THE ANALYSIS OF BUILDING OBJECTS INCLINATION CAUSED BY UNDERGROUND MINING EXTRACTION

ANALÝZA NÁKLONU STAVEBNÍCH OBJEKTŮ VYVOLANÉHO PODDOLOVÁNÍM

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Abstract

In mining areas, the protection of large buildings against mining damages is very often done by dividing them into smaller segments with some empty spaces left between them – expansion gaps. During mining extraction influences occurrence, such objects are more flexible. But it is necessary to ensure proper working conditions for expansion gaps – the neighbouring building segments should never be in contact. It is of special attention in case of higher objects, where small terrain tilt connected with compressive strain and concave curvature can cause object inclination that causes significant construction movement at the roof level. One can predict the behaviour of such buildings exposed to underground mining influences in the shape of subsidence, curvature, tilt and horizontal strain, so it can help in protection actions against possible mining damages. In the presented paper, the example of complex analysis of prognosticated building inclination has been described.

Abstrakt

V oblastech, kde probíhá těžba, se často ochrana velkých budov proti účinkům poškození vlivem dolování dělá tak, že budovy se rozdělí do malých segmentů, které mají ponechány mezi sebou prázdné prostory, nazvané expanzní dutiny. Takové objekty jsou pružnější při působení vlivu podzemní těžby. Je ale třeba zajistit řádné pracovní podmínky pro ony expanzní dutiny, a to tak, že sousední segmenty budov by nikdy neměly být ve vzájemném kontaktu. Zvláštní pozornost je třeba věnovat vysokým objektům, kdy malý náklon terénu spojený s tlakovým působením a konkávní křivostí může vyvolat naklánění objektu, což má za následek významný pohyb v konstrukci střechy. Lze tedy odhadnout chování takových budov vystavených vlivům podzemní těžby, jako jsou způsob poklesu, křivost, náklon a horizontální tlaky, což může pomoci ochraně budov proti možnému poškození. Tato práce popisuje příklad komplexní analýzy týkající se prognózování náklonu budovy.

Keywords

underground mining influences, geometric-integral theories, building expansion gap deformations

Klíčová slova

vlivy podzemního dolování, geometricko-integrální teorie, deformace budov vlivem šíření podzemního propadání

1 Introduction

Underground extraction of hard coal in the Upper Silesian Basin has been led under high urbanized areas. This fact causes many problems with possible mining damages to the buildings, especially those built with rigid construction. One of possible solution to this problem is the division of big rigid object into smaller independent parts by using expansion gaps. The main task of expansion gap is to isolate neighbouring segments in such way, when during mining deformation occurrence at the building location, should not be any direct contact between them. Of special importance is a proper design of building – the length of segment for rigid building should not exceed 36 m in the areas with mining influences up to II category of mining influences (horizontal strain ε<3 ‰, terrain tilt T<5 ‰, terrain curvature radius R>12 km). When mining influences exceed II category of mining influences, the maximum segment length should be at most 30 m. The width of expansion gap **s** depends mainly on the prognosticated terrain curvature $\mathbf{R_{min}}$ and horizontal strain $\boldsymbol{\varepsilon_{max}}$, as well as building height **H** and segments length $\mathbf{L_1}$, $\mathbf{L_2}$ and could be calculated by the following formula:

