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SETTLEMENT CALCULATION OF THE RADIOACTIVE WASTE DUMP IN MOCHOVCE

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1. Introduction

The Republic Radioactive Waste Dump (RRWD) located about 2 km from the area of the Mochovce Nuclear Plant in south-western Slovakia. The RRWD was built to store waste with low and medium activity arising from operation and disposal of nuclear power facilities as well as from research institutes, laboratories, hospitals and other institutions engaged in activities generating nuclear waste. Securing of the stability and reliable operation of RRWD in Mochovce is a complicated engineering task. The dump is built in difficult engineering-geological conditions determined by high compressibility. Also required reliability and lifetime have a significant influence on layout of these specific structures. Geotechnical problem is analyzed in [1]. In the first construction stage, two double lines of storage boxes with the total surface area of approx. 112000 m^2 were built. The general situation around the dump and its adjacent territory is shown on Fig. 1. Building of the temporary overlap of 1st double-line of storage boxes (serving during its filling up) is shown on Fig. 2. Section of the RRWD (realised two and planed eight storage boxes) is shown on Fig. 3. The paper deals with the issue of reliability of the Waste Dump in terms of calculating the size of the final settlements of the storage boxes of the RRWD for real loading states occurring during operation. The geotechnical problem of the interaction between foundations structure (of storage boxes) and subsoil is solved by mathematical modelling using Finite Element Method (FEM). Computer program ANSYS® [2] was used to solve the problem.

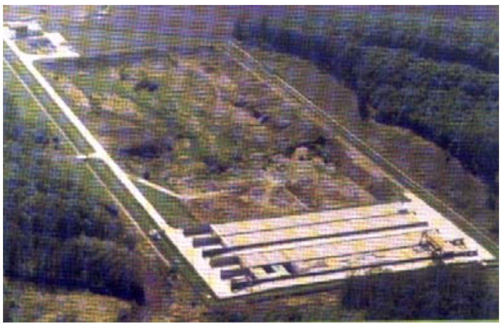


Fig. 1 View of placement of the Republic Radioactive Waste Dump in Mochovce

Fig. 2 Building of the temporary overlap of 1st double-line of storage boxes

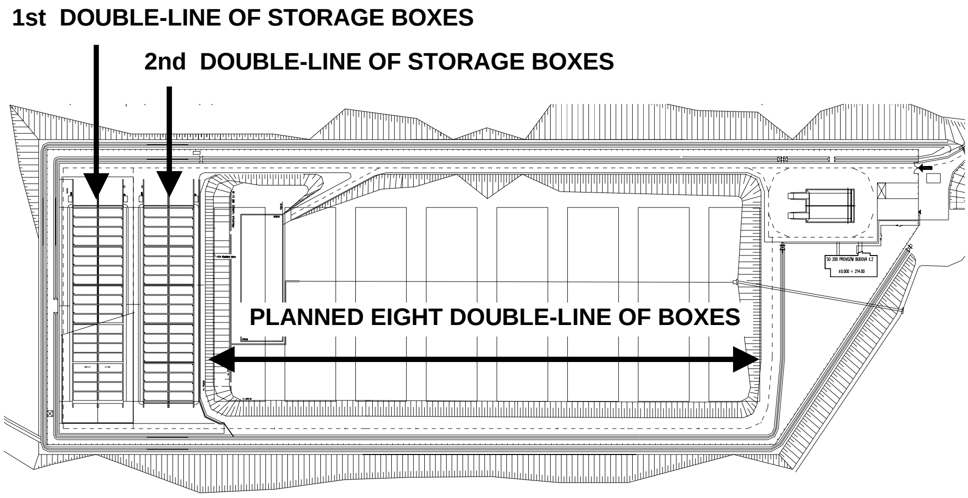


Fig. 3 Section of the RRWD in Mochovce (realised two and planed eight boxes)

