Mining exploitation forecasted effects caused by a hard coal extraction from a thick seam

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Abstract. Paper describes an example of underground mining exploitation which in a thick seam divided into a few layers has been conducted. It took place in the years 2013 – 2018 in the southern part of Poland, in the Upper Silesian Coal Basin and was carried out by the use of four, high longwalls with a roof rocks cave-in. In article a reprognosis of the mining exploitation impacts on a terrain surface has been done. For this purpose the EDN – OPN computer program was used. Extraction influences by the use of the Bialek's formula for subsidence have been predicted. There the subsidence, inclinations and horizontal strains after the end of every exploitation stage have been calculated. Thanks to that it is possible to determine the expected range and size of exploitation impacts on a terrain surface and the objects located on it.

1. Introduction

Mining exploitation of hard coal seams can wield a negative influence on environment and creatures living in it. It can cause changes in:

− a landscape by formation of dumping grounds and building of mine infrastructure objects;
− a landform by subsidence process of terrain surface and continuous deformations related to it [1-4];
− the water conditions by dehydration of rock mass and formation of new water reservoirs on land surface;
− a land surface development due to change of terrain meaning;
− a technical and road infrastructure because of so called mining damages;
− a location of outbuildings and residential buildings (declination in horizontal plane and deviation from vertical [5-11])

and in many other aspects.

Underground extraction effects can be different on land surface and in objects, and they depend on:

− a kind of useful ores;
− an exploitation system;
− a fulfillment way of resultant emptiness;
− the geological conditions of exploitation (e.g. depth, declination, disappearance of deposit, faults);
− a shape and the dimensions of excavations (especially their height);
− an earlier extraction.

Thickness of deposit (height of mining excavation) has a significant influence on size of terrain and buildings deformations which can cause the great damages. This is a reason why in the article an instance of exploitation of hard coal seam, which is characterized by a large thickness, has been presented. It has been shown what can be consequences of mining operation conducted in the seam divided into several layers.

2. Mining exploitation and land development characteristics

2.1. Mining exploitation

Exploitation of the 404 hard coal seam took place in Poland, in the Upper Silesian Coal Basin. It was conducted in the years of 2013 ÷ 2018, in two seam layers, namely in the 3rd and 5th layers. There was used a longwall system with roof rocks cave-in.

Exploitation of the 404/3 seam was carried out by use of the 1/II and 2/II longwalls. Height of these excavations was substantial and equal to 4.0 m (the 1/II longwall), 3.4 m (the 2/II longwall). Exploitation depth was from 410 m (on the east) to 575 m (on the west). Decline was large and amounted 17° in the north-western direction. Exploitation in the 1/II longwall was carried out from May to December 2013. Exploitation of the 2/II longwall was conducted from August 2016 to February 2017.

Extraction of hard coal from the 404/5 seam took place from November 2015 to June 2016 (the 1/II longwall) and from October 2017 to April 2018 (the 2/II longwall). Height of the longwalls was respectively amounted 3.3 m and 3.5 m. Depth of exploitation was amounted 470 m for the 1/II longwall and 550 m for the 2/II longwall. Declination of the 404/5 hard coal seam was substantial and amounted around 19°.

