

COMPARISON OF NUMERICALLY CALCULATED AND IN SITU MEASURED VALUES OF THE SETTLEMENTS OF ISFSF BUILDING

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1. Introduction

The building Interim Spent Fuel Storage Facility (ISFSF) is situated in the zone of nuclear power plant of Jaslovské Bohunice. In 1984 buffer stock started its operation and is used for the temporary (max 50 years) storage of ISFSF from the reactors. Due to filling of storage basins in buffer stock in 1997, the commission decided about the replacement of storages of type T12 by the compact storages of type KZ with higher capacity. New compact storages allow storing the spent fuel till the year 2021. The increase of capacity causes increase of load of the subsoil of foundation structure by $\Delta q=57.3 \text{ kN/m}^2$, what represents increase with respect to the previous loading ($q=275.0 \text{ kN/m}^2$) by 20.8%. Due to increase of loading the foundation structures may occur. Hence series of geotechnical calculations was made where various ways of replacement and filling of buffer stock in order to minimize the negative effects of final and non uniform settlements on the bearing building structures were modelled. The calculations of settlements of foundations structures were made considering the different planned operations and possible extreme loading states [1] that may occur in the durability structure's operational life. The optimal design of storages replacement resulted from the above-mentioned calculations. These procedures eliminate negative effect of re-settlements of foundation structures. Assumed values of settlement were compared with real values of settlements of ISFSF building, which were obtained by geotechnical monitoring in situ.

2. Subsoil properties used in numerical calculations

On the base of the engineering and geological survey and analysis of the actual deformation of the foundation plate the simplified layered subsoil with extrapolated deformation properties of the real material ground media was designed. Quaternary subsoil is formed into depth 6.0 m by made-up clays; from 6.0 m to 16.0 m by losses; from 16.0m to 40.0 m by gravel sand. The neogene subsoil begins from the depth 40.0 m and is formed by clays. From the point of view of the assessment of the stability of building structure to limit state of usability, the crucial parameter is deformation modulus of subsoil (E_{def}). Material properties used in geotechnical computation are presented in Table 1. Used subsoil model of the building ISFSF is showed in Fig. 2.

Table 1 Material properties used in geotechnical computation

Depth [m]	Type of soil	Deformation modulus [MPa]	Poisson's ratio [-]
0.0 – 6.0	Made – up ground (silt)	7.0	0.35
6.0 – 16.0	Loess	11.0	0.40
16.0 – 40.0	Sand to gravel sand	110.0	0.25
> 40.0	Clay (neogene)	30.0	0.42

3. Structural solution ISFSF building

The building ISFSF has a ground plan dimensions 68.0 m x 46.0 m. The building is divided into the part of four storage basins and service rooms. In the first three basins containers are stored and the fourth basin serves as operating (reserve) space for maintenance and repairs of three mentioned basins. In longitudinal direction the analysed building is divided into profiles A to H. Similarly the building is divided in the cross direction into profiles 1 to 12 (with axial distance 6.0 m), respectively. The plan of basin part is given in Fig. 1, and longitudinal cross-section of building ISFSF is published in [2].

