II b 5

"SOFT ROCK" (KURZAWKA)

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By divers authors and practicians the name of "Kurzawka" means different kinds of soil with different mechanical properties. With all it has been ascertained that it is a kind of sandy soil saturated with moisture which under a certain pressure assumes the character of a completely liquid volume. This volume generally consists of fine sand and Mo but may also consist of medium-or gruff-grained substance with colloidal percentage.

I may take it for granted that divers works especially that of Prof.Dr. Terzaghi and a very detailed work by the Russian professor Sawarenskij concerning this problem are well-known.

Since decades the "Kurzwaka" has been known and dreaded in its consequences in Upper-Silezia. It frequently caused heavy damages at shaft and gallery drivings, at bridge constructions and building.embankments. In different ways people tried to fight it.

At Prof.Dr. Terzaghi's suggestion systematical researches were made in our Institute of substance and properties, of this material. For this purpose "Kurzawka"-samples were brought from six different parts. The samples were labelled I, II, III, IV, V and VI; the index-number joint to the roman numerals indicates the soundings (depth) from which the samples were taken. The samples came from: I and II from Brzczescze, III to X from the surroundings of Sosnowiec, Upper Silezia.

The primary component of Silezia's "Kurzawka" consists of clay and very fine arenaceous quartz. Detailed researches are made -also at Prof.Dr. Terzaghi's suggestion- by Mr.Ralph E. Grim, the director of the Institute of the State Geological Survey Division. The Russian "Kurzawka" is supposed to be micaceous. Superficially regarded our samples don't show a unified feature. Some are similar to the common Portlandcement. Dried and grown hard in the open air they show the structure of unbound cement. Others are similar to grey sandy clay and dried gave the impression of grey argillaceous earth.

Our duty was to establish:

1) the soil-mechanical character of the "Kurzawka", and
2) the physical cause of the potential increased destructions which are evoked.

ad 1)

a) Definition of the grain size and their mechanical combination by means of standard-screens and mud-analysis. (Method:Casagrande.)

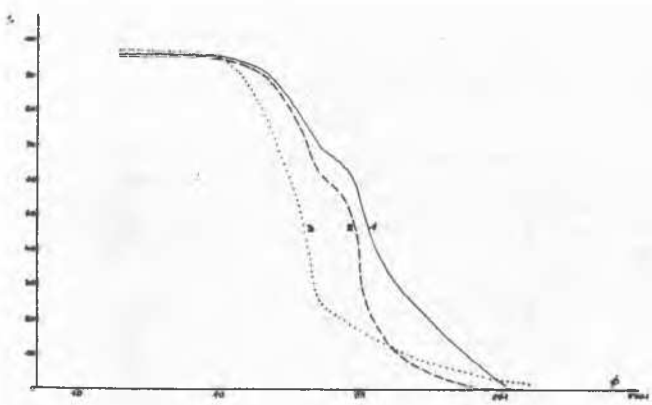


FIG.1

The graphical exhibitions (Fig. 1,2,3) demonstrate the screen, resp. areometrical curves correspondent to the numbered sample.

b) to establish Atterberg's consistency limit. The schedules demonstrate its systematical composing.

c) oedometrical experiments with dried and completely soaked testing material from the diagrams (fig. 4 to 13) we can see:

Condensation-line in dried condition:	Condensationline in wet condition:
II slowly, homogeneous	till 85 kg total-loading slow, afterwards rapid
III till 25 kg total-loading slow but heavy; afterwards slow till 385 kg	almost 30% higher nearly homogeneous
VI parabolic homogeneous	almost 50% higher nearly straight
VII increasing growth, parabolic	almost 50% higher nearly straight
VIII increasing growth, parabolic	almost 70% higher nearly straight
X irregular parabola of higher construction, increasing growth till 50 kg; afterwards slow till 325 kg	100% higher nearly straight

