

## **STRAND BOLTS APPLICATION FOR GATES REINFORCEMENT**

### **1. INTRODUCTION**

One of the most important aims in mining engineering is the improvement of safety in drifted roadways and the more effective application of support parameters. It is not easy to join both these strategies. From an economical point of view you should use cheaper materials but still strong enough or, for example, change the distance between standing support [3, 5]. From a safety point of view the underground constructions should be thicker, made more solid to prevent the roof from collapsing in larger and larger depths [2]. Combining the standing support and roof bolting can be a solution of the problem. It is practised in two ways in Poland: the sets of the standing support are fixed using a certain number of pairs of bolt, or the rock mass is bolted between the sets of support. The experience so far indicates that the former method is applied more frequently [3, 4, 5].



Fig.1 The photo of strand bolt

In the last years strand bolts are used in Polish coal mines more willingly and frequently, especially in longwall gates. They consist of several individual wires with diameters of 2÷5 mm. Their lengths are usually 4÷6 m (Fig.1). Strand bolts with the initial tension allow reinforcement of the rock mass before the separation in the roof occurs. However, bolting is a time consuming method, although it improves the rock mass stability very well,

especially in the gates. The strand bolts can be fixed by the means of resins or injections.

The bolting scheme depends strictly on the mining, geological and technological conditions [1, 2]. There is another type of cooperation between bolts and rock body in weak and hard rocks. The strand bolts application, based on the underground measurements in two different type of rocks, are shown in the paper.

### **2. The effectiveness of bolting**

The effectiveness of bolting depends on the time of the bolts fixing. It doesn't matter what type of bolt it is. If you allow the roof layers to separate and this separation increases 40÷50 mm it will be very difficult to take advantage of this kind of reinforcement. The problem associated with the appropriate time of bolting consists of two factors:

- Ø type of rocks,

Ø bolting technique.

It is well known that some type of rock bodies are exceptionally hard and stiff (majority of these are igneous and metamorphic rocks). They don't need any support at all or only very limited amount. Such rock mass is usually isotropic and continuous, and discontinuities appear there very rarely. The bedded type of rock mass, typical for sedimentary rocks, tends to be fractured and separates usually on the contact of the layers [1, 2]. The natural fracture intensity is strictly connected with the bed thickness. The worst situation is in schists and shales. These rock masses are very poor to bolt. If you leave unsupported length of working, even only a few meters long, the excess separation in the roof occurs nearly immediately.

The second important factor of bolting technique concerns the bolting equipment. One must notice that bolts in all development workings are used only as the second type of support [5, 6]. The primary one is steel yielding standing arch support. Then, under the Polish mining law, all calculations concern the standing support only. Bolting is used as reinforcement only and some coal mines don't use any bolts at all. It involves that heading machines are not supplied with bolting machines and that bolting is carried on after the face zone by portable pneumatic or hydraulic bolting machines. The distance between the face with standing support and bolting area is ca. 70÷100 m. It is in fact a too large unsupported space in an active way to prevent the roof layers from the separation. One must remember that yielding standing support "waits" for the rock mass slowly moving towards the empty space of the working. The functioning of this support is passive, contrary to bolting which is active [6].

Taking both above factors into consideration and having some experience in strand bolt application I can present two different possibilities of cooperation strand bolts - the rock mass.

