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Communication well strength analysis report

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1. General

This report deals with the strength analysis of the communication well installed into the ground. It is speculated in the calculations that the well is surrounded by thickened sand. The load applied to the hatch of the well increases linearly up to 400 kN. The communication well must withhold the load of 125 kN and the load is increased up to 400 kN, in order to analyze the behavior of the communication well in case of load greater than the rated load. The load of 125 kN is determined by the standard EVS-EN 13598-1:2003 (Table 3, class M). At this given force, the tensions and deformations in the structure are analyzed.

2. The model of finite elements

Boundary conditions

For the strength analysis, LS-Dyna, software that is based on finite elements (FE), was used. Due to symmetry, only one-fourth of the barrel and its surrounding soil is modeled. The rest of the model is replaced by boundary conditions that are shown in Figure 1. Symmetry conditions are used on the inner sides and on the outer sides, all degrees of freedom are fixed, except for vertical displacement. All degrees of freedom at the bottom joints are fixed. The barrel and the collar of the barrel are modeled by using two-dimensional shell elements and in modeling the surface, three-dimensional volumetric elements are used. The size of the modeled surface is 1.79x1.35x1.57 (length x width x depth).

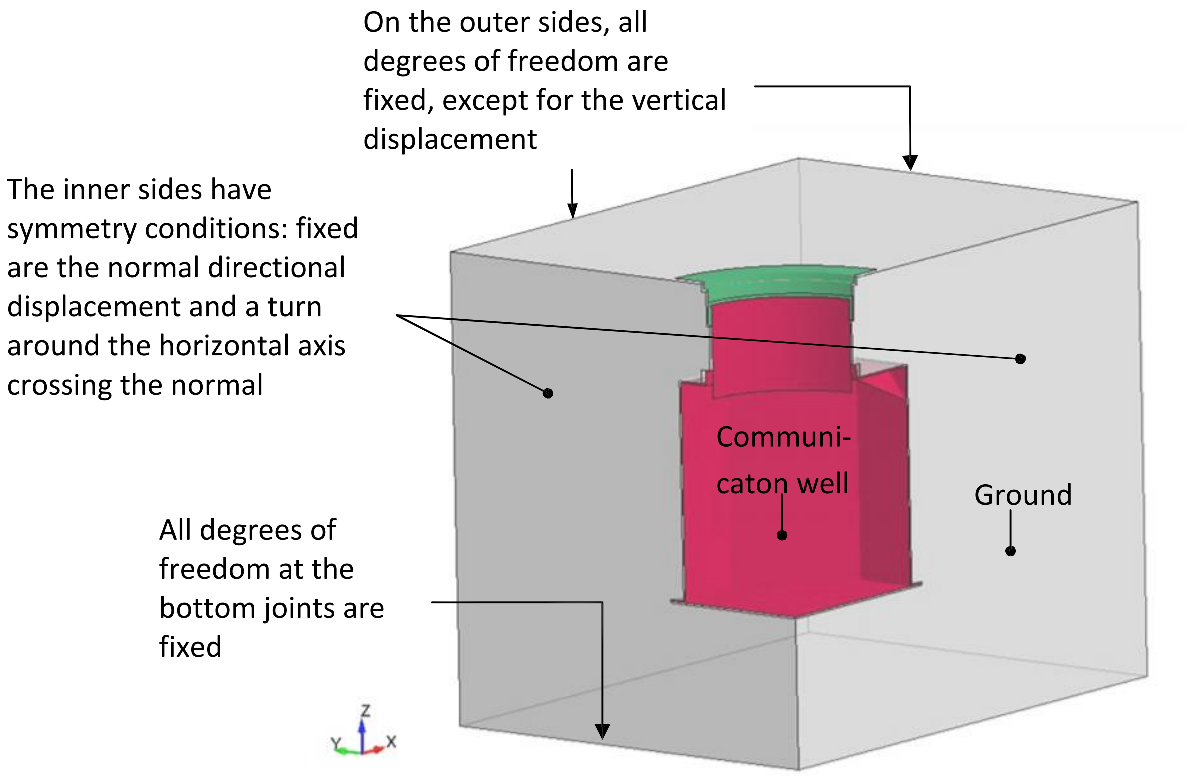

Figure 1 Boundary conditions in the FE-model

The material models of polyethylene and the soil

The communication well is made of polyethylene, and its properties were determined by tensile tests. The measurements of the used test pieces are presented in Appendix 1. Altogether seven test pieces were used, on which the strain-deformation curves were determined by the tensile test. Since in the calculations of FE-method, actual strains and deformations are used, the cross-section change of the test piece has been considered at determination. The resulting, actual strain-deformation curves are shown in Figure 2. The test machine can determine the deformations of the material up to the formation of collar in the test piece. Therefore the end points of the strain-deformation curve were determined with the help of the cross-section area of the test pieces and the tensile force at the end of the test. The resulting end-points are also shown in Figure 2. Based on these points and the curves from the test material, a material curve was compiled that was used in the FE-simulations.