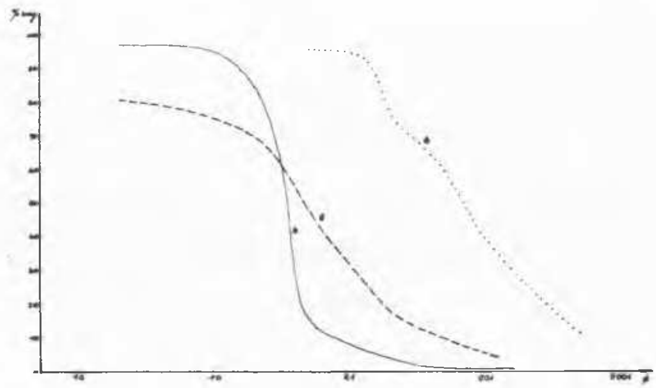


FIG.2

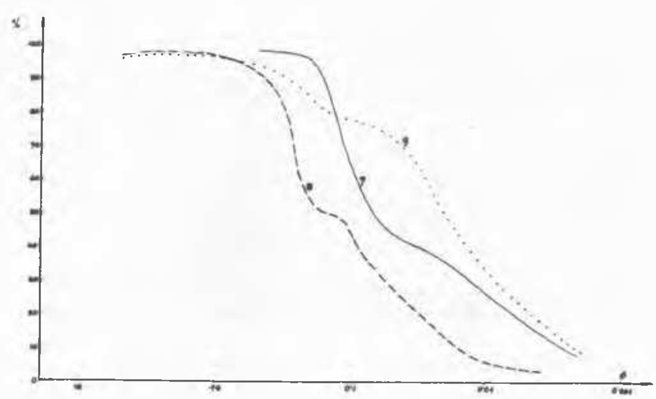
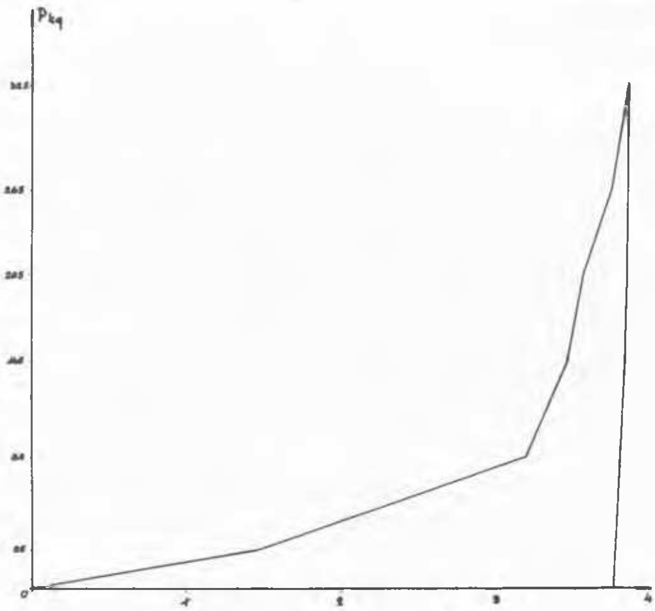
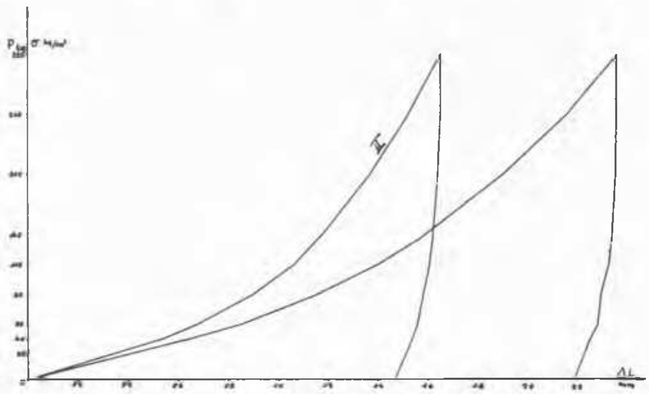


FIG.3



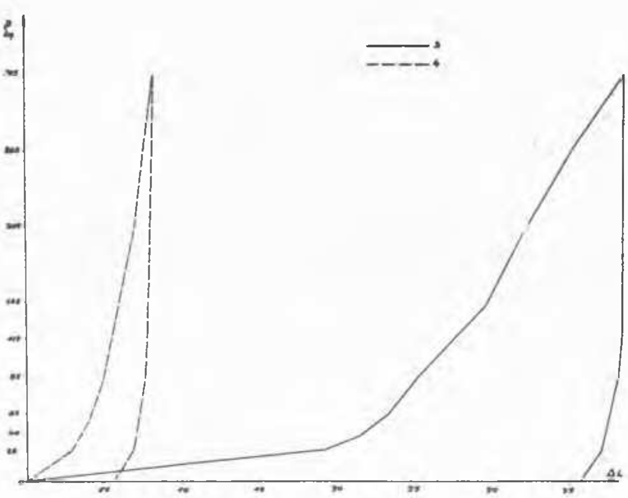
Wet condition to II.

