

## Modernization of technological process and equipment at floor level roadways execution in Velenje coal mine

### Modernizacija tehnoloških procesov in opreme pri gradnji jamskih prog v Premogovniku Velenje

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**Abstract:** In the period from 2008 to 2010 Premogovnik Velenje (Velenje Coal Mine) carried out an extensive research and development project on modernization of technological processes, materials and equipment needed in construction of the floor level roadways. The main purpose of this research project was a comprehensive update of all key processes in construction of roadways, which contribute to increasing advances in highly productive extraction by divergent method of mining, especially in the working phase of dismantling the steel arch support units on the accession lines during extraction. In the technological process of building floor level roadway elements such as a steel arch supports, wooden panels, composite bolts, composite nets and various insulating coatings that prevent the formation of oxidation processes are used for support. The bright roadway diameter lines represent the modified steel arches shape where the cross section ranges from 13 to 18 m<sup>2</sup>. Due to technological changes and new support elements a new appropriate shape of the roadway profile was constructed, tested and introduced. As well, new screw clamps, wire clamps for screw clamps and the new struts for connecting steel arch line frame supports were introduced. Analysis and the load bearing capacity tests of supports were carried out with intention of re-installing. There were several experiments, on the surface and underground, on materials and technologies which are used for isolation procedures. Experimental results during the construction phase were rather excellent, the situation will

be monitored further on in 2011, so a comprehensive technical evaluation could be defined. In case of equipment an extensive work has been done. A new conveyer, a mobile conveyor belt with continuous lengthening, won all the parameters which enable continuous operation without physical assistance. New feeder bars were introduced. In the field of equipment development the research was primarily aimed on complete mechanization and automation of all phases of roadway construction work and thus greatly improved security, technical and economic parameters. In this paper all the important achievements in the floor level roadways construction are presented.

**Izveček:** Premogovnik Velenje je v letih od 2008 do vključno 2010 izvedel obsežen razvojno-raziskovalni projekt pri modernizaciji tehnoloških procesov, materialov in opreme pri gradnji etažnih jamskih prog. Temeljni cilj razvojnega projekta je bil celovita posodobitev vseh ključnih procesov gradnje jamskih prog, ki bistveno pripomorejo k povečanju napredkov na visokoproduktivnih odkopih z odstopajočim načinom odkopavanja, predvsem pri delovni fazi demontaže jeklenega ločnega podporja v pristopnih progah ob napredovanju odkopa. V tehnološkem procesu gradnje jamskih prog se uporabljajo podgradni elementi v obliki jeklenega ločnega podporja, lesenega opaža, kompozitnih mrež in kompozitnih sider ter različnih izolacijskih oblog, ki preprečujejo nastanek oksidacijskih procesov. Svetli premer jamske proge so modificirani profili dimenzij od 13 m<sup>2</sup> do 17 m<sup>2</sup>. Na področju tehnoloških sprememb in novih podgradnih elementov je bil konstruiran, preizkušen in uveden nov ustrežnejši profil gradnje jamskih prog. Poleg tega so bile uvedene nove vijačne objemke, žične sponge za vijačne objemke in nove veznice za povezovanje okvirjev jeklenega ločnega podporja. Izvedena je bila analiza in preizkusi nosilnosti ločnega podporja, ki je namenjeno za ponovno vgradnjo. Na področju materialov in tehnologij izdelave izolacijskih oblog je bila izvedena vrsta poizkusov na površini in v jami. Rezultati poizkusov so bili v fazi gradnje dobri, stanje bomo spremljali še ob prehodu odkopa ob koncu leta 2011 in tako podali celovito tehnično oceno. Na področju opreme za delovišča je bilo opravljeno obsežno delo. Uveden je bil nov napredovalni stroj, pomični transporter, trak s kontinuiranim daljšanjem, osvojeni so bili vsi parametri avtomatizacije odvozov, ki omogočajo obratovanje odvoza brez posadk. Uveden je bil novi podajalnik lokov. Na področju opreme je bilo razvojno-raziskovalno delo usmerjeno predvsem v popolno mehanizacijo in avtomatizacijo vseh delovnih faz procesa gradnje jamskih prog in tako močno izboljšanih

varnostnih, tehničnih in ekonomskih parametrov. V prispevku smo celovito predstavili vse dosežke pri gradnji jamskih prog.

