Protection of galleries with the use of mineral binders conveyed pneumatically in Polish coal mines

Wojciech Klimas [1]

Due to the increasing depth of coal mining, the particularly difficult and also specific conditions of the environment that are present in the Polish mining industry, the new technical problems appear. The efficiency of mining industry depends, among others, on limiting the influence of underground mining on rock mass and surface, maintaining the underground excavations, improving the ventilation conditions and properly implementing the fire prevention. In practice, for the implementation of these tasks appropriate technologies are being used, such as: constructing packwalls as well as insulating and explosion-proof dams, sealing of rocks, filling voids in rock mass and behind the support. The article presents the current state of theoretical and practical knowledge on protecting galleries of longwalls with cavings through the construction of a packwall made of mineral binders. The author describes pneumatic binder conveying system with individual components of this system. The paper presents successive calculation steps of the pneumatic conveying system used in coal mining. Mode of transport of mineral binders has a significant impact on their physical and mechanical properties. The choice of pneumatic transport to convey mineral mining binders confirmed itself in practice in coal mines: "Julian", "Piast", "Marcel", Szczygłowice", "Anna", "Rydułtowy".

Key words*: protection of galleries, packwall, mineral binder, pneumatic conveying*

Introduction

The terms of maintaining preparatory excavations have a substantial influence on technical and economical results achieved during the process of mining coal deposits, and one of the main elements of maintaining dog headings stability during their use is the way of protecting the heading by the appropriate choice of support. In Polish mining industry, the maintenance of dog headings stability is ensured by the use of a yielding metal support.

During the exploitation, with the increase of depth, we have to deal with challenging and very difficult geotechnical conditions which require setting the frames of steel arch support in increasingly smaller distances from each other. This fact significantly raises the dog headings build and maintenance costs. Unfortunately, despite the compaction of frames in relation to one another, it is not always possible to obtain sufficient stability of these headings under high static loads, and especially the dynamic ones, which make it necessary to rebuild these headings in order to maintain the desired cross-sectional size and functionality (Prusek, 2010).

Polish coal mines protect galleries of longwalls with headings with the use of such methods as setting breakers from the side of gobs, the wooden box crib system without filling, the wooden box crib system filled with stone, the wooden box crib system filled with binder, the protective packwall made of mineral binder (Korzeniowski & Skrzypkowski, 2012; Madaj et al., 2001; Straś, 2007; Sidorova & Čorej, 2014).

One of the methods and also a very advantageous solution for improving the stability of preparatory headings is to protect them with protective packwalls set along the sidewalls of the heading, whose task is to create a very strong support pillars between longwall gobs and galleries. Protective packwalls allow for: limiting deformation effects of rock mass pressure, isolating the longwall gobs which prevents air migration through gobs and gas emission from gobs, reducing gas and fire dangers, and allows for significant increasing of the support frames clear interval (Polevshchikov, 2013; Sakwa & Chudek, 1987; Xiang-Chao et al., 2015).

Maintenance of the bottom gate and the effectiveness of protective packwall made of mineral binder depends not only on physical and mechanical parameters of bonded binder but also on the distance between the packwall and the longwall face. The packwall should be made of mineral binder with high strength gain over time dynamics, directly behind the wall advance, thus preventing the lowering of the roof and loosening of rock mass superstratum (overlying strata) (Chudek et al., 1995a, 1995b; Madaj et al., 2001; Niełacny, 2009). An important parameter causing a correct state of a packwall protected heading is appropriately matched width of protective packwall (Andrusikiewicz & Mazurkiewicz, 1993; Andrusikiewicz, 1994). Protective packwall width depends on the angle of dip, properties of floor rocks, the height of exploited seam, the exploitation system (from or to the field), the depth of occurrence, the width of the heading, the compressive strength of the material used and the dynamics of strength gain. Additionally, protective packwalls can be made with the use of waste, including environmentally burdensome material.

[1] *Dr inż. Wojciech Klimas,* Faculty of Mining and Geology, Silesian University of Technology, 44-100 Gliwice, ul. Akademicka 2, Poland, wojciech.klimas@polsl.pl, tel. 32 237 23 64

The most important factors affecting strength parameters of a protective packwall can be divided into three basic groups: mining and technical conditions present in the area of the longwall, strength parameters of binder forging the protective packwall and the quality of the packwall itself (its uniformity, consistency of binder, type of water).

Stability of headings

Considering the functionality of mine headings, by stability, we mean the ability to remain in complete technological usefulness during a certain period of time. In geomechanics, the mechanical processes taking place in the rock mass - support system, which course is controlled and predicted in advance are called the heading stability. When the loads carried by rock mass - support system are lower than the allowable loads and displacements of the heading contour are within the limits of prognosticated displacements, then one can say that the condition of heading stability is fulfilled. If the above conditions are not met, then, after setting and during the use of heading, a loss of heading stability takes place, demonstrating itself by displacement of heading contour, which leads to deformation of the support.

The loss of heading stability depends on the type of load affecting the heading support, and during the process, one can distinguish: slow phenomena, related to the rheological properties of rocks, violent phenomena, associated with sudden excretion of energy previously accumulated in the rock mass.

