TECHNICAL UNIVERSITY OF CIVIL ENGINEERING
BUCHAREST

PhD THESIS
Summary

ANTISEISMIC PROTECTION SYSTEMS OF CIVIL AND INDUSTRIAL CONSTRUCTIONS BY ISOLATORS AND SEISMIC MORTIZORS

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Bucharest
2020

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ANNEXES

CHAPTER I

CURRENT STATE OF SEISMIC INSULATORS AND SHOCK ABSORBER SYSTEMS

1.1 *Introduction*

The main objective of this paper is to study the reduction of the effect of seismic action on buildings by the method of insulating the support base.

The first chapter has an introductory character, in which the principles of the seismic isolation method of the base, the main advantages and a short history of it are presented. The main objectives and purpose of this research are established.

The location of the seismic insulators leads to an increase in the flexibility of the base in the horizontal plane, in order to increase the vibration period, so that the acceleration transmitted to the structure is considerably reduced. Comparing the variations of the displacements and of the forces acting on the structure, it is found that with the change of the vibration period, an increase of the displacements at the base level corresponds to a decrease of the forces acting on the structure.

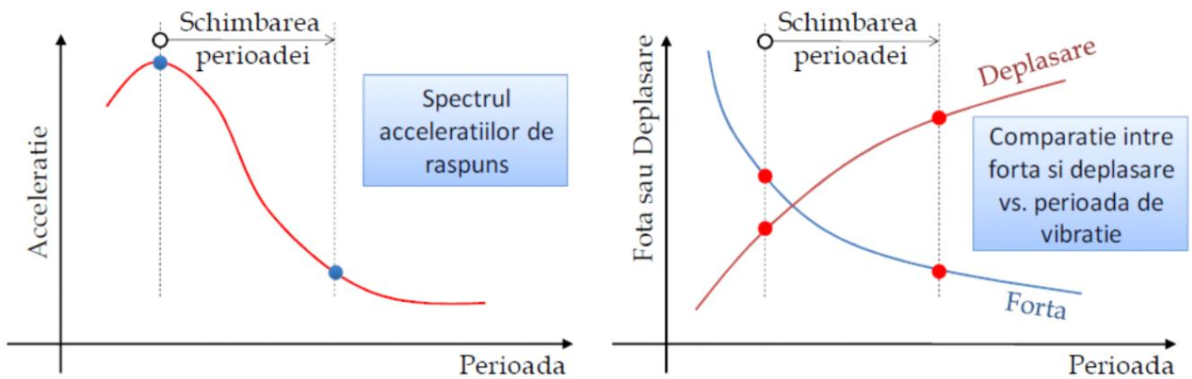


Figure 1.1-1 Theoretical principle of the base insulation method

a) The spectrum of absolute response accelerations b) Response displacement spectrum

1.2 *Current status in the use of anti-seismic systems*

The current stage of seismic protection development offers - through added damping - a possibility to register the structure both in behavioral parameters (associated, primarily SLS - service limit state) and in a state of rigidity associated with multi-storey structures. In the preliminary stage of the structural design an equivalence of the adoption of increased rigidity and / or of the added damping is necessary.

CHAPTER II

STUDIES ON REDUCING SEISMIC RESPONSE WITH ANTI-SEISMIC DEVICES

2.1 *General aspects*

More and more buildings, regardless of their importance, are designed to withstand seismic movement through the use of seismic damping technologies. These have the role of absorbing and then dissipating the energy induced in the structure by the seismic hazard. The purpose of their use is given by the need to improve the behavior of the structure in terms of ductility or to fully take over the seismic loads.

2.1.1 *Requirements for seismic protection solutions and technologies*

If you want to add additional dissipative elements (such as special technologies for active or semi-active seismic damping) the dynamic equilibrium equation becomes:

$M_{\ddot{q}}(t) + C_{\dot{q}}(t) + Q_r\big(q(t)\big) = -M_{\ddot{q}_s}(t) + D_u(t)$ (2.1.1-1)

where:

D represents the matrix of the application locations of the seismic control forces *u(t)*

2.1.3 Current technical solutions

It should be noted that at the level of current scientific contributions there is no clear delimitation or classification of special seismic damping technologies, both for civil constructions and for works of art. As such, the current classifications depend mainly on the type of shock absorbers designed by various companies.

The second chapter presents the types of anti-seismic devices used for seismic insulation of structures. The composition modes, the operating principles, their behavior, but also the calculation relations of the main characteristics necessary for their modeling are detailed. Both the types of established insulators, which have been used successfully in practice, and new isolation mechanisms proposed by researchers in this field are presented. The author presents the advantages and disadvantages of these devices, as well as their areas of applicability.

In general, this chapter presents a wide range of conclusions and results, both numerically - by calculation (using FRP Analysis, SeismoStruct, AmQuake programs) and theoretically - technologically, based on technical specifications on the behavior of systems for system depreciation. anti-vibration and anti-seismic of civil structures.

In this chapter was analyzed and studied the possibility of using, as an alternative to conventional methods of isolation and seismic conformation, special technologies for damping and dissipation of seismic energy in civil engineering. Also, following the study of the related bibliography, a series of partial conclusions were formulated corresponding to each stage of study specific to the issue of special technologies for damping and seismic dissipation.

From the comparative analysis of the obtained results, the following can be deduced:

1. The correct assessment of the seismic action on a structure must take into account the following factors: type of earthquake and its intensity (fast-slow, magnitude), type of soil of the site, structural characteristics (type of structure, materials used, structural system). Taking into account only the peak value of the terrain acceleration without taking into account the type of possible earthquake is not enough.

2. In evaluating the mechanism of plastic joint formation - in order to process seismic retrofitting, it is necessary to take into account all the characteristics of the structural elements to be rehabilitated (reinforcement, percentage of reinforcement, type of reinforcement) and not only the characteristics of the section or its rigidities;

3. Technologies that use the principle of isolating the base of structures have proven to be the most efficient and viable for the types of structures considered. Thus, a series of anti-seismic compliance requirements are noted, such as: the own vibration period of the insulation system must be chosen so as to exceed the vibration periods induced by the most probable seismic movement; for structures with an insulated base, a depreciation coefficient of at least 10% must be ensured in order to obtain the most appropriate depreciation efficiency; compared to TMD systems, in the case of base insulation, the damped structures have a relatively constant behavior during seismic stress;

4. The degree of reduction of the seismic action depends totally on the damped structural system, on the type of seismic isolation and on the seismic movement expected to be damped by

the dissipative systems;

5. The installation of damping and dissipation systems before the commissioning of conventionally rehabilitated buildings would have prevented structural damage in the event of earthquakes of more than 7.2 degrees on the Richter scale;

6. Although classical rehabilitation is effective, we have pointed out that there is a markedly improved structural behavior when using unconventional technologies;

7. In the case of the proposed unconventional system, no structural damage is expected which may affect the overall stability for seismic events of up to 7.8 degrees on the Richter scale with a peak ground acceleration of up to 0.6g.

8. The degree of improvement of the dynamic behavior for dissipative technologies (compared to classical rehabilitation technologies) is 25%;

9. The increase of the general damping does not help to decrease the maximum seismic amplitudes, but only to a faster attenuation of the movement, in certain limits of the damping;

10. There are a number of situations in which seismic damping technologies prove their limitations:

11. In some situations (over-damping), it has been found that systems with an isolated base have a much weaker damping response than systems without mounted dissipative technology;

12. In the case of systems with hydraulic pistons, their entry into service is made only after the seismic movement has registered the maximum amplitude;

13. In the case of pistons with viscous liquid, return forces are required to restore the dissipative system to its initial state;

Overall, strictly from the point of view of structural control, it has been shown that each of the listed technologies has a number of specific limitations in terms of the optimal installation or use of the systems in question. Ignorance or poor exploitation can lead to real disasters - progressive or widespread collapse, because many of these systems exert structural control forces that can be much more harmful than the seismic hazards themselves, in unfortunate cases.

