STRUCTURAL ASSESSMENT REPORT. POLYETHYLEN OPTIC ACCESS CHAMBER BURIED IN GROUND.

Structural Assessment Report

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Optics access chamber

Client

Vesimentor OÜ

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CONTENT

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1. GENERAL

This report presents the structural assessment of a polyethylene optics access chamber buried in ground. The calculations assume that the chamber is surrounded by compacted sand. A load is applied to the chamber hatch and the total load of 400 kN is used. The load is determined in accordance with EVS-EN 124-1: 2015 (class D). The stresses and strains in the structure are analysed for a given force.

2. FINITE ELEMENT MODEL

2.1. MODEL AND BOUNDARY CONDITIONS

LS-Dyna software based on the finite element (LE) method has been used for strength analysis. The model consists of steel hatch, polyethylene access chamber and the soil, see Figure 1. The modelled soil block is with the dimensions of 4x4x2 m. The displacements in the direction of surface normal are fixed for the side surfaces and bottom surface of the soil block. The access chamber and the well collar have been modelled using two-dimensional 4-node shell elements. Three-dimensional volume elements have been used in soil modelling. The dimensions of the modelled soil are 4x4x2 m (length x width x depth).

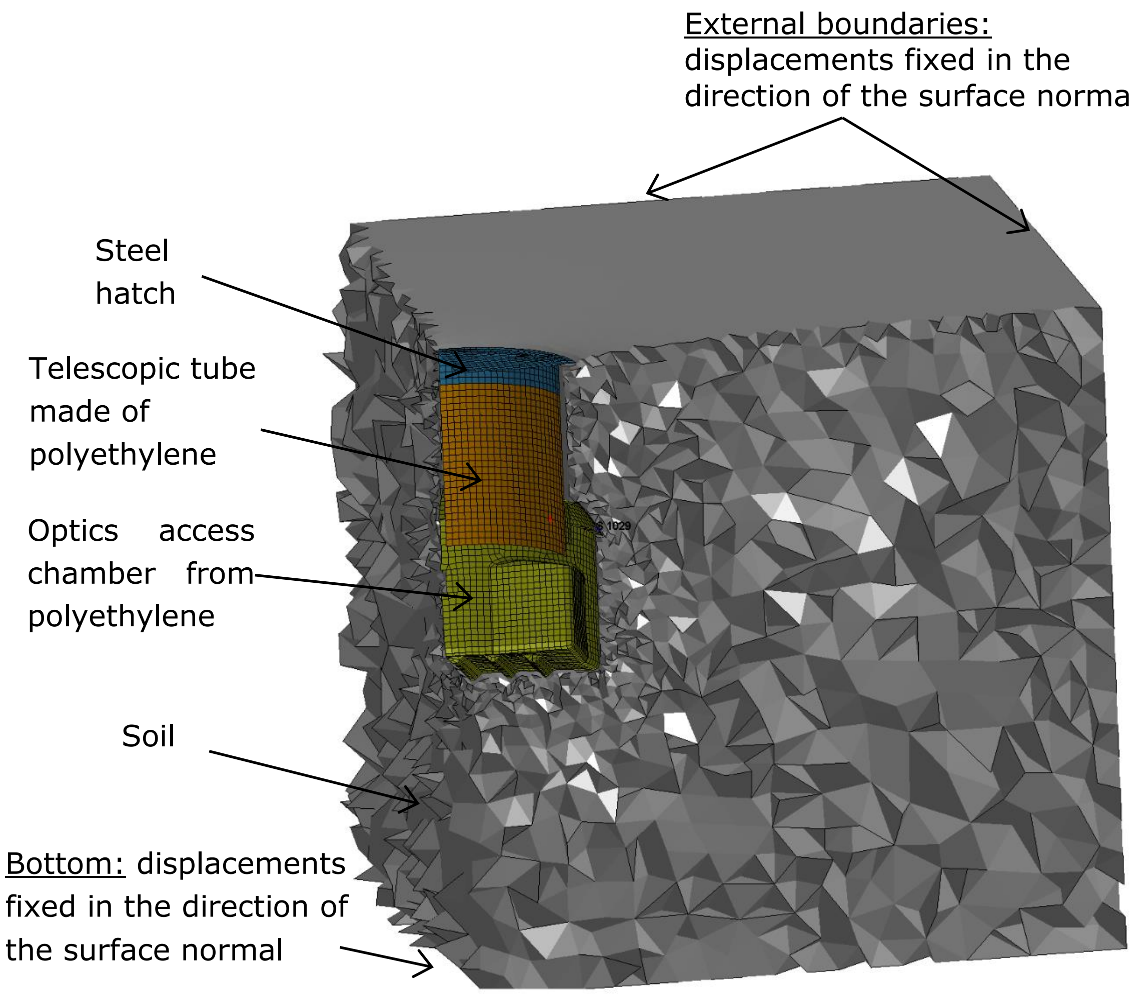


Figure 1. FE model and boundary conditions

2.2. MATERIAL MODELLING: POLYETHYLENE AND SOIL

The access chamber is made of polyethylene. Material properties and the stress-strain curves are determined by the tensile tests. The dimensions of the test specimens used are given in Annex 1. A total of five test specimens were tested. Since the calculations performed by the LE method the true stress-strain curve is used for analysis. Therefore, the change in the cross-section of the test specimen has been considered to obtain true stress-strain curve from test-curves. The test-curves are shown in Figure 2. Results show that the shape of the test curves depends from loading speed. Higher speed gives higher tensile strength and material stiffness as well. For the numerical simulation the test-curves with loading seed of 5 mm/min were used in order to be conservative. For the finite element analysis, the test curve has to be converted into true stress-strain curve format. In Figure 3 are presented the test-curve for loading speed 5 mm/min and true stress-strain curve that is obtained from test-curve by considering the actual cross-section of the tested specimen.

