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PANEL WIDTH AFFECTED BY ROCK MASS CLASSIFICATIONS (ABU-TARTUR PHOSPHATE MINES)

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ABSTRACT

Rock mass classification systems consider one of the design tools, which are used in conjunction with engineering assessments and other design approaches. There are many classification systems, which are widely employed in rock engineering. In this study one of these systems is used for the selection of the optimum panel width in phosphate mine Abu-Tartur area. Geological Strength Index (GSI) is one of these systems which enables for calculations of the panel width. Data for the GSI system are obtained from geological reports, some field measurements and laboratory tests. The obtained panel width (wall length) for Abu-Tartur area is calculated to be about 100m (102m) which differs strongly from the applied length in the area (150m). So, it is recommended to apply this obtained length to secure safe mining conditions without roof falls which is the main problem facing underground mining in this area.

Keywords: Rock Mass Classification - Geological Strength Index (GSI) - Abu-Tartur longwall phosphate mine- Panel width

1. Introduction

Rock mass property is governed by the properties of intact rock materials and of the discontinuities in the rock. The behaviour of the rock mass is also influenced by the conditions of the rock mass properties, in-situ stresses and groundwater pressures. The quality of a rock mass type can be quantified by means of rock mass classifications [1].

Most modern rock mass classification systems assess and rate the factors affecting the stability/instability of rock masses surrounding underground excavations and make support recommendations. It is for this reason that, for many years, rock mass classification systems have formed the basis of the design of mining methods, optimum excavation dimensions, and support requirements for shallow and deep mines [2].

There are many factors affecting the panel width such as geological conditions, rock mass properties, mining depth, ore properties, ore thickness, economical factors, type of extraction machines (cutter, loader cutter), ventilation conditions and type of supports. One of these factors is the rock mass properties needed for calculating the panel width which can be determined from rock mass classification systems; while in ancient years, panel width was determined mainly, by the type of extraction machines (cutter, loader cutter) and check it by ventilation conditions [3].

The aim of this research is to apply rock mass classification systems for the selection of the optimum panel width in longwall phosphate mine (Abu-Tartur area). One of these systems is GSI method proposed by Hoek and Brown [4, 5, 6] which determines

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rock mass properties to calculate panel width. GSI values for roof rocks and phosphate ore are determined from geological conditions, as lithology, structure of the interlocking of rock blocks and the conditions of the surfaces between these blocks. Laboratory tests are carried out to determine uniaxial compressive strength for phosphate ore and roof rocks. In calculating the panel width Salmon and Munro formula is used to calculate pillar strength. Taking into consideration that the factor of safety equals to 1.3 [7, 8, 9].

2. Rock mass properties

Estimates of the strength and deformation characteristics of rock mass are required for almost any form of analysis used for the design of slopes, foundations and design of underground excavations. Hoek and Brown proposed a method for obtaining estimates of the strength of jointed rock masses, based upon an assessment of the interlocking of rock blocks and the conditions of the surfaces between these blocks. This method was modified over the years, and eventually, the development of a new classification called the Geological Strength Index (GSI).[4,5,6,10]
Criterion for assessment of rock mass strength using generalized Hoek-Brown as follows.

$$\sigma_1 = \sigma_3 + \sigma_{ci}\left(m_b \frac{\sigma_3}{\sigma_{ci}} + s\right)^a \quad (1)$$

Where
σ_1 and σ_3 are the maximum and minimum effective principal stresses at failure,
m_b is the value of the Hoek-Brown constant m for the rock mass,
S and **a** are constants which depend upon the rock mass characteristics, and
σ_{ci} is the uniaxial compressive strength of the intact rock pieces.
In order to use the Hoek-Brown criterion for estimating the strength and deformability of jointed rock masses, three parameters of the rock mass strength have to be estimated. These are namely:

1. Uniaxial compressive strength σ_{ci} of the intact rock pieces
2. Value of the Hoek-Brown constant m_i for these intact rock pieces
3. Value of the Geological Strength Index GSI for the rock mass.

