ГЕОТЕХНОЛОГИЯ: ПОДЗЕМНАЯ, ОТКРЫТАЯ, СТРОИТЕЛЬНАЯ

DOI: 10.21440/0536-1028-2021-6-5-12

The effect of contact grouting on support load

Aleksandr S. Liskovets[1]*, Viktor P. Tatsienko[1], Viacheslav A. Gogolin[1]
[1] T. F. Gorbachev Kuzbass State Technical University, Kemerovo, Russia
e-mail: gva.pm@kuzstu.ru

Abstract

Introduction. *The paper analyzes contemporary methods of frame support design in permanent workings and reveals that contact grouting has received little attention. Contact grouting makes the tight contact between the hardened cement grout and the surrounding rock possible, whereas it is impossible when applying concrete lagging. The paper employs analytical method of arch support, grouting layer, and the surrounding rock calculation considering their softening. Analytical formulae determining support load has been obtained. The formulae take into account strain and strength characteristics of the surrounding rock, hardened cement grout, and support. Support load was calculated under various values of the grouting layer thickness and linear strain modulus and the depth of mining. The dependencies between the support load and the indicated parameters have been obtained, which makes it possible to select the cement grout composition for various mining and geological conditions.*

Research objective *is to determine the effect produced by grouting layer thickness and strain characteristics on arch support load value in order to check its strength in various mining and geological conditions.*

Methods of research *are built upon the physically based analytical methods of geomechanics to solve the problem of interaction between the support, grouting layer, and surrounding rock mass.*

Results. *The results of arched support load calculation are presented for various values of grouting layer thickness, its strain characteristics, and depth of mining.*

Conclusions. *The presence of the grouting layer in the void behind the support has a significant effect on the methods of arch support design. The developed methods take account of the fact that a layer of soft rock develops in the rock mass between the grouting layer and undisturbed rock. When the rock is being broken, its volume in this layer increases, which, in its turn, results in support load transfer growth through the grouting layer. It has been determined that the increase in the hardened cement grout strain and grouting layer thickness reduces support load.*

Keywords: *arch support; grouting layer; support load.*

Introduction. The most common type of mine support in Russian coal industry is steel ribs and reinforced concrete lagging whose main drawback is that it is impossible to provide tight contact between the support and the surrounding rock mass. So, the void behind the support requires filling to provide contact with the surrounding rock. If the void is not tightly filled, rock shifts, and support load therefore increases.

One way to ensure the tight contact between the support and the surrounding rock mass is contact grouting. The interaction between the arch support and the rock mass after contact grouting was fulfilled has received little attention and requires additional studies [1].

Currently, there is no method of calculating the parameters of a frame support with a grouting layer. The existing method of support design takes account only backfilling of the void behind the support.

In accordance with the Code SP91.13330.2012 "Underground mine workings", shifts compensated for by backfill compression depend on the material compressibility, backfill layer thickness, and design load on support, and are determined by experiment. For the backfill made of crushed rock with no experimental data, the shifts may be taken to be equal to 25% of the backfill layer thickness.

So, the normative method of frame arches design is based on applying a considerable number of correction factors, nomograms, and experimental data for particular mining and geological and mine technical conditions. It does not take full account of the grouting layer presence.

The scientists from the Tula school of geomechanics, namely, N. S. Bulychev, N. N. Fotieva, A. S. Sammal, S. V. Antsiferov, P. V. Deev, K. A. Golovin and others, have contributed heavily to the solution to the problem of support structures design for permanent mine workings [2–7].

The existing methods of the stress-strain state (SSS) design for various shells of mine workings in the rock mass are aimed at designing multilayered support structures in tunnels, subway, main crosscuts, and shafts with a heavy layer of concrete which prevents from rock destruction in the vicinity of these mine workings.

When mining in shafts, it is inadvisable to apply such layer of cement. For that reason, under certain mining and geological and mine-technical conditions of mining, the rock mass breaks, and a layer of soft rock develops between the grouting layer and the undisturbed rock mass. However, the development of a soft rock layer is neglected in the existing methods of SSS calculation. The variety of conditions requiring underground excavations support determines further study on the effect produced by different factors on the value of support load [8–13].