**Key words:** floor level roadways, steel arches, composite bolts, roadheader, conveyer, crusher

**Ključne besede:** etažne jamske proge, jekleno ločno podporje, kompozitna sidra, napredovalni stroj, transporter, drobilec

## INTRODUCTION

The starting point of the face development and open-up work is dictated by extreme thickness and geometry of the Velenje coal seam. As these conditions are unique in the world, it has not been possible to select an optimum mining method for years.

Coal extraction is carried out from the hangingwall to footwall of the seam, and it is based on the retreating mining method. This means that it is necessary to prepare all the roadways before starting to extract the coal. As the face advances, the roadways are simultaneously liquidated.

Development constructions, which enable access to the deposit and coal exploitation, are driven partly in the rock mass and mainly in the coal seam. At present, there are about 50 km of roadways driven in the coal deposit. A great concentration of roadways is typical, and all roadways are driven in the exploitation area that ensures nowadays the planned output (4 000 000 t

per year) of the coal mine. With regard to the mining system and the mining output it is necessary to drive about 7 km of roadways a year. The designing of individual floor levels and the sequence of extraction from hangingwall towards the footwall of the seam it is usually limited to the floor level working heights of 15 m. The designing method is conceived so that the level of coal seam exploitation is a maximum one. Each floor level is confined by two drift roads used for airing and for the transportation of coal and material.

A great number of underground structures in a limited exploitation field and their interaction during the exploitation process demand a systematic designing approach in order to achieve the necessary stability of the underground constructions.

While designing and driving the roadways the basic principle is taken into consideration, namely roadways have to remain stable without being additionally maintained or repaired during their life period. This demand can be

fully satisfied only by systematic evaluation of geological and geotechnical conditions, by evaluating other factors which have a significant influence on designing and roadway drivage, and by verification and improving the existent roadway drivage procedures. The qualitative and quantitative parameters collected in this way represent a good basis for the selection of optimal technically technological and economicaly most favourable solutions which can be used at designing method, support elements and at roadway drivage.

#### **INFLUENCING FACTORS IN BUILDING UNDERGROUND STRUCTURES**

Building floor level roadways at PV is affected by many factors<sup>[1]</sup>, which are mutually intertwined, they can be defined as follows:

- natural,
- planning,
- designing,
- technological and
- organizational.

#### **Natural factors**

Natural factors are set out in layer of coal and other materials where facilities are made. These are mainly:

- depth,
- depth inside the layer,
- geomechanical properties,
- tectonics and faults,
- microstructural properties,

- content of gas,
- water content,
- ash content,
- oxidation process susceptibility,
- and others.

#### **Planning factors**

Planning factors are determined by the method of planning and executing works. These are mainly:

- timeliness of preparation works before starting mining,
- the timely start of construction of the roadways,
- assurance of all resources (material, equipment, team),
- the adequacy of planning according to the number construction teams,
- interactions between the structures in terms of planning face out.

#### **Designing factors in terms of required lining capacity**

Designing factors are determined by load bearing capacity of the lining. These are mainly:

- distance from the hangingwall of the seam,
- distance from the old works,
- interaction of the roadways and the longwall face in terms of design,
- location of the roadway in the coal layer,
- method of excavation.

#### **Technological factors**

Technological factors occur in all phases of construction works during

the roadway drivage procedures. These are mainly:

- cutting and preparing the space for the new section,
- supporting,
- building a fire covering and back filling,
- coal transportation,
- material delivery,
- energy supply,
- water drainage,
- ventilation,
- factors affecting the security of the working area.

### **Organizational factors**

Organizational factors are related to the organization of work and contractors in the construction of underground objects. These are mainly:

- corresponding numerical and structural ensemble of performers,
- appropriate knowledge and practical skills of operators,
- adequate motivation of contractors,
- an appropriate organization of working time,
- an appropriate organized execution of the various stages of technological process.

In separate groups the presupposed influential parameters were selected on the basis of mathematical analysis. The link between natural, designing and technological conditions is worked out in the form of a mathematical model. The right choice and selection of in-

fluential parameters was confirmed by comparing the measured convergence with the convergence calculated on the basis of model.