FIG.4



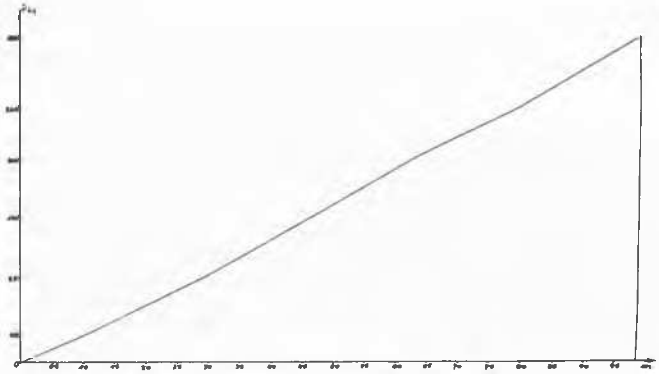
Dried condition to II.

FIG.5



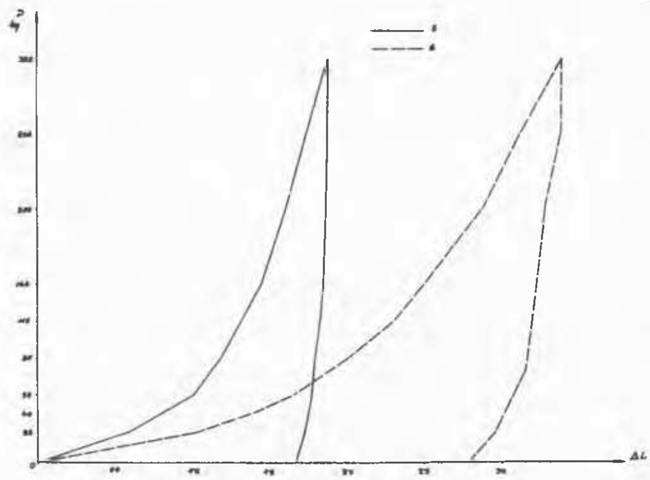
Dried condition to III nd IV.

FIG.6



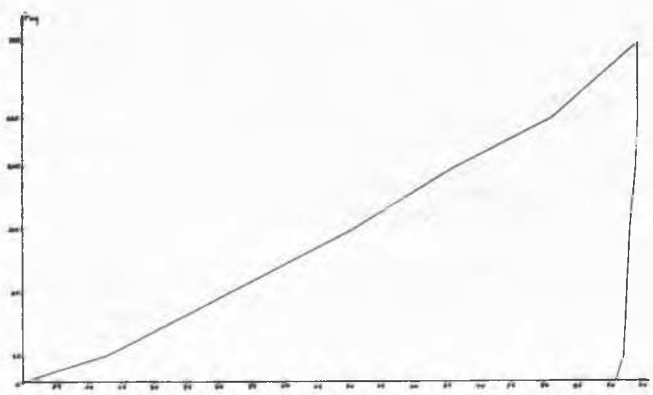
Wet condition to III and IV.

FIG.7



Dried condition to V and VI.

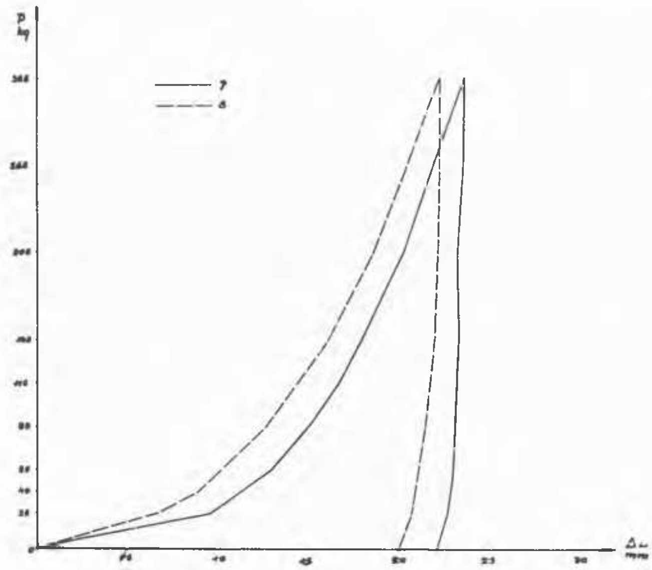
FIG.8



Wet condition to VI.

