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TECHNICAL CONSEQUENCES OF MINING IN SAARLAND, GERMANY

Doctoral dissertation– Excerpt

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The doctoral dissertation aims to study the influence of mining on the construction works situated in its vicinity. It responds to the fundamental question, namely, whether the works of mine are responsible for producing damage to buildings, and if so, how high is the financial responsibility, in this case of Ruhrkohle AG-RAG AG company.
At first, the particularities of the building which represents the studied objective are taken into consideration, namely its geometric dimensions, number of levels, its shape in horizontal projection, type of the foundation, location towards the mine, construction's structural system, the presence of stiffeners (Consolidation) or reinforcements, the building's history including the year of execution and previous seismic movements due to mining which have affected the building. For each answer, points are given which shall be aggregated and, depending on the amount it determines a maximum vibration speed-permissible construction. It is recognized that the foundations have vibrations with frequencies between 1 and 10Hz.
Based on measurements made in different areas in the vicinity of mining exploitation, the speed of vibration can be appreciated in the building area. If the effective vibration velocity is higher than the admissible one then the damage is due to mining exploitation, otherwise not.
The conclusions and rehabilitation recommendations provided in the 300 technical expertise carried out by the author in the mining area Saar, Germany, have been accepted without discussion by both sides in the dispute, on one hand the mining concern RAG responsible for the damages and the injured part, owners of real estate, which denotes the objectivity of the method used, taking into account the intensity and stakes disputes on this subject.
In order to determine the actual damage produced to the buildings, a practical methodology, based on measurements of the possible buildings' inclinations or displacements greater than the tolerances, either on the size of the cracks in the structure of the resistance, has been developed. Practical solutions are proposed to strengthen resistance structure, the condition being long-lasting stability and resilience of the building as well as low cost as possible.
Whereas damages produced by mining in the Saar area were very numerous and intense, the author analyses and recommends operational methodologies, i.e. making underground explosions, such as cumulative effects should be minimized.
The author simulates using the Finite Element Method a real building that underwent a drastic yielding under one of the corner strength pillars, and the virtual results were compared with in SITU measurements. Good concordance of theoretical results with those determined on field show the righteousness of the considered hypothesis.

CHAPTER 1, entitled **"INTRODUCTION"**, deals with the history of mining from the Saar mining region, Germany and emphasises the importance and topicality of the theme being studied.
The earliest documentation of mining exploitation from Saarland, near Neunkirchen, dates back to 1429. Of the 26 existing mines in the Saarland (mines Viktoria, Franziska, Heinitz, Kohlwald), only Duhamel

mine remained open until 30.06.2012 in Ensdorf. All mines in the Saarland were united with each other, which represented a major advantage for the safety of the operation. Mines in the Saarland reach depths of 2200m being considered the deepest in Europe.
The law governing both mining activity and damage and consequences in Germany is the federal mining law with Prussian origins from 1865 and German origins from 1934.
Chapter 1 also contains the subject-matter and the structure of the doctoral dissertation.

CHAPTER 2, entitled **"BEARING CAPACITY OF FOUNDATION SOIL"**, presents in detail the types of foundations which are used in engineering practice: surface foundations, precast and depth foundations.
In addition, a distinction is drawn between bearing and not bearing foundation soils.

CHAPTER 3, entitled **"THE EFFECTS OF UNDERGROUND MINING ON THE CONSTRUCTIONS"**, describes theoretical and practical aspects related to early warning systems implemented in the studied area, Saar. According to German standard DIN 45669-1 the three spatial components of vibration speed are measured using sensors based equipment. Additional, optical and acoustic sensors can be used if limit values are exceeded.
Allowable value of vibration is differentiated according to its influence people, as follows:

a) Frequency range between 1Hz and 80Hz and, in part, up to 315Hz;
b) Minor frequencies up to 5,6Hz;
c) An average appreciation for each interval of 0,125s;
d) Determining the maximum value in an interval of 30s;
e) Appreciation taking into account the date of the shock – day, night, rest period.

The shocks signal shall is interpreted according to a differential system according to DIN 4150 part 2. The maximum component of velocity is compared to a permissible value specified in standards.
DIN 4150, part 3 norm makes the difference between short-and long-term actions, where they can appear and resonant effects, particularly dangerous for the resistance structure. The maximum values are, however, crucial at the foundations and superior floor level. The measured values are compared to those admitted by DIN 4150, part 3. For residential buildings shall be considered, for example, the allowable values of the vibration speed of 5mm/s at frequencies between 1 and 10Hz and 15mm/s at a frequency of 50Hz. For floor vibration analysis, limit values measured in the centre of the floor of 20mm/s are given. For duration vibrations, limit values for the upper floor of 5mm/s for maximum horizontal displacement and 10mm/s for the vertical component are indicated. Impact on humans is measured where the strongest vibration in the measurement space has been produced. In case of vertical component, this place will be, as a rule, the middle of the floor. Measurement time will depend on the vibration (hour, duration, frequency, regularity). If necessary, a location for measurements over time can be installed.
In the final part of the chapter, controlled explosions seismology in the mining industry is detailed.

