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ANALYSIS OF STRUCTURE DISPLACEMENT FORMED AS A RESULT OF TORSION IN CASE OF USING RUBBER-METAL SEISMIC ISOLATORS

The study of a building with a complex planning solution, rubber-metal laminated seismic isolation supports (hereinafter referred to a RMLSIS) placed at the foundation level and with a reinforced concrete frame-braced system is presented, taking into account the displacement of the structure formed as a result of torsion. The analyses were conducted with the finite element method. The calculation schemes were modeled using the "Lira-SAPR" software. The displacement of the structure formed as a result of torsion of buildings having the same planning solution, different number of floors as well as with and without RMLSIS is estimated. The results obtained show that the displacement values of the structure formed as a result of torsion increased about 40% in buildings without RMLSIS and 25% in buildings with RMLSIS.

Keywords: *rubber-metal support, reinforced concrete structure, seismic isolation, finite element method, torsion.*

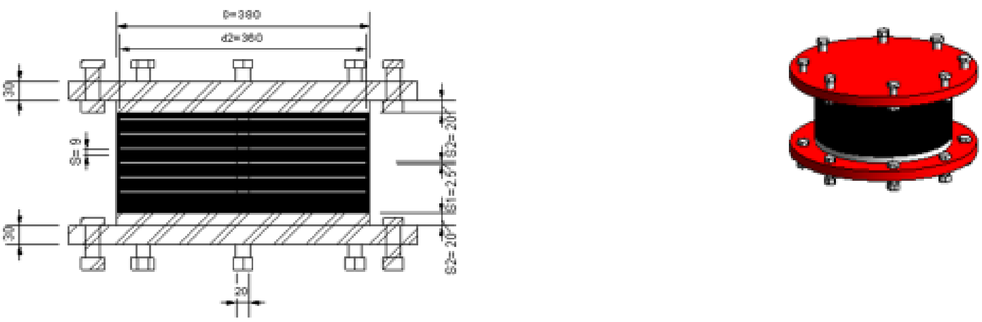
Introduction

In recent years, seismic isolation supports have become widespread. In the case of low-rise buildings, requirements of seismic codes can be fully met, but in the case of multistory buildings, the number of problems increases. In particular, the displacement of the structure formed as a result of torsion plays a significant role in the further operation of the building. Taking into account the fact that the Republic of Armenia is in the seismic zone [1], it is necessary to ensure the reliability and durability of the bearing systems of the buildings according to earthquake resistance, at the same time, taking into account the impact of the torsion on the building.

Surveys of buildings after the earthquake from the mid-twentieth century revealed damages caused by the torsion discovered by many local and foreign researchers. It should be noted that after the earthquake of 1985 in Mexico City, many buildings, destroyed because of torsion, were discovered. The damages caused by torsion accounted for 42% of the total number of destroyed buildings [2].

Materials and Methods

By now, indicators of the economic efficiency of seismic isolation supports have been studied and it has been shown that the use of seismic isolators is not very profitable [3-5]. The use of RMLSIS results in increased values of displacements of structures formed as a result of torsion. In particular, the displacement of the structure is significantly increased compared to the case without the use of RMLSIS [6,7]. The characteristics and geometric dimensions of RMLSIS used in RA are given in Table 1 and Fig. 1[1].



a *b*

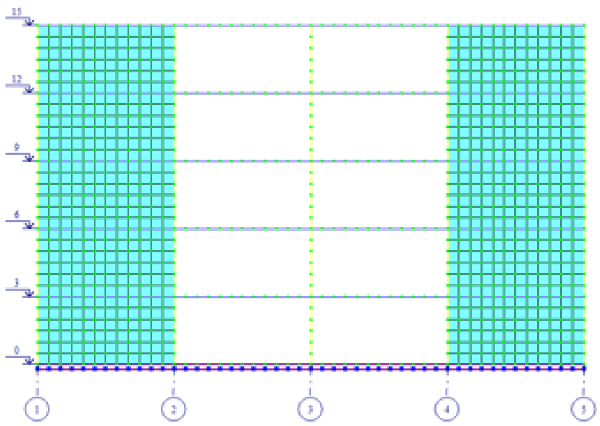
Fig. 1. *RMLSIS used in RA, mm. a - geometric appearance, b - three-dimensional appearance*

[1] HST 261-2007 Seysmamekusatsman shertavor retinametaghakan henaran. Tekhnikakan paymanner, Yerevan, 2007, p.17 (in Armenian).

