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Development process of introducing new stell arch in supporting roadways at Velenje Coal Mine

Vpeljava novega jeklenega ločnega podporja pri gradnji prog v Premogovniku Velenje

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Abstract

Due to increasingly demanding montan geological conditions in the Velenje Coal Mine, centralization of excavation (excavation of pit Pesje and Preloge are coming closer to each other and this leads to interactions), because of greater depths and increasing pressures we accede to the introduction of a new type of steel arch support TH29. The differences between the old K24 and the new TH29 supports is in the form of profile that enables continuous loosening and less threat in the release of rock burst in the roadways. Another difference is in material itself, the old steel arch were thermally processed (quenched and tempered), the new material has adequate strength ensured with the appropriate metallurgical additives and additional processing is not required, so production cost are achieved in savings. New steel arch support provides greater load capacity and lower risk for release of rock burst in the roadways. Introducing the new steel arch support units is a very complex operation, because this means changes in the technological process, even logistics and maintenance of equipment for repairing steel arch support.

Key words: coalmine, steel arch support, metallurgical additives, roadways, TH29 support, K24 support

Izvleček

Zaradi vse bolj zahtevnih montan geoloških razmer v Premogovniku Velenje, centralizacije odkopavanja (jami Pesje in Preloge se z odkopi vse bolj približujeta druga drugi in zaradi tega prihaja do medsebojnih vplivov), zaradi večjih globin in vse večjih pritiskov smo začeli uvajati nov tip jeklenega ločnega podporja TH29. Razlike med starim podporjem K24 in novim TH29 so v obliki profila, ki omogoča bolj zvezno popuščanje in s tem manjšo nevarnost pri sprostitvah napetosti v jamskih progah. Druga razlika pa je v samem materialu, ki je bil pri starem podporju dodatno termično obdelan (poboljšan oz. kaljen), novi material pa ima ustrezno trdnost zagotovljeno z ustreznimi metalurškimi dodatki in dodatne obdelave tako niso potrebne, zaradi česar je dosežen prihranek pri proizvodni ceni. Novo podporje zagotavlja večjo nosilnost in manjšo nevarnost za sprostitve napetosti v jamskih progah. Uvajanje novega podporja je zelo kompleksna operacija, saj za sabo potegne spremembe v tehnološkem procesu, celo logistiko in vzdrževanje opreme za popravilo jeklenega ločnega podporja.

Ključne besede: premogovnik, jekleno ločno podporje, toplotna obdelava, jamske proge, podporje TH29, podporje K24

Introduction

For many years, the Velenje Coal Mine has been systematically engaged in development in the construction of roadways. With the development we adapt to the increasingly demanding roadway construction conditions and to the increased needs of the load-bearing capacity of the pit support. With the development and introduction of new mechanical equipment, the need for greater loading gauge of the roadway increased. Thus the development of installation of support elements led to introduction of innovations in supporting the roadways with steel arch support. We have successfully introduced new screw clamps which helped us achieve greater carrying capacity of joints, ties between the frames of the steel arch support and anchoring substructure. At the moment, the potential for improvement is seen in the use of the new type of the steel arch support – TH29.

Currently, the most widely used arch support in the Velenje Coal Mine is K24. This type of steel arch support is thermally treated, as such treatment improves its load-bearing capacity characteristics. However, the required load-bearing capacity of the support is increasing due to pit centralization, excavation impact, and increasing depths, and can no longer be reached by reducing the distance between the arches. For that reason we started testing a new type of steel arch support TH29 for roadway construction.

Table 1: *Characteristics of the K24 arch support*

Yield limit (MPa)	Min. 510
Plasticity limit (MPa)	690–930
Moment of inertia (cm^4)	372.37
Mass (kg/m)	23.67

Table 2: *Characteristics of the TH29 arch support*

Yield limit (MPa)	Min. 480
Plasticity limit (MPa)	650
Moment of inertia (cm^4)	598.0
Mass (kg/m)	29.00

Comparison of characteristics of K24 and TH29 arch support

Currently, the K24 arch support is used in the pit of the Velenje Coal Mine. This type of support is thermally treated (tempered), which means that the arch is more steeled. In cases where there is major pressure on the K24 steel arch support, discontinuous yield of arch support occurs (instantaneous release).

