DESTRESS BLASTING AS A PROACTIVE MEASURE AGAINST ROCKBURSTS

PETR KONICEK
Czech Academy of Sciences, Institute of Geonics
1. Introduction
2. Natural and mining conditions
3. Destress blasting as an active measure
4. Evaluation of stress release
5. Case studies
6. Rockbursts and destress blasting in underground constructions
7. Conclusions
INTRODUCTION

Prognozis
Active rockburst measures
Pasive rockburst measures
Rockburst prevention
INTRODUCTION

- Main goals of destress blasting:
  - Desintegration of rock mass by means of explosion (without breaking into open spaces),
  - Redistribution of stress away from the working face (behind a preconditioned zone),
  - Destressing (without employees in underground workings).

- Using of destress blasting is not so much common technique in hardcoal mining yet.

- State-of-the-Art Review:
DETONATION PRINCIPLES, ROCK FRACTURING:

- Detonation – explosion of reactive material – greater speed than sonic velocity:
  - Shock wave
  - Chemical reaction – heat energy and high pressure gas
- Impact of stress in the shock front following pressure of gases after detonation.
- Crushing of rocks (near area of explosive charge) creation new fractures or reopening of existing fractures.
- Generation of elastic waves in rock mass in greater distance from explosive charge (possible stress release of rock mass)

According to PalRoy 2009
RANGE OF ROCK FRACTURING:

- Creation of new fractures and expansion of existing fractures—mainly in direction of maximal stress.

- With increasing depth (2000 m) → decreasing new fractures occurrence and reopening existing fractures ⇒ effect of high stress.

- Modulus of elasticity and tensile strength have insignificant role on fractures development in surroundings area of borehole.

- Modelling of explosives → emulsion types of explosives are more suitable for rigid and brittle rocks than ANFO types of explosives.

- Directional fracturing of rocks → technique of predispose notches ⇒ increasing of impact energy of explosives for more effective stress release ⇒ long fractures in different direction that direction of maximal stress.
STRESS RELEASE:

- Visual inspection of underground openings impacted by rockburst, which is an impact of stress release.
- Stress changes measurement.
- Geophysical methods.
- Due to engineers methods allow to evaluate of effect of stress release.
  - Destressability index (Andrieux and Hagigeorgiou 2008)
  - Seismic Effect (Konicek et al. 2013)
INTRODUCTION - LOCATION

Upper Silesian Coal Basin:
- Area: 7000 km² (78% – Poland, 22% – Czech Republic)
- Hardcoal deposit of Carboniferous age.
- Nowadays – exploitation mainly in Karvina Subbasin

---

7000 km² (78% – Poland, 22% – Czech Republic)

- Hardcoal deposit of Carboniferous age.
- Nowadays – exploitation mainly in Karvina Subbasin
SITE CONDITIONS

- Depth 800 – 1200 m.
- Coal seams (thickness 3 – 10 m).
- Interbeds – compact competent rocks (conglomerates and sandstones) – more than 80% share.

<table>
<thead>
<tr>
<th></th>
<th>UCS (MPa)</th>
<th>RQD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>10–30</td>
<td>–</td>
</tr>
<tr>
<td>Mudstone</td>
<td>35–65</td>
<td>–</td>
</tr>
<tr>
<td>Siltstone</td>
<td>40–150</td>
<td>60–90</td>
</tr>
<tr>
<td>Sandstone</td>
<td>50–170</td>
<td>70–90</td>
</tr>
<tr>
<td>Conglomerate</td>
<td>40–140</td>
<td>70–90</td>
</tr>
</tbody>
</table>
MINING CONDITIONS

- Long-term mining (more than 200 years).
- Mined out tens seams in carboniferous rock mass.
- Used mining method – longwall mining.
- Occurrence of many abandoned pillars in seams.
- Sometimes disrespectsing natural (geological) boundaries (abandoned pillars).
- Sometimes improper time sequences of mining (e.g. between neighbouring colliery claims).

