Strength Calculations of Block Elements of Room-and-Pillar Mining under the Permafrost Conditions

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ABSTRACT: The paper covers results of rheological properties of gypsum under natural conditions of permafrost and stress-and-strain conditions of room's roof rocks in gypsum quarries depending upon the ceiling thickness. The recommendations concerning room and pillar parameters are given.

1 INTRODUCTION

The study of both strength and rheological characteristics of rocks for specific mining and geological conditions helps to determine optimum dimensions of rooms and pillars for long-time strength.

Rheological properties of rocks are one of the most important factors which determine stress-and-strain conditions of rock massif to develop underground workings. Mining pressure in underground constructions, time effect on underground workings roof stability, displacement of rock mass while mining, etc. are results of changing mechanical properties of rocks connected with their rheological features.

Rocks of Olekminsk deposit (Yakutia, Russian Federation) are in permafrost zone. Rheological properties of the deposit gypsum have not been studied yet. The study of rheological properties of frozen gypsum is the most important. It is known that ice is very creepy. It can be suggested that frozen gypsum has the same properties under sufficient ice content.

Thus, studies of rheological properties of frozen gypsum are rather important to substantiate parameters of rooms and pillars.

2 STUDYING RHEOLOGICAL PROPERTIES OF GYPSUM

As effect of positive temperatures changes rheological properties of rock tests were performed under natural conditions of quarry. To do that one of the quarry rooms was used as a research laboratory. The temperature in the room was three degrees below zero Centigrade. The laboratory was located in such a way to avoid effect of mining process on the research results.

Cores were selected from monolith. Cores for were prepared manually. Tests were performed on spring-controlled stands. Samples were loaded using hydraulic jack. Jack pressure was measured with the help of manometer. Deformation was determined by means of clock indicators.

Before creep tests the strength of gypsum as for uniaxial compression was determined. The information is required for preliminary choice of loads on the sample (Erzhanov 1964). Fracture load was 110 MPa. 15 samples were taken for rheological tests. Three similar samples were under each load. Value of the loads was 0.3; 0.4; 0.5; 0.7; 0.85; 0.95 of fracture value. Rock creep tests lasted for 150 days. Time diagrams of deformation under constant load that is creep curves were developed on the basis of the data (Figure1).

Creep curves have the three specific areas: initial curvilinear area belonging to unstationary creep; rectilinear area called as stationary creep, and terminal area of curves belonging to progressive creep which results in fracture.

Rheological tests of frozen gypsum show that it has noticeable creep under loads being more than 0,4 of fracture one. If load was 0.3 of fracture one the deformation stopped after 20 days and creep was not available. The results give ability to make the conclusion. Strength margin equal to three may be taken if durable strength of construction and complete elimination of gypsum creep are required.

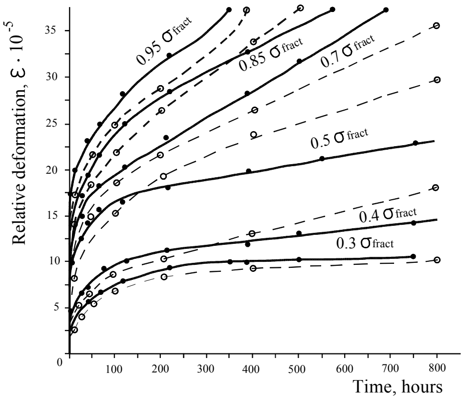

Figure 1. Curves of Gypsum Creep
— Experimental Curves;
– – Design Curves.

If loads are 0.5 to 0.85 of fracture one then creep rate is not important and irreversible deformations of pillars grow slowly. If it is required to keep the construction stability during several decades then strength margin can be decreased up to two. In this case the pillars will deform themselves. Their height will be decreased as a result of plastic deformation but fracture will not take place. Pillar will keep their carrying capability.

To determine absolute deformation of pillars in a long time the experimental data concerning gypsum creep are shown as a functional relation.

For sedimentary rocks congenital linear creep with sufficient degree of accuracy is described by an equation where creep memory function is expressed as exponential function which reflects initial stage of the rock creep process completely (Erzhanov 1964):

$$\varepsilon(t)=\varepsilon(\sigma_0)\left(1+\frac{\delta}{1-\alpha}t^{1-\alpha}\right) \qquad (1)$$

Where $\varepsilon(\sigma_0)$ is the sample deformation under rapid load up to stress value;

α and δ are the equation parameters (rheological characteristics of rock).

To determine α and δ parameters calculation method from (Guidelines 1972) was used. Initial data are:

- The value of initial deformation $\varepsilon(\sigma_0)$ for t = 0
- Deformation period
- Those corresponding to chosen deformation periods.

Creep curves for the loads under which experimental curves were obtained according to calculations of relative axial deformations were developed. The results are shown in Figure1.

Comparison of design data and results of natural research demonstrates good coincidence of the results. The deformation values coincides rather accurately if load is 0.3 σ_{destr} and if loads are more than 0.85 σ_{destr}. If loads are within 0.4 σ_{destr} and 0.7 σ_{destr} calculated deformation value is some higher. As it increases strength margin one may say that the calculation method reflects gypsum creep adequately.

Obtained values of relative deformations were used to determine absolute deformation of pillars with given height after 50 and 100 years. The results are in the Table 1.

Table 1. Relative and Absolute Deformations of Pillars under Durable Loads in Gypsum Quarry.

