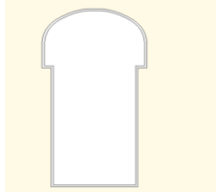
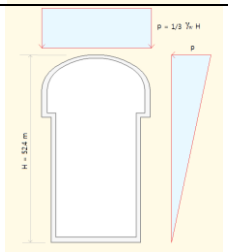
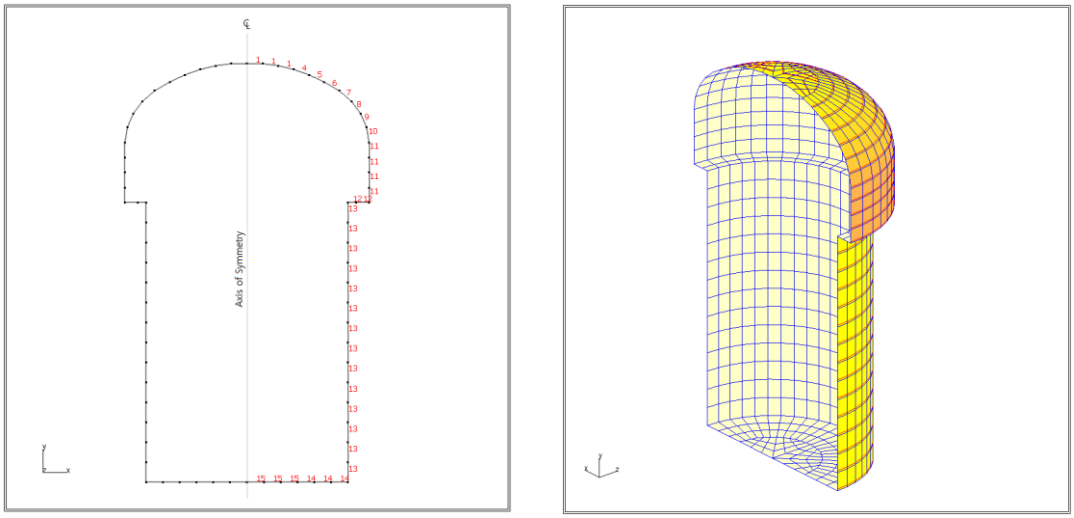
Although the underground silo was excavated step by step in construction stages, the effects of such multi-step excavations were ignored in this numerical study. Thus, the underground silo is assumed to be excavated in a single step, which is the most conservative. Therefore, construction sequences of the underground silo structure for LILW disposal facilities are simulated as schematically illustrated in Table 2.

Finite element modeling and numerical results on the stress distribution in rocks around underground silo at step 1 and 2 were presented by Kim and Kim (2020). Shotcrete of 50 cm thickness is installed simultaneously during one step excavation at step 3 and reinforced concrete lining is installed and subjected to its own self weight at step 4.

Residual water pressure may develop when drainage system is clogged or deteriorated. Silo lining may be statically subjected to residual water pressure in addition to its own self weight during the period of operation. The magnitude of residual water pressure used in the design of drainage tunnels to be 1/2 of the height of the tunnel for soil ground and 1/3 of the height of the tunnel for rock was proposed by KISTEC (2008). Therefore, it is assumed that reinforced concrete lining is subjected to residual water pressure of 17.47 meters equivalent to 1/3 of the height of the underground silo at step 5.

Table 2 Simulation of construction sequence

Step	Construction State	Descriptions
1,2		In Situ K_o State
3		Excavate Silo and install Shotcrete of 50cm Thickness
4		Install Reinforced Concrete Lining with its Own Self Weight
5		Lining is Subjected to Residual Water Pressure Head of 17.47 m



(a) 2-D Lining Element (b) 3-D Lining Element Inner Surface

Fig. 4 Finite Element Model for Liner Structure

3.3 2-D axial symmetric and 3-D finite element models

The finite element models of the underground silo structure are shown typically in Figs. 4. The results of displacement and stress obtained after performing this finite analysis of the underground silo are examined at lining element around the silo. Numerical results of 2-D and 3-D analyses are mainly compared at key location shown in Fig. 5.