Induced stress field is anisotropcic and non uniform!
HISTORY OF DESTRESS BLASTING

- Destress blasting application from 1980’s (the first destress rock blasting in 1973),
- In the beginning – using charges hundreds kg,
- In nowadays are using charges about thousands kg,
- Progressive improvement:
  - Technology of drilling,
  - Technology of blasting
  - Evaluation of range of fracturing from blasted boreholes,
  - Evaluation of stress release,
- Increase of application – due to increasing occurrence of competent rocks in connection with deep mining.
Disintegration of the rock mass for better caving.
Stress release of the rock mass.
SPECIFICATIONS

General technical conditions for carrying out the destress rock blasting:

- Boreholes diameter of 75 – 105 mm drilled usually from the gateways.
- Inclination of boreholes up to 30°.
- Length of boreholes up to 100 m (sometimes up to 120 m).
- Spacing of parallel boreholes 5–12 m (according to the purpose).
- Pneumatic charging of explosives into boreholes in cartridges.
- Use of rock gelatine explosives (Perunit and Danubit types).
- Blasting without delay in one-time level.
- Blasting charges from 400 kg up to 4780 kg.
- Up to now applied more than 3000 destress rock blastings.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of borehole [ m ]</td>
<td>30</td>
<td>120</td>
<td>70</td>
</tr>
<tr>
<td>Length of charge [ m ]</td>
<td>15</td>
<td>100</td>
<td>44</td>
</tr>
<tr>
<td>Percentage of charge [ % ]</td>
<td>45</td>
<td>85</td>
<td>70</td>
</tr>
<tr>
<td>Stage charge [ kg ]</td>
<td>400</td>
<td>4781</td>
<td>1660</td>
</tr>
<tr>
<td>Loading density diam. 76 [ kg.m⁻¹]</td>
<td>3.0</td>
<td>6.5</td>
<td>4.8</td>
</tr>
<tr>
<td>Loading density diam. 95 [ kg.m⁻¹]</td>
<td>5.1</td>
<td>12.0</td>
<td>8.5</td>
</tr>
</tbody>
</table>
PNEUMATIC LOADING OF EXPLOSIVES

1. Stand
2. Loading head
3. Operating valve
4. Safety valve
5. Pressure regulator
6. Pedal of loading barrier

Loading up to 3 kg of explosives altogether.

Antistatic pipe put into borehole.
EVALUATION OF STRESS RELEASE

- Evaluation of seismological monitoring data – registered seismic energy and data of destress rock blasting (weight of explosive charge).
- Calculation of seismic effect (SE) of destress rock blasting.
- Put SE into the practice in the 1990th of the last century (application about 20 years). Verification of methodology in 2009 and 2016.
Calculation of seismic effect (SE):

\[
SE = \frac{E_{OKC}}{K_{OKC} \cdot Q}
\]

Registered seismic energy

Equivalent of seismic energy corresponding to the size of the detonated charge weight

Where:

\( E_{OKC} \) – local (Ostrava-Karvina Coalfield – OKC) seismic energy of seismic event corresponding of destress blasting from seismological monitoring [ J ]

\( Q \) – weight of explosive charge [ kg ]

\( K_{OKC} \) combined coefficient which characterized by natural and mining conditions in OKC (\( K_{OKC} = 1.86 \)). More details in Konicek et. al 2013 and Konicek 2016.
EVALUATION OF SEISMIC EFFECT
(STRESS RELEASE)

<table>
<thead>
<tr>
<th>Seismic effect (E_OKR)</th>
<th>Evaluation of seismic effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE &lt; 2.5</td>
<td>Insignificant</td>
</tr>
<tr>
<td>2.5 ≤ SE &lt; 4.1</td>
<td>Good</td>
</tr>
<tr>
<td>4.1 ≤ SE &lt; 7.0</td>
<td>Very good</td>
</tr>
<tr>
<td>7.0 ≤ SE &lt; 13.6</td>
<td>Extremely good</td>
</tr>
<tr>
<td>SE ≥ 13.6</td>
<td>Excellent</td>
</tr>
</tbody>
</table>
LONGWALL NO 140 914 (LAZY COLLIERY)
LONGWALL NO 140 914 (LAZY COLLIERY)
### PARAMETERS OF DESTRESS BLASTING