### 3. Strand bolts using in hard rocks

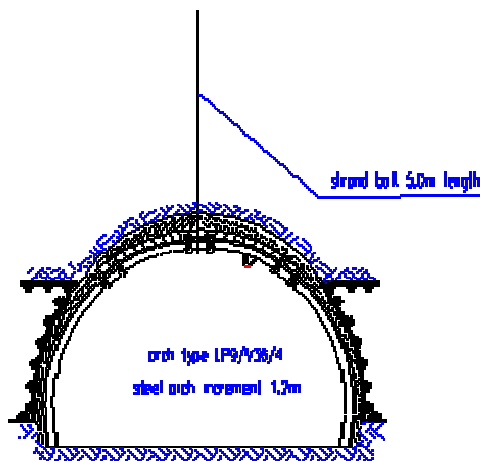


Fig.2 The typical scheme of standing-and-roof bolting support in hard rocks

Talking about hard rock mass whilst considering sedimentary carboniferous rocks you take into account only sandstones and siltstones. Both rock layers are rather thick and the immediate roof is usually at least 4÷6 m. Sometimes the sandstone bed is even 30÷40 m thick. If there is a 3÷4 m thickness layer of mudstone and sandstone in between these, you can treat it as a hard rock massiff.

Author experience in such a rock mass allow to show that the main scheme of combined standing-and-bolting support is the bolting

between the arch sets (Fig.2). In this case the distance between the face and bolting area is generally of no matter. Such a rock mass does not crack easy and very rarely is fractured. You can not only delay the time of fixing the bolts but slightly increase the increment of arch sets. You can do it only if you decide to use bolts in the very beginning. The strand bolts should be fixed in the main roof and their length no less than 4÷5 metres.

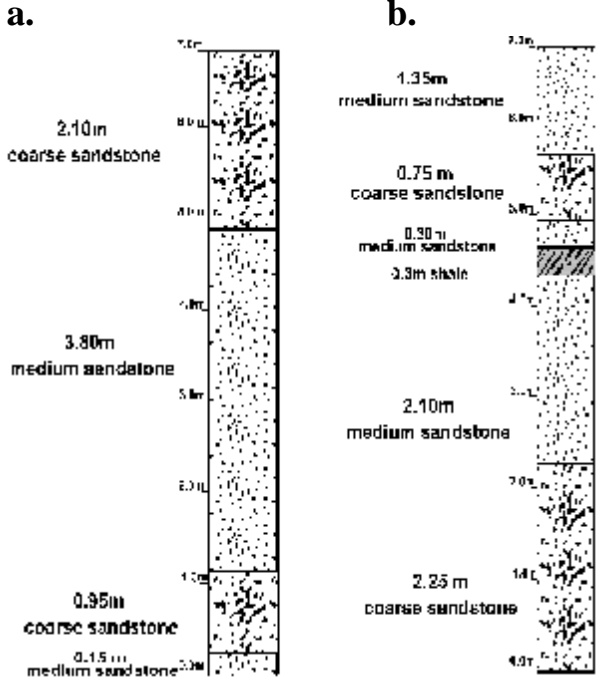


Fig.3 The typical lithology in the roof of a. Connection Roadway Z3, b. Maingate 2

There are two examples of using strand bolts in sandstones below: in Connection Roadway Z3 and in Maingate 2. There was a coal seam thickness of 1,5÷2,8 m with an inclination of  $2^0 \div 10^0$ . There were thick beds of sandstones in the main roof of both workings (Fig.3). The average compressive strength of coarse sandstone was 66 MPa, medium sandstone – 71 MPa in Connection Roadway Z3 and 56 MPa - coarse sandstone, 65 MPa - medium sandstone and 59 shale in Maingate 2. There were some mudstones in the floor and thick layers of sandstones too [3].

There was a yielding steel arch support V36 (unit weight 36 kg per metre of length), 3.5 m height and 5.5 m width, with increment 1.2 m in Connection Roadway Z3 and 1.5m in Maingate 2. Strand bolts were applied every second arch set with the length of 5.0 m. There was no influence of other workings on Maingate 2 and there was a running panel of 35m over Connection Roadway Z3.

The endoscopic research by an infrared camera was done initially in the boreholes. No cracks were displayed in Connection Roadway Z3 roof and only a few cracks until the depth of 0.7m in Maingate 2.

