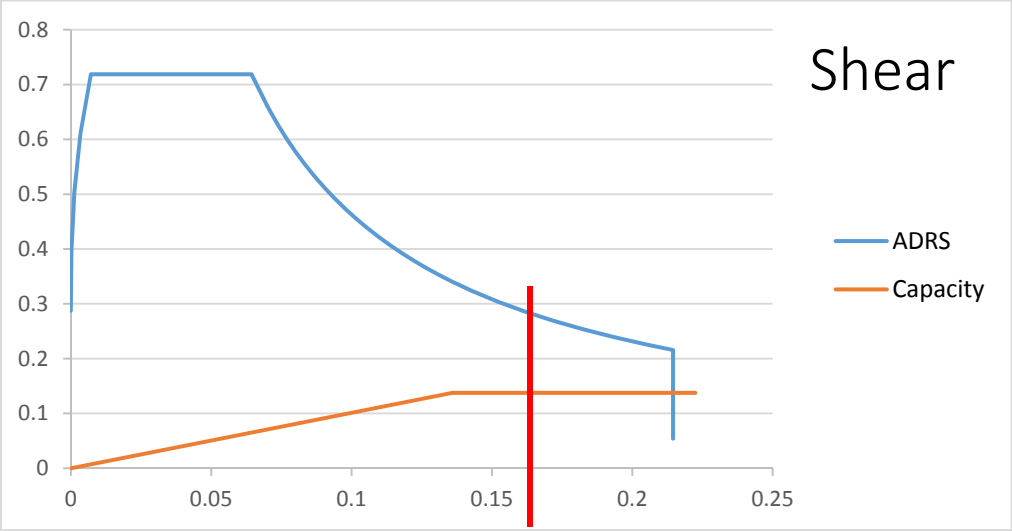
TABLE: Element Forces - Frames

Frame	OutputCase	Step	P	V2	V3	b (m)	h (m)	L (m)	∑A (cm2)	VR0 (MN)	VR5 (MN)	
C09_25	Modal y-y	33	-1281.036	17.803	178.085	0.45	0.45	3.1	24.10	0.191686275	0.176322928	Shear failure
C09_25	Modal y-y	33	-1274.331	17.803	178.085	0.45	0.45	3.1	24.10	0.192122174	0.176758826	Shear failure
C09_25	Modal y-y	33	-1267.625	17.803	178.085	0.45	0.45	3.1	24.10	0.192558137	0.177194789	Shear failure
C09_26	Modal y-y	33	-1252.861	32.056	174.95	0.45	0.45	3.1	24.10	0.193517958	0.17815461	No failure