2. Structural solutions of the Republic Radioactive Waste Dump

At the present, the RRWD consists of two double-lines of storage boxes made from reinforced concrete. Four boxes are grouped into one dilatation block with layout dimensions of 18.6 x 6.0 m and height of 5.5 m, placed on a common foundation slab 0.6 m thick. There are five dilatation blocks in one line. An expansion gap between the blocks is planned to be 50.0 mm thick. The storage boxes are covered by 0.5 m thick panels from reinforced concrete. A system of two drainages (control drainage and monitored drainage) is built at the bottom of the storage boxes and under the foundation. Side walls and the bottom of the monolithic storage boxes from reinforced concrete are protected by a layer of clayish soil. A 1.0 m thick layer of compacted clayish soil is located under the tanks to ensure waterproof basement for the storage boxes. On this layer is lying 0.6 m thick layer of sandy gravel. Vertical walls of boxes are protected by 3.5 m thick vertical clay sealing linked with a horizontal sealing soil layer, forming a compact unit (the so-called clay "sealing tub"). The double-lines are protected against climatic effects by a mobile steel hall when the storage boxes are filled with waste. Considering the general reliability of RRWD, the structures of the storage boxes are the most important and decisive building structures. A typical cross and longitudinal section of the 1st and 2nd double-line is shown on Fig. 4 and Fig. 5.

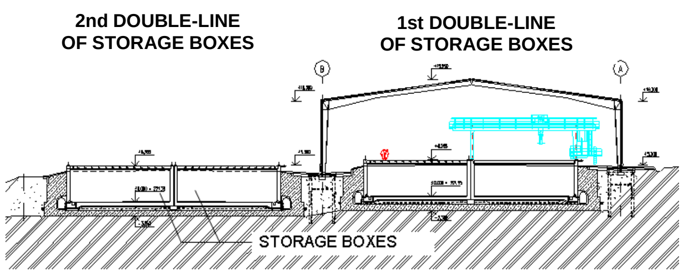


Fig. 4 Typical cross section of the 1st and 2nd double-line of storage boxes

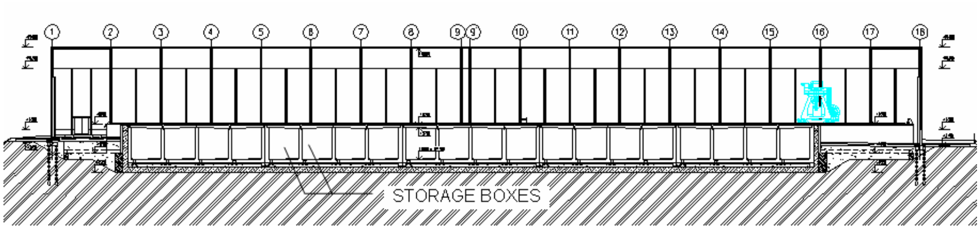
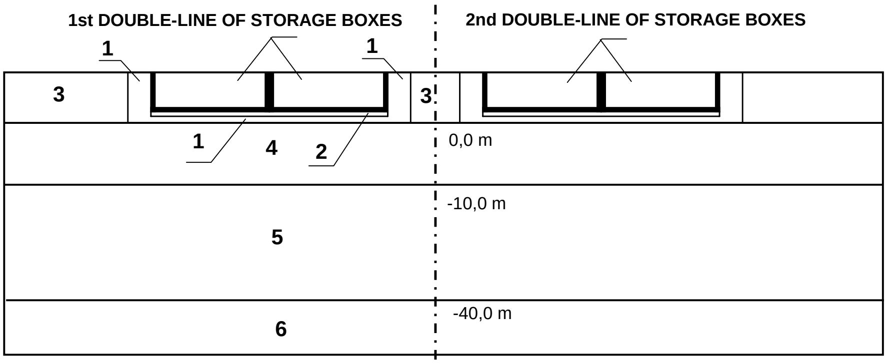


Fig. 5 Typical longitudinal section of the 1st double-line of storage boxes in RRWD

3. Defining of the subsoil geotechnical model

In order to determine the real composition of the natural geological environment of the area of interest was made out several geotechnical surveys. After evaluation of the geotechnical surveys was made geological model of the RRWD subsoil. The resulting transformation of the natural environment in geotechnical model of the subsoil, including earth structures and reinforced concrete storage boxes is shown on Fig. 6. Material properties of geotechnical model (subsoil and earth structures) used in numerical calculations are shown in Table 1.