These phenomena directly affect the possible loss of mine headings stability, which, in the case of slow phenomena proceeding in time, with the shift of heading contour and insufficient yield potential of the support, deforms it and in extreme cases brings on its total destruction.

The main factors influencing the stability of the heading are:

- mechanical, physical and rheological properties of rocks surrounding the heading,
- the depth of the heading location and its positioning in relation to mining headings, gobs (post-operating spaces) and tectonic disturbances,
- the pressure imposed on the support (static and dynamic),
- the slope of the rock mass layers,
- the size of crack zones in sidewalls of dog headings, etc.,
- rock mass effort (the state of exploitation relics and ongoing exploitation),
- the shape, size, and duration of the heading's use,
- support construction (support capacity, yield potential).

These factors have a significant influence on the conditions of maintaining dog headings in the state of complete technological usefulness. Therefore, the selection of protective packwalls construction depends also on the results of analysis and evaluation of these factors. However, the main factor which influences the design of the protected dog heading packwall is the type and size of loads affecting this heading.

The ways of protecting dog headings in terms of their stability conditions

The stability of dog headings (galleries) set in difficult mining and exploitation conditions (fields of exploitation) can be ensured by the proper cooperation of steel arch support frames with rock mass. Good cooperation of the support with rock mass cannot be ensured by the use of protecting galleries with breakers method (Fig. 1). It is difficult to ensure the effective protection of dog headings along galleries of longwalls with cavings by setting four-point or multipoint box cribs or box cribs filled with stone or binder (Fig. 2), it is also possible to set box cribs with notches, with or without filling, which increases the contact of beams along their whole length (Straś, 2007). Instead of wooden box cribs, one can use concrete discs or pillars supporting the roof (Korzeniowski & Niełacny, 2010). The optimal solution is to protect dog headings along galleries of longwalls with cavings by setting packwalls made of mineral binders (Fig. 3) (Madaj et al., 2001; Wesołowski & Klimas, 2015).

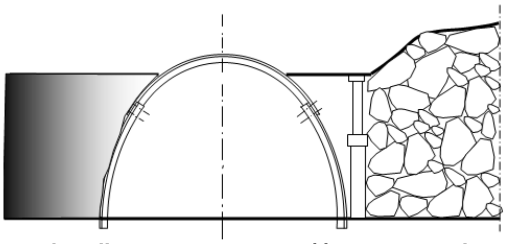


Fig. 1. The gallery protection system of ferroconcrete columns as breakers.

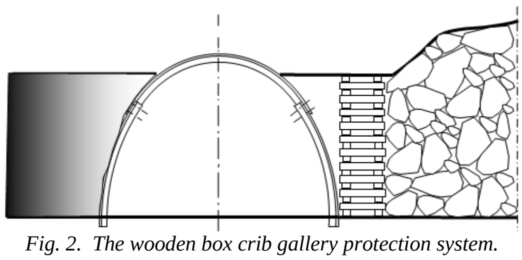
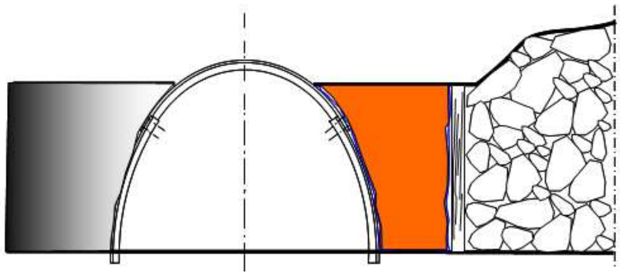


Fig. 2. The wooden box crib gallery protection system.



The protective packwall and the support of dog heading should actively interact with rock mass, preventing stratification, loosening and the collapse of rock mass superstratum (overlying strata). This is possible by the best possible match of support yield capacity to existing mining and geological conditions, by properly fit packwall dimensions and properly selected materials of which the packwall is being made.

Fig. 3. The gallery protection system with the protective packwall made of mineral binder.

Technology of mineral binders use for the construction of a packwall along the gallery of longwall with caving

In practice, coal mines use two types of mineral binders conveying systems: pneumatic and hydraulic, together with mixed conveying systems, and each of them has certain advantages and disadvantages. The mining mineral binders conveying systems affect the physical and mechanical properties of these binders, activating certain components of transported mixtures and preventing them from binding during transport (Stryczek et al., 2006). In the projected mineral binders conveying systems, it is a generally accepted principle that binder mixes are "ready made" at the site of their use (Jahn et al., 2010; Madaj et al., 1997; Klimas, 2013).

Polish coal mines often use pneumatic mode of conveying mineral binders from the mining level or surface to the place of their application, although one can observe the increasing interest in hydromechanical conveying (pumps) in recent years.

The advantages of pneumatic conveying include: reliability of the equipment, its simple and easy operation, high efficiency, the ability to regulate the amount of water added w/b (water/binder), the use of typical diameters of the conveying system pipes, the use of binder grout of the thick - plastic consistency, the possibility of conveying the immediately supporting binders of very short binding time. The disadvantages of pneumatic conveying are: the unevenness of the material stream feed, which affects the strength inhomogeneity of the structure, the possibility of plugs formation in the system in case of overly moist air or overly moist material, the possibility of dusting in the case of not enough humidified material.

