Study of rock displacement with the help of equivalent materials using room-and-pillar mining method

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ABSTRACT: Field study made with the help of equivalent materials to determine minimum dimension of interchamber and barrier pillars and limiting chamber span was carried out. Modeling was made for gypsum quarry.

1 INTRODUCTION

The aim of modeling rock displacement made with the help of equivalent materials is to determine general regularities of interchamber and barrier pillars operation as elements of underground construction.

Modeling results were used to design calculation diagrams to determine loads acting on barrier pillar. Furthermore, modeling enabled to determine limiting chamber span and minimum width of barrier pillars.

Geometrical and force similarity were taking into account in modeling [1, 2].

Force similarity were determined by the following equation

$$N_м = C_e \times C_\gamma \times N_H ,$$

Where C_e is geometrical model scale; C_γ is density scale; $N_м$, N_H is mechanical characteristic of model material and nature.

Breaking compressive stress was taken as a mechanical material characteristic.

Modeling was made in conditions of Olekminsk quarry. Density of gypsum $2{,}3 \cdot 10^{-3}$ kg/m^3, dolomite $2{,}5 \cdot 10^{-3}$ kg/m^3, silt stone $2{,}55 \cdot 10^{-3}$ kg/m^3, mudstone $2{,}5 \cdot 10^{-3}$ kg/m^3 was taken into account. Quartz sand with small amount of alabaster was used as an equivalent material. While studying set of tests materials which characteristic is given in Tables 1, 2 were selected.

Table 1. Breaking compressive stress for rock and model material at geometrical scale 1:100

Working model within rocks	Component name	Component weight , g	Model, 10^5 MPa		Nature, 10^5 MPa
			calculation	factual	
Gypsum	Sand	1000			
	Alabaster	4	0,66	0,54	110
Mudstone	Sand	1000			
	Alabaster	2,5	0,22	0,22	37
Silt stone	Sand	1000			
	Alabaster	6	0,78	0,75	130
Dolomite	Sand	1000			
	Alabaster	10	1,3	1,31	219

Density of model material was slightly changed at various component correlation and was $1{,}4 - 1{,}5 \cdot 10^{-3}$ kg/m^3. Strength of equivalent material at geometrical scale 1:200 was twice as little as that one given in the Table1.

The following stand dimensions to patternmaking were accepted: length is 2 m, height is 1 m, width is 0,25 m. The front wall of the pattern was made of glass.

Table 2. Breaking compressive stress for rocks and model material at geometrical scale 1:200

Working model within rocks	Component name	Component weight , g	Model, 10^5 MPa		Nature, 10^5 MPa
			calculation	factual	
Gypsum	Sand	1000			
	Alabaster	2	0,33	0,30	110
Mudstone	Sand	1000			
	Alabaster	1,3	0,11	0,10	37
Silt	Sand	1000			
	Alabaster	3	0,39	0,38	130
Dolomite	Sand	1000			
	Alabaster	5	0,65	0,60	219

Models had 8 layers imitating corresponding rock stratification within the nature. Layer characteristic at scale 1:100 is given in the table.

Rock name	Layer height within working, cm
Dolomite	10
Gypsum	8
Mudstone	3
Silt	2
Dolomite	2
Gypsum	4
Dolomite	4
Pumps	56

The process of patternmaking is the following: material was arranged by layers with 2-3-cm width and compressed by roller (10 cycles).

There are 2 panels with barrier pillars between them within the working. Chamber span in all models in nature is 8m, pillar width is 4 m. Ceiling within chamber of the roof is made of gypsum with 1-m thickness. The width of barrier pillars was 20 and 30 m (all dimensions here and then are given in terms of nature).

2 MODELING ROOM-AND-PILLAR MINING METHOD WITH 20-METER WIDTH OF BARRIER PILLAR

Model imitated the area of deposit. Barrier pillar is in the center of it. Chambers are worked-out to the left and to the right within 2 panels. This is initial position. Model scale is 1:100.