<table>
<thead>
<tr>
<th>stage</th>
<th>date and time</th>
<th>numbers of boreholes</th>
<th>explosive charge [kg]</th>
<th>registered seismic energy [J]</th>
<th>seismic effect (SE) [J.kg⁻¹]</th>
<th>evaluation of SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16.7.2006; 16:23:06</td>
<td>1-4, 51</td>
<td>1625</td>
<td>1.61E+04</td>
<td>5.3</td>
<td>very good</td>
</tr>
<tr>
<td>2</td>
<td>23.7.2006; 16:32:19</td>
<td>101-104, 151</td>
<td>1550</td>
<td>1.39E+04</td>
<td>4.8</td>
<td>very good</td>
</tr>
<tr>
<td>3</td>
<td>29.10.2009; 17:20:58</td>
<td>201-206</td>
<td>1725</td>
<td>2.40E+04</td>
<td>7.5</td>
<td>very good</td>
</tr>
<tr>
<td>4</td>
<td>12.11.2006; 16:17:17</td>
<td>5-8, 52</td>
<td>2000</td>
<td>3.19E+04</td>
<td>8.6</td>
<td>extremely good</td>
</tr>
<tr>
<td>5</td>
<td>19.11.2006; 16:27:38</td>
<td>105-108, 152</td>
<td>1775</td>
<td>3.03E+04</td>
<td>9.2</td>
<td>extremely good</td>
</tr>
<tr>
<td>7</td>
<td>17.12.2006; 16:51:27</td>
<td>207-210</td>
<td>1700</td>
<td>1.29E+04</td>
<td>4.1</td>
<td>good</td>
</tr>
<tr>
<td>8</td>
<td>14.1.2007; 16:14:05</td>
<td>211, 212, 213</td>
<td>1850</td>
<td>2.50E+04</td>
<td>7.3</td>
<td>very good</td>
</tr>
<tr>
<td>9</td>
<td>4.2.2007; 17:33:04</td>
<td>121-124, 154</td>
<td>2500</td>
<td>4.40E+04</td>
<td>9.5</td>
<td>extremely good</td>
</tr>
<tr>
<td>10</td>
<td>8.3.2007; 16:31:07</td>
<td>125, 126, 127</td>
<td>2125</td>
<td>5.00E+04</td>
<td>12.7</td>
<td>extremely good</td>
</tr>
<tr>
<td>11</td>
<td>11.3.2007; 17:50:30</td>
<td>221-227</td>
<td>1635</td>
<td>1.80E+04</td>
<td>5.9</td>
<td>very good</td>
</tr>
<tr>
<td>12</td>
<td>18.3.2007; 17:16:42</td>
<td>41-45</td>
<td>3450</td>
<td>2.40E+05</td>
<td>37.4</td>
<td>Excellent</td>
</tr>
<tr>
<td>13</td>
<td>25.3.2007; 17:34:01</td>
<td>141-145</td>
<td>3450</td>
<td>3.80E+05</td>
<td>59.2</td>
<td>Excellent</td>
</tr>
<tr>
<td>14</td>
<td>15.4.2007; 16:17:53</td>
<td>128-130</td>
<td>2250</td>
<td>6.20E+04</td>
<td>14.8</td>
<td>Excellent</td>
</tr>
<tr>
<td>15</td>
<td>29.4.2007; 22:41:06</td>
<td>131-133</td>
<td>2250</td>
<td>1.50E+05</td>
<td>35.8</td>
<td>Excellent</td>
</tr>
<tr>
<td>16</td>
<td>1.5.2007; 17:49:46</td>
<td>228-232</td>
<td>1850</td>
<td>1.90E+04</td>
<td>5.5</td>
<td>very good</td>
</tr>
<tr>
<td>17</td>
<td>6.5.2007; 21:48:46</td>
<td>134-136</td>
<td>2350</td>
<td>7.80E+04</td>
<td>17.8</td>
<td>Excellent</td>
</tr>
<tr>
<td>18</td>
<td>13.5.2007; 22:06:34</td>
<td>21-23</td>
<td>2350</td>
<td>1.40E+05</td>
<td>32.0</td>
<td>Excellent</td>
</tr>
</tbody>
</table>
ANIMATION OF LOGWALL ADVANCE