Before designing the technology of conveying mining binders via pneumatic system, one should discern if there is a possibility of using this system in a specific mine. The lack of compressed air is definitely not a problem, since it is possible to use compressors in underground conditions. The problem that has to be solved by the mine is the assumption of systems solutions universality and the degree of mechanisation of pneumatic binders conveying technology.

The method of constructing packwalls along galleries of longwalls with cavings involves setting 1 or 2 rows of wooden racks, so-called "organ", from the caving side (Fig. 3). Backfill or ventilation screen is then stretched on the organ to prevent penetration of mineral binder grout to the caving. The second row of racks can be placed at a distance equal to the width of the packwall, near the frames (base plate) of the steel support. From the caving side, the MM type mesh is placed on the ŁP support, covered with backfill or ventilation screen to prevent penetration of mineral binder grout to the gallery. Then the fenced off space is carefully filled with the grout of mineral binder, from the bottom to the top, up to the roof, to ensure precise binding of the packwall with rock mass and to prevent stratification of the roof rocks. The filling of the fenced off space should be carried out from the longwall face, along with the longwall advance.

In the course of setting the packwall, it is necessary to keep in mind the following rules:

- the consistency of binder grout which fills the fenced off space should be in accordance with the formula, most frequently it has a thick - plastic consistency, which ensures optimum strength parameters of the binder,
- the change of consistency can be carried out by the use of water valve built in on the outlet nozzle,
- it is necessary to observe the consistency visually on a regular basis because its change will result in a reduction of mineral binder strength parameters and prolonged binding time,
- space should not be filled with a dry binder because the lack of water causes the stoppage of binding process and thus causes the lack of strength of the hardened binder,
- the fenced off space should be carefully filled from the longwall face side, from the bottom to the top, to the roof, simultaneously with the longwall advance to prevent primary stratification of the roof rocks,
- before setting the packwall, coal dust and small stones should be thoroughly cleaned off the floor.

Pneumatic conveying of binders

The technology of mineral mining binders usage requires the development and application of properly selected mechanisation of the following processes: mixing the loose components, storage, transport and humidification in accordance with provided formulas. For the construction of packwalls along galleries of longwalls with cavings, the principle of composing binder by dynamic dosing of liquid (make-up water) to the flowing stream of conveyed mining mineral binders at the outlet of a pipeline in the point of their application is used. The assumption of the universality of projected solutions of pneumatic conveying mechanisation systems as the main set of devices for using the comprehensive technology of packwalls construction is optimal. Polish coal mines frequently use the "POLKO" system of mineral binders pneumatic conveying. This system belongs to high-pressure transport by lifting category.

The main problem in the process of designing the mineral binders application technology mechanization systems are always so-called "points of contact" of elements included in the pneumatic conveying systems with conventional transport previously used in the mine, where tumbling of loose materials (binders) and separation of particles from the transporting air takes place (Fig. 4).

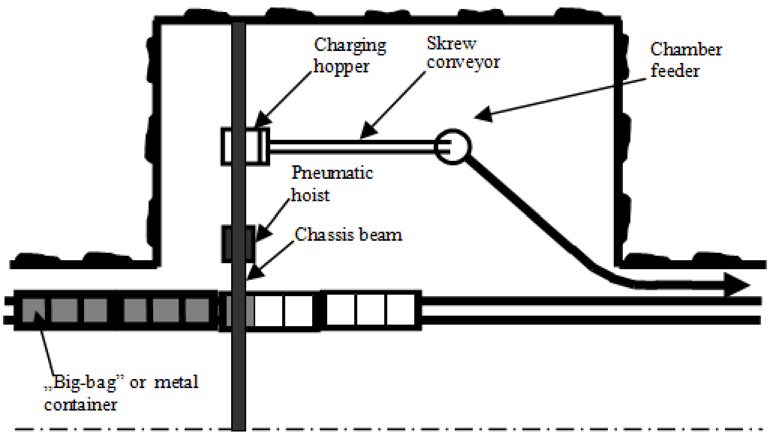


Fig. 4. The exemplary "points of contact" when pouring binders.

Depending on differences of the demand for material during the construction of packwalls along galleries of longwalls with cavings in given mine conditions, it is necessary to make sure that the system of storage and distribution of loose materials is flexible enough to be able to assure the variable requirements for the material at the site of its application.

When choosing the binders conveying technology, it is important to know the parameters of pneumatic conveying of these binders which definitely simplifies the design of mechanisation processes. These parameters may be known from earlier experimental research conducted by "POLKO" Cooperation and exploitation observations conducted by operational service teams. The installation of pneumatic conveying must be designed by so selecting the parameters of binder conveying that they meet technological requirements by minimising the cost and energy expenditures.

The loose material (mineral binder) is suitable for pneumatic conveying when it presents the following properties:

- grain size (up to 50 mm, less than 0,3 of the conveying pipeline diameter), shape, homogeneity of the fractions,
- moisture, excessive in the case of mineral binders, fosters the formation of agglomerates and "overgrowing" of conveying pipelines, which reduces their permeability,
- the strength of grains determines the speed limit of grains transport, which protects them from crumbling while keeping the stability of the flow resistance,
- the hardness of conveyed material, together with drift speed it affects the erodibility of transport lines (curves, pipelines),
- the density of conveyed material, its size and shape of grains affect the speed of movement,
- liquidity of the material refers to materials with a friability of less than 20 μm, such as binders, these materials behave similarly to a liquid.