The width of barrier pillar is 20 m (in nature).Six pillars were initially worked-out on the both sides of barrier pillar. Construction was in the stable state, there was no caving. Gradual interchamber pillar caving was imitated then. As a result, load acting on barrier pillar was increased. First, the width of 2 interchamber pillars was reduced up to 2 m (pillars 7-8- and 8-9) (Fig.1,a). There were no disturbances. It is natural, because pillar size was accepted with safety margin 2-3. Then these pillars were completely removed and chamber span was reduced up to 32 m. Such span was stable (Fig. 1, b).

Experiment showed that 8-m chamber span was accepted with rather high level of safety margin.

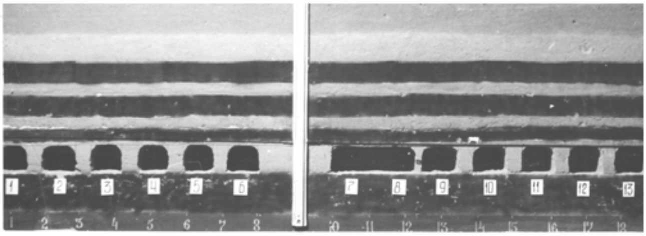
Such workout of interchamber pillar was carried out to the left of barrier pillar. Destruction of interchamber pillars has started. Pillar 4-5 was destructed first, then the rest interchamber pillars and at last the barrier pillar (Fig.1, c).

There was not arch formation within chamber roof. Entire rock mass above gypsum layer has completely collapsed.

Model 1 showed that 4-m width pillars and 8-m chamber span have rather high level of safety margin but barrier pillar hasn't performed its function. This pillar has destructed and couldn't prevent roof rock displacement.

Furthermore, this modeling showed that arch formation is not an obligatory element of roof collapse. Rock mass displacement up to the surface took place due to pillar destruction without arch formation in roof chamber and in the panel in a whole. On the basis of study described above width of barrier pillar in subsequent models was increased up to 30 m.

a



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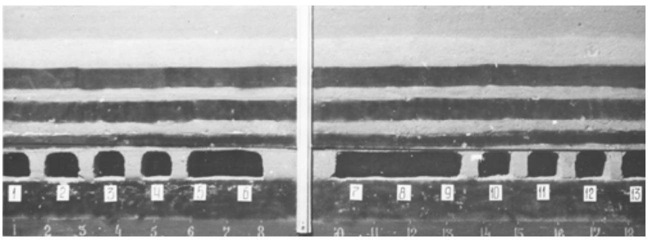

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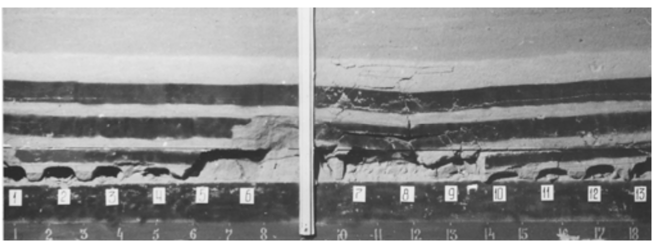


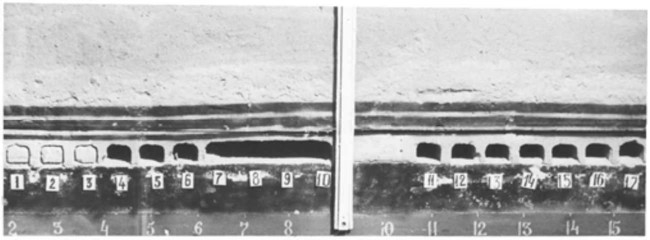
Figure 1. Model 1. Modeling concerning adequacy of pillars and chamber span to the level of strength: a – interchamber pillar was worked-out to the right of barrier one; b – interchamber pillar was worked-out to the left of barrier one; c – model after roof rock collapse

3 MODELING ROOM-AND-PILLAR MINING METHOD WITH 30-METER WIDTH OF BARRIER PILLAR

General construction of the model is the same as the previous one. Barrier pillar is in the center of the model, but its width was increased up to 30 m (all dimensions are given in terms of nature). Chambers are worked-out both to the right and to the left of it. 10 chambers are worked-out within the right panel and 7 chambers are worked-out within the left one. Chamber scale is 1:200.

