Strength assessment of ground source heat distributors

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1 SUMMARY

1.1 Executive summary

Strength assessment of the ground source heat distributors (GSHD) type GM-1 and GM-2 made of polyethylene was conducted. The distributed load with the resultant value of 12.5 tons was applied on the hatch cover of ground source heat distributors.

Single loading case 12.5 tons applied on hatch cover together with gravity load was considered.

Results show that the container GM-2 is more loaded than unit GM-1. This is caused by the fact that shorter telescopic neck is used and part of the load will be transferred directly to PE-container instead of soil. Also the modelled soil volume is smaller in GM-2 model and in real situation the larger area of soil will have ability to carry the load. As a result, the container itself is more stressed then container in case of GM-1. In case of GM-2 unit the yield stress 20 MPa is exceeded very locally in some sharp corners (see Figure 12). Nevertheless, they can be considered as hot spot point that will not affect the global strength of the container. The structure is far from rupturing, buckling or collapse.

Results prove that both installations have sufficient strength to carry the wheel load 12.5 tons. Unit GM-2 is more stressed but the load carried by PE-container can be reduced significantly by installing it sligtely deeper. Also the modelled soil in GM-2 model volume gives us very conservative strength assessment approach as in real situation larger soil area will participate in load carrying.

1.2 Revision history

Rev. 02 was issued for comments by company.

2 INTRODUCTION

2.1 Objectives and scope

The aim of the analysis is to prove that the strength of the ground source heat distributors (GSHD) of type GM-1 and GM-2 is sufficient to carry the wheel load equal to 12.5 tons. The loading is applied as distributed load on the top of hatch cover of ground source heat distributor. In installed condition the unit is surrounded with soil. Therefore the supporting effect of soil is included. The geometry of the unit of type GM1 and GM2 is presented in Figure 1.

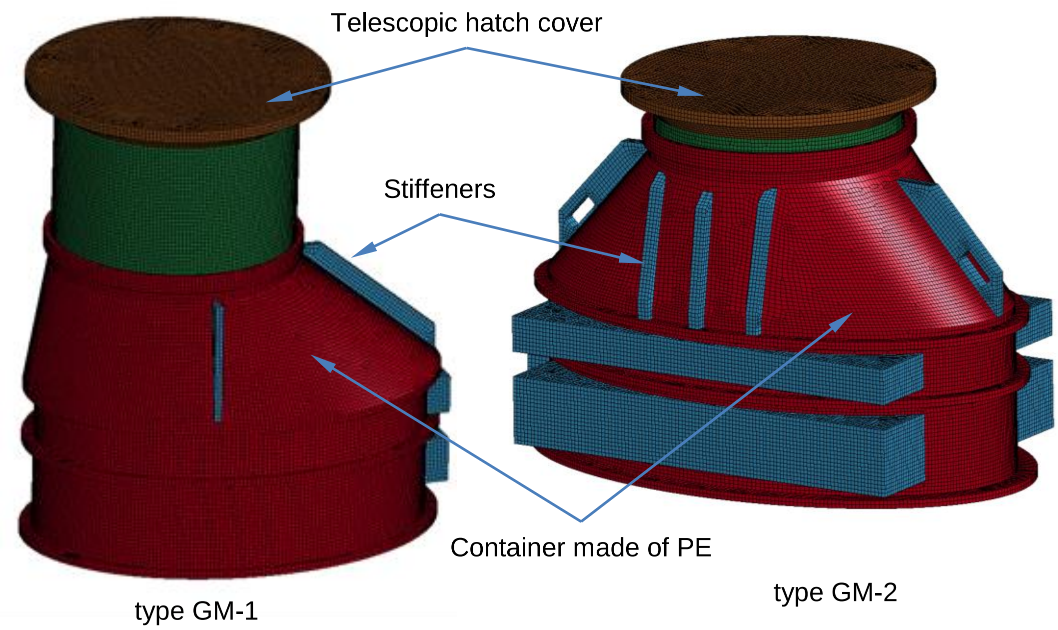

Figure 1. Ground source heat distributors of type GM-1 and GM-2

2.2 Analysis bases

The analyses were based on the drawings delivered by client.

3 ANALYSIS APPROACH

3.1 Analysis principles

Strength analysis is carried out with non-linear FE method. The analysis include nonlinear material model for polyethylene, large deflections and contact definitions. Contact is defined between the hatch cover, ground source heat distributor and soil. In order to avoid dynamic effects the applied load is smoothly increased up to the maximum value within 1 sec. Stresses and deflections in container are calculated and reported.

3.2 Design allowable limits

It is assumed that the maximum allowable global stress in container cannot reach to yield stress of PE material that is 20 MPa. Also it is assumed that the container hull must stay stable without buckling or collapse.

3.3 Analysis software

For non-linear analysis is used a finite element based program for nonlinear dynamic analysis of structures in three dimensions called LS-DYNA.

4 LOADING

A single load case is defined for ground source heat distributor container of type GM-1 and GM-2. The load is applied in both models to hatch cover as distributed load in the negative z-direction. The total load in z-direction will reach up to $122.6\ kN$ ($12.5\ tons$). It is assumed that the wheel load is distributed equally on the surface of hatch cover. In addition to wheel load the container and the soil are subjected to gravity loading. Gravity is defined as acceleration $9810\ mm/sec^2$ in negative z-direction.

