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STUDY ON THE NEW METHOD OF CONSTRUCTING SHEAR WALLS IN MULTI-STOREY BUILDINGS WITH SITE CAST REINFORCED CONCRETE FRAME SYSTEM

The article touches upon the comparative analysis of bearing system calculations of a multi-storey residential building with site cast reinforced concrete frame and shear wall constructed by two different methods. In the calculation models, the shear walls are constructed from site cast reinforced concrete in the first case, and from three-layer sound and thermal insulating bearing panels in the second. The calculations have been made considering the impact of the seismic force. According to the calculation results, the dynamic parameters of the bearing systems of the buildings and the economic efficiency indicators have been compared. Considering the fact that in the recent years three-layer sound and thermal insulating panels have been widely used in the world, the study attempted to reveal the efficiency of using such panels in the Republic of Armenia.

Keywords: *site cast reinforced concrete, three-layer panel, shear walls, seismic impact, multi-storey building.*

Introduction

Along with the development of the construction industry, technologies of the implementation of building structures are developing, new building materials are emerging and studies are being conducted to develop more accurate schemes for calculating those new technologies and materials in the world. The integrity of these processes is aimed at improving the reliability of buildings, as well as their indicators of economic profitability.

The article examines the efficiency of using three-layer sound and thermal insulating panels, widely used in the world, as shear walls in multi-storey buildings constructed in the Republic of Armenia.

It should be noted that the three-layer panels are most often used as external covering structures in Armenia. At the same time, over the years, numerous studies have been carried out in the direction of technologies of calculation and implementation of this type of panels, special methods for the implementation and modeling of their nodes have been developed. Taking into account the aforementioned, we have performed numerical analyses of the bearing systems of buildings with or without three-layer panels in case of seismic impacts on the example of multi-apartment buildings. The nodes of the structures were modeled to meet the requirements of seismic construction codes and rules for designing reinforced concrete structures[1] [1,2]. Calculation models of buildings were developed using computer software operating on the basis of finite elements, and loads affecting the models were taken as their actual values[2] [3-8].

The three-layer panels under study consist of two outer 6 *cm* thick concrete layers, one inner polyurethane foam layer, in which the reinforcing frame is woven from longitudinal and transverse reinforcement bars with a special technology. The technology of manufacturing and installing panels is implemented in stages: at the first stage, reinforcing frame is woven through a special production line, at the second stage it is covered with

[1] HHSHN II-6.02-2006. Seysmakayun shinararut’yun. Nakhagtsman normer. Yerevan, 2006, p.67 (in Armenian).
[2] SNiP 2.01.07-85*. Nagruzki i vozdejstviya, FGUP CPP, Moscow, 2005, p.44 (in Russian).

polyurethane foam, at the third stage it is moved to the construction site and installed in the design position. At the fourth stage the panel is connected to the bearing frame by specially developed nodes and at the fifth stage it is covered with thick layers of concrete from both outer sides[3].

The appearance of the three-layer sound and thermal insulating panels used in the multi-storey building under study is presented below (Figures 1, 2).

