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## Introduction of standardization of powered roof supports to increase production efficiency of Polska Grupa Górnicza S.A.

*Text* The introduction of the standardization of a powered roof support is a key point in increasing production efficiency in the mines of Polska Grupa Górnicza S.A. The introduced changes will increase the safety of the miners and affect the economic result associated with the exploitation of coal. The purpose of introducing this standardization is to systematize the construction solutions of roof supports in terms of power and control hydraulics, focusing on all technical conditions that powered roof supports operating in underground mining facilities must meet (including mining tremors). This article presents the method of standardizing the powered roof supports that are produced, modernized, and renovated by Zakład Remontowo-Produkcyjny within Polska Grupa Górnicza S.A.

Key words: *standardization, powered roof support, increased production efficiency*

### 1. INTRODUCTION

Polska Grupa Górnicza S.A. (PGG) currently conducts mining work in about 50 longwalls in 8 mines. The average working depth reaches 710 meters. The natural hazards mainly include tremors, methane, and water. The operation is carried out only by longwall systems based on caving, using a combine harvester as a mining machine [1, 2]. The thickness of the longwalls reaches about 2.6 m. The annual production of PGG is about 30 million tons (82 thousand tons a day on average). Supporting and shielding systems equipped with supporting legs are mainly used. Over 60% of the exploitation of longwalls are carried out under conditions of tremor hazards. The degree of the threat of rock mass impact assessed on the basis of the  $n_{tz}$  coefficient ranges from 1.1 to 1.4 [1–3], whereas the  $g$  indicator must stay within a range of 0.7 to over 1.2 to ensure the adequate maintenance of the roof described, which indicates that there is no optimized load-bearing capacity of the roof supports to

the actual needs. Between two and five types of roof supports are used in one longwall, with the basic supply pressure reaching 25 MPa. The majority of the control systems are based on RB, with pilot control being applied much less often. The electro-control has not been applied yet. In some cases, electronic pressure monitoring systems are used. There are about 200 types of roof supports registered. They are mainly supporting and shielding structures with various leg parameters (cylinder diameters, lengths). An exemplary list of the used supports of the selected PGG mines is presented in Table 1.

A considerable number of longwalls are equipped with several types of sections that often differ in their geometry and load-bearing capacity. There are cases when the original elements are replaced with *substitutes of dubious quality* for different reasons. (financial, organizational, no availability of original spare parts). This makes it difficult to exploit and maintain the support to a significant extent and to determine the real causes of a malfunction. It is worth noting

that the majority of powered roof supports operating in PGG's mines have been used for twenty years on average, and there are still supports that were introduced almost thirty years ago. Table 2 presents the number of sections operating in PGG, depending on the year of production.

**Table 1**  
**Exemplary list of used supports**  
**of selected PGG mines**

Type of powered roof support	Range of working height of section [m]
Fazos 08/22 2x2690	1.0–2.1
Fazos 08/22 2x2690-1	1.0–2.1
KW 09/26 POz/ZRP w. III	1.5–2.5
KW 09/26 POz/ZRP/BSN w. III	1.5–2.5
Fazos 16/37 POz	1.7–3.7
Fazos 16/37 POz/BSN	1.7–3.7
KW 16/37 POz/ZRP	1.8–3.6
KW 16/37 POz/ZRP/BSN	1.8–3.6
Tagor 18/36 POz	2.0–3.5
Tagor 18/36 POz/S	2.0–3.5
Fazos 19/35 OzM5	1.9–3.4
KW 20/36 POz/ZRP	2.2–3.5
KW 20/36 POz/ZRP/BSN	2.2–3.5
KW 20/36 POzW1/ZRP	2.2–3.5
KW 14/28 POz/ZRP	1.5–2.7
KW 14/28 POz/ZRP/BSN	1.5–2.7
Fazos 15/31 OzM5	1.7–3.0
BW 20/36 OzMR2	2.5–3.5
BW 17/43POz	2.0–3.6

**Table 2**  
**List of number of power roof supports in PGG with**  
**breakdown per year of production**

Year of production	Number of supports [pcs.]
By 1980	434
1981–2000	6620
2001–2016	8056

The variety of the types and technical solutions complicates the maintenance and the possibility of using working roof supports in other longwalls.