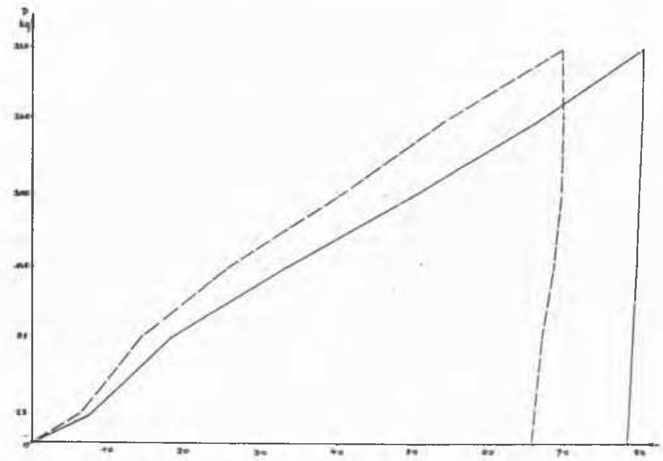
FIG.9

It is evident from these experiments that the reaction of the different "Kurzawka"-proofs on moisture-influence is not equal. Some proofs are nearly uninfluenced, others demonstrate nearly a 100% increasing of cendensation. Samples taken from different depths of the same pit demonstrate also a different reaction. Because of the possibility of change of the stratum caused through forcible moisture infiltration it is not possible to determine in advance and exactly the physical reaction of this soil substance. In any case the "Kurzawka" appears to be a particularly unreliable building grounds



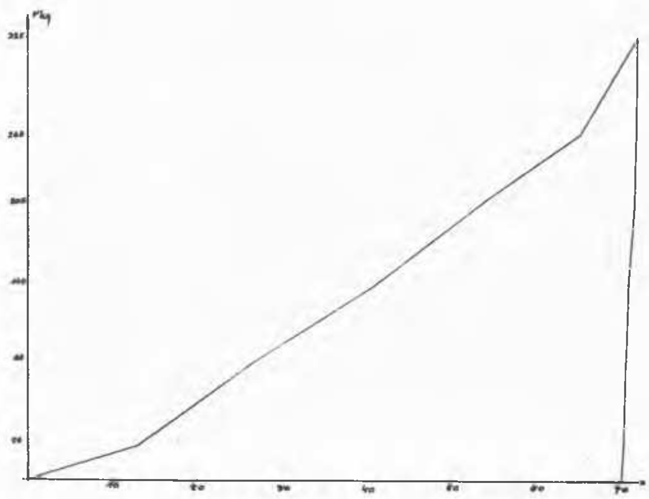
Dried condition to VII and VIII.

FIG.10



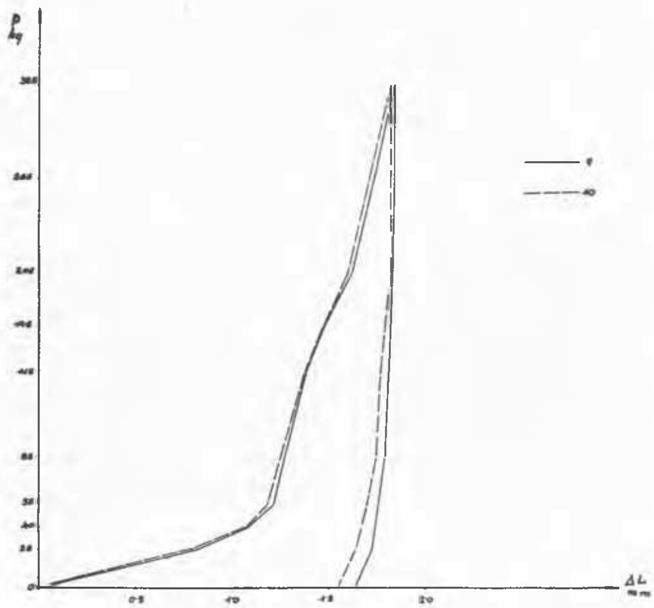
Wet condition to VIII and X.

