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ASSESSMENT OF SEISMIC EVENTS IN GERMAN HARD COAL MINING – OCCURRENCE AND PREDICTION

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ABSTRACT: Underground coal mining can cause seismic events. There is currently no way to predict such phenomena reliably, in particular the stronger events. That is why, given the current state of the art, empirical methods are employed in this field.

Some assessment criteria, which relate to the geological and mining situation and either stimulate or rather help to avoid seismic events, are presented in this paper. On a practical mining situation in Germany, these criteria are examined with a view to predicting possible seismic events.

INTRODUCTION

Mining-induced seismic events are part of underground mining operations (Preusse, 2008, Fritschen, 2002 and Sroka, 2008). They occur in different intensities, and the extent, to which they are perceptible on the surface, depends on several geological and mining operational factors.

According to international expertise it can be stated that the occurrence of mining-induced seismicity depends on natural and mining operational conditions. Natural factors include geological conditions as well as tectonic stresses. Besides the geological conditions, anthropogenic factors also play an important role, for example, multiple seam mining, existing mining boundaries, and residual pillars, as well as the mining method and the face advance rate at the time of the seismic event.

Fritschen (2002) demonstrated the static correlation between extracted coal volumes and released seismic energy. However, methods for detailed prognosis of seismic events are not available so far.

The currently used method to assess possible seismic events due to future mining operations in a certain part of a deposit, which is planned for mining, is an empirical approach, i.e. the prediction of seismic events in future mining fields is based on experiences made in other fields, whereas it is assumed, that the most significant parameters for the occurrence of seismic events do not change. The more similar the geological conditions between experienced and future mining situations are (e.g. thickness of seam, seam depth below surface and type of overlying rock strata), the more precise such a prediction would be.

On 23th February 2008, the German federal state of Saarland experienced an especially strong mining-induced ground vibration measuring 4.0 on Richter scale with a maximum vibration velocity of 93.5 mm/s (see Figure 1). Due to this event and the resulting endangerment for health and life of people, the mining authority of the provincial government imposed an immediate stop of the longwall that caused the tremors. Due to this seismic event, RAG Company decided to cease the entire production at *Saar* Colliery temporarily. In the following period, RAG investigated other opportunities to continue with mining operations in other mining fields with minimum risk of mining-induced seismic events. A conceivable alternative was to shift the production to *Grangeleisen* seam of the Nordfeld coal deposit, Saar Colliery. The mine is a multi-seam operations, which mines coal from separate levels and hence the term coalfield has been used in this context.

The risk of ground vibrations due to a continuation of panel *20.4 East*, *Grangeleisen* seam, was analyzed with regard to geological and mining operational conditions (Preusse, 2008). The assessment was based on a general technical expertise and findings from former seismic events at *Saar* Colliery.

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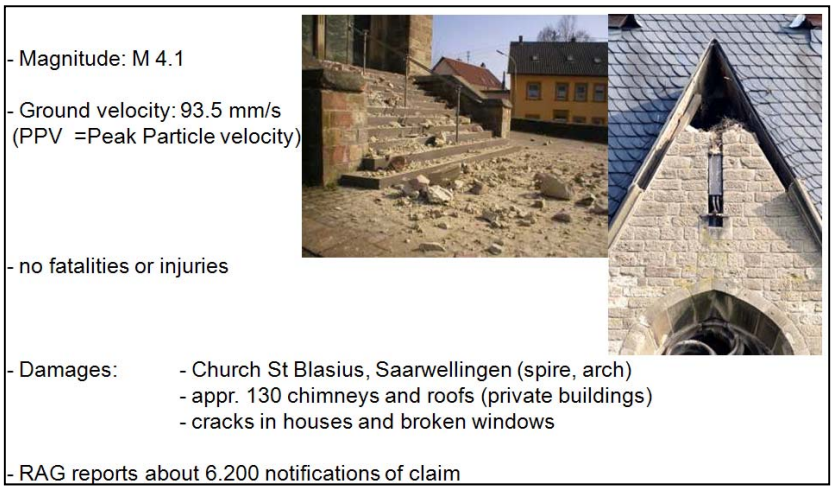

Figure 1 - Mining induced Seismic Event 2008/02/23, Saarwellingen

DEFINITION OF ASSESSMENT CRITERIA FOR THE OCCURRENCE OF MINING-INDUCED GROUND VIBRATIONS

Geological and mining operational assessment criteria

The following geological and mining operational (i.e. anthropogenic) assessment criteria (see Figure 2) are verifiably responsible for the occurrence of mining-induced seismicity. They can be found in international literature (Gibowitz and Lilko, 1994) as well:

- **Geological assessment criteria:**
  - Rock structure (competence of rock; especially sand rate)
  - Depth of planned mining horizons
  - Mined seam thickness
  - Maximum horizontal stress / anisotropic stress field in rock mass
- **Mining operational assessment criteria:**
  - Mining concentration (Initial panel / multiple seam mining)
  - Panel ribsides and residual pillar
  - Face length of longwalls
  - Face advance rate and its change
  - Already known zones of seismicity

Figure 2 - Assessment criteria for the occurrence of ground vibrations

Analysis of assessment criteria on the activation of ground vibration in German coal mines

The following factors are considered to influence the risk of various events:

Sandstone percentage in layers above the underground workings

Any thick layer with a high sandstone percentage above the extracted coal seams, increases the general risk of seismic events due to mining operations. The percentage of sandy particles included in rock layers above the workings at Saar Colliery was between 18 and 70 %.