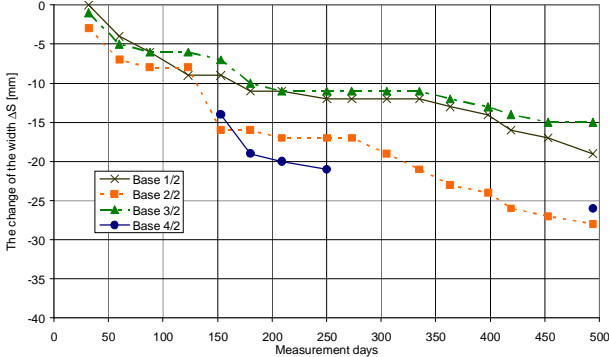


Fig.4 The change of width of Connection Roadway Z3

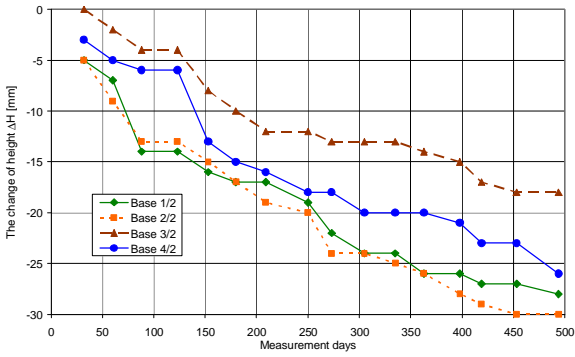


Fig.5 The change of height of Connection Roadway Z3

The results of convergence measurements carried out in the joint roadway Z3 shows that there was no problem to ensure the working stability (Fig.4 and Fig.5). After nearly 500 days of researching time average change of width was 22 mm and average change of height was 25mm. The tend of the convergence was linear, so it can be supposed that stand-up time of this working is several years with none other support applied.

It is interesting that the forces from rock mass pressure in the standing support were very low – about 30÷40 kN (Fig.6). It shows in fact that the sandstone rock layers didn't separate and the massiff was very stiff. Simultaneously the load bearing of the standing support LP9/V36/4 was 255 kN before the clamp sliding. 40 kN is only 16% of its load-bearing capacity [7].

Looking at Figure 7 you can see how high the axial forces were in the instrumented bolt with the 2.5m length fixing in the roof. The range from -160kN to 120 kN shows that roof movements were both up and down. Taking into consideration that the maximum load bearing of strand bolts is 200÷400 kN (in this case – 280 kN), they were only working below half of their load-bearing capacity, even strand bolts were not applied to every plot between arches, but to every second plot. It also shows that the stiff roof layers can not only decline but can move in opposite direction to the space of the roadway from time to time.