Pneumatic conveying equipment

The system of cyclic operation

The "POLKO" system cyclic operation chamber feeder (Fig. 5) in pneumatic conveyors of high-pressure pneumatic transport by lifting is a device that supplies the conveying pipeline with loose material. This feeder is a device that determines the way of inputting material and gas to the conveying pipeline and begins to move a biphasic mixture of solid matter and gas.

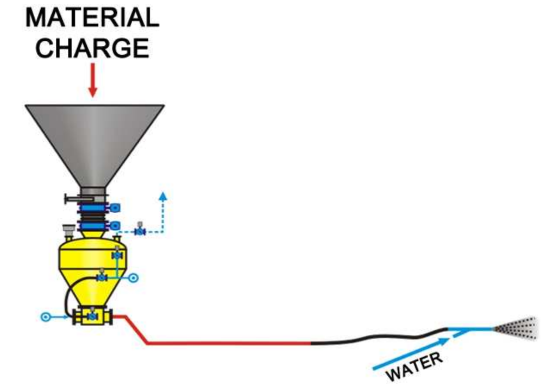


Fig. 5. The chamber feeder of cyclic operation (Majchrzak, 2013).

If mineral binders are conveyed pneumatically with the use of one pressure chamber feeder supplying the conveying pipeline, then it is a cyclic operation system with the absence of feeding the pipeline with binder during a feeder loading cycle. This affects the entire system performance. A characteristic feature of cyclic operation systems is the existence of time periods for the installation start-up, loading, material transportation and purging of the installation.

The use of cyclic operation system is closely related to the other elements of the technological process, in which a constant flow of loose materials (binders) should be assured. The pressure feeder is a combination of three elements simultaneously cooperating with each other: the mixing chamber, the nozzle assembly and a pressure vessel, which is closed by the bell closure from the top, and compressed air from the mine network is supplied by the D_n 50 pipeline.

The system of continuous operation

The choice and the use of continuous operation systems of pneumatic material conveying is influenced by the efficiency and the keeping of the technological process continuity, especially when large amounts of loose material are handled. The superiority of continuous operation systems of pneumatic conveying compared to cyclic operation systems is connected primarily with the elimination of purging of the transport installation, thereby increasing the efficiency of equipment and reducing losses associated with loading and unloading of conveyed loose material. The following sets of equipment of the "POLKO"" pneumatic conveying systems are used:

- **the vertical tandem** (the so-called tandem system) - continuity of loose material pneumatic conveying is provided by the interaction of two pressure chambers: the lower, which is a chamber feeder supplying the conveying pipeline with a continuous stream of material and the upper one, which is a sluice vessel, periodically adding material into the lower chamber feeder,
- **the horizontal tandem** (Fig. 6) - a system of two chamber feeders, standing next to each other and feeding in turns the conveying pipeline, it is used in cases of the limited amount of space. The possible height of the room in which the horizontal tandem is to be located as well as a way of loading chamber feeders with loose material determine the maximum height and thereby a net capacity of chamber feeders, which operate in turns in accordance with the operation cycle of a single chamber feeder.

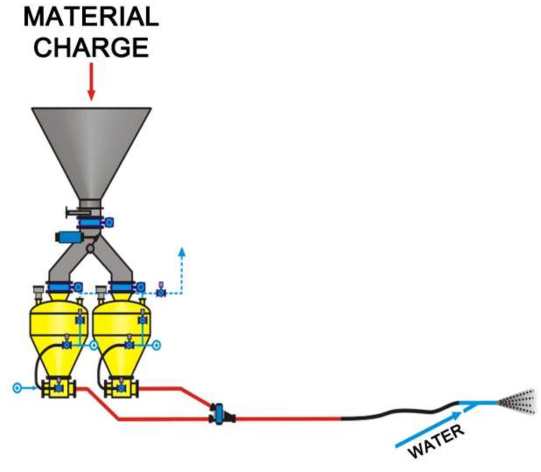


Fig. 6. Chamber feeders of continuous operation (Majchrzak, 2013).

.

Conveying pipelines

Pneumatic conveying of loose materials (binders) in mining conditions is carried out by conveying pipelines which are hermetically sealed spaces within which the transfer of loose materials takes place. Considering the specificity of transported materials transfer, pipelines and especially pipeline curves should be constructed of materials resistant to abrasive wear of mineral - metal type. In the mining conditions, it is necessary to pay particular attention to ensuring the airtightness of flange joints and building pipelines with curves of the biggest possible radius, assuming for the curve with a minimum bending radius of 1 m the equivalent length of approximately 30 m of the straight pipeline.

Humidification of the material at the conveying pipeline outlet

For transporting mineral binders which are used in underground engineering, the pneumatic conveying system "POLKO" uses various types of material (binders) hydrating systems at the outlet of the pipeline (Fig. 7).