From a theoretical point of view, it is found that at the level of current scientific contributions there is no clear delimitation or classification of unconventional seismic damping technologies, both for civil constructions and for works of art. As such, the current classifications are sometimes made empirically and depend mainly on the varied classification given by various companies developing special technologies for seismic dissipation and damping.

CHAPTER III

COMPARATIVE STUDY FOR BUILDINGS WITH REINFORCED CONCRETE WALLS USING THE PRINCIPLE OF INSULATION OF THE BASE IN SEISMIC DESIGN IN ROMANIA

3.1.2.1 The concept of base insulation

The fundamental principle of insulating the base is to modify the response of the building so that the ground moves under the building without transmitting its movement. The ideal system would consist of a total separation, but in reality it is necessary to have several contact areas between the structure and the terrain.

Figure 3.1.2.1-1 "The ideal base insulation system"

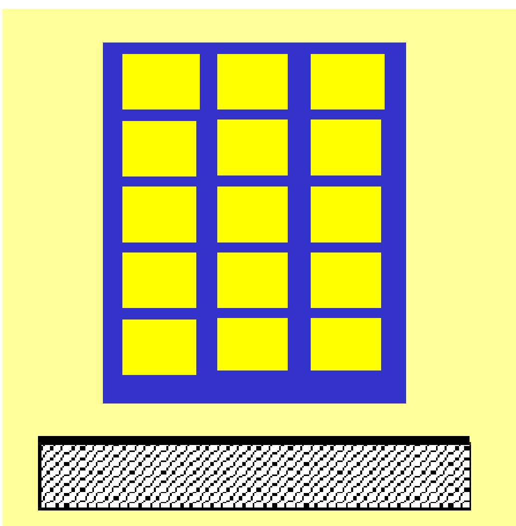
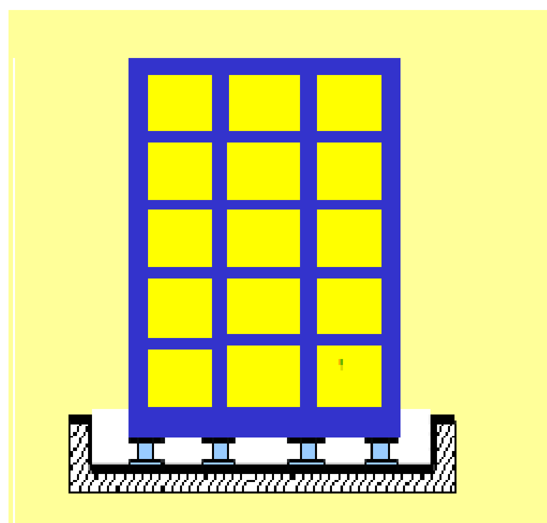


Figure 3.1.2.1-2 "The real system of isolation base"



The third chapter presents a comparative study of buildings with reinforced concrete walls using the principle of base insulation in seismic design in Romania. For the present study, 9 models of structures were analyzed, comparing the traditional design of structures (taking into account the modeling of the land-structure interaction) with the design of seismically isolated buildings (taking into account the insulation of the base).

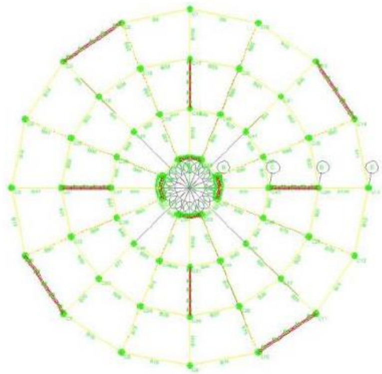


Figure 3.2.1-1
" Circular building plan "

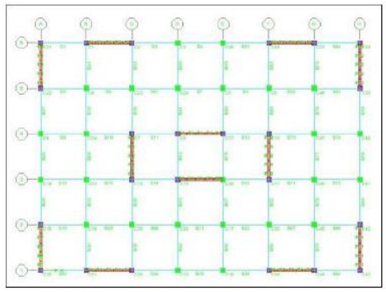


Figure 3.2.1-2
" Rectangular building plan "

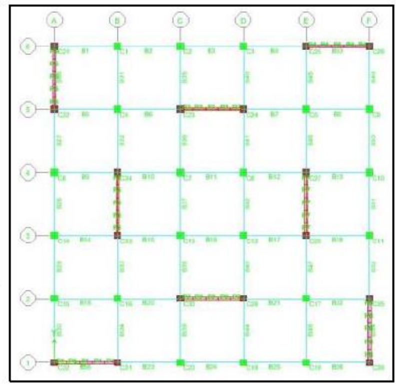


Figure 3.2.1-3

3.2.3.2 Insulator modeling

For the modeling of the base insulation system, in both variants, the structure placed on a reinforced concrete screed was considered. The insulation system is made of a number of insulators established for each building. Two types of insulators were used, namely High Damping Rubber Bearing (HDRB) and LRB (Lead Rubber Bearings) replaced for modeling with "link" type elements, for the calculation considering a damping coefficient ν = 16% respectively ν = 28% of the critical depreciation

3.3 Presentation of the content of the analyzes performed in the paper and the results obtained

3.3.1 Results obtained in non-insulated buildings

Following the pre-sizing, the following results were obtained:

- the thickness of the plate is Hpl = 13cm for all the analyzed buildings
- the beam section is 25x50 cm for rectangular and square buildings
- 3 sections were chosen for the circular buildings: 25x65cm, 25x50cm and 25x30cm
- the sections of columns and walls are shown in the following table

	Circular			Rectangular			Square		
Sections	S+P+4E	S+P+9E	S+P+14E	S+P+4E	S+P+9E	S+P+14E	S+P+4E	S+P+9E	S+P+14E
Walls	15cm	25cm	30cm	15cm	25cm	30cm	15cm	25cm	30cm
Columns	35x35cm	50x50cm	60x60cm	35x35cm	50x50cm	60x60cm	35x35cm	50x50cm	60x60cm

Table 3.3.1-1 "Elements sections"

3.3.2 Results obtained in isolated buildings

Following the pre-sizing calculations, the following types of insulators were chosen for the analyzed buildings.

- **Izolatori de tip HDRB**

Floors No.	Circulara			Dreptunghiulara			Patrata		
S+P+4E	Tip izolator	PmaxSLU	22050	Tip izolator	PmaxSLU	20150	Tip izolator	PmaxSLU	18900
	HDH800x128	PmaxSeism	19500	**HDH750x135**	PmaxSeism	14700	**HDH750x165**	PmaxSeism	10900
	Nr. Izolatori	Kr	5.5	Nr. Izolatori	Kr	4.58	Nr. Izolatori	Kr	3.75
	4	ξ	16	4	ξ	16	4	ξ	16
		Smax [mm]	260		Smax [mm]	270		Smax [mm]	330
S+P+9E	Tip izolator	PmaxSLU	36050	Tip izolator	PmaxSLU	22050	Tip izolator	PmaxSLU	20650
	HDH1000x180	PmaxSeism	26600	**HDH800x128**	PmaxSeism	19800	**HDH750x150**	PmaxSeism	12450
	Nr. Izolatori	Kr	6.11	Nr. Izolatori	Kr	5.5	Nr. Izolatori	Kr	4.12
	8	ξ	16	8	ξ	16	8	ξ	16
		Smax [mm]	360		Smax [mm]	260		Smax [mm]	300
S+P+14E	Tip izolator	PmaxSLU	47600	Tip izolator	PmaxSLU	40050	Tip izolator	PmaxSLU	28000
	HDH1200x168	PmaxSeism	47600	**HDH1100x154**	PmaxSeism	40050	**HDH900x144**	PmaxSeism	25200
	Nr. Izolatori	Kr	9.42	Nr. Izolatori	Kr	8.64	Nr. Izolatori	Kr	6.19
	8	ξ	16	8	ξ	16	8	ξ	16
		Smax [mm]	340		Smax [mm]	310		Smax [mm]	290

