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Impact of Mining Exploitation on Properties with Engineering Structures by Local Urban Development Plans

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Abstract. Discussed is one of the stages of an ongoing research study analysing the form and area of active mining impact on properties which include engineering structures. A general back analysis has been applied to the cause and effect method for defining the causes of empirically determined structural damage. One of the points of the analysis is to determine if the guidelines of The Local Urban Development Plan and then the conditions for building permits have been correctly issued. and whether they have taken into account all the adverse effects that may affect to be analysed engineering structures on the test field. In addition, examined all the documents which have an impact on the structure and the guidelines imposed by the local plans that takes into account the harmful impact of mining exploitation. In this publication was analysis of explores the current assumptions for mining damage forecasts for areas affected by a mine over a planned operation period, all well. Considering that mining forecasts specify the quantity, impact duration, as well as the form of static and dynamic forces responsible for stresses and deformations resulting from active mining, the information is most critical for the construction and industrial sectors. The Local Urban Development Plans for the analysed areas are based on the final information supplied by the forecasts, and show active mining areas clearly outlined; thus making it possible to delineate the active mining impact areas when preparing guidelines for building and structure construction permits. The mining damage area parameters determine the design and construction requirements for individual projects which must comply with engineering structure foundation specification for areas exposed to other than standard and highly damaging active mining impact. Mining forecast data allow for designing adequate structural, material, and geothermal safeguards which will stabilize the soil and reduce forces negatively impacting soil serviceability limit states. Owing to the high number of problems attributable to discrepancies between the mapped mining damage areas, the calculations and assumptions used in mining forecasts, and the actual conditions, this study aims to analyse the problem.

1. Introduction

Discussed is one of the stages of an ongoing research study to analyse the type and extent of active mining impact on properties featuring engineering structures. Initially, field trips were made to visit properties reporting damage. More than ten variables affecting the serviceability limit state SLS, and ultimate limit state ULS, of structures were collected for the analysed functions, which under certain cases strongly affect the behaviour of the structure [3], [5], [7], [10], [18]. Empirical tests carried out for various court cases and our own scientific investigations at the university using comparative analysis, mathematical, numerical, and statistical methods served to define a group of variables which

– under certain initial conditions –strongly impact the process of generating damage to buildings and structures [1-3], [13], [14].

The Poland construction industry is making a start in embracing BIM as a mining exploitation problems on area for building what providing the opportunity for reform and legal, engineering, geotechnics, economic, environmental and social success [7], [13], [14], [19]. The digital economy of subsoil models with dynamic forces from the exploitation of the mines are moving quickly towards, a which now is starting to have profound implications for our geotechnical, engineering structures and built environment. It is an interdisciplinary attempt to resolve mining damages. Study of all factors affecting the geotechnical conditions under the all old and new buildings in areas with mining effects and problem of deformation of the ground on the ground intended for the local land use Local Urban Development Plans without information about active mining impact on construction sites have been examined and analysed [1], [3], [5], [8], [12], [14].

One of the aspects of the research study analyzed here explores the current assumptions for mining damage forecasts for areas affected by a mine over a planned operation period. Considering that mining forecasts specify the quantity, impact duration, as well as the form of static and dynamic forces responsible for stresses and deformations resulting from active mining, the information is most critical for the construction and industrial sectors. Local urban development plans for the analyzed areas are based on the final information supplied by the mines, and show active mining areas clearly outlined; thus making it possible to delineate the active mining impact areas when preparing guidelines for future building and structure construction permits.

Figure 1. Information for Local Urban Development Plans to analyzed areas with mining impact

The mining damage area parameters determine the design and construction requirements for individual projects which must take into account the engineering structure foundation specification for areas exposed to other than standard and highly damaging active mining impact. Mining forecast data allow for designing adequate structural, material, and geothermal safeguards which will adequately stabilize the soil and reduce forces negatively impacting soil serviceability limit states. Owing to the high number of problems attributable to discrepancies between the mapped mining damage areas, the calculations and assumptions used in mining forecasts, and the actual conditions, this study aims to analyze the problem. Based on the information supplied and the author's own observations supported by empirical investigations, certain conclusions have been developed are presented in the final part of this paper.

2. General characteristics of the research project

As an assistant professor who deals with this issue in universities where I work and as a court-licensed expert witness in construction, mine damage and property valuation, I often prepare valuations and legal expert opinions for lawsuits contesting initial data, analytical methods, and calculations. For their analyses, mining industry experts use information submitted by mines to forecast potential active mining impact with respect to time, area, and type.