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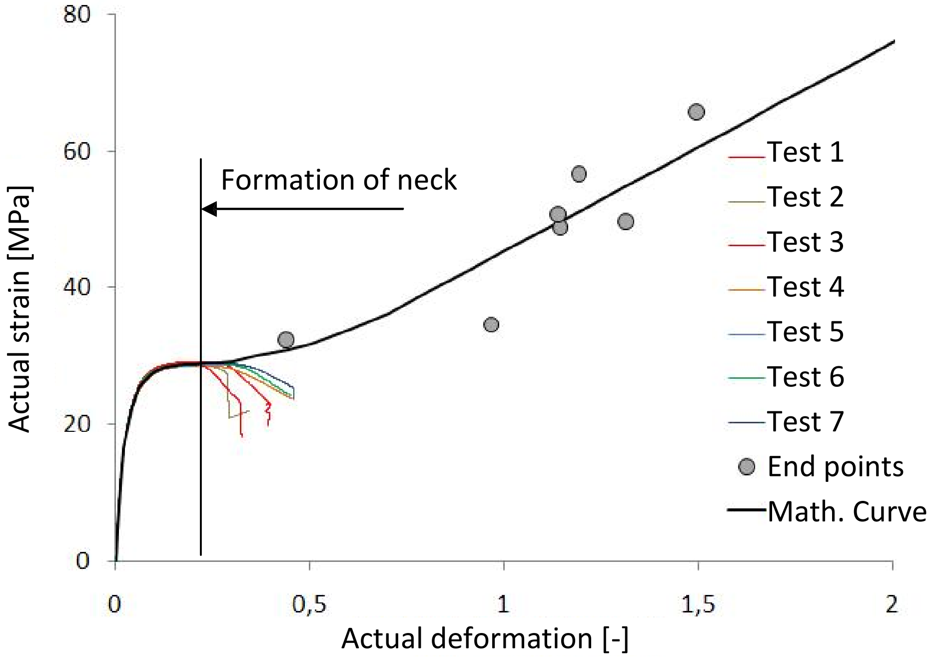

Figure 2. Results of the tensile tests

The density of polyethylene in the FE calculations was ρ=3000 kg/m^3, the modulus of elasticity E=1.5 GPa and the Poisson factor v=0.3. It was complicated to exactly determine the yield strength in the tensile tests, because there was no clear linear part in the curve describing the behavior of the material. The approximate yield strength was an estimated Ϭ≈10-15 MPa and the neck formed in the material at the strain of approximately 30 MPa.

It was speculated in the calculations that the communication well is buried in the tightened sand. In modeling the sand and determining the properties of the soil references [2] and [3] were used. The soil is modeled using LS-Dyna material model MAT_FHWA_SOIL [4]. The main soil parameters used in modeling are presented in Table 1. The calculations are made in three different volumetric and offset modules to take into account the variability of the soil properties. The used parameters describe relatively soft soil, to ensure the conservative calculations. All parameters used in the calculations are shown in Appendix 2.

Table 1. Main material parameters for tightened sand

Value	Unit	Description
ρ=2.350	[ton/m^3]	Density
K=11, 15, 19	[MPa]	Bulk modulus
G=7, 9, 11	[MPa]	Shear modulus
Φ=0.524	[rad]	Inner friction angle (30 degrees)

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Load

Accordingly to Table 3 in the reference [1], the applied load to the communication well is 125 kN (Class M). The load is applied as a uniformly distributed load on the collar of the hatch, as shown in Figure 3. It is presumed that the load 125 kN is applied in 0.125 seconds. After that the load of the well is increased linearly up to 400 kN and the deformations of the communication well are analyzed. The load of 400 kN is applied in 0.4 seconds. Additionally the whole model is influenced by gravity.