FIG.12



Wet condition to VII.

FIG.11



Dried condition to X.

FIG.13

TABLE I. Screens-analysis.

Sieve ø		1		2		3		4		5		6		7		8		9	
		fract of weight	% of falling grains	fract of weight	% of falling grains	fract of weight	% of falling grains	fract of weight	% of falling grains	fract of weight	% of falling grains	fract of weight	% of falling grains	fract of weight	% of falling grains	fract of weight	% of falling grains	fract of weight	% of falling grains
		4.03		4.06		3.26		3.49		3.47	96.13	4.41		2.22		3.01		3.33	
	5.000	–	95.97	–	95.94	–	96.74	–	96.51	15.12	81.01	–		–		–	96.99	–	96.67
	1.000	0.46	95.51	0.57	95.37	1.61	95.12	0.47	96.04	2.08	78.93	–		–		0.19	96.80	0.16	96.51
	0.500	4.01	91.50	5.14	90.23	16.63	78.50	14.36	81.68	7.84	71.09	–		–	97.78	3.38	93.42	1.47	95.04
30 Din	0.200	23.56	67.94	28.72	61.51	54.52	23.98	69.27	12.41	29.56	41.53	–	95.59	0.23	97.55	43.36	50.06	11.08	83.96
40 Din	0.150	1.76	66.18	3.32	58.19	1.95	22.03	1.19	11.22	3.21	38.32	0.11	95.48	21.53	76.02	0.07	49.99	0.23	83.73
50 "	0.120	3.98	62.20	6.64	51.55	2.10	19.93	1.42	9.80	2.55	35.77	0.08	95.40	6.02	70.00	1.13	48.86	5.96	77.77
60 "	0.100	8.12	54.08	16.55	35.00	1.81	18.12	1.30	8.50	4.08	31.69	0.45	94.95	7.35	62.65	6.59	42.27	0.20	77.57
70 "	0.088	8.74	45.34	10.91	24.09	1.59	16.52	1.43	7.07	3.99	27.70	0.19	94.76	4.48	58.17	5.60	35.67	0.08	77.49
80 "	0.075	5.01	40.33	3.94	20.15	1.93	14.60	1.55	5.52	3.11	24.59	0.17	94.59	6.41	51.76	2.68	33.99	0.13	77.36
100 "	0.060	4.92	35.41	6.09	14.06	1.08	13.52	1.32	4.20	2.77	21.82	0.69	93.90	5.93	45.83	1.99	32.00	0.03	77.33
		35.41		14.06		13.52		4.20		21.82		93.90		45.83		32.00		77.33	

TABLE II. Mud-analysis.

1				2				3				4				5			
Time	R	Ø mm	%	Time	R	Ø mm	%	Time	R	Ø mm	%	Time	R	Ø mm	%	Time	R	Ø mm	%
30"	26.0	0.062	83.46	30"	25.4	0.062	81.53	30"	28.1	0.057	90.20	30"	30.0	0.054	96.30	30"	26.5	0.058	85.07
60"	23.5	0.045	75.35	60"	20.1	0.047	64.52	60"	24.0	0.045	77.04	60"	22.5	0.045	72.23	60"	23.5	0.045	75.46
2'	20.0	0.034	64.20	2'	13.5	0.037	43.34	2'	20.1	0.034	64.52	2'	18.0	0.035	57.78	2'	19.8	0.033	63.56
5'	14.4	0.023	46.22	5'	7.0	0.025	22.47	5'	14.0	0.023	44.94	5'	14.4	0.023	46.22	5'	16.0	0.023	51.36
15'	6.5	0.015	20.87	15'	2.0	0.016	6.42	15'	9.5	0.014	30.50	15'	9.0	0.014	28.89	15'	10.1	0.014	32.42
30'	2.8	0.011	8.99	30'	1.0	0.011	3.21	30'	7.4	0.011	23.75	30'	7.5	0.011	24.08	30'	8.0	0.011	25.68
60'	0.3	0.008	0.46	60'	0.3	0.008	0.96	60'	5.7	0.008	18.30	60'	6.5	0.008	20.87	60'	6.0	0.008	19.26
								120'	4.5	0.006	14.45	120'	5.5	0.006	17.66				