Regardless of the way they are placed on the market, all roof supports are subject to additional assessments of the load-bearing capacity often conducted by a scientific research unit in the case of usage under conditions of rock mass impact. Table 3 shows the number of support sections in PGG, depending on the method of placing on the market.

**Table 3**  
**Number of supports in PGG depending**  
**on method of placing on market**

Year of production	Number of supports [pcs.]	Legal basis for market introduction
By 2004	7443	admission issued by the President of the Higher Mining Office
Since 2004	7667	EC type examination certificate

Currently, roof supports are introduced on the market in compliance with the security requirements set out in the European Parliament's Machinery Directive [4] and harmonized Polish standards PN-EN 1804 series [5–7]. Due to the fact that the standards of the PN-EN 1804 series include a record excluding their validity in the case of rock mass hazard, the support should be adapted by "allowing" it to take over dynamic loads under the Regulation of the Minister of Energy of November 23, 2016, [8] on the detailed requirements for running underground mining facilities (effective July 1, 2017).

In contrast to the previous regulation of the Minister of Economy of June 28, 2002, on the Occupational Health and Safety, Traffic, and Specialized Fire Protection in Underground Mines (valid until July 1, 2017), The new regulation of the Minister of Energy does not recognize the requirement assessment of the possibility of the cooperation between different types of supports in one longwall. This means that, in light of the currently binding legal acts, the assessment of the possibility of the cooperation of several roof supports in one longwall is optional and rests solely on the manager of the mining department, who may support the opinion of appointed teams of consultants. The use of several types of powered roof supports in one longwall leads to a number of issues. Analysis [9] shows that an important stage in the process of adapting the support to the prevailing geological and min-

ing conditions in a given excavation is the selection of its support system [10, 11], strictly resulting from the assessment of roof maintenance index  $g$ . Therefore, for the safe and effective operation of a long-wall complex, further cooperation with the Central Mining Institute is recommended. Roof index  $g$  should be included in the process of selecting the support for the actual operating conditions. This paper presents the standardization process of powered roof supports (both renovated and produced) as a part of PGG S.A.

## 2. RULES FOR OPERATION OF ROOF SUPPORTS

The prospect of meeting the requirements of the market enforces the decisive rationalization of the costs of coal mining through the improvement of the organization, employment, and degree of use of the machinery, which should lead to an increase in daily output from the wall. Such a tendency should be maintained with deteriorating mining conditions and strong external competition. The benefits of the above process include ensuring the operation of the long-wall system as well as the functionality while minimizing the purchase and operation costs.

The standardization was initiated at Zakład Remontowo-Produkcyjny, which has been a branch of Polska Grupa Górnicza for ten years. Cooperation with scientific and research units (including the Main Mining Institute and the KOMAG Institute of Mining Technology) was indispensable. The increasingly difficult mining and geological conditions contribute to the increase in the risk of rock mass shocks, precisely imposing the technical conditions that the powered roof support must meet and indicating the need to standardize the support structure.

Based on an analysis of this state and the anticipated needs for the coming years, the most important directions of action in the field of standardization of the construction of powered roof supports were set out [12]. Determining the basic directions of the standardization of roof support construction has allowed us to optimize roof support management, taking full advantage of the existing powered roof supports and the production potential of Zakład Remontowo-Produkcyjny.

The standardization included three main components of a roof support:

- construction of the section,
- power hydraulics,
- control hydraulics.

