

# ***Experimental Hall 3D deformation analysis***

## ***Asian Region Design***

### **CONVENTIONAL FACILITIES AND SITING**

# Contents

## Study 1 : Excavation analysis

Evaluate the distribution of loosened zone around E/H

- TDR designed E/H dimension
- Parametric study because rock mass properties and initial ground stress are under now investigation

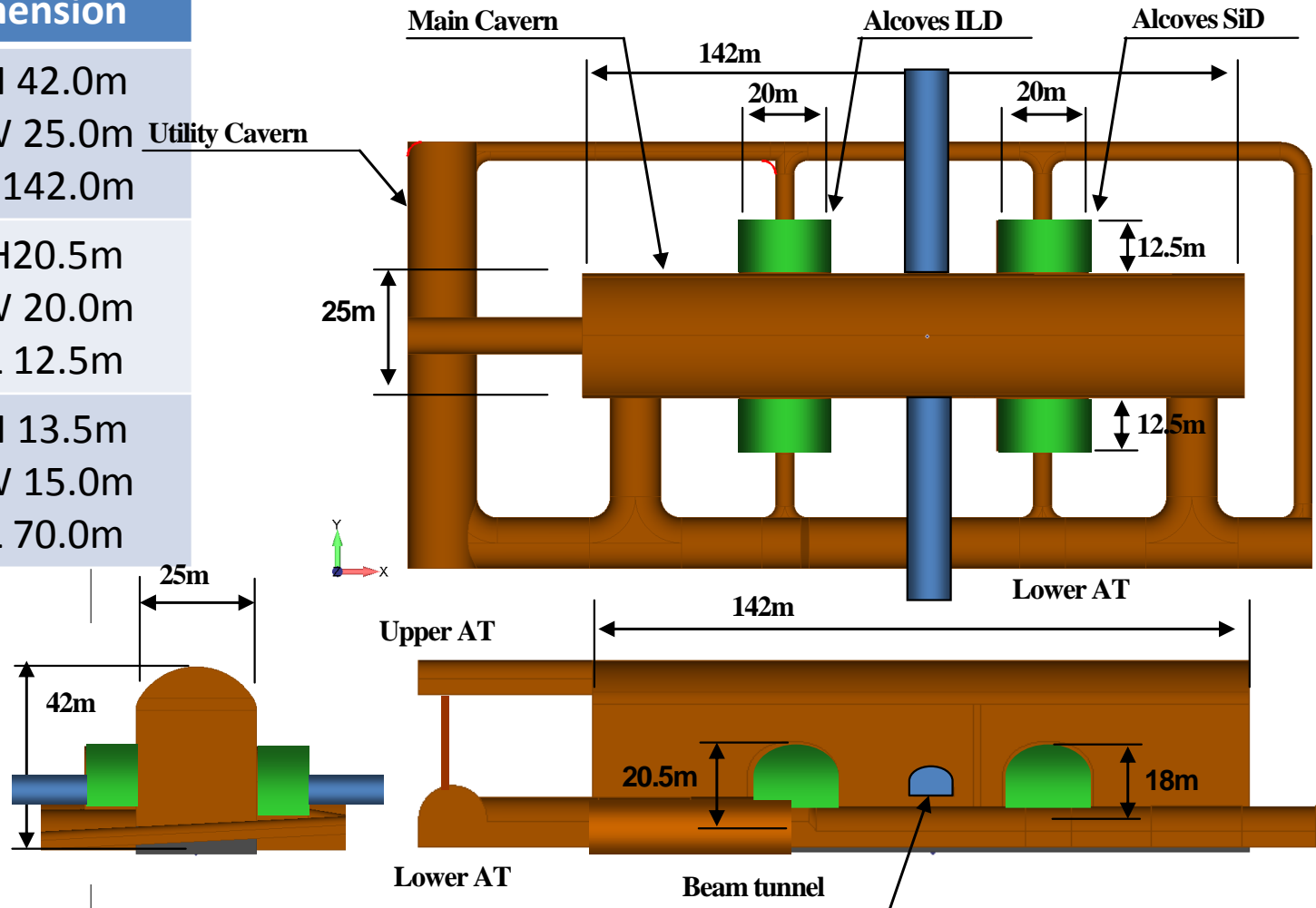
## Study 2 : Bedrock displacement installing Detector