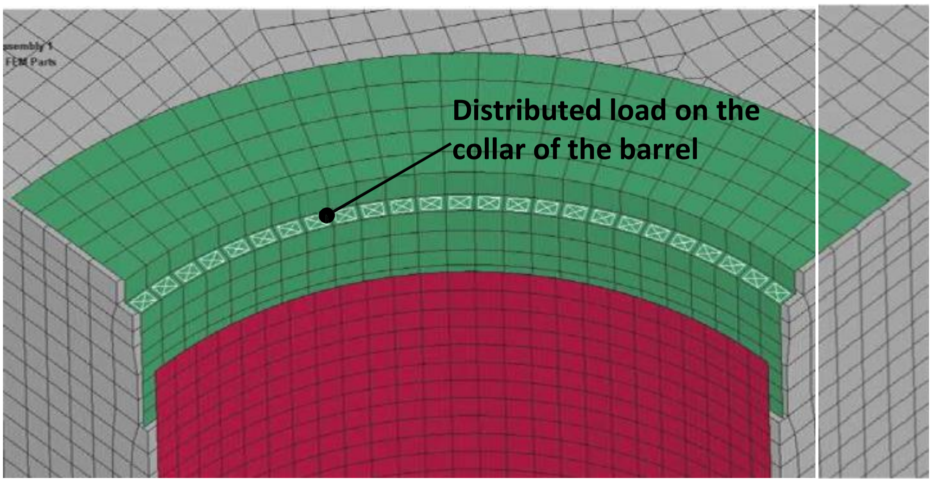

Figure 3. Distributed load

3. Calculation results

The results of the calculations are presented as the distribution of equivalent tensile stresses (von Mises) and the vertical deflection of points A and B (Figure 4). The results obtained from the softest soil are shown on Figures 5 and 6. Figure 5 shows that the maximum equivalent tension stresses are at the joining point of the reinforcement and the wall of the well where the tensile stresses are approximately 10 MPa. Figure 6 presents vertical deflection at the edge of the well's opening where the maximum deflection at 400 kN is approximately 40 mm.

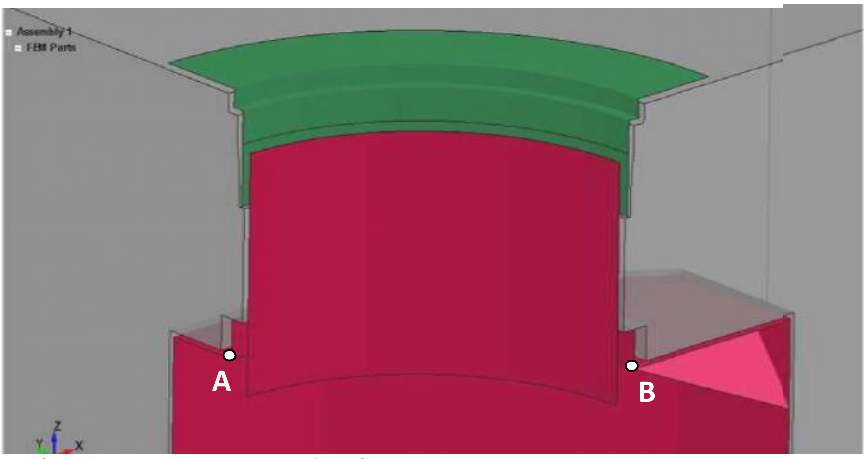

Figure 4. Junctions for determining vertical deflection.