1 - Clay, high plasticity (sealing barrier); **2** - Gravel (drainage layer); **3** - Clay, medium plasticity (embankments around storage boxes); **4** - Clay, medium plasticity (subsoil in depth: 0 - 10 m); **5** - Clay, high plasticity (subsoil in depth: 10 - 40 m); **6** - Clay, high plasticity (subsoil in depth: > 40 m)

Fig. 6 Geotechnical model of the subsoil including earth structures and reinforced concrete storage boxes

4. Geometric and static boundary conditions of the numerical (FEM) model

In the numerical solution of the problem symmetry was used in the longitudinal direction of the RRWD. It was made in the longitudinal direction only half of the RRWD model. Scheme for the RRWD numerical model is shown on Fig. 7.

Geotechnical calculations define four load states (**LS**) describing the following significant stages of dump construction and operation:

- **1st LS** – Load on the subsoil due to own weight of the reinforced-concrete storage boxes (size of the load on the foundation gaps of 1st and 2nd one is q=59.2 kN.m^{-2}),
- **2dn LS** – Load after filling the 1st double line with waste containers (size of the load on the foundation gaps of 1st double lines is q=183.11 kN.m^{-2} and 2nd one is q=59.2 kN.m^{-2}),

- **3rd LS** – Load after filling the 2nd double line with waste containers (size of the load on the foundation gaps of 1st and 2nd double lines is q=183.11 kN.m^{-2}),
- **4th LS** – Load after closing the 1st and 2nd double lines and the final coverage of the dump (size of the load on the foundation gaps of 1st and 2nd one is q=238.13 kN.m^{-2}).

Table 1 Physical properties of subsoil and storage boxes used in numerical solutions

Labeling	Description of the layer and structure	Depth /m/	Volume gravity γ /kN.m^{-3}/	Poisson's ratio ν /-/	Deformation modulus E_{def} /MPa/
1	Clay, high plasticity (sealing barrier)	-	20.5	0.42	10.6
2	Gravel (drainage layer)	-	20.0	0.20	250.0
3	Clay, medium plasticity (embankments)	-	21.0	0.40	10.0
4	Clay, medium plasticity (subsoil)	0 – 10	21.0	0.40	18.2
5	Clay, high plasticity (subsoil)	10 – 40	20.5	0.42	27.0
6	Clay, high plasticity (subsoil)	> 40	20.5	0.42	42.7
-	Reinforced concrete (storage boxes)	-	25.0	0.15	27 000