Research objective is to determine the effect produced by the thickness of the grouting layer and its strain characteristics on the arch support load value in order to check its strength in various mining and geological conditions.

Methods of research. Papers [14, 15] considered a solution to the problem of stress-strain state design for the *arch support–grouting layer–rock mass* system. It was taken into account that the zone of partial destruction is developed in the rock mass between the grouting layer and the undisturbed rock mass. This zone has a considerable effect of support load. When the rock is being broken, its volume in this layer increases, which, in its turn, results in support load transfer growth through the grouting layer.

When making calculation, the arched support is modeled by circular support like in paper [2], for instance. Such approach makes it possible to apply the analytical method of calculation and allows defining the arched support stress state well enough.

General pattern of calculation is presented in Figure 1, where P is pressure in undisturbed rock mass, MPa; R_d is the radius of the partially destroyed rock, m; h_d is the width of the partially destroyed rock, m.

Calculation is carried out for a circular mine working with R radius, m. With the known value of the mine working cross-sectional area S, m^2, the reduced radius $R = \sqrt{S / \pi}$, m, is calculated. Computational domain consists of four blocks.

Block 1 – support with strain and strength characteristics: E_k is the modulus of deformation; ν_k is the Poisson ratio; σ_k is the tensile strength of the material the support is made of (steel), MPa.

Block 2 – hardened cement grout with strain and strength characteristics: E_t is the modulus of deformation; ν_t is the Poisson ratio; σ_t is the compressive strength of hardened cement grout, MPa.

Block 3 – the zone of partially destroyed rock (behind limit deformation) where circumferential and radial stresses are proportional.

Block 4 – the zone of the surrounding rock in elastic state with strain and strength characteristics: E is the modulus of deformation; ν is the Poisson ratio; σ_{compr} is the compressive strength, MPa.

Zone edges remain continuous, so when transferring through the zone edges, radial shifts and stresses must be continuous, which determines the interaction between the blocks.

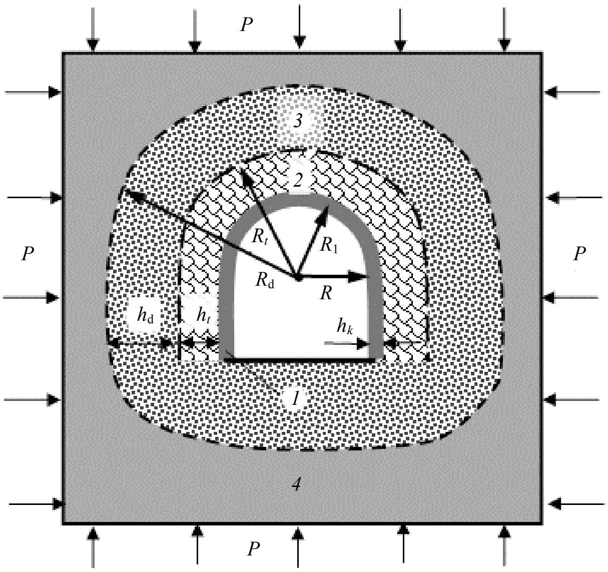

Figure 1. Calculation scheme:
1 – support; 2 – grouting layer; 3 – partially broken rock;
4 – surrounding rock
Рисунок 1. Расчетная схема:
1 – крепь; 2 – тампонажный слой; 3 – частично разрушенные породы; 4 – вмещающие породы

The calculation method was presented in paper [3]. The mine working is considered at a depth of H, m. The mine working is beyond the zone of high rock pressure (HRP), initial rock pressure $p = \gamma H = 0.025$H, MPa.

The AKP support (arch ring yielding support) with SVP-17…33 profile (purpose-built interchangeable profile) with the equivalent height of h_k, m, the value of which is selected from [1]. Support strain modulus is $E_k = (2…4) \cdot 10^3$ MPa.

Modulus of deformation E, Poisson ratio ν, compressive strength σ_{compr}, and structure weakening ratio k_s for rock are set for particular mining and geological conditions.