Table 3.3.2-1 " Types of HDRB insulators "

- **LRB type insulators**

Nr. Etaje	Circulara			Dreptunghiulara			Patrata		
S+P+4E	Tip izolator	PmaxSLU	14800	Tip izolator	PmaxSLU	2000	Tip izolator	PmaxSLU	9650
	LRN900x162	PmaxSeism	10800	**LRS450x96**	PmaxSeism	1150	**LRS1000x180**	PmaxSeism	7100
	Nr. Izolatori	Kr	5.23	Nr. Izolatori	Kr	0.89	Nr. Izolatori	Kr	240
	8	ξ	28	48	ξ	28	8	ξ	28
		Smax [mm]	330		Smax [mm]	200		Smax [mm]	360
S+P+9E	Tip izolator	PmaxSLU	36250	Tip izolator	PmaxSLU	5350	Tip izolator	PmaxSLU	18900
	LRN1400x252	PmaxSeism	26750	**LRS750x135**	PmaxSeism	3900	**LRN1000x200**	PmaxSeism	11600
	Nr. Izolatori	Kr	8.16	Nr. Izolatori	Kr	1.8	Nr. Izolatori	Kr	5.23
	8	ξ	28	48	ξ	28	8	ξ	28
		Smax [mm]	510		Smax [mm]	270		Smax [mm]	400
S+P+14E	Tip izolator	PmaxSLU	26450	Tip izolator	PmaxSLU	7500	Tip izolator	PmaxSLU	25550
	LRN1200x116	PmaxSeism	19450	**LRS900x144**	PmaxSeism	6750	**LRN1200x192**	PmaxSeism	25550
	Nr. Izolatori	Kr	6.99	Nr. Izolatori	Kr	2.4	Nr. Izolatori	Kr	7.87
	12	ξ	28	48	ξ	28	8	ξ	28
		Smax [mm]	440		Smax [mm]	290		Smax [mm]	390

Tabel 3.3.2-2 " Types of LRB insulators "

- **The following lateral displacements were obtained at the base**

	HDRB			**LRB**		
	x	y	Dmax_HDRB	x	y	Dmax_LRB
S+P+4E_c	0.2567	0.2428	0.26	0.2092	0.1941	0.33
S+P+4E_d	0.2411	0.2411	0.27	0.1913	0.1914	0.2
S+P+4E_p	0.2418	0.2418	0.33	0.1919	0.1919	0.36

Tabel 3.3.2-3 " Table of lateral displacements at the base "

- **The following efforts have been achieved in the structural elements:**

	Rectangular			**Circular**			**Square**		
	Neizolata	**HDRB**	**LRB**	**Neizolata**	**HDRB**	**LRB**	**Neizolata**	**HDRB**	**LRB**
E4	642.895	217.906	252.43	1281.713	680.11	1087.778	608.648	266.873	294.97
E3	1669.5	890.329	1206.407	3438.277	2254.427	3589.311	1720.798	1015.046	1095.384
E2	2962.693	1938.017	2832.863	6188.765	4707.779	7461.123	3209.613	2298.216	2435.44
E1	4573.064	3207.521	5205.792	9364.081	7859.779	12374.42	5032.192	4175.411	4281.551
P	6518.477	4378.952	8677.503	12765.28	11331.96	17618.74	7105.622	6779.988	6485.193

Table 3.3.2-4 " Maximum moments in the walls of Ug + Gf + 4F buildings "

	Dreptunghiulara			Circulara			Patrata		
	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E4	261.92	112.78	149.64	471.81	265.64	422.92	162.75	45.94	149.64
E3	439	272.19	396.66	796.63	575.87	912.95	347.55	210.93	396.66
E2	551.5	395.16	618.39	1019.21	866.21	1365.77	488.9	389.92	618.39
E1	662.46	462.22	858.1	1173.9	1092.2	1702.34	609.51	587.15	858.1
P	748.63	414.52	1202.81	1229.37	1184.22	1789.92	682.43	824.87	1202.81

Table 3.3.2-5 "Maximum shear forces in the walls of Ug + Gf + 4F buildings"

	Dreptunghiulara			Circulara			Patrata		
	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E4	-536.65	-536.65	-536.65	-427.49	-430.33	-425.72	-284.32	-287.61	-286.91
E3	-1027.69	-1027.69	-1027.69	-838.64	-845.8	-833.78	-558.64	-566.12	-564.3
E2	-1511.25	-1511.23	-1511.23	-1243.76	-1254.4	-1235.01	-829.36	-840.48	-837.55
E1	-1986.01	-1986.08	-1986.08	-1644.08	-1656.89	-1630.64	-1097.67	-1111.62	-1107.64
P	-2447.85	-2447.55	-2447.55	-2036.53	-2049.16	-2017.99	-1362.52	-1378	-1372.65

Table 3.3.2-6 "Maximum axial forces in the walls of Ug + Gf + 4F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E9	910.957	780.605	1214.427	983.244	733.173	822.641	987.515	890.81	899.654
E8	1247.835	647.019	1010.928	2030.905	594.032	666.667	1283.737	881.693	888.849
E7	1991.456	646.256	991.612	3911.67	473.368	531.811	1987.953	331.63	331.436
E6	3227.297	1022.773	1523.491	6773.159	2592.802	2907.485	3302.395	1006.529	1019.203
E5	4900.981	2548.431	3812.149	10583.13	5803.468	6503.1	5096.286	2653.887	2683.915
E4	6976.785	4576.993	6839.032	15285.84	10126.39	11341.83	7331.978	4852.904	4905.249
E3	9460.469	7165.017	10727.13	20804.09	15518.45	17376.12	10028.56	7661.773	7741.685
E2	12372.76	10391.52	15749.47	27006.91	21779.46	24385.25	13215.88	11188.81	11302.38
E1	15799.13	14412.76	22667.44	33711.18	28489.52	31906.25	16977.84	15780.16	15936.81
P	19585.9	19802.24	33232.69	40567.08	34871.34	39092.34	21178.25	22255.15	22472.19

Table 3.3.2-7 "Maximum moments in the walls of Ug + Gf + 9F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E9	194.77	111.44	173.15	290.27	116.14	129.32	197.57	142.35	143.64
E8	464.25	216.13	335.06	653.72	208.37	234.08	472.6	225.41	227.89
E7	634.46	377.81	581.87	1002.46	527.59	591.8	666.81	401.52	405.93
E6	774.51	531.57	812.27	1337.22	876.65	982.56	817.3	570.12	576.25
E5	895.34	687.61	1041.84	1648.83	1240.16	1389.11	948.4	742.56	750.34

E4	1007.8	851.07	1281.75	1933.29	1606.88	1798.96	1076.72	922.34	931.72
E3	1116.64	1026.89	1553	2179.9	1952.85	2185.8	1203.46	1114.56	1125.55
E2	1222.52	1220.5	1902.54	2367.71	2223.57	2489.53	1324.8	1333.62	1346.43
E1	1347.71	1455.32	2490.04	2477.57	2343.33	2626.59	1460.42	1656.55	1672.16
P	1396.62	1868.22	3639.66	2449.58	2194.91	2471.31	1532.27	2237.99	2258.9

Table 3.3.2-8 "Maximum shear forces in the walls of Ug + Gf + 9F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E9	-621.83	-621.81	-621.81	-501.03	-517.04	-511.18	-633.92	-634.39	-634.37
E8	-1196.42	-1196.38	-1196.38	-969.91	-1007.47	-993.91	-1220.57	-1221.46	-1221.43
E7	-1767.67	-1767.61	-1767.61	-1432.94	-1492.07	-1470.67	-1804.27	-1805.54	-1805.49
E6	-2335.37	-2335.29	-2335.29	-1892.51	-1972.48	-1943.11	-2383.85	-2385.46	-2385.41
E5	-2898.06	-2897.96	-2897.96	-2348.95	-2448.08	-2410.71	-2957.81	-2959.71	-2959.64
E4	-3454.58	-3454.46	-3454.46	-2803.74	-2919.37	-2874.17	-3524.71	-3526.84	-3526.76
E3	-4003.63	-4003.5	-4003.5	-3258.66	-3387.28	-3334.69	-4083.02	-4085.33	-4085.24
E2	-4543.88	-4543.72	-4543.72	-3715.89	-3853.29	-3794.08	-4631.16	-4633.6	-4633.51
E1	-5074.03	-5073.89	-5073.89	-4178.08	-4320.37	-4255.73	-5167.33	-5169.77	-5169.67
P	-5592.24	-5592.14	-5592.15	-4646.28	-4787.78	-4719.72	-5690.25	-5693.91	-5693.81