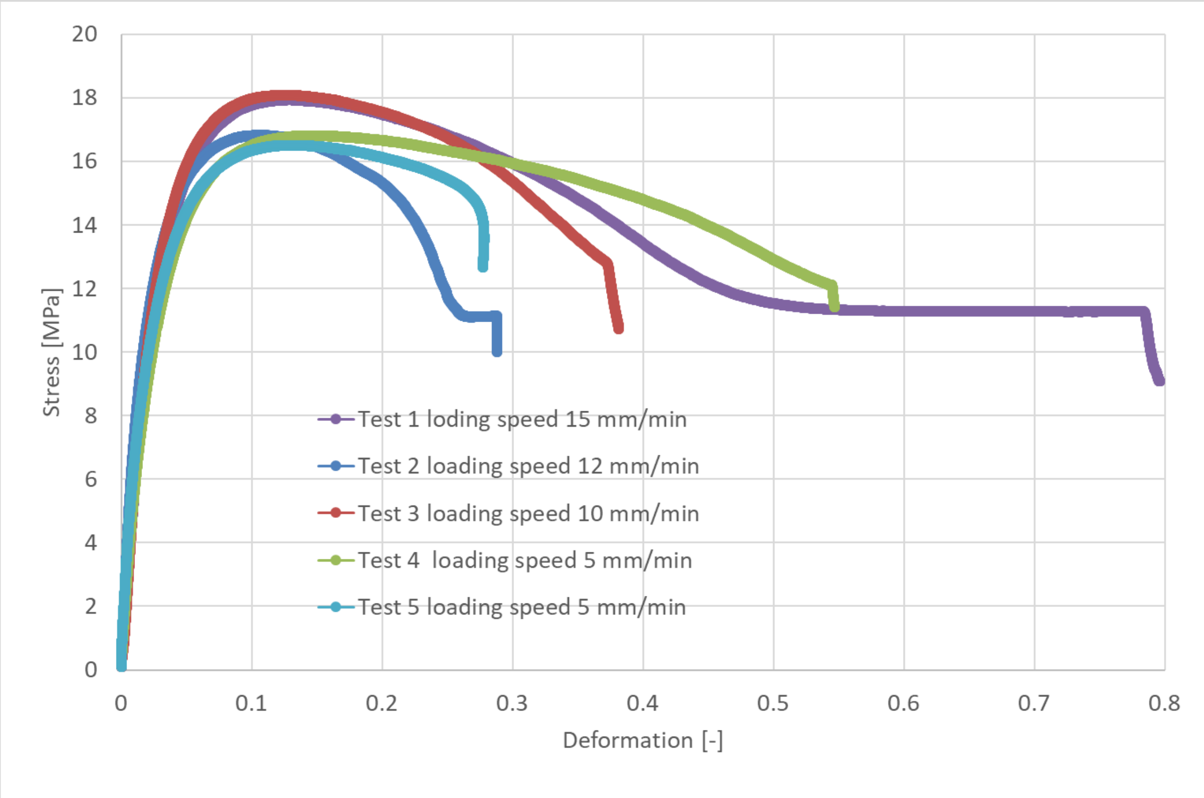


Figure 2. *Stress-strain curves obtained from testing.*

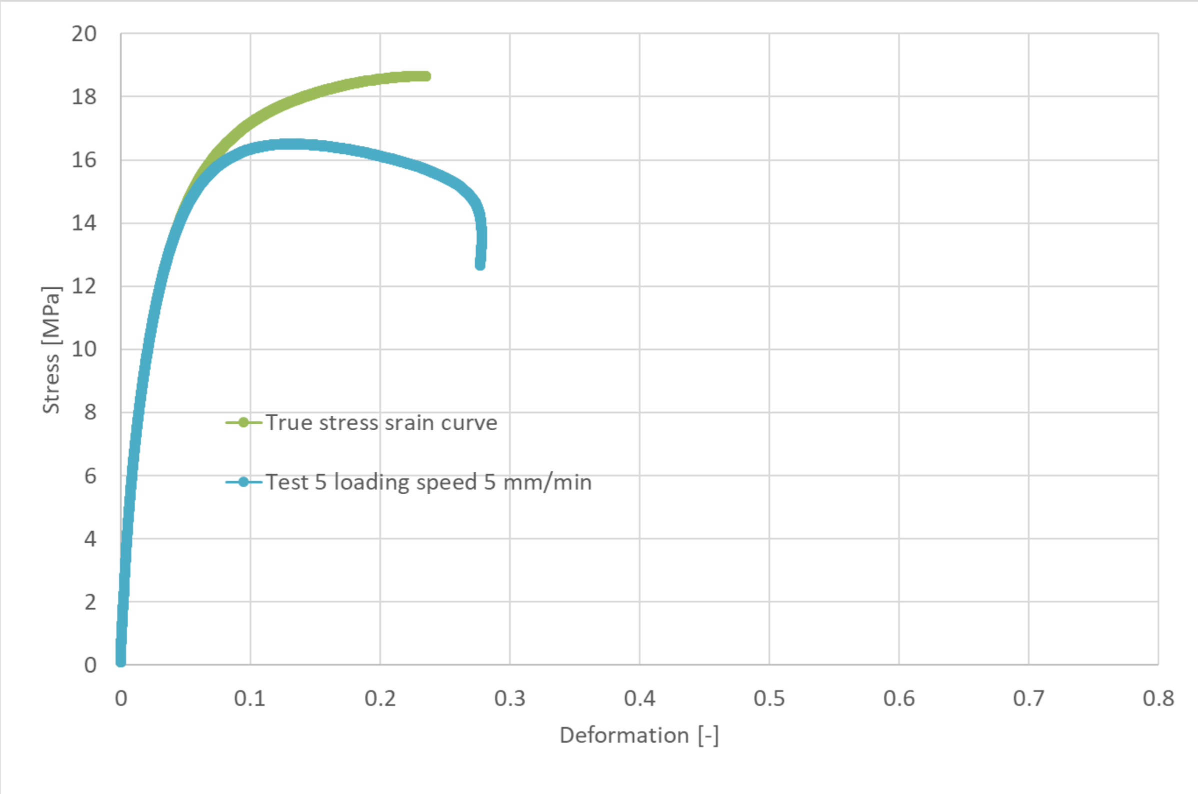


Figure 3. *True stress-strain curve.*

The density of polyethylene in the FE calculations was taken as ρ= 1200 kg/m^3, the modulus of elasticity E=331 MPa is determined from the material test-curve. The Poisson's ratio was taken as ν= 0.3. The approximate yield strength is estimated to be 15 MPa.

The calculations assume that the access chamber is buried in compacted sand. References [2] and [3] were used to model the sand and determine the soil properties. The soil has been modelled using the LS-Dyna material model MAT_FHWA_SOIL [4]. The main soil parameters used in the modelling are presented in Table 1.

Calculations have been performed for three different bulk and shear modulus to consider the variation of soil properties, see Table 1. The parameters used describe a relatively soft surface to ensure the conservatism of the calculations. All parameters used in the calculations are presented in Annex 2.

Table 1. Material characteristics for compact sand.

Value	unit	definition
ρ=2.350	[ton/m3]	density
K=11, 15, 19	[MPa]	bulk modulus
G=7, 9, 11	[MPa]	shear modulus
ϕ=0.524	[rad]	shear strength angle (friction angle) (30 deg)

2.3. LOADING

The loading is defined according to reference [1] (class D). The load of 400 kN is applied as an evenly distributed load on top of the hatch of the access chamber, see Figure 4. In addition to distributed load, the whole model is affected by gravity. In order to minimize dynamic effects in loading the load is applied using cosine function. The gravity load is applied within $0.2\ sec$ sec from $0.0\ m/sec^2$ to $9.8\ m/sec^2$ and pressure load on the top of the hatch is applied within $1.0\ sec$ havng the total load from $0\ kN$ to $400\ kN$, see Figure 5.