3. Intact rock properties

For the intact rock pieces that make up the rock mass, equation (1) simplifies to the following form:[2]

$$\sigma_1 = \sigma_3 + \sigma_{ci}\left(m_i \frac{\sigma_3}{\sigma_{ci}} + 1\right)^{0.5} \quad (2)$$

The values of σ_{ci} are determined by laboratory tests and m_i values are obtained making use of data shown in Table (1). [4, 5,10]

Table 1.
Values of the constant m_i for intact sedimentary rocks, by rock group. Note that values in parenthesis are estimates

Rock Type	class	Group	Texture			
			Coarse	medium	fine	Very fine
sedimentary	Clastic		Conglomerates* (21 ± 3) Breccias (19 ± 5)	Sandtones 17 ± 4	Siltstone 7 ± 2 Greywacke (18 ± 3)	Claystone 4 ± 2 Shales (6 ± 2) Marls (7 ±)
	Non-classtic	carbonates	Crystalline Limestone (12 ± 3)	Sparitic Limestones (10 ± 2)	Micritic Limestone (9 ± 2)	Dolomites (9 ± 3)
		Evaporates		Gypsum 8 ± 2	Anhydrite 12 ± 2	
		Organic				chalk 7 ± 2

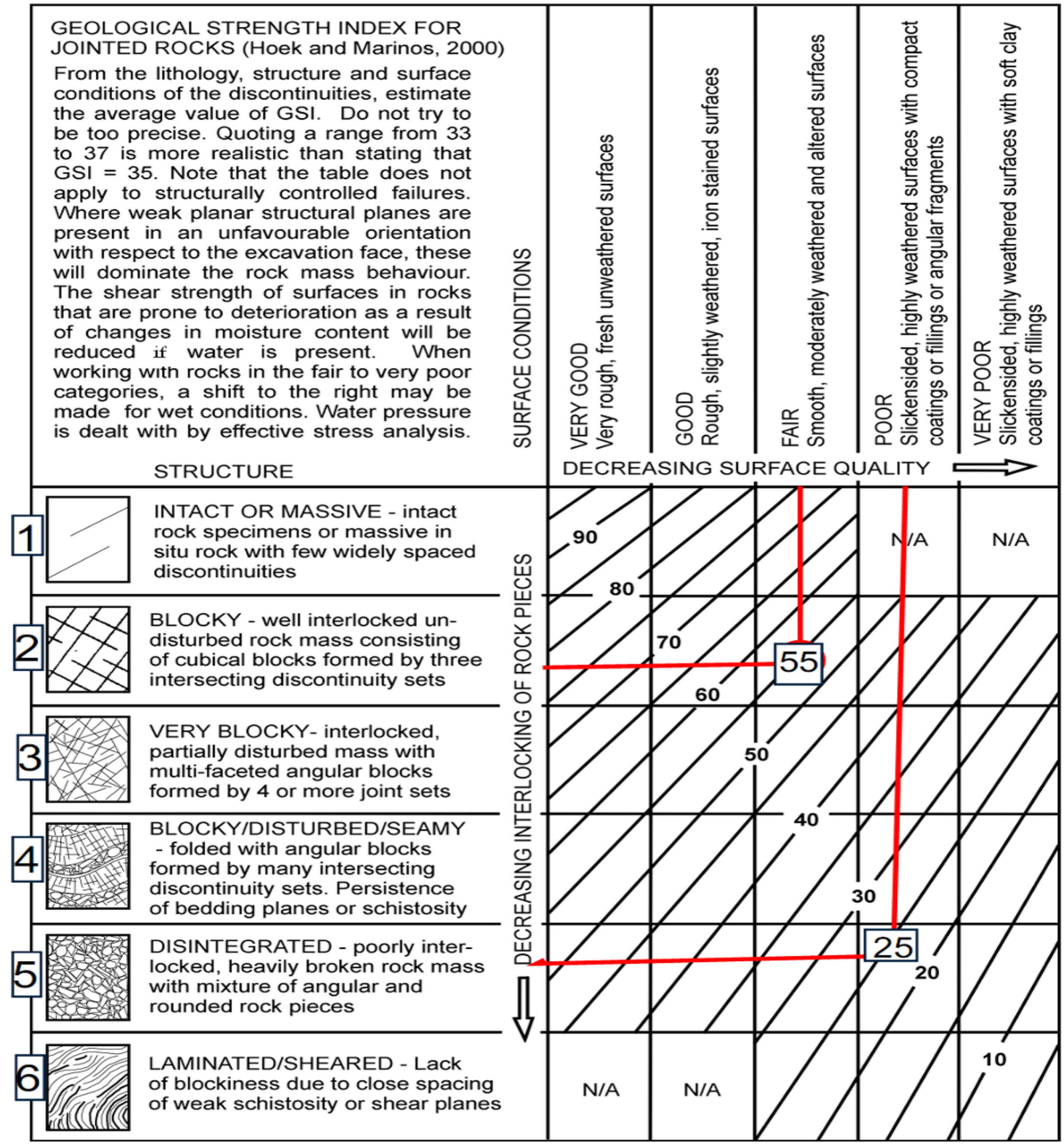
*Conglomerates and breccia may present wide range of m_i values depending on the nature of the cementing material and the degree of cementation, so they may range from values similar to sand stone to values used for fine grained sediments.