The interchamber pillars were removed in the left panel and chamber span was increased up to 44 m (Fig. 2, a). After that pillar destruction between chambers 6, 5 and 4 took place. Rocks within the panel collapsed up to the model surface (Fig. 2, b). Barrier pillar remained the same and caving didn't spread to the neighboring model. So, width of barrier pillar was adequate to the level of strength. There was not arch formation in this model as well as in the previous one. Caving spread to the model surface at once.

a



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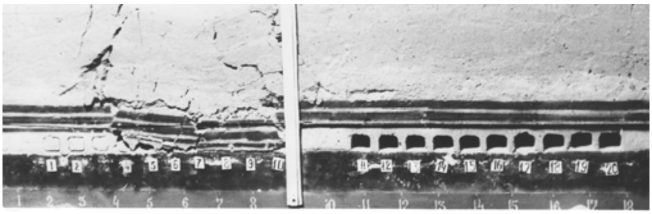

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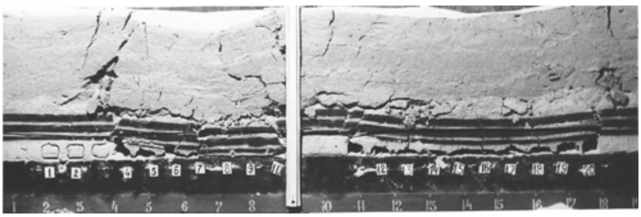


Figure 2. Model 2. Modeling the process of roof collapse in case of interchamber pillar destruction: a – model before roof collapse within the left panel; b – roof collapse within the left panel; c – roof collapse within the right panel after working-out pillars 15–16.

After that pillar 15-16 was removed within the first panel. It was not enough to collapse the rest pillars and shifting rock mass to the surface (Fig.2, c). There was not arch formation. Barrier pillar left the same. It confirmed an adequacy of its dimensions to the level of strength in case of emergency.

4 MODELING LIMITING CHAMBER SPAN

In the first two cases stable chamber span was 32 and 44 m. To check this result one more time model No 3 was worked-out (Fig. 3, a). Span of a single chamber was being gradually increased within this model. Roof collapse took place at 44-m span that confirmed results obtained in the models 1 and 2.It should be noted that under roof collapse within such single chamber, arch was formed but its contour is indistinct (Fig. 3, b).

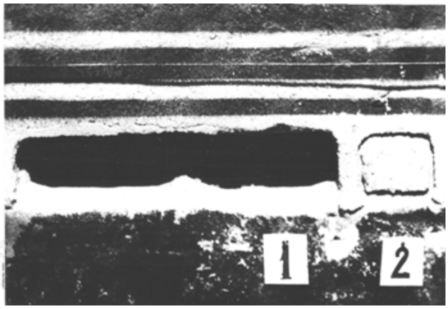
5 DETERMINING LOADS ACTING ON BARRIER PILLAR

It was supposed to determine the character of enclosing rock displacement within the panel confined by barrier pillars with the help of modeling in case of destruction of interchamber pillars. It is required to design the diagram determining loads acting on barrier pillar.

It was determined that after destruction load of three or four interchamber pillars acting on neighboring pillars increases and they are destructed as well. Entire rock mass displacement to the surface takes place then. Moreover, rocks are cut along the boundary of barrier pillar. Arch is not formed. Entire rock mass is shifted to the surface at once. If the width of barrier pillar is insufficient, it can be collapsed.