Petitioners and defendants submit descriptions and photographic material showing actual damage suffered by the properties involved. The main requirement for launching a claim for damage to buildings and structures consists in proving the property is indeed located within the mining impact area marked out in the documents supplied by the mines. However, there are cases where new buildings, after merely a few years of proper use and maintenance, show numerous and growing problems caused by tilting and shifting of the building and floors tilting at various levels, very big problems are in cracking and fractures of floors, lintels, walls and shifting and tilting damage to expansion joints, chimneys, porches, balconies, water and sewer systems and central heating systems, etc. – figure 2.

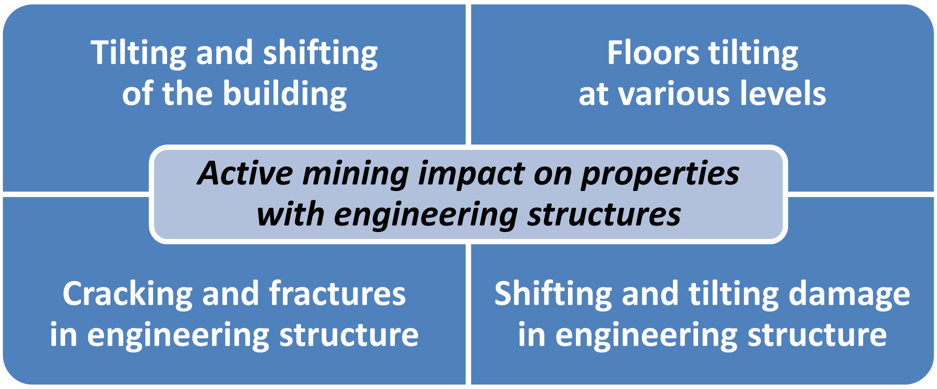

Figure 2. Active mining impact on properties with engineering structures

For the representative group of data for the analysis of the subjective assumptions each test case has urban development plans and mining forecasts without information about adverse effects on building structures. The analysis area earmarked for development is classified strictly as a housing area free from any active mining interactions, i.e. located outside a mining damage area.

Moreover, construction permits issued for such buildings do not include any guidelines which would require structural safeguards to protect them from any static and dynamic mining impact. Owners of damaged buildings demand their homes be repaired while the mine insists the damage has not been caused by mining impact since the buildings are located outside any active mining areas. Quite frequently, mines suggest various hypothetical reasons for the impact which might have led to structural damage. Such lawsuits give rise to questions from the bench which an expert witness attempts to answer using a cause and effect method based on data available in the court files and the results of potentially feasible calculations and simulations.

3. Fundamentals of forecasting the type and extent of active mining impact

The S. Knothe – W. Budryk theory is widely used to predict the impact of underground mining operations. The theory was first proposed in the 50's of the previous century as a continuation of the Schmitz – Keinhorst theory dating back to the early 20th century. It is based on observations of the ground behavior in the analyzed area and that is why certain initial assumptions ideally corresponded to the number, type and extent of the mining impact. The major findings of those investigations were limited to information that the active mining area impact is far-reaching and may stretch out over a certain distance from the active mining area. Furthermore, they provided information about the type of active mining impact, later used to formulate guidelines for the shape of subsidence troughs and soil settling calculations. The Budryk–Knothe theory is the popular in coal mines departments of compute. This theory basis of the measurement's results provided on observing lines localized over hard coal's extraction fields, but now they have changed the types and value of impacts and the nature structure of the subsoil. So, we have the question: is it possible to use now Budryk-Knothe theory for predicting mines influences on surface of ground and buildings placed in areas from the effects of the mines exploitation? [1-5], [14], [18].

The theory proved very useful since it produced estimated values consistent with empirical testing of the problem and hence allowed for developing hypothetical assumptions and defining the derivative of a subsidence trough by means of the Gaussian function. The active mining impact estimate theory must meet the requirements of a mathematical model of the medium, i.e. it must satisfy specific requirements, such as the transitivity requirement which determines the properties of the variability function of the major active mining impact radius for the analyzed area. The requirement typically represents the result of calculating displacements at a certain level which is independent of the location used in calculations, i.e. it is immaterial whether the calculations are performed directly for the analyzed level or whether displacements at intermediate calculation levels are determined during the calculations.

