Influence of Mining Shocks on Residential Buildings in Poland

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Abstract. The article presents the methodology for determining the dynamic resistance of residential prefabricated buildings subjected to mining shocks. The calculations were performed using simplified 2D models and response spectrum methods. The results of calculations may in the future be used in the assessment of the impact of the predicted accelerations of ground vibrations on building structures.

1. Introduction
The impact of mining shocks on residential buildings in Poland is the subject of current research and analysis. In particular, this problem concerns brick and single-family buildings [1]. It is connected with the exploitation of coal seams, brown coal and copper ore. In the 1970s, a large number of prefabricated construction facilities were established in Poland. One of the housing construction systems used at that time was the OWT 67 / N system. The paper presents the assessment of dynamic resilience of the OWT 67 / N system on the example of a city in southern Poland.

2. Adopted models of analyzed building
Due to the large number of objects located in the analysed area, it was decided to select several representative facilities for which calculations were carried out. Due to the fact that construction objects made in the OWT technology are very similar to each other, it was decided to build "simpler" models that better describe the entire analysed building, and at the same time allow to obtain sufficiently accurate results. The following assumptions were made when constructing models:

- the model must be simple to easily interpret the obtained results and compare them with the standard values,
- the results must be presented in an engineering manner and be easily interpreted by a person who is an engineer,
- models must be general (they cannot be too detailed, as they refer to a group of objects and not a single object) due to the need to represent a group of objects with similar but not identical dimensions, construction layout and soil parameters,
- results obtained for models must be within the range of possible solutions (consistent with the results for similar objects for which in situ verification was carried out)
- the models do not take into account the technical condition of the facility, assuming its proper execution, in accordance with the available technical documentation,
- good technical condition is taken into account in the models.
For the construction, discrete models were adopted in the form of an arrangement of vertical brackets fixed in a foundation, described, among others, in the works [2, 3] (see Figure 1a). This model has been simplified to the model shown in Figure 1b. According to [2], this simplification leads to slight differences compared to the model in Figure 1a, which from the point of view of the calculations will not be relevant.

The discretization of building mass is carried out in levels of ceilings and flat roofs, taking into account the full permanent load plus 50% of the life load (according to ITB 391/2003 [4]).

![Figure 1. Dynamic models of the analysed buildings.](image)

In the calculation of the susceptibility matrix, the bending, shear and susceptibility of the subsoil are considered. Depending on the dimensions of the building, the individual members of the vulnerability matrix contribute a greater share in the oscillation of the object. For the orientation in Fig. 2 it is presented for [5] when it is important to consider the individual elements of the vulnerability matrix in the dynamic calculations of longwall buildings.

![Figure 2. Pattern of building vibrations on a flexible ground [5].](image)

While modeling buildings with brackets, it is usually assumed that they are elastically fixed in the object foundation level, which is justified by the fact that research on this type of objects shows that the building is subject to displacement during vibrations [2]. In the case of a very rigid basement part (e.g., a rigid monolithic chest) it is allowed to fix the roof ceiling above the basement. The model buildings from the whole group of facilities located in the analyzed area were selected for the analyzes. Representative buildings were selected due to the number of storeys. Models were adopted for three-, four-, five-, nine- and twelve-story buildings. Detailed results are given for the selected five- and twelve-
story model. The presentation of five-and twelve-story models is dictated by the fact that the 12-story model is the most heavily loaded due to constant impacts, while the 5-story model is most loaded with the acceleration response spectrum due to its dynamic characteristics.

Dynamic models were adopted in accordance with Fig. 1b. The models were installed elastically in the level of foundation of the objects. Fig. 3 and 4 show the load-bearing wall systems for the five and twelve-story models, respectively. The transverse walls assumed in the calculations are marked red, while the longitudinal walls accepted in green are marked in red. All structural walls were made as concrete or reinforced concrete walls, with a wall thickness of 14 cm.

Due to the lack of information regarding the soil parameters lying under the foundations of the analyzed buildings, the second category of soil was adopted according to the standard [6]. This assumption is characterized by the coefficient $C_z = 40 \text{ MPa} / \text{m}$.

The dynamic characteristics of the adopted calculation models have been verified with the available code [7].