For this concept, actions have been taken in the following areas:

- 1) construction of section:
  - adjusting the working height of the powered roof support to the current needs;
  - increasing the load-bearing capacity of the roof support while strengthening the structures of the roof supports owned by PGG;
  - introduction of proprietary procedures – Zakład Remontowo-Produkcyjny has tightened the safety coefficients imposed by standards on the load on stand seats (introduction of Coefficient 2 instead of the required 1.5) [13];
  - introduction of facilities to the roof support at the request of representatives of the mines that facilitate operation and repair;
  - introduction and application of the same auxiliary cylinders for different types of roof supports (longwall face shield actuator, transition cover, side shield correction actuator).
- 2) power hydraulics:
  - legs were limited to one type, with a two-telescopic structure with a bottom valve, with first-stage diameters:
    - 0.21 m – KW-08/22-POz/ZRP, KW-09/26-POz/ZRP,
    - 0.25 m – KW-14/28-POz/ZRP, KW-18/34-POz/ZRP, KW-20/36-POz/ZRP, KW-17/43-POz/ZRP,
    - 0.32 m – KW-16/37-POz/ZRP;
  - hydraulic legs are equipped with ZRP connections:
    - size I: DN12/DN12 – min. flows for 60 MPa 450 l/min at 15% flow losses for a 0.21 m diameter,
    - size II: DN19 / DN12 – min. flows for 60 MPa 650 l/min with flow losses of 15% for a leg with a diameter of 0.25 m and 0.32 m.
- 3) control hydraulics – introduction of a procedure to select the protection of the powered roof support sections against dynamic overloads based on the method of determining the resultant flow of the system: connection-valve (Fig. 1). For this purpose, Zakład Remontowo-Produkcyjny has developed detailed requirements for the purchase of pressure/relief valves.

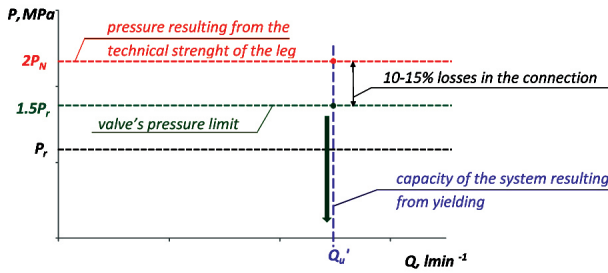


Fig. 1. Method of determining resultant flow of connection-valve system

### 3. DIRECTION OF STANDARDIZATION

The section of the powered roof support in accordance with machinery directive [2] is a machine consisting of a structure as well as power and control hydraulics and, as a whole, should be placed on the market and used unchanged throughout the life of the machine. This is extremely important for safety, technical, and cost reasons; any deviation from the above-mentioned principles results in a radical increase in the risk of failure, which translates into a deterioration in work safety. A derivative issue that is also beneficial is the unification of the demand for purchasing elements, the simplification of maintenance works, and all kinds of repairs.

To meet these requirements, PGG S.A. has decided to secure its immediate needs in the field of long-wall development and powered roof supports acquired based on its own documentation, taking into account the standardization and aggregation of the purchase system. An analysis was based on the scope of work of the roof support sections through 2020 (Tab. 4) carried out in order to assess these needs.

Table 4

List of needs in area of powered supports sections for 2018–2020

Scope of work	Number of sections
1.0–2.5	178
1.8–3.3	425
2.0–4.0	318
2.6–4.6	121

Having regard to the above needs and optimizing the working ranges for newly designed powered roof supports in Zakład Remontowo-Produkcyjny, design work was undertaken to develop new types of roof supports. Three basic types of support and shielding

systems based on a pitch of 1.5 m were determined (Fig. 2):

- I: geometric 1.2–2.4 m; working 1.4–2.3 m,
  - II: geometric 1.5–3.5 m; working 1.7–3.4 m,
  - III: geometric 1.9–4.1 m; working 2.1–4.0 m,
  - IV: geometric above 4.1 m, working above 4.0 m,
- where a pitch of 1.75 m is recommended to ensure the stability of the support.