The values of the parameters of Knothe' theory determined as: coefficient of roof control for: caving and deflection of roof, hydraulic stowage and stone stowage, tangent of main influences angle and coefficient. The results of calculations indices of deformation based on this theory and the estimated method on the basis of empirical data are not consistent. The parameters of mining subsidence, maximal value of inclination, inclination in direct connected with x and y axis, afterwards the parameter of maximal value of horizontal deformation and deformation in direct connected with x and y axis, are very different. Building information modelling is a process involving the generation and management of digital representations of physical and functional characteristics of places [2], [4], [6], [7], [11], [12] - BIM is described as a digital representation of the building, so information about physical and endurance parameters, as well as the influence of the underground exploitation are very important for future projects carried out by BIM [6], [7], [11].

The soil in which mining is carried on represents a multi-phase medium we learn more and more about and for which we can now develop very detailed calculation models [7], [8], [11], [12]. The theory has given rise to an entire function of various mining interaction ranges in the rock mass. Currently, investigations are underway to test various models of the Knothe theory modification which attempt to define factors that take the existing output data into account.

A number of theoretical analyses have looked at basic mining operations only; whereas the results of contemporary empirical investigations are presented as a function of numerous variables. A number of calculations strictly follow the Knothe theory guidelines which do not correspond to the measured impact values.

4. Variances and inconsistencies of mining forecasts

A number of reports enclosed with mining activity forecasts show variances between the estimated and actual measured parameters. The data support selection of parameters for a theory of forecasting surface deformation and mining impact types when excavating successive longwalls and beds of bituminous coal. To understand the reason for such discrepancies, detailed analyses were carried out using existing Central Mining Institute (GIG) studies. [1], [2], [7], [9]. The description of the type and time of earlier mining operations carried out within the analyzed area provides most important information together with data pertaining to the combined depth of the worked out area, as well as the operations timeline and the date the measurements were first taken. Another key element is provided by the history of the analyzed area since it makes it possible to build the required soil model to run the

planned analyses. Very often, the currently active mining areas were first mined in the second half of the 20th century; subsequently, other beds were mined with the roof falling in early 21st century. The compiled reports show the parameters of the operations factor *a*, rock mass *tgβ,* and border *p* for specific working depths of individual beds.
Considering the numerous mining activities and the total measured surface subsidence, one may perform independent calibration of the Knothe theory parameters, in line with the generally available knowledge of surface deformation following maximum subsidence. The mining bed thickness (layer), or the so-called mining layer *g*, and the mining factor both significantly affect the shape of surface deformation. The underlying reasons for the variance between the forecast and later measurements of the deformation factors result from all points on figure no 3.

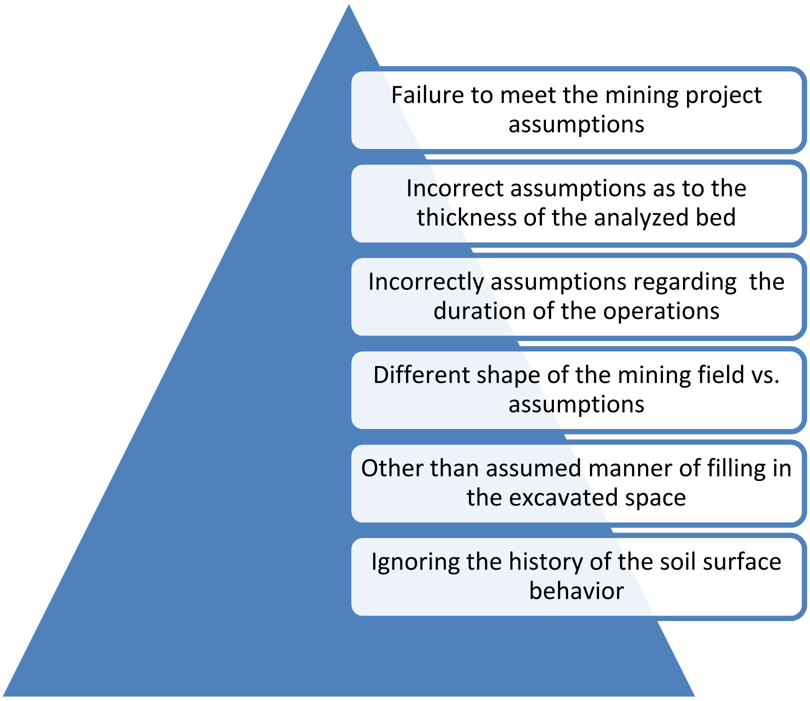

Figure 3. The underlying reasons for the variance between the forecast and later measurements of the deformation factors results

The comparative analyses carried out prove the shape and size of the mining field as originally designed do not differ from the map of the bed used for stocktaking of the completed operations, a highly dubious fact. The analyzed walls were mined with roof supports to the approved mining layer height and with roof cave-in. The operating factors used for the forecast are compatible with the current theory of how deformations develop; however, it does not serve the deformation analysis of the entire area, including several beds which have been mined multiple times before. The analyzed studies generated mining forecast parameters showing errors of 38.07% to 64.85% when compared to the actual data.