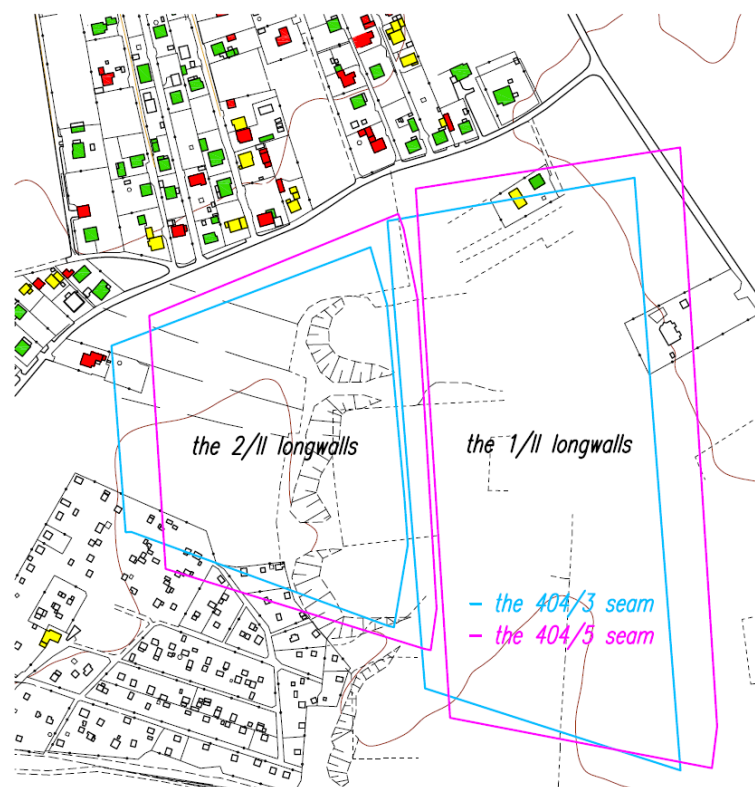The basic information about extraction of hard coal from the 404 seam in the Table 1 have been shown.

Figure 1. Excavations in the 404 hard coal seam and a land surface development

Table 1. Exploitation of the 404 hard coal seam in the years 2013 – 2018

Parameter	the 404/3 seam		the 404/5 seam	
Longwall number	1/II	2/II	1/II	2/II
Run [m]	460	245	500	300
Length [m]	220	243	230	233
Height [m]	4.0	3.4	3.3	3.5
Declination [°]	18.8	15.8	16.9	21.1
Depth [m]	410÷500	500÷575	430÷510	500÷600
Time	05.2013÷12.2013	08.2016÷02.2017	11.2015÷06.2016	10.2017÷04.2018

2.2. Land surface development
Analyzed area is located on lowland. Land surface has an average, absolute altitude of 265 m. Escarpments are localized in an area middle part, above the 2/II longwalls (Figure 1). In an area eastern part are meadows, fields and pastures, in a southwestern part of region – allotments and in a region northern part – outbuildings and residential, single-family buildings.

Most of buildings has two storeys and load-bearing construction which resists on the walls. Buildings are resistant to impacts of underground mining exploitation and have some resistance categories what at Figure 1 can be seen. Buildings, which have the 2nd resistance category, by use of yellow colour have been marked. The 3rd resistance category by use of red colour has been shown. Green colour represents the 4th resistance category.

3. Influences reforecasts
As has been said at the beginning, reforecasts of the subsidence, inclinations and horizontal strains values after termination of exploitation of each longwall have been done. There the extreme values of continuous deformations indicators have been calculated.

