RESEARCH OF CASE FAILURE OF SLUICE FOUNDATION ON EXPANSIVE CLAYS

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A b s t r a c t
The paper presents surveys related of determining effect of expansive Pliocene clays which caused of destruction of reinforced concrete foundation slab built on the lower head of stage of fall located in the 300 km of the Odra river in Poland. Executive mistakes and the lack of swelling pressure cushion sand bags in a water access brought about the ground swelling, which in terms of occurrence of significant buoyancy of water caused a large swelling pressure. Tests were performed on samples taken from the drilled surface of the concrete base plate, which apart from determinations of basic geotechnical parameters also swelling pressure in terms of existing states of stress and swelling index in the cross-section of channel with existing loadings.

S t r e s z c z e n i e
W pracy przedstawiono terenowe i laboratoryjne badania mające na celu wykazanie roli ekspansywności plioceńskich iłów w powstaniu spękań żelbetowej płyty stanowiącej fundament konstrukcji głowy dolnej budowanej śluzy żeglownej w 300 km Odry. Błędy wykonawcze, a przy tym brak amortyzującej ciśnienia pęcznienia poduszki piaskowej w warunkach dopływy wody w strefę kontaktu płyty z ekspansywnym podłożem były przyczyną uruchomienia procesów pęcznienia podłoża. Badania pęcznienia w warunkach laboratoryjnych przeprowadzono na próbach NNS w wariantach odciążania i obciążania podłoża odpowiadających stanom naprężeń występujących w kolejnych etapach budowy. Maksymalne wartości ciśnienia pęcznienia wyniosły 250 kPa, co przy zróżnicowanych obciążeniach płyty spowodowało w jej środkowej części duże naprężenia zginające skierowane ku górze. Naprężenia pod bocznymi ścianami głowy śluzy wyniosły 350 kPa, gdzie płyta zginana była w dół. W wyniku tego powstały 3 linie pęknięć, których charakter udokumentowano spękaniem widocznym na podłużnym przekroju otworu nr 7 i na pozyskanym rdzeniu betonu.

K e y w o r d s: **Swelling; Foundation; Hydrotechnical structures.**

1. INTRODUCTION

In order to estimate the expansive clay behaviour which are forming the substrate in foundation structure, in each case conditions of change and stress history should be analysed. The case concerns the construction of barrage on Odra river in Malczyce including the sluice which is one of elements of this structure. The swelling of the grounds affected by interruptions during the investment as well as underestimated the importance of geotechnical issues caused destruction problems.

