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NIEKTORÉ PRVKY OPTIMALIZÁCIE PODZEMNÝCH TESNIACICH STIEN ŽIVICAMI

SOME OPTIMIZATION ASPECTS OF UNDERGROUND GROUTING WALLS BY RESINS

Predmetom príspevku je predloženie niektorých aspektov prvkov optimalizácie (dôležitých pre projekčnú činnosť) pri budovaní podzemných tesniacich stien (PTIS) pomocou injektáže na báze živíc. Autor uvádza niektoré skúsenosti s budovaním PTIS na skládke RSTO Duslo, a.s. Šaľa, vo fáze experimentálnej. Súčasťou je tiež otázka aplikácie možných kontrolných metód počas výstavby PTIS.

Matter of this contribution is presentation of some optimization aspects by constructing of UGW's, on the base of injection by resins. The author presents some experience of UGW construction in experimental stage on waste dump RSTO Duslo, a.s. Šaľa (SR). Simultaneously, is also important to develop methods quality checking during UGW construction and during next monitoring, when UGW will be fully in action. In this contribution some methods could be found.

Foreword

At present, we will observe construction of underground grouting walls (UGW) for deep foundation of objects, reclamation of waste dumps, etc. Their significance is mainly in the fortification of fundaments, or build up of isolating bar against underground water flow, alt. dispraise these a.m.

From a technical and economical point of view, the UGW constructed by building chemistry agents application has a number of facilities on the contrary to the classical UGW (e.g. hollowed mud - cement UGW, etc.); namely, higher corrosion resistance, lower expense, non-challenge of working area, quantity of excavated and highly contaminated soils, etc. This trend is comparable to both our experience and foreign experience. At present, the CSN and STN standards don't define their carrying out and quality control. Newly prepared European Standard CEN WG 8 (according to issued standards for anchorage, micropiles, etc.) is fully filling up this legislative gap. From our experience, we can define some elements which have to be an accepted phase of the advance project stage for high quality of UGW's. Definition of the ways for checking and controlling IGW's quality is also important from time point of view. We must account that the properties of UGW's (esp. for resin) will arrive the full sealing effects in underground geological conditions in longer time (one year or more).

Procedure for UGW project

As a first stage of UGW project is geological prospection works and laboratory analyses, to obtain the basical physical and mechanical properties of soils (background), to check underlay, chemical properties of ground water, velocity and direction of flow incl. changes in horizontal and vertical directions. The second stage contains the laboratory tests for study of isolating properties of applied mass, incl. temperature and viscosity. As a third stage is necessary to carry out the model tests in triaxial cell, for modelling of injection technology in bigger scale than in lab (pumping pressure, radius of injected area, etc.). The all results have to be verified at worksite (workplace), on small experimental UGW section. The size of this experimental UGW section is not limited (the size depends on the total number of injected holes and distance between them, e.g. 1 %). The experimental UGW section is closed, in circle or square form. The section contains observing holes and observating wells for pumping tests. This system allows the pumping tests between inner and outer wells, for determination of filtration coeff., before and after injection works. The mode of pumping tests must to be proportional to the flow of ground water, according to given geological conditions.

The project of works contains the technological procedure in details (e.g. quantity of materials for injection, pressure of injection at maximum, radius of injection around the hole, etc.).

The radius of injection is possible to calculate by addapted Maag's formula:

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$$R = \left[\frac{2}{\frac{L}{(L^2 - 4r_o^2)^{0.5}} \cdot \ln \cdot \frac{L + (L^2 - 4r_o^2)^{0.5}}{2r_o}} \cdot \frac{K_m \cdot t \cdot H}{n_{ef}} + r_o^2 \right]^{0.5} \qquad (1)$$

where: R radius of injected area (m),
L length of hole (m),
r_o halfdiameter of hole (m),
k_m soil filtration coeff. for resin (m.sec^{-1}),
t time of injection (sec),
H pressure height (pressure of inj. in m),
n_{ef} effectiveness porosity.