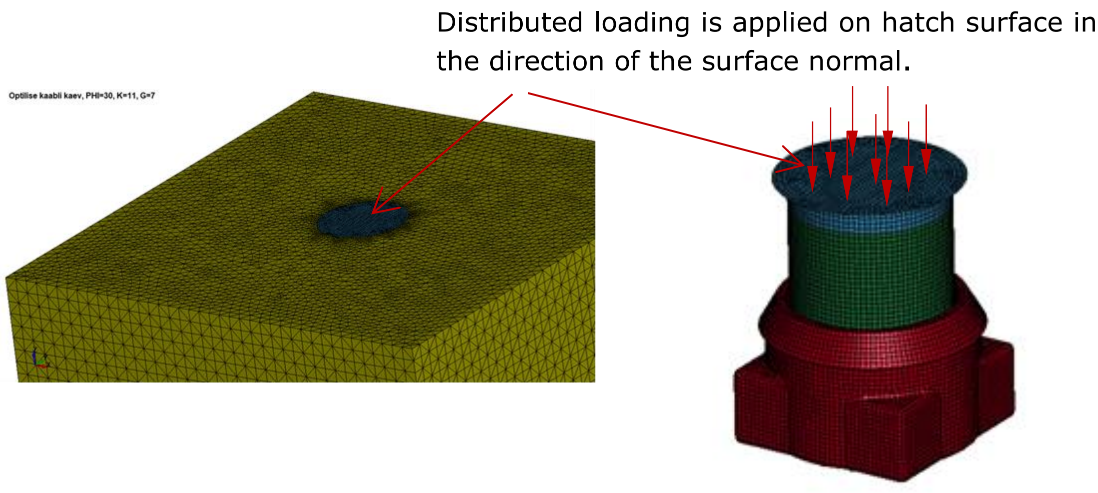


Figure 4. Distributed loading on hatch of the access chamber

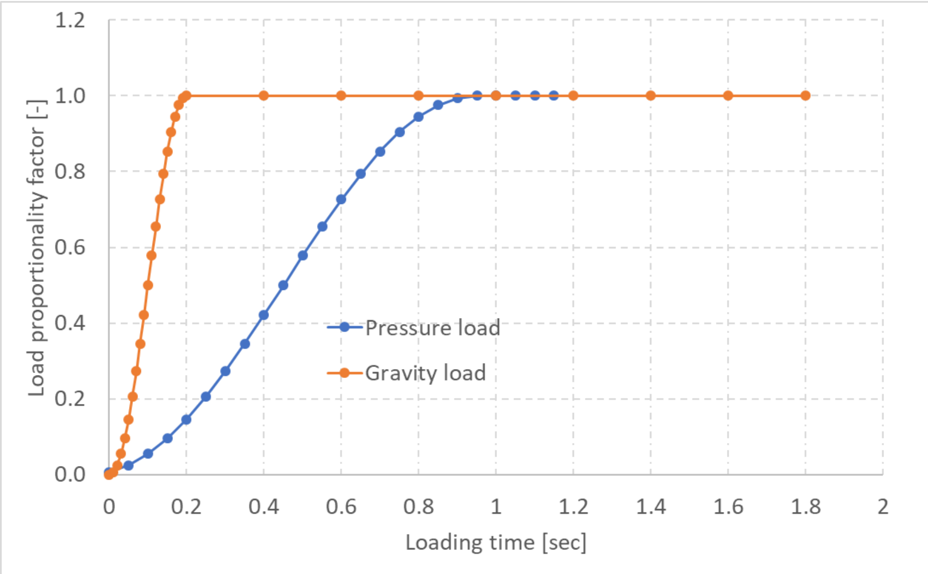


Figure 5. Loading of the structure as function of time.

3. CALCULATION RESULTS

The calculation results are presented as the distribution of equivalent stresses (von Mises) in the access chamber and as the vertical deflection of locations A,B,C and D (Figure 6). Figure 7 presents the displacement fields of access chamber and soil in case of soft soil. It can be concluded that deformations in soil are rather local. However, the soil enables efficiently transverse the load from hatch into soil surrounding the access chamber.

Figure 8, Figure 10 and Figure 12 indicate that the general equivalent stress level in access chamber stays below yield limit. The actual maximum equivalent stresses are 6 MPa in soft soil, 