Grouting layer is built up using cement with carbon filler with the modulus of deformation E_t corresponding to coal. The grouting layer thickness is h_t, m.

The radius of the mine working and the support is $R_1 = R + h_k$, m.

The radius of the mine working and the grouting layer is $R_t = R_1 + h_t$, m.

Parameters determining the support load are calculated in a sequential order:

1) $c = \dfrac{1-\nu}{\nu}$ is the coefficient determining the value of maximum circumferential stress;

2) $k = \dfrac{2cP + k_s\sigma_{compr} / (1+\nu)}{2P - k_s\sigma_{compr}/(1+\nu)}$ is the dimensionless ratio, determining the distribution of stresses in the zone of disturbed rock;

3) $\sigma_m = \dfrac{2cP + k_s\sigma_{\text{compr}} / (1+\nu)}{c+1}$ is the maximum circumferential stress of the surrounding rock, MPa;

4) $\beta = \dfrac{1}{2} \cdot \left[\dfrac{E_t R(R_t^2 - R_1^2)}{E_k h_k R_t^2} + \dfrac{R_t^2 + R_1^2}{R_t^2} + \nu_t \dfrac{R_t^2 - R_1^2}{R_t^2} \right]$ is the factor of proportionality between the support load and grouting layer load;

5) $\alpha = \dfrac{\beta^2 \left(R_t^2 + R_1^2 \right) - 2\beta R_1^2}{R_t^2 - R_1^2} - \nu_t \beta^2$ is the coefficient determining the support load.

Support load is defined by the formula

$$q = \frac{\sigma_m}{2} \cdot \left(\frac{E_t\beta}{E\alpha} + \sqrt{\left(\frac{E_t\beta}{E\alpha} \right)^2 \frac{4E_t}{Ek\alpha}} \right).$$

Results. With the help of the developed methods, the support load has been calculated for the situation with the presence of the grouting layer. Calculation has been carried out under the following geometry, strain, and strength parameters:

– mine depth H = 100…300 m;
– support width h_k = 0.145 m (SVP-22, SVP-27);
– grouting layer thickness h_t = 0.1; 0.5 m;
– modulus of rock linear strain $E = 10^4$ MPa;
– modulus of support linear strain $E_k = 2 \cdot 10^3$ MPa;
– modulus of grouting layer linear strain $E_t = 10^3 \ldots 10^4$ MPa;
– rock Poisson ratio ν = 0.25;
– support Poisson ratio ν_k = 0.2;
– grouting layer Poisson ratio ν_t = 0.25;
– cross sectional area of the mine working S = 25 m^2.

Calculation results are presented in Table 1.

Table 1. Load on support *q*, MPa
Таблица 1. Давление на крепь *q*, МПа

H, m	h_t, m	E_t, MPa		
		10^3	$5 \cdot 10^3$	10^4
100	0.1	0.0766	0.0661	0.0611
	0.5	0.0753	0.0648	0.0622
200	0.1	0.3476	0.2619	0.2175
	0.5	0.2994	0.1940	0.1614
300	0.1	0.5700	0.4256	0.3507
	0.5	0.4867	0.3080	0.2522

Figure 2 depicts the effect produced by the modulus of grouting layer linear strain E_t on the support load q under various depth of mine working H and width of the grouting layer h_t. According to the reference book [16], the modulus of linear strain of coal is within (2…8) · 10^3 MPa. Blue markers show change in the support load at a depth of 100 m, yellow – 200 m, and red – 300 m.

Under H = 100 m depth of the mine working, the modulus of linear strain E_t and the width of the grouting layer have no marked impact on the value of the support load q.

Increase in the depth of mining results in higher support load. However, under same depth H, increased modulus of linear strain E_t and increased width of the grouting layer h_t reduce the support load.

So, under $H = 300$ m, increased modulus of linear strain E_t reduces the support load from 0.4867 to 0.2522 MPa, i.e. by 48%. Under $H = 200$ m, increased width of the grouting layer h_t reduces the support load from 0.2619 to 0.1940 MPa, i.e. by 26%. While under $H = 300$ m, increased width of the grouting layer ht reduces the support load by 28 %.

