E3S Web of Conferences 21, 01018 (2017) DOI: 10.1051/e3sconf/20172101018
The Second International Innovative Mining Symposium

Parameters of Solidifying Mixtures Transporting at Underground Ore Mining

Vladimir Golik[1,2,*], and *Yury* Dmitrak[1]

[1]North-Caucasian State University of Technology, 44 Nikolaev street, Vladikavkaz, 362021, Russia[1]
[2]Vladikavkaz Scientific Center of the Russian Academy of Sciences and the Government Republic of North Ossetia-Alania, 22, Markusa street, Vladikavkaz, 362027, Russia

Abstract. The article is devoted to the problem of providing mining enterprises with solidifying filling mixtures at underground mining. The results of analytical studies using the data of foreign and domestic practice of solidifying mixtures delivery to stopes are given. On the basis of experimental practice the parameters of transportation of solidifying filling mixtures are given with an increase in their quality due to the effect of vibration in the pipeline. The mechanism of the delivery process and the procedure for determining the parameters of the forced oscillations of the pipeline, the characteristics of the transporting processes, the rigidity of the elastic elements of pipeline section supports and the magnitude of vibrator' driving force are detailed. It is determined that the quality of solidifying filling mixtures can be increased due to the rational use of technical resources during the transportation of mixtures, and as a result the mixtures are characterized by a more even distribution of the aggregate. The algorithm for calculating the parameters of the pipe vibro-transport of solidifying filling mixtures can be in demand in the design of mineral deposits underground mining technology.

1 Introduction

Concrete mixtures occupy a significant place in modern underground mining. An important characteristic of them is the moisture that determines its congealing, liquefaction and other parameters. Therefore, technologies using water as a vehicle are getting restricted up to the evicting, and technologies that can be applied without the addition of water as the transporting media are obtained [1-2].

The problem becomes particularly relevant for the underground mining of mineral deposits, especially in cases where adapted mining works are used for transportation, for example, with reverse bias.

To the technology of using concrete mixtures, the following requirements are set: the possibility of moving them to a considerable distance, reliability, minimal costs, loyalty to the environment,

* Corresponding author: v.i.golik@mail.ru

 DOI: 10.1051/e3sconf/20172101018

The peculiarity of the transportation of mixtures is the force acting on the pipe-line [3-4]. Vibration reduces the resistance to transportation and allows the flow under pressure to move concrete mixes.

The parameters of transportation are significantly influenced by the parameters of force impact. With the increase in the amplitude of the action at a constant frequency, the thickness of the water-cement film of the mixture increases due to the inertness of the mixture.

The peculiarity of the movement of the granular mixture through the pipes is the compliance of the pipeline diameter to the fineness of the mixture components, which must be at least 5/1. The grain size of the material should not exceed 15 mm, and the ratio "large – fine" filler must be provided within 2:3.

Next to the pipeline for concrete mix for its maintenance it is necessary to locate the main rifles of compressed air and water. Compressed air is supplied to the pipelines through ejectors mounted at an angle of 15-300 with an interval of 50-70 m.

2 Materials and methods

The main place in the study is given to industrial experiment.

The first use of this technology refers to the practice of developing deposits of the consern "Wismut" (Germany).

In the USSR, the technology was used in the development of the Shokpak-Kamyshovoye deposit in Kazakhstan to deliver hardening mixtures over a distance many times higher than the vertical height. When feeding the packing mixture for a distance of up to 2.5 km, the energy consumption was 0.15-0.22 kW/m3. The particular interest to this technological precedent is that during transportation the strength of the solidifying mixture has increased by 20-25%.

To increase transportability through pipelines, water is usually added to the concrete mixes before the cone 11 precipitating. With the new technology, the mixture is transported to the precipitation of cone 9 without the premix reducing the water-reducing strength.

The installation for solidifying filling mixtures transportation worked under the following conditions: diameter of air tapping is 40 mm, diameter of pipeline is 170 mm, the pressure of compressed air in air pipeline is 6 MPa, the capacity is 60 m^3/h.

Parameters of the vibro-transport installation are the following: compulsive force is 2-5 kN, amplitude of the pipeline oscillation is 1.2-2.0 mm, oscillation frequency is 6.0-13 Hz, influence of one exciter is 200-220 m. The range of the mixture supply was 2 times higher than possible for traditional technologies.

For delivery of filling mixes in underground conditions gravity, gravity-pneumatic and vibration schemes of pipeline transport are used. The first scheme provides stable delivery for a distance of 850 m, the second – for 1200-1500 m, and the possibilities of the third scheme have not been studied enough to estimate the quantitative parameters of delivery. It can only be asserted that the vibrators give the pipeline the functions of the mixer-activator [5-6].