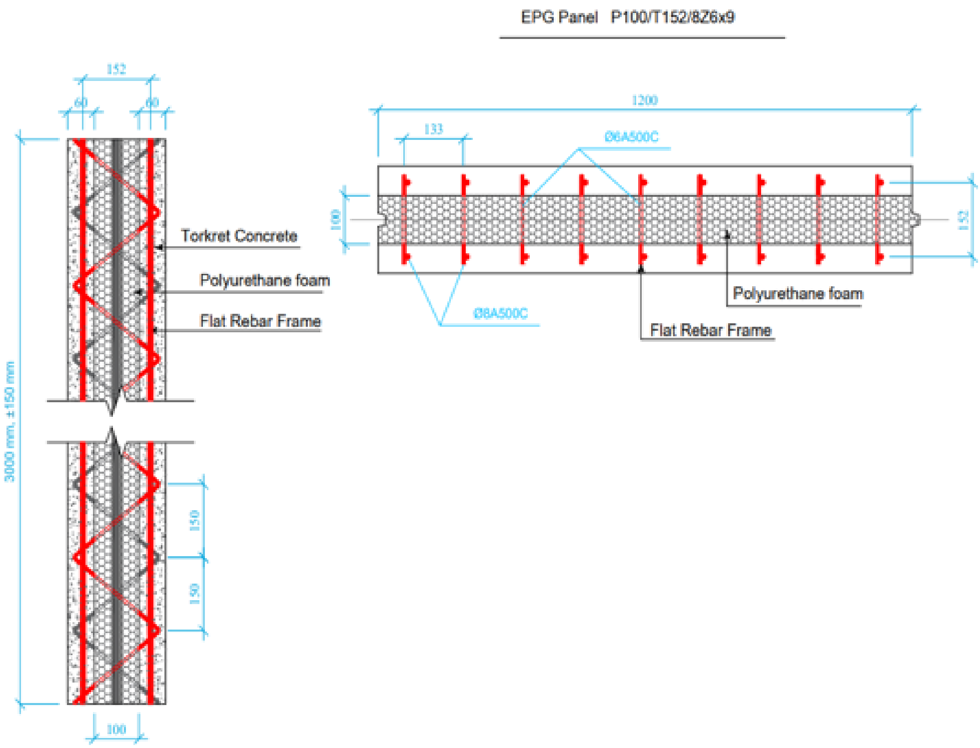

Fig. 1. *Transverse and longitudinal sections of three-layer sound - and thermal insulating panels*

Fig. 2. *Three-layer sound- and thermal insulation panels during installation*

[3] EPG Wall, Floor and Roof System by Eco Panel Group, ICC Evaluation Service, Report, Glendale, 2018, p.274.

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 Yerevan[4] [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)•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 HHSHN 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 c*m* 40x60 *cm* ($E_b = 2.3\text{x}10^5$ *MPa*),
- Column - 40x40 *cm*, ($E_b = 2.3\text{x}10^5$ *MPa*),
- Beam - 40x60 *cm* (in the direction of *X*), 40x40 *cm* (in the direction of *Y*) ($E_b = 2.3\text{x}10^5$ *MPa*),
- Roofing slab - 20 *cm* ($E_b = 2.3\text{x}10^5$ *MPa*),
- Shear wall - 40 *cm site cast* ($E_b = 2.3\text{x}10$), 22 *cm* three-layered ($E_b = 2.0\text{x}10^5$ *MPa*),
- Heavy concrete B25,
- Reinforcement bar A500C, A240,
- $a_{crc} = 0.3$ 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* (Eb = 2.3x105 MPa),
- Column - 40x40 *cm* (Eb = 2.3x105 MPa),
- Beam - 40x60 *cm* (in the direction of X), 40x40 *cm* (in the direction of Y) (Eb = 2.3x105 MPa),
- Roofing slab - 20 *cm* (Eb = 2.3x105 MPa),
- Shear walls - 40 *cm* site cast (Eb = 2.3x10), 22 *cm* three-layer (Eb = 2.0x105 MPa),
- Heavy concrete B25,
- Reinforcement bar A500C, A240,
- a_{crc} = 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/m²*	Load reliability coefficient, γ_f	Calculated load, *n/m²*
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).

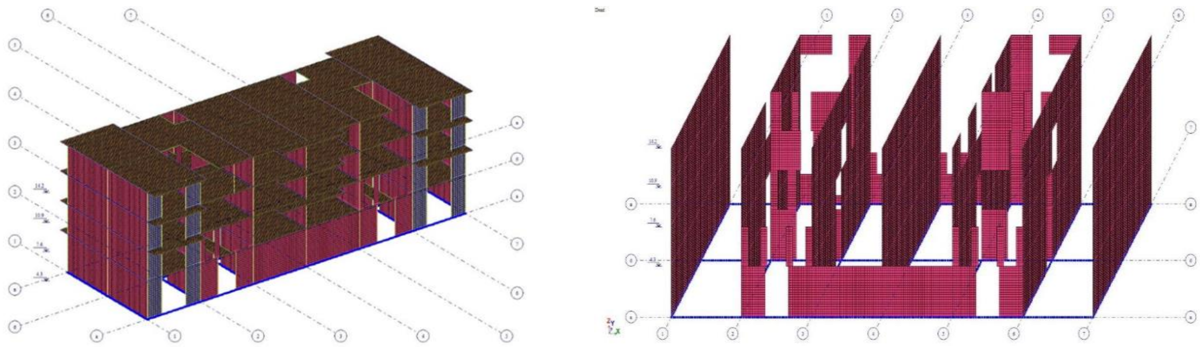

Fig. 4. *Multi-storey residential building model image developed by LIRA software (I, II models)*

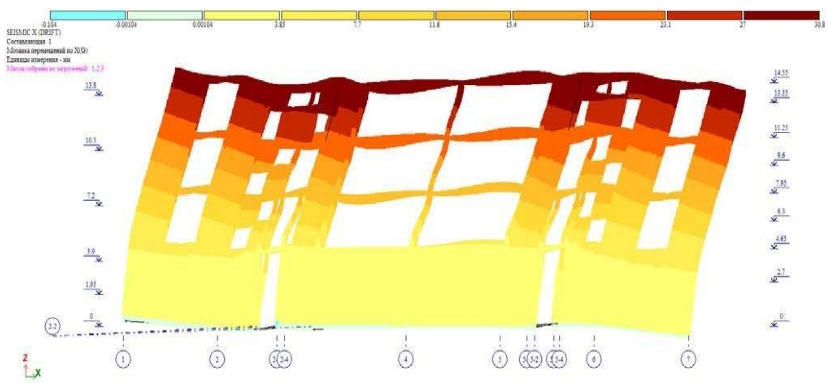

Fig. 5. *Analytical image of floor movements of the first model from seismic horizontal load in direction of X*

