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Project management for the construction sector in the field of foundation of designed residential building located in this area with the expected impact of mining operation

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Abstract: The current knowledge of scientists and practitioners in the field of protecting and modernizing buildings in areas with mining impact is constantly developing and modernized. Confirmation design and executive guidelines obtained so far allow you to predict an additional impact of adverse impact of subsoil mechanics on building structures in mining areas and indicate the optimal ranges of guidelines regarding the security and protection of construction investment. The information in the presented article show current knowledge about the strengthening and protection of residential buildings located in mining areas.

The publication also discusses the legal and methodological foundations that are practiced in Poland and Europe regarding the standards and instructions related to the design of buildings in mining areas. The articulated analysis and concept of the optimal solution for securing and strengthening the newly designed residential building together with an analysis of costs for Silesia areas in Poland. Determining the amount of adaptation of the building to not typical conditions in relation to the costs of the entire investment gives very good information to the management sector of the entire construction and to the anaizy investment risks of the project.

Keywords: Project management, design of buildings on area with mining influes, geotechnical models of soil substrates, models and methods of construction project management.

Introduction

In mining areas, small single-family residential buildings are most often built, made according to typical repetitive designs that require adaptation to a given location and ground conditions. In the case of locating buildings in mining areas, it is necessary to carry out an analysis in terms of implementing special protection against the harmful effects of mining. Designing and constructing a properly secured building structure is a complex task, requiring knowledge of the mining impacts acting on the surface of the site as well as legal, standard and methodological guidelines regarding the preparation of the building to transfer additional loads. Implementation of such protection involves additional costs that the investor must incur, and then estimate and document in order to apply for compensation from the mining company operating in the area.

Legal conditions and norm rules

Polish law regulates the proceedings in the field of liability for mining damage both for existing buildings and in the case of designing and implementing new investments. The most important legal act for the construction of buildings is the Construction Law, while in the case of designing buildings in mining areas, the Geological and Mining Law and the relevant regulations are also applicable. However, the provisions contained in the laws and regulations do not indicate the course of proceedings related to the construction of facilities in mining areas, but only the general requirements that the facility should meet in connection with ensuring safety. Acts and regulations contain references to standards related to construction, in which more detailed guidelines can be found, but Polish Standards and Eurocodes do not provide methods for determining mining impacts, designing the load-bearing structure, additional protections, calculating individual elements on the impact of predicted terrain deformation indicators. Such guidelines and many others, based on many years of experience and scientific research, can be found in the instructions issued by the Building Research Institute and in specialist literature on the subject of the impact of mining damage on buildings. Below is a diagram containing the sources of legal and standard guidelines.