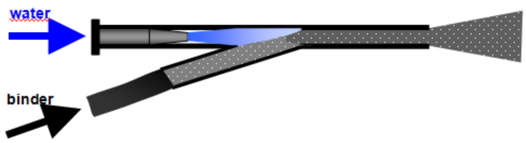


Fig. 7. Binder humidification system (Majchrzak, 2013).

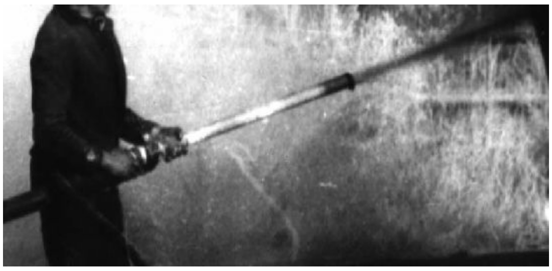


Photo 1. Lance (Majchrzak, 2013).

Humidification system is always chosen in dependence on the conveying line operation parameters, the type of transported material and the type of operation (grout, filling of cavities, setting packwalls, etc.).

Depending on mineral binder's water demand, compact or separated lances are used. The first ones are connected directly to the liquid dispenser and the second ones are separated with rubber cable of a suitably selected length.

In the case of mineral binders conveying it is often required to mix them more precisely, which can be achieved by separating the lance and the liquid distribution pipe from the dispenser by increasing the length of binders mixing effective section. Humidification system enables the lance operator to dispense the appropriate amount of water defined in the binder formula, while simultaneously minimising dust emission.

The selection of pneumatic conveying equipment

When choosing the optimal solutions of mineral binders pneumatic conveying systems for specific conditions and capabilities of a mine, for building packwalls along galleries of longwalls with cavings, it is necessary to take into consideration the following matters:

- the maximum use of equipment currently present in a mine (silos, chamber feeders, transit stations, pipelines, etc.) in order to minimise investment costs,
- adjusting the mechanisation of loading to the conditions in existing mine headings,
- the selection of pneumatic conveying parameters to best fit the existing route configuration, ensuring the proper flow of binder and minimising the amount of compressed air,
- ensuring the stability of certain properties of the conveyed mineral binders,
- mineral binders range of applications,
- reliability of the equipment.

The technology of setting packwalls along galleries of longwalls with cavings bases on the so-called "semi-dry" method, which means a displacement - transport by lifting - of mineral binders by conveying pipelines, while at the outlet of the pipeline, in the place where a packwall is being set, the make-up liquid (water) is dynamically dosed into a stream of conveyed biphasic mixture of solid matter and gas.

The construction of a packwall by a dynamic hit of a three-phase stream (gas-liquid-binder), into the space fenced off by backfill screen, gives a very good binding effect of the mineral binder itself, together with rapid increments of its strength parameters. The proper consistency of binder, which guarantees the optimal parameters of binded material, is achieved by adjusting the length of the mixing chamber section where the conveyed mineral binder gets mixed with liquid. The adjustment range of the devices should contain the highest performance requirements specified by the technology of mining the longwall.

The designing of conveying installations for building protective packwalls in galleries of longwalls with cavings should include the following steps (Korzeniowski & Niełacny, 2010; Niełacny, 2009; Piątkiewicz, 1999; Sakwa & Chudek, 1987):

- determining the mode of binder conveying to the area of a designed longwall,
- determining the need for compressed air and the selection of compressors if necessary,
- testing the movement of material(binder) on research - test stand made on a technical scale,
- for the calculated width of a packwall, the height of the exploited area and the daily advance of the wall during its start-up phase and later operation, the space that must be filled with the binder is calculated,
- the daily performance of binder transport installation which allows filling the fenced off space with the binder is calculated,
- calculation of the average real hourly performance,

- determining the location of the discharge chamber considering a way of mineral binder delivery and unloading, and the chamber's ability to be supplied with compressed air,
- calculating the equivalent length L_Z of mineral binder for the packwall setting conveying route as an adequate effective length of pneumatic conveying pipelines.

$$L_Z = L_h + L_v + L_\alpha \quad (1)$$

where: L_Z - equivalent length of pipeline route [m],
L_h - total length of horizontal pipelines (with a maximum tolerance of 10%) [m],
L_v - equivalent length of the vertical sections recalculated for horizontal [m],
L_α - equivalent length of all the curves in the installation [m].

- conveying pipeline route selection, while minimising the number of curves (minimum bending radius r_{min} = 1m),
- based on measurements, the feeding air pressure is checked, and the minimum value of it is determined as p_z = 0,45 MPa,
- the allowable quantity of water in the feeding air is determined (< 1 g/l),
- the maximum pressure of water added to the binder in front of the dispenser is determined (< 1,0 MPa),
- calculation diagram is prepared to calculate the available pressure difference to overcome the movement resistance of the conveying system two-phase mixture (gas-binder),
- the average pressure drop per unit length of the pipeline $\Delta p/l$ is calculated

$$\Delta p / l = \frac{\Delta p}{L_z} \quad (2)$$

where: p/l – pressure drop per unit [MPa/m],
Δp – available pressure difference [MPa],
L_Z - equivalent length of pipeline route [m],