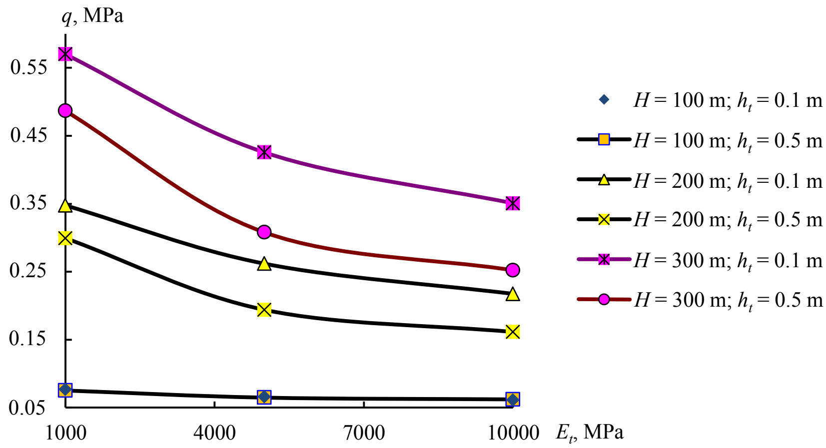

Figure 2. Influence of the grouting layer linear strain modulus E_t on the support load q at various depths H of mining and the widths h_t of the grouting layer
Рисунок 2. Влияние модуля линейной деформации тампонажного слоя E_t на давление на крепь q при разной глубине расположения выработки H и ширине тампонажного слоя h_t

Conclusions. The presence of the grouting layer in the void behind the support has a significant effect on the method of arch support design. To carry out an adequate mathematical simulation of the interaction within the *support-grouting layer-rock mass* system, the formulation of the problem of a circular mine support design is considered.

The developed method takes account of the fact that a layer of soft rock develops in the rock mass between the grouting layer and undisturbed rock. When the rock is being broken, the volume of rock in this layer increases, which, in its turn, results in support load transfer growth through the grouting layer.

Increase in the depth of mining results in the increased support load. However, under same depth H, m, the increased modulus of linear strain E_t and increased thickness of the grouting layer h_t, m, reduce the support load.

When mining at a depth of 100…300 m with the cross section of 25 m^2, the increase in the modulus of hardened cement grout linear strain from 10^3 to 10^4 MPa reduces the support load by up to 48%. Under grouting layer width increase from 0.1 to 0.5 m, support load reduces by up to 28%.

REFERENCES

1. Liskovets A. S., Tatsienko V. P. Analysis of support and tamping methods of the behind-anchoring space of mine workings and methods for calculating the interaction of the support with the rock massif. *Tekhnika i tekhnologiia gornogo dela = Journal of Mining and Geotechnical Engineering*. 2021; 1(12): 27–52. (In Russ.) Available from: doi: 10.26730/2618-7434-2021-1-27-52

2. Bulychev N. S. *Mechanics of underground structures*. Moscow: Nedra Publishing; 1982. (In Russ.)

3. Sammal A. S., Voronina I. Iu., Shelepov N. V. Mathematical modelling the interaction of parallel non-circular underwater tunnel multilayer linings with the technologically heterogeneous rock mass. *Izvestiia Tulskogo Gosudarstvennogo Universiteta. Nauki o Zemle = Proceedings of the Tula State University. Earth Sciences*. 2016; 3: 154–163. (In Russ.)

4. Sammal A. S., Sergeev S. V., Antsiferov S. V., Deev P. V. Estimating concrete shaft lining application field in zones of tectonic disturbance. *Izvestiia Tulskogo Gosudarstvennogo Universiteta. Nauki o Zemle = Proceedings of the Tula State University. Earth Sciences*. 2018; 4: 317–326. (In Russ.)

5. Antsiferov S. V., Fotieva N. N., Bulychev N. S., Gribanov V. B. About the calculation of tunnel lining, constructed in a soil massif, subject to preparatory strenghtening. *Izvestiia Tulskogo Gosudarstvennogo Universiteta. Nauki o Zemle = Proceedings of the Tula State University. Earth Sciences*. 2015; 3: 98–107. (In Russ.)