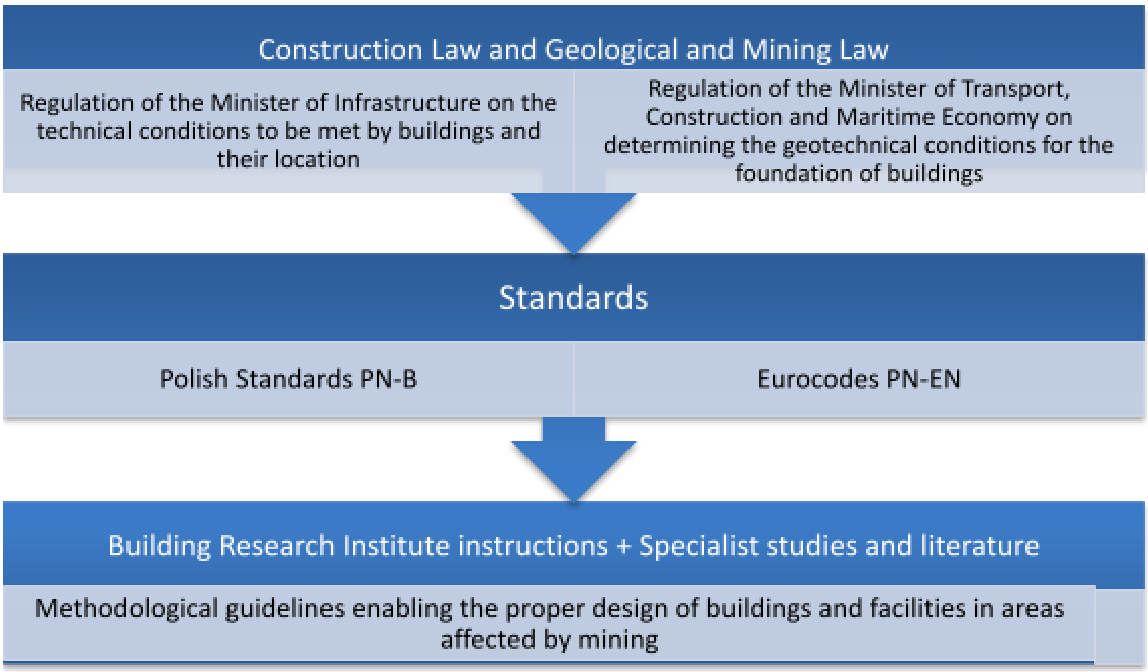

Figure 1 Scheme of legal guidelines and standards [own elaboration]

Design data

Basic information on the expected impact of mining on the surface is contained in the deposit development plan and the mining plant operation plan. Such information is issued by mining supervision authorities or mining plants, most often in the form of information on mining and geological conditions. Most of the prepared mining and geological information includes only the information necessary from the point of view of the construction process, but it can be stated that this is a sufficient scope of data for the design of most buildings. The most important data are indicators of continuous land deformations such as land depression, land slope, horizontal ground deformation and land curvature radius. In addition, data on the possibility of discontinuous deformations, mining tremors and changes in water relations in a given area. Based on these data, it is possible to define mining area category according to the table below.

Table 1 Mining area categories [Michalik i Gasiorowski, 2015]

Mining area category	Deformation value		
	slope T [mm/m]	curvature radius R [km]	horizontal deformation ε [mm/m]
0	$T \le 0,5$	$40 \le \lvert R \rvert$	$\lvert \varepsilon \rvert \le 0,3$
I	$0,5 < T \le 2,5$	$20 \le \lvert R \rvert < 40$	$0,3 < \lvert \varepsilon \rvert \le 1,5$
II	$2,5 < T \le 5,0$	$12 \le \lvert R \rvert < 20$	$1,5 < \lvert \varepsilon \rvert \le 3$
II	$5 < T \le 10$	$6 \le \lvert R \rvert < 12$	$3 < \lvert \varepsilon \rvert \le 6$
IV	$10 < T \le 15$	$4 \le \lvert R \rvert < 6$	$6 < \lvert \varepsilon \rvert \le 9$
V	$15 < T$	$\lvert R \rvert < 4$	$9 < \lvert \varepsilon \rvert$

In order to design the building's protection against mining impacts, basic technical data concerning the facility are also needed, such as geometrical dimensions, type of construction, adopted material and technological solutions and subsoil data at the site of the planned investment. Pursuant to the regulations, construction facilities located in areas affected by mining should be included in the third geotechnical category, where it is required to prepare geological and engineering documentation, which contains a very wide range of data on ground conditions. However, in the case of the construction of single-family houses, this obligation is rarely fulfilled. In the diploma thesis, a single-family, detached, single-family residential building without a basement, with 2 above-ground floors - ground floor and usable attic was analyzed. The building has a usable area of 194.15m2 and floor plan dimensions of 14.90m x 10.10m. The facility is located in the village of Przecieszyn, located in the "Brzeszcze" mining area, within the limits of the planned exploitation on the surface of the area.