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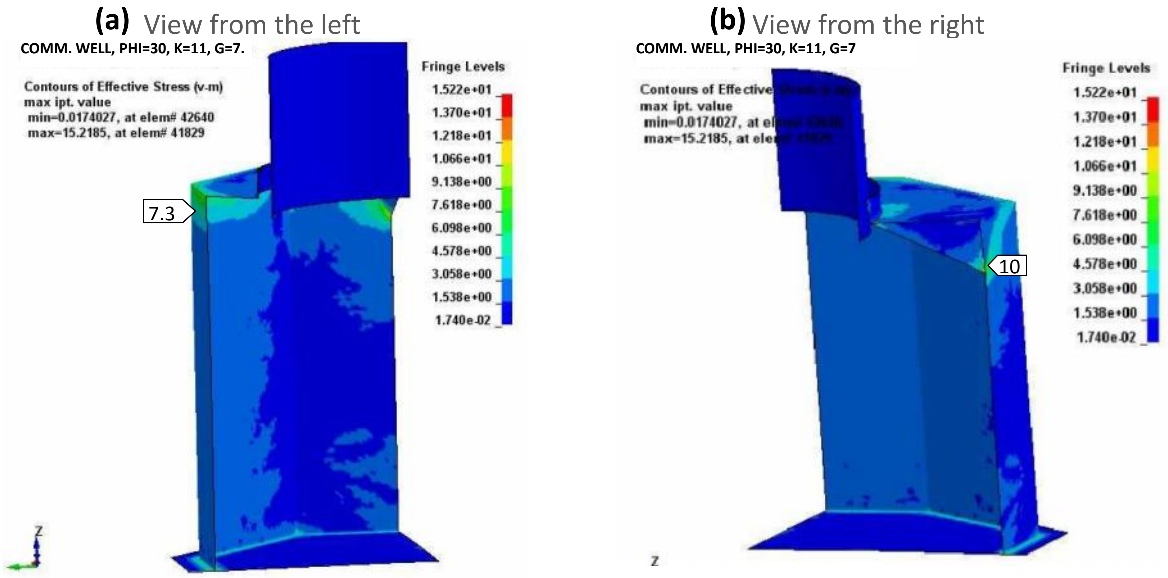

Figure 5. Distribution of equivalent tensile stresses in the well at the load of 125 kN and in case of the softest soil (K=11 MPa, G=7 MPa).

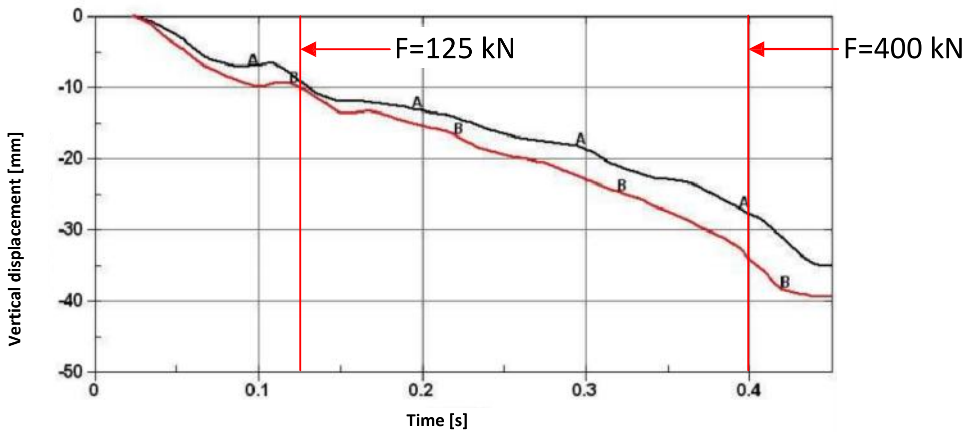

Figure 6. Vertical displacement in the joints A and B in the case of the softest soil (K=11 MPa, G=7 MPa).

The results of the calculations in case of medium rigidity soil are shown on Figures 7 and 8, and for the hardest soil, on figures 9 and 10. As the rigidity of the soil increases, the soil carries bigger share of the load and the tension stresses in the well's wall, as well as the deflection and flexibility of the well decreases. At the same time, the local tensions exceed the yield strength in case of all the calculations. The tension stresses are the greatest at the joining point of the angle reinforcement and the vertical wall of the well.