20-m width barrier pillar collapsed within the first model. 30-m width pillar appeared to be stable within the second one.

a



b

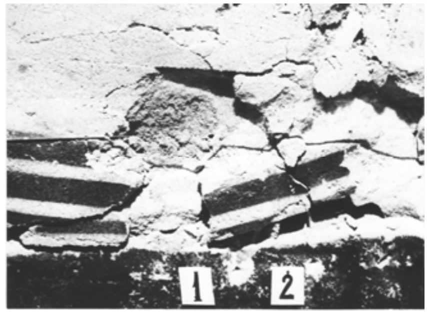


Figure 3. Model 3. Modeling limiting span of a single chamber: a – span chamber extension; b – chambers after collapse

How to make barrier pillar stable after interchamber pillar destruction? Obviously, it should take load from entire rock mass within panel, i.e. the load which interchambers pillars took earlier. According to the study described above calculation diagram to determine load R on running meter of barrier pillar is offered (Fig. 4, a). This diagram shows that load calculation acting barrier pillar is

$$P = (L + B)H\gamma$$

Where L is panel width, m; B is width of barrier pillar, m; H is depth from the surface to the roof and the layer, m; γ is density of roof rocks, kg/m^3.

Compressed stresses within barrier pillar will be

$$\sigma = \frac{(L + B)H\gamma}{B}$$

These stresses should be less than assumed ones. It enables to recommend small level of safety margin equal to 1,5 – 2.

It is pointed out that this conclusion doesn't correspond to that one offered by V.V.Kulikov (Fig. 4, b) in his paper [3].

It is supposed that V.V. Kulikov’s hypothesis should not be considered as universal one and acceptable to all mining conditions. Probably, it can be true in definite conditions. Modeling carried out for gypsum quarries proved that the work at these quarries differs from the diagram offered by V.V.Kulikov.

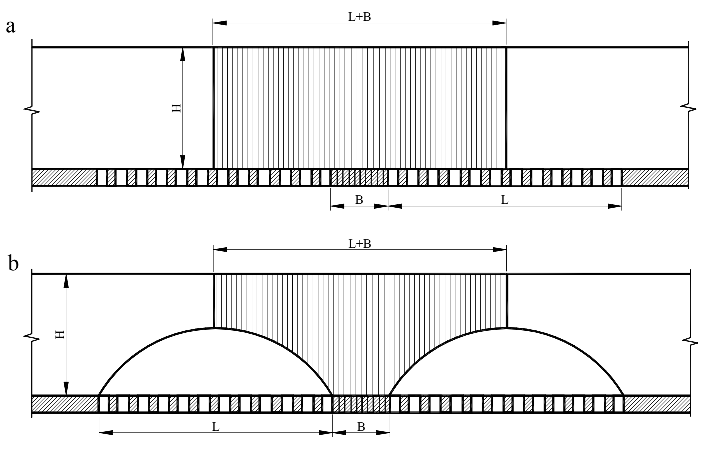


Figure 4. Calculation diagrams to determine load acting on barrier pillar: a – according to modeling results; b – according to V.V.Kulikov’s data

4 CONCLUSION

Calculation diagram to determine load on running meter of barrier pillar was obtained by modeling made with the help of equivalent material. This calculation diagram of barrier pillar is true to conditions where modeling was carried out, that is, rock mass above roof rock is 60-70 m, panel width is 100-200 m with particular rock stratification.

It was determined that arch formation under interchamber pillar caving at gypsum quarries doesn't take place.

Some studies showed that load acting on pillars fewer than rock mass from layer to surface. It is determined by rock weight   from the roof layer to pressure curve. However, diagram of determining load acting on pillar is confirmed by this study. According to this diagram load acting on pillar is determined by the weight of entire rock mass from layer to surface.

Roof of the chambers seemed to be stable while increasing span up to 44 m. It is unexpected conclusion. In future it will be required to carry out the study of tension stresses within the roof of chambers with the same span using the method of elasticity theory to explain validity of such large spans.

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