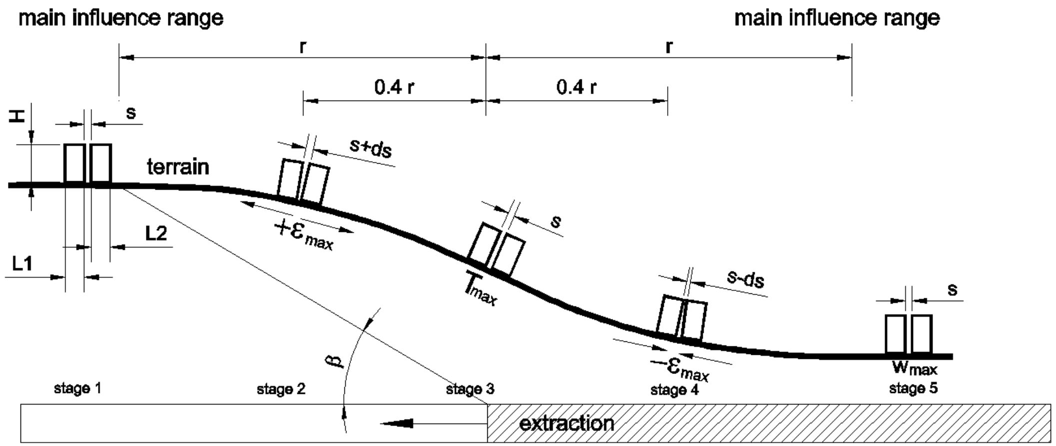


Fig.1 the phases of the expansion gap behaviour under mining influences

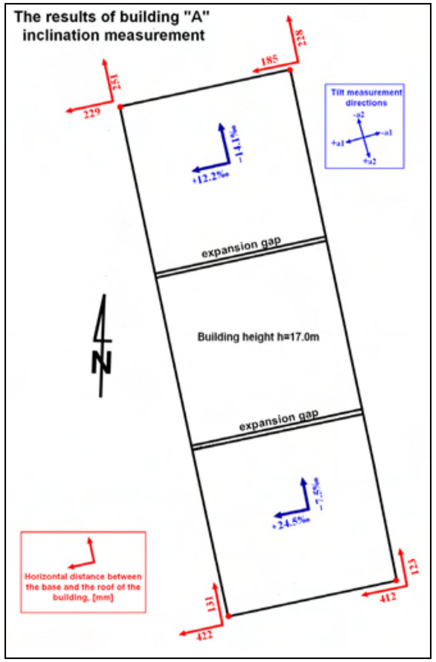
$$s = \left(\varepsilon_{\max} + \frac{H}{R_{\min}} \right) \cdot \frac{L_1 + L_2}{2} \tag{1}$$

During extraction led directly under building constructed with expansion gaps, one can distinguish the following stages of their deformation - fig.1 (after Kawulok 2010):

- **stage 1** – building is out of influence range. The width of expansion gap is in its initial distance **s**;
- **stage 2** – approaching extraction edge causes maximum horizontal tensile strain $\mathbf{+\varepsilon_{max}}$. The expansion gap increases its width and reaches maximum value **s+ds**, when extraction edge takes the position approx. 0.4 of the main influence range **r** in front of the considered gap;
- **stage 3** – the extraction edge is located directly under expansion gap. The gap width goes back to the initial distance **s**. There is maximum terrain tilt $\mathbf{T_{max}}$ at this stage;
- **stage 4** – extraction edge passes the gap and terrain goes into compressive deformation phase with maximum compressive strain $\mathbf{-\varepsilon_{max}}$. The gap width decreases as extraction goes further and reaches minimum value **s-ds**, when extraction edge takes the position approx. 0.4 of the main influence range **r** behind considered gap;

- **stage 5** – extraction edge moves further behind the gap, so it goes out of influence range. The expansion gap width should go back to the initial distance **s**.

a)



b)

Fig.2 The photograph of building "A" (left) and the state of its present inclination (right)

A complete analysis necessary to describe the behaviour of building exposed to underground mining influences should consist of several stages, which one can divide into two main components :

- **Documentation of previous deformation state** caused by finished extraction. Usually it is done by employing geodetic measurements of terrain subsidence and building inclination due to irregular subsidence. In special cases there are strain measurements of building construction elements carried out. But for high or long buildings equipped with expansion gaps, their inclination is of special attention. In such cases it is possible to measure the width of expansion gaps between adjoining building segments.
- **Forecasting of deformation state** necessary to accomplish the knowledge of future construction behaviour. In cases of long buildings it helps to estimate the working conditions of expansion gaps, especially when measured up-to-date gap width is at one's disposal. The forecast can be done in two directions :
    - estimation of changes in deformation indices values for terrain surrounding the building. Modern prognostic software in the field of forecasting of underground mining influences enables preparation of "step-by-step" prognoses (for specific states of planned

extraction) and present the results as contour maps of subsidence, tilt and strain distribution as well as tilt vector field for considered area. The example of such interpretation is shown in the next point of this paper;

- detailed forecast of chosen deformation indices changes over time for single calculating points located on the building ground plan. This procedure can be executed with special functions of prognostic software – simulation of extraction development. If there are up-to-date survey data available, one can use them for adjusting forecast results – in this case it is possible to determine the "close-to-real" future changes of building construction inclination.

