

Research part

The studies are carried out on the basis of calculation results of the bearing system of a single building of multi-storey residential complex with reinforced concrete frame, which is currently under construction in Yerevan⁴ [1-8]. The bearing system of the multi-storey building under study has been modeled with two different shear walls – site cast reinforced concrete and three-layer bearing panels [1-8]. The article presents a comparative analysis of the results of the calculations made with the two aforementioned options. When considering the operation of the bearing system of a multi-storey building, the baseline data used for the calculations, such as the properties of the soil used as a foundation, seismic characteristics of the site, and the loads affecting the structure, were assumed to be the same. The calculations were made using a calculation software operating with the finite element method [7-10]. The appearance of the three-dimensional models of the residential complex and of one building under study is presented below (Fig. 3).

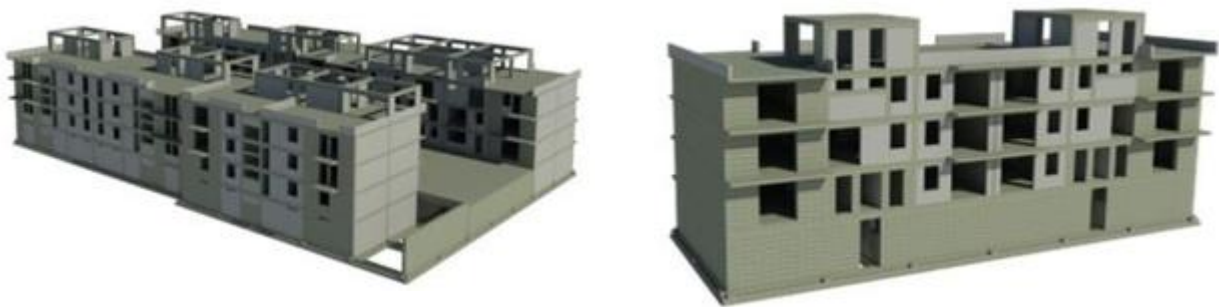


Fig. 3. Three-dimensional models of the multi-storey residential complex and the building under study

The following numerical studies were performed during the calculations:

- static calculation according to the first group limit state,
- static calculation according to the second group limit state,
- seismic calculation according to the first group limit state, taking into account the coefficient of allowable damages,
- seismic calculation to check the deviations.

Making the calculations, it was taken into account that:

- in case of static calculation, the concrete elasticity modulus is accepted with a coefficient of 1.0,
- in case of seismic calculation, the concrete elasticity modulus is accepted with a coefficient of 0.75,
- in the case of seismic calculation for buildings with reinforced concrete frame systems, when the allowable damage coefficient is $k_1 = 1$, the maximum deviation value should not exceed $(1/300) \cdot H$ (where H is the floor height), in this case the elasticity modulus in the calculation is accepted with a coefficient of 0.75. The regulating coefficient of 0.8 for displacements by HSHN II-6.02-2006 has not been applied,
- when making calculations, it was taken into account that the magnitude of the ground subgrade coefficient - c_1 , varies during static and seismic calculations [11-13].

The bearing system elements of the first design model have the following sections:

- Foundation - T-beam 120x30x60x60 cm 40x60 cm ($E_b = 2.3 \times 10^5$ MPa),
- Column - 40x40 cm, ($E_b = 2.3 \times 10^5$ MPa),
- Beam - 40x60 cm (in the direction of X), 40x40 cm (in the direction of Y) ($E_b = 2.3 \times 10^5$ MPa),
- Roofing slab - 20 cm ($E_b = 2.3 \times 10^5$ MPa),
- Shear wall - 40 cm site cast ($E_b = 2.3 \times 10^5$), 22 cm three-layered ($E_b = 2.0 \times 10^5$ MPa),
- Heavy concrete B25,
- Reinforcement bar A500C, A240,
- $a_{rc} = 0.3$ and 0.4 mm from the condition of preservation of the reinforcement bar.

⁴ SNiP 2.03.01-84*. Betonnye i zhelezobetonnye konstrukcii, Moscow, 1998, p.80 (in Russian).

The elements of the bearing system of the second design model have the following sections:

- Foundation - T-beam 120x30x60x60 cm, 40x60 cm ($E_b = 2.3 \times 10^5$ MPa),
- Column - 40x40 cm ($E_b = 2.3 \times 10^5$ MPa),
- Beam - 40x60 cm (in the direction of X), 40x40 cm (in the direction of Y) ($E_b = 2.3 \times 10^5$ MPa),
- Roofing slab - 20 cm ($E_b = 2.3 \times 10^5$ MPa),
- Shear walls - 40 cm site cast ($E_b = 2.3 \times 10^5$), 22 cm three-layer ($E_b = 2.0 \times 10^5$ MPa),
- Heavy concrete B25,
- Reinforcement bar A500C, A240,
- $a_{cr} = 0.3$ and 0.4 mm from the condition of the preservation of the reinforcement bar.