6. Golovin K. A., Kovalev R. A., Kopylov A. B. Calculation of lining which interacting with layer of widened rock. *Izvestiia Tulskogo Gosudarstvennogo Universiteta. Nauki o Zemle = Proceedings of the Tula State University. Earth Sciences*. 2016; 4: 174–178. (In Russ.)

7. Deev P. V., Sammal A. S., Antsiferov S. V., Shelepov N. V. Influencing technological gap value by stress state of tunnel linings. *Izvestiia Tulskogo Gosudarstvennogo Universiteta. Nauki o Zemle = Proceedings of the Tula State University. Earth Sciences*. 2018; 4: 287–293. (In Russ.)

8. He S., Lai J., Zhong Y., Wang K. Damage behaviors, prediction methods and prevention methods of rockburst in 13 deep traffic tunnels in China. *Engineering Failure Analysis*. 2021; 121: 105178. Available from: doi: 10.1016/j.engfailanal.2020.105178

9. Szurgacz D., Brodny J. Adapting the powered roof support to diverse mining and geological conditions. *Energies*. 2020; 13(2): 405. Available from: doi: 10.3390/en13020405

10. Malkowski P., Ostrowski L., Brodny J. Analysis of Young's modulus for Carboniferrous sedimentary rocks and its relationship with uniaxial compressive strength using different methods of modulus determination. *Journal of Sustainable Mining*. 2018; 17(3): 145–157.

11. Yu Y., Bai J., Wang X., Zhang L. Control of the surrounding rock of a goaf-side entry driving heading mining face. *Sustainability*. 2020; 12(7): 2623. Available from: doi: 10.3390/su12072623

12. Chen Z., He P., Yan D. M., et al. Upper-bound limit analysis of tunnel face stability under advanced support. *Yantu Lixue*. 2019; 40(6): 2154–2162. Available from: doi: 10.16285/j.rsm.2018.1903

13. Vokhmin S. A., Kurchin G. S., Maiorov E. S., Kirsanov A. K., Kostylev S. S. An overview of deep horizons excavation lining technologies at Oktyabrsky deposit. *Izvestiya vysshikh uchebnykh zavedenii. Gornyi zhurnal = News of the Higher Institutions. Mining Journal*. 2019; 7: 45–52. (In Russ.) Available from: doi: 10.21440/0536-1028-2019-7-45-52

14. Tatsienko V. P., Gogolin V. A., Ermakova I. A., Lesin Iu. V., Liskovets A. S. Calculation of the support with filling of the space behind the support. *Vestnik Kuzbasskogo Gosudarstvennogo Tekhnicheskogo Universiteta = Bulletin of the Kuzbass State Technical University*. 2019; 3: 75–81. (In Russ.)

15. Liskovets A. S., Tatsienko V. P., Gogolin V. A., Ermakova I. A. Engineering method for calculating pressure at the support and displacement of crown with filling of the space behind the support. *Vestnik Kuzbasskogo Gosudarstvennogo Tekhnicheskogo Universiteta = Bulletin of the Kuzbass State Technical University*. 2020; 2: 97–102. (In Russ.)

16. Shtumpf G. G., Ryzhkov Iu. A., Shalamanov V. A., Petrov A. I. *Physical and mechanical properties of rock and coal of the Kuznetsk Basin*. Moscow: Nedra Publishing; 1994. (In Russ.)

Received 17 June 2021

Information about authors:

Aleksandr S. Liskovets – senior researcher, Institute of Industrial and Ecological Safety, T. F. Gorbachev Kuzbass State Technical University. E-mail: liskovets@sgp.su; https://orcid.org/0000-0002-0679-1750
Viktor P. Tatsienko – DSc (Engineering), Institute of Industrial and Ecological Safety, T. F. Gorbachev Kuzbass State Technical University. E-mail: tatsienkovp@kuzstu.ru; https://orcid.org/0000-0001-5922-113X
Viacheslav A. Gogolin – DSc (Engineering), Professor, professor of Mathematics Department, T. F. Gorbachev Kuzbass State Technical University. E-mail: gva.pm@kuzstu.ru; https://orcid.org/0000-0003-4533-3741

УДК 622.831 DOI: 10.21440/0536-1028-2021-6-5-12

Влияние параметров тампонажа закрепного пространства на давление на крепь

Лисковец А. С.[1], Тациенко В. П.[1], Гоголин В. А.[1]
[1] Кузбасский государственный технический университет имени Т. Ф. Горбачева, Кемерово, Россия.