Reforecasts by use of the *EDN-OPN* computer program have been done (the *EDBJ2* module). It the Bialek's formula has been applied. This formula takes into account:
− the far impacts;
− an operating periphery;
− a reactivation of old goafs;
− a desymmetrization of subsidence trough profile above the exploitation edges;
− the influences coming from a few seams.
There the following values of formula parameters have been assumed:
− an operation coefficient (a coefficient of roof rocks subsidence): $a = 0.9$;
− a tangent of the β angle which corresponds the range of main impacts: $tg\beta = 2.0$;
− a parameter of operating periphery: $A_1 = 0.15$;
− the Awierszyn's proportionality coefficient (for the horizontal strains): $B/r = 0.32$ [m];
− a coefficient of influences deviation (deviation due to a seams declination): $k = 0.7$;
− the coefficients of subsidence velocity: $C_1 \cdot r = 1400$ [m/year] and $C_2 = 6$ [1/year];
− a time and a coefficient of relaxation: $T_{rel} = 2.5$ and $A_{rel} = 0.4$.
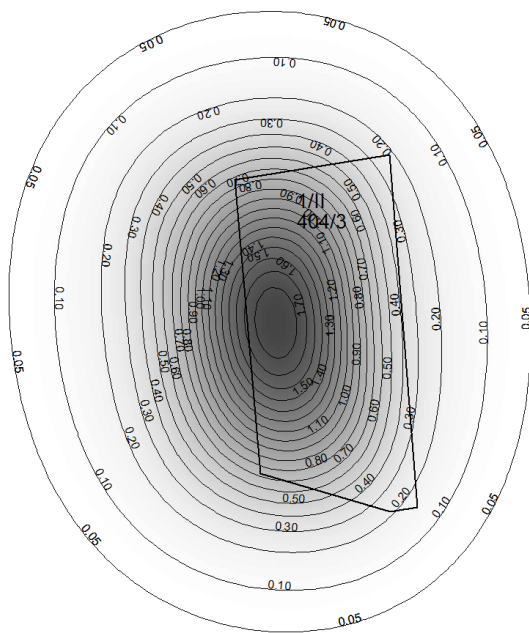
3.1. Reprognosis of subsidence
Results of made reforecasts (Figure 2a and Table 2) show that after the end of exploitation of the 1/II longwall in the 404/3 coal seam, maximum value of subsidence should equal to -1.8 m and occur on the left side of mining excavation. It's visible a movement of exploitation impacts towards the seam declination.
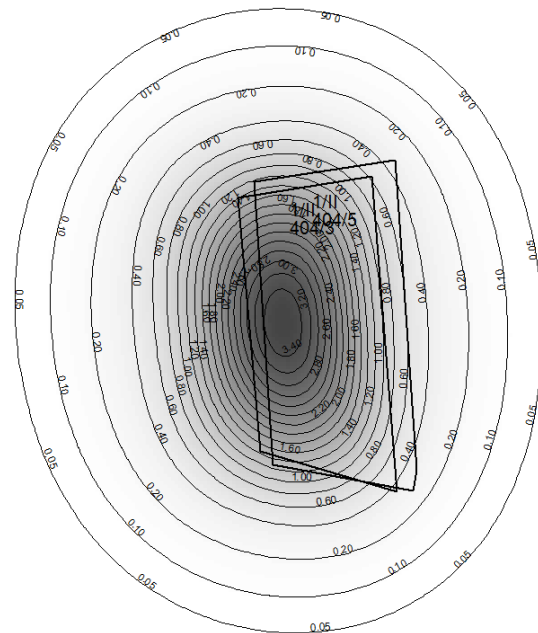
Exploitation of the 1/II longwall in the 404/5 seam can cause almost twofold increase of maximum value of subsidence to -3.4 m (Table 2, Figure 2b). Still is visible a displacement of operation influences towards the hard coal beds inclination.

Hard coal extraction from the next longwall number 2/II in the 404/3 seam should cause growth of subsidence maximum value by 0.6 m (Table 2 and Figure 2c). It can be seen that the subsidence trough has changed its shape and range of operating influences.
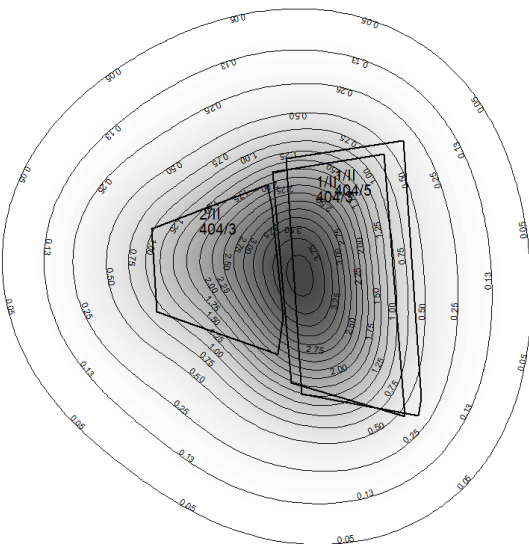
Last stage of exploitation – exploitation of the 2/II longwall in the 404/5 coal bed (Table 2 and Figure 2d) caused occurrence of subsidence on terrain surface, which maximum value equals to -4.5 m. It should be emphasized that this value is significant because it will occur during five years.