The new arches TH29, which are still being tested at the pit, are softer than the K24 arches, but certain metallurgical additives improve their load-bearing capacity characteristics. They have a higher moment of resistance which is the result of a larger cross section of the arch. Under the increased pressure, these arches are a lot friendlier to the material itself. In the event of increased pressure, these arches continually yield and there is no instantaneous movement of the arcs as in the K24 support.

It is evident from the tables that the mass of the arches only differs by 4 kg/m. Despite the fact that the K24 arch has been thermally treated, its yield limit is only 9 % higher than in the TH29 arch, to which only certain chemical compounds have been added. When comparing the moment of inertia in arch supports, we determined that the moment of inertia was 62 % higher in TH29 arch support than in K24 arch support. Therefore, as far as the load-bearing capacity is concerned, the T29 arches are more appropriate for installation in the pit of the Velenje Coal Mine[1].

In addition to the difference in material between the arches K24 and TH29, the difference is also in their cross sections and in abutment of arches. In the K24 arch, the arches abut on a greater surface than in the TH29 arch, where the arches only abut on the edges. The difference in the shape of the arches is visible in Figures 1 and 2.

Figure 1: *Cross section of the arch K24 (left).*
Figure 2: *Cross section of the arch TH29 (right).*

Laboratory tests of steel arch support

Numerous laboratory tests were carried out on the new TH29 arches and on the K24 arches before the installation of the new arch support began. The tests were performed in a certified laboratory for mining support testing in Opava, Czech Republic.
The following tests were carried out:

Test A: Standard joint carrying capacity test according to CSN 44 4410 or DIN 21538 standard

Test B: Bending joint test according to DIN 21538-2003-5 standard

Performance of the tests

The tests were ordered by our supplier of steel arch support and their representative was present at the laboratory. The laboratory has all the necessary accreditations and is engaged in testing of steel arch support for the mines and for the manufacturers of steel arch support elements, located nearby. They also carry out stress tests of wide-front support and hydraulic cylinders. They also have an electrical department where they test the electrical mining equipment[1].

Results of the tests

Summary of test results for joint carrying capacity (Table 3).

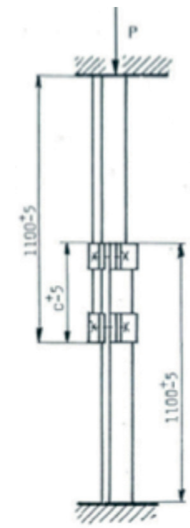

Figure 3: *Illustration of test A.*

Screw tightening torque 400 Nm
Arch covering: 450 mm

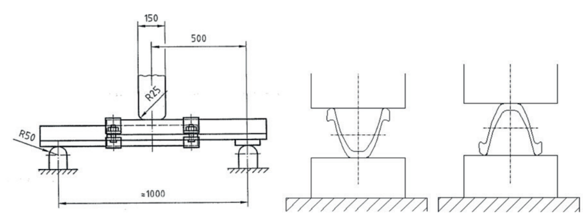

Figure 4: *Illustration of test B.*

Screw tightening torque 400 Nm
Arch covering: 450 mm

Bending test results

The sample was tested according to DIN 21530-4 Art. 4.1.2.2.2 “Biegetrag fähigkeit” – joint load bending test. Maximum force F_{max} was measured in the test. The test ended with the maximum bending of the sample, allowed by the test device. The value was determined by the reading from the graph (Table 4).

Conclusions of the tests

Sliding joint carrying capacity decreases with the wear of the arch to 15–20 % in arches that are worn out to the extent that they cannot be used and to 10 % with the used arches R2 which can still be used. The load-bearing capacity of R1 quality arches is practically the same as in the new ones.