Table 1 presents a comparison of the obtained periods of natural vibrations with those available in the literature.

| Model  | Calculated | Calculated on the basis of [7] – eq no. 1 | Calculated on the basis of [7] – eq no. 2 |
|--------|------------|-----------------------------------------|-----------------------------------------|
| 5 floors | 0.240      | 0.320                                    | 0.250                                    |
| 12 floors | 0.735      | 0.700                                    | 0.740                                    |
Analysing the data presented in Table 1, it can be concluded that the proposed model well reproduces the dynamic characteristics of the analysed buildings.

Similar conclusions can be drawn by comparing the calculated periods of natural vibrations with the results for similar buildings presented, among others in the work [2], where using analogically constructed models, the basic vibration frequencies for the five-story building built in the DOMINO system were determined.

Similar results obtained on the basis of calculation models and studies of the object on a natural scale were presented by the authors of the work [8]. This work analysed five- and twelve-story buildings built in the WWP system (Wrocławska Wielka Płyta). Differences in the 1 and 2 ranges of vibration frequencies obtained on the basis of tests for a twelve-story building do not exceed 10% compared to those presented in this work. Similarly, the first vibration frequency for a five-story building is within the range determined on the basis of the studies cited here.

Considering the above, it can be assumed that the models proposed in the work describe the dynamic characteristics of the analysed building well and are within the range of results obtained by simplified methods and results obtained on the basis of quoted studies of similar objects in situ.

3. Dynamic resistance of the analyzed buildings

In the work of prefabricated large-panel constructions, structural elements can be indicated which, from the point of view of horizontal loads, are the most important. These include: walls parallel to horizontal loads, vertical joints and horizontal joints. For these structural elements load conditions have been formulated taking into account the specificity and technology of production and execution of the OWT 67 / N system.

The following criteria were selected in the work:

- Criterion for the load-bearing capacity of the stiffening wall
- Criterion of load capacity of the vertical joint
- Criterion for the load capacity of the horizontal joint
- Criteria for the load-bearing capacity of the lintel due to the shear force
- Criterion for tensile stress in the horizontal joint and the structural wall

All of the above criteria have been developed on the basis of standards applicable when designing the analyzed buildings. Detailed criteria are presented in [9]. The selected analysis results are presented below.

The lowest permissible values of ground vibration accelerations were recorded for the horizontal joint load capacity criterion. For this case, the permissible values of soil vibration acceleration are shown in Tables 2 and 3 for the transverse and longitudinal directions, respectively.

| Model | \( N_{\text{max}} \) \((a_p=120 \text{ mm/s}^2)\) [kN] | \( U_T \) [kN] | Criterion of carrying capacity \( N_{\text{max}} / U_T \) [%] | \( a_{\text{dop}} \) [mm/s^2] |
|-------|---------------------------------|----------------|---------------------------------|------------------|
| 5 floors | 323,38 | 572,17 | 56,52 | 782 |
| 12 floors | 671,30 | 700,0 | 95,9 | 183 |
Table 3. Criterion for the load-bearing capacity of the horizontal joint in the outer wall - transverse direction.

| Model   | \(N_{\text{max}}\) (a\(_p\)=120 mm/s\(^2\)) [kN] | \(U_T\) [kN] | Criterion of carrying capacity \(N_{\text{max}} / U_T\) [%] | \(a_{\text{dep}}\) [mm/s\(^2\)] |
|---------|----------------------|------|-----------------------------|------|
| 5 floors| 230,91               | 515,96| 40,36                      | 1045 |
| 12 floors| 482,59              | 630   | 76,6                       | 452  |

4. Conclusions
The system – OWT 67/N belonged to the so-called closed systems of large-panel construction and thus characterized by relatively small typological diversity of individual objects, except for obvious height variation. This assessment could therefore be made for a selected group of representative buildings with heights ranging from 3 storeys to 12 storeys.

The OWT 67/N system has been developed in a renowned design team.

The analysis of the safety status of the selected buildings was made with the help of norms and literature sources from the end of the 20th century, modern standards for reinforced concrete and large-panel structures do not include this type of construction, especially certain specific design tasks. As an example, it can be stated that the assessment of the load capacity of a horizontal joint has its formal authority only in the sources listed above.

Due to the relatively weak dynamic force (a\(_p\)) in most of the selected zones in the load-bearing structure, very large "load bearing capacity" was obtained so far that there could be higher predicted values of a\(_p\) in order to create a threat. However, this positive result of the study does not concern the safety assessment of the group of the highest buildings (9, 10 and 12 storeys).

References
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