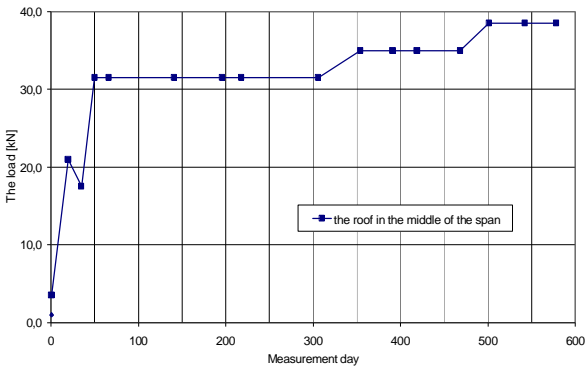


Fig.6 Rock mass load on the standing support in Connection Roadway Z3

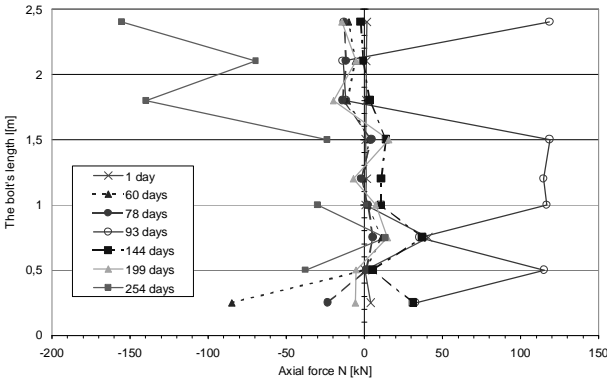


Fig.7 Axial force in the instrumented bolt in Connection Roadway Z3

The results of und research carried out in the Maingate 2 were very similar. The convergence of the working was also inconsiderable. The avearge horizontal convergence was ca. 13mm with the range 6÷28 mm (Fig.8). The average vertical convergence was ca. 20mm with the range 7÷51 mm (Fig.9). Both average values could be lower but there were higher increments of the convergence on Base 7 and Base 9. Although the time of measurements was only half a year one can say that such a low change of the working dimensions absolutly ensures its stability.

Results of the load control can be seen in Figures 10 and 11. Hydraulic dynamometers fixed on the roof-bar and under both side arches indicated that the load on the support frame was asymmetric and its' value is very low from 13 kN to 26 kN. Comparing it to the load-bearing

capacity which for this type of frame (ŁP9/V29/4) is 210 kN, it is easy to conclude that it was working until the range of 13% of its maximum load possibility [7].

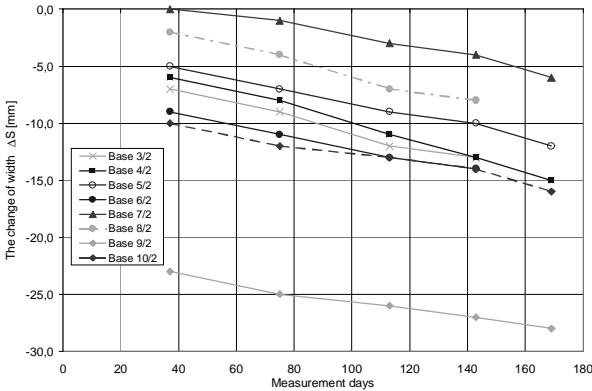


Fig.8 The change of width of Maingate 2

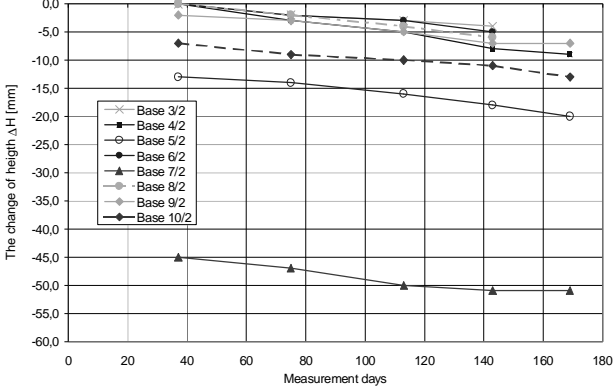


Fig.9 The change of height of Maingate 2

Axial force in the instrumented bolt is lower than in the joint roadway Z3. Its value was maximum of 41 kN. It means that strand bolts were loaded very poor.

In both cases one can say that roof bed separation nearly didn't occur. The reinforcement in such a stiff rock mass improved the load-bearing capacity essentially.