Реферат

Введение. *В работе анализируются современные методы расчета рамных крепей капитальных выработок. Показана недостаточная изученность этого вопроса при наличии тампонажа закрепного пространства. Наличие тампонажа закрепного пространства позволяет осуществить полный контакт тампонажного камня с вмещающими породами, что не удается сделать при применении бетонных затяжек. В работе используется аналитический метод расчета арочной крепи, тампонажного слоя и вмещающих пород с учетом их разупрочнения. Получены аналитические формулы, определяющие давление на крепь, которые учитывают деформационные* *и прочностные характеристики вмещающих пород, тампонажного камня и крепи. Проведены расчеты давления на крепь при разных значениях толщины тампонажного слоя, его модуля линейных деформаций и глубины проведения выработки. Получены зависимости давления на крепь от этих параметров, что позволяет выбирать состав тампонажного камня для различных горно-геологических условий.*

Цель исследования *– установить влияние толщины тампонажного слоя и его деформационных характеристик на величину давления на арочную крепь для проверки ее прочности в различных горно-геологических условиях проведения выработки.*

Методология исследований *основана на применении физически обоснованных аналитических методов геомеханики для решения задачи о взаимодействии крепи, тампонажного слоя и массива вмещающих пород.*

Результаты. *Приведены результаты расчетов давления на арочную крепь при разных значениях толщины тампонажного слоя, его деформационных характеристик и глубины проведения выработки.*

Выводы. *Наличие тампонажного слоя в закрепном пространстве оказывает существенное влияние на методику расчета арочной крепи. Разработанная методика учитывает, что в массиве горных пород возникает слой разупрочненных пород между тампонажным слоем и неразрушенным массивом горных пород. При разрушении горных пород в этом слое происходит увеличение объема породы, что, в свою очередь, приводит к увеличению давления на крепь через тампонажный слой. Установлено, что увеличение модуля линейной деформации тампонажного камня и толщины тампонажного слоя уменьшает давление на крепь.*

Ключевые слова: *арочная крепь; тампонажный слой; давление на крепь.*

БИБЛИОГРАФИЧЕСКИЙ СПИСОК

1. Лисковец А. С., Тациенко В. П. Анализ способов крепления, тампонажа закрепного пространства горных выработок и методов расчета взаимодействия крепи с массивом горных пород // Техника и технология горного дела. 2021. № 1(12). С. 27–52. DOI: 10.26730/2618-7434-2021-1-27-52

2. Булычев Н. С. Механика подземных сооружений. М.: Недра, 1982. 272 с.

3. Саммаль А. С., Воронина И. Ю., Шелепов Н. В. Математическое моделирование взаимодействия многослойных обделок параллельных некруговых подводных тоннелей с технологически неоднородным массивом пород // Известия Тульского государственного университета. Науки о Земле. 2016. № 3. С. 154–163.

4. Саммаль А. С., Сергеев С. В., Анциферов С. В., Деев П. В. Определение области применения бетонной крепи стволов в зонах тектонических нарушений // Известия Тульского государственного университета. Науки о Земле. 2018. № 4. С. 317–326.

5. Анциферов С. В., Фотиева Н. Н., Булычев Н. С., Грибанов В. Б. О расчете обделок тоннелей, сооруженных в массиве грунта, подверженного предварительному укреплению // Известия Тульского государственного университета. Науки о Земле. 2015. № 3. С. 98–107.

6. Головин К. А., Ковалев Р. А., Копылов А. Б. Расчет крепей, взаимодействующих со слоем расширяющихся пород // Известия ТулГУ. Науки о Земле. 2016. Вып. 4. С. 174–178.

