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COMPARISON OF RESIDENTIAL BUILDING WITHOUT RUBBER-STEEL BEARINGS AND WITH RUBBER-STEEL BEARINGS

In the article there are presented calculations of 17 stories cast in situ reinforce concrete frame-wall residential building without rubber-steel (further r/s) bearings and with r/s bearings, under influence of seismic forces and torsion moments. The building has three spans in one direction and four in the other. Horizontal seismic load Q and torsion moment $M_k^{кр}$ are identified, which have influence on the building, the results are inserted into the program packet "LIRA 9.6 R9". As it was mentioned above, appropriate calculations were made without r/s isolators and with r/s isolators and were reinforced via "LIR-ARM". Then, the following characteristics were compared: seismic forces, reinforcement percents, periods of vibration, displacements and vertical forces of r/s isolators.

Keywords: **seismic isolation system, period of vibration, horizontal displacement, laminated bearing, decrement of damping, reinforcement percent**

INTRODUCTION

Seismic isolation is one of the most ancient and perspective methods of active seismic protection. The structure is called isolated when the seismic influence is significantly reduced: via elements or systems located between base and building.

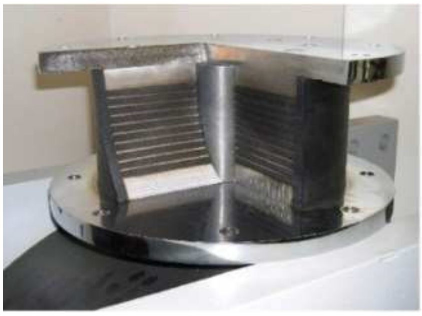

Fig. 1. Laminated rubber-steel bearing

One of the seismic isolation systems is laminated rubber-steel bearings (Fig. 1) which are used in buildings and structures. In the beginning these bearings were received widespread in bridge construction, but after certain cultivations they started to be used in buildings for seismic isolations too.

Rubber-steel bearings became widespread in the world, especially in China, the USA, Russia and Japan. In Armenia r/s bearings are used too and approximately 40 buildings are erected with rubber-steel bearings. The purposes of using r/s bearings are the following: decreasing of seismic forces, displacements of building, floor distortions, reinforcement percents and economical reasons.

1. INPUT DATA OF RESIDENTIAL BUILDING

In the article there was calculated and compared 17 stories cast in situ reinforce concrete frame-wall residential building with and without r/s bearings which have the same layout shape.

All parameters of the residential building were taken according to the second seismic zone (A = 0.3).

The spans of the building are equal to 6.2 m and the spacings are equal to 6.0 m. The layout scheme is shown in Figure 2.

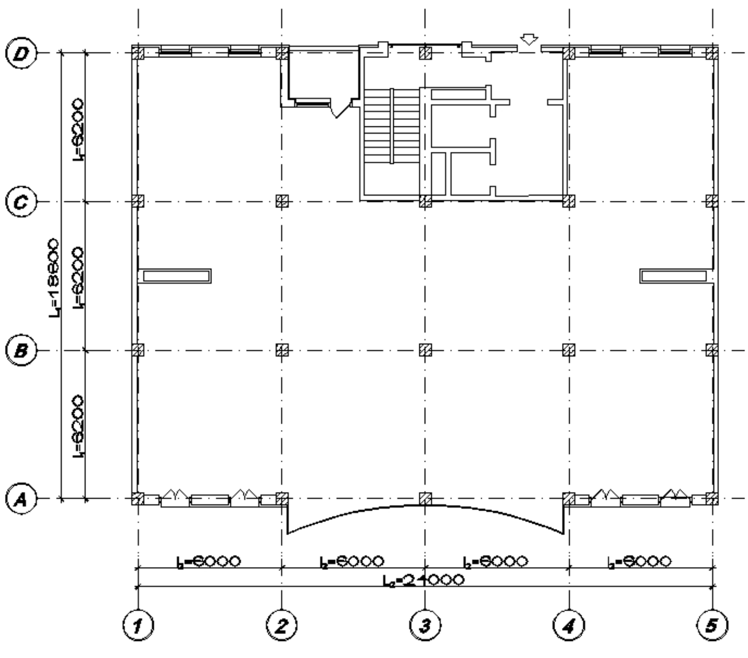

Fig. 2. Layout of the residential building

The structure has two basement stories, the heights of which are equal to 3.3 m, the heights of the first two floors are equal to 3.9 m and the heights of the remaining stories are equal to 3.3 m.