4. Geological strength index

The Geological Strength Index (GSI), introduced by Hoek, Kaiser and Brown provides a number which, when combined with the intact rock properties, can be used for estimating the reduction in rock mass strength for different geological conditions. This system is presented in Table (2), for blocky rock masses [11, 12].

Experience shows that most geologists and engineering geologists are comfortable with the descriptive and largely qualitative nature of the GSI table and generally have little difficulty in arriving at an estimated value. On the other hand, many engineers feel the need for a more quantitative system in which they can “measure” some physical dimension [5, 13, 14, 15].

Table 2.
Characterization of blocky rock masses on the basis of interlocking and joint conditions



The relation between m_b and m_i, GSI is as follows:[8,14]

$$m_b = m_i \exp\left(\frac{GSI - 100}{28}\right) \tag{3}$$

The relation between S and GSI is as follows:[6,12]

$$s = \exp\left(\frac{GSI - 100}{9}\right) \tag{4}$$

The relation between a and GSI is as follows:[6,12]

$$a = \frac{1}{2} + \frac{1}{6}\left(e^{-GSI/15} - e^{-20/3}\right) \tag{5}$$

5. Rock mass strength

The uniaxial compressive strength of the rock mass σ_c is given by equation 6. Failure initiates at the boundary of an excavation when σ_c is exceeded by the stress induced on that boundary. The failure propagates from this initiation point into a biaxial stress field and it eventually stabilizes when the local strength, defined by equation 1, is higher than the induced stresses σ_1 and σ_3. Hoek and Brown proposed this equation for estimating of rock mass strength [18].

$$\sigma_{cm} = \sigma_{ci} \frac{\left(m_b + 4s - a(m_b - 8s)\right)\left(\frac{m_b}{4} + s\right)^{(a-1)}}{2(1+a)(2+a)} \tag{6}$$

6. Case study-Abu Tartur mining conditions

The data for this case study are collected making use of the reports made by the company for the geological conditions of Abu-Tartur Plateau and properties of roof rocks and phosphate ore.

6.1. Geological conditions of Abu-Tartur plateau

Geological conditions of Abu-Tartur Plateau are collected from Executive Summary on Geological, Geomechanical and Geotechnical Characteristics of Abu Tartur Deposits [22].

The area is subjected to three major faults, these faults had affected on the plateau by two types of deformations mainly:

l- Ductile deformation.

These deformations have two major effects:

a - They caused folds reaching about (2 – 10 km.) which lead to erosion, inflexions and some fracture

b- They had an influence on sedimentation giving rise to lateral lithological variations.

2- Brittle deformation.

These deformations resulting from faults, so the Russian Researchers had stressed on the importance of the following two major normal fault directions,

a - North Western trend, these faults are spaced 50 - 75 m apart and run 330o -340o, they vary in length from several hundred meters to 6 - 7 km. These faults can be classified into normal faults.

b- North Eastern trend , these faults are large (active) normal faults spaced 700 - 1000 m and running 55o- 60o and traced along the strike for a distance of 2- 8 km [22] .

From these previous geological conditions in the presence of faults and folds with poor properties of the papery shales (weak, loosing) shear zone in shale rocks is resulted, or rock is disintegrated. So the structural form for shale can be represented by the category number five in Table (2); while the interlocking between surfaces of shale rocks can be considered poor.

6.2. The roof of the ore

Generally, the total thickness of the overburden country rocks up to the surface of the plateau ranging from 140 to 290 m. it may be formed by three main formations, from surface downwards, they are [22]:

i-The kurkur formation "limestone "ranges from 6 to 134 m thickness, ii- The Dakhla formation " shales" ranges from 100 to 135m, iii-The rest of Dawi formation other than ore body ranges from 20 to 40 m.

The full characteristics of papery shale (roof rocks) can be considered as an average of all the rock types of 30 m thickness above the ore. Table (4), shows physical and mechanical properties of the roof rocks [22].

Table 3.

physical and mechanical properties of papery shales.