Table 3.3.2-9 "Maximum axial forces in the walls of Ug + Gf + 9F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E14	2415.263	2036.086	2677.733	2852.705	2399.668	2151.141	2534.532	2071.147	2091.418
E13	2996.79	2622.627	3440.517	4668.414	4054.142	3631.338	3276.733	2844.378	2869.429
E12	3061.522	2666.389	3485.517	5520.025	4818.178	4312.055	3336.684	3042.594	3065.778
E11	2974.29	2294.683	2983.003	5678.265	4594.53	4107.425	3024.186	2793.101	2809.626
E10	3140.67	1509.017	1938.713	5928.97	3362.577	2999.992	2711.289	2096.914	2102.435
E9	3980.779	340.714	409.679	7428.605	1161.476	1026.431	3199.497	947.383	938.395
E8	5582.972	1441.198	1930.501	10667.05	2456.347	2232.195	4878.081	1084.39	1112.863
E7	7831.007	3618.254	4751.221	15396.04	6868.098	6182.842	7409.548	3304.779	3356.702
E6	10619.28	6331.722	8231.747	21346.37	12478.99	11199.75	10547.72	6106.699	6185.118
E5	13891.32	9618.808	12407.52	28374.7	19359.35	17344.1	14193.34	9512.188	9620.426
E4	17632.01	13535.85	17357.73	36398.81	27562.61	24665.8	18312.33	13569.56	13710.88
E3	21854.94	18161.54	23250.07	45335.05	37031.63	33127.98	22917.1	18358.06	18535.85
E2	26623.9	23595.99	30454.2	55050.51	47451.32	42486.15	28090.93	24049.45	24267.8
E1	32100.17	30172.09	40153.53	65358	58171.79	52227.38	34027.35	31322.97	31590
P	37882.26	38793.35	54374.47	75838.89	68060.87	61399.81	40354.65	41186.87	41518.68

Table 3.3.2-10 "Maximum moments in the walls of Ug + Gf + 14F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E14	469.67	402.74	528.81	646.75	550.85	491.78	498.19	420.3	424.24
E13	395.01	111.44	150.34	472.51	249.94	221.03	339.93	81.88	83.41
E12	622.04	299.85	399.45	649.02	51.35	47.45	582.88	275.88	279.71
E11	793.96	449.51	596.63	989.33	383.86	346.36	766.98	429.16	434.7
E10	949.97	598.75	791.99	1360.44	732.95	658.94	944.13	585.95	593.04
E9	1093.45	752.96	991.99	1717.01	1084.97	973.91	1117.53	751.09	759.63
E8	1229.86	913.5	1197.38	2051.01	1443.68	1294.32	1280.85	924.38	934.26
E7	1359.51	1080.21	1406.68	2365.18	1816.21	1626.48	1430.67	1104.45	1115.55
E6	1479.67	1252.99	1618.75	2663.6	2209.21	1976.07	1566.67	1289.9	1302.1

E5	1592.62	1432.91	1835.75	2948.42	2623.91	2344.33	1689.99	1480.4	1493.55
E4	1700.95	1623.2	2068.42	3215.89	3047.91	2721.62	1804.49	1678.53	1692.52
E3	1807.12	1829.3	2343.85	3453.16	3441.57	3076.53	1918.56	1892.32	1907.11
E2	1926.28	2056.29	2726.77	3636.73	3716.36	3337.58	2049.91	2150.43	2166.15
E1	2086.17	2379.15	3485.79	3742.5	3757.73	3412.85	2228.01	2619.8	2637.66
P	2087.6	2987.72	4897.56	3690.46	3408.89	3156.91	2258.96	3408.46	3431.02

Table 3.3.2-11 "Maximum shear forces in the walls of Ug + Gf + 14F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E14	-675.86	-675.83	-675.83	-767.86	-735.27	-724.95	-684.14	-685.85	-685.8
E13	-1303.57	-1303.52	-1303.52	-1574.26	-1498.55	-1474.57	-1321.86	-1325.15	-1325.05
E12	-1929.3	-1929.22	-1929.22	-2378.25	-2258.91	-2221	-1957.91	-1962.69	-1962.54
E11	-2553.09	-2552.98	-2552.98	-3183.73	-3020.5	-2968.29	-2591.88	-2598.1	-2597.91
E10	-3174.08	-3173.95	-3173.95	-3988.65	-3781.94	-3715.05	-3222.9	-3230.49	-3230.26
E9	-3791.66	-3791.51	-3791.51	-4790.57	-4541.69	-4459.8	-3850.24	-3859.12	-3858.85
E8	-4405.14	-4404.95	-4404.95	-5586.5	-5297.71	-5200.61	-4473.14	-4483.2	-4482.89
E7	-5013.79	-5013.58	-5013.58	-6372.98	-6047.43	-5935.09	-5090.8	-5101.93	-5101.58
E6	-5616.89	-5616.65	-5616.65	-7146.02	-6787.75	-6660.36	-5702.39	-5714.47	-5714.08
E5	-6213.68	-6213.4	-6213.4	-7901.19	-7514.99	-7373.05	-6307.06	-6319.92	-6319.51
E4	-6803.35	-6803.05	-6803.05	-8633.61	-8224.91	-8069.21	-6903.88	-6917.38	-6916.94
E3	-7385.09	-7384.75	-7384.75	-9337.9	-8912.6	-8744.35	-7491.87	-7505.87	-7505.41
E2	-7957.99	-7957.62	-7957.62	-10008.2	-9572.45	-9393.32	-8069.99	-8084.35	-8083.87
E1	-8521.21	-8520.84	-8520.84	-10638	-10197.3	-10009.5	-8637.12	-8651.61	-8651.12
P	-9073.39	-9073.2	-9073.2	-11221.1	-10780.4	-10588.6	-9192.08	-9208.27	-9207.77

Table 3.3.2-12 "Maximum axial forces in the walls of Ug + Gf + 14F buildings"

- **Columns efforts**

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E4	37.309	33.515	39.515	36.563	32.216	38.088	34.229	31.548	31.778
E3	31.196	27.652	33.503	33.074	29.141	34.871	29.15	26.59	26.799
E2	30.618	27.201	33.322	33.056	29.518	35.104	28.828	26.428	26.688
E1	29.533	28.776	34.077	33.639	32.47	37.572	28.255	28.746	28.698
P	15.339	8.811	5.532	14.812	8.324	7.094	15.094	4.449	7.81

Table 3.3.2-13 "Maximum moments in the pillars of Ug + Gf + 4F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E4	28.59	25.82	30.26	26.34	23.23	27.34	25.92	24	24.17
E3	20.26	17.99	21.86	21.76	19.18	23	19.01	17.39	17.53
E2	20.35	18.27	22.25	21.95	19.7	23.42	19.09	17.71	17.88
E1	18.94	18.27	21.62	21.79	20.9	24.21	18.03	18.13	18.17
P	11.43	4.65	5.97	12.36	5.79	6.31	11.05	4.23	4.67

Table 3.3.2-14 "Maximum shear forces in the pillars of Ug + Gf + 4F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E4	-139.58	-141.04	-138.57	-191.1	-188.42	-193.34	-137.86	-139.64	-139.51