For k_m coeff. calculation is formula:

$$K_m = k_f \cdot \frac{\eta_v}{\eta_p} \cdot \frac{\chi_p}{\chi_v} \qquad (2)$$

where: η_v water dynamic viscosity (mPa.sec),
χ_v water density (g.cm^{-3}),
η_p resin dynamic viscosity (mPa.sec),
χ_p resin density (g.cm-3; pract. 1.10(1.80 gcm^{-3})
k_f filtration coeff.of soils in situ (m.sec^{-1}).

The consumption of resin by injection according to CSN Std. (see [5], [8]) formula is calculated:

$$Q = a_1 \,.\, a_2 \,.\, a_3 \,.\, n \,.\, V \qquad (3)$$

where: Q resin quantity (m^3),
a_1 resin enlarge coeff. (practically 1.1 - 1.4)
a_2 pressure displacement coeff. (water by resin, 1.2 - 1.4),
a_3 porous filling coeff. (0.4 - 0.7),
n soil porosity,
V theoretical soil volume for injection (m^3).

The theoretical results and practical results (testing section of UGW) have to be continuously compared.

Some experience of UGW construction.

As a specimen of UGW construction, it is possible to show the situation in the waste dump RSTO Duslo, a. s. Šaľa (south Slovakia). At this time, the waste dump is under reconstruction. The waste dump near the river Váh was in action by chemical works for a long time. The waste dump is squared large, app. 30 ha.

The geological conditions are very complicated. Continuous jointing layer is at the depth 13 – 15 m, jointing interlayer is at depth 7 m on some places only. The soils are watery sands and gravels, quarter and neogen periods. The flow of underground water is from north to south, the average flow velocity is 5 cm/day. In observation wells around the waste dump, there are higher concentrations of salts, hard metals, etc. Previously the 3 m thickness of clay as an upperlayer of waste dump has been partly removed. In these places, the oil substances can be indicated. Filtration coeff. are $X \,.\, 10^{-4} - X \,.\, 10^{-5}$ m . sec^{-1}.

The UGW as a continuous vertical wall around the waste dump is projected. For higher safety, 10 – 12 pumping wells in inner side will be drilled and cased. The project calculates with vibrating and casing of holes (depth 13 – 15 m, 0.5 m fastly to the clay bottom) by steel tubes O. D. 48 mm/4 mm, perforated á 20 cm (the total length of perforation is 10 m), distance between holes is 1 m. Injection of hole from bottom to the top (2 stages) by polyuretan (PUR) type 3P of Hungarian provenience, or Bevedan - Bevedol WF of German provenience.

Injection works are carry out through packers ANKRA (Czech construction) up 3 MPa pressure at maximum. In given geological conditions, this value of pressure sinks the danger of "clacage" (see Fig. 3 - down). The injection radius is 55 cm, acc. calculation by Maag's formula (see (5)).

The quantity of PUR is 70 – 80 kg/hole, calculated by formula (2). Foaming in situ is 7 – 8 x (increasing of material volume). Before injection works, the hole has to be clean up to the total depth, as the same as both neighbouring ones.

The filtration coeff. in range $X \,.\, 10^{-8} - X \,.\, 10^{-9}$ m. sec^{-1}, from laboratory tests on samples has been determined.

There is a situation (lay down) of the experimental UGW section where holes No. 11 - 16 are parts of UGW waste dump on Fig. 1.

On Fig. 2 there is a situation (cross section) after injection works of one half experimental UGW section.

The pumping test shows filtration coeff. in range $X \,.\, 10^{-5} - X \,.\, 10^{-6}$ m.sec^{-1}.

After total injection of experimental UGW section is executed, we obtain a filtration coeff. in the range $X \,.\, 10^{-6} - X \,.\, 10^{-7}$ m.sec^{-1}.This value is sufficient for tightness of UGW in situ. In the future when UGW will be in full action, tightness embodies higher values. This is proportional to the foreign experience (see [5]).

Conclusion

For the high UGW's quality, we can define the principles as following.