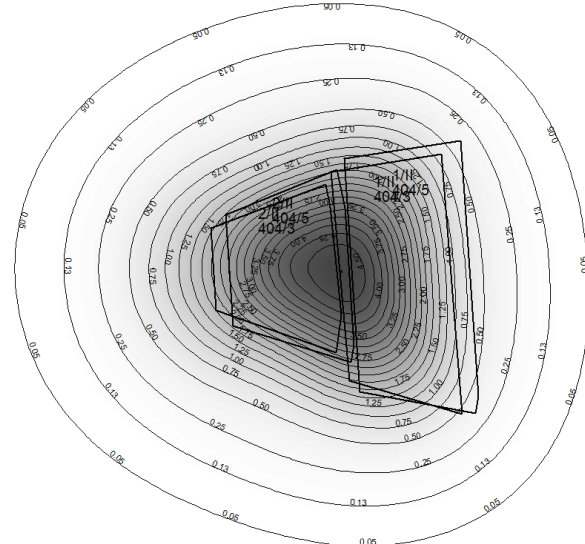a) Subsidence after exploitation end of the 1/II longwall in the 404/3 seam

b) Subsidence after exploitation end of the 1/II longwalls in the 404/3 and 404/5 seams

c) Subsidence after exploitation end of the 1/II longwalls in the 404/3 and 404/5 seams, and the 2/II longwall in the 404/3 seam

d) Subsidence after exploitation end of the 1/II and 2/II longwalls in the 404/3 and 404/5 seams

Figure 2. Isolines of reforecasted subsidence of land surface above an operating area after the end of exploitation subsequent stages in the 404/3 and 404/5 hard coal seams

Table 2. Extreme values of deformation indicators

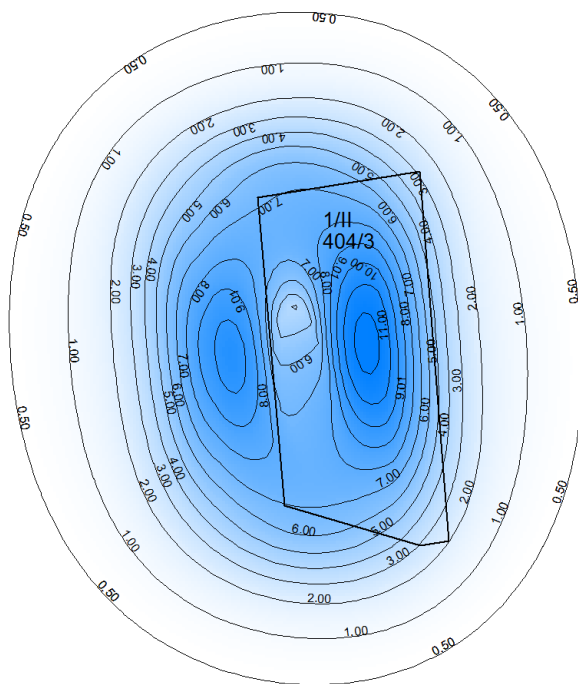| Exploitation stage	Subsidence $S\,[m]$	Inclinations $I\,[mm/m]$	Horizontal strains $\varepsilon\,[mm/m]$
1st	-1.8	12.4	6.0
2nd	-3.4	22.6	10.5
3rd	-4.0	24.2	10.9
4th	-4.5	25.5	11.2