Source of data parameter	Russian researcher Max.	Min.	Ave.	Consultant Sofremine Max.	Min.	Ave.	Miscellaneous Max.	Min.	Ave.
σ_c, Mpa.	28.9	4.3	14	-		-	19.3	16.2	17.8*
T, Mpa.	4.8	0.4	2.24	-		3	5.1	3.2	4.15*
φ, ^{0}	33	18	27.7	36	27	31.5	30	15	22.5*
μ	0.3	0.3	0.3	-		-			
C, Mpa.	6.4	1.9	3.4	-		0.8	7.7	5.5	6.6*
E, Gpa.	2.8	0.24	1	-		0.6			0.72*
γ, g/cm^3	2.41	1.98	2.14	2.09	1.52	1.7			1.82*
W, %	---	---	---	27	11	22			

*Note: * Russian –Moscow 1973 , σ_c uniaxial compressive strength ,T tensile strength , φ angle of internal friction, , μ Poisson's ratio ,C cohesion , γ bulk density, E modulus of elasticity, W moisture content .*

7. Estimations of rock roof properties

Geological Strength Index GSI value is determined based on geological descriptions of Abu-Tartur area and making use of data shown in Table (2) category no. 5, so the value of GSI will equal to 25 (GSI = 25)

The value of mi (Hoek-Brown constant) = 6 taken from Table (1) (clastic sedimentary rock, shales)

σ_{ci} = 14 Mpa. From Table (3)

From equation (4)

$$s = \exp\left(\frac{GSI-100}{9}\right) \qquad \therefore s = \exp\left(\frac{25-100}{9}\right) = 2.404\times10^{-4}$$

From equation (5)

$$a = \frac{1}{2}+\frac{1}{6}\left(e^{-GSI/15}-e^{-20/3}\right)$$

$$\therefore a = \frac{1}{2}+\frac{1}{6}\left(e^{-25/15}-e^{-20/3}\right) = 531.267\times10^{-3}$$

From equation (3)

$$m_b = m_i \exp\left(\frac{GSI-100}{28}\right)$$

$$\therefore m_b = 6\times\exp\left(\frac{25-100}{28}\right) = 411.967\times10^{-3}$$

From equation (6) of Rock mass strength

$$\sigma_{cm} = \sigma_{ci}\frac{\left(m_b+4s-a(m_b-8s)\right)\left(\frac{m_b}{4}+s\right)^{(a-1)}}{2(1+a)(2+a)}$$

$$\therefore \sigma_{cm} = 14\frac{\left(0.412+4\times2.404\times10^{-4}-0.531\left(0.412-8\times2.404\times10^{-4}\right)\right)\left(\frac{0.412}{4}+2.404\times10^{-4}\right)^{(0.531-1)}}{2(1+0.531)(2+0.531)}$$

$$\therefore \sigma_{cm} = 14\frac{195.086\times10^{-3}\times2.89906}{7.75209} = 1.021\ Mpa.$$

8. The ore body (phosphate)

The phosphate seam is not faulted and has been only subjected to folding tectonics. According to the detailed geological study above the mine, it can be said that the mine area had suffered from two types of joints.

a-The first one, is one bedding set with aperture from 1 - 2.5 cm filled with gypsum, parallel to the bedding plane

b-The second one is the three similar Structural Sets all of them having an aperture ranging from 0.2 – 1.0 cm filled with gypsum.

1. First set is N 80^o - 100^o (direction from the north) which is parallel to the brittle direction N 80^o E which causes well marked faults with 5 to 20 m throw.
2. Second set is N 120^o - 140^o which is in parallel to the brittle direction N 120^o E which appears discontinues in limestone causing local faults with a throw of several meters
3. The third set is , N 180^o - 200^o which is nearly in parallel to the supple direction N - S which causes undulations of great amplitude about (10km) marked by inflexions reaching to 3^o or 4^o .

From these previous geological conditions in the presence of structural joints, blocky structure is formed by three intersecting discontinuity surfaces. So, the structural form for phosphate ore can be represented by category number two in Table (2); while the interlocking between surfaces of shale rocks is considered fair.

8.1. Physical properties of phosphate ore

The thickness of ore body ranges from 0.75 – 9.8 m, averaging 3.5 m , the average excavated bed thickness amounts to 3.0 - 3.2 m including the following rock types from top to bottom [22]:

1. Dolometic phosphate; ranges from 0.1 to 1.1 m averaging 0.4 m.
2. Granular phosphate; ranges from 0.9 to 2.2 m averaging 1.5 m
3. Black clay "intercalation" ranges form 0. 15 to 0.4 m averaging 0.14 m
4. Soft phosphate; ranges from 0.4 to 1.3 m averaging 0.9m

Table 4.

Physical - mechanical properties of dolomatic phosphate [22].