Analysis and concept of the building security project

The design analysis of reinforcements and protections for the building in areas affected by mining exploitation was made on the basis of literature in the form of standards, legal basis, Building Research Institute instructions, directives and scientific publications. The analysis presents information on shaping the body of the building and detailed technical solutions of individual structural elements contained mainly in the Building Research Institute instructions and other scientific publications. The presented solutions were then matched to the predicted deformation indexes of the mining area and a typical residential building design, allowing for the determination of the optimal scope of securing the planned investment. In terms of the architecture of the building, the shape of the horizontal projection of the building was changed, moving two walls by about 60 cm, a more favorable rectangular shape was obtained. In the designed building, in order to absorb the horizontal deformations of the terrain, the layer of lean concrete under the foundation will be replaced with a bedding made of non-cohesive soils - medium sand or coarse sand, made at the degree of compaction Id < 0.6. It is planned to change the foundation in the form of spot footings and combined footings to a reinforced foundation grillage. The material for the construction of the walls of the above-ground storeys was specified as small-sized ceramic elements with a compressive strength of min. 15MPa, type of mortar as cement-lime or cement mortar and the method of masonry with filled vertical joints. Attention was also paid to the correct connection of longitudinal and transverse walls to ensure spatial rigidity of the entire building. Prefabricated ceramic lintels were replaced with monolithic reinforced concrete ones, 25 cm high, reinforced with 4Ø12 main bars, Ø8 stirrups every 12cm, and a minimum length of the lintel support on the walls was set at 25cm. For the reinforcement of reinforced concrete structural elements, the steel grade was changed to B500SP class of high ductility steel. It was also adopted to change the structural concrete of class B20 to concrete of class B25. Based on the conducted analysis, a set of guidelines for the most optimal characteristics of newly built residential buildings with respect to mining impacts was collected and presented in table 2.

Table 2 List of guidelines for newly constructed buildings [own elaboration]

Range	**Guidelines for optimal building characteristics**	
Shape	The shape of the building body is similar to a cuboid with the same height. The shape of the floor plan is the most consistent and simplified, similar to a rectangle, hexagon or circle, without concave outer contour angles	
Dimensions	I and II mining category maximum building or segment length ≤ 36m III and IV mining category maximum building or segment length ≤ 30m	
Materials	Concrete of load-bearing structures of at least class B20 Characteristic compressive strength of the wall $f_k \geq 3$MPa Cement-lime or cement mortars Characteristic compressive strength of mortars $f_m \geq 5$MPa Reinforcing steel class A-I grade St3SY, optionally grade A-II grade 18G2 and grade A-III grade 34GS, if welding of the reinforcement is not expected	

Carrying system	Wall, frame with masonry filling or mixed, Layout of load-bearing walls as symmetrical as possible in relation to the longitudinal and transverse axis of the building	
Type of construction	Foundations	Reinforced concrete foundation grillage - for a grid footing span exceeding 6m, a foundation grillage with diagonal ties, optionally a grid with a foundation reinforced concrete slab
	Basement storeys	Shaped in the form of a box with a constant height within the segment, made in a monolithic structure, with concrete or reinforced concrete walls
	Aboveground storeys	Walls forming a shield system, properly connected in the longitudinal and transverse directions, made of the same material on a given floor. Reinforced concrete frame structures with masonry infill are acceptable
	Ceilings, building wreath and lintels	Reinforced concrete monolithic shields stiffened in their planes with reinforced concrete ring beams, made on site and installed around the perimeter and along the internal load-bearing and stiffening walls

The analysis was carried out in order to determine the scope of works needed to strengthen the structure of the building in the area affected by mining exploitation and thus to determine the dependencies affecting the amount of expenditure incurred.

Change of the foundation in the form spot footings and combined footings to a reinforced foundation grillage