Evaluate the influence of vertical displacement at E/H bottom floor and surrounding area by push-pulling of detectors

- Detectors are heavy but lighter than excavated rock mass weight.
- Behavior of displacement is almost elastic.
  - Total weight of excavated rock mass : 350,000 tons at least
    - $950\text{m}^2 \times 142\text{m} \times 2.65 \text{ ton/m}^3 = 357,000 \text{ tons}$
  - Detectors weight : 25,000 tons

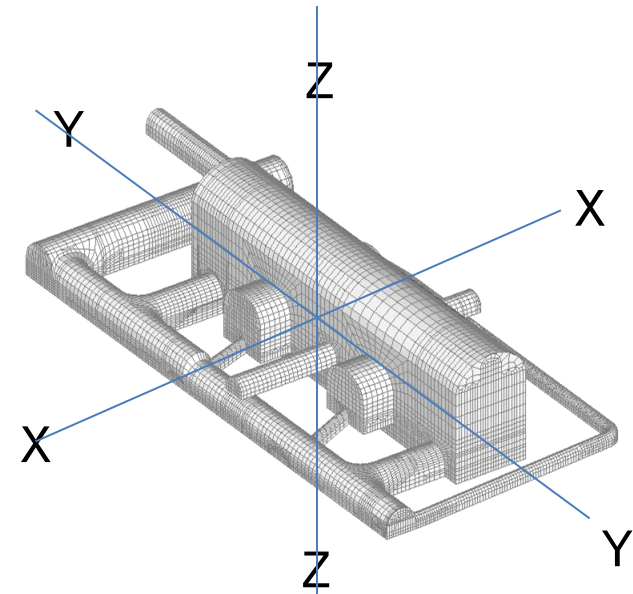
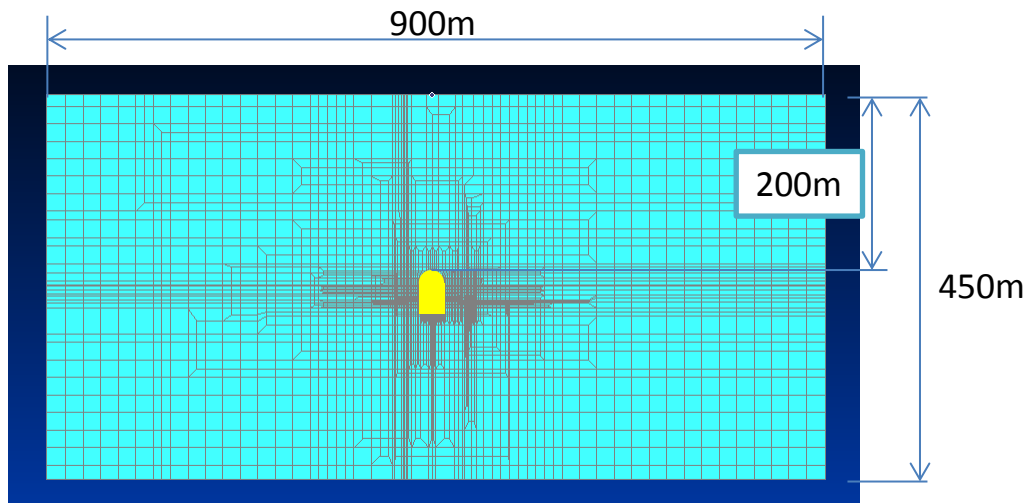
# Design of Experimental Hall of Asian site

Cavern	Dimension
Main hall	H 42.0m W 25.0m L 142.0m
Alcoves	H 20.5m W 20.0m L 12.5m
UT cavern	H 13.5m W 15.0m L 70.0m