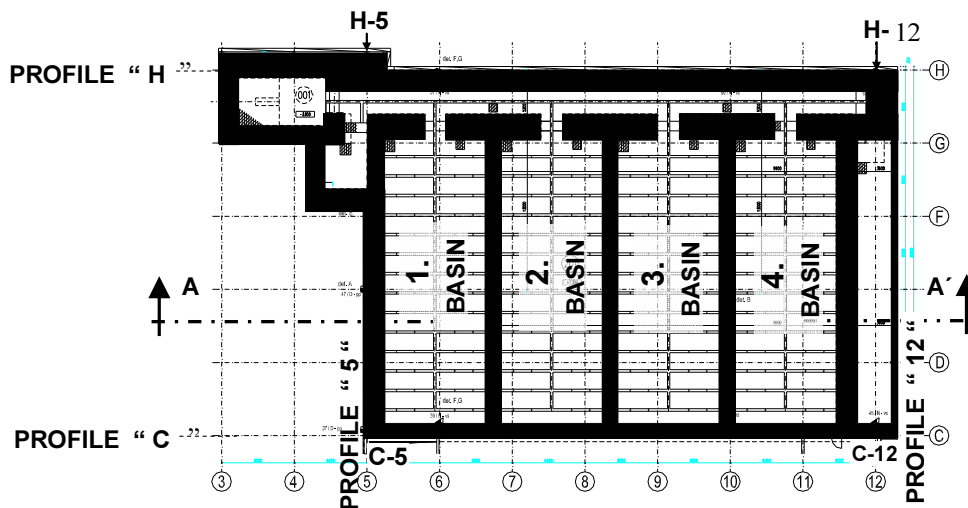


Fig. 1 The plan of the dilatation unit of the basin part of building ISFSF

Basin part (including storage basin, communication channel, and control shaft) consists of stiffness reinforced concrete monolithic block from ground elevation – 6.0 m to 7.20 m. The walls of storage basins are made from reinforced concrete with thickness from 1.25 m to 1.5 m. The surfaces of the walls are covered by double steel lining made from carbon steel and stainless steel. Basin part contains monolithic block in to level 7.200 m. In cross profile (line 3 to 5) the basin part is lengthwise dilated from the service room. The operation rooms in cross-section profile 1 – 3 are founded on the underground walls of the dimensions 5.1 m x 0.8 m. On the other parts the operation rooms are founded on the reinforced concrete plate of the thickness 0.5 m – 1.0 m. The basements rooms under level ± 0.00 are made from the monolithic reinforced concrete. The load-bearing system of operating hall is formed by steel columns combined with horizontal supporting system.

4. Define a computational model and loading states

The problem of the settlement below the building ISFSF was solved as a 3D problem according to the assumptions of the theory of layered elastic half space. For numerical calculation the FEM was used. In the formulation of the calculation model large amount of input parameters considering the physical principles of the mutual interaction of structure with the natural rock medium were generalized. Geometrical shape and dimensions of foundations structures of the building were taken from the design documentation. Model of foundation structure has the ground dimensions 66.0m x 45.0m. The stiffness of foundation structure ISFSF is affected by thickness of foundation plate 6.0 m, and in the area of basin with total thickness of plate 12.0 m. Model of foundation structure in longitudinal profile No. 1 up to No. 12 has the real thickness of structure which consists of 1.5 m thick reinforced concrete plate and 4.5 m thick based concrete layer. In profile No. 1 and No. 3 the effects of underground walls to system of foundation structures is considered. The layered subsoil of the building ISFSF is taken into account in numerical solutions. The 3D model of subsoil together with the model of ISFSF building has dimensions 200.0 m x 100.0 m x 80.0 m. Scheme of the analyzed model is given in Fig. 2.