The building has one main entrance.

2. TECHNICAL CONDITIONS OF LAMINATED RUBBER-STEEL BEARING

According to AST 261-2007 laminated r/s seismic isolator specification [1] a bearing consists of 14 rubber and 13 steel layers, which are glued to each other. The exterior diameter is equal to 380 mm and the height is equal to 202.5 mm. The weight of r/s bearing is approximately 80 kg.

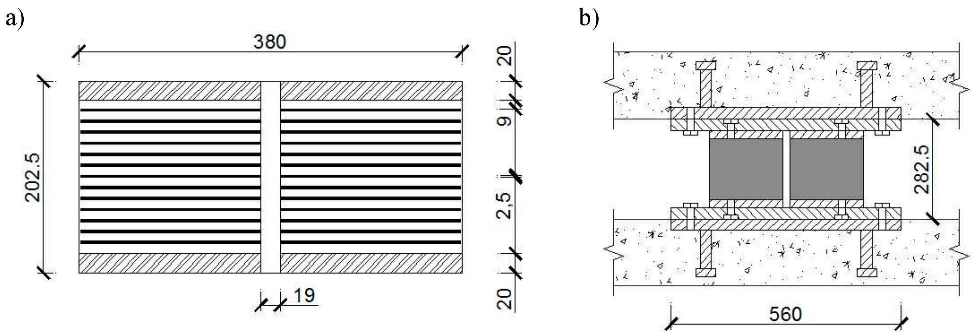

Fig. 3. Scheme of laminated r/s bearing
a) shape and sizes of r/s, b) node of r/s with reinforce concrete beams

The vertical stiffness (R_z) of r/s bearing must be not less than 300 kN/mm and the horizontal stiffness ($R_{x,y}$) be not less than 0.81 kN/mm. A r/s bearing can resist maximum 1500 kN into vertical load (N_{MAX}) and the maximum horizontal displacement (D_{MAX}) must be not more than 280 mm: $N \le N_{MAX}$, $D \le D_{MAX}$.

The bearing is stable from –40 to 60°C temperature conditions. Serving period of r/s bearings is approximately 70 years, after this period the bearing is capable for changing.

As well as [2], around the structure there must be seismic space which should be at least 1.5 times larger than the design displacement that structure can move freely in horizontal direction on seismic isolations.

3. CALCULATIONS OF RESIDENTIAL BUILDING

Calculations are completed by the program packet "LIRA 9.6 R9", in which for inserting the horizontal seismic loads Q_i^k (i - quantity of floors, k - number of nodes) are calculated all weights from constructions and loads in accordance with nodes. Horizontal seismic loads Q_i^k are presented in Table 1.

Inserting the seismic loads in program packet "LIRA 9.6 R9" are determined the seismic forces and then are calculated the torsion moments which are presented in Table 2.

In the k[th] level of structures the value of torsion design moment $M_k^{кр}$ is calculated with the following equation:

$$M_{к}^{кр} = P_{к}(e_{к} + e) \quad (1)$$

when:
$P_{к}$ - the transverse force in k^{th} level of floor [t],
$e_{к}$ - eccentricity value between mass and stiffness centers in k^{th} level of floor [m],
e - design eccentricity value from rotary motion of soil [m].

Table 1. **Results of seismic loads**

Seismic loads for first floor [kN]				Seismic loads for second floor [kN]			
Q_1^{I}	Q_1^{II}	Q_1^{III}	Q_1^{IV}	Q_2^{I}	Q_2^{II}	Q_2^{III}	Q_2^{IV}
208	325	328	223	225	351	354	226
Seismic loads for third to sixteenth floor [kN]				Seismic loads for last floor [kN]			
Q_3^{I}	Q_3^{II}	Q_3^{III}	Q_3^{IV}	Q_{17}^{I}	Q_{17}^{II}	Q_{17}^{III}	Q_{17}^{IV}
243	376	376	228	90	151	153	157

Table 2. **Values of torsion moments without r/s bearings and with r/s bearings**