In Table 1 the values of calculation loads are presented.

Table 1. Loads included in the calculations and their values

| Load name | Normative load, n/m^2 | Load reliability coefficient, γ_f | Calculated load, n/m^2 |
|---|-------------------------|--|--------------------------|
| Permanent | | | |
| r/c slab 0.2 m | 3000 | 1.1 | 3300 |
| floor layers and partitions | 3200 | 1.1 | 3500 |
| Additional permanent load from the weight of the longitudinal partition of the building - 12002 n/m | | | |
| Temporary | | | |
| short term | 2400 | 1.2 | 2880 |
| long term | 1200 | 1.2 | 1440 |

A three-dimensional image of the models developed by the LIRA software and the results obtained are presented below (Figures 4-8).

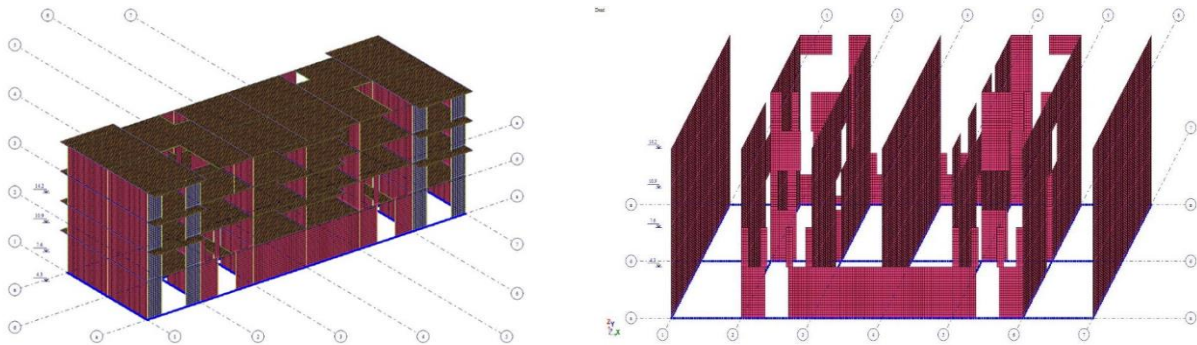


Fig. 4. Multi-storey residential building model image developed by LIRA software (I, II models)

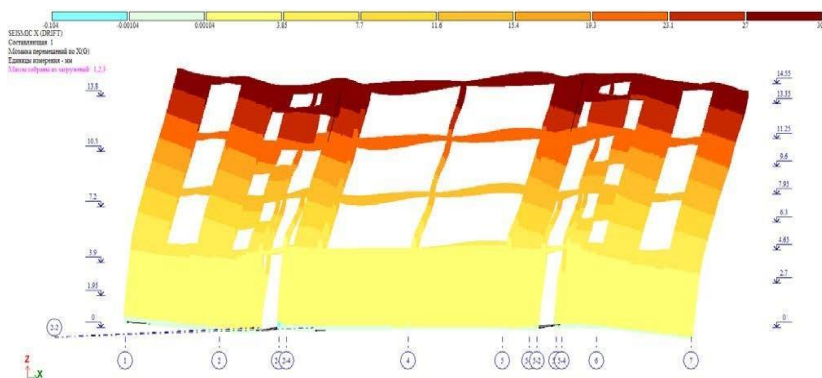


Fig. 5. Analytical image of floor movements of the first model from seismic horizontal load in direction of X

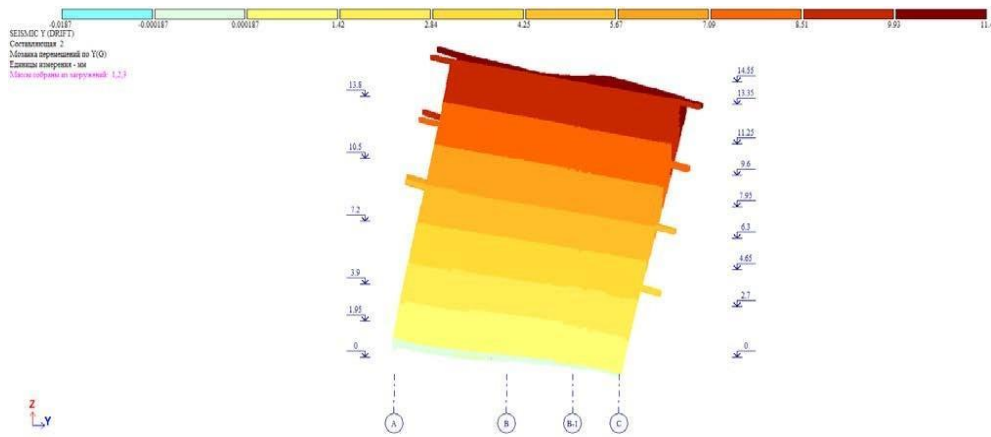


Fig. 6. Analytical image of floor movements from seismic horizontal load in the direction of *Y*