Load in Parts of Fracture One	50 Years		100 Years	
	Relative Deformation, $E\cdot10^{-5}$	Absolute Deformation, mm	Relative Deformation, $E\cdot10^{-5}$	Absolute Deformation, mm
0,3	80,5	6,4	99,4	8,0.
0,5	244,7	19,6	328,3	26,4
0,7	517,8	41,4	697,5	56,0

3 EFFECT OF CEILING THICKNESS ON STRESS IN IT

It is not difficult to determine dimensions of interchamber pillars while substantiating room parameters. Results of numerous research show that simple calculation methods are expedient for gypsum deposits (Melnikov 1964, Methods 1962).

It is much more difficult to determine maximum allowable room distance. The issues are highlighted completely in construction standards and regulations where room roof is considered as a slab with equally distributed load. Gypsum quarries have not “false roof”. Roof is rock layers with different strength and elastic properties. There is some kind of tie between layers that is rocks transit into each other gradually. Listed peculiarities should be taken into account to calculate strength of room distance.

If roof rocks are weaker than gypsum then the gypsum ceiling is left in the roof. If so it is necessary to test strength of the ceiling.

Finite element method (Zienkiewicz & Taylor 2000) is used to calculate ceiling stresses if room distance in gypsum quarry is constant and ceiling thickness is 1, 2 and 3 m. The calculations are required to determine effect of ceiling thickness on stress in it.

The results show that if ceiling thickness increases the stresses in it increase too.

Calculation m0ethod of Privarnikov-Philippov (Philippov 1979) was used for similar conditions. Calculation results on the two methods are in the Table 2.

Stress values in the ceiling calculated according to the two methods may be considered as equal ones. The data are used to obtain the dependence of tension stresses in ceiling depending upon its thickness variation (Figure 2).

Table 2. Results of Ceiling Stress Calculations.

Method	Tension Stresses (MPa) in Room Roof is Ceiling Thickness is		
	1m	2m	3m
FEM	5,91	8,90	9,10
Privarnikov-Philippov	6,17	7,05	8,23

Following conclusions are possible. Usually, the ceiling is considered as a support beam or a slab loaded with equally distributed load. In this case stresses decrease if thickness increases. Actually stratified medium with layers tied is available in room roof. The analogy with support beam is not expedient. Besides if ceiling thickness increases the height of room decreases, and it results in stress increase in roof.

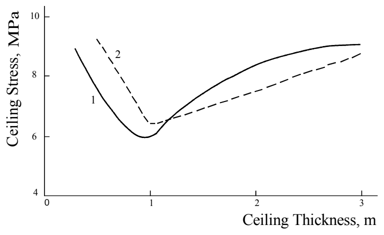

Figure 2. Dependence of Tension Stresses in Room Roof on Ceiling Thickness: 1 – on FEM; 2 – on Privarnikov-Philippov Method.

4 SUBSTANTIATING DIMENSIONS OF ROOM AND PILLARS

The results were used to calculate strength of interchamber pillars and room distance of gypsum deposit by the finite element method.

Design values of compressive stresses within pillars and tension stresses within distance center were compared with allowable stresses as for compression and tension for rock. Elastic characteristics of rock taken for calculations are in the Table 3.

Finite element method was used to calculate stresses in the construction. It is determined that strength margin equal to three will correspond to 4m pillar width, 8m room distance, and 1m thickness of gypsum ceiling.

Table 3. Elastic Characteristics of Gypsum and Rocks of Olekminsk Deposit.

Rocks	Elastic Modulus, $E \cdot 10^4$ MPa	Poisson Ratio
Gypsum	38	0,27
Dolomite	50	0,28
Argillite	11	0,30
Siltstone	20	0,13

Finite element method helped to take into consideration effect of rock stratification on stressed state of pillars and room roof. Besides, the method allows determining stresses around rooms having complicated forms (Figure 3).

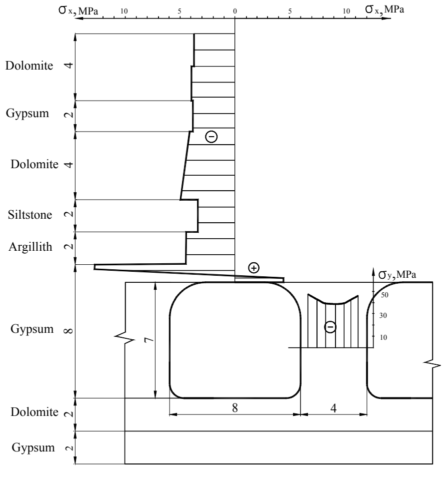

Figure 3. Design Diagram and Stress Epures in Roof and Pillar Rooms.

5 CONCLUSIONS

The research helps to come to the conclusions. The studies of rheological properties of frozen gypsum show that under 0.35-0.85 loads of fracture one the rate of stable creep is not important. In 50 years the absolute pillar deformation will be 41 mm if load is 0.7 of fracture one. Creep stops in 15-20 days if loads are less than 0.35 of fracture one. In 100 years absolute deformation of pillars will be 26mm as a result of stable creep under load equal to 0.5 of fracture one. Strength margin can be equal to three if it is required to have durable strength of construction and to avoid gypsum creep completely. Thus recommended parameters of rooms are: width of pillars is 4m, room distance is 8m, and thickness of gypsum ceiling within the roof is 1m. Using the parameters of rooms for Olekminsk deposit helped to decrease gypsum losses by 30%.

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