Slip 'P' in the Berzdorf opencast

Glissement 'P' en mine à ciel ouvert Berzdorf

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SYNOPSIS: The mining of lignite in slip areas demands high quality of the geotechnical and technological works. Possibilities for safe lignite mining at the foot of a large extented slip area (slip volume of about $10 \cdot 10^6$ m³) in the open-pit-mine Berzdorf/GDR is presented. On the basis of a geological-hydrological model and specially investigated soil parameters is described how with help of a large measurement and observation system the mining process is carried out. Analytical estimations based on the Kinematic-Element-Method.

INTRODUCTION

The Berzdorf lignite opencast is situated in the southeastern part of the German Democratic Republic (GDR). In a basin, a coal seam with an average thickness of 80,0 m is worked in this place since about 80 years. Yearly output amounts to $(12...15) \cdot 10^6$ metric tons.

In views of the through structure of this deposit, special stability investigations have always been needed when working approached to the basin slopes.

In 1981, cracks were observed northwest of the opencast in a distance of about 400 m whose occurrence could not be explained by the mechanism of failure which had been assumed to be the only up to this moment. At the beginning of cracking, the field was opened by five overburden cuts and two lignite cuts. Depth was about 100 m. Further advancement of mining in depth together with three new lignite cuts led to the formation of a slip area of about 1,2 km² (Fig. 1).

The amount of slip rock was about $90 \cdot 10^6$ m³. The slip rock sank vertically by about 20,0 m (fault down) (Fig. 2). At the bottom of the slips, heaves of up to 25,0 m were observed. The whole complex is designed as Slip P. Lignite mining at the bottom of the slope continued notwithstanding considerable vertical and horizontal shifts (Fig. 3). Geotechnics and mining specialists together had found technologies to cope with the situation.

The report explains the causes of the slip, the cracking mechanism, and a part of the calculations carried out.

GEOLOGICAL AND HYDROGEOLOGICAL SITUATION

The Berzdorf basin formed at the turn from Oligocene to Miocene. It is a graben fault in the basement rock, the Seidenberg granodiorite. Maximum depth is at 370 m. The sides are steeply inclined, maximum 1 : 1. The bottom is not even and consists of individual blocks. The granodiorite weathered intensively even before the setting, the weathered layer amounting to between some decimeters and 70,0 m.

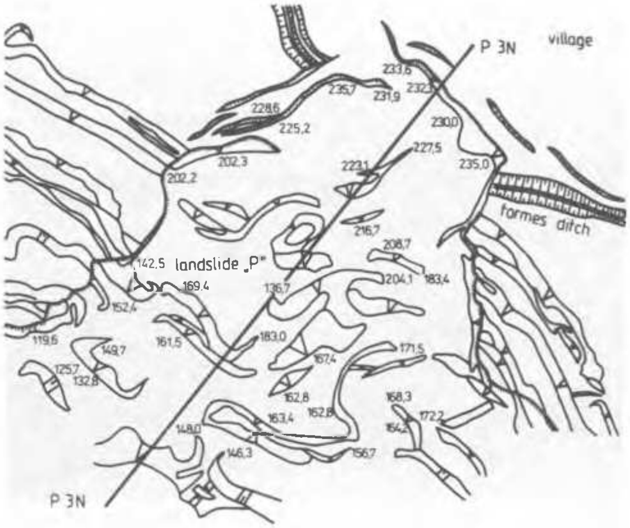

Figure 1. Open-pit-mine Berzdorf landslide "P"

As early as during the setting of the basin, products of decomposition of the surrounding rock were deposited on the slopes thus forming a rock mantle with a thickness of up to 120,0 m. With increasing setting, slips and shifts of the rock mantle were effected. Fossile sliding surfaces were formed both in the rock mantle and at its bottom, being finally responsible for the slip P.