- when knowing the mass flow rate of gas $\dot{m}$ (most frequently measured is the volumetric flow rate $\dot{V}$ with the use of flanges, measuring nozzles, rotameters or thermal, turbine, ultrasonic counters, etc.) and its density ρ_g the conveying air demand V_m during the transport of material (binder) is calculated,
- also the gas velocity in the characteristic points of the installation w_x (at the beginning of the conveying pipeline and in diameters changing point) is calculated,

$$w_x = \frac{\dot{m}}{A \cdot \rho_x} \quad (3)$$

where: w_x – air velocity in the characteristic point of the installation [m/s],
$\dot{m}$ – gas volume flow rate [m^3/s],
A – section area of the pipeline [m^2],
ρ_x – gas density in the characteristic point of the installation [kg /m^3],

$$\rho_x = \rho_g + \rho_p \quad (4)$$

$$\rho_g = \rho_N \frac{(p_5 - \varphi \cdot p_p) \cdot T_N}{p_N \cdot T_r} \quad (5)$$

$$\rho_p = \varphi \cdot \rho'' \quad (6)$$

where: ρ_g - dry gas density [kg /m^3],
ρ_p- density of water vapor contained in gas [kg /m^3],
ρ''- density of saturated water vapor [kg /m^3],
ρ_N =1,2829 kg/m^3 - density of dry gas in standard conditions (T_N= 273,16 K, p_N= 101,325 kPa),
p_p- pressure of saturated vapor for the air temperature in the pipeline T_r.

- the gas velocity at the point of mineral binder discharge should be placed within the specified range of 10 – 20 m/s,
- the particle velocity value w_c is most frequently determined approximately, by taking the slip rate of 0,5 – 0,8 of gas velocity w. It depends on the density and diameter of particles together with the material flow rate,
- the material flow rate $\dot{m}_c$ is calculated [kg/s]

$$\dot{m}_c = \frac{m_m}{t_t} \quad (7)$$

where: m_m - mass of material in kg,
t_t - transport time in s,

- mass concentration of the mixture in the conveying pipeline μ is calculated,

$$\mu = \frac{\dot{m}_c}{\dot{m}} \tag{8}$$

where: μ – mixture concentration [kg/kg],
$\dot{m}_c$ – material (binder) mass flow rate [kg/s],
$\dot{m}$ – gas mass flow rate [kg/s],

- the Reynolds number Re, which determines the similarity of viscous forces, is also calculated

$$Re = \frac{w_x \cdot d \cdot \rho_x}{\eta} \tag{9}$$

where: w – gas phase velocity [m/s],
d – diameter of the pipeline [m],
ρ – gas density [kg/m^3],
η – the dynamic coefficient of gas viscosity [Pa·s].

The mechanisation of manufacturing and conveying of binders

Depending on the technical and organisational conditions of a mine, the conveying of binders and the packwall along the gallery of longwall with caving can be set by pneumatic conveying in two variants (Madaj et al., 1997, 2002, 2002; Klimas, 2013; Majchrzak, 2013):

- **variant I** (Fig. 8) - the transport of mineral binders to their areas of application is performed with the use of pressure chamber feeders, located at a given level (“Anna” and “Piast” coal mines). This requires, however, delivering packages of mineral binders (bags or big- bags) to a given level with mine carts and then unloading binder and reloading it into the feeder. These operations are time-consuming and require additional organisational and economic costs.
- **variant II** (Fig. 9) - is a delivery of mineral binders from the mine surface to the place of their application by pneumatic conveying (“Julian” coal mine). For this purpose, the pressure chamber feeders are set on the surface and at a given extraction level (together with transit stations if necessary). The advantage of this variant is the long distance of binder conveying, efficiency, speed and fluency of the works, as well as eliminating the exposure of maintenance staff to a binder.

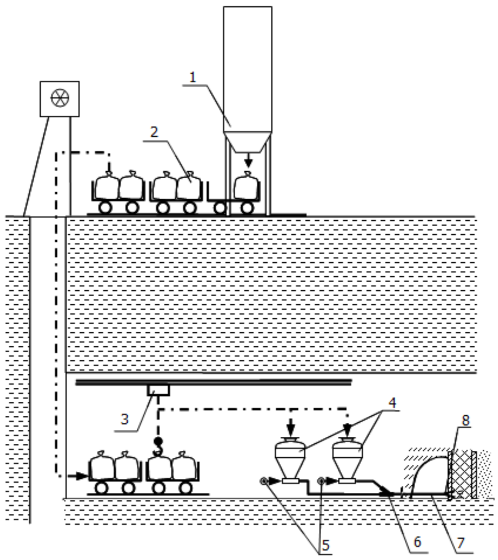


Fig. 8. The diagram of binders conveying system from the mine surface to the place of their application in a coal mine conditions: 1. silo, 2. big-bags with binder, 3. hoist , 4. chamber feeders, 5. power supply, 6. divider, 7. pipeline, 8. lance (Madaj et al., 2002).

Photo 2a,b. Wheeled transport of binder from the surface in “big-bags” and its loading into chamber containers in “Anna” and “Piast” coal mines (Madaj et al., 2002).