5 MODELLING

5.1 Co-ordinate system

The origin of the co-ordinate system used in FE-model is located in the middle of the bottom plate of the access chamber. The x-axis and y-axis are located in the same surface with the bottom plate of the access chamber.

5.2 Material properties for polyethylene

For material following elastic material properties were used for polyethylene (PE)

- Young's Modulus of elasticity $E = 1500\ MPa$ and
- Poisson's ratio $\nu = 0.3$.

The nonlinear behaviour of PE is defined with elasto-plastic material model. Thus, up to yield stress 20 MPa the material behaves elastically and after reaching the yield the material behaves according to stress-strain curve presented in Figure 2. The material curve is based on tests carried out for PE material delivered by client.

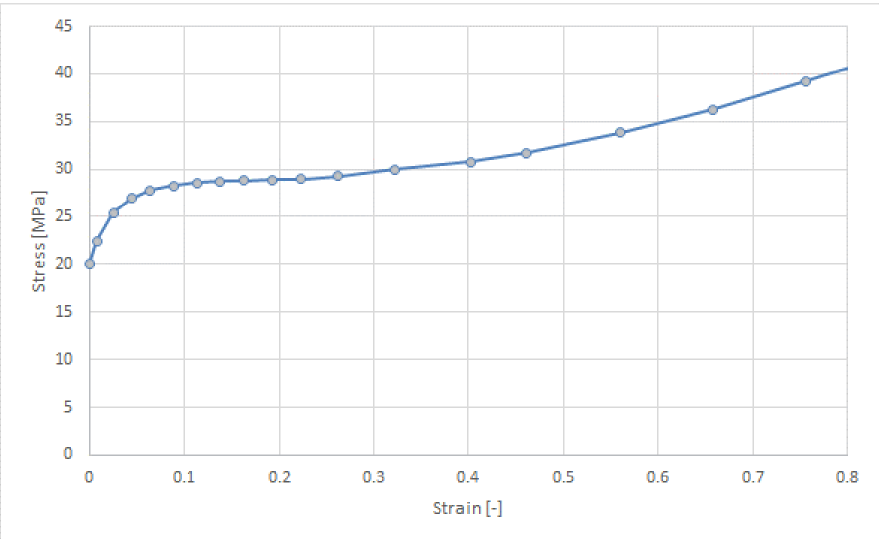

Figure 2. Assumed stress strain curve for polyethylene.

5.3 Material properties for soil

It is assumed that the GSHD is mounted on top of sand pad and surrounded with tightened sand. The mechanical properties of soil are determined based on tightened sand and using references [1] and [2]. In LS-Dyna analysis for soil the material model MAT_FHWA_SOIL is used, presented in more detail in reference [3]. Parameters for soil are presented in

. Kõik arvutustes kasutatud parameetrid on esitatud Lisas 2.

Table 1. Material parameters for soil (tightened sand).

Value	unit	description
$\rho = 1.90$	$[ton/m^3]$	Density
$K = 15$	$[MPa]$	Bulk modulus
$G = 9$	$[MPa]$	Shear modulus
$\varphi = 0.524$	$[rad]$	Friction angle (30 deg)

5.4 Extent of models & mesh properties

The finite element method based calculation model consists of PE container, telescopic hatch cover and soil. For PE container and hatch cover there are used four node shell elements with approximate dimensions of 10x10 mm. The soil is modelled with four-node tetrahedral solid elements with the approximate side length equal to 80 mm. The GM-1 model consists of 53283 shell elements and 84826 solid elements. The GM-2 model consists of 65524 shell elements and 46106 solid elements. For better understanding of FE-models see Figure 3 and Figure 4.