In **CHAPTER 4** entitled **"DAMAGE CAUSED BY MINING ACTIVITIES – THE DEGREE OF DAMAGE"**, the author deals with a number of issues related to mining damage: ground damage, causes of subsidence, liquefaction of the earth during the vibration produced by earthquakes, changes that may occur to buildings and foundations and general calculus considerations by describing Bousinesq Winkler, and Flemish model calculations.
The last chapter presents a classification of stabilization methods of existing buildings in the study area. They aim at preserving buildings' bearing capacity. Temporary measures, such as supporting allegations or lasting solution, for example with hydraulic balancing bracing can be distinguished. At the same time the foundation soil can be improved by injecting cement milk, limestone etc., compacting of the ground or filling the underground empty spaces.
Measures for the conservation and consolidation depend upon the movements of the structure, vertical or horizontal displacements, and consolidation measures are carried out on an existing structure or

outside its area of influence. In the case of a strong subsidence of the soil, inside hydraulic presses are used, compression, or elastic fastening systems workload, and, in the case of differential subsidence of the land, stiffener in the resistance structure. Outside the area of influence, the rehabilitation is done by lifting the construction and applying land pressure injections.

Preventive measures relate to the necessary permits in the areas of mining in which the State Inspectorate in Constructions requires further steps to strengthen the achievement of new buildings, for example concrete slabs at the base or the upper belts of reinforced concrete wall, additional costs being subsidised by the mining enterprise.

Another important issue is prevention of the pollution of groundwater due to mining exploitation. For this purpose the phreatic water level is decreased with the aid of special pumps thus the mine water do not reach come into contact with groundwater.

Unused galleries are completed with construction material and through vertical shafts, water is inserted in a controlled manner to form a resistant material.

CHAPTER 5, entitled **"VIBRATION-INFLUENCE ON PEOPLE AND BUILDINGS"**, includes elements relating to the loss of the bearing capacity of structures, with an emphasis on strengthening methods, respectively safety measures.

Mining safety from the technical point of view includes checking the level of groundwater and ensuring the galleries.

CHAPTER 6, entitled **"MONITORING OF CONSTRUCTION DEFORMATION PROCESSES"**, includes description of both classic processes (connecting vessels and improved methods), and modern technologies used in Germany for the determination and representation of objectives deformations.

Verification of possible displacements or subsidence phenomena which have affected special constructions such as power plants, bridges, churches, dams is done using a sensors-based early warning system. This very simple and verified in practice system refers to measurement systems based on communicating vessels combined with pressure sensors and computer controls. Visualisation of the results obtained is done using a specialized program, Vibrosoft.

The final part of the chapter comprises in the description of maximum vibration speeds used in Germany for vibrations measurement according to DIN 4150 (Vibrations in constructions) norm.

CHAPTER 7, entitled **"DOCUMENTATION AND REGULATORY DAMAGES"**, addresses the mode of damage regulatory from mining activities. Registering the damage is realized by following strict principles laid down by the BbergG-Bergbauschädengestz-Law of mining damage, ranging from damage registration until full rehabilitation of the building or financial compensation for the damage.

Damage can be classified on the basis of the information obtained on the spot and their registration. Classification of construction in terms of sensitivity to vibration due to mining events allows a comparison with other structures.

According to the Pohl method/Ph.D. Pohl/points are given dependent on certain building parameters:

- building dimensions e.g. length and number of floors – maximum 20 points can be given. Then the arrangement of the adjacent buildings is appreciated, with points from 0 to 10;
- shape of the foundation systems and location of the neighbouring mine – at the same level with the basement, different levels or partially with cellars etc. Points are given from 0 to 8;
- resistance structure and type of floors:
    - resistance structure can be rigid – 0 points,
    - less rigid, e.g. brick constructions with wooden floors – 6 points,
    - not rigid, e.g. wood lattice or totally wood – 12 points;
    - existence of bracing systems;
- technical condition of the building – history and previous deterioration of the building are taken into consideration.

The points assigned add up and then the building is classified into one of four classes I...IV depending on the score obtained; the permissible vibration speed is also indicated. If the effective speed due to a mining event is over the permitted speed then the cause of the destruction is due to mining exploitation.