A (5,0...10,0) m thick lignite clay is deposited above the rock mantle. It is the basis for the coal seam which is divided into thirteen archs. The failure mechanisms observed before slip P presupposed the formation of sliding surfaces between rock mantle and lignite clay, or between lignite clay and lignite. The bottom of the lignite clay has always been looked upon as safe.

Figure 2. Border of the landslide

Figure 3. View of the region at the foot of the slide

The roof of the deposit is formed by a silt of low thickness and, predominantly, Quarternary sediments (sand, gravel, till). Diluvial ice advancements have heavily bulged the roof and the upper seam archs. The profile thus formed is shown in Fig. 4.

Quarternary sands and gravels of the overburden from the aquifer 1 which is empty in the environment of the opencast. Tertiary sands within the lignite seam (lenses) are referred to as aquifer 2. Non-binding sediments (small-grained granodiorite replacements, quartz grains) form the aquifer 3 below the rock mantle, or in it. Such formations occur but locally. The water contained in them is not under pressure so that pore-water pressures are not to be expected in the sliding surfaces.

SOIL PHYSICAL INVESTIGATIONS

After it had been established by geological and geophysical investigations, as well as an analysis of the geometry of the slip, that the major sliding surface had to be either in the rock mantle or at its bottom, extensive investigations of the material from these fossile sliding surfaces were carried out.

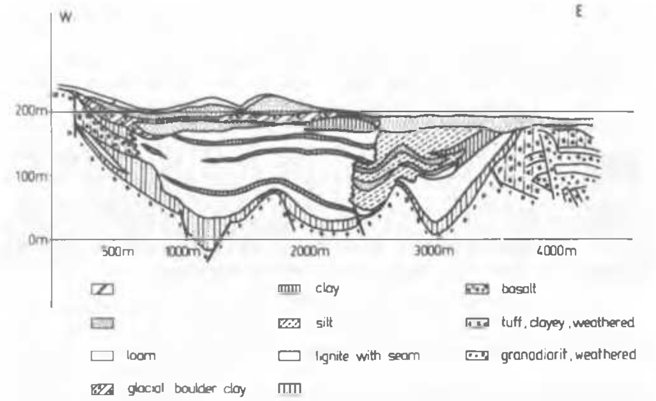

Figure 4

Major minerals forming the clay were determined by X-ray analysis. The shear strength was determined in torsion shear apparatus. In accordance with their genesis, there were two materials to distinguish, i. e. material of basaltic and granitic origin. Table 1 shows the results.

Table 1. Results of analysis of rock mantle materials

		Basaltic	Granodioritic
Colour		dark grey to red	light grey to green
Clay content (0,002 mm)	/%/	40...60	50...60
Montmorillonit content	/%/	60...80	50...70
Kaolinit content	/%/	10...20	20...40
Bulk density ρ_n	kg/m³	1940	1960
Shear strength φ'	x°	24...28	22
Cohesion c'	kN/m²	14...41	30...41
Residual strength φ'_R	x°	4...6	6...9
Liquid limit w_L		0,8...1,3	0,9...1,1
Plastic limit w_P		0,4...0,6	0,4...0,55
Plasticity indes I_P		0,5...0,7	0,5...0,65
Activity A		1,1...1,5	0,7...1,1

The fact that major shifts have taken place on the potential sliding areas in the past allows the assumption that the residual shear strength must be the decisive factor. This is borne out by soil statical calculations.

SOIL MECHANICAL CALCULATIONS

As an example, Fig. 5 shows a section of the slip area to illustrate the geological situation and the situation of the sliding surface as established by geological investigations. It is valid for the period before the opening of the third lignite cut. (Meanwhile, lignite is won in five cuts.) Continuous mining, of course, leads to continuous change of the geometry of the sliding mass. Therefore, and in view of the complicated geologic situation, considerable simplification of the calculation model was needed. The decisive geotechnical an technological influencing factors on calculation were determined from a greater number of variants. As the method best suited, the Kinematic Element Method (KEM) (Fiebig/Kluge 1988, Gußmann 1986) was employed. The least favourable geometry of the sliding mass was determined on the basis of an optimization method. A system of 5 rigid bodies describes the mechanism with sufficient accuracy (Fig. 6). The investigations resulted in a safety factor S = 1,0...1,1, with account to the residual strength in the main sliding surface but without account to water pressure.