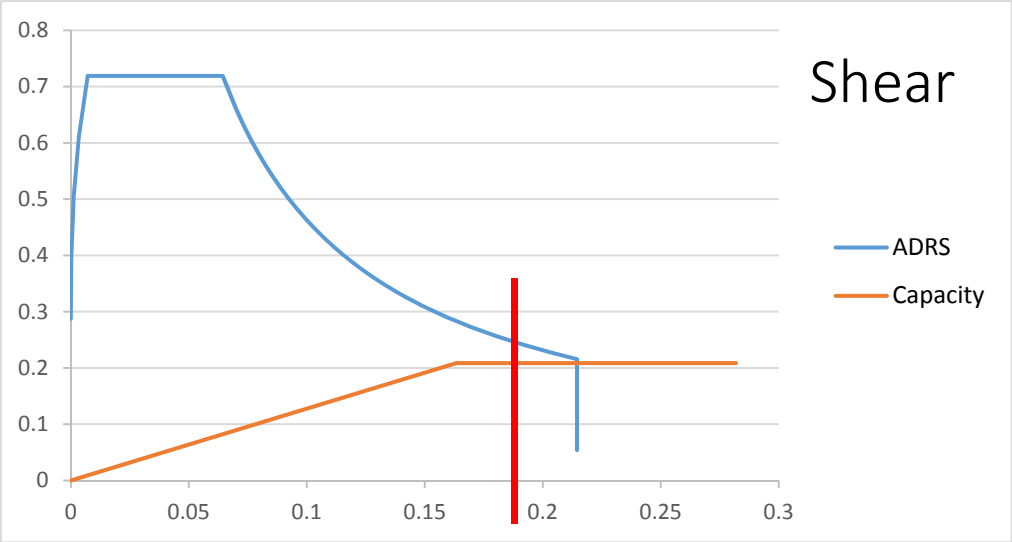
TABLE: Element Forces - Frames

Frame	OutputCase	Step	P	V2	V3	b (m)	h (m)	L (m)	∑A (cm2)	VR0 (MN)	VR5 (MN)	
C05_12	Uniform y-y	39	-2564.332	-29.398	314.506	0.55	0.55	3.1	58.90	0.355455262	0.309525997	Shear failure
C05_12	Uniform y-y	39	-2554.598	-29.398	314.506	0.55	0.55	3.1	58.90	0.356273369	0.310344103	Shear failure
C05_12	Uniform y-y	39	-2544.864	-29.398	314.506	0.55	0.55	3.1	58.90	0.357091475	0.31116221	Shear failure
C07_25	Uniform y-y	39	-1734.487	24.661	251.194	0.5	0.5	3.1	40.30	0.277646157	0.24880149	Shear failure
C07_25	Uniform y-y	39	-1726.208	24.661	251.194	0.5	0.5	3.1	40.30	0.278263076	0.249418409	Shear failure
C07_25	Uniform y-y	39	-1717.929	24.661	251.194	0.5	0.5	3.1	40.30	0.278879995	0.250035328	Shear failure
C07_26	Uniform y-y	39	-1682.986	38.177	245.425	0.5	0.5	3.1	40.30	0.281483813	0.252639145	No failure

Demand and Shear Capacity



Modal



Uniform

Demand and Shear Capacity

Shear Capacity

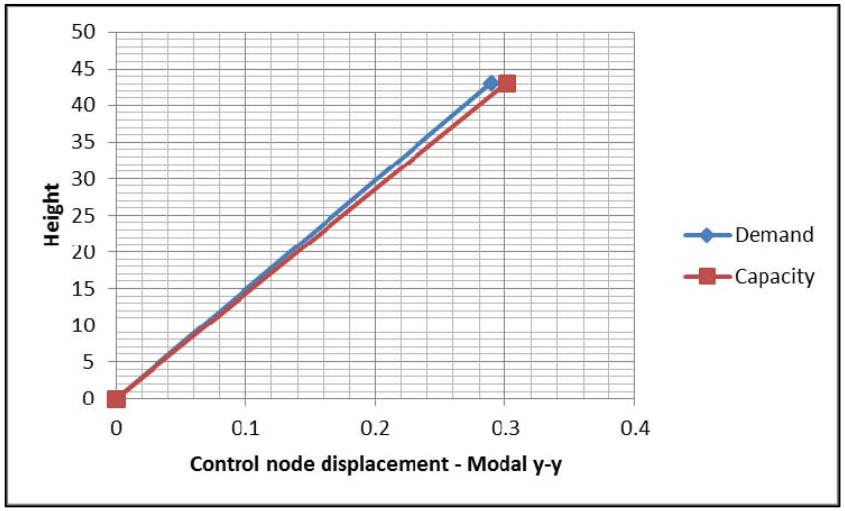
TABLE: **Demand and Shear Capacity**

Load case	Demand displacement (m)	Capacity displacement (m)
Modal y-y	0.289	0.2185
Uniform y-y	0.259	0.2544