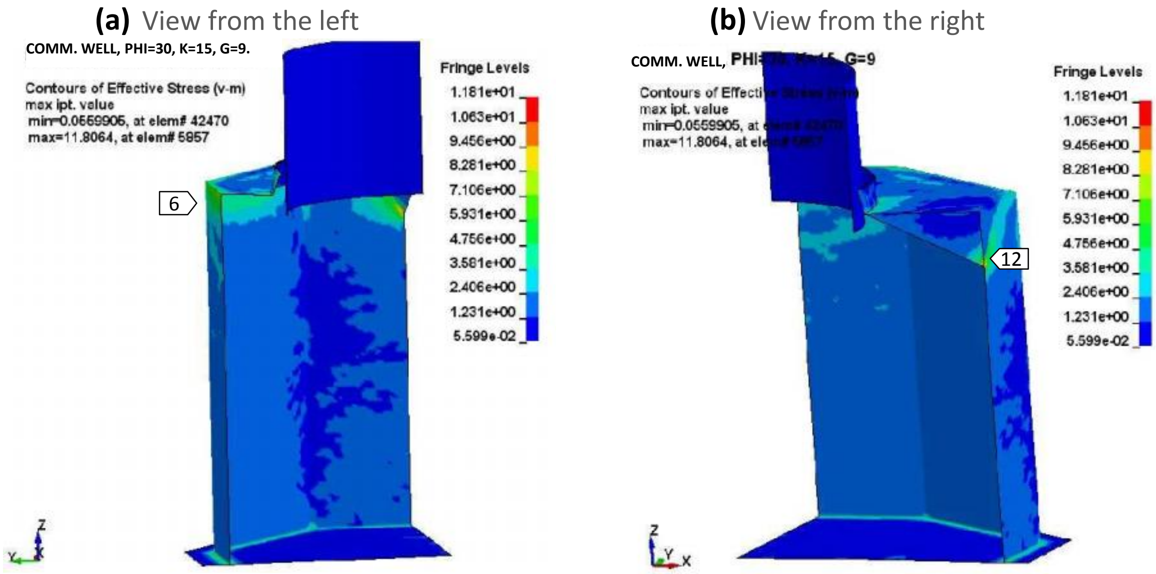

Figure 7. Distribution of equivalent tensile stresses in the well at load 125 kN and in case of medium rigidity soil (K=15 MPa, G=9 MPa).

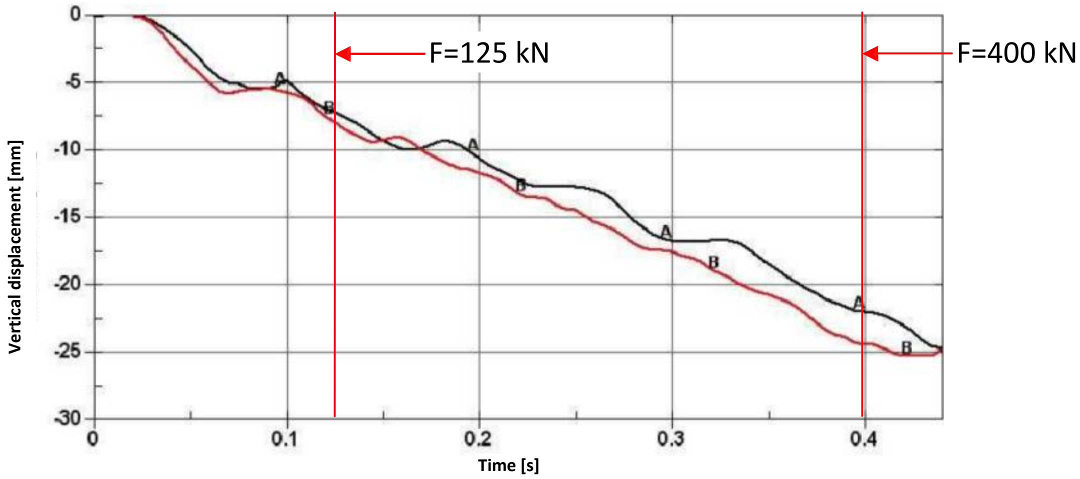

Figure 8. Vertical displacements in the joints A and B in case of medium rigidity soil (K=15 MPa, G=9 MPa).