Sesimic effect:
- Insignificant
- Good
- Very good
- Extremely good
- Excellent

Legend:
- Roadway
- Blasthole
- Mine area in the seam N° 512 in overburden
- Mine area in the seam N° 530, in overburden
- Mine area in the seam N° 559, in overburden

Cross-section C-D:
- 59.2
- 37.4

Cross-section A-B:
- 205
- 108
- 9
Main goals:

- Create a physical separation between the deformed mining areas and the non-deformed safety pillar area and this way decrease the impact of additional stress induced inside the safety pillar area.
- Stress release without employees in underground openings.
CUTTING DESTRESS BLASTING

Case No. 1: longwall 140 914
Case No. 2: longwall 140 704
Case No. 3: longwalls near the SW crosscuts safety pillar
- 2 funs of borehole in the same vertical plane.
- Borehole diam. 93 mm
- Length of borehole 93 – 100 m.
- Borehole inclination 4° to 35° (upwards).
- 2 stages of destress blasting.
- Pneumatic loading explosives in cartridges.
- % of the loaded lengths: 67-80%.
- Charge from 595 to 780 kg per blasthole (according to length and position).
- Length of stemming (sand) 20 – 30 m.
- Firing without time delay (electric detonator).
- Stage 12–boreholes 41-45 (3450 kg explosive), 158 m from longwall face, released energy 2.4 E+05 J, SE 37.4.
- Stage 13–boreholes 141-145 (3450 kg explosive), 152 m from longwall face, released energy 3.8 E+05, SE 59.2.
- 2 funs of borehole in the same vertical plane.
- Borehole diam. 95 mm.
- Length of borehole 93 – 100 m.
- Borehole inclination 4° to 34° (upwards).
- 2 stages of destress blasting.
- Pneumatic loading explosives in cartridges.
- % of the loaded lengths: 50-80%.
- Charge from 415 to 700 kg per blasthole (according to length and position).
- Length of stemming (sand) 20 - 46 m.
- Firing without time delay (electric detonator).
- Stage 19–boreholes 71-75 (2900 kg explosives) 168 m from longwall face, released energy 1.5 E+05 J, SE 27.8.
- Stage 20–boreholes 171-175 (2975 kg explosives), 132 m from longwall face, released energy 2.8 E+05, SE 50.6.
- 52 blastholes in roof rocks of mined coal seam, 13 distress blasting stages.
- Borehole diameter 93 mm, spacing 7 m (parallel boreholes).
- Length of boreholes varied from 25 to 80 m.
- Charge from 415 to 700 kg per blasthole (according to length and position).
- Length of charges varied from 18 to 60 m.
- Length of stemming (sand) 7-20 m.
- Firing without time delay (electric detonator).
- Pneumatic loading explosives in cartridges.
- Stage charge range from 1130 to 2760 kg.
<table>
<thead>
<tr>
<th>Stage</th>
<th>Blasthole number (-)</th>
<th>Explosive charge (kg)</th>
<th>Released seismic energy (J)</th>
<th>SE (Jkg⁻¹)</th>
<th>Seismic effect evaluation (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>501-504</td>
<td>1560</td>
<td>1.70E+04</td>
<td>5.9</td>
<td>Very good</td>
</tr>
<tr>
<td>2</td>
<td>516-519</td>
<td>1656</td>
<td>1.50E+04</td>
<td>4.9</td>
<td>Very good</td>
</tr>
<tr>
<td>3</td>
<td>505-508</td>
<td>1656</td>
<td>1.50E+04</td>
<td>4.9</td>
<td>Very good</td>
</tr>
<tr>
<td>4</td>
<td>520-523</td>
<td>1656</td>
<td>1.20E+04</td>
<td>3.9</td>
<td>Good</td>
</tr>
<tr>
<td>5</td>
<td>512-515</td>
<td>1688</td>
<td>2.10E+04</td>
<td>6.7</td>
<td>Very good</td>
</tr>
<tr>
<td>6</td>
<td>509-511</td>
<td>1130</td>
<td>1.30E+04</td>
<td>6.2</td>
<td>Very good</td>
</tr>
<tr>
<td>7</td>
<td>524-527</td>
<td>1728</td>
<td>2.30E+04</td>
<td>7.2</td>
<td>Extremely good</td>
</tr>
<tr>
<td>8</td>
<td>1.7</td>
<td>1488</td>
<td>2.30E+04</td>
<td>8.3</td>
<td>Extremely good</td>
</tr>
<tr>
<td>9</td>
<td>12.14</td>
<td>1275</td>
<td>7.60E+03</td>
<td>3.2</td>
<td>Good</td>
</tr>
<tr>
<td>10</td>
<td>8.11</td>
<td>1296</td>
<td>1.50E+04</td>
<td>6.2</td>
<td>Very good</td>
</tr>
<tr>
<td>11</td>
<td>528-530</td>
<td>1344</td>
<td>1.10E+04</td>
<td>4.4</td>
<td>Very good</td>
</tr>
<tr>
<td>12</td>
<td>531-533</td>
<td>1506</td>
<td>1.00E+04</td>
<td>3.6</td>
<td>Good</td>
</tr>
<tr>
<td>13</td>
<td>15-19</td>
<td>2760</td>
<td>2.00E+04</td>
<td>3.9</td>
<td>Good</td>
</tr>
</tbody>
</table>
Example – preconditioning for roadway driving:
Length to face: N=7 to 12 m (safety area according to methodology) + planned face advance.
Length to ribs: N=7 to 12 m (safety area according to methodology), spacing max. 5 m.