It should be noted that the same 3-D finite element model is to be used for seismic analysis subjected to horizontal base accelerations. In such case, 2-D axial symmetric finite element model is not applicable for the underground silo subjected to the horizontal motion.

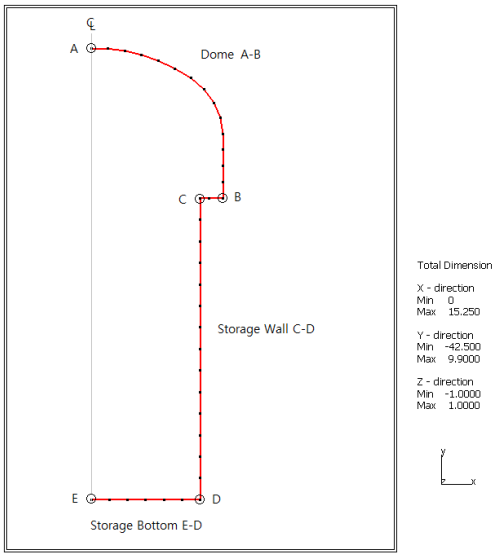
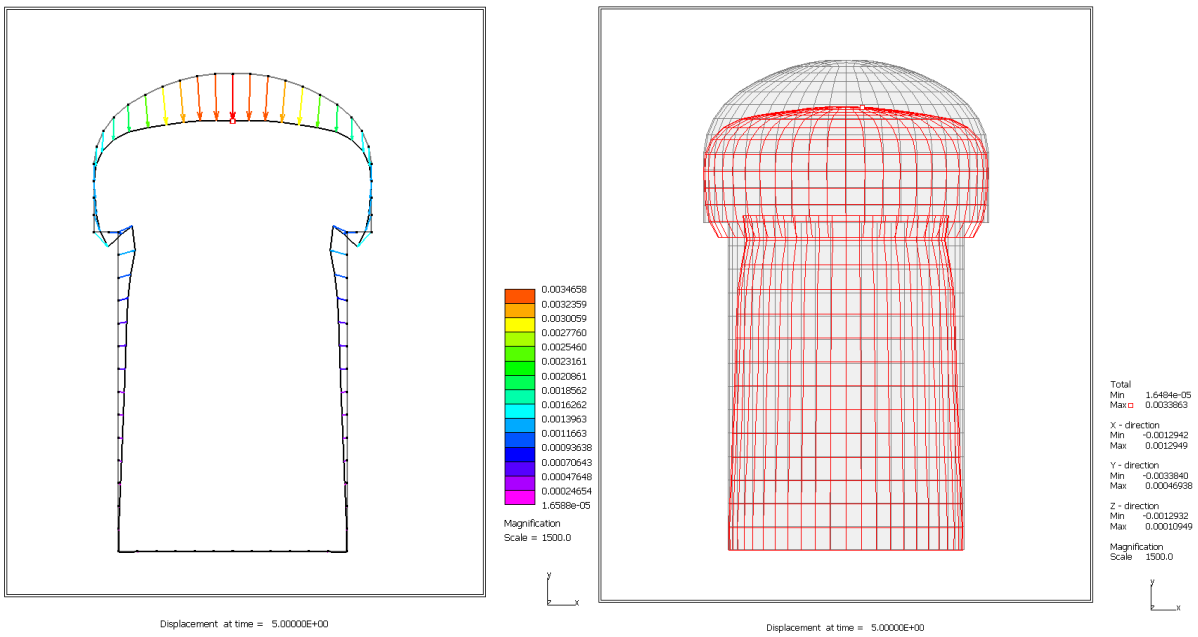