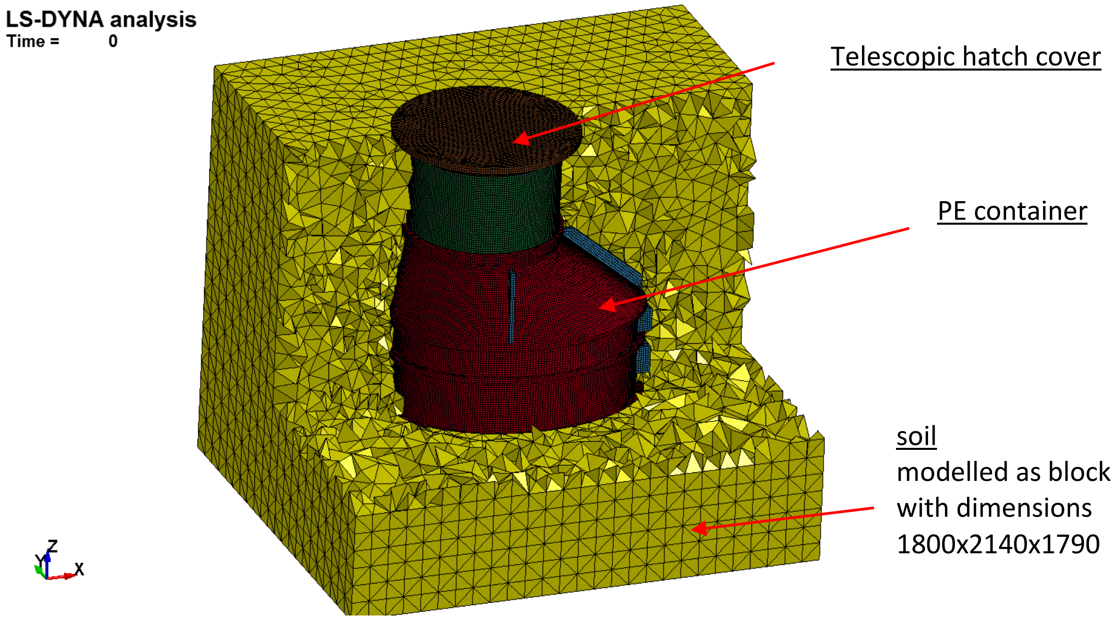

Figure 3. Model of a ground source heat distributor of type GM-1 including soil.

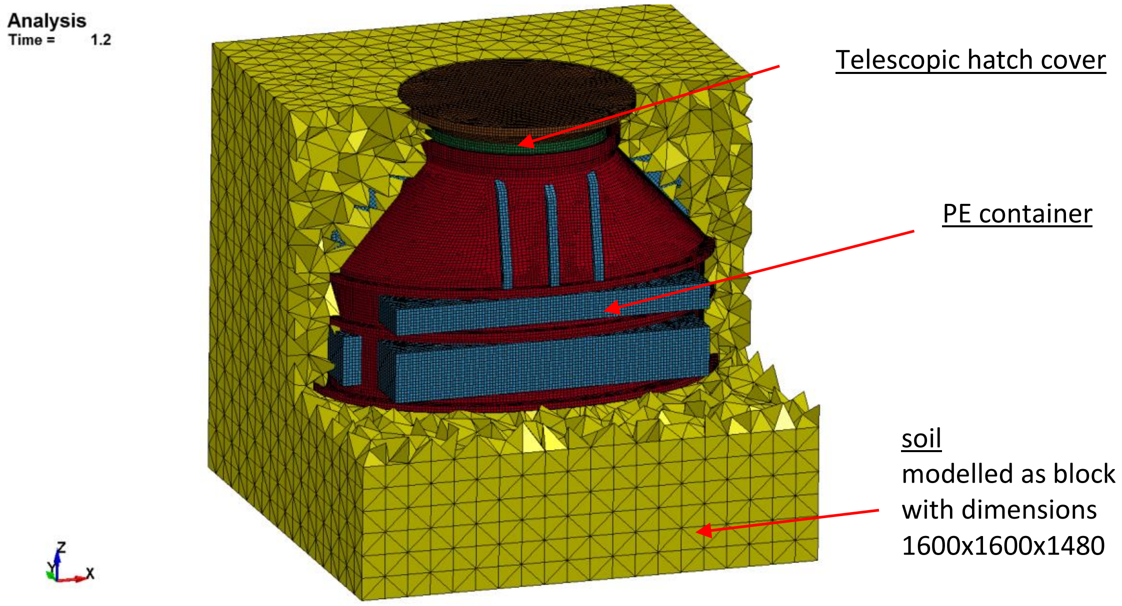

Figure 4. Model of a ground source heat distributor of type GM-2 including soil.

5.5 Model geometry and scantlings

The thickness scantlings for ground source heat distributor of type GM-1 and GM-2 are shown in Figure 5 and Figure 6. The main dimensions of the container are based on drawings delivered by vendor.

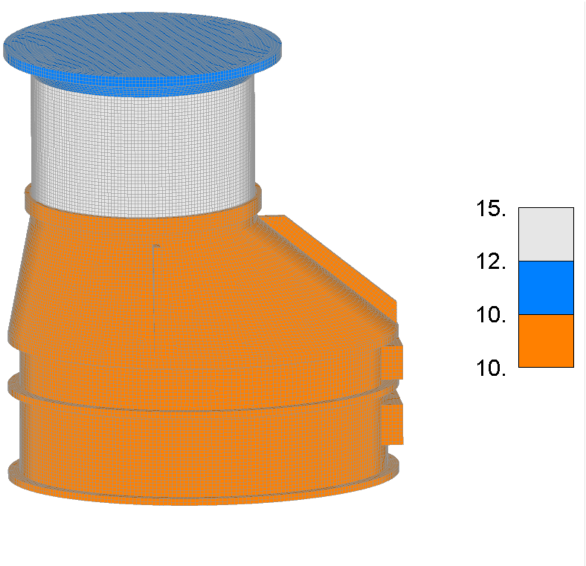

Figure 5. Wall thickness scantlings for ground source heat distributor of type GM-1.