\[
\begin{array}{c|cccccccccccccccc}
\text{Borehole length [m]} & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 \\
\hline
\text{Explosives length [m]} & 3 & 3 & 4 & 4 & 5 & 6 & 7 & 7 & 8 & 8 & 9 & 9 & 10 & 10 & 10 & 10 \\
\end{array}
\]
Example – preconditioning for longwall mining:
Length to face: \( N = 7 \) to \( 12 \) m (safety area according to methodology) + planned face advance; general spacing max. \( 5 \) m., spacing in the same row max. \( 15 \) m, do not drilling holes in the same place!
PROVOKED ROCKBURST – STAGE 13

- Boreholes Nos.215,216,108,109, 170,142,143,56,57,91
- Borehole explosive charge 250-576 kg
- Stage explosive charge 3700 kg
- Average load length of borehole – 68%
- Distance from longwall face 50 m
- Registered seismic energy – 9.7E+06
- Calculated seismic effect (success of stress release) -1409
ROCKBURST IMPACT IN MAINGATE

- Length of deformation - 131 m.
- Bottom swelling up to 3.5 m.
- Deformation of steel arch.
- Broken hydraulic probes.
- Yeild of steel arches up to 0.6 m.
- Damage to conveyor belt and scatter of facilities.

→ More details in FRAGBLAST conference proceedings
Tunnels for hydropower station Jinping II (China)

- Depth 1500 – 2525 m (limestones and ultrabasic dykes – UCS 80 – 114 MPa; E – 25 – 40 GPa, great horizontal stress!)

- Recorded rockbursts during driving ⇒ design modification – seismic monitoring, rockburst measures – destress blasting.
CONCLUSIONS

- Destress blasting in longwall mining are used for relatively long time.
- Experiences with application of this technique in difficult natural and mining conditions are very good.
- Many longwalls influenced by destress blasting have been mined with minimum rockburst problems.
- Seismic Effect methodology was verified and its regularly used as a part of rockburst prevention. Technique was successfully tested in different regions too (Poland).
- In some specific conditions rockburst can be provoked.
- Experiences from underground mining can be inspiration for rockburst prevention in deep tunnels.
- Also this technique similarly like another rockburst control techniques has its own limits, because nature is powerful.
THANK YOU VERY MUCH FOR YOUR ATTENTION!

CONTACT:
Assoc. Prof. Petr Konicek, Ph.D.
Department of Geomechanics and Mining Research
Czech Academy of Sciences,
Institute of Geonics
Studentská 1768
708 00 Ostrava-Poruba
Czech Republic
E-mail: petr.konicek@ugn.cas.cz
Tel.: +420 596 979 224