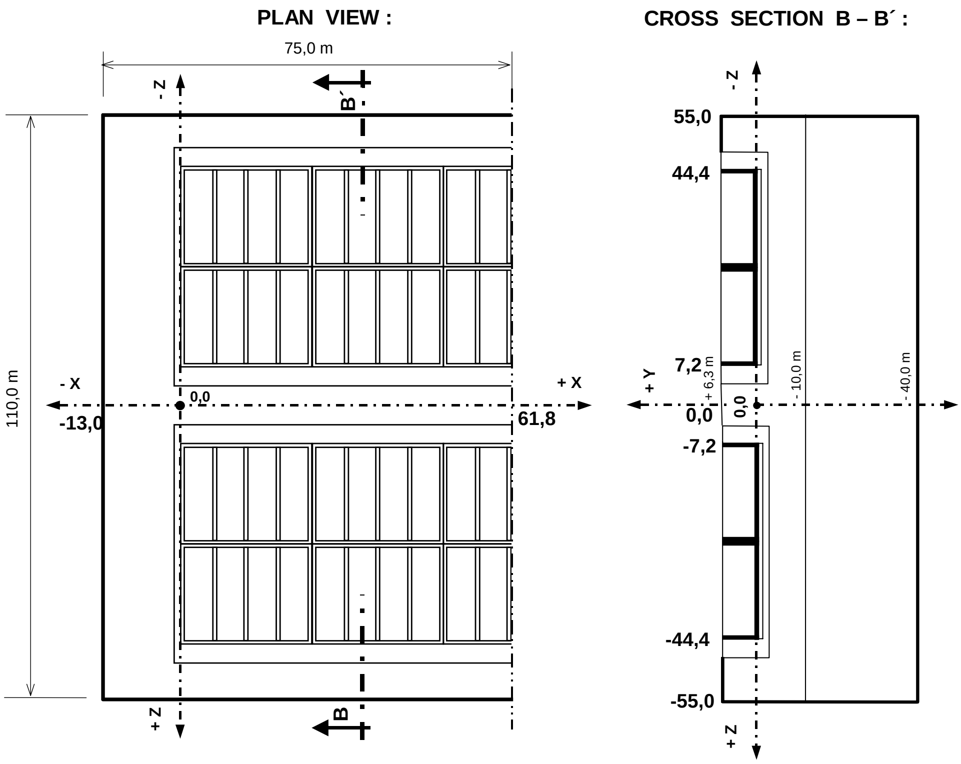


Fig. 7 Scheme for the RRWD numerical model

5. Results of numerical calculations of settlements of the storage boxes

From realized numerical calculations, we have obtained many quantitative and qualitative results of vertical displacement (settlements) of the storage boxes subsoil for defined load states. Settlement of the storage boxes and surrounding area in the foundation gaps for 1st to 4th load state is shown on Fig. 8 (in the transverse direction) and Fig. 9 (in the longitudinal direction). 3D results of settlements (isoareas of settlements) of the subsoil under the storage boxes calculated for the 2nd and 4th load state are shown on Fig. 10. The calculated maximum settlement is about the size of 171.1 mm. Obtained results of numerical calculations of the final and unequal settlements were used in the final design of the storage boxes, sealing and drainage layers in their subsoil.

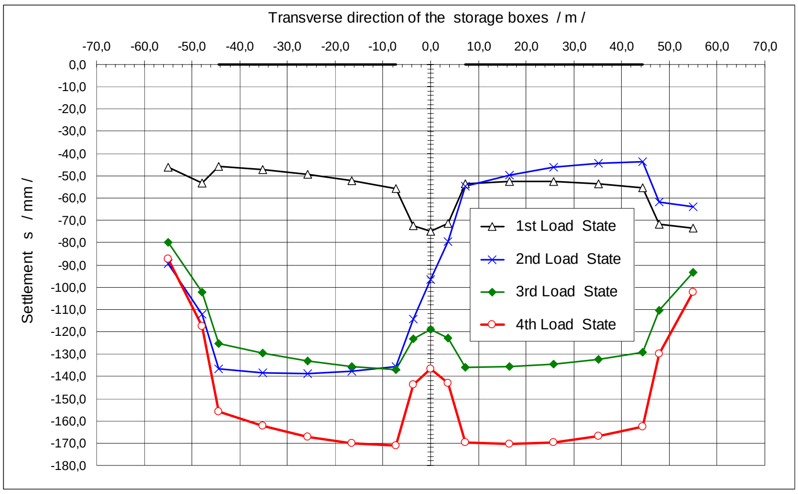


Fig. 8 Settlement of the storage boxes and surrounding area of the foundation gaps level in the transverse direction