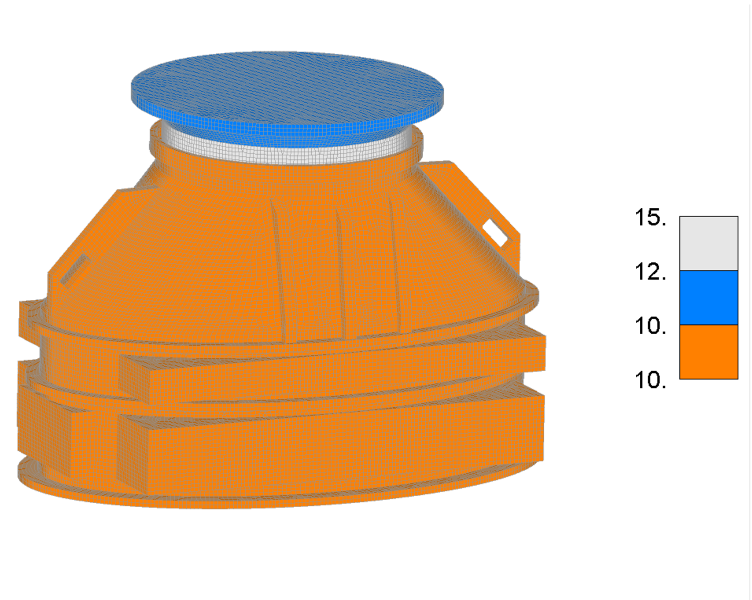

Figure 6. Wall thickness scantlings for ground source heat distributor of type GM-2.

5.6 Boundary conditions

The ground source heat distributor is installed in soil and part of the wheel load will be carried by soil. Therefore, the soil and container of the GSHD have to interact when hatch cover is loaded. The contact definition is determined between the soil and GSHD container. Due to this the interaction between the PE container and soil is possible. Outer boundary of the soil has additionally displacements restraints in direction normal to external surface. So the soil particles located on boundary surface can move only inside of this particular surface. For better understanding see Figure 7.

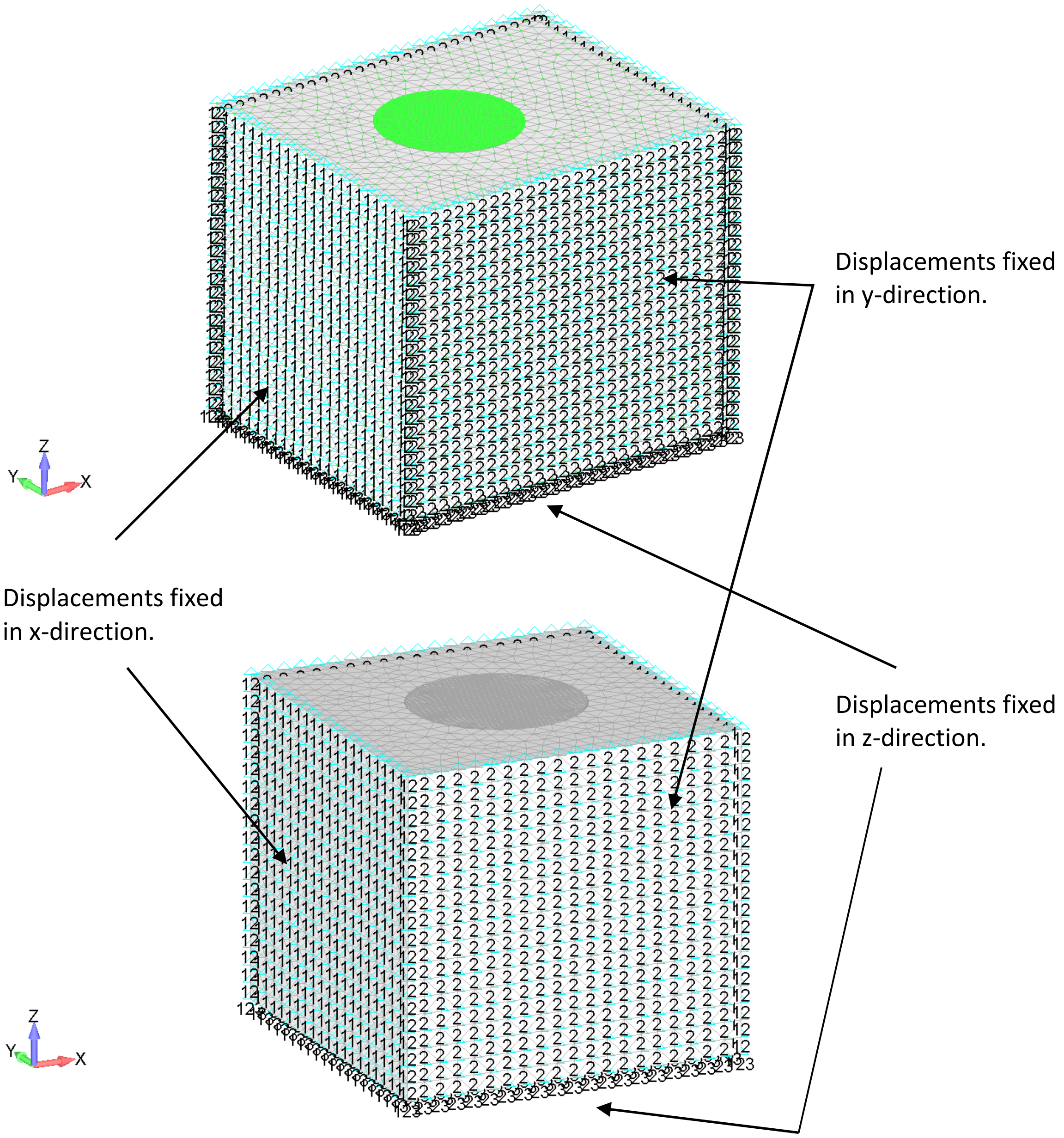

Figure 7. Boundary conditions for ground source heat distributor of type GM-1 and GM-2.