Without r/s bearing		With r/s bearing	
Floor	Torsion moment $M_{к}^{кр}$ [t*m]	Floor	Torsion moment $M_{к}^{кр}$ [t*m]
XV	67.4	XV	38.6
XIV	237.4	XIV	121
XIII	398.7	XIII	201.4
XII	549.8	XII	279.4
XI	689.9	XI	354.6
X	818.2	X	427.2
IX	934.5	IX	497
VIII	1038.2	VIII	563.6
VIII	1129.1	VIII	627.2
VIII	1207	VIII	687.5
VIII	1272	VIII	744.5
IV	1324.4	IV	798.2
III	1365	III	848.5
III	1396.5	III	900
I	1415.7	I	949.4
- II	1422.8	- II	992.3
			992.4
- I	1425	- I	993

The values of torsion moments are obtained from the aggregating seismic forces of the floor levels. Inasmuch in layout the spans are different, consequently depends on nodes the seismic forces will be different.

According to RABC II-6.02-2006 earthquake resistant codes [2] during design of a building you must provide free entrance towards each r/s and for necessity cases to change it unimpededly. r/s bearings are placed between foundation and above-ground part (above from the blind area) or several lower floors (maximum two) and above-ground.

Additionally [2] in case of seismic isolation systems, for second seismic zone the allowable coefficient of damages k_1^z is equal to 1.

Making appropriate calculations for residential building there were obtained 204 r/s bearings. The location schemes of the bearings are shown in Figure 4.

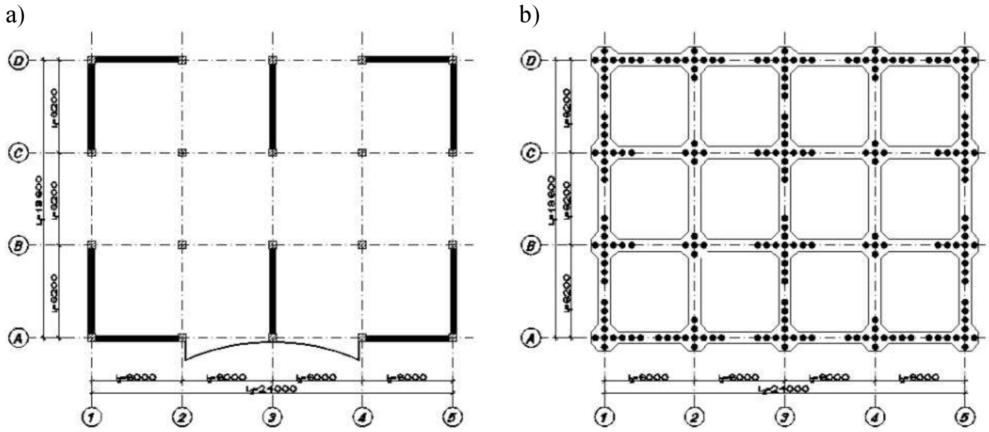

Fig. 4. Location layouts of diaphragms (a) and laminated r/s bearings (b)

The sizes of bearing structures are the following: column: $h_c \times b_c = 60 \times 60$ cm, beam: $h_b \times b_b = 70 \times 55$ cm, slab: h = 20 cm, diaphragm to the 10th floor $\delta = 40$ cm, from the 11th up to 17th floor $\delta = 30$ cm.

All conditions for laminated r/s bearings were satisfied (Tab. 3).

Table 3. **Final main characteristics of laminated r/s bearing**

Number of r/s bearing	Maximum displacement of r/s bearing [mm]		Maximum vertical forces of r/s bearing [t]
	X direction	Y direction	
1	112.1	113.7	150.2
2	107	113.7	130.1
3	104.4	112.4	145.2
4	107.6	112.6	149.4
5	107.9	114.3	143.2

In accordance with seismic codes [2], seismic isolation is used for those buildings and structures of which the main periods of natural vibration is within the limits of 0.1÷1.0 s for usual foundation cases (without seismic isolation) and not more than 3.0 s for seismic isolation cases. Periods of vibration of the building are presented in table 4.

The decrement of damping for r/s bearing is equal to 8÷10%.