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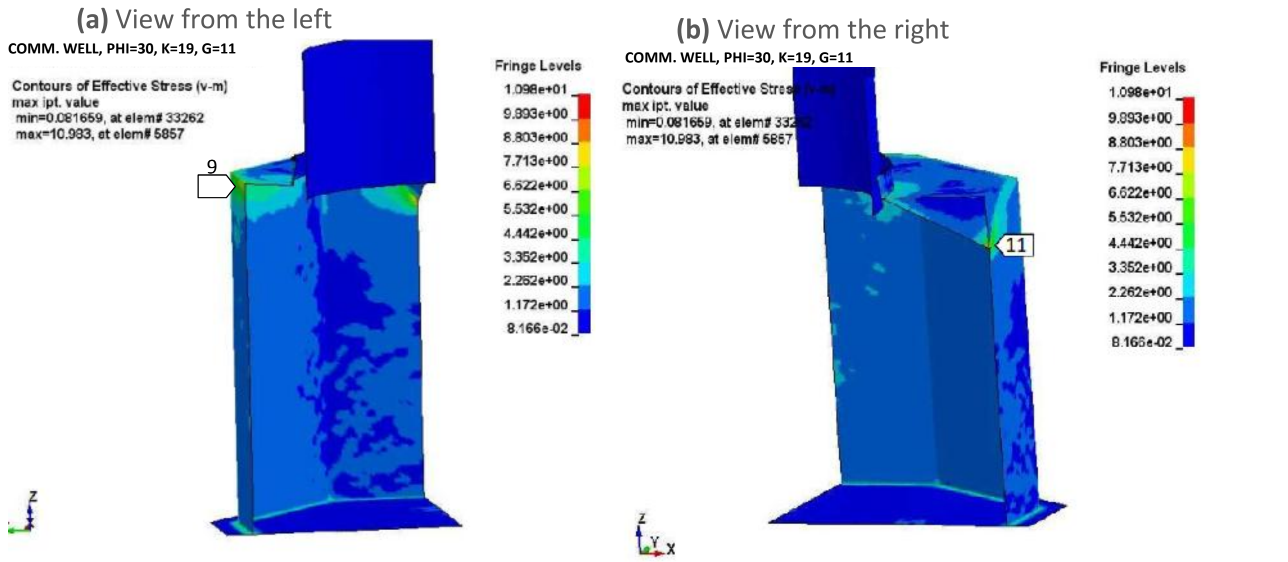

Figure 9. Distribution of equivalent tensile stresses in the well at load 125 kN and in case of the most rigid soil (K=19 MPa, G=11 MPa).

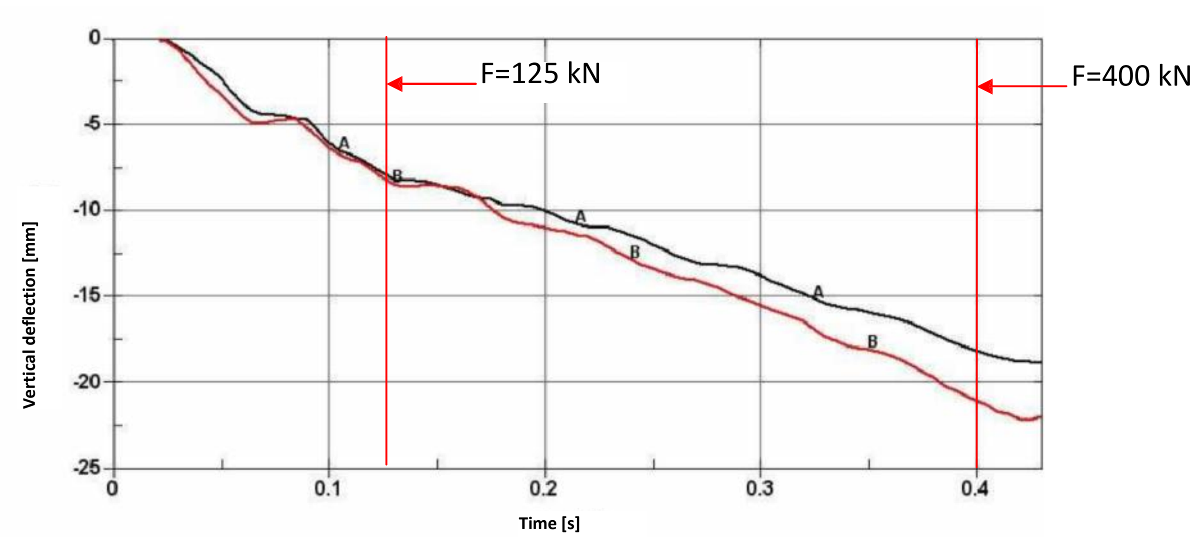

Figure 10. Vertical displacements in the joints A and B in case of the most rigid soil (K=19 MPa, G=11 MPa).