Source of data	Russian researcher			Consultant Sofremine			Miscellaneous		
Parameter	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
σ_c , Mpa.	77.1	14.9	42	70	30	50	77.3	20.7	44.7*
T, Mpa.	5.5	1	3	-	-	-	5.58	3.03	4.19**
φ , 0	-	-	-	-	-	-	-	-	39***
μ	0.25	0.25	0.25	-	-	-	-	-	-
C, Mpa.	-	-	-	-	-	-	-	-	11.2***
E, Gpa.	13.81	7.65	10.2	-	-	3.8	-	-	-
γ , g/cm^3	2.72	2.36	2.5	2.5	1.9	-	-	-	2.1***

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9. Estimations of the ore body properties

Geological Strength Index GSI value is determined based on geological descriptions of Abu-Tartur area and making use of data shown in Table (2) category no. 5, so the value of GSI will equal to 55 (GSI = 55)

The value of $\mathbf{m_i}$ (Hoek-Brown constant) = 9 taken from Table (1) (nonclastic sedimentary rock, nearly to Dolomites)

σ_{ci} = 40 Mpa. From laboratory tests,

From equation (4)

$$s = \exp\left(\frac{GSI - 100}{9}\right) \qquad \therefore s = \exp\left(\frac{55 - 100}{9}\right) = 6.738 \times 10^{-3}$$

From equation (5)

$$a = \frac{1}{2} + \frac{1}{6}\left(e^{-GSI/15} - e^{-20/3}\right)$$

$$\therefore a = \frac{1}{2} + \frac{1}{6}\left(e^{-55/15} - e^{-20/3}\right) = 504.048 \times 10^{-3}$$

From equation (3)

$$m_b = m_i \exp\left(\frac{GSI - 100}{28}\right) \qquad \therefore m_b = 9 \times \exp\left(\frac{55 - 100}{28}\right) = 1.804$$

From equation (6) of Rock mass strength

$$\sigma_{cm} = \sigma_{ci} \frac{\left(m_b + 4s - a(m_b - 8s)\right)\left(\frac{m_b}{4} + s\right)^{(a-1)}}{2(1+a)(2+a)}$$

$$\therefore \sigma_{cm} = 40 \frac{\left(1.804 + 4 \times 6.738 \times 10^{-3} - 0.504\left(1.804 - 8 \times 6.738 \times 10^{-3}\right)\right)\left(\frac{1.804}{4} + 6.738 \times 10^{-3}\right)^{(0.504-1)}}{2(1+0.504)(2+0.504)}$$

$$\therefore \sigma_{cm} = 40 \frac{0.94882 \times 2.0797}{5.0081} = 15.760 \ \ Mpa.$$

10. Calculations of panel width

The conditions of mining are, average thickness of the bed ore (h) = 3.5 m, rock mass strength (σ_{cm}) (calculated) = 15.76 Mpa. and volumetric weight of rock (γ) = 25kN/ m^3, factor of safety for square chain pillars (f.s) =1.3 and bord (B) =3m.

10.1. One row of chain pillars

Take panel width (W_L) to vary as (60, 90, 120, 150, 180 m) and width of pillar (W_P) varies as (15, 20, 25, 30 m) and depth of cover (H) varies as (100, 110, 120,……, 200m) . As shown in Fig (1).

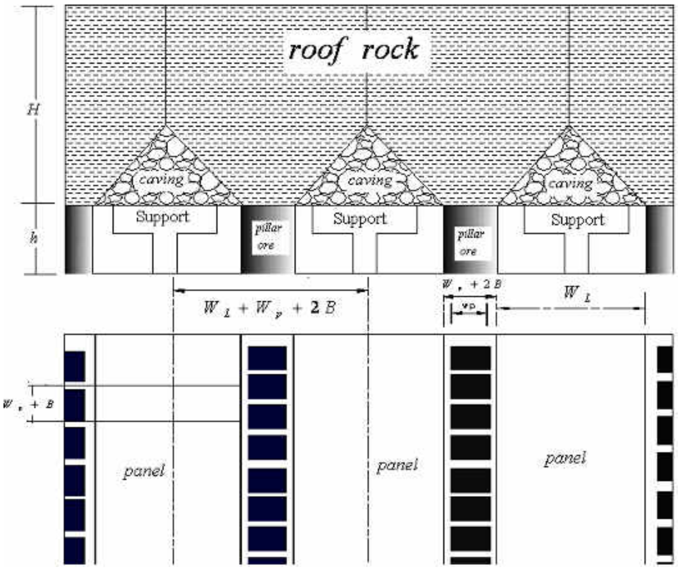

Fig. 1. Elevation and plan of the panel system and parameters.

Extraction ratio (r) is calculated by the following method [23].

$$r = \frac{(W_P + B)\times(W_L + W_P + 2B) - W_P^2}{(W_P + B)\times(W_L + W_P + 2B)} = \frac{(30+3)*(60+30+2*3) - 30^2}{(30+3)*(60+30+2*3)} = 0.716$$

And the losses (1-r) = 0.284

Factor of safety

$$F.S = \frac{\sigma_{cm} \times W_P^{0.46}}{h^{0.66}} * \frac{1-r}{\gamma * H}$$

$$F.S = \frac{15.76 * 30^{0.46}}{3.5^{0.66}} * \frac{0.284}{0.025*200} = 1.872 \quad > 1.3 \quad (safe)$$

Table (5) shows all calculations of the factor of safety due for various panel widths, pillar widths and mining depths.