E3	-294.54	-298.35	-291.82	-411.68	-404.66	-415.93	-287.55	-292.06	-291.74
E2	-449.57	-455.37	-444.9	-631.78	-620.87	-638.3	-438.79	-445.54	-445.06
E1	-606.36	-613.52	-599.58	-851.35	-837.55	-860.46	-592.93	-601	-600.44
P	-765.24	-773.04	-756.44	-1067.84	-1051.47	-1078.02	-751.94	-761.05	-760.63

Table 3.3.2-15 "Maximum axial forces in the pillars of Ug + Gf + 4F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E9	115.782	116.838	127.915	147.529	116.838	127.915	117.353	97.881	98.723
E8	103.181	106.979	117.925	136.951	106.979	117.925	104.541	86.657	87.421
E7	106.245	109.45	120.651	139.593	109.45	120.651	109.426	91.201	92.011
E6	105.57	109.768	121.245	138.867	109.768	121.245	109.441	92.276	93.104
E5	102.824	108.361	119.896	135.05	108.361	119.896	107.523	92.342	93.178
E4	97.012	104.069	115.395	127.187	104.069	115.395	102.29	89.923	90.742
E3	87.598	95.762	106.512	114.58	95.762	106.512	93.312	84.419	85.191
E2	74.127	84.952	94.901	96.543	84.952	94.901	79.661	74.371	75.056
E1	54.177	49.681	55.393	70.441	49.681	55.393	60.153	59.876	60.421
P	42.708	0	0	57.101	0	0	47.237	0	0

Table 3.3.2-16 "Maximum moments in the pillars of Ug + Gf + 9F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E9	90.72	75.31	108.61	113.73	90.08	98.58	92.51	77.2	77.86
E8	67.73	55.96	81.39	90.63	70.72	78.08	68.4	56.77	57.27
E7	71.44	59.52	86.7	93.63	73.7	81.25	73.58	61.66	62.21
E6	70.26	59.28	86.82	92.46	73.56	81.25	72.61	61.71	62.27
E5	67.81	58.29	85.76	89.19	72.21	79.86	70.63	61.28	61.83
E4	63.12	55.52	82.06	83.04	68.71	76.1	66.2	58.89	59.42
E3	55.88	50.52	75	73.57	62.37	69.22	59.1	54.19	54.68
E2	45.73	42.65	63.71	60.29	53.43	59.44	48.75	46.25	46.67
E1	31.59	31.38	46.17	42.07	32.28	35.81	34.59	34.92	35.23
P	19.56	4.47	8.01	27.33	15.77	17.88	21.45	5.96	6.01

Table 3.3.2-17 "Maximum shear forces in the pillars of Ug + Gf + 9F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E9	-134.18	-137.96	-130.33	-167.77	-160.25	-143.2	-193.18	-194.56	-194.47
E8	-289.5	-295.91	-282.99	-358.97	-340.12	-300.02	-355.05	-357.32	-357.18
E7	-443.2	-452.44	-433.44	-550.63	-520.16	-456.7	-519.6	-522.84	-522.63
E6	-596.99	-608.87	-583.49	-743.68	-700.73	-612.91	-686.77	-690.94	-690.66
E5	-751.18	-765.39	-733.33	-938.98	-882.82	-770.1	-857.81	-862.83	-862.48
E4	-906.46	-922.54	-883.71	-1137.51	-1067.69	-930.09	-1033.71	-1039.48	-1039.07
E3	-1063.66	-1081.05	-1035.68	-1340.34	-1256.95	-1095.35	-1215.57	-1221.94	-1221.47
E2	-1223.76	-1241.87	-1190.61	-1548.68	-1452.54	-1268.97	-1404.55	-1411.34	-1410.82
E1	-1387.94	-1406.39	-1350.49	-1763.96	-1657.15	-1455.37	-1601.73	-1608.67	-1608.11
P	-1557.47	-1575.12	-1516.41	-1987.37	-1872.53	-1657.27	-1809.44	-1816.14	-1815.56

Table 3.3.2-18 "Maximum axial forces in the pillars of Ug + Gf + 9F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E14	232.969	188.833	238.846	293.34	230.443	214.253	231.541	181.814	183.439

E13	142.843	105.648	147.17	269.195	210.712	195.458	151.147	109.55	110.896
E12	148.515	109.983	153.047	276.533	216.356	200.661	158.359	114.907	116.314
E11	154.431	115.402	159.892	281.032	220.346	204.165	164.842	120.603	122.056
E10	160.217	121.374	167.446	284.496	224.242	207.57	171.666	127.221	128.724
E9	165.081	127.309	174.85	285.593	226.969	209.861	177.526	133.8	135.343
E8	168.38	132.612	181.335	283.551	227.82	210.415	181.759	139.77	141.339
E7	169.523	136.687	186.111	277.588	226.024	208.529	183.657	144.476	146.051
E6	167.96	138.914	188.362	266.983	220.794	203.477	182.57	147.243	148.799
E5	163.161	138.643	187.227	251.022	211.26	194.468	177.88	147.355	148.862
E4	154.612	135.151	181.774	228.989	196.546	180.681	169.021	143.992	145.412
E3	141.766	127.801	171.089	200.176	175.15	160.879	155.33	136.754	138.051
E2	124.272	116.44	155.863	163.825	150.285	137.065	136.586	123.048	124.167
E1	96.048	92.637	116.761	116.701	88.228	84.678	105.496	105.784	106.713
P	103.217	7.81	17.281	85.549	0	0	115.955	2.262	2.246

Table 3.3.2-19 "Maximum moments in the pillars of Ug + Gf + 14F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E14	128.8	95.09	94.27	226.05	177.5	165.06	136.94	99.04	100.28
E13	95.48	70.96	70.37	177.78	139.18	129.03	101.11	73.61	74.51
E12	101.87	76.02	75.39	186.14	145.86	135.27	108.81	79.5	80.46
E11	105.37	79.69	79.04	188.68	148.35	137.43	112.4	83.14	84.13
E10	108.41	83.37	82.68	190.65	150.87	139.63	116.08	87.22	88.24
E9	110.46	86.66	85.95	190.81	152.4	140.91	118.6	90.84	91.88
E8	111.11	89.17	88.43	188.71	152.52	140.88	119.66	93.68	94.72
E7	110	90.47	89.72	183.84	150.7	139.06	118.78	95.26	96.28
E6	106.77	90.13	89.37	175.72	146.4	134.96	115.54	95.11	96.1
E5	101.05	87.69	86.93	163.88	139.02	128.04	109.56	92.72	93.65
E4	92.51	82.62	81.88	147.83	127.95	117.72	100.44	87.52	88.37
E3	80.75	74.43	73.7	127.09	112.26	103.21	87.76	79.08	79.82
E2	65.46	62.68	62.22	101.12	92.89	85	71.26	65.94	66.54
E1	44.29	43.72	41.34	68.53	55.07	52.33	48.11	49.37	49.8
P	35.44	2.02	4.29	40.2	23.41	18.99	39.68	4.2	4.1

Table 3.3.2-20 "Maximum shear forces in the pillars of Ug + Gf + 14F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E14	-134.71	-139.97	-140.09	-171.01	-223.18	-216.49	-129.14	-131.86	-109.3
E13	-291.52	-300.43	-300.63	-370.34	-474.05	-459.81	-279.4	-284.33	-261.77
E12	-446.12	-459.09	-459.38	-572.26	-728.3	-706.26	-428.94	-436.47	-413.9
E11	-599.96	-617.02	-617.41	-776.04	-987.96	-957.66	-579.35	-589.39	-566.82
E10	-752.98	-774.1	-774.6	-982.31	-1253.59	-1214.54	-730.89	-743.14	-720.56
E9	-905.42	-930.44	-931.07	-1191.41	-1525.51	-1477.25	-883.98	-897.92	-875.35
E8	-1057.61	-1086.26	-1087.03	-1403.57	-1803.59	-1745.7	-1038.99	-1054	-1031.42
E7	-1210.03	-1241.89	-1242.81	-1618.91	-2087.26	-2019.43	-1196.29	-1211.65	-1189.07
E6	-1363.23	-1397.8	-1398.88	-1837.42	-2375.49	-2297.6	-1356.15	-1371.22	-1348.64
E5	-1517.91	-1554.59	-1555.85	-2059.03	-2666.78	-2578.89	-1518.8	-1533.08	-1510.5
E4	-1674.87	-1713.02	-1714.47	-2283.53	-2959.08	-2861.55	-1684.42	-1697.64	-1675.06
E3	-1835.03	-1874.02	-1875.69	-2510.65	-3249.74	-3143.28	-1853.23	-1865.37	-1842.8
E2	-1999.47	-2038.72	-2040.64	-2740.02	-3535.44	-3421.16	-2025.54	-2036.77	-2014.2
E1	-2169.37	-2208.58	-2210.72	-2971.3	-3811.78	-3691.4	-2201.74	-2212.52	-2189.95