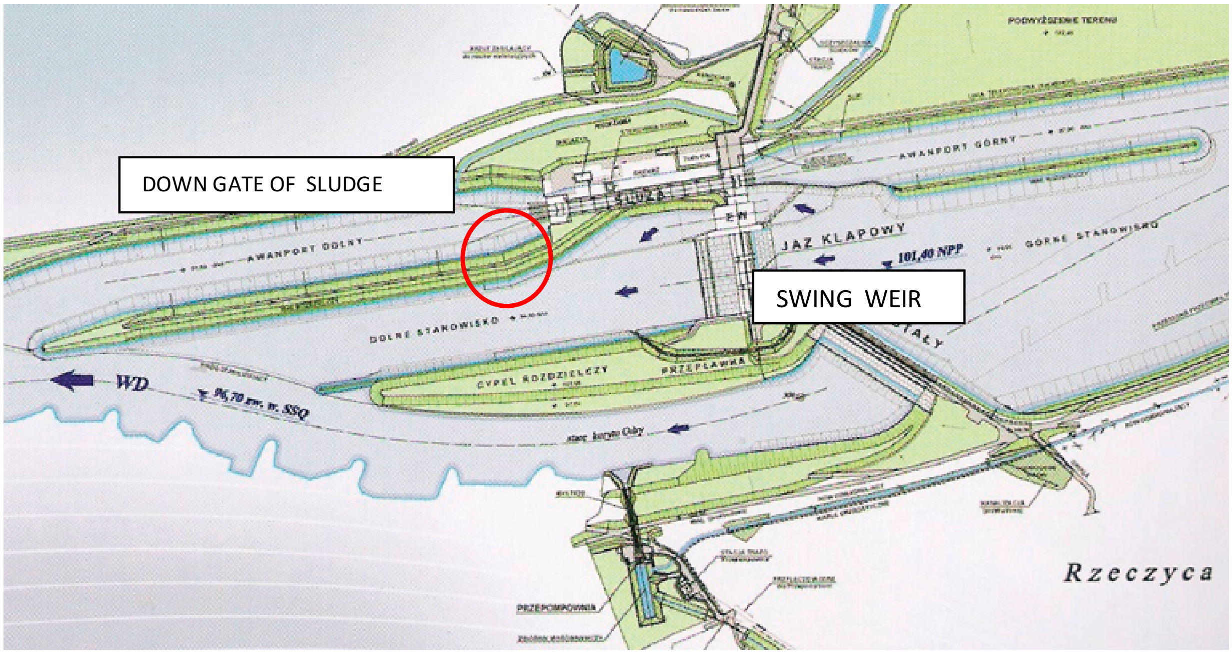

Figure 1.
Location of the Malczyce stage of fall construction

2. CONDITIONS AND MODE OF THE SLUICE FOUNDATION

Navigable sluice whose length is 190 m, width 12 m, with walls of the canal of 12 m height, and 3.5 m deep water at their threshold is dilated by 6-segmental docked construction which is placed directly onto 6 m below clay layer. The upper position of the sluice is designed building of upper head with two channels of circulation for the filling sluice (Fig. 2a) and steel gate. The height of sluice to level of upper water is 5.2 m. From the upstream side the head of distribution of foundation loads on the base slab is protected against filtration process by a tight wall steel sheet of 2 m depth. In the same manner the foundations of the five dilated canal sludge sections were also protected. Set on a plate of the dimensions 30.4 × 29.3 m on monolithic of docs construction head on both walls had a horizontal circulating channel into outflow of water from sludge (Fig. 2a) and situated vertically mounting cavity closures and also cavity for mounting bolts and control systems. The walls of the head widths of 9.2 m each have a height 15.3 m, which at a density of concrete gives the order of 24 t/m^3 base load unit around 350 kN/m^2. However, tensions under the slab foundation with a thickness of 3.5 m which is in the cross-section of lower head, after taking into account the buoyancy of water during construction in the level were about 50 kN/m^2 [4]. That large diversity of loads requires substrates with low compressibility. Design assumptions required after the final foundation earthwork excavation, rapid made of the foundations and slab perimeter seal sheet tight wall stuck in the clay 2 m below the foundation (Fig. 2c).

The mistake caused by inflows of surface rainwater from area under of foundation plate. Positioning under substructure about 2 cm of sand layer has enabled the infiltrate of water to expansive clays. In the result the processes of swelling expansive clays was activated. It caused complicated deflections of theoretically line of axis plate substructure, and it was main reason of appearing 3 vertical cracks to the sluice axis (Fig. 2c). In order to solve this problem the loadings should be determined as well as the operating tension in the basis of the should be predicted.

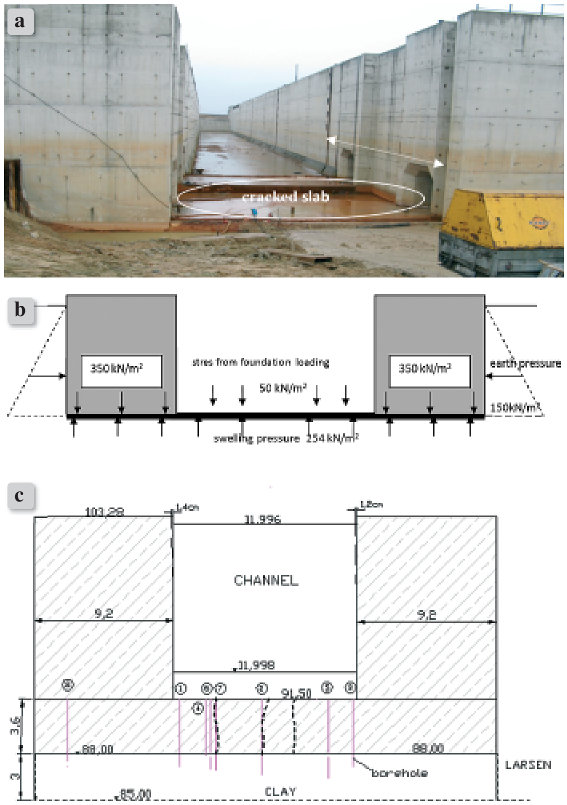

Figure 2.
Cross-section of lower head, a) Fissured benthic slab of lower head, b) the distribution of foundation loads on the base slab, c) location of vertical cracks of slab, and boreholes