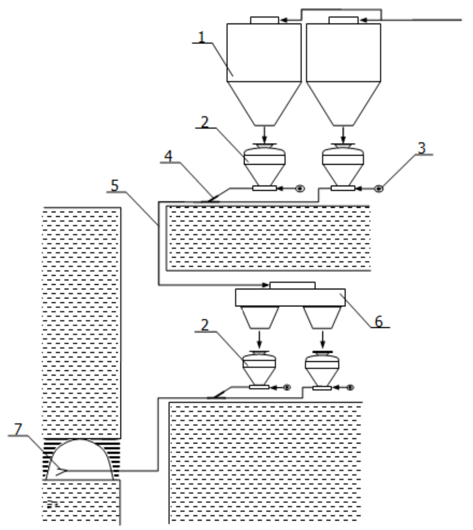


Fig. 9. The diagram of binders conveying system from the mine surface to the place of their applications in a coal mine conditions: 1 - binder storage silos, 2 - chamber feeder, 3- power supply, 4 - pneumatically controlled two-way divider, 5 - transport pipeline, 6 - dump station , 7 – lance, in "Julian" coal mine (Majchrzak, 2013).

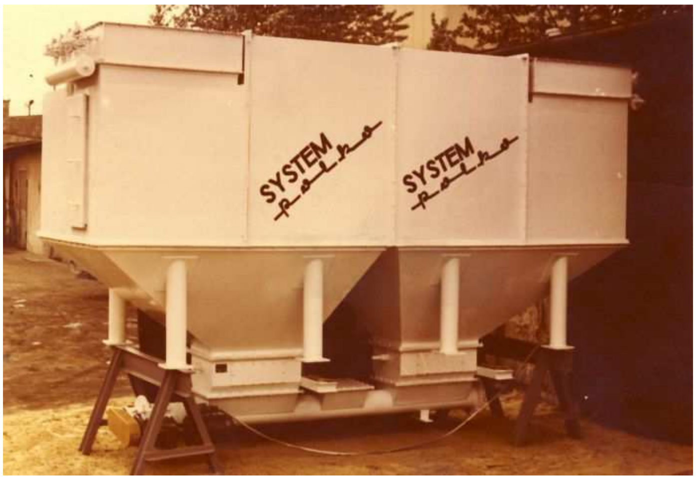


Photo 3. Dump station (Majchrzak., 2013).

Recapitulation

1. Getting the mining exploitation down to a greater depths causes more and more problems with the proper protection of dog headings.
2. The choice of support of higher performance and its compaction does not always ensure the stability of galleries.
3. It is essential to comprehensively secure dog headings with the use of additional methods and means to maintain the desired size and functionality of the headings cross-sections.
4. Among the different ways of securing dog headings, the best effects are achieved by setting a packwall made of the mineral binder.
5. The effect of making a protective packwall in a gallery is the reduction of rock mass reforming pressures influence, isolation of gobs, which reduces gas and fire risks, and a significant increasing of the support frames clear interval.
6. The effectiveness of a protective packwall made of mineral binder depends not only on binder's physical and mechanical parameters, but the distance of a packwall from the longwall's face is also very important.
7. The protective packwal should be made of the mineral binder with a high dynamics of strength gain, along with the advance of the longwall, which prevents the lowering of the roof and loosening of roof rocks which encumber the support and the packwall.
8. Very important is the width of a packwall, which depends on the dip angle, the properties of floor rocks, the height of seam, the system of exploitation, the depth of exploitation, the width of the heading, the strength of binder and the dynamics of strength gain.
9. Coal mines use pneumatic, hydraulic and mixed mineral binders conveying systems.
10. Conveying systems affect the physical and mechanical properties of mining mineral binders because they activate certain components of conveyed mixtures and prevent them from binding during transport.
11. In Polish coal mines, the pneumatic mode of mineral binders conveying is preferred, although recent years have seen increased interest in hydromechanical conveying (pumps).
12. The advantages of pneumatic conveying are: reliability of equipment, its simple and easy operation, high efficiency, ability to regulate the amount of added water w/b (water/binder), the use of typical diameters of pipes in the conveying systems, the use of grout with thick - plastic consistency, the ability of conveying the immediately supporting binders with very short binding time.
13. The disadvantages of pneumatic conveying are: the unevenness of the material stream feed, which affects the strength inhomogeneity of the build up the structure, the possibility of plugs formation in the system in case of overly moist air or overly moist material and the possibility of dusting in the case of not enough moistened material.
14. The building of roadside packs along galleries of longwalls with cavings by means of pneumatic conveying system adopts the formulation of binder mixture via the dynamic introduction of fluid (make-up water) to the flowing stream of conveyed binders at the outlet of the pipeline in the point of their application.

15. A major problem is the assumption of systems solutions universality and the mechanisation degree of binders pneumatic conveying technology.