1. In details, to evaluate the results of geological and hydrological prospection acc. stages (see [1]).
2. In details, to evaluate the results of laboratory and model tests (triaxial cell) and start put down starting he technological procedures for experimental UGW section. The calculation of material quantity, injection radius, etc., alt. exploitation of inertial materials - muds (see [5], [6], [10]) is possible.
3. To define precisely the number of injection stages and pressures at maximum.

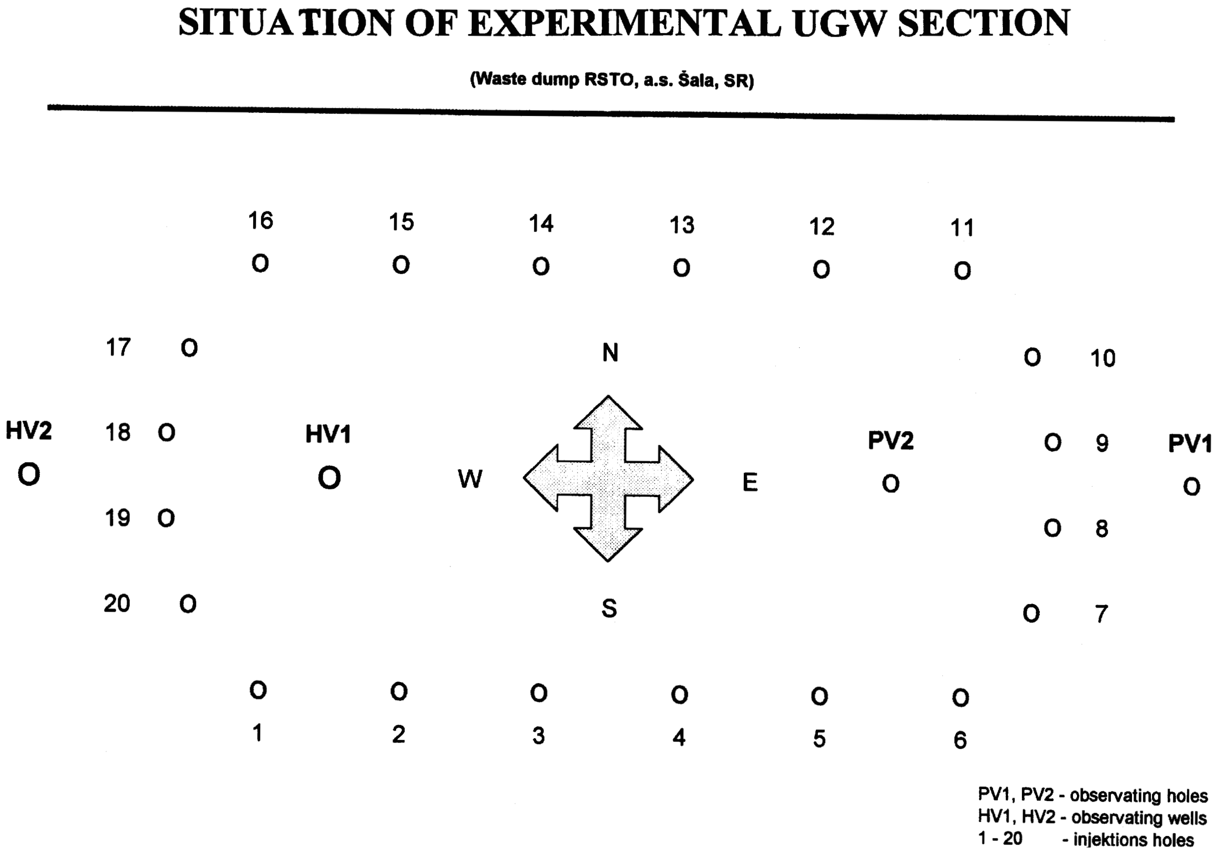

SITUATION OF EXPERIMENTAL UGW SECTION
(Waste dump RSTO, a.s. Šala, SR)
16
15
14
13
12
11
17
N
10
HV2
18
HV1
PV2
9
PV1
W
E
19
8
20
S
7
1
2
3
4
5
6
PV1, PV2 - observating holes
HV1, HV2 - observating wells
1 - 20 - injektions holes