Table 4. **Results of periods of vibration in X and Y directions**

Direction of vibration	Form of vibration	Period of vibration [s]	
		Building without r/s bearings	Building with r/s bearings
X direction	1	0.97	1.76
	2	0.38	1.00
	3	0.26	0.52
	4	0.13	0.23
	5	0.10	0.19
Y direction	1	0.83	1.68
	2	0.47	1.22
	3	0.20	0.47
	4	0.12	0.28
	5	0.09	0.15

According to RABC II-6.02-2006 earthquake resistant codes [2], in cast in situ reinforce concrete frame-wall construction cases the distortion of floor must be not more than 1/300 of floors height, consequently, for current building the maximum distortion for first two floors should be not more than 13 mm and for the remaining floors not more than 11 mm (Tab. 5).

Table 5. **Distortions of residential building dependent on stories**

Number of stories	Distortion of floor [mm]			
	Without r/s bearing option		With r/s bearing option	
	X direction	Y direction	X direction	Y direction
3	3.6	3.0	3.5	2.8
6	4.9	4.4	3.7	2.0
8	5.5	4.8	3.6	3.0
11	5.2	4.8	3.3	2.9
16	3.7	3.9	2.4	2.3

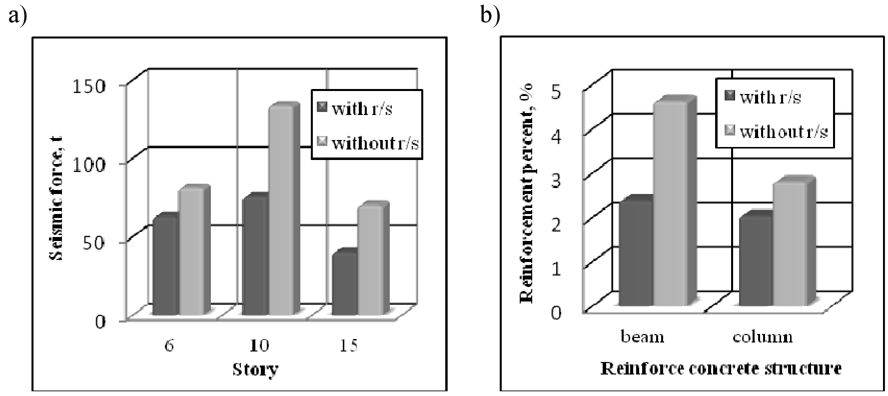

Fig. 5. Diagrams of seismic forces (a) and reinforcement percentage (b)

Depending on level of the floor, seismic forces are changed, moreover, the maximum value is obtained in the lower and middle stories. Consequently, the reinforcement percent of bearing structures is reduced (Fig. 5).

CONCLUSION

Comparing the results which are presented in the article the values of periods of vibration are bigger with r/s isolators than without r/s bearings, it means that in the case of with r/s bearings the building is more flexible. However, the seismic forces are approximately 20÷40% less with r/s isolators than without r/s isolators. As well as the reinforcement percents are 40÷50% less for column and 25÷30% less for beams with r/s bearings case, than without r/s bearings. The distortions of floors are decreased 30% with r/s systems too.

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PORÓWNANIE BUDYNKU MIESZKALNEGO BEZ ŁOŻYSK GUMOWO-STALOWYCH I Z ŁOŻYSKAMI GUMOWO-STALOWYMI

W artykule przedstawiono obliczenia dla 17-piętrowego żelbetowego ramowego budynku mieszkalnego bez wkładek stalowo-gumowych (r/m) i z częściami stalowo--gumowymi dla obiektu narażonego na działanie sił sejsmicznych i pochodzących

od nich momentów. Schemat rzutu budynku przedstawiono na rysunku 1. Budynek posiada w jednym kierunku trzy przęsła, w drugim kierunku cztery. Określono działające na budynek poziome siły sejsmiczne Q i momenty obrotowe M_k^{kr} i wprowadzono je do programu komputerowego LIRA 9.6 R9. Jak wspomniano, obliczenia przeprowadzono bez i z uwzględnieniem wkładek gumowo-metalowych oraz obliczono zbrojenie za pomocą programu LIR-ARM. Porównano następujące parametry: siły sejsmiczne, procent zbrojenia, okresy wahań, przemieszczenia i pionowe siły we wkładkach gumowo-metalowych.

Słowa kluczowe: **sejsmiczne systemy izolacji, okres drgań, poziome przemieszczenia, laminowane łożyska, dekrementacja tłumienia, procent zbrojenia**