P	-2346.42	-2384.6	-2387.09	-3203.42	-4074.29	-3949.37	-2382.57	-2392.1	-2369.54

Table 3.3.2-21 "Maximum axial forces in the pillars of Ug + Gf + 14F buildings"

- **Beams efforts:**

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E4	49.939	49.94	49.94	101.545	101.548	101.548	46.655	46.656	46.656
E3	46.835	46.836	46.836	101.518	101.518	101.518	44.334	44.337	44.337
E2	46.14	46.134	46.134	102.553	102.569	102.569	44.045	44.038	44.038
E1	46.097	46.138	46.138	102.467	102.37	102.37	44.601	44.644	44.644
P	45.489	45.306	45.306	104.313	105.016	105.016	44.832	44.644	44.644

Table 3.3.2-22 "Maximum positive moments in the beams of Ug + Gf + 4F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E4	-101.866	-101.865	-101.865	-108.716	-108.703	-109.924	-111.236	-111.229	-111.229
E3	-98.077	-98.079	-98.079	-147.199	-147.189	-146.944	-101.312	-101.3	-101.3
E2	-92.599	-92.593	-92.593	-140.571	-140.539	-140.891	-97.049	-97.051	-97.051
E1	-85.795	-85.859	-85.859	-132.394	-132.512	-129.614	-89.393	-89.288	-89.288
P	-76.223	-76.027	-76.027	-119.315	-118.436	-106.37	-80.438	-80.59	-80.59

Table 3.3.2-23 "Maximum negative moments in the beams of Ug + Gf + 4F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E4	96.95	96.95	96.95	104.7	104.7	79.55	99.57	99.57	99.57
E3	91	91.01	91.01	126.54	126.53	98.53	91.32	91.32	91.32
E2	88.35	88.34	88.34	124.86	124.86	96.99	89.36	89.36	89.36
E1	85.4	85.45	85.45	122.38	122.39	93.83	86.31	86.28	86.28
P	81.03	80.86	80.86	119.02	118.96	87.87	82.56	82.54	82.54

Table 3.3.2-24 "Maximum shear forces in the beams of Ug + Gf + 4F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E9	73.675	96.95	88.069	87.129	75.315	78.25	74.608	57.637	55.134
E8	95.356	78.937	114.287	113.942	95.37	99.193	107.197	85.925	80.333
E7	93.807	77.876	113.382	112.327	94.501	98.321	105.366	84.658	79.927
E6	93.087	77.917	114.316	111.577	94.548	98.469	105.012	85.358	80.843
E5	89.552	75.97	112.549	107.963	93.167	97.116	100.928	83.457	79.354
E4	83.191	71.855	107.765	100.996	89.854	93.731	93.053	78.665	75.054
E3	73.383	64.797	98.876	89.976	83.944	87.599	80.489	69.859	66.857
E2	59.606	54.043	84.732	74.278	74.717	77.954	62.47	55.933	53.654
E1	41.407	38.697	64.347	53.157	61.194	63.781	38.249	35.799	34.248
P	18.334	18.192	35.534	27.395	44.425	45.952	7.284	7.709	8.899

Table 3.3.2-25 "Maximum positive moments in the beams of Ug + Gf + 9F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E9	-168.171	-148.677	-190.473	-221.367	-192.506	-199.095	-170.852	-151.357	-145.905
E8	-181.855	-159.482	-207.835	-270.858	-237.089	-244.659	-185.964	-163.688	-156.929
E7	-181.917	-159.843	-209.242	-268.976	-235.771	-243.395	-186.233	-164.251	-157.975
E6	-180.796	-159.829	-210.339	-267.813	-235.945	-243.741	-185.615	-164.794	-158.857

E5	-176.231	-157.454	-208.205	-262.223	-233.186	-241.014	-181.431	-162.917	-157.504
E4	-167.743	-152.076	-201.873	-251.518	-226.573	-234.231	-173.159	-157.916	-153.148
E3	-154.568	-142.701	-189.936	-234.567	-214.685	-221.866	-159.935	-148.681	-144.69
E2	-135.992	-128.287	-170.877	-210.37	-196.009	-202.308	-140.946	-134.058	-130.972
E1	-111.325	-107.646	-143.158	-178.022	-169.104	-174.041	-115.376	-112.862	-110.772
P	-79.633	-79.719	-104.288	-136.689	-132.192	-135.086	-82.28	-83.373	-83.409

Table 3.3.2-26 "Maximum negative moments in the beams of Ug + Gf + 9F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E9	77.51	69.48	86.69	92.06	83.64	85.57	108.29	100.19	74.06
E8	78.41	68.72	89.65	111.27	100.98	103.29	112.71	103.03	74.17
E7	79.48	69.99	91.22	112.15	102.07	104.38	112.36	102.87	75.52
E6	80.81	71.78	93.51	113.21	103.51	105.89	112.14	103.15	77.32
E5	81.25	73.17	95.01	113.55	104.72	107.1	110.31	102.31	78.63
E4	80.6	73.86	95.29	112.86	105.27	107.61	106.72	100.13	79.11
E3	78.55	73.45	93.78	110.83	104.78	106.98	100.99	96.12	78.33
E2	74.83	71.53	89.85	107.16	102.81	104.74	92.76	89.78	75.83
E1	69.13	67.54	82.83	101.58	98.86	100.38	81.7	80.6	71.04
P	61.47	61.36	71.84	94.23	93.01	93.91	67.46	67.8	64.19

Table 3.3.2-27 "Maximum shear forces in the beams of Ug + Gf + 9F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E14	174.253	139.951	178.863	201.707	159.075	141.646	166.545	125.868	127.198
E13	203.893	163.199	209.639	264.947	210.836	187.757	203.752	156.178	157.732
E12	204.09	163.454	210.378	263.228	209.293	186.055	205.672	157.715	159.295
E11	207.832	167.156	215.535	269.149	214.651	190.58	211.087	162.589	164.22
E10	210.221	170.288	220.129	273.047	219.14	194.212	214.725	166.624	168.296
E9	210.869	172.546	223.693	274.494	222.359	196.63	216.603	169.856	171.557
E8	208.967	173.178	225.241	272.28	223.214	196.864	215.793	171.474	173.186
E7	203.86	171.495	223.861	265.406	220.686	194.014	211.597	170.791	172.49
E6	194.912	166.762	218.581	252.909	213.697	187.126	203.301	167.037	168.692
E5	181.51	158.202	208.368	233.853	201.095	175.178	190.221	159.394	160.971
E4	163.041	144.976	192.107	207.3	181.604	157.045	171.689	146.992	148.449
E3	138.883	126.181	168.587	172.289	153.837	131.504	147.045	128.895	130.188
E2	108.388	100.791	136.472	127.842	116.177	97.146	115.602	104.074	105.152
E1	70.894	67.774	93.894	72.78	66.647	52.257	76.697	71.24	72.046
P	26.607	24.446	43.721	65.275	46.599	42.076	30.018	30.688	31.171