Mining depth

The probability of having mining-induced ground vibrations increases consistently with the mining depth. This assumption was proved by several seismic events that occurred in the past. The strongest event so far occurred due to mining operations of Saar Colliery at a depth of approximately 1,450 m.

Mined seam thickness

The mined seam thickness as well is an influencing factor on mining-induced seismicity. Based on experiences derived from mining activities in Saarland, it can be stated that a mined seam thickness between 3.0 and 3.5 m will most likely cause ground vibrations with a higher intensity. For the mining operations in the *Grangeleisen* seam, *Nordfeld* coal field, however, the workable thickness was about 2.3 m.

Horizontal stress/ anisotropic stress field in underground rock strata

A further geological criterion with an impact on increased seismicity is an anisotropic stress field in the rock strata. This means there is a significant difference between the horizontal and vertical stresses. Therefore, information about the range of horizontal stress is investigated *in- situ* by drilling in an unaffected area.

Multiple seam mining

In the extensively mined parts of the deposit (multiple seam mining), it can be assumed that the structure of rock strata as well as the hanging side of the roof strata is weakened and loosened (Kratzsch, 1997). This increases the sequence of ground movements, which will unavoidably occur due to underground coal extraction. However, according to documents and findings at Saar Colliery, mining operations that were preceded by mining in two or three different seams above the recent workings have actually provided better situations. This is proved by seismic activities which occurred due to mining operations in other mining fields of Saar Colliery.

Undermining of panel boundaries and residual pillars

Undermining panel boundaries and residual pillars, which were left behind by upper seam mining, generally increases the risk of seismic events. This fact can be concluded from mining operations in panel *20.3 East* in the *Grangeleisen* seam of the *Nordfeld* coal field (see Figures 2 and 3), where two previously mined seams were undermined.

Face length (single face/ double face mining operations)

Based on the experiences at Saar Colliery it can be concluded that double face mining operations (two directly adjoining longwalls with same face advance) have a negative impact on possible mining-induced seismic events. Consequently, any mining operation at Saar Colliery should be converted from double face to single face mining.

Face advance rate and its change

According to findings at Saar Colliery, fast face advance rates as well as significant changes of the face advance rate have negative impact on potential seismicity. This is why operations should advance moderately and constantly, without any long periods of stoppage (e.g. extended weekends).

Zones of seismic events which are already known

Previous seismic events, which resulted from mining activities in the past, might have had different reasons, e.g. high percentage of sandy particles in the surrounding rock, larger seam thickness and undermining of residual pillars. However, they are indicators for further seismic events which will possibly follow due to subsequent mining activities.

An analysis of the previous seismic events in other coal fields of Saar Colliery pointed out that the occurrence of these events concentrates on narrow vibration corridors and their intersecting areas. However, such findings are presently not on hand for operations in the *Grangeleisen* seam *in Nordfeld.*.

ASSESSMENT ON POTENTIAL SEISMIC EVENTS DUE TO OPERATIONS AT SAAR COLLIERY

THE SITUATION AT SAAR COLLIERY IS AS FOLLOWS:

Until 2008, the coal fields of *Saar* Colliery were *Primsmulde South*, *Dilsburg East*, *Dilsburg West* and *Nordfeld*. The operations took place in *Schwalbach*, *Wahlschied* and *Grangeleisen* seams (from the upper to the lower seams). On 23th February 2008, when the strong seismic event occurred and mining activities at Saar Colliery had to be stopped, the following seams were mined:

- Primsmulde South: S*chwalbach seam*, panels *Prims1* and *Prims2*
- Nordfeld: *Grangeleisen seam*, panel *20.4 East*

The operations in *Schwalbach*, *Wahlschied* and *Grangeleisen* seams of the *Nordfeld* are shown in Figure 3. Figure 4 focuses on the mining situation in Grangeleisen seam.