3.2. Reprognosis of inclinations

Made reforecasts of mining exploitation impacts indicate that maximum value of inclination after the exploitation end of first longwall is equal to 12.4 mm/m and occurred above the middle of the 1/II longwall in the 404/3 seam (Figure 3a).
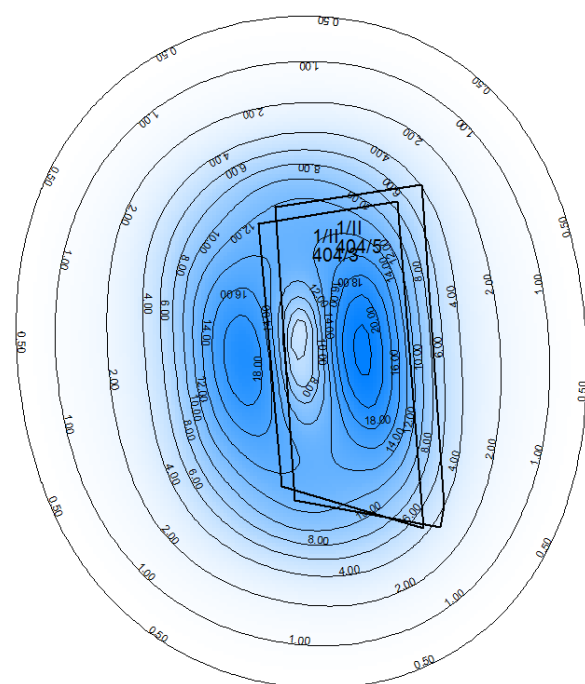
Maximum inclination reached the value of 22.6 mm/m after the operation termination in the 1/II longwalls in the 404/3 and 404/5 hard coal seams. It also occurred above the central part of mining excavations (Figure 3b).

After the third exploitation stage inclination reached the maximum value of 24.2 mm/m still above the middle of the 1/II longwalls (Figure 3c).
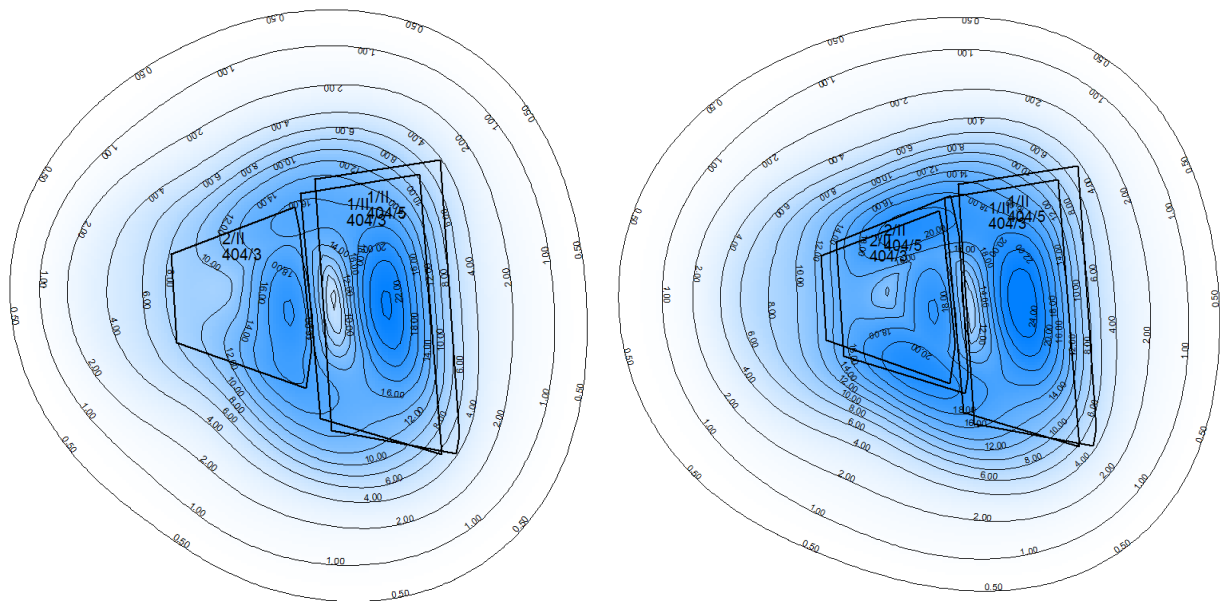
Exploitation of fourth longwall number 2/II in the 404/5 coal seam caused an increase of maximum inclination to the value of 25.5 mm/m (center of the 1/II longwalls). There have been arisen two zones of the large values of inclinations above initial and final edges of the 2/II longwalls (Figure 3d).