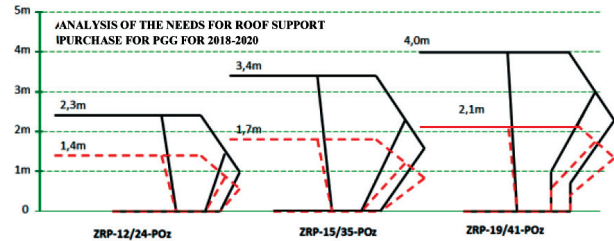


Fig. 2. Operating scope chart, supply for 2018–2020

The simplification of the components of a powered roof support and their unification is the next step in the standardization process. After completion of the already-started process, Polska Grupa Górnicza will be able to obtain a whole range of measurable benefits, such as:

- 1) increased work safety for miners:
  - the structures will become repetitive, known to miners,
  - equipment training will be easier and faster,
  - good knowledge of a given structure directly reduces the risk of an accident resulting from poor knowledge about a given structure;
- 2) simplification of the structure – standardization:
  - fewer technical solutions,
  - optimal selection of component construction,
  - interchangeability of basic elements, such as canopies and floor bases, auxiliary cylinders for all three types of newly designed roof supports;
- 3) improvement of purchase procedures of construction elements, power and control hydraulics;
- 4) significantly increase the possibility of using roof supports in other mines/longwalls;
- 5) basic reduction of costs related to renovation, modernization, and production of new support;
- 6) increased production capacity.

In Zakład Remontowo-Produkcyjny, Polska Grupa Górnicza, an algorithm of actions was developed to improve the investment process in the scope of servicing mines with the required types of powered roof supports (Fig. 3). The improvement of the efficiency of the repairs, modernization, and production of the new roof supports is based primarily on the process of aggregation of the components. Figure 4 presents ex-



amples of the possibilities of using standardized components to adapt the roof supports to the individual needs of the mines on the example of a prototype type ZRP-15/35-POz roof support. On the basis of the at-

tached example, the principle of aggregation is clarified in which a given roof support can be configured depending on the requirements of the mine and the specific conditions of the extraction longwall.