Table 1. Characteristics of rubber-metal laminated seismic isolation supports

Support diameter (D), *mm*	380.0
Flange diameter (d), *mm*	560.0
Number of rubber layers, (NR)	14
Number of metallic layers, (NS)	13
Thickness of metallic layers (tS), *mm*	2.0
Thickness of rubber layers (tR), *mm*	9.0
Height (H), *mm*	206.0
Horizontal stiffness (KH), kN / *mm*	0.81
Maximum displacement in the horizontal direction (L), *mm*	280.0
Vertical stiffness (KV), kN / *mm*	300.0
Maximum allowable vertical load (P), *kN*	1500.0

Five, seven and nine - story buildings of the same planning were considered (Fig. 2).



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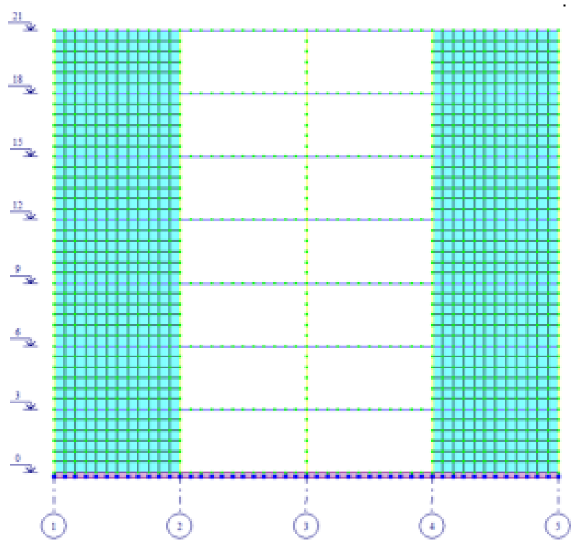

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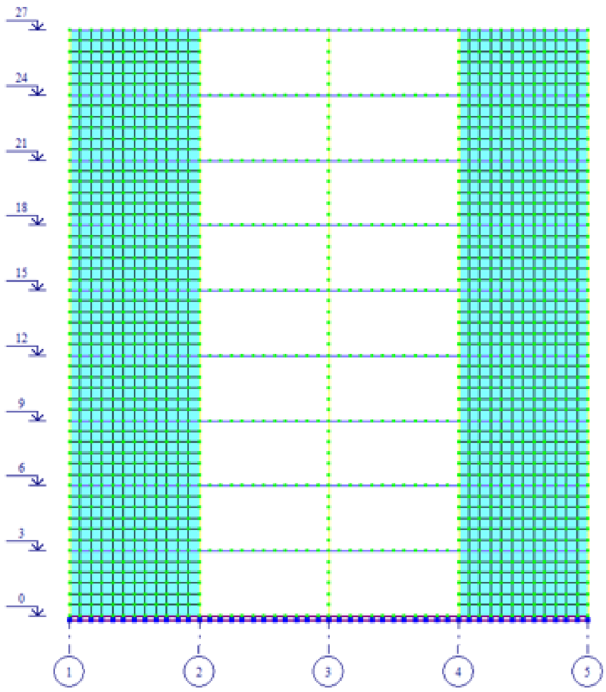

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Fig. 2. *Five-story (a), seven-story (b) and nine-story (c) building sections with "D" axis*

Bearing elements in the structure are made of monolithic reinforced concrete, sections of which are presented in Table 2.