Safer conditions are summarized and represented in Table (6), which shows panel widths, pillar widths and mining depths.

Table 5.

One row chain pillars

(W_P+B), m	W_P, m	W_L, m	r	1-r	Depth of mining (H), m										
					200	190	180	170	160	150	140	130	120	110	100
33	30	60	0.716	0.284	1.873	1.971	2.081	2.203	2.341	2.497	2.675	2.881	3.121	3.405	3.745
		90	0.784	0.216	**1.427**	**1.502**	**1.585**	1.678	1.783	1.902	2.038	2.195	2.378	2.594	2.853
		120	0.825	0.175	1.152	1.213	1.280	**1.356**	**1.440**	1.536	1.646	1.773	1.921	2.095	2.305
		150	0.853	0.147	0.966	1.017	1.074	1.137	1.208	**1.289**	**1.381**	**1.487**	1.611	1.757	1.933
		180	0.874	0.126	0.832	0.876	0.925	0.979	1.040	1.110	1.189	1.280	1.387	1.513	1.664
28	25	60	0.755	0.245	**1.487**	**1.565**	**1.652**	1.749	1.858	**1.982**	2.124	**2.287**	2.478	2.703	2.973
		90	0.816	0.184	1.118	1.177	1.242	**1.315**	**1.398**	**1.491**	**1.597**	1.720	1.864	2.033	2.236
		120	0.852	0.148	0.896	0.943	0.996	1.054	1.120	1.195	1.280	**1.378**	**1.493**	1.629	1.792
		150	0.877	0.123	0.747	0.787	0.831	0.879	0.934	0.997	1.068	1.150	1.246	**1.359**	**1.495**
		180	0.894	0.106	0.641	0.675	0.712	0.754	0.801	0.855	0.916	0.986	1.069	1.166	1.282
23	20	60	0.798	0.202	1.106	1.164	1.229	**1.301**	**1.383**	**1.475**	**1.580**	**1.702**	**1.844**	**2.011**	2.212
		90	0.850	0.150	0.820	0.863	0.911	0.965	1.025	1.093	1.172	1.262	**1.367**	**1.491**	1.640
		120	0.881	0.119	0.652	0.686	0.724	0.767	0.814	0.869	0.931	1.002	1.086	1.185	**1.303**
		150	0.901	0.099	0.540	0.569	0.601	0.636	0.676	0.721	0.772	0.832	0.901	0.983	1.081
		180	0.916	0.084	0.462	0.486	0.513	0.543	0.577	0.616	0.660	0.710	0.770	0.840	0.924
18	15	60	0.846	0.154	0.739	0.778	0.822	0.870	0.924	0.986	1.056	1.138	1.232	**1.345**	**1.479**
		90	0.887	0.113	0.540	0.568	0.600	0.635	0.675	0.719	0.771	0.830	0.899	0.981	1.079
		120	0.911	0.089	0.425	0.447	0.472	0.500	0.531	0.566	0.607	0.654	0.708	0.772	0.850
		150	0.927	0.073	0.350	0.369	0.389	0.412	0.438	0.467	0.500	0.539	0.584	0.637	0.701
		180	0.938	0.062	0.298	0.314	0.331	0.351	0.373	0.397	0.426	0.458	0.497	0.542	0.596
13	10	60	0.899	0.101	0.402	0.424	0.447	0.474	0.503	0.537	0.575	0.619	0.671	0.732	0.805
		90	0.927	0.073	0.289	0.304	0.321	0.339	0.361	0.385	0.412	0.444	0.481	0.525	0.577
		120	0.943	0.057	0.225	0.237	0.250	0.265	0.281	0.300	0.321	0.346	0.375	0.409	0.450
		150	0.954	0.046	0.184	0.194	0.205	0.217	0.230	0.246	0.263	0.283	0.307	0.335	0.369
		180	0.961	0.039	0.156	0.164	0.173	0.184	0.195	0.208	0.223	0.240	0.260	0.284	0.312

Underlined values are the factor of safety calculated (safer conditions ≥ 1.3)

Table 6.
Summarized panel widths, pillar widths and mining depths at safe conditions.