Bending joint carrying capacity is decreasing with the wear of the arch in the same proportion, on average, as in the sliding tests.
Tightening. When testing sliding joint carrying capacity, the joint carrying capacity is even more dependent on the tightening torque than it is in the new arches. Applying additional tightening is of little use if the arch does not sit better in the joint after the tightening. This phenomenon is even more present, due to the fact that the arches that have already been repaired, are bent. Therefore, maximum attention should also be given to proper functioning of tightening machines in the nut tightening stage also in the future. It would be reasonable to introduce further joint tightening when they start to yield – it is best to do it just before making the cover. The reason for that is in the form of the K support – which is slightly deformed in the used ones; a greater number of turns of the thread is needed for the arch to sit in the other arch. This phenomenon is much less present in the TH support, as the latter does not rest on the wedge but on the edge of the joint[1].

Table 3: *The stated values are calculated as the average of three test items for each quality*

Sample	Central sliding joint carrying capacity N_{zsr}/kN	Maximum sliding joint carrying capacity $N_{Z\ max}$ F_{max}/kN	Measurement uncertainty U/kN
R1	372.9	431.0	3.3
R2	355.7	394.8	3.1
R3	305.7	377.9	3.2

Table 4: *The stated values are calculated as the average of three test items for each quality*

Sample	Demolition - type	Load F_{max}/kN	Measurement uncertainty U/kN
R1	yes - screws	621.4	5.0
R2	yes - screws	574.3	4.8
R3	yes - arch	512.7	4.6