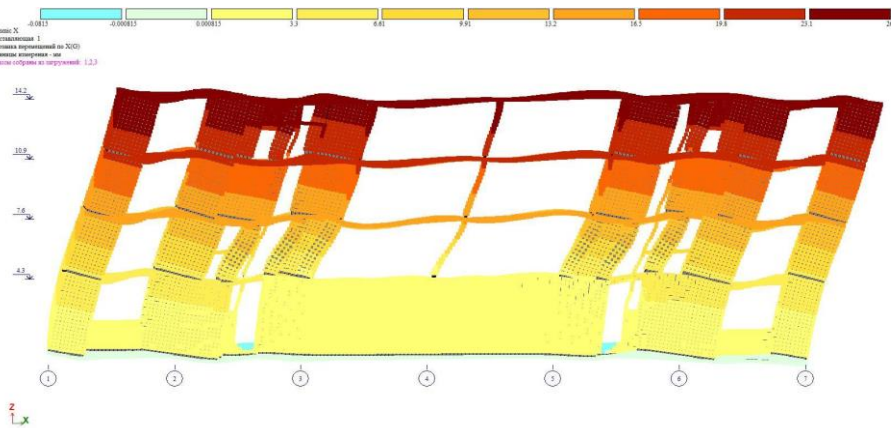


Fig. 7. Analytical image of floor movements of the second model from seismic horizontal load in the direction of *X*

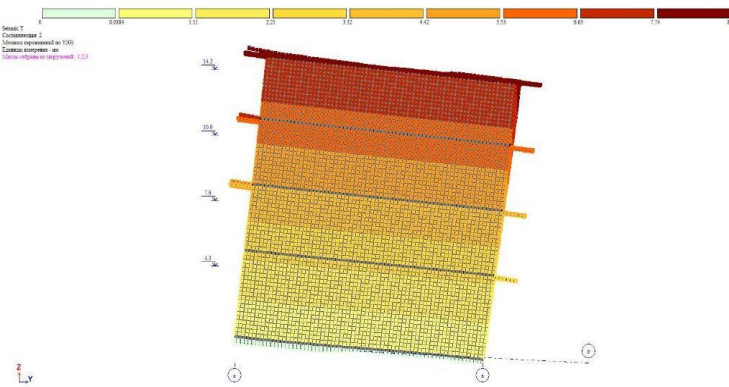


Fig. 8. Analytical image of floor movements of the second model from seismic horizontal load in the direction of *Y*

Results and Discussion

According to the analysis of the calculations, the strength and reliability of the proposed structure can be provided both with site cast reinforced concrete and in the case of shear wall modeling with three-layer panels. Some of the data obtained from calculation results are presented below.

Table 2. Dynamic characteristics obtained by calculation for the structure

| N | Periods of vibrations | Maximum floor displacement in the direction of <i>X</i> , mm | Maximum floor displacement in the direction of <i>Y</i> , mm |
|-------------|-----------------------|--|--|
| First model | 0.302 | 8.3 | 3.37 |

| | | | |
|--------------|-------|-----|------|
| Second model | 0.267 | 7.2 | 2.09 |
|--------------|-------|-----|------|

Table 3. Shear wall material consumption according to calculation results

| N | The total value of shear walls reinforcements, <i>t</i> | The volume of concrete used in shear walls, <i>m</i> ³ | The volume of polyurethane foam used in shear walls, <i>m</i> ³ |
|--------------|---|---|--|
| First model | 13.581 | 137.28 | 144 |
| Second model | 21.425 | 228.8 | 0 |

As we can see it from Table 2, the second structural model is more rigid and has better indicators from the point of view of dynamic characteristics. According to Table 2, the volume of reinforcement bar required in the first model is about 25% smaller than in the second model. In terms of concrete consumption, the first model saves 90 *m*³, but increases the cost of 114 *m*³ of polyurethane foam. By reducing the volume of concrete, the natural weight of the first model is reduced by 220 tons.

Volumes of the reinforcements of other elements of bearing systems of design models are not given in Table 3, since their differences do not exceed 1.5% and do not make any sense in terms of comparison.

Conclusion

According to the obtained data, during the comparative analysis it becomes clear that the bearing system of the structure with site cast reinforced concrete shear walls is more rigid than the bearing system of the structure with three-layer panels, therefore the first model has small floor deviations. It can be concluded that under favorable soil conditions it is more expedient to make shear walls from three-layer panels, taking into account the profitability of their economic indicators.

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