5.7 Contact definitions

In order to consider the effect of soil the interaction between the installed PE-container, hatch cover and soil has to be taken into account. This can be done by considering the contact loads between different structural elements. In Figure 8 are shown the contact pairs that are taken into account for soil interaction with GSHD-unit. Thus the interaction between the hatch cover and soil, hatch cover neck and soil, hatch cover neck and PE container and PE container with soil are taken into account.

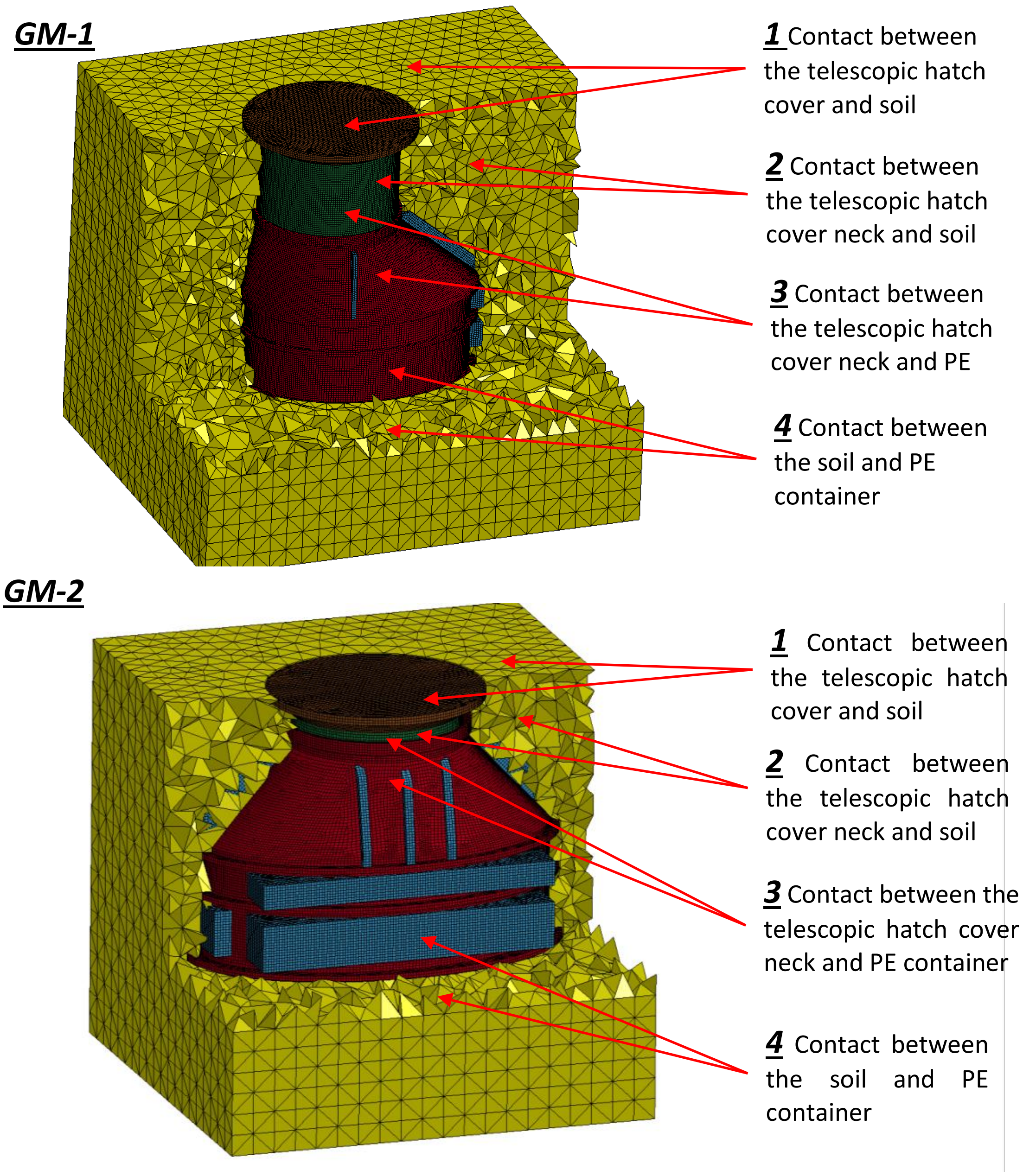

Figure 8. Contact definitions for ground source heat distributor of type GM-1 and GM-2.

5.8 Modelling loads

The loading is applied on hatch cover of access chamber as distributed load. The direction of load is negative z co-ordinate direction. The load is increased in time so that in one seconds of integration time the total load in z-direction will reach up to $122.6\ kN$ ($12.5\ tons$). The loading curve is presented in Figure 9. The applied load is shown in Figure 10. In addition to wheel load the container and the soil are subjected to gravity loading. Gravity is defined as acceleration $9810\ mm/sec^2$ in negative z-direction. Also gravity load is increased in time according to loading curve presented in Figure 9.