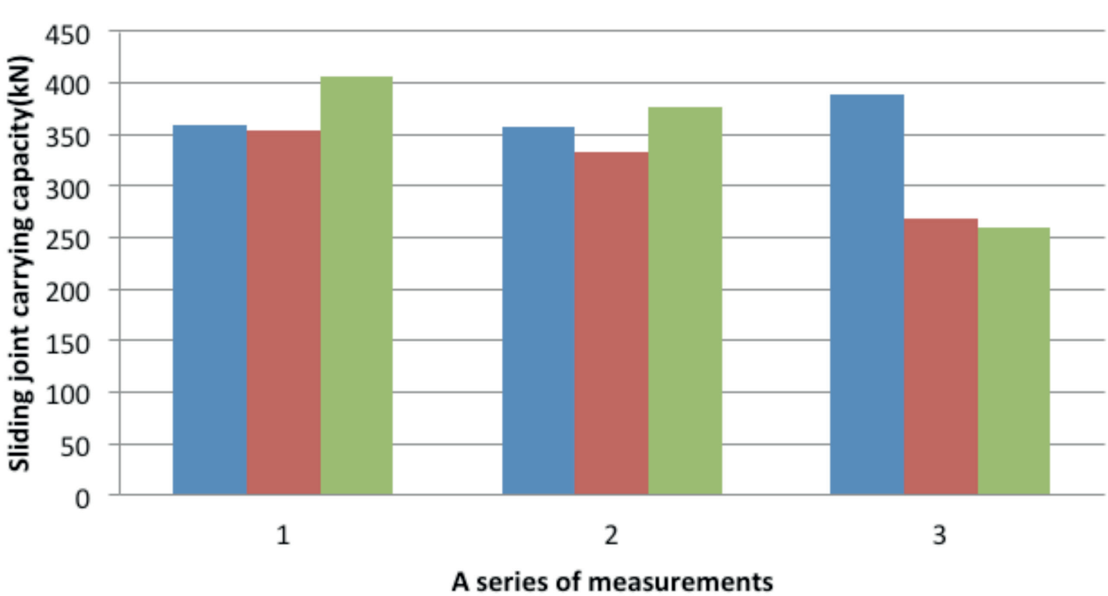

Figure 5: *Sliding joint carrying capacity (kN).*

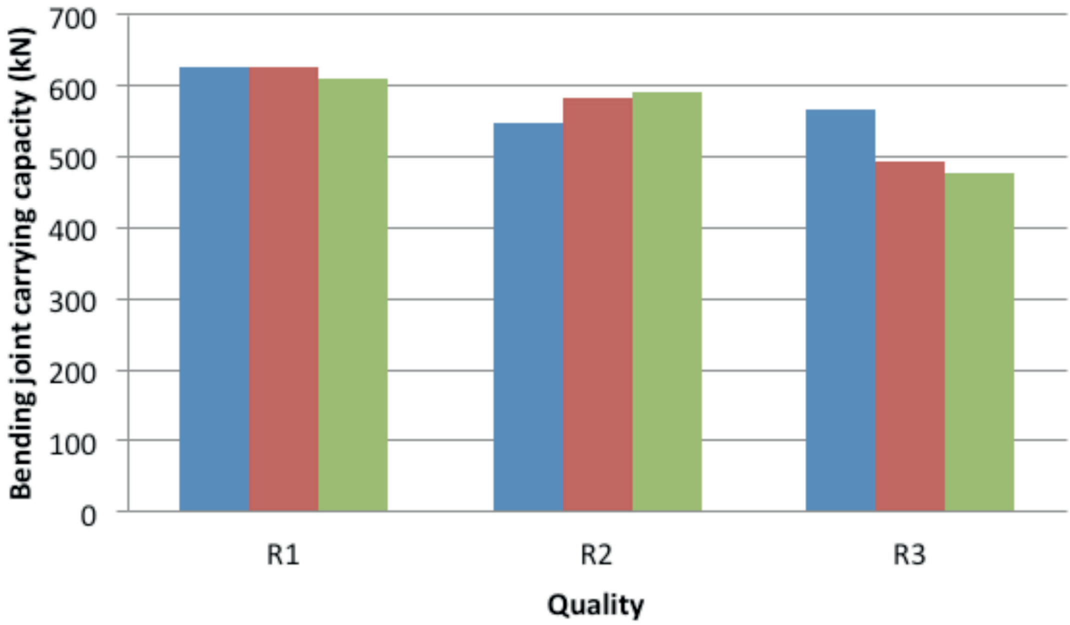

Figure 6: *Bending joint carrying capacity.*

Tearing of screws. Tearing of screws occurred in all cases, except in the R3 quality (the worst) when the arch yielded. Strong deformation of the screw occurred in all cases in the axial direction and in the rear and front zone (see Figures). It was also necessary to modify the test device in this series of tests. If it is assessed that the tearing of the M20 screws is a problem, it would be reasonable to start using the M24 screws. This will not eliminate the problem, but it will be present to a lesser extent[1].

Yielding of the arches is even more impetuous than with the new K24 arches. We have assessed that the yielding in TH29 arches is less impetuous and that less energy is released in the process. The introduction of TH29 would also have a positive impact on reducing the number of accidents due to the release of tension. On one hand, the reason for that is the form of the profile, where the sliding occurs on the edge of the profile and less on the side (side of the profile). On the other hand, however, the TH29 material is softer and contains less steel and consequently accumulates less energy which is released upon the release of tension[1].

Tests in the pit of the Velenje Coal Mine

In the recent years, we have carried out several tests of installation of TH29 arches in the pit of the Velenje Coal Mine. The first test was performed at the outlet roadway of the A k–130 excavation site in the Preloge pit.

The first section in the length of 13.4 m was installed 90 m away from the assembly chamber of the excavation site, whereas the second section in the length of 17.5 m was installed 458 m away from the assembly chamber of the excavation site (Figure 7). The rest of the outlet roadway was supported by the K24 steel arch support[2].

In the first test section, stirrup clamps were used in the installation of the K24 steel arch support, while in the TH29 steel arch support, new screw clamps were used (Figure 7). In the second test section, the new screw clamps were used in the K24 steel arch support and in the TH29 steel arch support (Figure 7).

By testing the TH29 steel arch support (the first section), the following conclusions were made:

— JLP TH29 tolerates the arising pressure well,
— deformations of JLP are small and occur approx. 3–5 m before the excavation site.