The errors found in calculation models result from an inadequate model used to predict the actual results. Random factors attributable to deformation indicators distributed around the average forecast value should be taken into account in forecasting procedures. Our own investigations [5], [11], [15], [16], [17] show there are variances between estimated calculations and later measurements which may even be higher by the value of a single standard variation with a 70% probability. Unfortunately, no such values were obtained in any of the lawsuits we analyzed.

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Factors affecting the subject of this paper have been selected by means of logical reasoning based on observations of other similar actual processes and the knowledge of their construction, mining, legal, and financial interpretation. Special consideration should be given to the relationships between the analyzed events and the respective indicators which may differ in their extent and complexity.

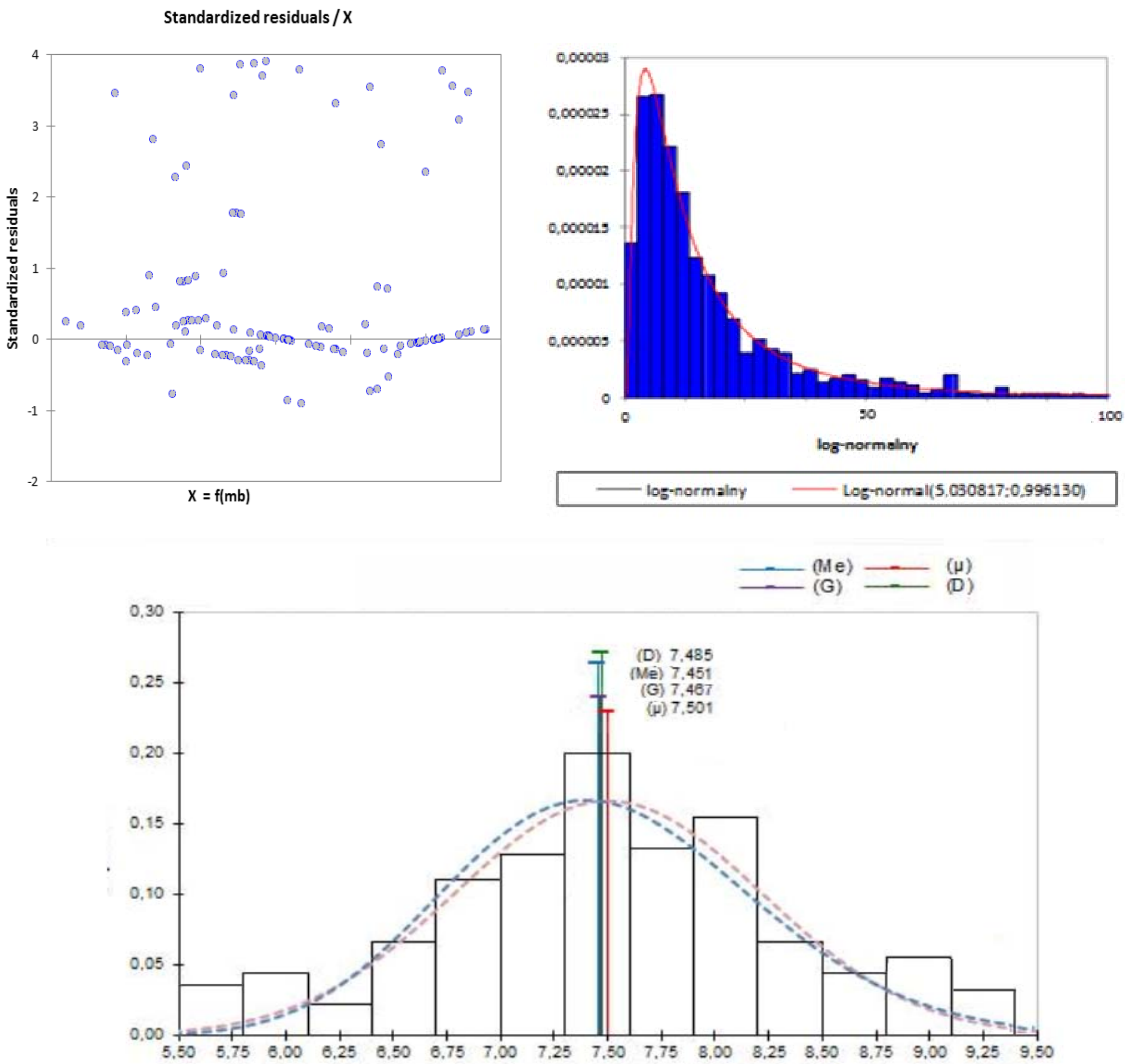

Figure 4 a), b), c) Statistical analysis – model for operations impact on urban sites, according to the local urban development plan and the distribution of one modal asymmetrical with the dominant for the aspect of the predictions for the local urban development plan;