5.8 MPa in medium soil and 5.5 MPa in hardest soil. Therefore, in all the cases the equivalent stress in access chamber stays well below the yield point of PE material. The most stressed region of the access chamber is the upper edge of the chamber near the telescopic tube. There the soil has the biggest vertical effect on the access chamber.

Figure 9, Figure 11 and Figure 13 present the displacements of the access chamber in the case of soft, medium and hard soil. The hatch of the access chamber has the highest displacement which is 63 mm, 50 mm and 41 mm corresponding to the soft, medium and hard soil. The displacement of the upper edge of the chamber is 26, 21 and 17 mm corresponding to variation of soil. The bottom deflection of the chamber stays in all cases below 20 mm.

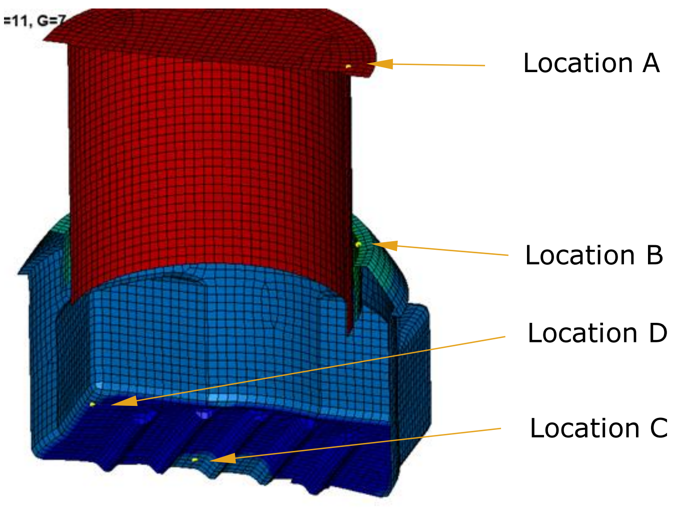
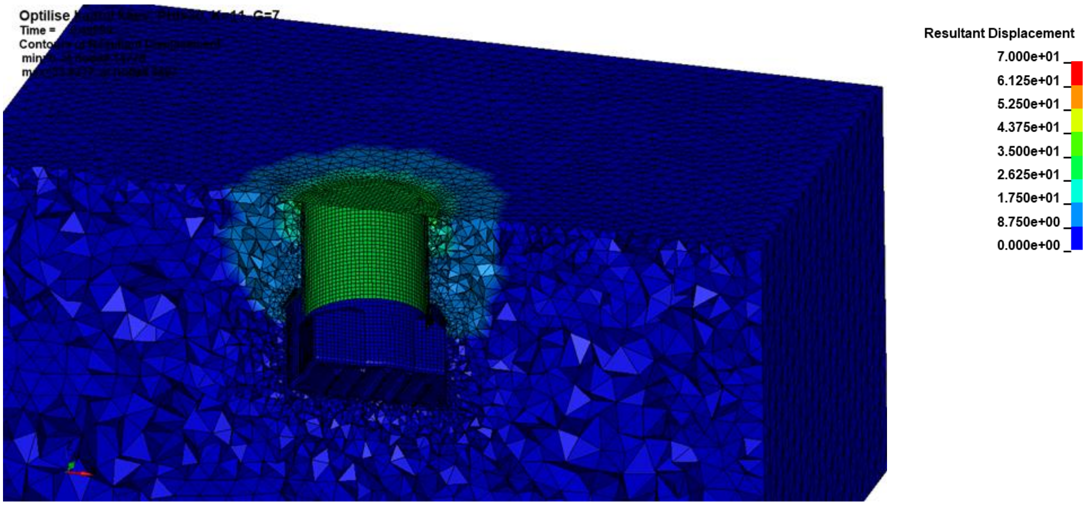