6				7				8				9			
Time	R	Ø mm	%	Time	R	Ø mm	%	Time	R	Ø mm	%	Time	R	Ø mm	%
30"	52.2	0.060	80.89	30"	29.5	0.052	94.70	30"	28.0	0.055	89.88	30"	29.0	0.057	93.09
60"	24.0	0.045	77.04	60"	28.0	0.040	89.88	60"	24.5	0.045	78.45	60"	28.1	0.042	90.20
2'	23.1	0.032	73.83	2'	27.1	0.030	86.99	2'	21.2	0.033	68.05	2'	25.1	0.031	80.57
5'	20.3	0.022	65.16	5'	24.3	0.020	78.00	5'	14.5	0.023	46.55	5'	19.7	0.022	63.24
15'	16.1	0.013	51.68	15'	20.0	0.012	64.20	15'	8.2	0.015	26.32	15"	15.5	0.014	49.76
30'	13.2	0.010	42.37	30'	17.4	0.009	55.85	30'	6.7	0.011	21.51	30'	12.5	0.010	40.12
60'	11.0	0.007	35.31	60'	14.1	0.007	45.26	60'	5.0	0.008	16.05	60'	10.8	0.007	34.67
16^h	4.0	0.002	12.40	16	5.1	0.002	16.37	180'	3.5	0.004	11.35	16	3.9	0.002	12.52

1		2		3		4		5		6		7		8		9	
Ø mm	% wag	Ø mm	% wag	Ø mm	% wag	Ø mm	% wag	Ø mm	% wag	Ø mm	% wag	Ø mm	% wag	Ø mm	% wag	Ø mm	% wag
0.062	29.55	0.062	11.46	0.057	12.20	0.054	4.04	0.058	18.56	0.060	75.96	0.052	43.40	0.055	28.76	0.057	71.99
0.045	26.68	0.047	9.07	0.045	10.42	0.045	3.03	0.045	16.47	0.045	72.34	0.040	41.19	0.045	72.34	0.040	69.75
0.034	22.73	0.037	6.09	0.034	8.72	0.035	2.43	0.033	13.87	0.032	69.33	0.030	39.87	0.033	21.78	0.031	62.30
0.023	16.36	0.025	3.16	0.023	6.08	0.023	1.94	0.023	11.21	0.022	61.19	0.020	35.75	0.023	14.90	0.022	48.90
0.015	7.39	0.016	0.90	0.014	4.12	0.014	1.21	0.014	7.07	0,013	48.53	0.012	29.42	0.015	8.42	0.014	38.48
0.011	3.18	0.011	0.45	0.011	3.21	0.011	1.01	0.011	5.60	0.010	39.79	0.009	25.60	0.011	6.88	0.010	31.02
0.008	0.34	0.008	0.13	0.008	2.47	0.008	0.88	0.008	4.20	0.007	33.16	0.007	20.74	0.008	5.14	0.007	26.81
				0.006	1.95	0.006	0.74			0.002	11.64	0.002	7.50	0.004	3.63	0.002	9.68

TABLE III. Atterberg limits .

% H_2O	1	2	3	4	5	6	7	8	9
shrinking limit	7.8	7.0	4.7	11.2	7.6	16.3	14.6	6.9	11.0
plastic limit					12.3	15.5	22.1	12.5	27.7
sticky limit	24.1	24.9	12.5	23.0	18.6	23.0	25.8	16.7	27.6
liquid limit	19.8	21.8	11.9	18.7	20.8	31.7	61.8	30.7	41.5

ad 2)
The water which exists under pressure in the "Kurzawka" exercises an immense influence on the "Kurzawka"'s destructive power. To examine this influence the following apparatus was used:

Of the two communicating vessels one is stable and provided with a hole closed by a valve. The second vessel is vertically adjusted to be able to change the pression to one's liking in the fixed vessel. This vessel was successively filled up with the different proof material fractionned according to the size of grains, and after adequate vertical shifting of the second vessel the hight of the pressure which is necessary to make the grains floating was read off. This height of pressure is decisive to the "Kurzawka" exercises a greater pression than the pure water and colloidless floating sand. How and to what an extend the kinematical energy or the proceeding of colloidical forces play their role on the increasing of colloids is still to be examined.