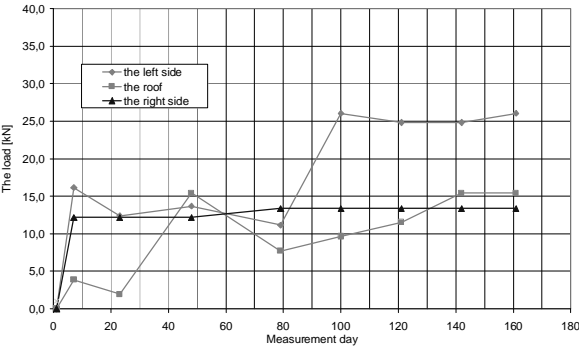


Fig.10 Rock mass load on the standing support of Maingate 2

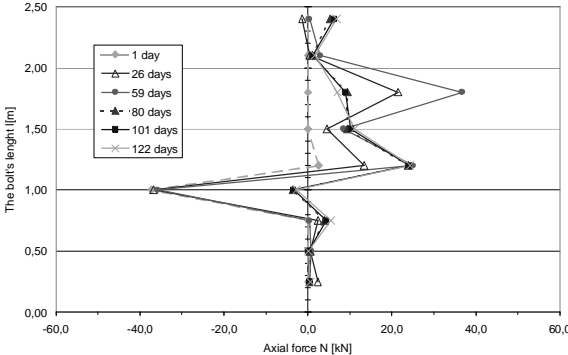


Fig.11 Axial force in the instrumented bolt in Maingate 2

**4. Using strand bolts in weak rocks**

If you want to use bolts in weak rocks it is very important to firstly check the level of fracture intensity around the working. If there are a lot of cracks and fractures, especially in the roof, the effectiveness of bolting can be unsatisfactory. You can use the endoscope for the purpose of observing discontinuities in the face and you can fix telltales in the roof or sides to control the separation intensity.

Experience in using strand bolts in weak roofs, usually in shales or schists, indicates that you can't build bolts between arches of standing support. The better effect is to use crown runners fixed to the roof bars by bolts (Fig.12). The typical use of such a mixed support shows the

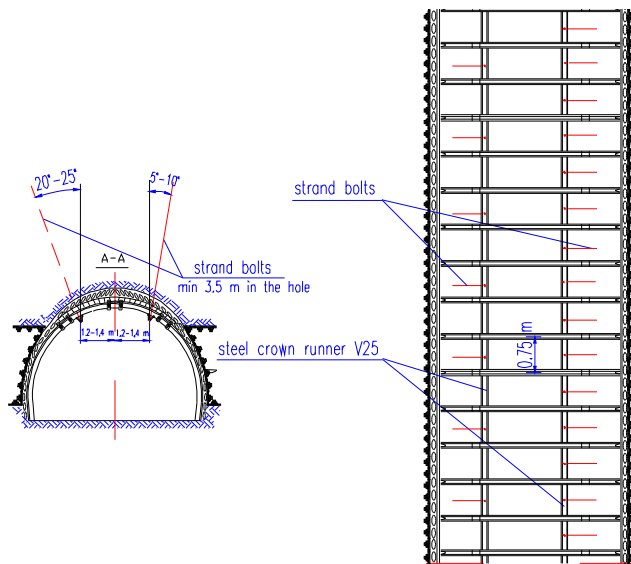


Fig.12 The typical scheme of standing-and-roof bolting support in weak bedded rocks

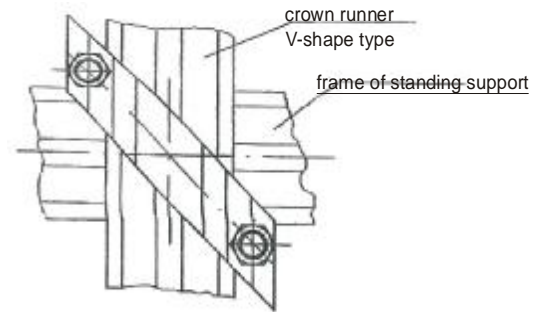


Fig.13 Special slanted clamp for crown runners fixed by bolts

There are two lanes of crown runners with holes. The strand bolts are fixed to the immediate roof by the holes. The crown runners are joined with the standing support roof-bars by special slanted clamps (Fig.13). For gates application the bolts are built to every plot between standing support from the longwall panel side and to every second plot from the solid.

scheme on Figure 12. There are two lanes of crown runners with holes. The strand

There is an examples of using strand bolts in shales in Roadway B-7. There was a coal seam thickness  $1,41 \div 1,81$  m with an inclination of about  $5^0$ . The average compressive strength of rock beds are as follows: shale and sandy shale – 82 MPa and mudstone – 95 MPa (Fig.14). There were shales in the immediate floor, then mudstones and sandstones. In fact the rock mass in the site was not weak but very bedded. There were also some caving edges over the roadway B-7 with the distance of  $17 \div 120$ m.