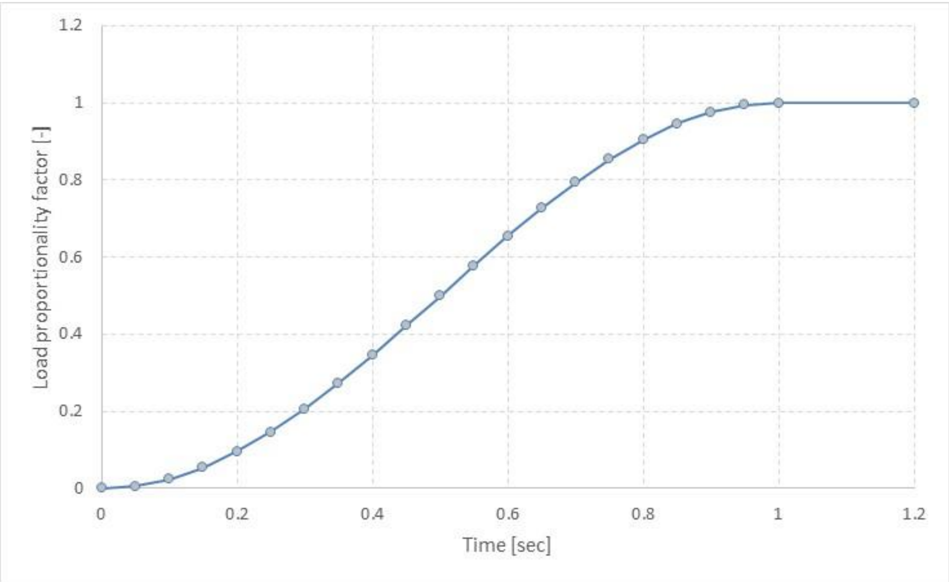

Figure 9. Loading curve for a ground source heat distributors

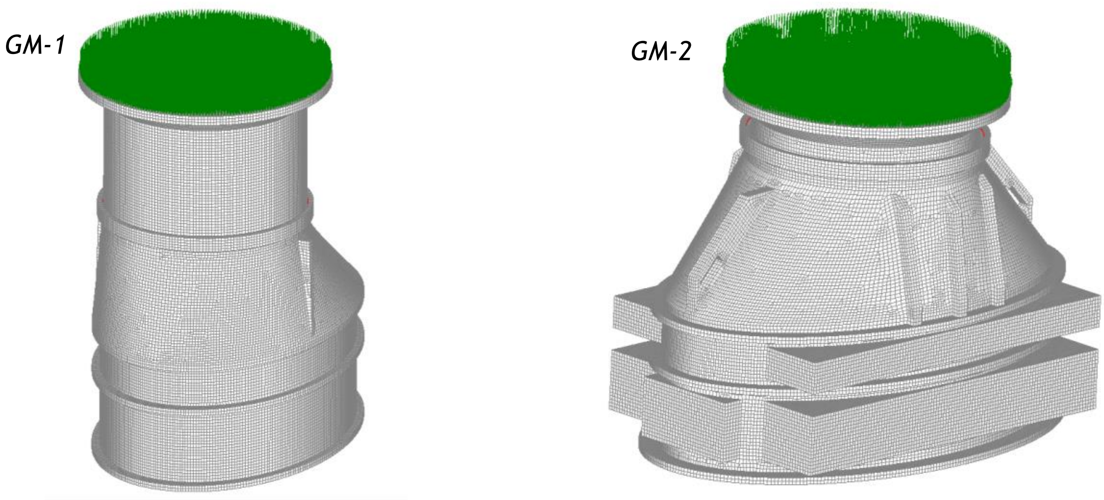

Figure 10. Pressure applied on model of type GM-1 and GM-2.

6 ANALYSIS RESULTS

In Figure 11 is presented equivalent stress in soil for models GM-1 and GM-2. The stress in soil is below 1 MPa. The stress values in model GM-1 are smaller as there the hatch cover has larger diameter $(\mathrm{d} = 810\ \mathrm{mm})$ than for model GM-2 $(\mathrm{d} = 790\ \mathrm{mm})$. Also for model GM-1 the modelled soil volume is larger and the container is installed with longer hatch cover neck. Therefore, the load can be distributed into lager area and will not cause high large stresses in soil.

In Figure 12 is shown the equivalent stress in PE-container. Also hear can be seen that the larger modelled soil volume helps to distribute stresses so that the container will be less loaded (GM-1). In container GM-2 the edge of the container is almost below the hatch cower and therefore it carries also significant amount of total load. As a result, the container itself is more stressed then container in case of GM-1. In case of GM-2 unit the yield stress 20 MPa is exceeded very locally in some sharp corners (see Figure 12). Nevertheless, they can be considered as hot spot point that will not affect the global strength of the container. The structure is far from rupturing, buckling or collapse.

The total load applied to the unit and load carried by PE-container are shown in Figure 13 as a function of displacement. It can be seen that unit GM-1 will experience also less deformations as soli is taken majority of loads that are applied on hatch cover.