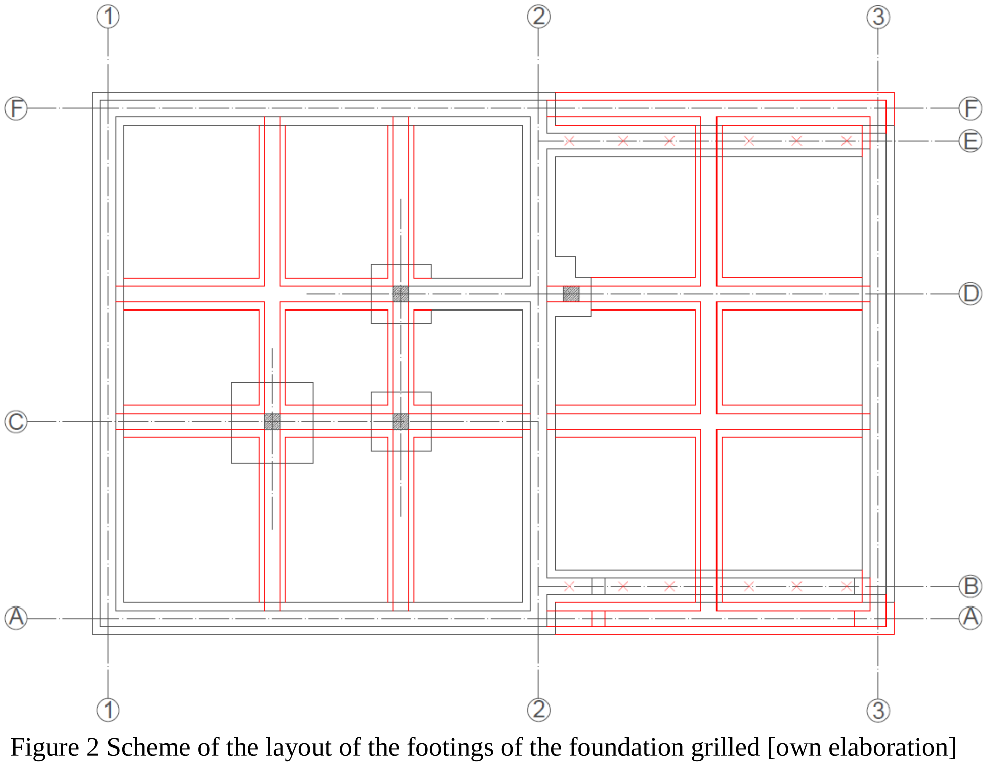

Figure 2 Scheme of the layout of the footings of the foundation grilled [own elaboration]

In accordance with the recommendations of the Building Research Institute 416/2006 instruction, in order to transfer horizontal forces and ensure the geometric invariance of the building's horizontal projection, it was designed to change spot footings and combined footings to a reinforced foundation grillage. The scheme of the adopted layout of the footings of the foundation grillage is shown in the drawing of the foundation projection, changes in the existing layout of the foundation projection are marked in red.

After adopting a new geometrical arrangement, it was necessary to calculate the structure of the foundation grilled on the impact of horizontal deformations of the terrain caused by mining. Data on the foundation conditions were used for the calculations in accordance with the information contained in the geotechnical analysis of the area and the obtained geological and mining information. Calculations were made in accordance with the guidelines of Building Research Institute 416/2006 Design of buildings in mining areas, according to the diagram shown in Figure 3.