Table 3.3.2-28 "Maximum positive moments in the beams of Ug + Gf + 14F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E14	-248.336	-210.522	-253.508	-367.711	-318.583	-298.204	-258.154	-214.185	-215.622
E13	-277.057	-235.267	-283.094	-443.159	-386.289	-361.707	-276.4	-227.912	-229.497
E12	-279.313	-237.272	-285.978	-443.4	-386.402	-361.436	-280.659	-231.336	-232.962
E11	-282.898	-240.874	-291.017	-449.397	-391.93	-366.114	-285.999	-236.167	-237.843
E10	-285.347	-244.105	-295.736	-453.514	-396.743	-370.026	-289.847	-240.412	-242.131
E9	-285.971	-246.403	-299.359	-455.09	-400.249	-372.69	-291.788	-243.751	-245.501
E8	-283.978	-247.032	-300.912	-452.824	-401.276	-373.064	-290.983	-245.444	-247.205
E7	-278.68	-245.271	-299.439	-445.634	-398.721	-370.181	-286.696	-244.769	-246.515

E6	-269.421	-240.362	-293.936	-432.487	-391.43	-363.014	-278.195	-240.934	-242.636
E5	-255.565	-231.5	-283.329	-412.38	-378.158	-350.464	-264.775	-233.1	-234.721
E4	-236.482	-217.817	-266.456	-384.309	-357.53	-331.317	-245.748	-220.371	-221.869
E3	-211.528	-198.374	-242.051	-347.251	-328.03	-304.245	-220.434	-201.79	-203.119
E2	-180.039	-172.134	-208.721	-300.152	-287.928	-267.74	-188.138	-176.324	-177.431
E1	-141.335	-138.003	-164.847	-241.96	-235.474	-220.247	-148.143	-142.834	-143.664
P	-94.908	-93.813	-111.131	-172.028	-169.345	-160.932	-99.493	-100.411	-100.904

Table 3.3.2-29 "Maximum negative moments in the beams of Ug + Gf + 14F buildings"

	Dreptunghiulara			Circulara			Patrata		
Etaj	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB	Neizolata	HDRB	LRB
E14	137.17	120.78	139.4	154.83	95.51	89.63	149.91	130.67	131.3
E13	159.74	141	162.42	189.59	117.06	109.64	156.35	134.52	135.23
E12	160.3	141.51	163.24	189.36	118.74	111.24	157.75	135.64	136.37
E11	161.96	143.17	165.56	191.22	121.58	113.81	160.2	137.85	138.6
E10	163.06	144.62	167.68	192.47	124.82	116.78	161.9	139.73	140.5
E9	163.35	145.65	169.31	192.94	128.11	119.82	162.77	141.22	142.01
E8	162.47	145.94	170.02	192.24	131.13	122.63	162.4	141.98	142.77
E7	160.1	145.15	169.37	190.05	133.55	124.95	160.47	141.67	142.45
E6	155.97	142.96	166.92	186.06	135.03	126.47	156.65	139.94	140.71
E5	149.77	139	162.18	179.96	135.22	126.87	150.63	136.43	137.15
E4	141.24	132.89	154.65	171.46	133.71	125.8	142.1	130.71	131.39
E3	130.07	124.2	143.76	160.24	130.06	122.88	130.74	122.38	122.97
E2	115.99	112.46	128.89	145.98	123.77	117.67	116.25	110.95	111.45
E1	98.67	97.2	109.24	128.35	114.29	109.68	98.32	95.88	96.25
P	78.05	77.31	85.63	107.4	101.8	99.14	76.66	77.02	77.24

Table 3.3.2-30 "Maximum shear forces in the beams of Ug + Gf + 14F buildings"

The results obtained from the analyzes performed for non-insulated and insulated structures were presented, from which the following results::

- **In terms of fundamental periods of vibration:**

- For buildings with 5 levels, the fundamental vibration periods increase by about 20 times in the case of using HDRB type insulators, respectively 15 times in the case of using LRB type insulators;
- For buildings with 10 levels, the fundamental vibration periods increase by about 9 times in the case of using HDRB type insulators, respectively 7.4 times in the case of using LRB type insulators;
- For buildings with 15 levels, the fundamental periods of vibration increase about 5.4 times in the case of using HDRB type insulators, respectively 4.7 times in the case of using LRB type insulators;.

- Conclusion - the more rigid the buildings, the shorter the duration of the fundamental periods of vibration by using seismic insulators.
- In general, the fundamental vibration periods in the case of using LRB type insulators are about 80% of the fundamental vibration periods in the case of using HDRB type seismic insulators (so the HDRB makes the structure 20% more flexible than the LRB).

In terms of displacement:

- For buildings with 5 levels, the drifts increase in case of using HDRB type seismic insulators by about 30% respectively by 50% in case of using LRB type seismic insulators;
- For buildings with 10 levels, the drifts increase in the case of using HDRB type seismic insulators by about 2% and by 20% in the case of using LRB type seismic insulators;
- For buildings with 15 levels, the drifts decrease in case of using HDRB type seismic insulators by about 2% respectively and increase by 2% in case of using LRB type seismic insulators;
- In the case of using seismic insulators, the more levels the buildings have (the more flexible they are) the drift decreases, respectively the more rigid the buildings (fewer levels) the drift increases. It is found that HDRB type seismic insulators are more efficient in terms of drift.
- At the base it is found that on average the displacements increase more for the buildings that use seismic insulators of LRB type compared to HDRB.
- For buildings with 5 levels the displacements are on average about 30 cm, for buildings with 10 levels are 35 cm, and for buildings with dual structure with 15 levels reach about 40 cm.

From the point of view of the sectional efforts in the elements of the structure:

- **For the walls in b.a:**

- The sectional efforts of the type bending moments and shear forces, at the walls of b.a., in case of using seismic insulators, are reduced to about 48-93% of the efforts corresponding to the non-insulated structure;

- The sectional efforts of the axial forces type practically remain with the same values;

- Sectional stresses decrease more when using HDRB type seismic insulators compared to LRB.

• For the pillars in b.a:

- The sectional efforts such as bending moments and shear forces, at the b.a. pillars, in case of using seismic insulators, are reduced to about 68-98% of the efforts corresponding to the non-insulated structure;

- The sectional efforts of axial force type practically remain with the same values;

- Sectional stresses decrease more when using HDRB type seismic insulators compared to LRB.

• For beams from b.a:

- By using seismic insulators, the sectional stresses on the beams (positive and negative bending moments as well as the shear forces) decrease only for buildings with more than 5 levels. The more levels the building has, the more and more there is a decrease (86-95% at 10 levels).

- It is also found that (in the sense of those presented above) the efforts decrease more in the case of using HDRB type seismic insulators than LRB type ones.

Considering all the above, for the buildings that are designed with the dual structure of b.a. with low and medium height regime (up to 15 levels) it is found that HDRB type seismic insulators are more efficient than LRB type seismic insulators.

CHAPTER IV

PERFORMANCE REQUIREMENTS FOR INSULATORS. TESTS. INTERPRETATION OF RESULTS

4.1 *Performance requirements for insulators*

Seismic insulators must take on the gravitational loads of the structure without developing significant slow-flow effects and withstand non-seismic actions, such as wind loading and temperature-induced displacements. They must provide the structure with a low value of its own frequency of horizontal vibration, by means of a reduced horizontal rigidity or other means. They must be able to track the large horizontal displacements produced by the seismic action, while being able to safely take over the gravitational loads of the structures and the vertical stresses produced by the seismic action. They must provide a sufficient level of damping to adequately control the horizontal movements produced by the seismic action, unless damping is provided by additional devices.

Insulators must be designed and produced in such a way as to be able to follow the translational and rotational movements imposed by seismic action and other actions, while being able to take on the vertical stresses produced by gravitational loading, seismic action and other variable actions. They must function properly if they are subjected to environmental actions during the design service. Where insulators are subject to exceptional environmental and application conditions, such as immersion in water, exposure to oil or chemicals, or installation in an area with a high risk of fire, measures must be taken. (see EN 1337-9) in the light of a precise definition of the conditions.