Table 2. Baseline data required for analysis

Geometric dimensions of load-bearing elements (*cm*)	
Monolithic columns	50x50
Monolithic beam	40x60
Monolithic r/c walls	20
Roofing tile	20
Heavy concrete	
Concrete type/class	B25
Average density, kg/m^3	2500
Elasticity modulus, (Eb), *MPa*	30000
Compressive calculation strength (Rb), *MPa*	14.5
Reinforcement bar	
Reinforcement bar type/class	A-III (A400c)
Tensile calculation strength (Rs), *MPa*	375
Reinforcement bar elasticity modulus (Eb), *MPa*	200000
Compressive calculation strength (Rsc), *MPa*	375

The calculation is carried out taking into account the own weight of the structures, permanent, temporary, long-term and short-term loads and seismic impacts (in the X and Y directions) [8-10].

All loads were accepted according to construction codes. constant: q_1 = 7519 kN/m^2, temporary long – q_2 = 0.36 kN/m^2, temporary short – q_3 = 1.44 kN/m^2, on the roof (constant: q_4 = 6.3 kN/m^2, snow load: q_5 = 0.98 kN/m^2). Calculation of structural elements was carried out on the main and special combinations of loads taking into account horizontal seismic loads. During determination of seismic loads, combination coefficients were accepted: constant - 0.9, temporary long-term - 0.8, temporary short-term - 0.5. Main coefficients of building calculation are accepted according to RABC II-6.02-2006 (RA Building Codes) normative document[2].

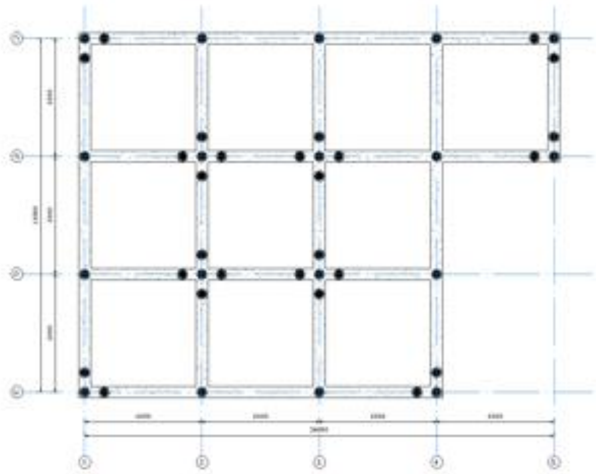
Results and Discussion

The calculations were carried out by the finite element method using the "Lira-SAPR" software[3] [11-15]. Six problems were considered in the calculation, in three of which RMLSIS are installed at the level of the foundations of five-, seven- and nine-story buildings (Fig. 3), and in three other cases the buildings were without RMLSIS.

The number of RMLSIS has been determined according to the maximum allowable horizontal displacement (L) and vertical loading (P) conditions, as well as the technical and economic conditions have been taken into account. In Fig. 4 the displacement calculation scheme of the building formed as a result of torsion is presented.

[2] HHSHN II-6.02-2006 Seysmakayun shinararutyun. Nakhagtsman normer, Yerevan, 2006, p.67 (in Armenian).
[3] SNiP 2.01.07-85*. Nagruzki i vozdejstviya, FGUP CPP, Moscow, 2005, p.44 (in Russian).
SNiP 2.03.01-84*. Betonnye i zhelezobetonnye konstrukcii, Moscow, 1998, p.80 (in Russian).

The comparative graphs of the calculation results are summarized in Fig. 5 and Fig. 6.



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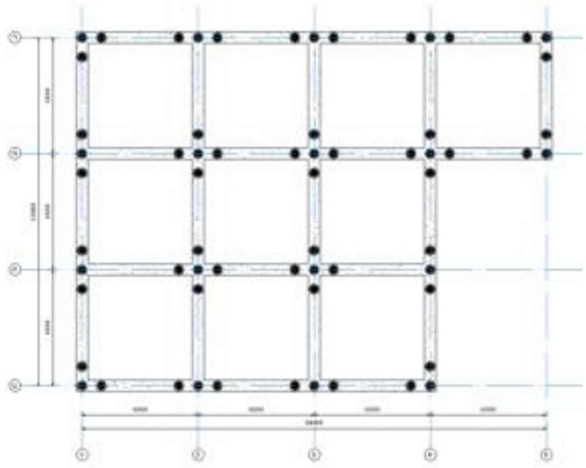