Fig. 5 Key Locations for Stress Plot

4. NUMERICAL RESULTS

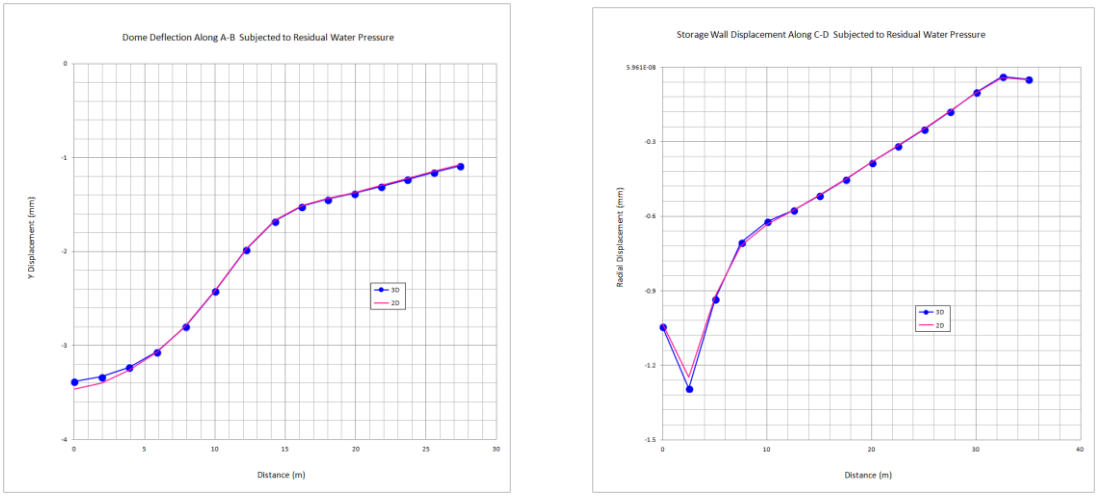
The lining deformed shape subjected to both self-weight and residual water pressure at Ko=2 are shown in Fig. 6. The lining deformations at key locations are also compared in Fig. 7. The numerical results of 2-D axial symmetric analysis were almost identical to them of 3-D analysis as illustrated in Figs. 6-7.

Stresses in reinforcing bar of reinforced concrete lining subjected to both self-weight and residual water pressure at Ko=2 are shown in Fig. 8.



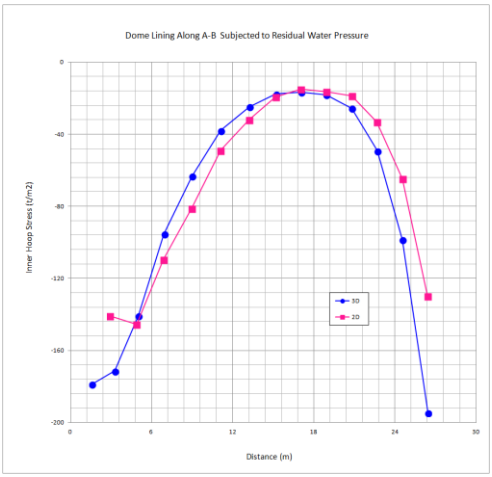
(a) 2-D Model (b) 3-D Model

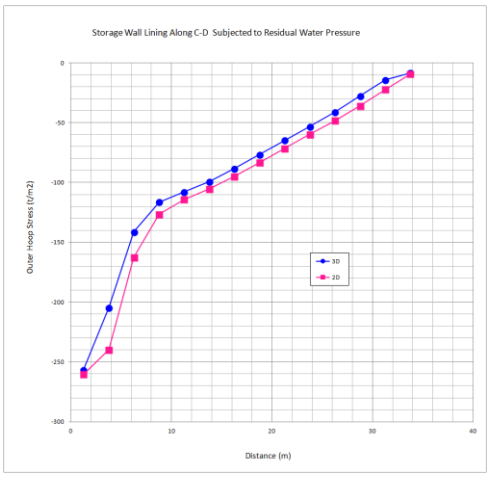
Fig. 6 Lining Deformation subjected to Residual Water Pressure (K_o=2.0)



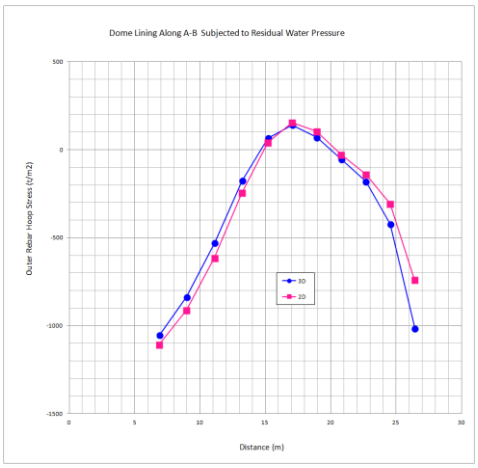
(a) Dome deflection along A-B (b) Storage wall radial displacement along C-D