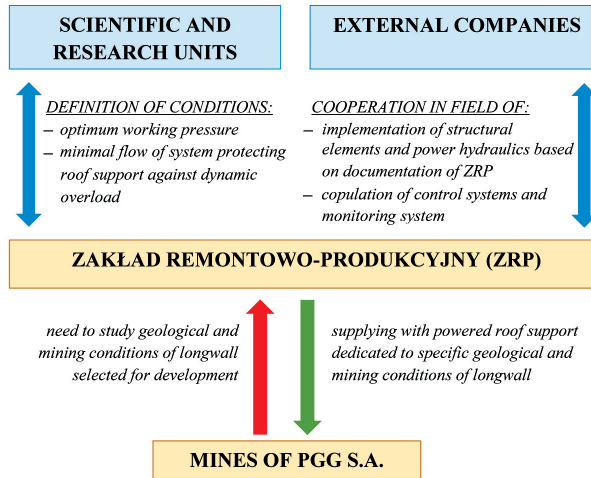


Fig. 3. Algorithm developed by Zakład Remontowo-Produkcyjny

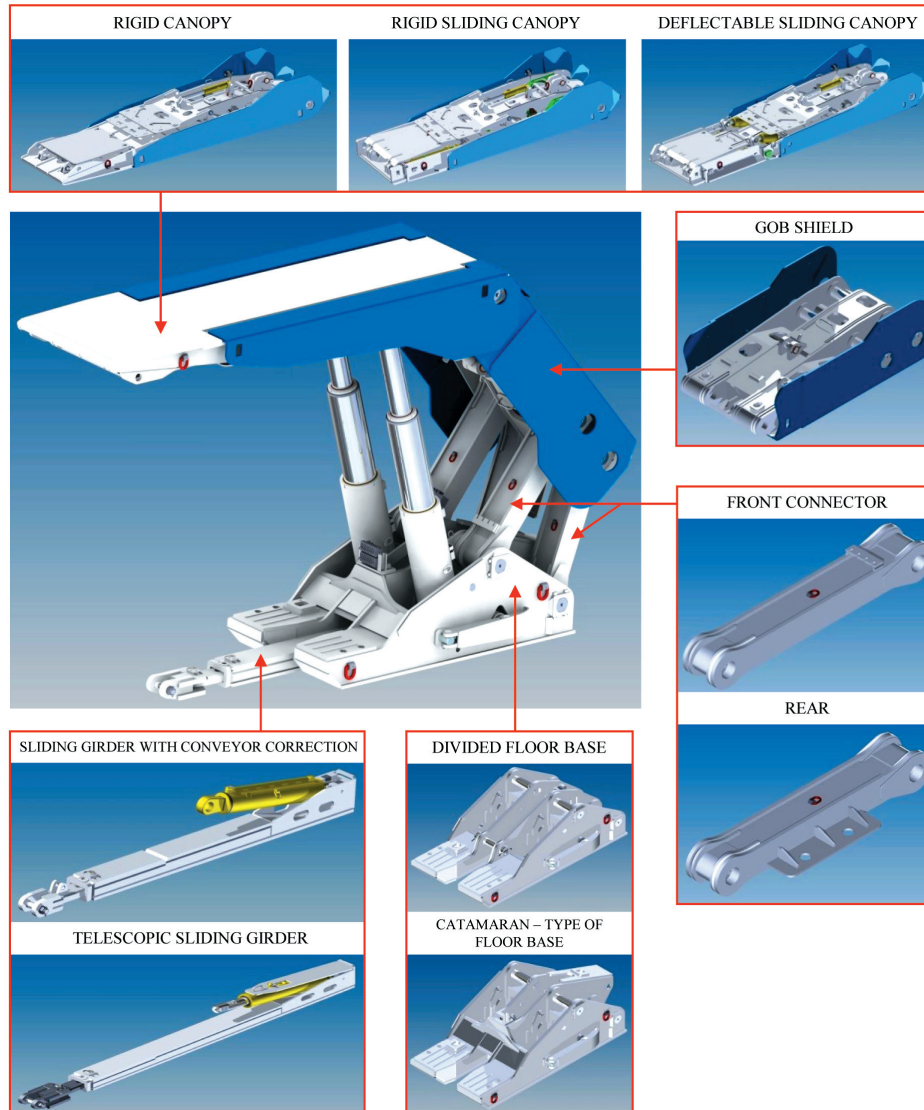


Fig. 4. Principle of aggregation – configuration of powered roof supports components

The roof support can be configured from standardized elements (which are repeatable and fully meet safety and technical requirements and, to a significant extent, reduce production costs). The introduction of aggregation allows for the use of the same canopy or floor base for both the medium and high roof support produced, for example. It is also possible to use a canopy in various construction variants (rigid, rigid sliding, or deflectable sliding) in one support. Aggregation of the power hydraulic elements (standardization of actuators: wall face shields, transitions shields, correction of side shields of canopy and shield support, section shifters) as well as the control gear will enable the unification of the whole range of solutions and increase the production and purchase capacities and reduce costs.

#### 4. CONCLUSION

Polska Grupa Górnicza implements the standardization process for powered roof supports. It is a difficult and demanding plan that will help bring tangible benefits. The risk of mining tremors is a significant natural threat to which the produced and modernized roof support should be adapted. For this purpose, activities were undertaken by Zakład Remontowo-Produkcyjny to obtain a high degree of safety of powered roof supports by means of technical and organizational measures as well as the method of production. Changes in Polish mining and the constantly deteriorating conditions for selecting coal deposits require the consistent implementation of rational solutions. The aggregation of the components of powered roof supports is constantly being developed and improved by Zakład Remontowo-Produkcyjny in close cooperation with scientific institutions; i.e., the Central Mining Institute and research laboratories. The purpose of the activities undertaken by Zakład Remontowo-Produkcyjny, PGG, is primarily to improve the safety of the work in underground longwall excavations while at the same time streamlining costs.

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