3. INTERNAL STRUCTURES OF FISSURED PRECONSOLIDATED PLIOCENE CLAYS

Pliocene Clays which occur in subsoil with thickness exceeding 100 m belong to a group of heavily preconsolidated grounds which are fissured clays with high cohesion. However, they can fundamentally differ by primary structure [2,5]. It may also exist a secondary structure which has developed later, e.g. after the formation of the soil during the sedimentation process. The characteristic features are irregular mosaic systems of micro scratches with tessellated texture and surfaces separated irregularly. Increasing the load in geological history and the difference between horizontal and vertical tensions additionally increase these micro fissures [1,3]. Such changes could also occur during the construction of sludge. Realization of the earthwork and leaving it in the difficult condition for not less than six months caused in a tendency to expansion of both clays upwards and in the horizontal direction, which in consequence caused migration of water into these micro fissures. Penetrating water does not cause softening of the clays and even swelling which is probably caused by formation of new scratches. This process is called expansion the clay in higher water content area and it proceeds in a continuously declining way and lasts until the clay does not become plastic. [5]. At the same time, a progressive softening of the substrate located in deeper lasts, and it results in accessing water to deep less irrigated zones of clay, and it begins a similar process as at a lower level. Completely predictions in this mechanism are complicated, because of the difficulty with assessing these overlapping which mechanisms describe swelling.

4. COMPRESSION AND SWELLING TESTS

Physical properties of tested clays were defined for samples about undisturbed structure, extracted from various depths, 1.5 m below foundation slab.

Figure 3.
Foundation rupture at surface and cross-section of concrete in borehole no 7

After drilling in reinforced concrete foundation slab 8 boreholes of 0.2 m diameter, of geotechnical tube diameter 0.1 m were pressed into clay of subsoil. There were also several boreholes made by manual gimlet.

In laboratory the following were tested; grain size distribution, consistency limits, liquidity index, oedometric modulus and swelling pressure. Those parameters enables to measure degree of clay expansion [2,3]. Characteristic results were given in Table 1.

Table 1.
Clay samples properties taken from different samples of grouting

No of sample	Depth (m)	f_i	f_π	f_p	w_n (%)	w_P (%)	w_L (%)	I_L	I_p	A_k $\frac{I_p}{f_i}$	Potential of expansion
1/3	0.90	52	38	10	20.99	20.95	72.30	0.12	51.3	0.98	very high
2 /1	0.10	50	40	10	27.78	21.24	48.60	0.24	27.4	0.55	average
2/5	2.25				28.89	22.09	77.05	0.12	76.9		-
5/2	0.20	52	43	5	20.73	20.24	72.80	0.01	52.6	1.01	very high
5/6	0.70	52	43	5	25.11	21.76	72.30	0.07	50.5	0.97	very high
6/1	0.10	32	46	21	27.03	21.76	72.30	0.12	50.5	1.10	high
6/8	1.10	50	38	12	21.32	21.45	68.20	-0.03	46.7	0.92	very high
6/9	1.30	46	42	12	21.32	21.98	68.20	-0.03	46.2	1.43	very high
7/3	0.40	54	40	6	23.66	22.12	73.00	0.03	51.9	1.44	very high
7/7	0.95	53	39	8	19.57	20.08	74.15	-0.01	54.1	1.02	very high

In swelling processes determination of natural water content in the investigated soil and their variation is valid. Generally it decreases with depth. For example for 9 samples extracted from borehole no 6 at depths from 0.1 to 1.3 m, water content varied from 27.03% to 21.32%. Similar changes were in samples extracted from borehole no 2 and 7. Those changes were caused by clay saturation, and this process followed from top layer due to the water flow into the clay layer. It caused swelling process. The sources of water flow in clay was thin layers of sand under foundation, where the water flowing from places leakiness seal sheet [4].

With increasing water content increased also liquidity index of clays from 0.24 indirectly under surfaces of plat foundation to – 0.03 in some deeper levels. For appreciation prognoses results of swelling pressure effects and settlement of foundation parallel to oedometric validation of compressibility modulus were made for clay samples with the same initial properties [1,4]. This test also simulated changeability of stress caused by loading. Those conditions were identical to with the ones on construction site. The swelling pressure test was made by modified triaxial apparatus. It simulates variation of stress and displacements between foundation of different slab parts, and clayey soil (Fig. 4).