7. Деев П. В., Саммаль А. С., Анциферов С. В., Шелепов Н. В. Влияние величины технологического зазора на напряженное состояние обделок тоннелей // Известия Тульского государственного университета. Науки о Земле. 2018. № 4. С. 287–293.

8. He S., Lai J., Zhong Y., Wang K. Damage behaviors, prediction methods and prevention methods of rockburst in 13 deep traffic tunnels in China // Engineering Failure Analysis. 2021. Vol. 121. P. 105178. DOI: 10.1016/j.engfailanal.2020.105178

9. Szurgacz D., Brodny J. Adapting the powered roof support to diverse mining and geological conditions // Energies. 2020. Vol. 13. No. 2. P. 405. DOI: 10.3390/en13020405

10. Malkowski P., Ostrowski L., Brodny J. Analysis of Young's modulus for Carboniferrous sedimentary rocks and its relationship with uniaxial compressive strength using different methods of modulus determination // Journal of Sustainable Mining. 2018. Vol. 17. Issue. 3. P. 145–157.

11. Yu Y., Bai J., Wang X., Zhang L. Control of the surrounding rock of a goaf-side entry driving heading mining face // Sustainability. 2020. Vol. 12. No. 7. P. 2623. DOI: 10.3390/su12072623

12. Chen Z., He P., Yan D. M., et al. Upper-bound limit analysis of tunnel face stability under advanced support // Yantu Lixue. 2019. Vol. 40. No. 6. P. 2154–2162. DOI: 10.16285/j.rsm.2018.1903

13. Вохмин С. А., Курчин Г. С., Майоров Е. С., Кирсанов А. К., Костылев С. С. Технологии крепления горных выработок глубоких горизонтов Октябрьского месторождения // Известия вузов. Горный журнал. 2019. № 7. С. 45–52. DOI: 10.21440/0536-1028-2019-7-45-52

14. Тациенко В. П., Гоголин В. А., Ермакова И. А., Лесин Ю. В., Лисковец А. С. Расчет крепи с учетом тампонажа закрепного пространства // Вестник КузГТУ. 2019. № 3. С. 75–81.

15. Лисковец А. С., Тациенко В. П., Гоголин В. А., Ермакова И. А. Инженерная методика расчета давления на крепь и смещения верхняка крепи при тампонаже закрепного пространства // Вестник КузГТУ. 2020. № 2. С. 97–102.

16. Штумпф Г. Г., Рыжков Ю. А., Шаламанов В. А., Петров А. И. Физико-механические свойства горных пород и углей Кузнецкого бассейна. М.: Недра, 1994. 447 с.

Поступила в редакцию 17 июня 2021 года

Сведения об авторах:

Лисковец Александр Сергеевич – старший научный сотрудник Института промышленной и экологической безопасности Кузбасского государственного технического университета имени Т. Ф. Горбачева. E-mail: liskovets@sgp.su; https://orcid.org/0000-0002-0679-1750
Тациенко Виктор Прокопьевич – доктор технических наук, директор Института промышленной и экологической безопасности Кузбасского государственного технического университета имени Т. Ф. Горбачева. E-mail: tatsienkovp@kuzstu.ru; https://orcid.org/0000-0001-5922-113X
Гоголин Вячеслав Анатольевич – доктор технических наук, профессор, профессор кафедры математики Кузбасского государственного технического университета имени Т. Ф. Горбачева. E-mail: gva.pm@kuzstu.ru; https://orcid.org/0000-0003-4533-3741

Для цитирования: Лисковец А. С., Тациенко В. П., Гоголин В. А. Влияние параметров тампонажа закрепного пространства на давление на крепь // Известия вузов. Горный журнал. 2021. № 6. С. 5–12 (In Eng.). DOI: 10.21440/0536-1028-2021-6-5-12
For citation: Liskovets A. S., Tatsienko V. P., Gogolin V. A. The effect of contact grouting on support load. *Izvestiya vysshikh uchebnykh zavedenii. Gornyi zhurnal = News of the Higher Institutions. Mining Journal*. 2021; 6: 5–12. DOI: 10.21440/0536-1028-2021-6-5-12