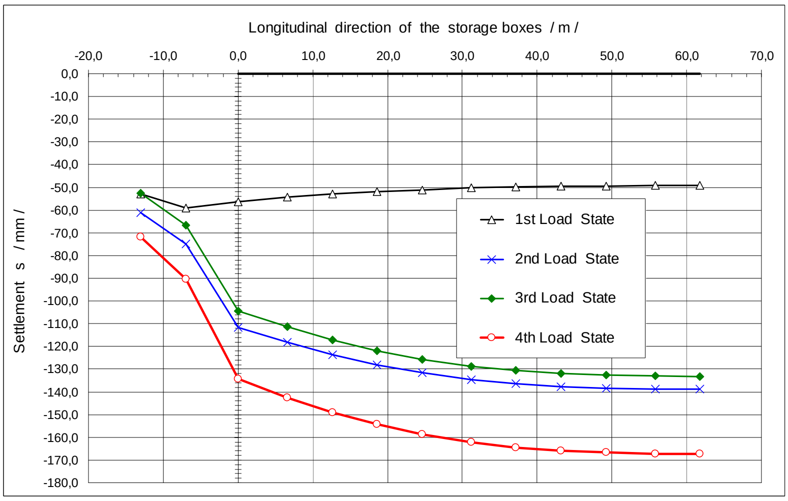


Fig. 9 Settlement in the axis of the 1st double-line of storage boxes and surrounding area of the foundation gaps level in the longitudinal direction

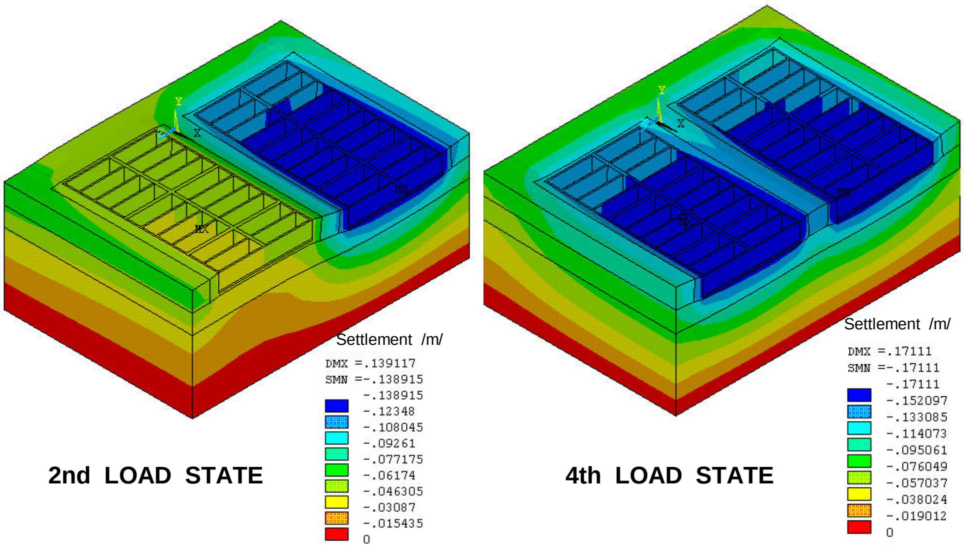


Fig. 10 Isoareas of subsoil settlement for storage boxes calculated for the 2nd and 4th load state

6. Conclusion

The size of the final and unequal settlements of the storage boxes have a significant influence on the reliability of designed sealing and drainage layers occurring in the subsoil and usability of the storage boxes. Obtained results of numerical calculations were used in optimize the design of structures of the Radioactive Waste Dump in Mochovce.

References

[1] Hruštinec Ľ. - Kuzma, J.: Experimental Assessment of the Republic Radioactive Waste Dump in Mochovce. (In Slovak), Bratislava 1988.
[2] ANSYS®: User's Manual, Swanson Analysis System, Inc., Volume I. - IV., 1999.

VÝPOČET SADNUTIA ÚLOŽISKA RÁDIOAKTÍVNEHO ODPADU V MOCHOVCIACH

Resumé

Článok sa zaoberá výpočtom konečného a nerovnomerného sadnutia úložných boxov Republikového úložiska rádioaktívneho odpadu v Mochovciach. Veľkosť sadnutia úložných boxov má významný vplyv na spoľahlivosť navrhnutých tesniacich a drenážnych vrstiev vyskytujúcich sa v podloží úložných boxov, ako aj na funkčnosť samotných železobetónových úložných boxov. Získané výsledky numerických výpočtov boli využité pri optimalizácii návrhu konštrukcií úložiska rádioaktívneho odpadu. Pri riešení prezentovaného náročného geotechnického problému bolo využité numerické modelovanie s využitím matematického aparátu metódy konečných prvkov (MKP), výpočtový program ANSYS®.