Fig. 1

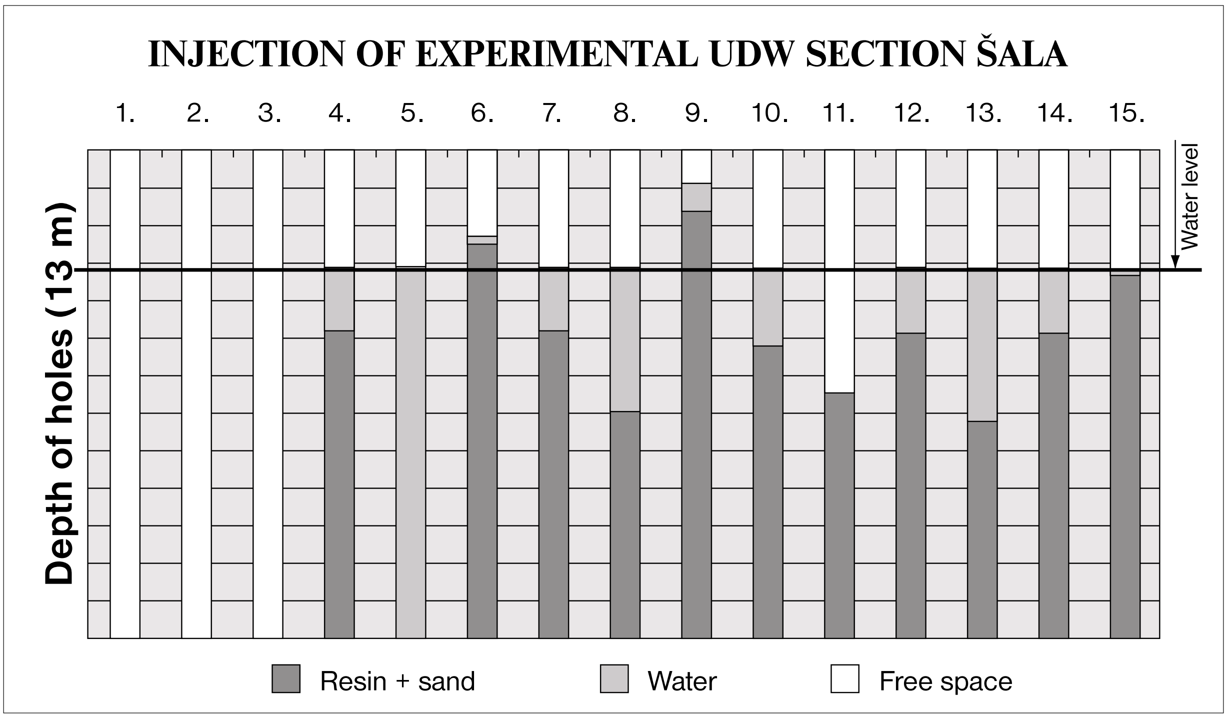
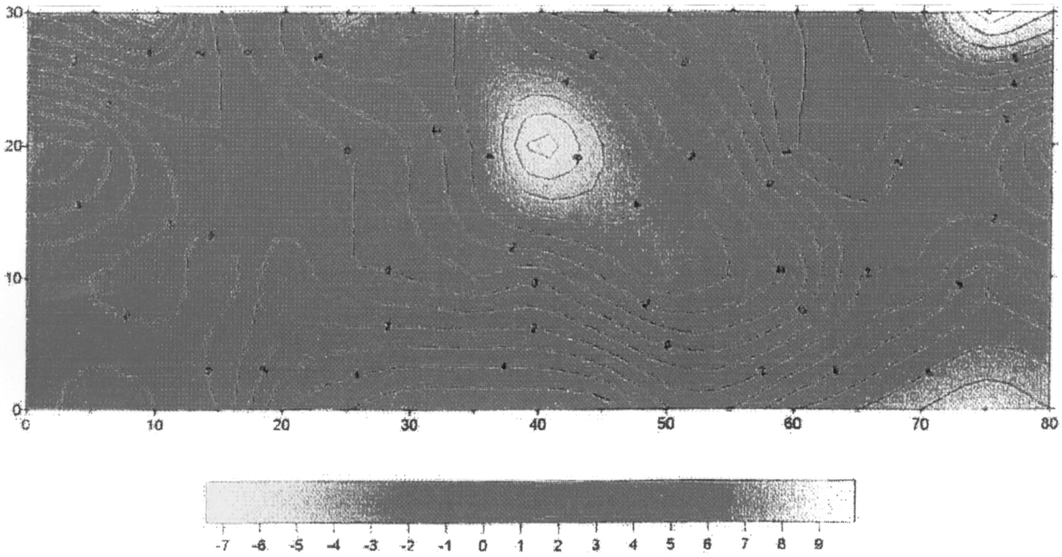