The basic factors selected and examined for our analysis include: serviceability limit state, ultimate limit state of subsoil on area to allocate in the local urban development plans as a residential, homes and commercial areas without mining impacts and with this impacts, and of of course the effect on geotechnical parameters of the subsoil which interacts with the existing structures and buildings erected of the analyzed engineering structure. Calculating the extent to which such individual factors affect the standard deviation obtained by means of the comparative analysis is mostly, a question of individual preference.

Depending on how the effect of such factors on the overall variation is calculated, there are a number of detailed cause-effect analysis methods to be used, i.e. the iterative method, the method of chains substitution , or the differentiation method. The cause and effect diagram proves a good tool for the analysis since it helps separate the cause from the effects and appreciate the complexity of the analyzed problem.

The soil medium is difficult to define due to compound effects of its plasticity, anisotropy, and physical nonlinearity. Unfortunately, earlier and simpler soil models do not meet the computational requirements presented by much more complex interactions between the soil and, for example, a higher number of engineering structures located in the analyzed area, or the type, extent, and frequency of mining interactions, or even from the soil 'memory', etc. Groups of models, such as elastic-perfectly-plastic, elastoplastic with isotropic amplification (including critical state soil models and "cap" type models) or kinematic amplification, are currently utilized for simulating soil interactions. The models have been discussed in a number of publications [4], [5], [6], [10], [11], [12] in professional reviews [1], [2], [3], [8], [9], [18], [19]. The models are typically built into geotechnical computer software used for numerical analyses of soil-structure interactions (ABAQUS, PLAXIS, ZSOIL). The details of creating computational models will be described and analyzed in another publication, later this year.

5. Conclusions

The results of our analyses conclusively show that had the area been clearly marked in the local urban development plant as an active mining area, the design and structure of the building would have included special structural safeguards to protect against mining interactions and – most likely – the analyzed damage would have assumed a different scale and extent. The analyzed building had been erected according to standards suitable for stable soil conditions – geotechnical category I or II; thus, it was not designed to withstand active mining interactions.

The forecast error scale, of prognosis of mining influence for the local urban development plans, is directly proportional to the type, quantity and quality of the inputs. Mining impact calculations will be reliable if they are accurate; however, there is no clear definition for such forecast quality. It would be a mistake to assume forecasts are 100% reliable and that if the mining forecast excludes any chance of mining damage occurring, the damage will surely not occur. Furthermore, forecasting a higher value, with room to spare, is also incorrect.

An indisputable proof of this are true cases of damage on analysis properties with damage from influence, which should never be in this area – due to the above-mentioned regulation in the local urban development plans.

The engineering, construction, and geotechnical aspects of the analysis take into account the impact of mining interactions on the structural damage suffered by the analyzed buildings and structures. An opinion rendered based on such analyses should reflect all the relevant findings. In the event that the rendered opinion differs from the initial analysis, however, the underlying reasons for errors must be investigated. Once the assumptions made for every solution have been examined, i.e. comparing inputs to outputs by using the back analysis, the source of errors must be identified and the data adjusted accordingly. In the course of our investigation the method for calculating the estimated surface deformation values should be changed to reflect the incorporation of the diffusion phenomena. The diffusion phenomena are mainly used by experts in the process of approving mining operations; such approach takes into consideration building strain effects for medium forecast values including diffusion. The method must be adapted since previously applied data may no longer prove adequate and conform to such highly modified soils. This approach will allow for the correct approach to creating entries in the local urban development plan. and give the possibility to correct design design for the adverse impact which may arise in the area of the project. Structure plans must be the best way to promote a better understanding of the inter-relatedness of issues and proposed management approaches to be used in a particular area. structure plan may be implemented through regulatory and non-regulatory methods, or both. Non-regulatory approaches offer greater flexibility and adaptability to changing needs, mainly for the delivery of projects of buildings with protection against all potential threats of analysis areas.

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