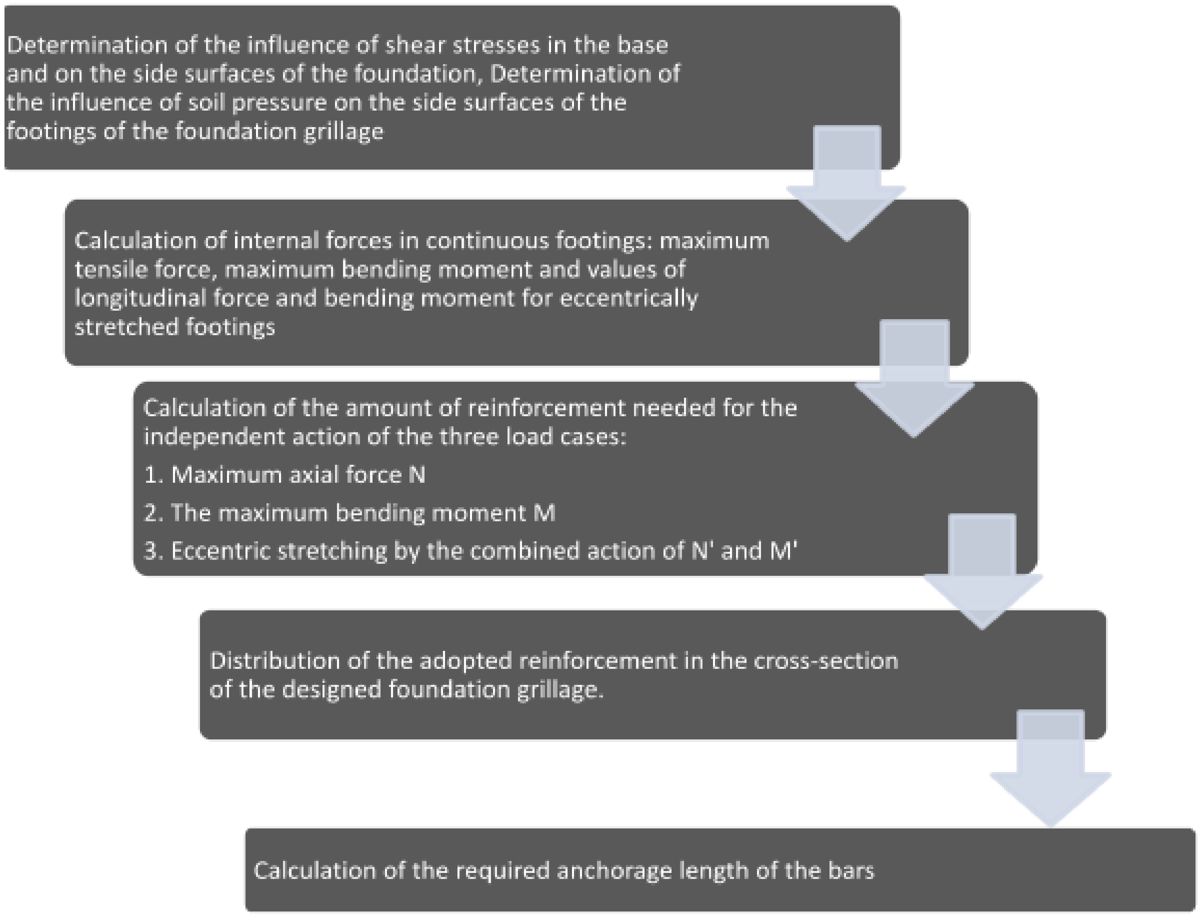

Figure 3 Scheme of calculations of the foundation grillage on the impact of horizontal terrain deformations [own elaboration]

In the adopted system of footings of the foundation grillage, internal forces were calculated as the sum of forces caused by tangential stresses in the foundation base, forces caused by tangential stresses on the side surface of the foundation, forces caused by tangential stresses in the base of footings adjacent to the calculated footing, and soil pressure on the side surfaces of footings. Based on the obtained results, the reinforcement of the footings of the foundation grilled was dimensioned and the distribution of bars in the cross-section was assumed due to axial stretching, bending and eccentric stretching. For the most heavily loaded footings, reinforcement with 7 rods of Ø16mm was adopted.

Due to the length of the building and the projected radius of the curvature of the terrain, the calculations of the building on the impact of the curvature of the terrain were omitted in accordance with the technical requirements for buildings erected in mining areas contained in the instruction Building Research Institute 364/2007.

The performed calculations made it possible to determine the amount of materials and labor necessary in the further part of the work, related to securing the building on the projected impact of mining operations.

Cost analysis

For the purpose of the analysis, a bid cost estimate was prepared, which summarizes all the costs that the investor must incur to secure the single-family building analyzed in this paper, located in an area with mining impacts. The analysis and conception carried out allowed us to determine the scope and cost of making a typical residential building safe from the impacts of mining operations for the projected deformation of the area. The analysis shows that the protection of the analyzed building to the impacts of mining exploitation according to the average market prices for the fourth quarter of 2022 increases the cost of construction of a single-family house in a closed state according to the selected design by 7.7%. With regard to the cost of use and repair management of a building located in the area of mining influence, it was estimated that, in the case of an unprotected building, its maintenance and repair costs over 50 years would be approximately 45% higher than for the same building located outside the area of mining damage

Summary and Conclusions

The analysis summarizes various possible solutions for individual elements of the building along with an attempt to optimize the scope, type and costs. Analyzes, design calculations and valuations performed in the work show a model of adapting projects to unfavorable and unusual impacts of mining exploitation. As the work has shown, design guidelines for the most appropriate characteristics of buildings located in such areas can be found. The presented scope of design modification of a typical single-family building project is the optimal solution for the assumed mining impact class. For such a reinforced building with an estimated average finish standard, the range of additional investment costs is less than 10% of the total cost. Analysis of a different type of real estate with the need for more design and executive modifications generates subsequent average values of the increase in construction investment costs. The result of the analysis is influenced by many variables, and the coefficients of variation should be estimated for the specified detailed characteristics of the investment under construction. The work performed confirmed the possibility of determining the percentage amount of the entire investment needed to design and implement reinforcement of the structure of buildings located in areas with the adverse impact of mining.

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