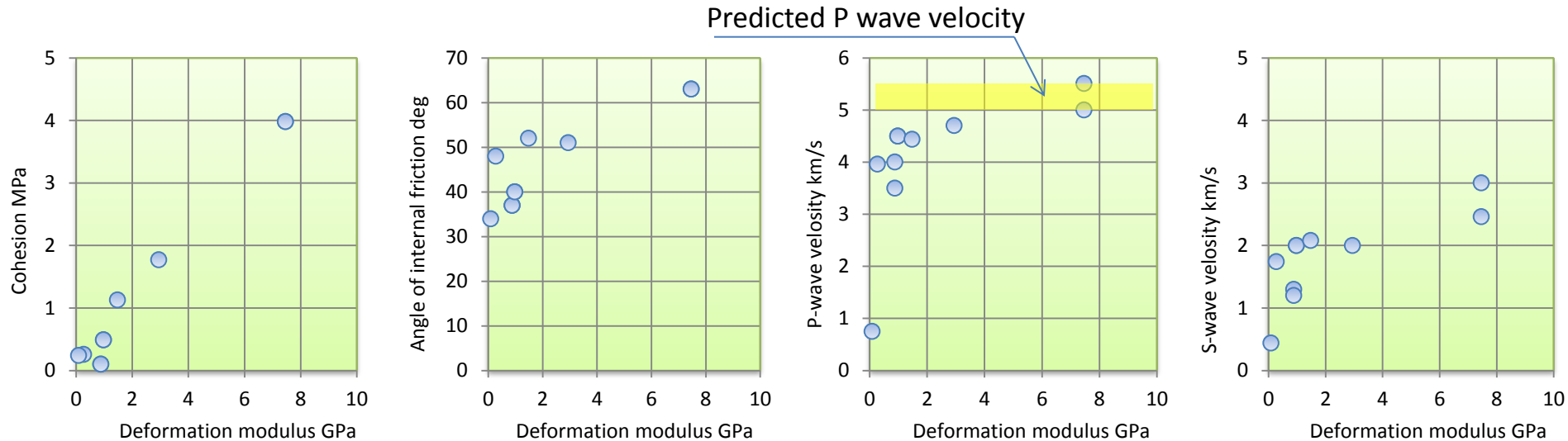
# Analysis conditions

- Analysis method :
  - 3D Elastic FEM analysis considering excavation step
  - Deformation modulus at fractured elements reduced to one-100<sup>th</sup> by every excavation step considering plasticity.
  