The installation of vibro-pneumatic transport included a pipeline and vibrators. The system of vibro-transport of the concrete mix consisted of a vertical section of 175 m height and a horizontal section of 2500 m long (Fig. 1).

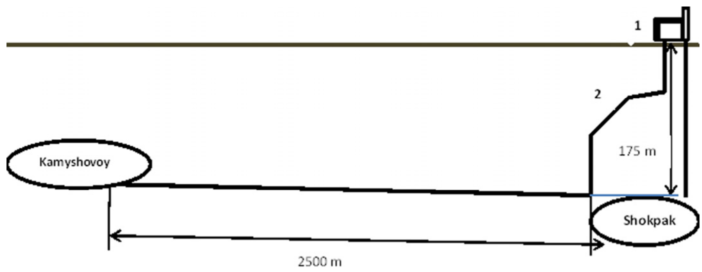

Fig. 1. Scheme of use of the filling complex of the Shokpak deposit for the delivery of hardening mixtures to the development of the Kamyshovoye deposit: 1-packing complex; 2-vertical part of the pipeline; 3 - horizontal part of the pipeline

If the length of delivery of the filling mixture according to the traditional scheme rarely exceeds 1.5 km at a ratio of the vertical and horizontal parts of the pipeline 1:5, then with the new technology this ratio was 1:20.

The composition of the transported mixture (kg/m^3) is the following: cement up to 100, blast furnace slags – 160-250, water – 380. Feeding range of the mixture: horizontal with a lift up to 14 m – 2500 m. Speed of the mixture through the pipeline is 1.2 -1.5 m/s. The maximum capacity of the system is 100 m^3/h.

The pressure drop over the length of the section during the feeding of the mixture was: in the self-cooling mode – 0.6-1.0 MPa, grad P = 3.0-5.0 kPa/M, with the application of vibration – 0.12-0.20 MPa, grad P = 0.8-1.0 kPa/M.

The transported hydro-mixture is characterized by plasticity within 1-7% (Tab. 1).

Table 1. Plasticity of solid part of hydro-mixture

Plasticity,%	**Samples**					**Average**
	1	**2**	**3**	**4**	**5**	
The limit of fluidity	39	37	39	38	37	38
The limit of unrolling	33	33	34	33	33	33
The indicator of plasticity	6	5	4	5	5	5

With traditional delivery technology, transportation of the mixture is carried out at an increased water flow, which reduces its strength. The use of vibration technology in combination with pneumatic gravity flow eliminates this drawback.

The accumulated experience allows the authors to develop an algorithm for the project of concrete mixtures supplying containing 0.1-0.35 dispersed particles, with a solids concentration in water of 0.10-0.85 and with settlement of a standard cone of 10-13 m.

3 Results and discussion

The main parameters of the vibrodelivery are the following: transport length (*L*), vertical line height (*H*), section length (l_1) and vibration exciter location within section (l_2) (Fig. 2).

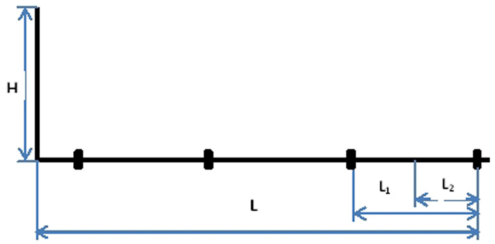

Fig. 2. Scheme for the calculation of vibrotransport: *l*- length of the pipeline, m; l_1 - distance between the vibrators, m; l_2-distance of installation of the vibrator on the section

The effective influence of vibration on the mixture is ensured by the oscillation of the pipeline with minimum amplitude A_m

$$A_m = \frac{\rho_\text{r} - \rho_o}{\omega^2 \rho_\text{r}} g \tag{1}$$

where: $p,$ – the density of filling particles, kg/m^3;

p_o – the density of dispersed media, kg/m^3;

When the vibration exciter is located in the center of inertia of the section, its length is:

$$l_1 = b\frac{A - A_m}{a_1} \tag{2}$$

where: b is the coefficient considering the location of the vibrator exciter (2);

a_1- coefficient of attenuation of oscillations (0.007-0.008 mm/m).

Stratification of the mixture is eliminated at a speed of its movement of 0.5-0.7 m/s - for mixtures with aggregate size up to 5.0 mm and 0.7-1.0 m/s - for mixtures with a filler of 5.0- 40.0 mm. Herein the internal diameter of the pipeline is:

$$D = 24.45 V_{av} \times d_{av} \times \sqrt{\frac{\rho}{\tau_o}} \tag{3}$$

where: V_{av} – average velocity of transporting material, m/sec;

d_{av} – average diameter of transporting material, mm.

The most effective vibration effect on the solidifying filling mixture at a speed of its movement is 1.0-1.5 m/s.