Figure 6. Nodes used to report the vertical displacement.

F=200 kN



F=400 kN

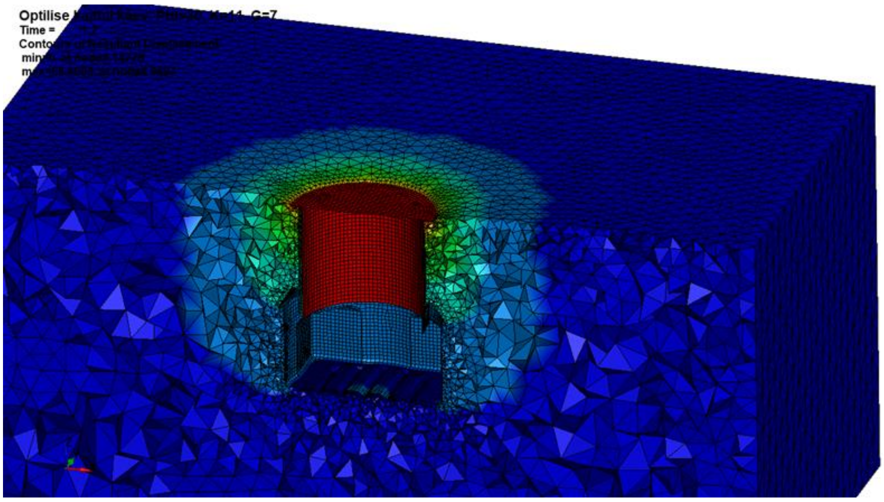
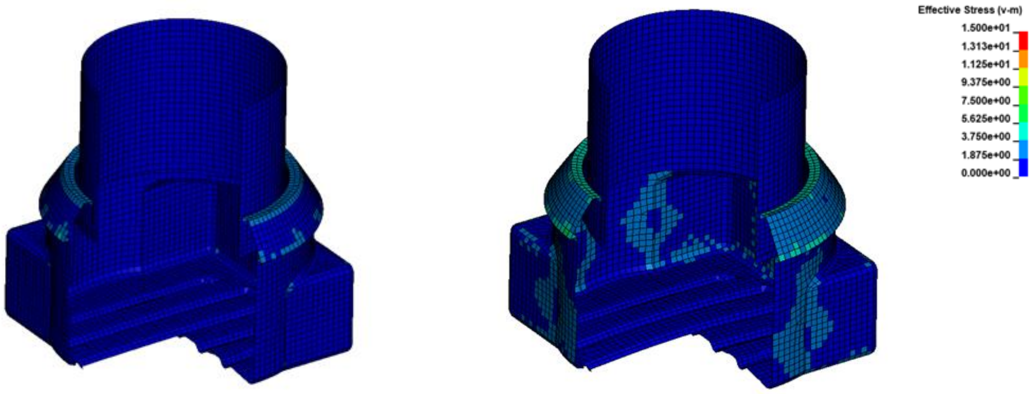


Figure 7. Deformed shape of the access chamber in soil (soft soil: K=11 MPa, G=7 MPa).



F=200 kN F=400 kN

Figure 8. Equivalent stresses in MPa (soft soil: K=11 MPa, G=7 MPa).