In **CHAPTER 8**, entitled **"TECHNICAL CONSIDERATIONS REGARDING BUILDINGS' DESTRUCTION"**, practical examples of destructions and means of building enhancing are dealt with, respectively financial appreciation rewards to the beneficiaries. Age of the construction and eventual execution errors that may enhance susceptibility to shocks due to mining exploitation are also considered. The author has conducted approximately 300 expertise related to buildings destruction as a result of mining exploitations. The "Marienkirche 14 Year" building affected by the mining operation from Westfeld is analysed in this chapter. As consolidation solution lifting of the building was chosen because of the construction tilt.

In **CHAPTER 9**, entitled **"NUMERICAL SIMULATION USING FINITE ELEMENT METHOD (FEM)-MEF"**, a case study is presented, starting with the degradations suffered by a building, based on three action assumptions, the building subjected to mining influences is simulated using Finite Element Method special calculus software used in engineering offices from Germany, namely ANSYS-FEM.
First calculation hypothesis considers a reinforced concrete foundation type resting on a cushion of ballast bed with coefficient of 0,15N/mm^3 with a constant uniform distribution. Loading hypothesis is the action of its own weight.
Second calculation hypothesis refers to a reinforced concrete foundation type resting on a cushion of ballast bed with coefficient of 0,15N/mm^3 that has an uneven distribution, on 90% of the foundation's surface, and on 10% coefficient is 0,01N/mm^3. Loading hypothesis is the action of its own weight.
Calculation assumption 3 studies a reinforced concrete foundation type resting on a cushion of ballast bed with coefficient of 0,15N/mm^3 that has an uneven distribution, on 90% of the foundation's surface, the rest of the surface presenting a continuous settlement of maximum 40mm at corners.
In the case of each hypothesis vertical settlements of the foundation are shown.

CHAPTER 10, entitled **"ECONOMIC ASPECTS"**, describes the preventive financial measures for mining damages caused in the study area chosen by the author, Saarland, Germany.
According to DIN 4150-3 buildings are divided into three categories:

1. Residential buildings for which the vibration speed is 5mm/s;
2. Historical monument buildings – 3mm/s;
3. Industrial buildings – 20mm/s.

RAG Corporation has provided funds for all possible situations that may arise after finalizing the mining exploitation. For example, in 2011, the amount of compensation has raised to 3.26 billion euros. However, prolonged costs related to maintenance and cleaning water, lasting damage to buildings, personnel costs, pensions etc. may appear.

CHAPTER 11, entitled **"TECHNICAL SURVEYS CARRIED OUT IN SAARLAND"**, covers two study cases conducted by the author, a residential building and fire hall with additional buildings. A classification of these buildings with respect to sensitivity in relation to vibration/ ground movements due to mining activity is made, then the damage sustained by each of them is determined in accordance with the principles described in the previous chapter (10).

CHAPTER 12, entitled **"CONCLUSIONS AND PERSONAL CONTRIBUTIONS"**, presents the findings of the study conducted by the author and personal contributions relating to mining that produce strong vibrations and shocks with negative effects upon neighbouring buildings.
Personal contributions brought by Mr. eng. Lothar Becker-Daugherty to actual research in this area can be summarized as follows:

- German rules inventorying of the laws and normatives which set the framework of mining activities.
- Realizing measurements on 23.02.2008 at a building in Rotwäldchen 2 in order to determine the causes of the damage. Seismic wave velocity as a result of a mining event was 40mm/s,

the admitted one being 12mm/s. On this basis the cause of the impact was determined and the mining enterprise has paid compensation in order to repair the shattered building;

- Popularization of designing a Rissbreitmesser-template for measuring cracks;
- Creating a methodology for measuring construction's tilt as a result of execution errors correlated with not framing into the allowed tolerances (e.g. a tilt of 3.65%);
- Materialization of a measurement system based on communicating vessels and pressure sensors.
- Proper technological developments L. Becker, Sb.
- Realizing of approximately 300 expertise concerning damages buildings as a result of underground mining in the Saarland area, Germany.
- FEM (Finite Element Method) simulation of a concrete building subjected to uneven settlements due to mining exploitation, the results obtained being very close to in situ measurements.
- The conclusions and rehabilitation recommendations set out in more than 300 technical expertise carried out by the author in the mining area Saar, Germany, were accepted without discussion by both sides in the dispute, on the one hand the mining concern RAG responsible for the damages, and on the other hand, the prejudiced buildings' owners, which denotes the objectivity of the method used, taking into account the intensity and stakes on this subject.
- In order to determine the actual damage produced to the buildings, a practical methodology, based on measurements of the possible buildings' inclinations or displacements greater than the tolerances, either on the size of the cracks in the structure of the resistance, has been developed. Practical solutions are proposed to strengthen resistance structure, the condition being long-lasting stability and resilience of the building as well as low cost as possible.

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