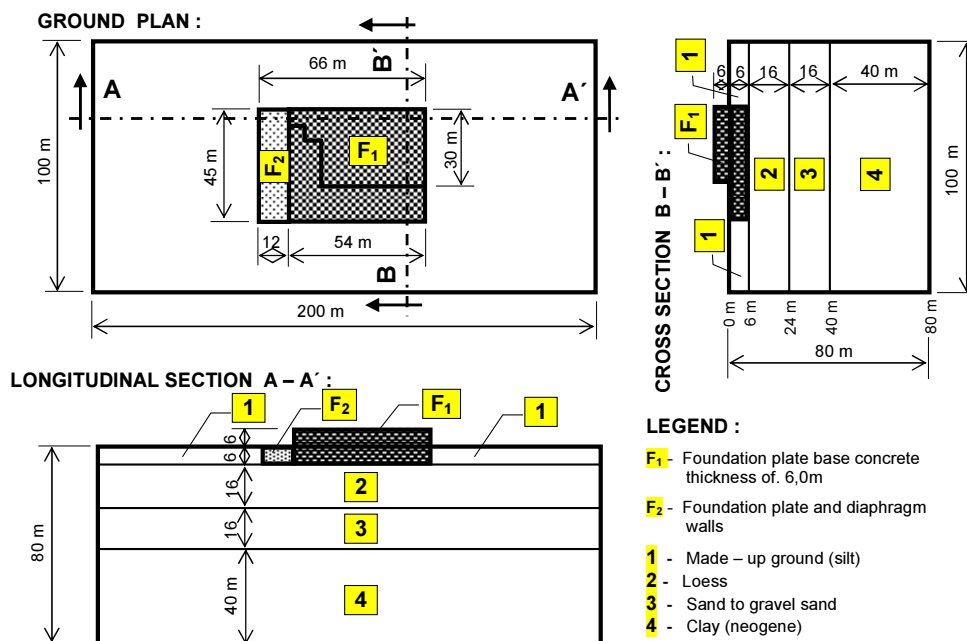


Fig. 2 Schematic representation of geotechnical subsoil of the ISFSF model with geometric and material boundary conditions

In the numerical analysis following types of loading were considered: dead load, service load (loads of the basin part due to storage tanks T12 and KZ) with uniformly distributed surface imposed load values:

- a) dead load
 - in basin part $q_s=211,1 \text{ kN.m}^{-2}$
 - in transport channel..... $q_s=317,0 \text{ kN.m}^{-2}$
 - in transport and control shafts of fuel holders $q_s=227,0 \text{ kN.m}^{-2}$

- in adjacent working compartments..... $q_s=110,0 \text{ kN.m}^{-2}$
- b) service water loading..... $q_s= 63,0 \text{ kN.m}^{-2}$
- c) service loading of basins T12..... $\Delta q(\text{T12})=21,5\text{kN.m}^{-2}$
- d) service loading of basin KZ..... $\Delta q(\text{KZ})=57,3\text{kN.m}^{-2}$.

Process of capacity increase will be carried-out under real condition of buffer stock service. It will be limited by technical and technological conditions of service operator of building. The phase replacement of storages T12 by KZ for the period from 1998 (1st Loading State) to 2012 is scheduled. As an initial state of storages lay out is dated to the term 31.12.1998. Final time where first three basins (No.1,2,3) by compact storages of type KZ will be filled is 31.12.2021 (6th Loading State). More detailed information about the capacity increase process is given in [1].

5. Geotechnical monitoring of the building ISFSF (measurement of the foundation settlements)

Geotechnical monitoring is performed systematically since building up of the ISFSF (since 1984). Last evaluated periodic measurements were carried out in December 5, 2012 (161st measurement). Geotechnical monitoring is performed systematically since building up of the ISFSF (since 1984). The positions of the measuring points of the vertical displacements on the basins part of the building ISFSF and characteristic longitudinal (C, H) and cross profiles (3, 5, 12) are shown in Fig. 3.