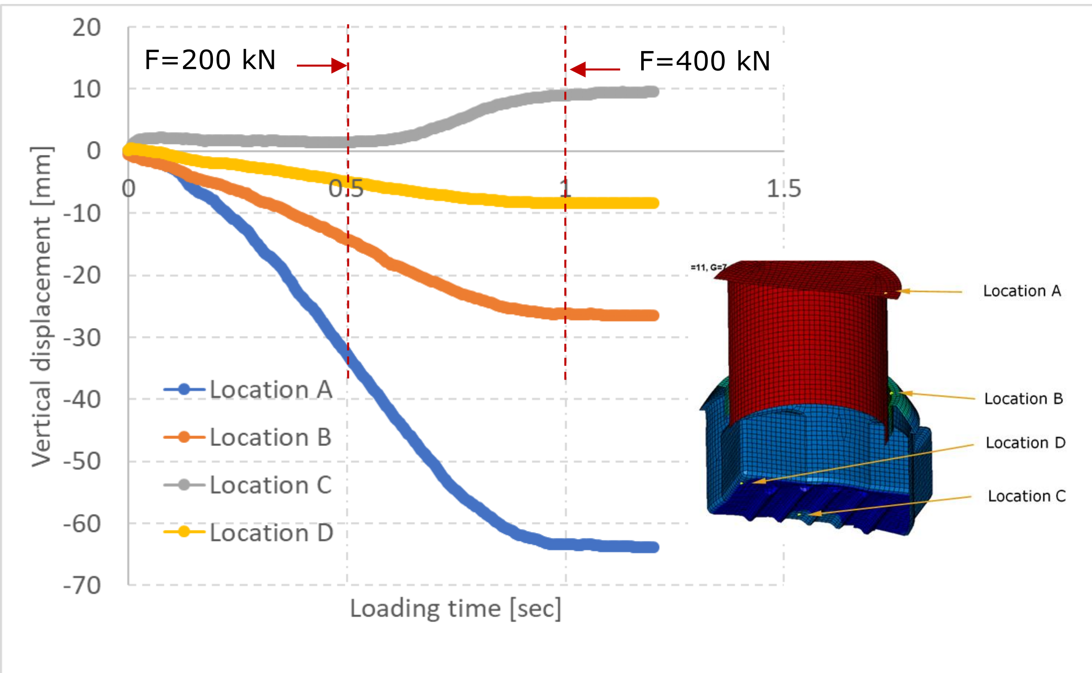


Figure 9. Vertical deflections at locations A-D (soft soil: K=11 MPa, G=7 MPa).

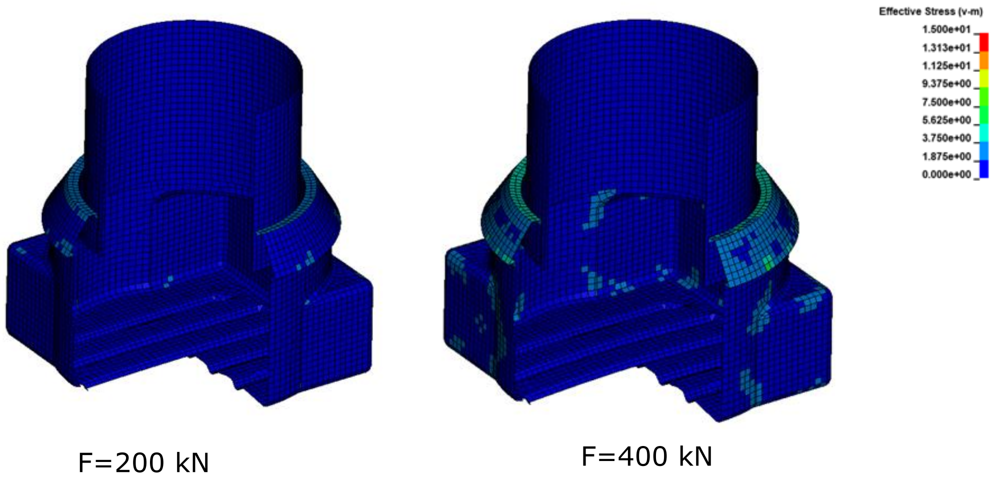


Figure 10. Equivalent stresses in MPa (medium soil: K=15 MPa, G=9 MPa).