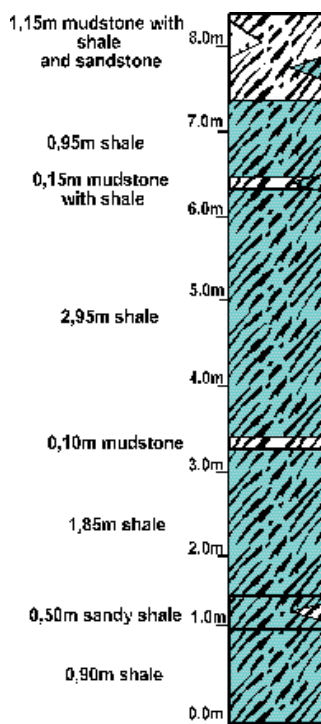


Fig. 14. Roadway B-7 lithology

The main support was the yielding steel standing arches LP9/V29 type. In order to determine separation the endoscopic research was carried out and there were only few cracks in the roof. Then the sonic probe was used to control the rock mass movements in the roof. The operation of the gauge was based on changing of the position of magnetic anchors fixed to the rocks in the borehole.

The values of separation measured in a nearly 400-day period were between -13 and 72mm. The most significant separation occurred in a distance of 0.5 from the working's contour, but generally they were very low.

Measurements of convergence were carried out using laser distance

meter. The maximum value of the horizontal convergence was 60mm but one has to notice that both the increase and decrease of the roadway's width was observed (Fig.17). The vertical convergence was also negative and positive (from -112mm to 108mm – Fig 18). All presented values were higher than for sandstones roof in Connection Roadway Z3 and Maingate 2. In this case the longwall face was approached but the nearest distance to it (in the last day of measurement series) was 80÷130m. This means that however, the general size of workings consequently decreases, the roof can occasionally go up and sides can occasionally go outwards. The intensity of convergence is strictly dependent on the type of rocks, their strength and their bedding in the place of research.