4. Suggestions

To lower the stresses in the communication well, outside reinforcement ribs could be used instead of the welded elbows inside. The advantage of the ribs is their simple installation and better efficiency which concerns the stresses. In this construction, the tip of the elbow ends in the middle of the wall plating that creates stress concentration. In case of reinforcement ribs the rigidity begins at the collar of the well and ends at the bottom of the well.

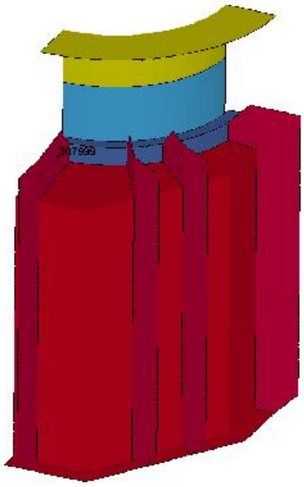

Figure 11. Recommended reinforcement of the barrel wall.

5. Conclusion

This document includes the strength calculations of a polyethylene communication well installed into tightened soil. The force applied on the collar of the communication well is 125 kN, that complies with Class M of standard EVS-EN 13598-1:2003. If the load is applied, tensile stresses will occur in the well, which do not exceed the yield strength of polyethylene. The biggest stresses occur on the tips of the elbows added to the communication well. The yield strength of polyethylene could be 15 MPa. The 125 kN force applied to the collar of the communication well creates equivalent tensile stresses that remain below 10 MPa. The state of the stress does not change significantly in case of less rigid soil. Therefore it could be said that the well in question can bear, together with the soil, the load of 125 kN, or 12.7 tons. Assuming that the biggest allowed axle load on Estonian roads is 10 tons and only one pair of wheels can be on the communication well (with the load of 5 tons) at a time, it can be claimed that in case of well tightened soil, the strength of the communication well is sufficient.

6. References

[1] Eesti Standardikeskus. Plastic piping systems for non-tension underground drainage and sewerage – Unplasticized poly(vinyl chloride) (PVC-U), polypropylene (PP) and polyethylene (PE) – Part 1: Specifications of ancillary fittings including shallow inspection chambers. Eesti Standard EVS-EN 13598-1:2003

[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 web page: www.fhwa.dot.gov/publications/research/safety/04094/04094.pdf

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

Appendix 1. The measurements of the test pieces

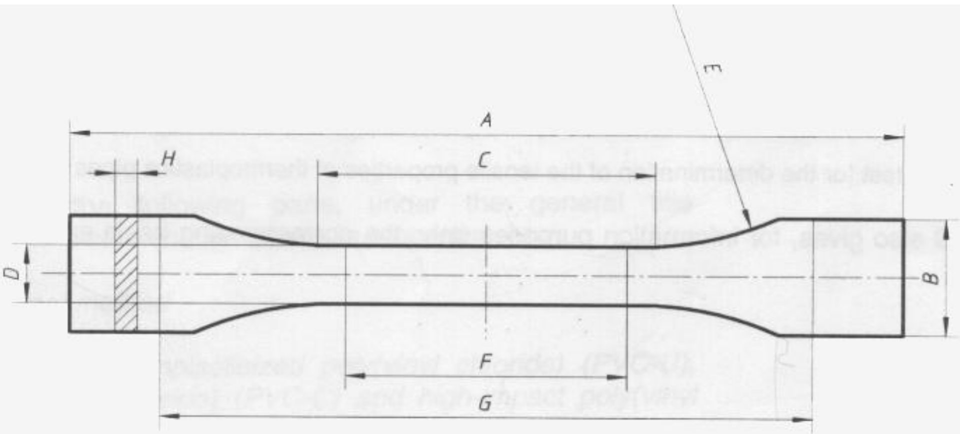

Table 1 — Dimensions of type 1 test pieces

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

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Appendix 2. The parameters used for modeling the soil and their description in English

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 waterr 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 to describe the dependency of material properties of the load speed. This dependency is not taken into account in the calculations.

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