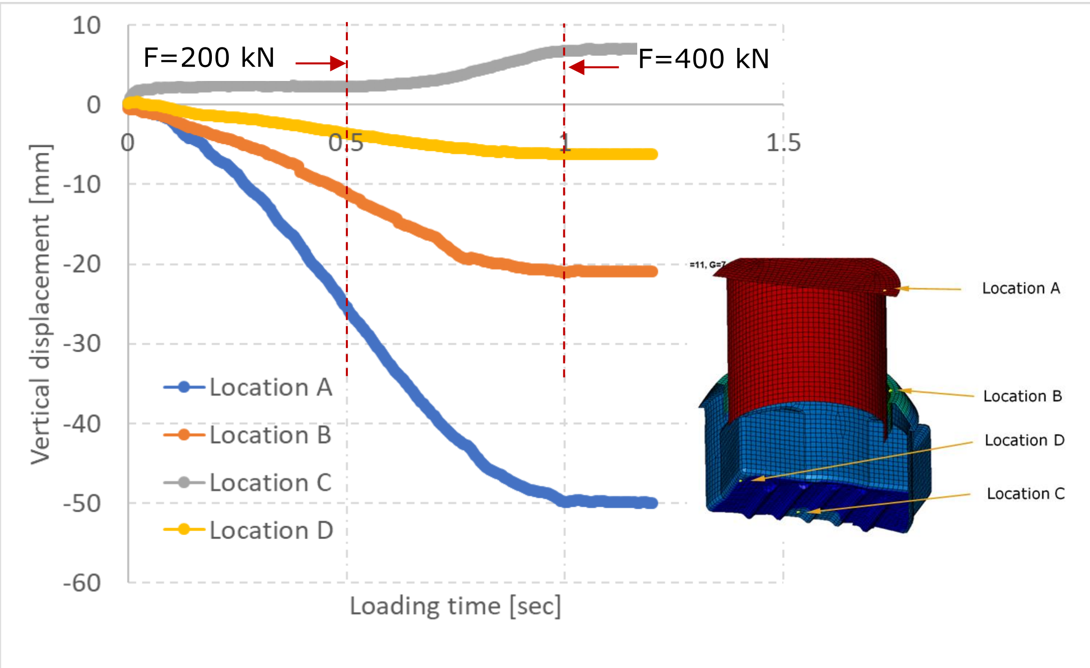


Figure 11. Vertical deflections at locations A-D (medium soil: K=15 MPa, G=9 MPa).

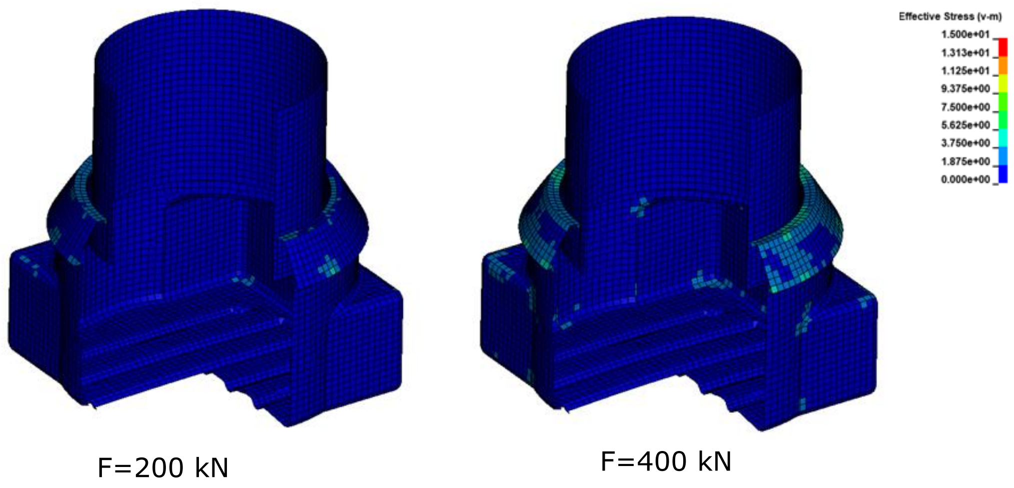


Figure 12. Equivalent stresses in MPa (hardest soil: K=19 MPa, G=11 MPa).

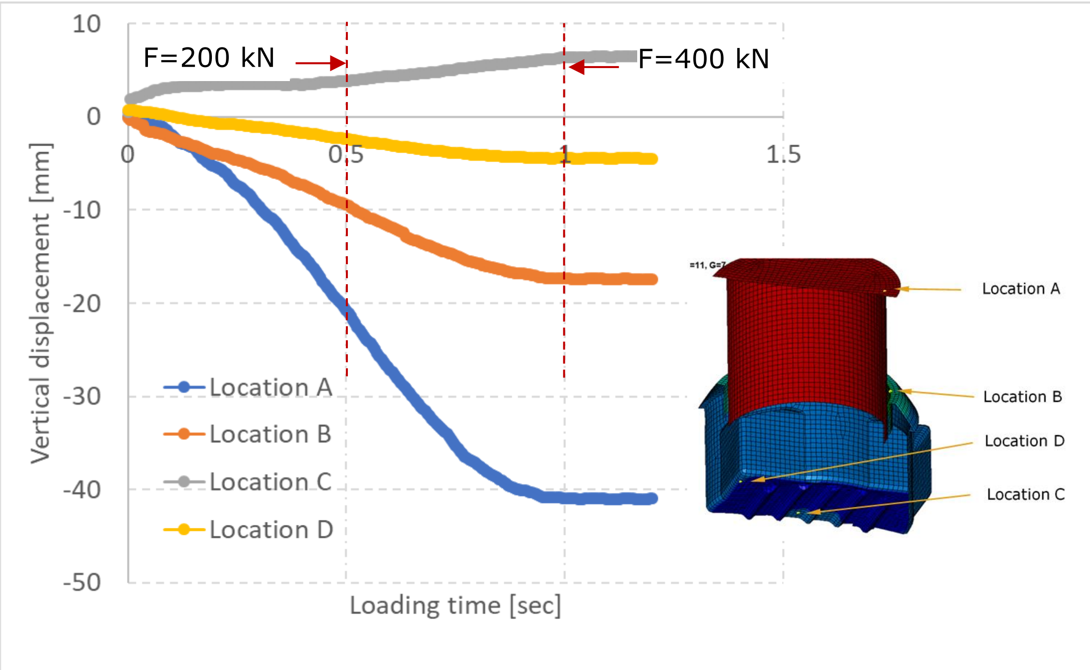


Figure 13. Vertical deflections at locations A-D (hardest soil: K=19 MPa, G=11 MPa).