(W_P)=15 m		(W_P)=20 m		(W_P)=25 m		(W_P)=30 m	
(H), m	(W_L), m	(H), m	(W_L), m	(H), m	(W_L), m	(H), m	(W_L), m
100	71	100	120	100	177	130	177
110	62	110	107	110	158	140	162
		120	96	120	142	150	148
		130	87	130	130	160	137
		140	79	140	118	170	127
		150	72	150	108	180	118
		160	65	160	99	190	110
		170	60	170	91	200	102
				180	85		
				190	79		
				200	73		

From the results shown in Table (6), we see that with the increase of mining depth, the panel width will be decreased at a constant pillar width; while the panel width will be increased with increasing pillars widths at a constant mining depth as shown in Fig (2); while Fig. (3), shows relation between the extraction ratio and panel width at different pillar widths.

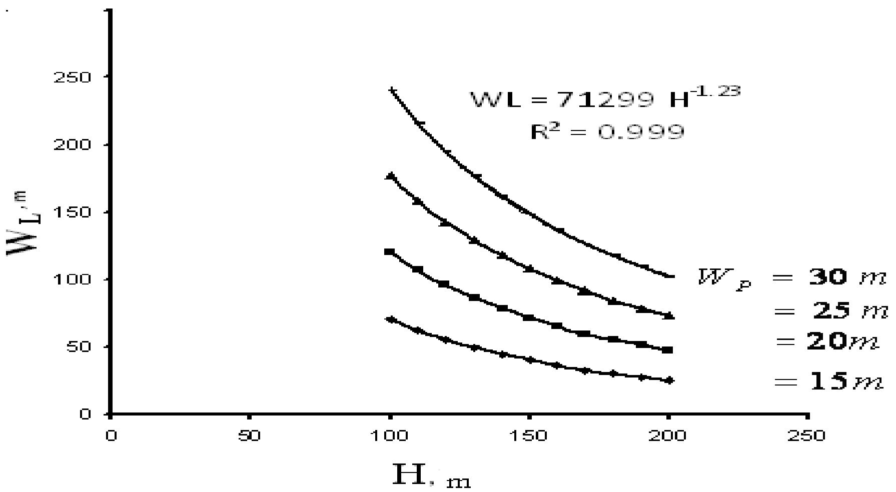

Fig. 2. The relation between width of panel and mining depths for different pillar widths.

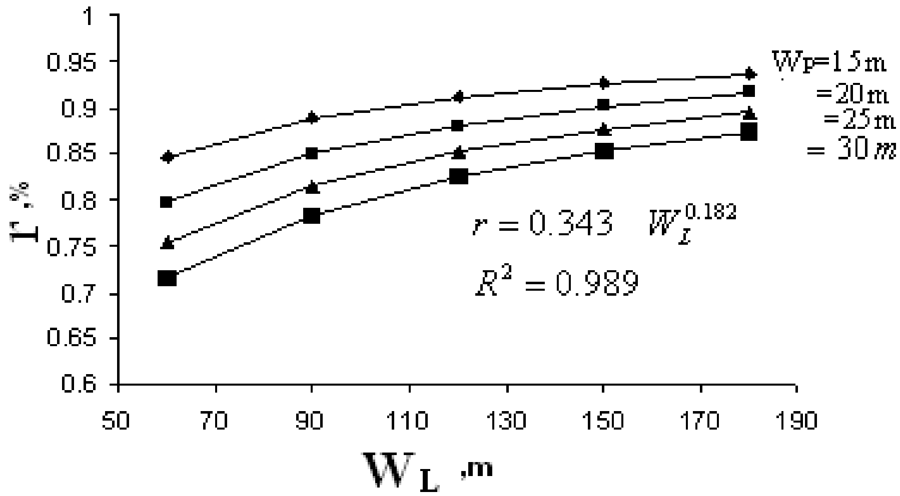

Fig. 3. The relation between extraction ratio and panel width for different pillar widths.

For the conditions of Abu-Tartur the depth of mining varies from 140 to 290 m with an average of 200m therefore, the optimum panel width is 102 m and pillar width 30m with extraction ratio = 80 % as shown in Table (7)

Table 7.
Extraction ratio at different pillar widths and panel widths.