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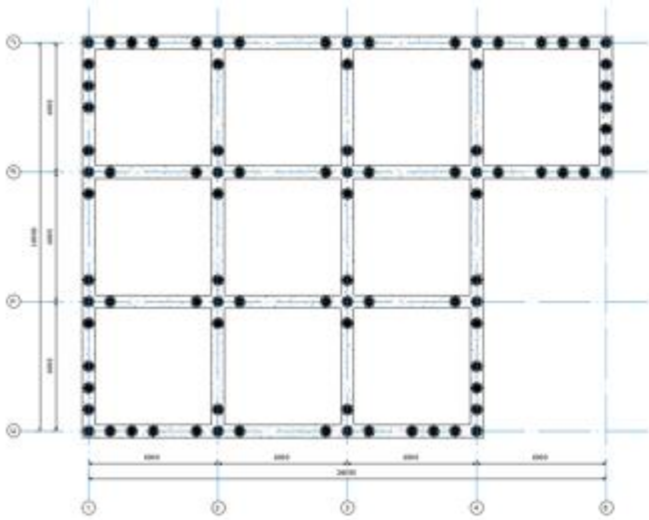

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Fig. 3. *RMLSIS layout planning of five-story (a), seven-story (b) and nine-story (c) buildings*

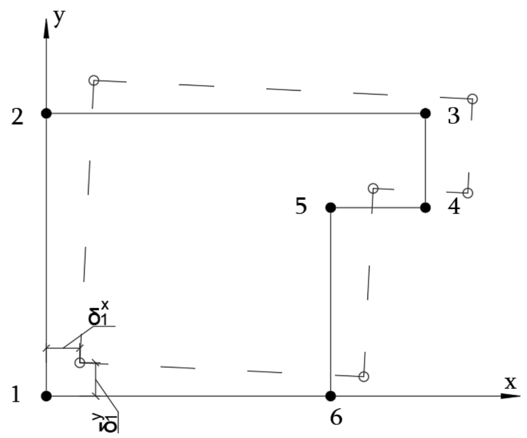
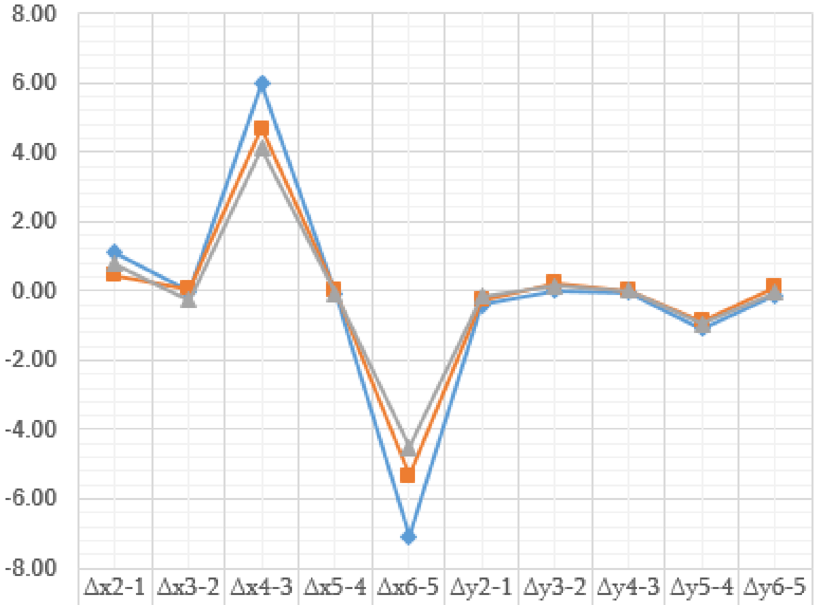