2 The present state of chosen building in the light of measurements

The considered in the paper objects there are 5-storey blocks of flats with horizontal dimensions 72 x 11m. Every building is divided into 3 segments with expansion gaps that serve as the protection against mining damages. The photograph of one exemplary building "A" is shown in fig.2a. There are geodesic measurements led in this area aiming at registration of mining influences. The results of present inclination state for outer segments of building "A" are shown in fig.2b with blue vectors and values. As the last measurement shows, the building is inclined in the NW direction due to the past mining activity. North segment has the resultant inclination of 18.6 ‰, south segment 25.6 ‰. In fig.2b red vectors and values show the horizontal difference in [mm] between coordinates of building corners at the ground and the roof level.

3 The forecast of underground mining influences

In the vicinity of the considered buildings there is underground extraction planned of 3 long walls positioned in two coal seams: 501 and 510 at the depth in the range of 550-600m.

Basic mining data is presented in table 1. For minimization of influences at

Tab.1

Seam No	Longwall No	Start date	Finish date	Seam thickness [m]	Angle of dip [deg]	Depth [m]	Roof controlling
501/1	3	01-01-2017	30-06-2017	3.0	4	564	stowing
501/2	3a	01-01-2018	30-06-2018	2.0	4	561	stowing
510/2	232	01-01-2014	31-12-2014	2.6	4	568	stowing