INJECTION OF EXPERIMENTAL UDW SECTION ŠALA
1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.
Depth of holes (13 m)
Water level
Resin + sand
Water
Free space

Fig. 2

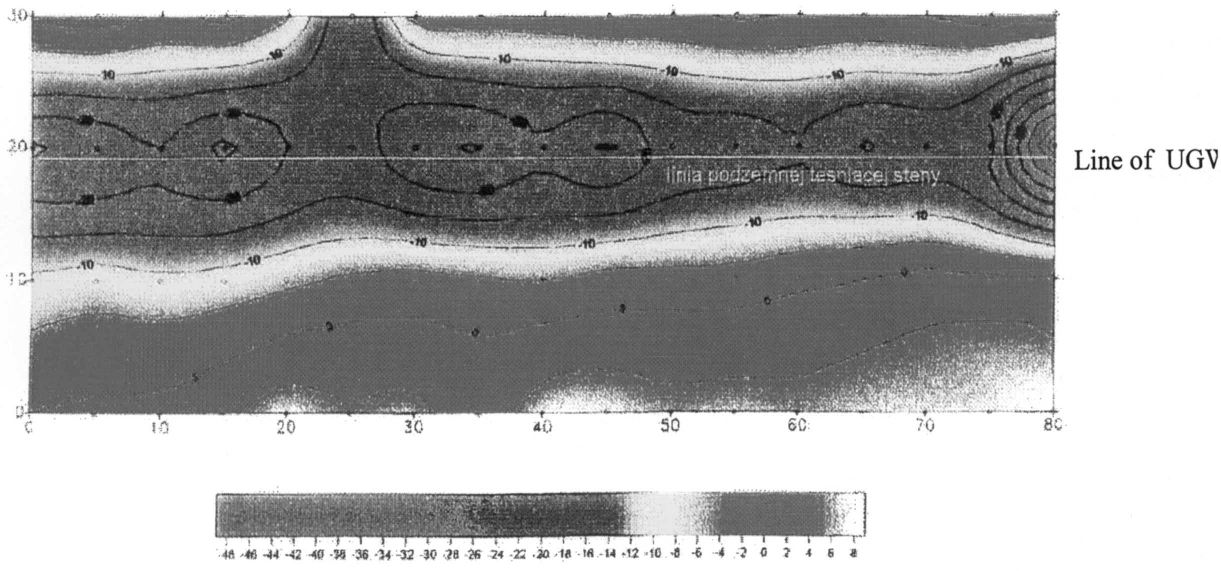
THE FLAT LAY – DOWN OF NATURAL ELECTRICAL FIELD OF UGW SURROUDING AREA

Situation before building up of UGW



filtration potencials (mV)

Situation after building up of UGW



natural elektrical field (mV)

Fig. 3

With this connection it is very favourable to apply retrievable packers (repair works in hole).

4. To document each hole (work sheet) for vibrating, casing, injection pressure, material consumption (flowmeter, accurate balance, etc.).
   This working sheet has to be verified by a supervisor daily.
5. For checking of experimental UGW section tightness quality and to carry out the pumping tests (the mode has to be proportional to geological conditions in a given area),
6. To apply geophysical methods (VES, SP and MEPNI) in the course of UGW realisation (see Fig. 3, [3], [7], [9]). The methods in controversial cases by dynamic penetration test could be added.

These principles are in brief form, however, they are valid for the whole number of UGW injections.

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