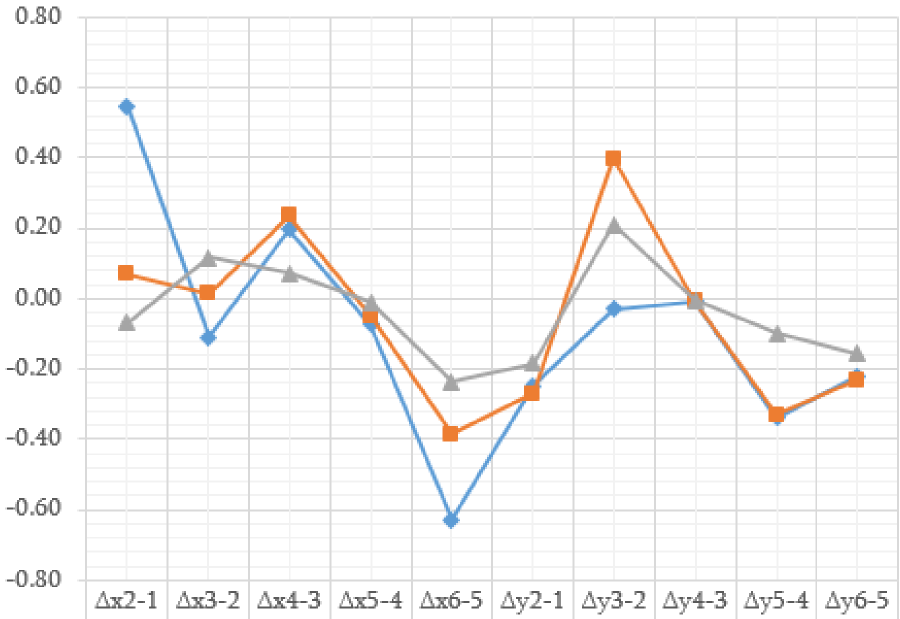
Fig. 4. *Calculation scheme of displacement of the building formed as a result of torsion,* *δ_1^x, δ_1^y – displacement in x and y directions in point 1*

The displacement of a structure formed as a result of torsion can be calculated for each section using the following formulas:



	Δx2-1	Δx3-2	Δx4-3	Δx5-4	Δx6-5	Δy2-1	Δy3-2	Δy4-3	Δy5-4	Δy6-5
In a nine-storey building with RMLSIS	1.09	-0.02	5.97	-0.07	-7.09	-0.41	0.00	-0.04	-1.08	-0.14
In a seven-storey building with RMLSIS	0.45	0.06	4.67	0.01	-5.32	-0.28	0.22	0.01	-0.87	0.11
In a five-storey building with RMLSIS	0.77	-0.27	4.12	-0.07	-4.50	-0.16	0.13	0.00	-0.95	-0.04

Fig. 5. *Comparative graph of results of displacement values of buildings with RMLSIS formed as a result of torsion*



	Δx2-1	Δx3-2	Δx4-3	Δx5-4	Δx6-5	Δy2-1	Δy3-2	Δy4-3	Δy5-4	Δy6-5
In a nine-storey building without RMLSIS	0.55	-0.11	0.20	-0.07	-0.63	-0.25	-0.03	-0.01	-0.34	-0.22
In a seven-storey building without RMLSIS	0.07	0.01	0.24	-0.05	-0.39	-0.27	0.40	-0.01	-0.33	-0.23
In a five-storey building without RMLSIS	-0.07	0.12	0.07	-0.01	-0.24	-0.18	0.21	0.00	-0.10	-0.16

Fig. 6. *Comparative graph of results of displacement values of buildings without RMLSIS formed as a result of torsion*

Conclusion

From the calculation results, it becomes clear that as a result of the use of the RMLSIS, the displacement values of structures formed as a result of torsion are significantly decreased. The consideration of this problem is very important to accurately observe the further problems of the operation of buildings and structures. The result of the analysis shows that the displacement values of the structure formed as a result of torsion increased about 40% in buildings without RMLSIS and 25% in buildings with RMLSIS.

Summing up the results obtained, it can be noted that this problem should be taken into account when designing buildings and structures.

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