The research of natural, designing and technological conditions resulted in the elaboration of systematization of supporting methods, and in the calculation of the supporting load bearing capacity and of the combination of supporting elements.

Categorisation of geological and geotechnical conditions and the necessary supports load bearing capacity is dealt with separately for three basic groups (trunk, access, gate) of underground roadways.

### **UNDERGROUND STRUCTURES AND EXECUTION METHODS**

PV underground structures are divided into three groups<sup>[3]</sup>:

- the main or trunk underground roadways,
- important or access underground roadways and
- floor level or gate objects (allowed convergence 20 %).

### **Trunk roadways**

Trunk roadways are designed at safety pillar distance totalling 120 m. The allowed common convergence ensuring permanent roadway stability is

estimated at 5 %. In order to ensure the stability of the roadways we have to select the support system with load bearing capacity of at least 450 kPa at 8,35 MPa compressive strength, at least 500 kPa at 5,43 MPa compressive strength, and at least 650 kPa at 3 MPa compressive strength.

### **Access roadways**

They are designed at safety pillar distance which totals 50 m for such roadways. The allowed common convergence of access roadways is 10 %. To ensure the stability at this convergence the load bearing capacity of the supporting system has to total 300 kPa at 8,35 MPa compressive strength, at least 350 kPa at 5,43 MPa compressive strength, and at least 450 kPa at 3MPa compressive strength.

### **Gate roadways**

Besides taking over the influences caused by face advance during the roadway drivage, gate roads have to take load also dynamic tensions developing in front of the active coal face. So the worst case is considered in the categorisation, namely when the face crosses over the roadway. The allowed convergence still enabling the use of roadway is 20 %. To ensure this stability we have to select the support system with load bearing capacity totalling at least 150 kPa at 8,35 MPa uniaxial compressive strength, at least 200 kPa at 5,43 MPa compressive strength, and

at least 300 kPa at 3MPa compressive strength.

### **Roadway drivage**

Technological procedures of driving roadways depend on the use and the life period of roadway. Gate roads are developed exclusively in the coal seam, their life period is on average 1 year. They are supported by girders and wooden struts. The density of building in girders is from 0,83 of girders set per one meter of roadway to 2,5 of set per one meter of driven roadway. As additional supporting measures anchor systems with composite and rope bolts are used, or the isolation of roadway frame with backfilling mixtures made of electrofilter ash functioning at the same time as prevention against the oxidation processes in roadways. Successful use of backfilling mixtures has decreased the range of coal mine fires by more than 95 %, whereas the reconstructions of roadways has been almost completely reduced.

Access roads are supported in a similar way as gate roads, the minimum density of building in girders amounts to 1,66 of set per one meter of driven roadway. Besides this, different anchor systems are included in supporting the roadways. Trunk roadways are supported by girders, bolts, and shotcrete. The life period of this roadways is up to 10 years.

Technological procedures of trunk roadway drivage are represented by the driving technology using concrete or shotcrete combined with anchoring systems. The life period of trunk roadways is more than 10 years, and even to the very end of coal mine exploitation.

### **Technology of building gate roadways with steel arches, isolation and backfilling the frame with fly ash mixtures**

The basic feature of the technology<sup>[2]</sup> is primarily linked on supporting roads with a steel arch supports and filling edge lines with different mixtures of fly ash. This kind of technology is basically used in execution of floor level roadways and also in making access roadways with a shorter life time. By filling voids between wooden panels and the coal in particular security against the development of oxidation processes in coal and the stability of the road is improved.

Excavation of profile is achieved by using roadheader. Profile cutting is usually performed in three phases, which are divided onto the ceiling, side and floor of profile. Step advancement depends of the conditions at working area, ranging from 0.8 m to 1.6 m.