Deformations in both types of the arch support were only shown in slips (covering of the steel arch support).

Only the straight floor arches K24 and TH29 were deformed (rolled in a spiral), but no other deformations were observed in TH29.

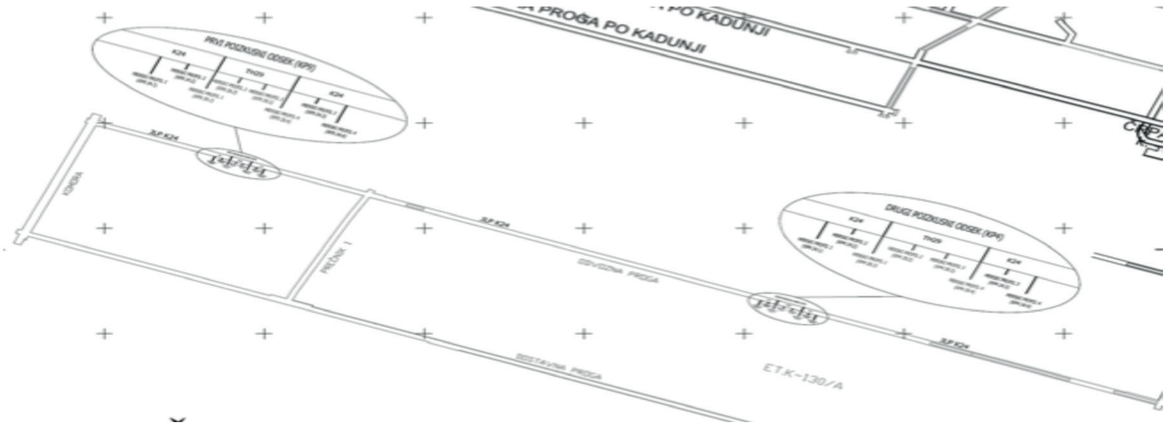

Figure 7: *Test locations.*

Comparison of the measurement results of the first test section shows that:

1. The TH29 arches started yielding somewhat sooner and to a somewhat greater extent. On average, the TH29 arches started yielding 1.5 weeks (11 d) before pillaging. However, on average, the K24 arches started yielding 1 week (7 d) before pillaging.
2. On the joint (covering), the TH29 arches yielded to a somewhat greater extent than the K24 arches. The average measured slip at the K24 joint was 3.25 cm on the left and 5 cm on the right side. The average measured slip at the TH29 joint was 4.5 cm on the left and 8.5 cm on the right side.

Visual assessment of arch bending at the mouth of the excavation shows that the TH29 arches are far less deformed than the K24 arches. Since the deformations are very small, this cannot be assessed according to the assessment key.

The first assessment shows that in the second and third uses, the ZH29 arches would be less deformed than the K24 arches and the percentage of reuse could be higher. The reason for that is a more favourable ratio between the yield and the bending carrying capacity of the arch.

No major problems occurred due to the weight of the arches in the construction (pillaging) of the steel arch support. However, it has been assessed that the arches of 29 kg/m represented the upper limit of acceptability for manual handling.

The second test of TH29 arch installation was performed at the outlet roadway of the G3/C excavation site in the Preloge pit (north wing). The distance between the frames was 0.5 m, because we wanted to check if these arches can bear greater loads and to determine the consequences at the time of the crossing of the adjacent excavation site –65/F and of the excavation site for which this outlet roadway is intended (G3/C).

The first section in the length of 30.0 m was installed 606 m away from the assembly chamber of the excavation site G3/C, whereas the second section in the length of 40.5 m was installed 576 m away from the assembly chamber of the excavation site. The rest of the outlet roadway was supported by the K24 steel arch support (spacing between the frames is 37 cm).

In the first test section, repaired arches were used in the installation of the TH29 steel arch support, which had already been installed in the outlet roadway K.–130A, in combination with the new screw clamps. The new TH29 arches were installed in the second section, also in combination with the new screw clamps.