- Model size :
  - H450m x W900 x L900m
  - Overburden : 200m



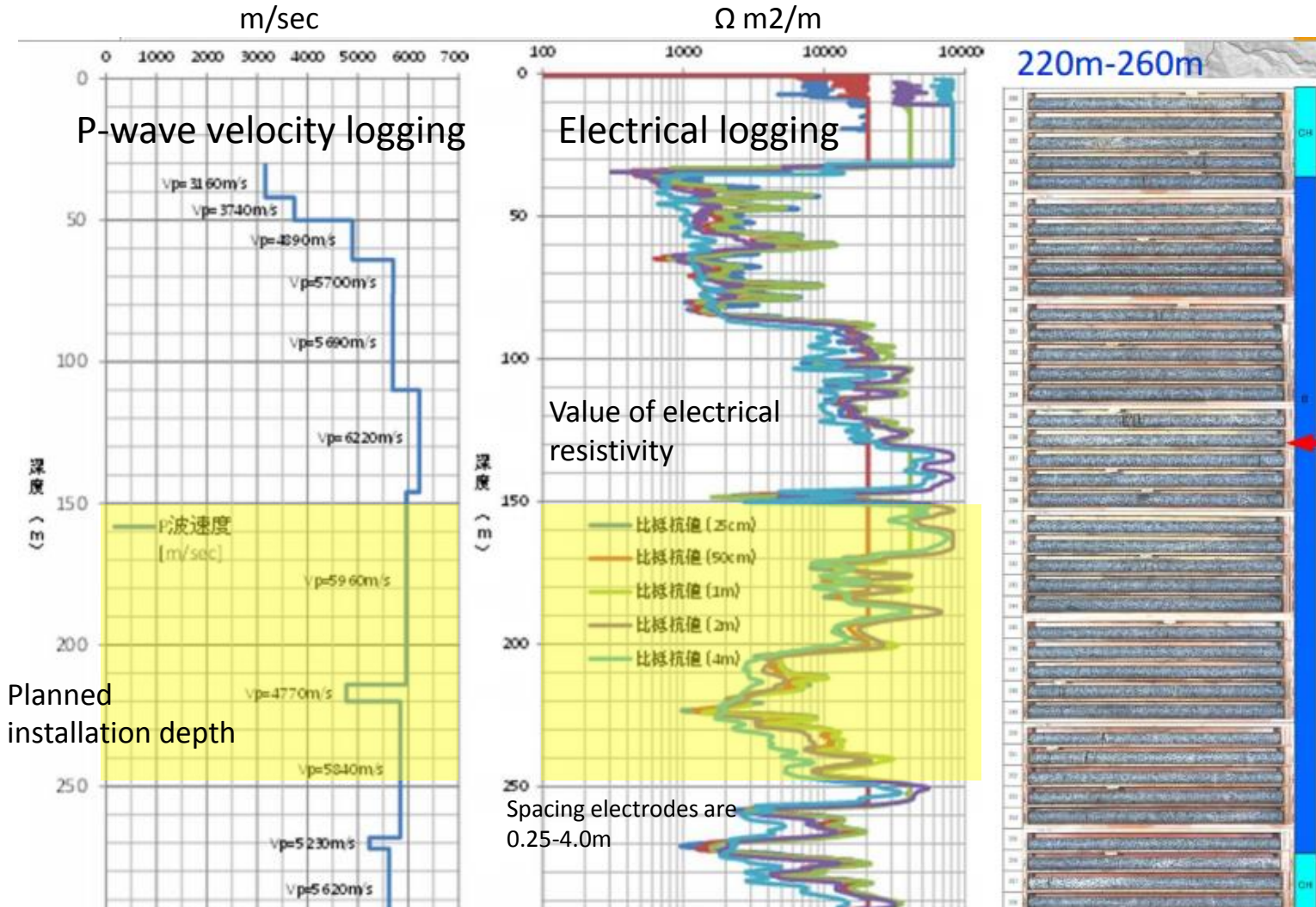
# Assumption of Rockmass properties

Deformation modulus for analysis set to three classes “H, M, L” considering candidate site rock condition. Share strength is assumed by relationship between properties of previous other granite investigation.



	High class	Middle class	Lower class
Density	26.5 kN/m <sup>3</sup>	26.5 kN/m <sup>3</sup>	26.5 kN/m <sup>3</sup>
Deformation modulus	10.0 GPa	5.0 GPa	2.5 GPa
Poisons ration	0.3	0.3	0.3
Shear strength	4.0+ $\sigma$ tan60° MPa	2.5+ $\sigma$ tan55° MPa	1.2+ $\sigma$ tan45° MPa

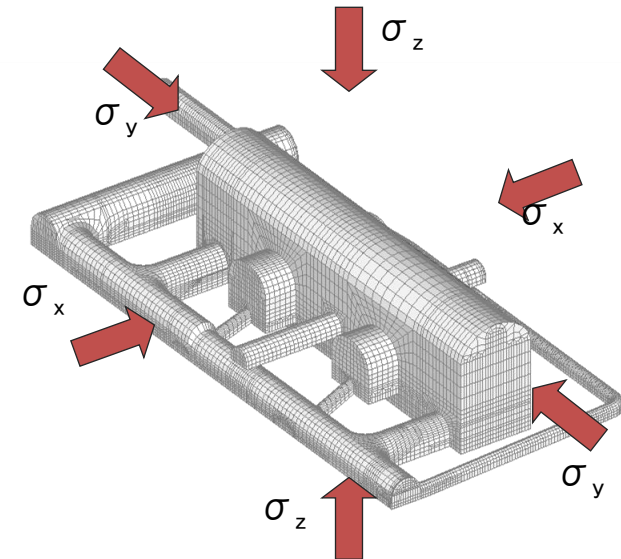
# Borehole logging test at investigation borehole near E/H site