The fourth chapter presents the performance requirements for insulators, tests on them and interpretation of the results obtained. A test report is presented on HDRB type insulators (high damping rubber bearings), and on LRB type insulators (rubber bearing and lead core), tests carried out in the ISOLAB laboratory, Italy (laboratory belonging to the Soletanche-Freyssinet Group).

The anti-seismic insulators tested were produced for these tests and are prototypes. These insulators are not provided for any installation and for any building.

4.4.1 Laboratory testing of HDRB type insulators

4.4.1.1 Introduction

FPC Italia operates with a quality assurance system according to the EN ISO 9001: 2015 standard. All the mentioned tests were performed at ISOLAB in Montebello della Battaglia (Pavia, Italy) on July 24, 2018 and October 30, 2018, being assisted by ICECON-CERT certification body.

4.4.1.2 Aplication domain

The devices type: HDRB 1,4-16 2-700x900x120, provided for the work: CANTIERE SVILUPPO GENOVA, are composed by assembling two elastomeric elements of geometry: 700x900x120 each. This report refers to tests that were performed on a single elastomer element type HDRB 1.4-16 700x900x120.

HDRB 1,4-16 700x900x120		
Maximum vertical load associated with the ultimate limit state (SLU)	$N_{ULS,max}$	6030 kN
Maximum vertical load in the seismic design situation	$N_{Ed,max}$	3206 kN
Permanent load	N_{sd}	2596 kN
Minimum vertical load in the seismic design situation	$N_{Ed,min}$	898 kN
Modulul de forfecare	G	1.4 MPa
Maximum displacement of the device	d_{max}	± 180 mm
Maximum displacement of device calculation	d_{bd}	±120 mm
Maximum force	F_{max}	1323 kN
Effective rigidity	K_{eff}	7.35 kN/mm
Effective depreciation	β_{eff}	16%
Total rubber thickness (6 layers, 20 mm each)	H_g	120 mm
Total vulcanized height	H_t	205 mm

Table 4.4.1.2-1 HDRB device characteristics

4.4.1.3 *Test equipment*

The tests were performed using equipment with a vertical load capacity of 50000 kN (figure 4.4.1.3-1) and equipment with a vertical load capacity of 70000 kN (figure 4.4.1.3-2), available in the ISOLAB laboratory.

Figure 4.4.1.3-1 Equipment with capacity of vertical load of 50000 kN

Figure 4.4.1.3-2 Equipment with capacity of vertical load of 50000 kN

4.4.1.7 Test protocol

test #	test name	label	main dof	Ampl. [m]	max vel [m/s]	freq [Hz]	load shape	vert load	cycles [#]	notes	notes
1	Compression Stiffness	CS	vert	-	259,55 kN/min	-	loading ramp	2596	-	test performed on a single elastomer element	load applied at a constant loading rate.
2	Horizontal Cyclic Characteristics	HC	long	±0.006	0.019	0.50	sine	3780	3	test performed on a single elastomer element	
3	Horizontal Cyclic Characteristics	HC	long	±0.012	0.038	0.50	sine	3780	3	test performed on a single elastomer element	
4	Horizontal Cyclic Characteristics	HC	long	±0.024	0.075	0.50	sine	3780	3	test performed on a single elastomer element	
5	Horizontal Cyclic Characteristics	HC	long	±0.060	0.188	0.50	sine	3780	3	test performed on a single elastomer element	
6	Horizontal Cyclic Characteristics	HC	long	±0.120	0.200	0.27	sine	3780	3	test performed on a single elastomer element	
7	Horizontal Cyclic Characteristics	HC	long	±0.180	0.200	0.18	sine	3780	3	test performed on a single elastomer element	
8	Repeated Cycling	RC	long	±0.120	0.200	0.27	sine	3780	10	test performed on a single elastomer element	
9	Compression Capacity	CC	vert	-	259,55 kN/min	-	loading ramp	2596	-	test performed on a single elastomer element	load applied at a constant loading rate Nsd kept for 3 mins, during which inspection for signs of failure is required
10	Lateral capacity	LC	long	0.207	0.005	-	-	898	-	test performed on a single elastomer element	1) Maximum shear displacement held for 2 mins during which checks for visual signs of failure shall be carried out. The checks also after removing the lateral displacement, but maintaining the compressive load. 2) The horizontal displacement capacity shall be checked up to a displacement of 207 mm (1.15*dmax) or a horizontal load of 1521 kN, whichever is reached first.
11	Lateral capacity	LC	long	0.207	0.005	-	.	3206	-	test performed on a single elastomer element	

Table 4.4.1.7-1 Test protocol.

4.4.1.8 *Test charts*

a) HDRB 1.4-16 700x900x120 Device # 01

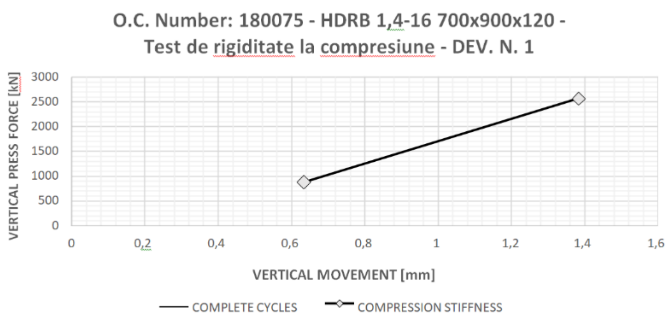


Figure 4.4.1.8-1 Compressive stiffness test. Vertical force-vertical displacement

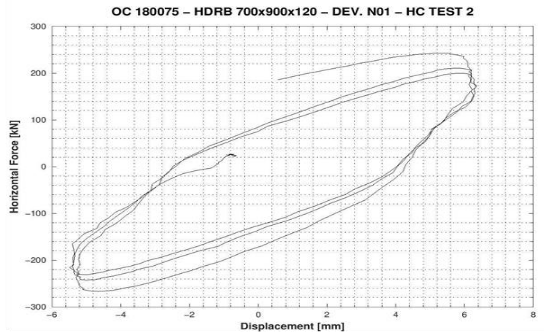


Figure 4.4.1.8-2 Horizontal force diagram - displacement diagram (device 1 - test 2)

4.4.1.9 *Photos*

Figure 4.4.1.8-21 Photos during the tests

It is found that the results obtained meet the performance requirements of the standards in force. The standards and documents applied to these tests are EN 15129 (SR EN 15129) and the test protocol for each test.

For LRB type insulators, tests were performed similarly to HDRB type insulators.

CHAPTER V

CONTRIBUTIONS AND FUTURE RESEARCH DIRECTIONS

The last chapter has a classical structure and presents a synthesis of the conclusions resulting from the research carried out by the author in the previous chapters. Own contributions are underlined and future research directions are established.

5.1 Conclusions regarding the achievement of objectives and personal contributions

In the content of the doctoral thesis the following objectives were met:

• Deepening the knowledge on the types, characteristics and calculation models of anti seismic devices;

• Documentation on the use of insulation devices in reinforced concrete constructions;

• Carrying out case studies on the performance and efficiency, in practical cases, of the two types of technologies available for seismic rehabilitation and / or seismic conformation: conventional (classical) and unconventional (special);

• Carrying out comparative case studies, for 9 models of structures from b.a., designed in accordance with the current codes, taking into account the modeling of the land-structure interaction, compared to the isolation of the base;

• Comparison of efficiency between HDRB type seismic insulators and LRB type seismic isolators, including by testing them in the laboratory.

5.3 *Future research directions*

- Carrying out comparative case studies, for existing buildings with structure from b.a., designed in accordance with codes P13-63; P13-70; P100-78; P100-82 and P100-92, in case of choosing the seismic isolation solution of the base;
- Carrying out comparative studies on the seismic insulation of the base of adjacent sections of existing buildings with dual structure. Avoiding collisions between sections by using special devices to attenuate them or by coupling the sections.

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