However, results show that both installations have sufficient strength to carry the wheel load 12.5 tons. Unit GM-2 is more stressed but the load carried by PE-container can be reduced significantly by installing it sligtely deeper. Also the modelled soil volume gives us very conservative strength assessment approach as in real situation larger soil area will participate in load carrying.

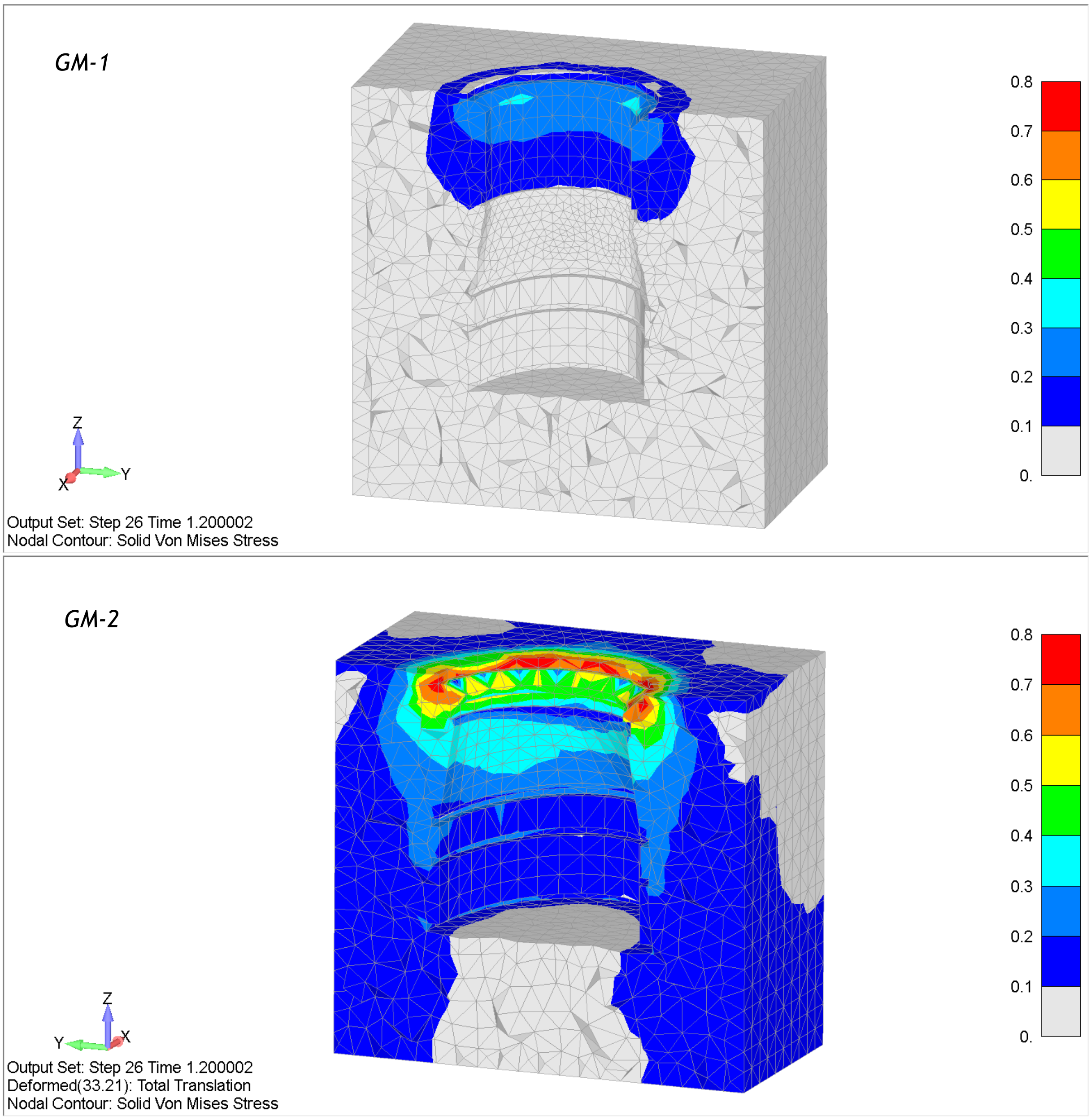

Figure 11. Von Mises equivalent stress in soil at maximum load [MPa].