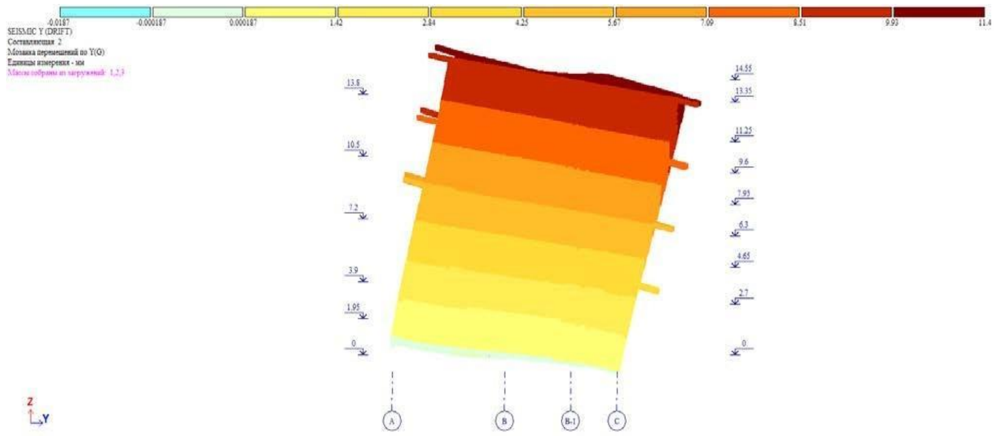

Fig. 6. *Analytical image of floor movements from seismic horizontal load in the direction of Y*

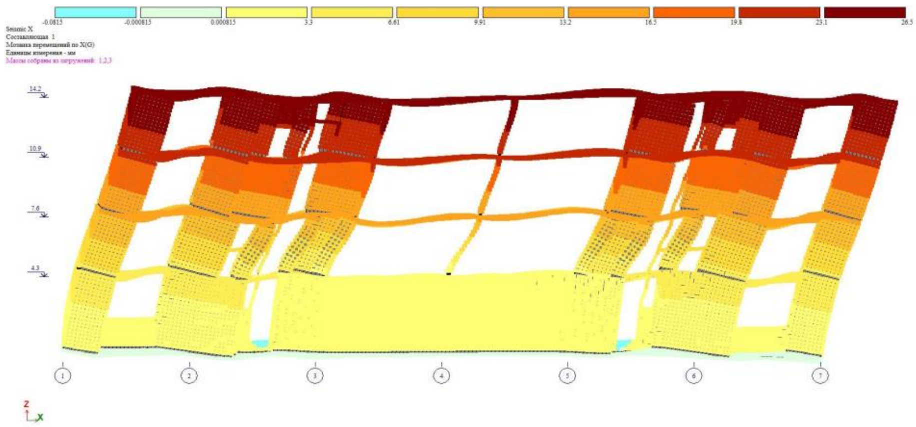

Fig. 7. *Analytical image of floor movements of the second model from seismic horizontal load in the direction of X*

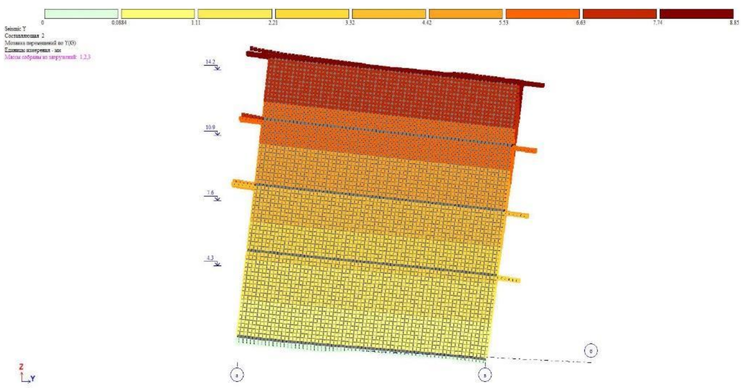

Fig. 8. *Analytical image of floor movements of the second model from seismic horizontal load in the direction of Y*

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 X, *mm*	Maximum floor displacement in the direction of Y, *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, *t*	The volume of concrete used in shear walls, m^3	The volume of polyurethane foam used in shear walls, m^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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