# Ground stress

- Isotropic case but Anisotropic cases
  - Horizontal stress is larger than vertical stress in case of candidate site condition by some reports
- Desirable for E/H direction and max. principle stress direction are same

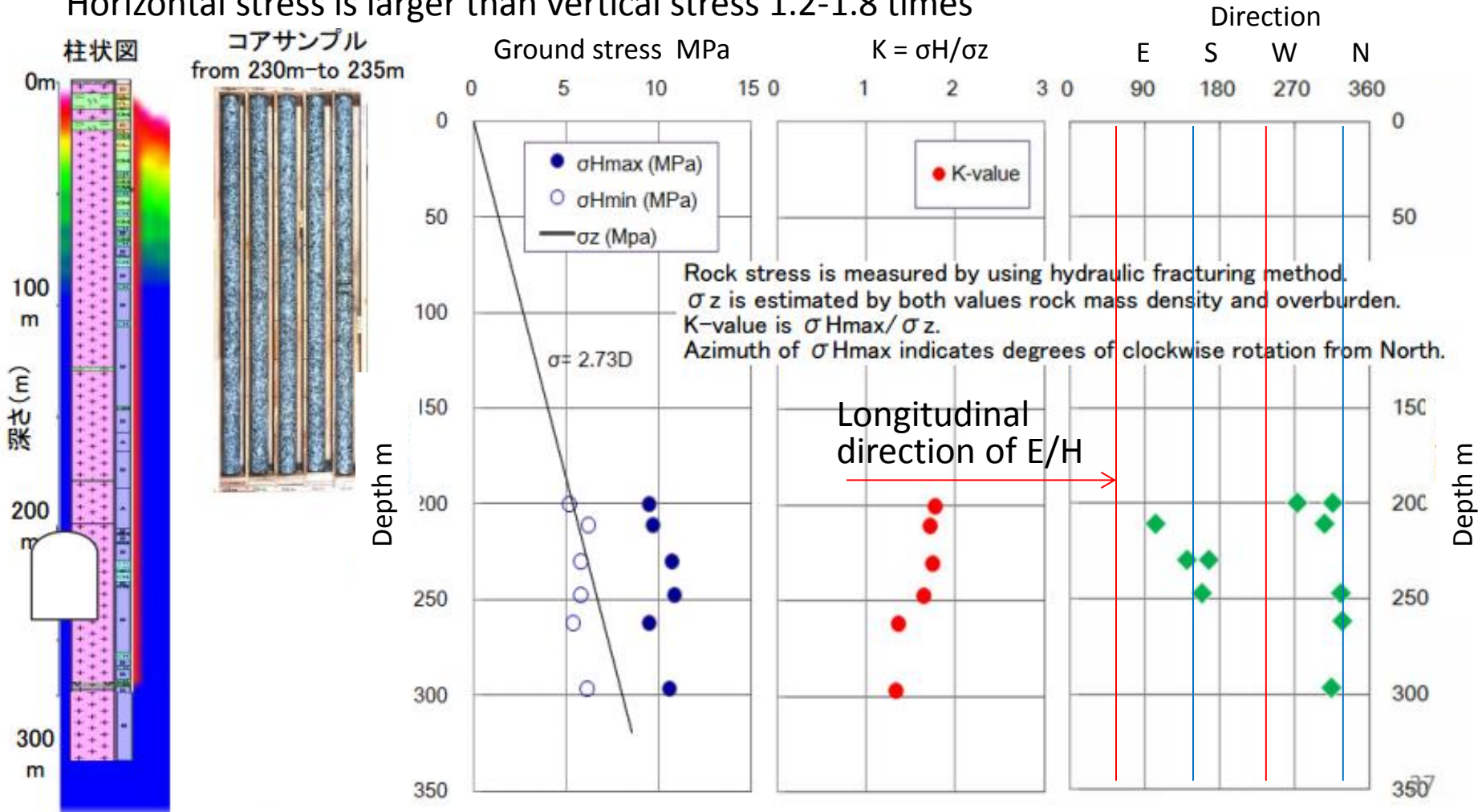
	Case	$\sigma_x$ Beam line	$\sigma_y$ E/H axis	$\sigma_z$ Vertical
Isotropic	Stress-A	1	1	1
Anisotropic	Stress-B	2	2	1
	Stress-C	2	1	1
	Stress-D	1	2	1