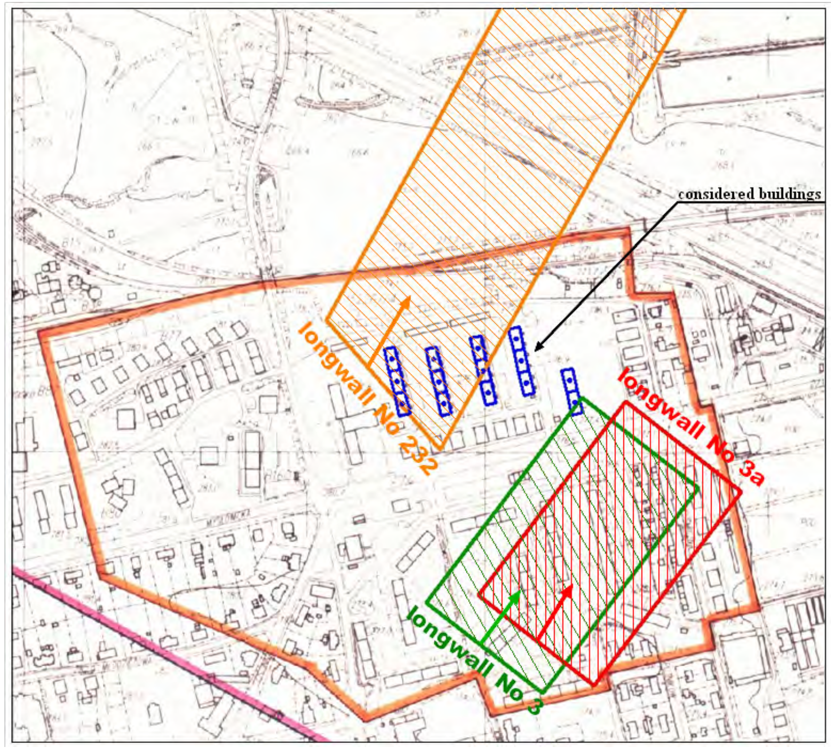


Fig.3 Location of planned extraction against considered buildings

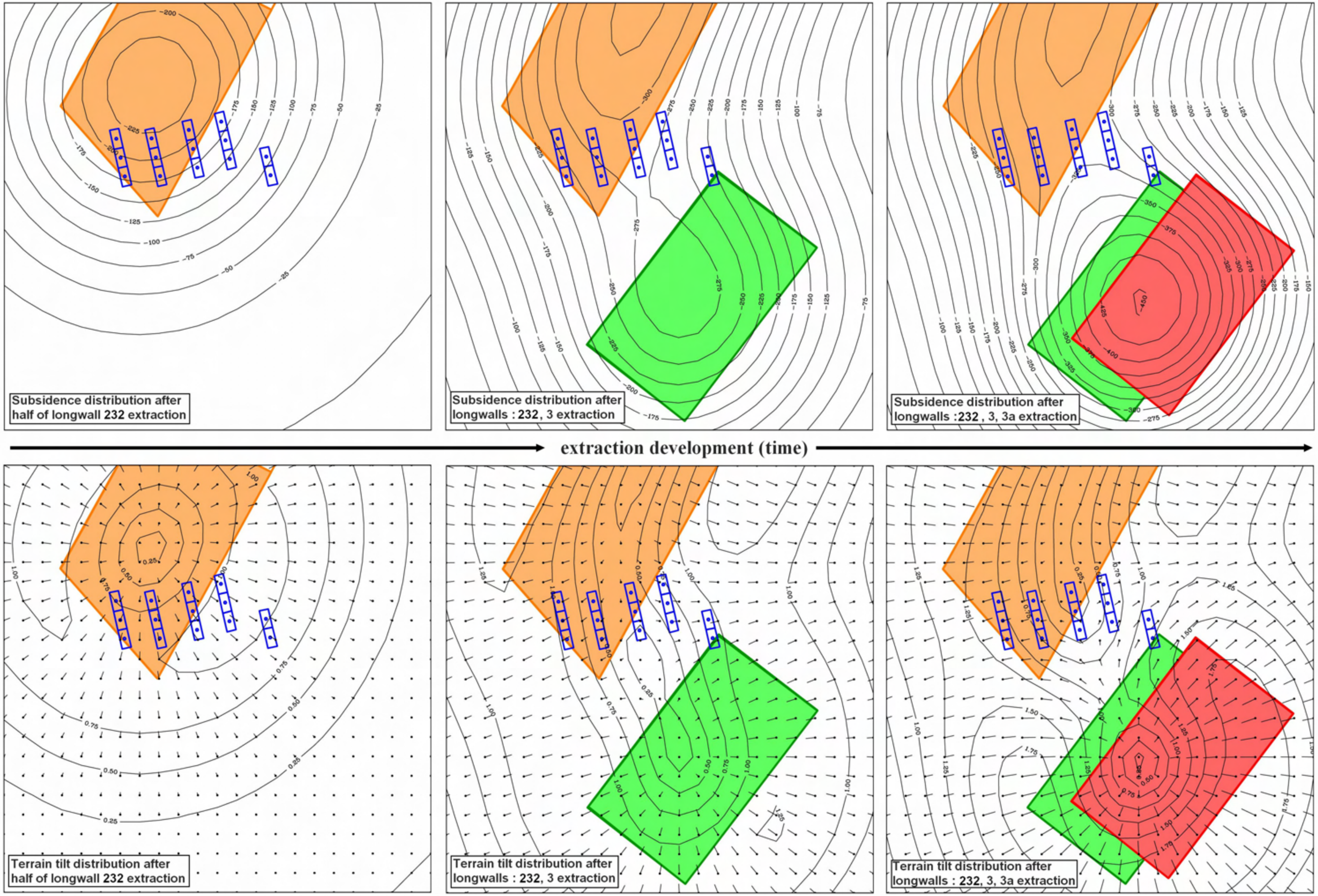


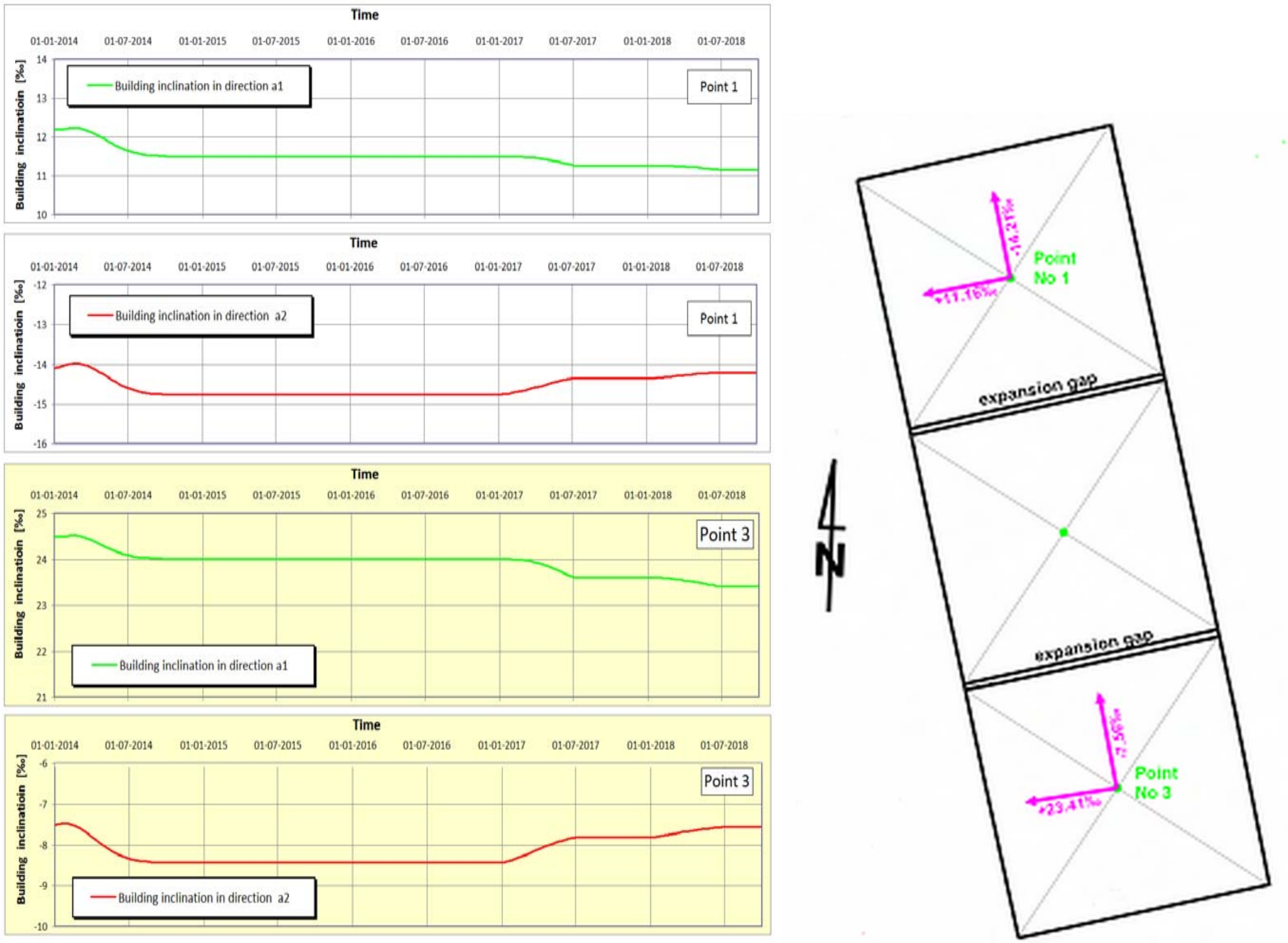
Fig.4 The development of subsidence [mm] and tilt [‰] due to designed extraction in the vicinity of considered objects

the surface, the extraction is planned with stowing. Location of buildings against mining works is presented in fig.3.

The prognostic calculations where done by using W.Budryk-S.Knothe theory (Knothe 1953), implemented into software named DEFK - Win, worked out by the author (Ścigała 2003, 2008). This software enables multivariate forecasts for asymptotic or instantaneous state of deformation with employing simulation of extraction advance in time and space coordinates.

As it was stated in the introduction, calculations were led in two directions:

- for terrain around buildings there were calculations done for several stages of extraction edge positions. On the basis of these calculations maps were worked out with the distribution of subsidence, tilt and horizontal strain – fig.4.
- for precise locations of each building there was computer simulation of extraction advance done. Thanks to that it was



a) *b)*

Fig.5. The results of predicted inclination changes over time for two outer segments of building "A" – figure a) and final state of inclination (after extraction finishing – figure b))

possible to show the predicted changes over time of chosen deformations indices. Taking into account that there are survey results at one's disposal, it is possible to "accumulate" them with forecast, having in this way as accurate as possible future changes of construction deformation state.

- This procedure is especially dedicated to the building inclination, assuming that predicted terrain tilt is calculated along the same directions as measured – fig.5.

4 Conclusions

Polish black-coal mining industry in the Upper Silesian Basin operates under high urbanized areas. So it is of special attention to ensure proper safety conditions for building constructions during underground mining. There are many important issues necessary to be taken into account during designing of underground mining. One of the important problems is the determination of long and high building behaviour exposed to variable profile of subsidence trough, with special attention paid to proper working conditions of expansion gaps. The exemplary analysis of building inclination changes due to mining extraction development has been shown. The analysis bases on the distribution over time of subsidence, tilt and horizontal strain. Together with up-to-date measurement results one can predict the behaviour of the whole building as well as individual expansion gaps. Author's own software used in this example makes possible to consider complicated mining extraction cases and calculate required deformation indices for any number of calculation points (buildings) in a relative simple way.

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