The "Kurzawka"'s dynamical effects which become visible, are:

a) hydrostatic -- when the stratum is enclosed, and

b) hydrodynamic -- in case that through disengagement of some hole the "Kurzawka" is put into motion.

ad a) When enclosed the "Kurzawka"'s effect on tunnel, - walls, bridge-foundings, is without evident or measurable motion of the floating and in a sort of way liquid state of the grains. There is a static equilibrium. At this state the working powers can be characterized as follows:

$$p_x = p_f(\gamma - 1)\cdot(1-n) + (p_w) + \left[p_x \cdot \alpha \cdot (1-n) \right]$$

in which:

α = percentage of colloidical constituents

p_x = the hydrostatic pressure of the "Kurzawka"

p_f = " " " " " " solid substance in dry condition,

p_w = the hydrostatic pressure of the water

p_k = the colloidic pressure resulting from the dry colloids sucking of moisture

γ = the average specific gravity of the dry substance,

n = the porosity

The hydrostatic pressure can be greater(higher) than the total of pressures of the dry substances and the pressure of water. Sometime the total of these pressures in mines are some 10 or even some 100 atmospheres. The pressure exercised by colloids depends on the moment in which the colloids are attacked by water. A maximal effect results when a dried "Kurzawka" suddenly gets a flow of water standing under pressure. In practical life there unfortunately are such sudden flows of water. In practical life there unfortunately are such sudden flows of water (shaft-sinking, etc.,) generally followed by great disasters.

ad b) Because of the streaming water the "Kurzawka" gets in motion, sometime slightly, yet sometime at a considerable spead (catastrophical bursting.)

Concerning the above mentioned equation it is necessary to take also into consideration -- when hydrodynamical condition exist -- the additional dynamic, the so-called d'Alembert's dynamic.

Our experiments demonstrate that the potentially increased work of destruction is caused by three factors:

by hydrostatic pressure

by the pressure of floating sand which through hydrostatic pressure may exercise an impact. (floating substance in current)

by colloidal pressure of the previously dry but after water-supply in motion set colloids.

So much of the soil-mechanical researches concerning the "Kurzawka".

And now some remarks upon the practical resistance against the "Kurzawka"-danger concerning underground-workings.

Generally known methods are:

1) the cementing process
2) the congelation-system

ad 1) In our laboratories injections of cement were made into "Kurzawka"-samples. The sample was taken under hydrostatic pressure and it is easily comprehensible that the injection-pressure must be higher than that which works on the "Kurzawka".

There were two kind of samples examined:

such of bigger grain-size than the size of cement-grain

such of smaller grain-size than the size of cement grain

With bigger grain-size the cementing was partially successful. It shows a greater influence of colloidic ingredients. The smaller the colloidic ingredients the better the cementing with small sized grains the cementing was impossible.

ad 2) Of the congelation-system we are able to give an example from our practice:

In the mine of Piekari in Upper Silezia a shaft of 140 m depth was driven through a mighty "Kurzawka"-shift during a great flow of water. There the congelation method was applied and our laboratories were in command of the scientifical supervision. According to well-known methods the ground has been cooled down to about - 20 degrees. Through the frozen shift the shaft was driven as through rocky boulders and layed out with brick-work, cement-mortar and beton. Especial care was necessary to tie the cement in the proximity of the ground cooled down. But because this problem is not one of the soilmechanic problems, we don't want to enter into full particulars. It is only to be said that the shaft which more or less a year ago was built and frozen down to 140-150 cm has melted off after a few months. Examinations and measurements which afterwards took place did not demonstrate any kind of deformation of the shaft-walls in spite of the hydrostatic pressure which --according to evidence-- works to an extent of 12 atmospheres on the bricklaying. A detailed measurement of the "Kurzawka"-pressure was unfortunately not taken. At a similar shaft-sinking in Russia measurements of density have been taken from the frozen "Kurzawka"-shift and the following results obtained:

from a shift af sand majority and small coloidal contents
at a temperature of - 15 to - 20 degrees
a density of 130 to 180 kg/cm^2
from a shift of colloidal majority
at a temperature of - 15 to - 20 degrees
a density of 20 - 80 kg/cm^2

It is worthy of notice that
at a temperature of - 15 degrees the ice has a density of 18 kg/cm^2.

In greater depths the method of congelation is very expensive. The rational mining industry has to look after other kind of methods to fight the dangers caused by "Kurzawka". Our Institute is now busy with experiments and researches to get at this problem. We shall give further reports after finishing our researches.

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