Pillar width	Panel width	Extraction ratio	Comment
15	25	0.73	Very short longwall*, small extraction ratio
20	47	0.76	short longwall, fair extraction ratio
25	73	0.79	longwall, small panel width
30	102	0.80	Optimum panel width

* Short wall mining length (45-60) m. [23]

10.2. Panel width from the ventilation point of view

This checking is to be done to satisfy the requirements of the mining regulations which prescribe the maximum velocity and minimum quantity of air to be passed thorough face. Panel width can be calculated by ventilation as follows:. [3]

$$W_{LV} = \frac{60\,V.b.m_e.\psi}{i.r_1.q_a.\gamma.m_p.c.\delta}, \qquad meters. \qquad (7)$$

Where:
$\mathbf{W_{LV}}$ is panel width by ventilation, **V** is maximum air velocity = 4 m/s, **b** is minimum width of working place in productive face = 2.5m, m_e is the extracted thickness ore bed

=3.5m, ψ is the coefficient accounting for the narrowing of the cross-section of the airway =0.95 for steel face support, **i** is the number of productive cycle =1, $\mathbf{r_1}$ is the depth of cut 1.6 m, $\mathbf{q_a}$ is the quantity of air m^3/min. per ton of daily production of the face depending on gas emission, no gas emission in our case assume first category (very small gas emission) therefore $\mathbf{q_a}$= 1 m^3/min.per ton of daily productive, **γ** is the average volume weight for phosphate ore = 2.5t/m^3, $\mathbf{m_p}$= productive thickness of ore bed =3.5 m, **c** is the coefficient of ore recovery = 0.80 and **δ** is the coefficient accounting for the fact some quantity of the air will leak into goaf assume all air goes to face = 1.

$$W_{LV} = \frac{60\times4\times2.5\times3.5\times0.95}{1\times1.6\times1\times2.5\times3.5\times0.80\times1} = 178m$$

So, the ventilation requirement does not limit the width of panel and can take safely panel width equal to 102m (100 approximately).

The effect of panel width (longwall face length) on strata control is uncertain. Investigations in Great Britain have shown that longer face do not experience more roof failure than shorter ones , and mining research in west found that, in strong roof strata, caving was improved in longer faces. [24]

No relationship between optimum panel width and strata control has been developed.

Therefore, selection of the panel width is guided largely by economic consideration. Cost of equipment ownership increase with panel width increase [25].

11. Conclusions

From this study, the following conclusions can be drawn:

1) From the mechanical properties of roof rocks (papery shales) and phosphate ores with applying GSI system, the value of σ_{cm} is as follows :

1-1-for roof rocks, $\sigma_{cm} = 1.021 MPa.$

a) for phosphate ore are $\sigma_{cm} = 15.760\ Mpa.$

2) The relation between panel width and depth of mining can be expressed for Abu Tartur mines conditions by this equation $w_L = 71299H^{-1.23}$ at pillar width is 30m.

3) The relation between extraction ratio and panel width can be expressed by this equation $r = 0.343W_L^{0.182}$ when pillar width equals to 30m.

4) The panel width by ventilation is calculated to be 178 m: so, ventilation requirements do not limit the panel width (102m)

5) No relationship between optimum panel width and strata control has been developed. Therefore, selection of the panel width is guided largely by economic consideration. Cost of equipment ownership increase with panel width increase.

6) The optimum panel width for the condition of Abu-Tarur phosphate mine is 102 m with an extraction ratio = 80% when pillar width = 30m as show in Table (7), while the panel width (wall length) applied in Abu Tartur mines area is 150m. The recommended value (102) varies differently from the applied longwall length. So we recommend the application of panel width to be about 100m to secure safe mining conditions and the probability of roof falls may be decreased which is the major problem facing underground mining in this area.

12. References

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تأثير تصنيفات الكتل الصخرية على حساب أطوال واجهة الحش(مناجم فوسفات ابو طرطور)

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ملخص:

تعد نظم التصنيف للكتل الصخرية واحدة من أدوات التصميم الهندسي، والتي تستخدم للربط بين طرق التصميم المختلفة ونظريات التصميم الأخرى. وهناك العديد من هذه النظم التي تستخدم على نطاق واسع في هندسة الصخور. وفي هذه الدراسة تم استخدام واحدا من هذه النظم وهو نظام "معامل المقاومة الجيولوجية" Geological Strength Index(GSI)للاستفادة منه في حساب طول واجهة الحش ، وقد أسفرت الدراسة عن حساب الطول الأمثل لواجهة الحش بمقدار(102 متر) وذلك إختلافا عن الطول المتبع بالمناجم حاليا في هذه المنطقة وهو(150 متر) ونحن نعتقد أن هذا الطول يسبب العديد من المشاكل ومنها تكرار حدوث تساقط السقف. ولذا نوصي بأستخدام هذا الطول(100متر) بدلا من (150متر) المطبق حاليا بالمناجم و الذي يمكن مع استخدامه تقليل إحتمالية تساقط أسقف المناجم. وقد تم الحصول على البيانات المطوبة لهذا البحث من التقارير الجيولوجية المتاحة لدى الشركة مع إجراء بعض القياسات الميدانية.