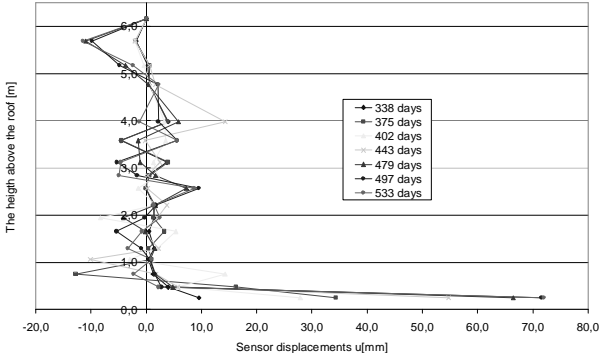


Fig.15 Roof layers displacement in Roadway B-7

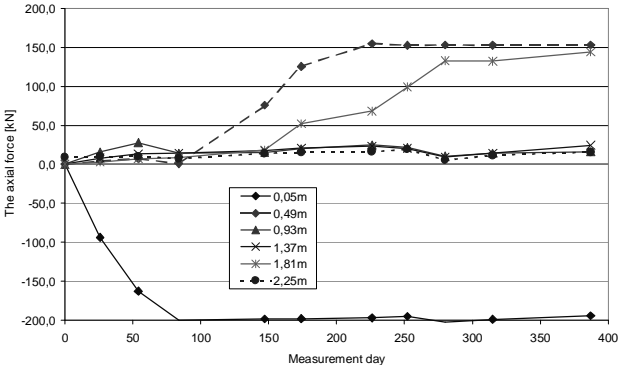


Fig.16 Axial force in the instrumented bolt in Roadway B-7

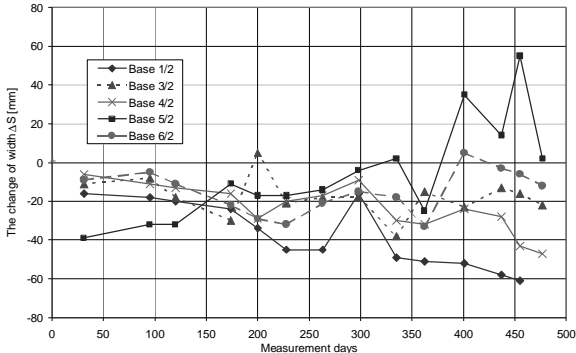


Fig.17 The change of width of Roadway B-7

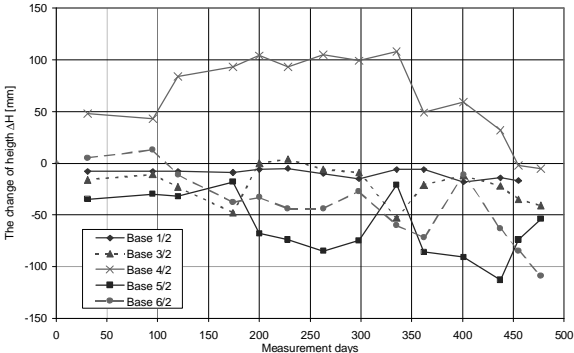


Fig.18 The change of height of Roadway B-7

**5. Summarize**

1. The mixed standing-and-roof bolting support can be applied in any type of rocks. Experience gives that you should use strand bolts between arches of steel support in hard rocks and use crown runners to fix the steel support by strand bolts in weak rocks.
2. It is very essential to check the intensity of discontinuities before bolting. The effectiveness depends strictly on the range of crack zone and the separation of layers

in the roof. The best way of bolting is to do it right in the heading face, together with building the standing support.

3. The mixed support improves the working's stability significantly. If there is no gob influence on a working, the convergence in hard carbiferous rocks is ca. 15÷20mm per year and in weak rocks – ca. 50÷100mm per year.
4. The loading capacity of combined support is significantly higher than in the single one, as it allows to build a reinforced standing support even into a bigger distance. The application of bolts in gates also gives a possibility for sustaining the gate for neighbouring designed longwall panel.

### **Bibliography**

1. Hoek E., Kaiser P.K., Bawden W.F.: *Support of Underground Excavations in Hard Rock*. A.A. Balkema, Rotterdam/Brookfield, 1995.
2. Li C. C.: *Design Principles and Desired Performance of Bolts for Rock Support Deep Mining*. Sixth International Symposium: Rockbolting in Mining & Injection Technology and Roadway Support Systems. Des Instituts fuer Bergbaukunde I an der RWTH Aachen 14-15.05.2008. Aachen 2008, s.101-120.
3. Majcherczyk T. Małkowski P. Niedbalski Z.: *Badania nowych rozwiązań technologicznych w celu rozrzedzania obudowy podporowej w wyrobiskach korytarzowych*. Monografia, Uczelniane Wydawnictwa Naukowo-Dydaktyczne AGH, Kraków 2009 (in printing).
4. Majcherczyk T. Małkowski P. Niedbalski Z.: *Ruchy górotworu i reakcje obudowy w procesie niszczenia skał wokół wyrobisk korytarzowych na podstawie badań „in situ”*, Monografia, Katedra Geomechaniki, Budownictwa i Geotechniki AGH, Kraków 2006.
5. Majcherczyk T. Małkowski P. Niedbalski Z.: *Strata control in underground tunnels – perspectives for development*. Kwartalnik AGH: Górnictwo i Geoinżynieria, Kraków 2005, R. 29, z. 3/2 s. 61–76.
6. Praca zbiorowa pod redakcją K. Rułki: *Stalowe obudowy odrzwiowe. Nowe rozwiązania konstrukcyjne i metody projektowania*. Wydawnictwa Głównego Instytutu Górnictwa, Katowice 2006.
7. [www.hutalab.pl](http://www.hutalab.pl)