Convergence profiles were also installed in these two test locations. The first profile is located at 245 m and the second at 260 m from the starting point of the outlet roadway. Periodic profile measurements are performed at these two locations, in order to obtain information on the extent of deformation, caused by the pressure on the steel arch support.

Monitoring of measurements of the convergence profiles has shown no significant support deformation. The first deformations in these sections can be expected in the crossing of the adjacent excavation –65/F through these sections. Another impact will come from the crown of G3/C in the crossing of these two sections[2].

Results of the convergence point measurements on the test sections

Convergence profiles are measured every 14 d. It can be concluded, according to the obtained results, that the support is well tolerant of rock pressure, as the support displacement was minimal.

Conclusion

The method of introducing new support elements in pit roadways and the technological process of construction can be regarded as successful, particularly in testing and introduction of new arch support TH29. However, at this point we cannot say that we recommend the replacement of support, despite some successful experiments in the pit and good laboratory results. Definitive introduction of new support elements requires changes in the entire technological process of repairs of these support elements. In addition, we need to get further information on the behaviour of this type of arch support by carrying out additional tests in the pit.

Its successful introduction would bring at least 65 % increase in load-bearing capacity due to a higher moment of resistance and weaker yield due to the shape of the profile and less steel material.

The introduction of TH29 support is necessary in the light of the increasingly demanding conditions. Namely, with the roadways and excavations, the conditions are such that we no longer achieve the necessary load-bearing capacity by reducing the distance between the frames of the steel arch supports.

Table 5: *Measurements of the convergence*

Date of installation	Date of measurement	Method of measurement	Length of profile sides (mm)		
			side A	side B	side C
20 July 2012	25 July 2012	measurement lath	3 110	3 152	4 545
	7 August 2012	measurement lath	3 110	3 152	4 545
	13 August 2012	measurement lath	3 110	3 152	4 545
	29 August 2012	measurement lath	3 109	3 152	4 543
	27 September 2012	measurement lath	3 100	3 152	4 534
	4 October 2012	measurement lath			
	15 January 2013	measurement lath	3 098	3 152	4 536
	1 February 2013	measurement lath	3 098	3 152	4 536
	15 February 2013	measurement lath	3 098	3 152	4 536

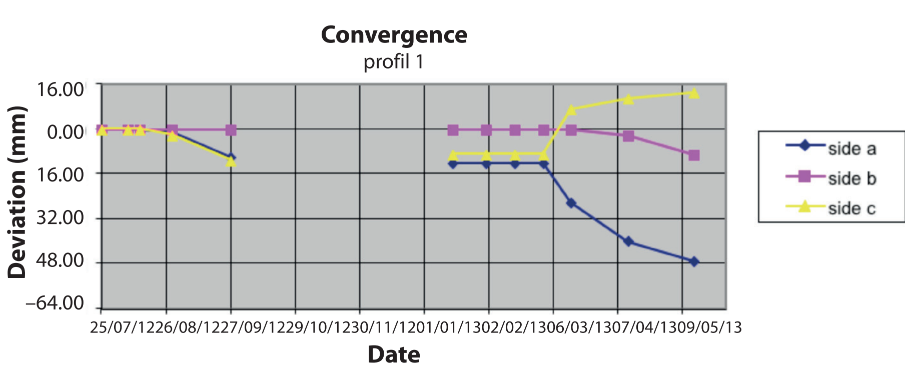

Figure 8: *Measurement of convergences on profile 1.*

References

[1] Pohorec I., Sotler B., Mayer J., Lednik S. (2011): Zbor poizkusov v okviru razvojne skupine za izdelavo etažnih jamskih prog v Premogovniku Velenje za leto 2011. Tehnična dokumentacija Premogovnika Velenje, pp. 62–69.

[2] Pohorec I., Sotler B., Mayer J., Lednik S. (2012): Zbor poizkusov v okviru razvojne skupine za izdelavo etažnih jamskih prog v Premogovniku Velenje za leto 2012. Tehnična dokumentacija Premogovnika Velenje, pp. 35–44.