I. Primary compressibility stress in excavation of foundation level before excavation
II. State relaxation stress
III. Test in secondary stress $\sigma_1 = 84$ kN/m^2, after performing of foundation in the base of foundation (without buoyancy of pore water pressure)
IV. Lose swelling of clay in condition which σ_1 is zero
V. Compressibility caused by stress involved by loading of corps wall of sludge.

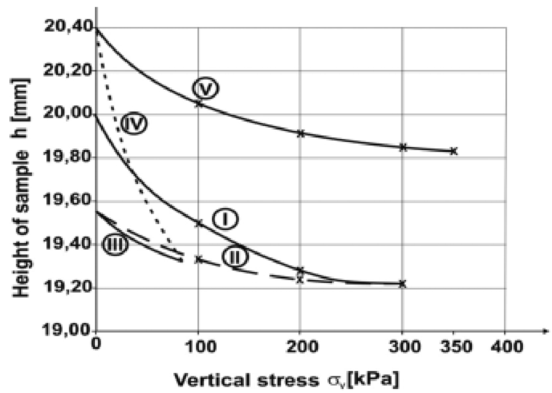

Figure 4.
Tests of compressibility changes and swelling pressure of clay samples in phases I-V

Second interpreted research variant was conducted in condition constant sample height. It fits the model of subsoil movement where vertical moves are impossible (Fig. 5).

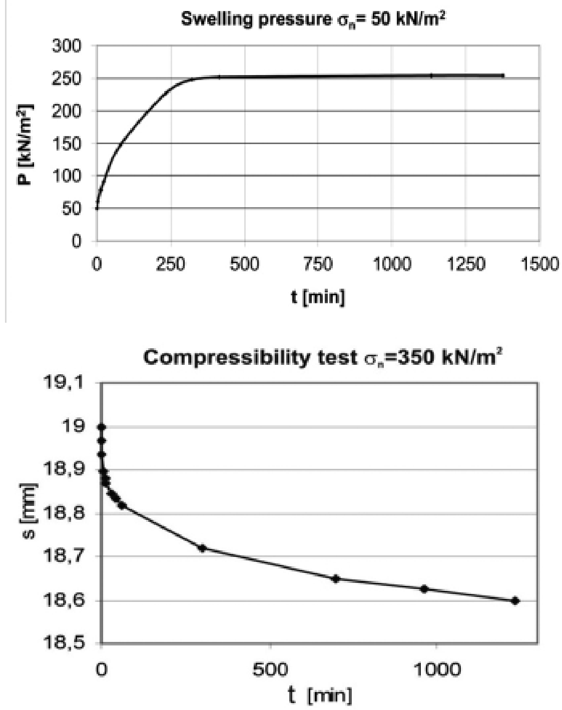

Figure 5.
Swelling pressure determined on constant sample height and compressibility test and settlement of wall head sludge

5. CONCLUSIONS

In order to interpret of rapture of slab foundation sluice about thickness 3.6 m, parallel to axis of channel sluice the obtained results of tests were analysed. Under zone channel line of sluice where tension caused by buoyancy of water was 50 kPa and swelling pressure was 254 kN/m^2. The foundation slab was bent on the top by press of swelling above 200 kN/m^2 (Fig. 2). Foundation of this slab, located under walls of sluice zone, with swelling pressure taken into consideration is loaded with tension circa 100 kN/m^2 and bends slab axis downwards. Furthermore in results additionally forces from passive soil pressure on these walls the slab about thickness 3.6 m fall fractures as in Fig. 3. For explaining of this destruction of the laboratory tests compressibility and swelling pressure of clay samples was made. That failure was repairing by injections.

REFERENCES

[1] *Chen F.H.*; Foundation on expansive soils, Elsevier, Amsterdam, 1988

[2] *Gawriuczenkow I.*; Geological engineering characteristics of expansive Pliocene clays from central Poland, XV-th Polish National Conference Soil Mechanics and Geotechnical Engineering, Bydgoszcz 2009; p.329-333

[3] *Niedzielski A.*; Factors defining free swell pressure of Pliocene clays in Poznań region. Annals of Agricultural University in Poznań, Scientifics dissertation No 238, Poznań 1993

[4] *Parylak K.*; Evaluation tests and analysis of event cracks of the foundation down head of sluice on Odra river in Malczyce, Progeos, Wrocław 2010

[5] *Skempton A., Petley D.*; The strength along structural discontinuities in stiff clays, Proc. of Geotechnical Conference, Oslo 1967