Thus, the major assumptions can be seen to be proven.

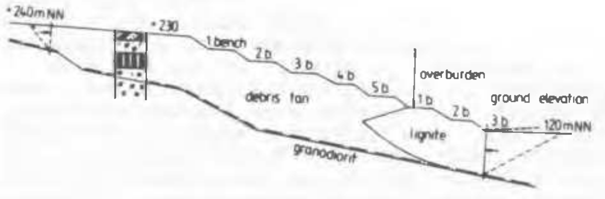

Figure 5. Landslide "P"; cross section

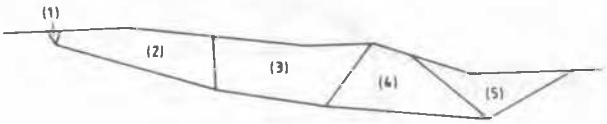

Figure 6. Failure mechanism

Moreover, the following results must be named:
- The greatest contribution to the "driving" forces is made by the weight of the rock mantle (downslope force); earth pressure (rigid body 1) is, in comparison, negligible since the shear strength of the rock mantle outside the sliding surfaces is high.
- The decisive contribution to the "resisting" forces is made by the earth resistance (rigid body 5) in the area of solid lignite. Here, the movement is considerably influenced on by mining. Friction in the main sliding surface contributed but little due to the low strength of the rock mantle materials.

In connection with mining advancement, the results allow a prediction of new movements both locally and in terms of time. The intensity of the movement was in proportion to the reduction of the safety factor and the extent of this reduction below S = 1,0.

The direction of movement was in agreement with the inclination of the rock mantle basement and could thus be determined from isophyse maps showing its height.

POSSIBILITIES FOR LIGNITE MINING IN FRONT OF SLIPS

On the basis of our calculations, a far-reaching programme of slip observation has been compiled (Jolas 1985).

The following measurements were agreed upon:
- survey monitoring (aerophotogrammetrical and terrestrial)
- extensometer and inclinometer measurement
- pore pressure measurement
- geologic mapping of slopes.

Among these, the surveying measures were most successful, whereas the amount of shift has proved to be too great for the other forms of measurement, particularly inclinometers. The latter signalize the start of a movement but have to be excluded from operation after this. The slip area is exactly delimited, and safety areas are established. Technologically controlable limits are know for the extent of the movement (shift and speed). These are the basis for the technological conception of the application of equipment. The measures to be taken when the limits are exceeded are well known to the staff and the operating personnel. An alarm system has been introduced.

New instability is indicated by cracks in the basin rim. They are followed by upheavals of the working level of the cut which caused the movement. The influence of mining on the large sliding mass is small in a given period of times. In effect, the equilibrium limit is not considerably fallen below so that each movement leads to a new state of equilibrium. The soil resistance wedge is lifted so that it can be won if it consists of lignite. Hazards are created by cleavages and cracks in the lifted bodies, and the breaking away of parts of the latter. Observers are used during excavating to prevent damage of the equipment.

The winning process has been continued up to horizontal shifts of 1,5 m/d and upheavals of 1,0 m/d.

SUMMARY

Due to the specific geologic situation, a slip with a volume of almost 100 million m^3 occurs in the opencast of Berzdorf, German Democratic Republic. This was caused by the existence of fossile sliding surfaces in the deep bottom in which residual strength was the only factor still effective. Calculations according to the Kinematic Element Method (KEM) confirmed preliminary assumptions and allowed to continue lignite meaning after the introduction of an extensive measurement and observation system.

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