a) Inclinations after exploitation end of the 1/II longwall in the 404/3 seam

b) Inclinations after exploitation end of the 1/II longwalls in the 404/3 and 404/5 seams

c) Inclinations after exploitation end of the 1/II longwalls in the 404/3 and 404/5 seams, and the 2/II longwall in the 404/3 seam

d) Inclinations after exploitation end of the 1/II and 2/II longwalls in the 404/3 and 404/5 seams

Figure 3. Isolines of reforecasted inclinations of land surface above an operating area after the end of exploitation subsequent stages in the 404/3 and 404/5 hard coal seams
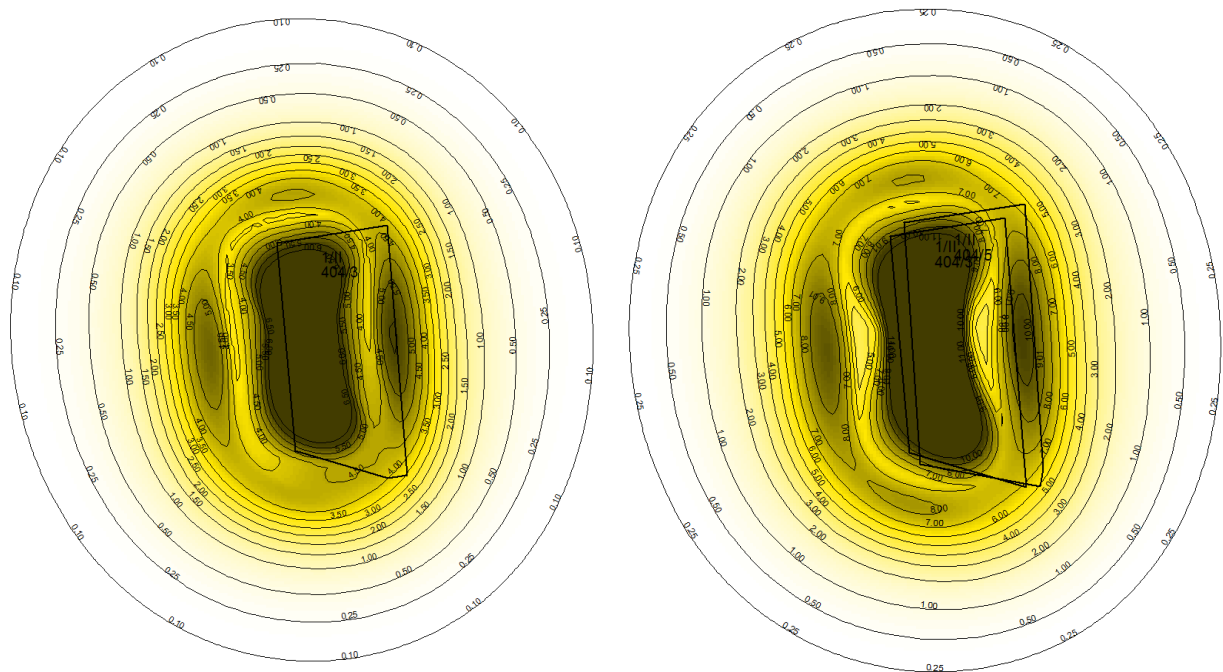
3.3. Reprognosis of horizontal strains

Figure 4 presents formation of horizontal deformations of terrain surface caused by an exploitation of the 404/3 and 404/5 hard coal seams, by use of the 1/II and 2/II longwalls.

After the first operational stage (Figure 4a) the maximum value of horizontal strain (6 mm/m) should occur above the 1/II longwall in the 404/3 seam. It can be seen that the mining influences are displaced in the west direction, according to a coal bed declination.