The range of feed of the solidifying mixture by the installation can be defined as:

$$l = \frac{\rho_c}{\Delta\rho} \tag{4}$$

where: p_c – the density of solidifying filling mixture, kg/m^3.

The distance between the elastic supports should not exceed l_{o1}:

$$l_{o1} = 0{,}5 l_o \tag{5}$$

The design diagram of the pipeline section is given in Fig. 3.

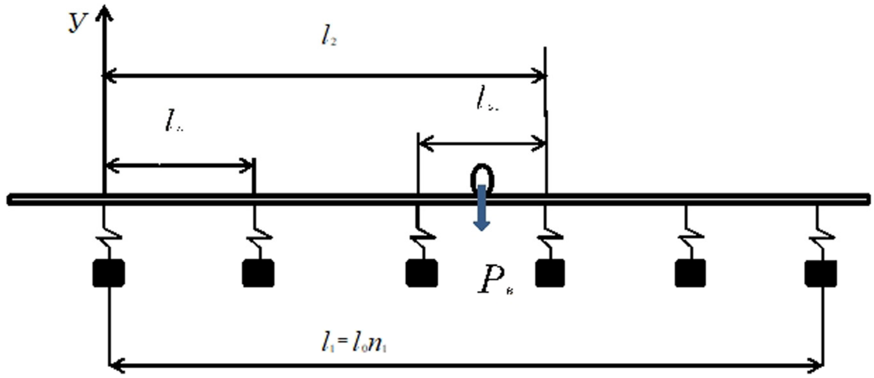

Fig. 3. The design diagram of the pipeline section.

The dynamics of hydraulic losses during transportation of water are shown in Tab. 2.

Table 2. The dynamics of hydraulic losses

Velocity, m/sec	Chezy's velocity factor,	Coefficient of hydraulic friction	Loss of pressure calculated	Pressure loss experienced	Error, %
1	38.5	0.05	5.8	6.6	-11.7
1.5	-	-	12.1	13.0	-6.8
2.0	-	-	21.5	21.7	-0.6
2.5	-	-	33.6	33.5	+0.5

Vibro-transportation increases the length of delivery of the solidifying mixture, which allows solving the problem of their transportation, both for the peripheral sections of the deposits and on the ground surface.

The increase in the activity of the hardening mixture during its transportation makes it possible to involve low-active production waste into recycling, to save the earth's surface from destruction during the extraction of mineral components of the mixture and to reduce the costs of surface and underground mining facilities and related industries objects construction [7].

The results of the study correspond with the specialists in this area of mining opinion [8-9].

4 Conclusions

1. The quality of concrete mixtures increases with the rational use of physical and energy resources during their transportation.

2. Activation in the pipeline improves the quality of the mixture due to a more even distribution of the aggregate, better hydration conditions for the binders.

3. The use of the new technology opens up new possibilities for using resource-saving technologies for underground mining of ore deposits with the achievement of a multi-area effect, including by peripheral areas installing without the construction of additional filling complexes.

Acknowledgement

The article contains the results of researches made under Programme Erasmus + 574061-EPP-1-2016-1-DE-EPPKA2-CBHE-JP "Modernization of geological education in Russian and Vietnamese universities".

References

1. G. Li R. Wang, E. J. M. Carranza, F. Yang. Ore Geol. Rev. **71**, 592–610 (2015)
2. M.E. Jarvie-Eggart, *Responsible Mining: Case Studies in Managing Social & Environmental Risks in the Developed World* (Society for Mining, Metallurgy and Exploration Englewood, 2015)
3. Xiao Li-ping, *Study on Pollution Laws of Coal Gangue Leaching Solution to Ground-water System* (Fuxin : Liaoning Technical University, 2007)
4. Onica, E. Cozma, T. Goldan, AGIR Rev. **3**, 14-27 (2006)
5. J. Broder, *Groundwater Geochemistry. A practical guide to modeling of natural and contaminated aquatic systems* (Springer, New York, 2005)
6. Weijing Wang, Shaofeng Huang, Xiaobo Wu, Qingfei Ma, J. Soft. Engin. Applic. **4**, 329–334 (2011)
7. Zhen-Dong Liu, Gan-Jiang Tao, Qing-Yun Ren, Dong-Sheng Yang, J. Ch. Coal Soc. **36:4**, 450-455 (2011)
8. Haifeng Wang, Yaqun He, Chenlong Duan, Yuemin Zhao, Youjun Tao, Cuiling Ye, *Development of Mineral Processing Engineering Education in China University of Mining and Technology* (Springer-Verlag, Berlin Heidelberg, 2012)
9. V.I. Golik, Yu.I. Razorenov, V.N. Ignatov, Z.M. Khasheva J. Soc.l Sci. **11:15**, 3742-3746 (2016)