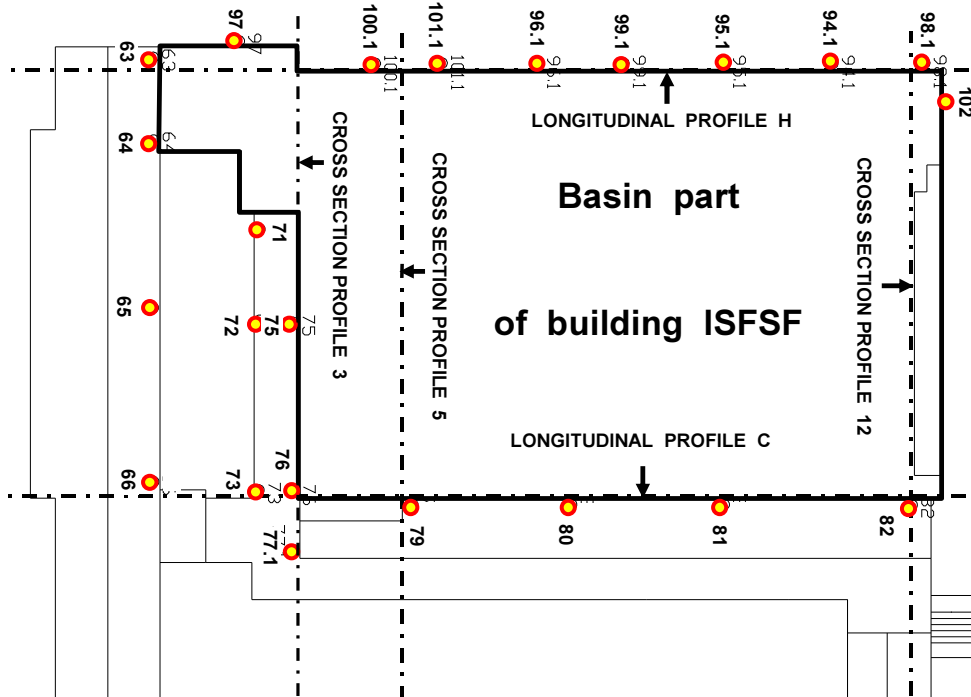


Fig. 3 The positions of the measuring points and characteristic profiles

6. Comparison calculated and measured values

From the calculations of or the individual loading states the complex model of settlements of analyzed building ISFSF was obtained. In the evaluation of results we have aimed at the deformations in footing bottom. In Table 2 is shown selected measured and calculated (1st and 6th Load State) settlements for intersection points (C-5, C-12, H5, H-12).

Table 2 Calculated and measured values of settlements for 1st and 6th loading state

State of loading	Position of point			
	C-5	C-12	H-5	H-12
	settlement s			
	/ mm /	/ mm /	/ mm /	/ mm /
December 12, 1990 (measured)	-19.30	-28.70	-83.00	-106.10
December 19, 2000 (measured)	-22.00	-31.30	-80.00	-102.30
November 27, 2008 (measured)	-26.50	-35.40	-85.90	-107.70
December 5 2012 (measured)	-25.50	-35.30	-88.50	-109.60
1st Load State (calculated)	-43.37	-63.57	-89.86	-111.82
6th Load State (calculated)	-48.76	-70.36	-98.40	-121.70

Space projection of foundation plate settlement under basin part of building ISFSF by isosurfaces for final loading state (6th LS) characterizing gradual capacity increase is given in Fig. 4. Graphical comparison of the measurement and calculated settlements values in longitudinal profile H is given in Fig. 5. The evaluated results show that the calculated and the measured values are comparable.

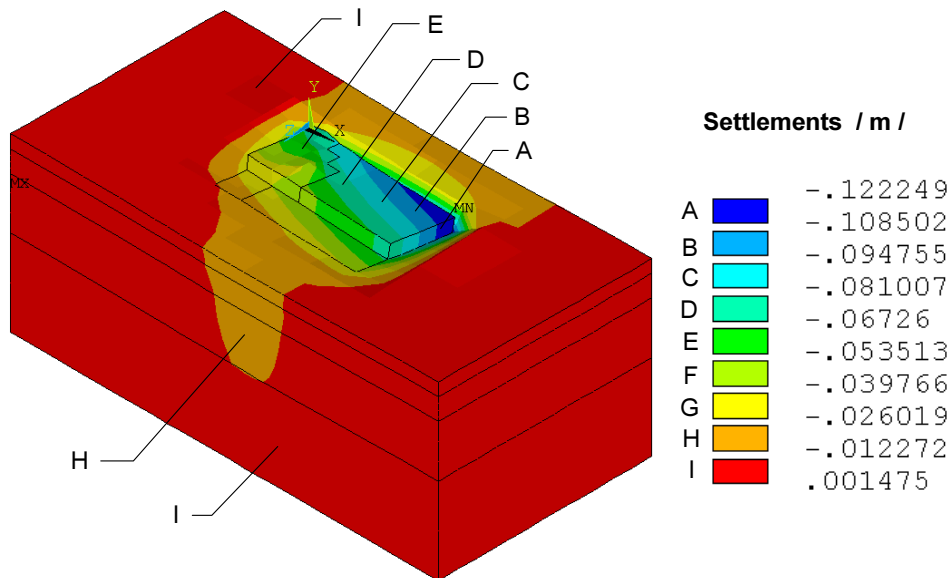


Fig. 4 Isosurfaces of settlements for 6th Load Step (after exchange T12 with KZ)