References

Andrusikiewicz W.; Mazurkiewicz M., Ochrona wyrobiska przyścianowego anhydrytowym pasem podsadzkowym – propozycja metody określania jego szerokości. *Zeszyt Naukowy Politechniki Śląskiej s. Górnictwo, z. 221, Gliwice 1994*

Andrusikiewicz W.: Optymalizacja parametrów anhydrytowego pasa ochronnego przy wybieraniu węgla systemem ścianowym. [Praca doktorska]. *AGH, Kraków 1993.*

Chudek M, Madaj M, Majchrzak R, Klimas W.: Technologia wykonywania ochronnych pasów podsadzkowych ze spoiw mineralnych. *Międzynarodowa Konferencja Naukowa, Ostrava 1995a.*

Chudek M, Madaj M, Majchrzak R, Klimas W.: Spoiwa mineralne do wykonywania ochronnych pasów podsadzkowych wzdłuż chodników przyścianowych ścian zawałowych. *Międzynarodowa Konferencja Naukowa, Ostrava 1995b.*

Jahn Ch., Madaj M., Klimas W.: Sposoby transportu górniczych spoiw mineralnych. Międzynarodowa Konferencja Naukowo-Techniczna Ochrona Środowiska w Górnictwie Podziemnym, Odkrywkowym i Otworowym. *Zawiercie 2010*

Klimas W.: Wczesnopodporowe spoiwa górnicze a system ich transportu w warunkach budownictwa podziemnego. Budownictwo Górnicze i Tunelowe. *Wydawnictwo Górnicze, Katowice 2013 R. 19 nr 2*

Korzeniowski W., Niełacny P.: Metody i skuteczność wzmacniania chodników przyścianowych w KWK „Ziemowit". *Przegląd Górniczy 5/2010.*

Korzeniowski W., Skrzypkowski K.: Badania porównawcze nośności i charakterystyk obciążeniowo-odkształceniowych kasztów o różnym wypełnieniu. *Przegląd Górniczy, Katowice 4/2012*

Madaj M., Kubek E., Wesołowski M.: Ochronny pas podsadzkowy ze spoiwa mineralnego w warunkach KWK "Anna". Bezpieczeństwo Pracy i Ochrona Środowiska w Górnictwie 2002 nr 11

Madaj M, Majchrzak R, Klimas W.: Systemy transportu mineralnych materiałów wiążących w kopalniach węgla kamiennego. III Szkoła Geomechaniki. Sposoby wzmacniania i uszczelniania masywu skalnego dla minimalizacji ujemnych skutków podziemnej eksploatacji złóż na środowisko górnicze i naturalne. Międzynarodowa konferencja, Gliwice - Ustroń, 23-26 listopada 1997 r. *Materiały konferencyjne. Cz. 1. Politechnika Śląska. Wydział Górnictwa i Geologii.*

Madaj M, Majchrzak R, Klimas W, Wesołowski M.: Dobór optymalnego sposobu ochrony chodnika przyścianowego ściany zawałowej w świetle badań numerycznych Międzynarodowa Konferencja IV Szkoła Geomechaniki, *Gliwice – Ustroń 2001.*

Madaj M., Kubek E., Homa D.: Transport pneumatyczny systemu POLKO w warunkach KWK „Anna". VIII Międzynarodowa Konferencja Transport Pneumatyczny *Ustroń 10-12.04 2002*

Majchrzak R.: Transport pneumatyczny spoiw mineralnych systemu POLKO w kopalniach węgla kamiennego. Seminarium „Beton i spoiwa mineralno-cementowe w budownictwie górniczym" *Jastrzębie Zdrój 07.06.2013*

Niełacny P.: Dobór technologii utrzymywania wyrobisk przyścianowych w jednostronnym otoczeniu zrobów na podstawie pomiarów przemieszczeń górotworu. *Praca doktorska niepublikowana AGH Kraków 2009.*

Piątkiewicz Z.: Transport pneumatyczny. *Wydawnictwo Politechniki Śląskiej. Gliwice 1999.*

Polevshchikov G. Ya.: Deformation-wave processes under production face advance in coal and rocks. *Journal of Miting Science, Vol. 49, Issue 5, 2013*

Prusek S.: Empirical-statistical Model of Gate Roads Deformation. *Archives of Mining Sciences, Vol. 55, No. 2, 2010*

Sakwa W., Chudek M.: Spoiwa anhydrytowe oraz urządzenia do ich transportu pneumatycznego systemu „Polko" w górnictwie podziemnym. *Wyd. PAN 1987.*

Sidorova M., Čorej P.: Mining and unloading system of talc deposit in Rodoretto mine (Italy). *Acta Montanistica Slovaca, Vol. 19, No 3, 2014*

Straś J.: Ochrona chodników przyścianowych w jednostronnym otoczeniu zrobami. Konferencja „Popioły lotne i spoiwa mineralne Utex w technologiach górniczych" *Wisła 14-15 czerwca 2007*

Stryczek S., Wiśniowski R., Gonet A.: Influence of Mineral Additives on the Technological Properties of Sealing Slurries for Geoengineering Works. *Acta Montanistica Slovaca Roč. 11 (2006), č.1*

Wesołowski M., Klimas W.: Modelowanie wpływu eksploatacji ścianowej na chodnik podścianowy. Budownictwo Górnicze i Tunelowe. *Wydawnictwo Górnicze, Katowice 2015 R. 21 nr 1*

Xiang-Chao Shi, Ying-Feng Meng, Li Gao, Xu Tian, Xu Yang, Wu-Qiang Cai, Shuai Mao.: Numerical study of changes in coal permeability in a mining workface. *Acta Montanistica Slovaca, Vol. 20, No 3, 2015*