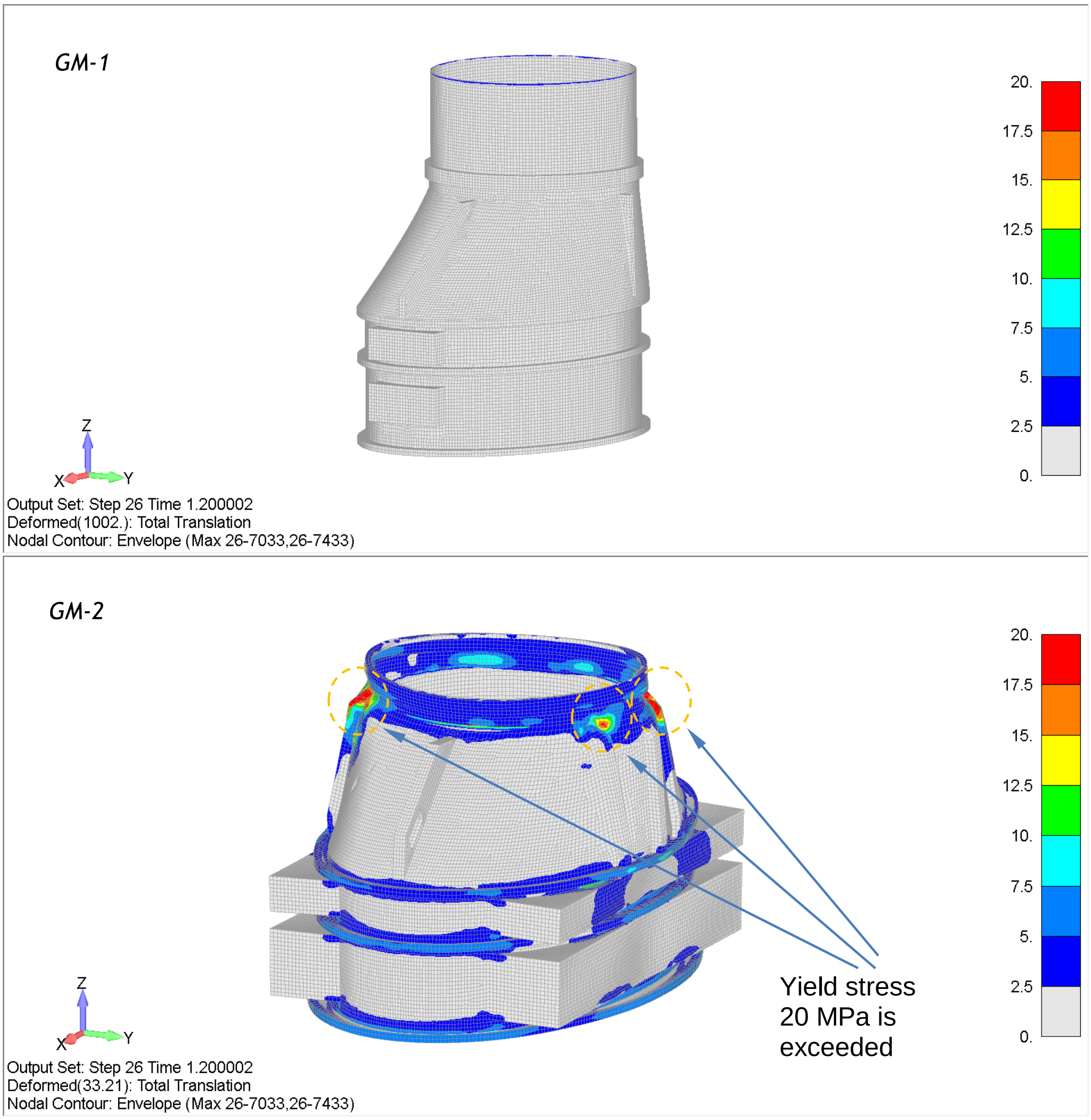

Figure 12. Von Mises equivalent Stress in PE container at maximum load [MPa].

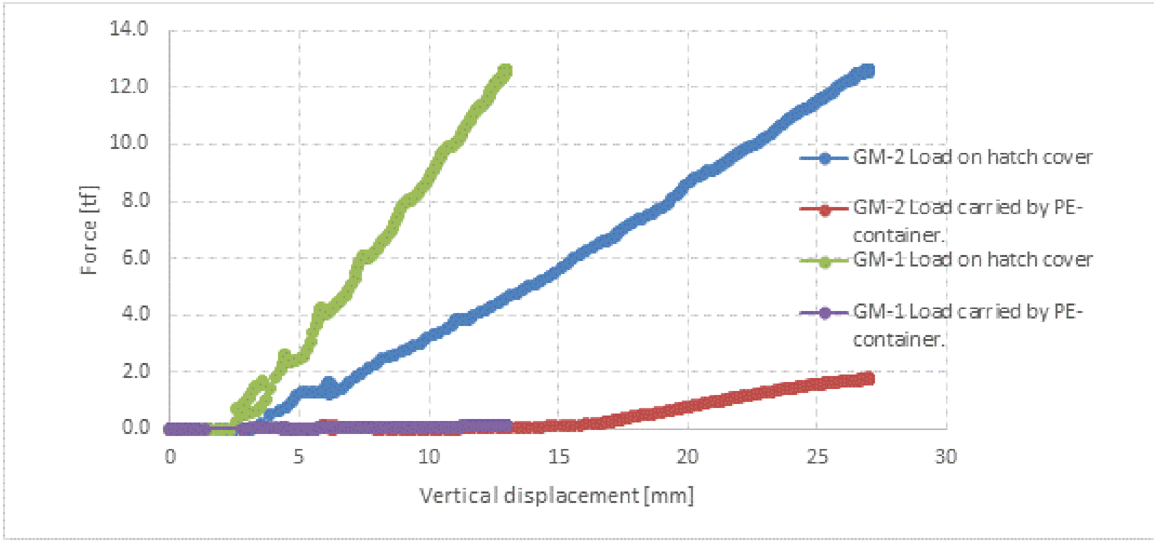

Figure 13. Load carried by hatch cover and PE-container of ground source heat distributer of type GM-1 and GM-2.

7 REFERENCES

[1] 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.

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

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