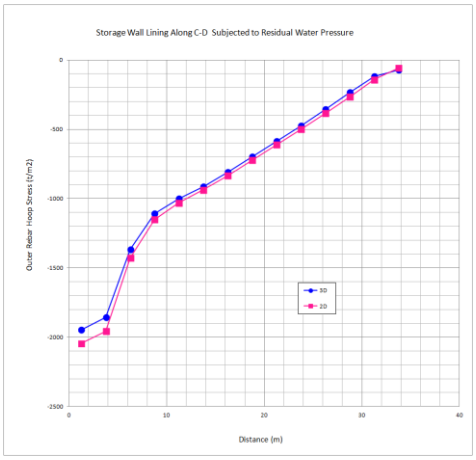
Fig. 7 Lining Deformation subjected to Residual Water Pressure (K_o=2.0)





(a) Inner fiber hoop stress along A-B (b) Outer fiber hoop stress along C-D





(c) Outer rebar hoop stress along A-B (d) Outer rebar hoop stress along C-D

Fig. 8 Lining Stresses subjected to Residual Water Pressure (K_o=2.0)

5. CONCLUSIONS

Finite element analysis of the underground silo structure surrounding rock for LILW (Low- and Intermediate-Level radioactive waste) disposal facilities in Korea is carried out. The effects of construction sequence under various ratios of horizontal stress and vertical stress are considered in this study. The numerical results of 2-D axial symmetric analysis were almost identical to them of 3-D analysis. Stresses in reinforcing bar of reinforced concrete lining is expected to have maximum value on top of the storage wall, but reinforced concrete lining seems to be securing structural safety.

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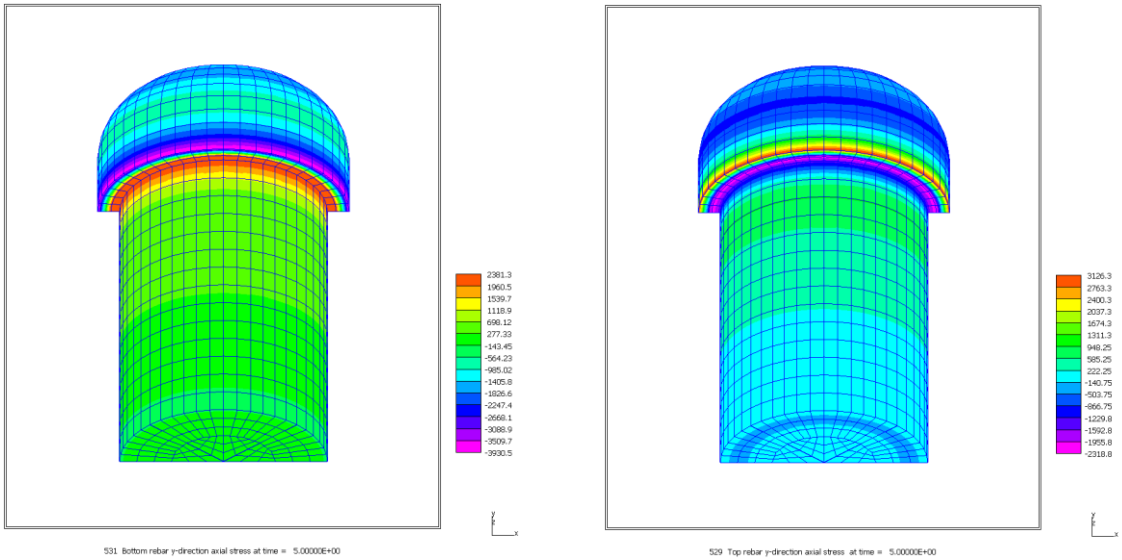

(a) Inner rebar meridian stress (b) Outer rebar meridian stress

Fig. 8 Lining Deformation subjected to Residual Water Pressure (3-D)