4. CONCLUSIONS

The well has been subjected to the load of 400 kN according to EVS-EN 124-1: 2015 class D. The maximum vertical displacement of the hatch in soil is around 60 mm. The walls of the access chamber withstand the load and will not buckle. It is assumed that the thickness of the walls is not below 10 mm. Due to the compressed soil, the maximum equivalent stress stays below 6 MPa that is sufficient to avoid plastic deformations.

Analysis shows that the access chamber has sufficient strength in soil when subjected to vertical load of 400 kN.

REFERENCES

[1] EVS-EN 124-1:2015 Gully tops and manhole tops for vehicular and pedestrian areas – Part 1: Definitions, classification, general principles of design, performance requirements and test methods.

[2] Wang J, 2001; Simulation of Landmine Explosion Using LS-DYNA3D Software: Benchmark Work of Simulation of Explosion in Soil and Air, DSTO Aeronautical and Maritime Research Laboratory, Report DSTO-TR-1168, Australia, p.30.

[3] Evaluation of LS-Dyna soil material 147, U.S. Department of Transportation, Federal Highway Administration, publicaiton FHWA-HRT-04-094. Available at: www.fhwa.dot.gov/publications/research/safety/04094/04094.pdf

[4] LSTC. LS-DYNA Keyword User's Manual. Livermore Software Technology Corporation. Available at: http://lstc.com/pdf/ls-dyna_971_manual_k.pdf.

Appendix 1. Specimen dimensions

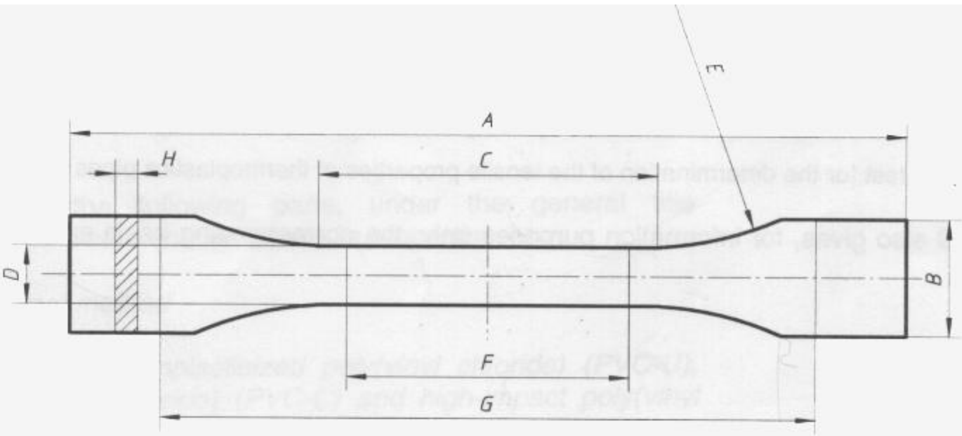


Table 1 — Dimensions of type 1 test pieces

Symbol	Description	Dimensions mm
A	Overall length (min.)	150
B	Width of ends	20 ± 0,2
C	Length of narrow, parallel-sided portion	60 ± 0,5
D	Width of narrow, parallel-sided portion	10 ± 0,2
E	Radius	60
F	Gauge length	50 ± 0,5
G	Initial distance between grips	115 ± 0,5
H	Thickness	That of the pipe

Appendix 2. Parameters used to model the soil.

RO=2.350	[ton/m3]	Mass density
NPLOT=1		Plotting options
SPGRAV=2.65	[-]	Specific Gravity of Soil used to get porosity [3]
RHOWAT=1.0	[ton/m3]	Density of water
Vn=1.1*		Viscoplasticity parameter
GAMMAR=0*		Viscoplasticity parameter
INTRMX=4		Maximum number of plasticity iterations
K=11	[MPa]	Bulk Modulus
G=7	[MPa]	Shear modulus
PHIMAX=0.524	[rad]	Peak Shear Strength Angle (friction angle)
AHYP=5.37e-4		Coefficient A for modified Drucker-Prager Surface [3]
COH=6.2e-3		Cohesion [3]
ECCEN=0.7		Eccentricity parameter for third invariant effects [3]
AN=0		Strain hardening parameter
EN=0		Strain Hardening parameter
MCONT=0.034		Moisture Content of Soil
PWD1=0		Parameter for pore water effects on bulk modulus
PWKSK=0		Skeleton bulk modulus-
PWD2=0		Parameter for pore water effects on the effective pressure
PHIRES=1e-3		The minimum internal friction angle, radians (residual shear strength)
DINT= 0.00001		Volumetric Strain at Initial damage threshold
VDFM=6e-5		Void formation energy
DAMLEV=0.99		Level of damage that will cause element deletion
EPSMAX=2		Maximum principle failure strain

* parameters describing the loading rate dependency. This dependency is not considered in the calculations.