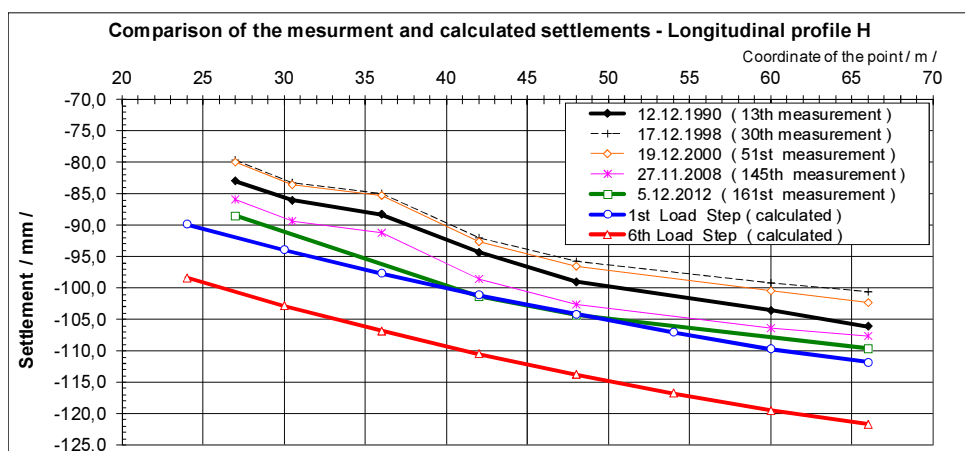


Fig. 5 Comparison of the measurement and calculated values in longitudinal profile H

7. Conclusion

The series of geotechnical calculations of settlements of the building ISFSF in Jaslovské Bohunice indicates a trouble free replacement of the storage tank for spent fuel type T12 by compact type KZ. An interactive calculation of final settlement by the numerical procedures based on the FEM was made. Six operational and eleven extreme loading states and their possible combinations, which may occur during operation of ISFSF were considered. Comparison of measured and assumed values of settlements and inclination of foundation structure of the building ISFSF shows, that obtained results were less than limiting values prescribed by Slovak standard (STN 73 1001).

References

- [1] Kuzma, J. - Hruštinec, Ľ.: Calculation of Settlement of ISFSF Building Considering the Increase of the Storage Tanks Capacity. Bratislava 1991, 63 pp.
- [2] Kuzma, J. – Sumec, J. - Hruštinec, Ľ.: Influence of Loading Intensity Changes on Increasing of Settlement of the Difficult Building. In: *Int. Sci. Conf. VSU' 2008 – Vol. 2.*, 2008. ISBN 978-954-331-020-3, p. IX-13 - IX-16.
- [3] STN 73 1001 Geotechnical structures. Foundation. Slovak Standard, 2010,(In Slovak).

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POROVNANIE VYPOČÍTANÝCH A IN SITU NAMERANÝCH HODNÔT SADNUTIA OBJEKTU MSVP

Zhrnutie

Kapacita medziskladu vyhoreného paliva (MSVP) v Jaslovských Bohuniciach je bola vyčerpaná. Preto bolo potrebné zvýšiť kapacitu zásobníkov paliva. Výmena zásobníkov s vyššou kapacitou mala za dôsledok zvýšenie zaťaženia a následné dosadnutie objektu. Numericky vypočítané sadnutia MKP boli porovnané s nameranými hodnotami.