Exploitation of second longwall caused almost twofold increase of horizontal strain maximum value to 10.5 mm/m (Figure 4b). Around operational edges have been arisen the areas of heightened values of horizontal deformations.
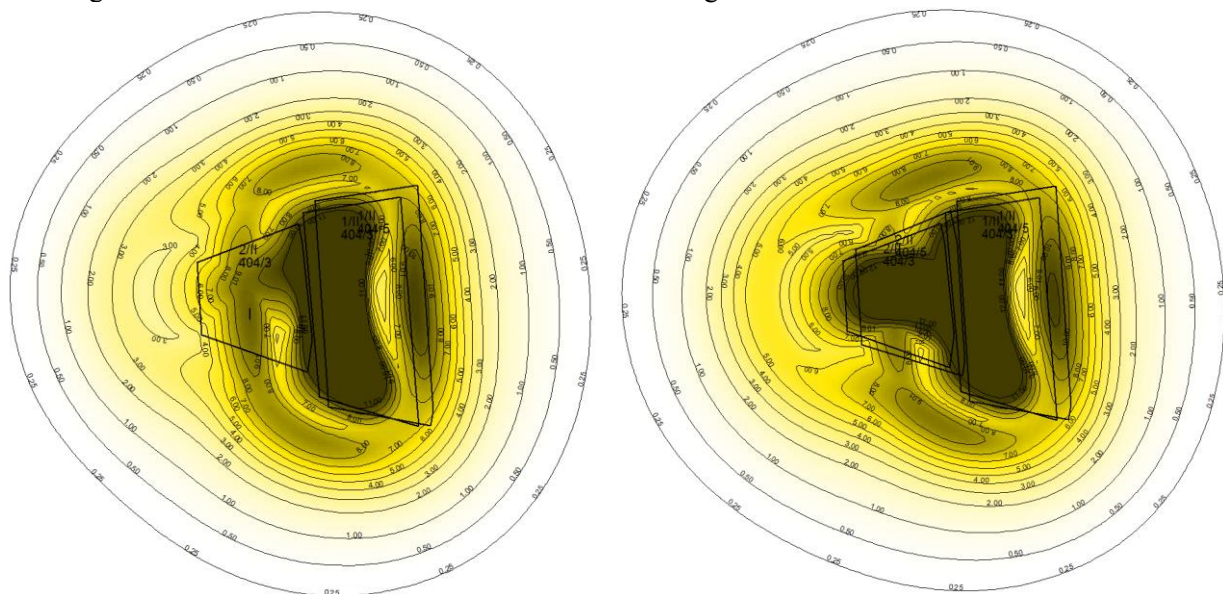
After the exploitation end of the 2/II longwall in the 404/3 seam, maximum value of horizontal deformation amounted almost 11 mm/m. Maximum values area has greater dimensions in comparison with last stage (Figure 4c).

Final value of maximum deformation amounted more than 11 mm/m after an exploitation termination of four longwalls. Area of maximum values of horizontal strains has shape of a three – leafed clover (Figure 4d).

a) Horizontal strains after exploitation end of the 1/II longwall in the 404/3 seam

b) Horizontal strains after exploitation end of the 1/II longwalls in the 404/3 and 404/5 seams

c) Horizontal strains after exploitation end of the 1/II longwalls in the 404/3 and 404/5 seams, and the 2/II longwall in the 404/3 seam

d) Horizontal strains after exploitation end of the 1/II and 2/II longwalls in the 404/3 and 404/5 seams

Figure 4. Isolines of reforecasted horizontal strains of land surface above an operating area after the end of exploitation subsequent stages in the 404/3 and 404/5 hard coal seams

4. Summary and conclusions

Article presents an extraction instance of hard coal from two, thick seams which have a significant declination. Exploitation was conducted on a small depth and by use of four longwalls with a roof rocks cave-in. There reforecasts of land surface deformations (subsidence, inclinations and horizontal strains) caused by exploitation of each longwall have been done.

Results of made reprognoses show that:

− maximum subsidence will have a value of -4.5 m;
− maximum value of inclination should equal to 25.5 mm/m (the 5th category of mining terrain);
− maximum horizontal strain will amount 11.2 mm/m (the 5th category of mining terrain);
− mining exploitation impacts are moved towards seams declination, what is especially visible in case of first two longwalls exploitation;
− most of influences should occur after exploitation end of the 1/II longwalls;
− exploitation of thick seams only with a roof rocks cave-in can cause serious effects on a terrain surface and in the buildings.

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