Roadway support consists of steel arches supports and wooden panels placed successively after each phase of

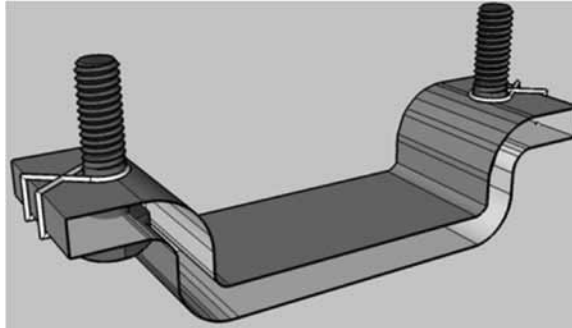
the cutting profile of a roadway. There are severe types of steel arches support profiles used, they consist of 6 or 7 modified profiles.

The advantage of the modified (bell shaped) profile can be determined by providing the same support quality as a circular profile and also offers space advantages in terms of required usable area of the constructed roadway and in phase of excavation

The designed profile area is between 13 m<sup>2</sup> and 18 m<sup>2</sup>. The over all design profile radius is 2 200 mm or 2500 mm. In accordance with increase of a profile the length and the overall weight of support system increases. At present we use K 24 steel arch supports, 24 kg/m weight.

In the past, several types of steel arches supports were tested. In 2011, we installed TH29 steel arches support. First results of the experiment show that this kind of support could be a good choice in replacing the existing K24 steel arches support. Joints in steel arches support units are interconnected with body clamps. Due to the studies and research of capacity of the clamp, the result is that screw clamps which have been tested and implemented had a better performance. Their advantage is represented by a greater strenght of screw clamps, easier remove and when overstressed, it does not fail instantly. Clamp is shown in Figure 1.

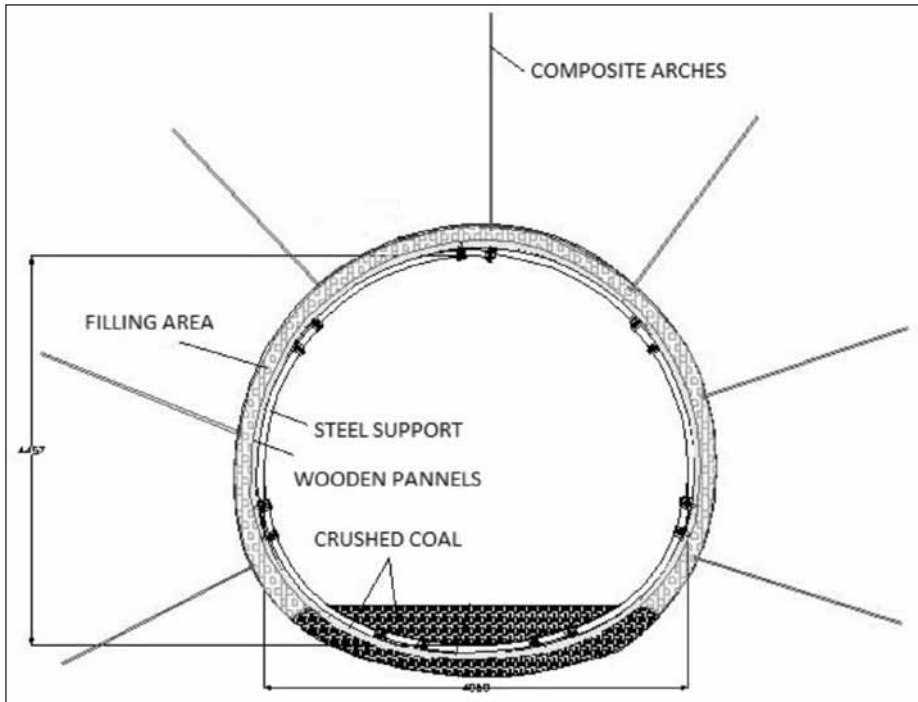




**Figure 1.** Screw Clamp



**Figure 2.** Strut for connecting steel frames of arch support units



**Figure 3.** Cross section of the roadway



To achieve greater stability of roadways steel arches are interconnected on four sides with struts. By replacing the clamp it was necessary to design a new strut, which is shown in Figure 2.