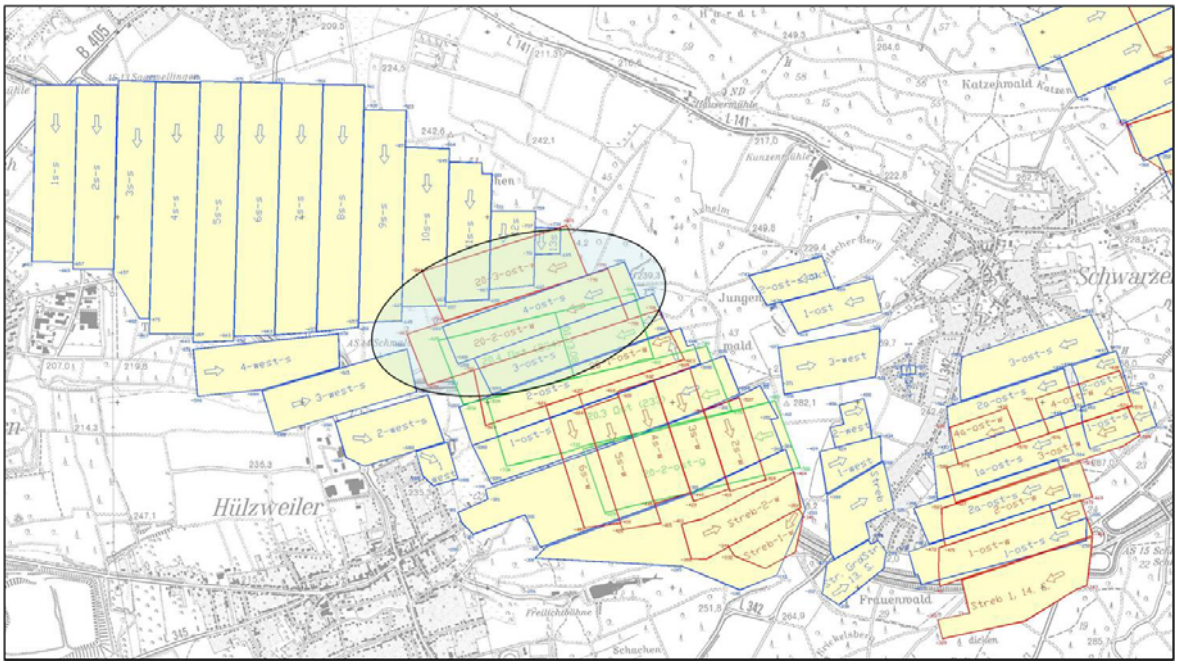

Figure 3 - Mined panels in mining field *Nordfeld* at RAG Saar Colliery

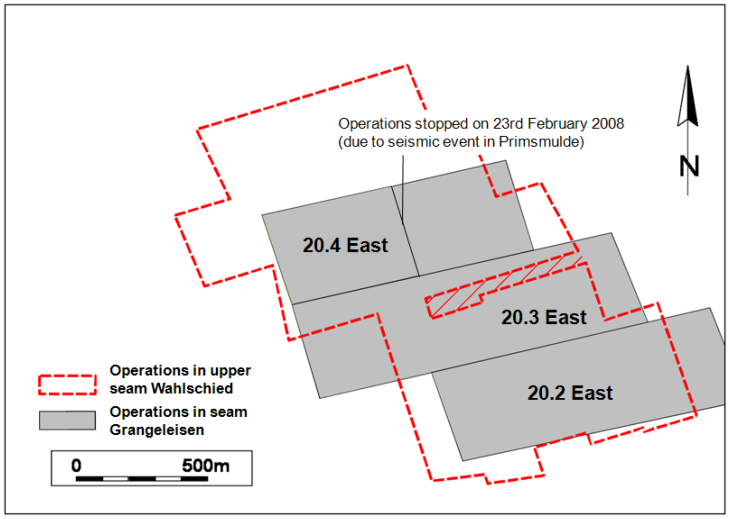

Figure 4 - Plan view of panels in seam *Grangeleisen* as well as working boundaries and pillars in seam *Wahlschied*

Concerning the continuation of mining in panel 20.4 East, *Grangeleisen* seam, the following results were derived from the analysis of the assessment criteria (see previous section), examining the activating conditions for mining-induced ground vibrations.

Relatively favourable conditions are:

- Low percentage of sandy particles in overlying strata (18%)
- Relatively low seam thickness (about 2.3 m)
- Extensive previous extraction in *Schwalbach* and *Wahlschied* seams located above
- Single face mining (face length about 360 m)

Neutral conditions are:

- Moderate face advance rate (up to 5 m/ day)
- Medium mining depth (between 1050 and 1170 m)

Highly unfavourable conditions when encountering:

- Panel boundaries
- Residual pillar in *Wahlschied* seam (south of panel 20.4 East)
- Seismic events already occurred in the past

Based on the above described assessment it was assumed that no stronger seismic events were to be expected while mining operations continued in panel *20.4 East*, *Grangeleisen* seam, after it had been restarted gradually. Finally, panel 20.4 East was mined as planned, verifying the described assessment.

SUMMARY

Underground hard coal mining can cause seismic events. Currently, there is no method available to reliably predict such occurrences, especially in terms of stronger seismic activities. According to the state of technology, any assessment on that topic is thus based on empirical methods.

Several geological and mining-operational criteria, which either support or rather help avoid the occurrence of seismic events, are presented. They are examined for the given mining situations in Saarland, Germany, with the purpose of assessing possible mining-induced ground vibrations.

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