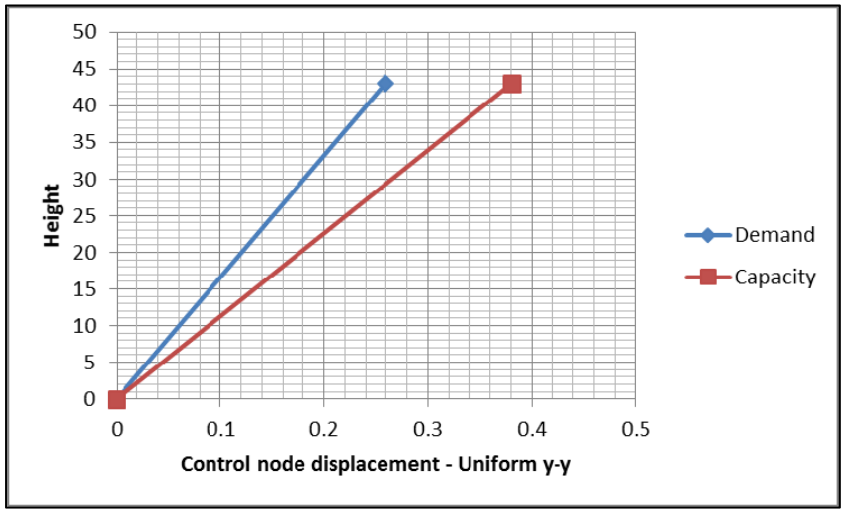
Conclusions

Flexure check

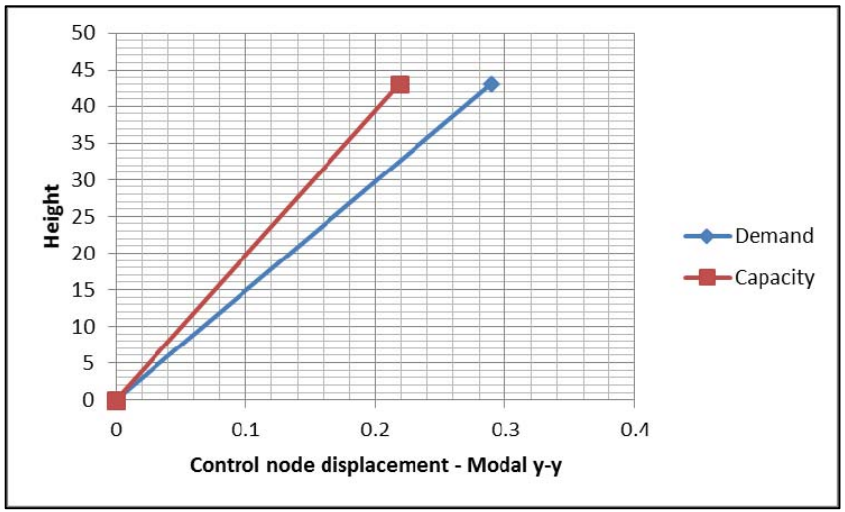
Modal

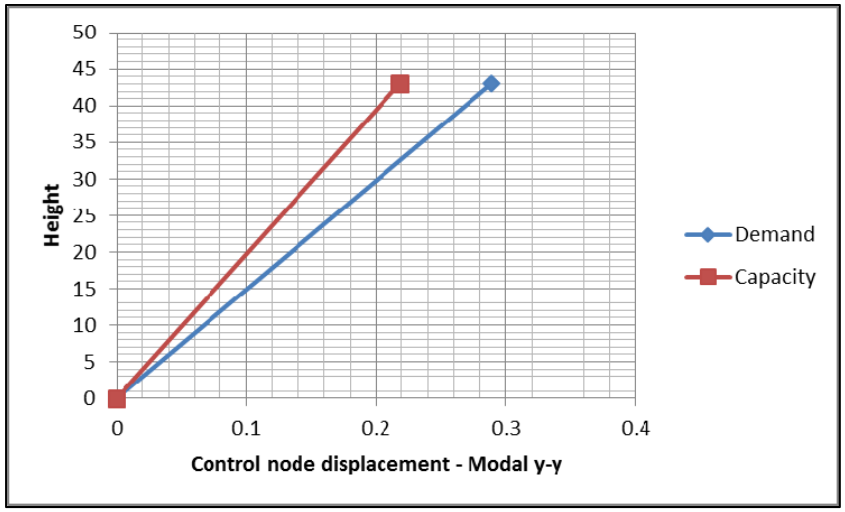


Uniform



Shear check





Conclusions

- The behavior of the structure in flexure check indicates the ductile behavior of the entire structure and the satisfaction of the requirements in terms of allowable demand. The structure has ductile behavior, even though there are sections with very little ductile, the relation of ultimate by yielding displacements. In terms of calculation, the following values are shown graphically.
- The behavior of the structure in shear check indicates the brittle behavior of the entire structure and not the satisfaction of the requirements in terms of allowable demand. The structure has brittle failure at the start of plastic (nonlinear) zone. The ratio of the existing shear capacity with demand is especially expressed in the modal load pattern. In terms of calculations, the values are shown graphically.

Thanks For Your Attention