It is possible to combine steel arch support with other types of anchors or bolts. To protect the head wall during construction phase of roadway (from falling pieces of coal) we temporary use composite bolts, which are combined with wooden paneling. For anchoring in the roadway we use steel anchors, composite bolts and plain strand cables. Composite bolts are used in gate roads of the longwall face panel because steel anchors can not be cut by shearer. Composite bolts provide similar load bearing capacity as steel anchors. As using composite bolts the advancement of the longwall face rapidly increases because of the ability of the longwall shearer to cut them. Loading of bore holes for composite bolts is carried out with artificial quick-setting materials. With composite bolts we managed to reduce the overall installation of steel arches supports because the distance between two sets of support is longer. (from 0.4 m to 0.6 m in some cases 0.75 m)

Wood turned out to be the most effective material for framework of the roadway, it provides sufficient support for the pressure of shotcrete filling mixture and it is easier to remove

when necessary. Using this technology wood is economically accepted. For execution of framework we use oak panels, acacia and pine trees, thickness of the panels ranges from 40 mm to 100 mm. As an alternative material for the framework, it is possible to use a composite mash, which is processed in order of good connection with shotcrete materials for outdoor insulation paneling.

With the aim of preventing leakage of thin mixture at filling voids between the framework and the outside material layers it is necessary to seal the framework. It is done by making a thin lining over the entire surface of the roadway.

Two procedures at the same time are provided, excavation and supporting on one hand and isolating and filling-in on the other. Disposition of a roadway is shown in Figure 3.

The results of geotechnical research show that the interaction between installed liner and surrounding materials is efficient when the filling-in of space between them is carried out right after the installation of the liner.<sup>[6]</sup> According to those researches PV changed the roadway excavation procedure and the installation of the necessary liner support.

The excavation area of the roadway face is more extensive because of the addi-

tional installation of shotcrete fly ash filling. Radius of the roadway increases by 150 mm. However, this method is not suitable for the roadway excavation in faulted coal layers where cracking begins right after cutting out the profile.

After cutting the roadway, face steel supports are installed into the segments. Then we install composite mesh which is covered with fabrics. The fabrics prevent from the leakage of fly ash filling mixture. Another alternative is installation of wooden panels, where the outer layer is fabrics with the same assignment as before. When the framework in length between 0.8 m and 1.6 m is finished we immediately fill-in with fly ash filling mixture from the bottom to the top of the framework. Fly ash filling is distributed through high pressure pipelines from the mixing device through the pump to the side. The overall density of the thick filling material consists of a mixture of fly ash, lime, cement, clay, and water in accordance to appropriate recipe.<sup>[5]</sup>

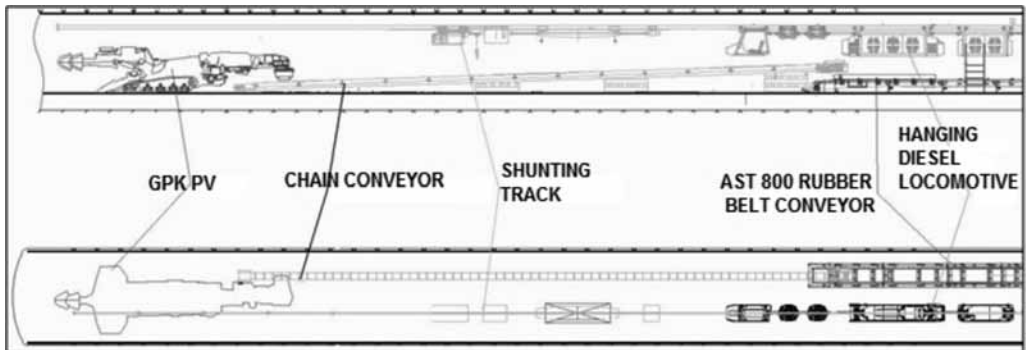
Filling-in is carried out on a distance of 30 m to 50 m from the roadway face. We use a thin mixture of fly ash and water.

### **Development and technological improvements of equipment used in construction of the roadway**

Analysis of equipment at the roadway excavation side showed that it is nec-

essary to achieve greater efficiency and humanization of the technology, and that a comprehensive renewal of equipment is necessary. GPK roadheader was an appropriate solution for the construction of roadways in PV, but it was technologically obsolete. Removal of coal from the roadway excavation site has been edited by a chain conveyor, which length was manually increased or decreased, similar to the belt conveyor. It was also necessary to allocate workers at each conveyor intersection. This method of removal has proven to be economically unappropriate solution. Accordingly the delivery of the materials to the site was arranged by diesel locomotives and monorail transportation and it was proper solution. Delivery of material to the excavation site has been edited by hand, which represented a lot of hard physical work to be carried out for the employees. In Figure 4 there is a drawing of equipment prior to the technological modernization.

Update of the existing and in development of new equipment for the construction of roadways has been linked to all stages of technological processes. The update was made on the cutting roadway face with the new roadheader, on installation of support elements with steel sets of feeding equipment and drilling rig for drilling anchor boreholes, on the crushing and conveying system with a continuous extension of



**Figure 4.** Disposition of equipment on site (before the update)

the transport. The system of roadway excavation has been fully automated. In this paper, we briefly summarize the achievements in the development of equipment in technological processes. [4]

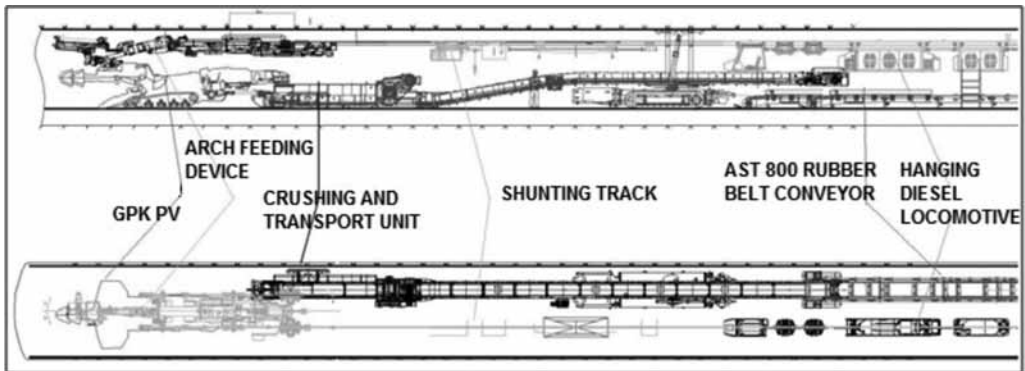
New GPK PV roadheader is the product of Coal Mine Velenje which meets the requirements of the technological process of roadway building from 13 m<sup>2</sup> to 18 m<sup>2</sup>. Electrical equipment for the roadheader has been developed in cooperation with Bartec company. Hydraulic steering system is our own Coal Mine Velenje development result. Steel base structure was built by Russian manufacturer.

Hazemag MCS 27 crushing and conveying system equipped with a continuous extension of the transportation is the product of collaboration between our own experts and the German manufacturer Hazemag. It serves to crush and transport coal between the roadway



**Figure 5.** Automating removal excavations from roadway site

excavation machine and belt conveyor. Crushed coal is transported by a chain conveyor to a belt conveyor. Hazemag MCS 27 crushing and conveying system with a continuous extension of the transportation is self-advanced unit pulled behind belt conveyor 800 AST transporter with a belt width of 800



**Figure 6.** Disposition of equipment at excavation site (after comprehensive technological renovation)

mm designed for conveying coal from excavation site. Conveyor consists of the main steel segments, the drive and convey unit. The unit has ability of continuous belt conveyor lengthening.

Removal of the excavated material with the use of Hazemag unit is fully automated by implemented steering sistem Mincos. Figure 5 shows the control unit.

For updated delivery and installation of material has been developed a new steel sets feeding equipment PL 08 PV. Development of this equipment is the result of collaboration between experts in Coal Mine Velenje and companies DBSS (steel works) and Bartec (steering system). The GTA company has developed a mobile drilling unit for drilling boreholes in the roadway face and anchoring boreholes around the roadway liner. In Figure 6 there is a drawing of equipment at the roadway

excavation site undergoing update of equipment and facilities.

## CONCLUSION

In the years from 2008–2010 there has been an extensive research development in roadway excavation. Update of the existing and development of new equipment for the construction of roadways has been linked to all stages of technological process. Numerous applications of research developments improved all stages of technological processes of roadway excavation. It is absolutely necessary to continue the research development in the future.

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