# Ground stress test at investigation borehole near E/H site

Horizontal stress is larger than vertical stress 1.2-1.8 times





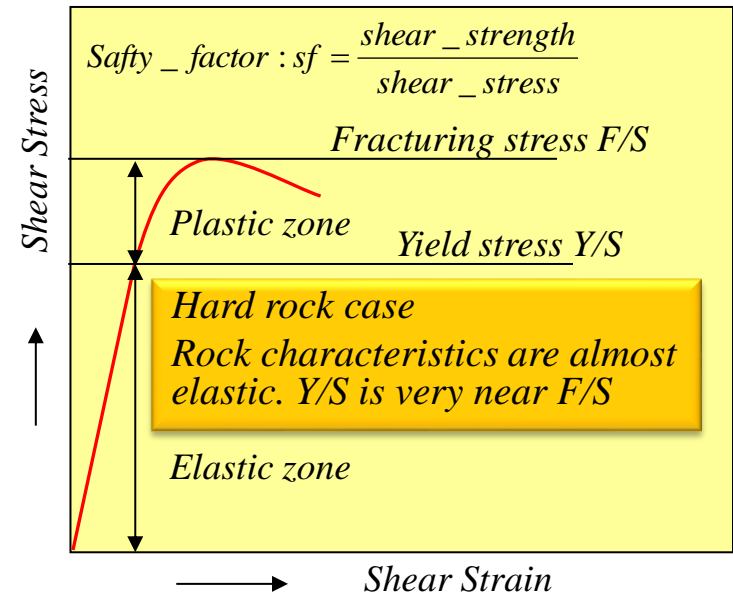
# Loosened zone around cavern

Loosening around cavern is caused by stress releasing and blasting.

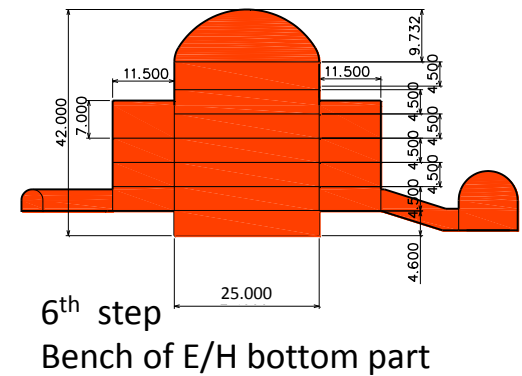
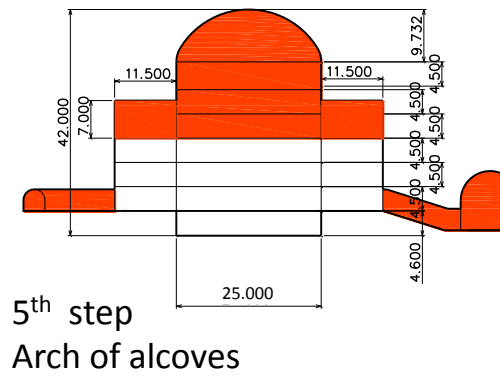
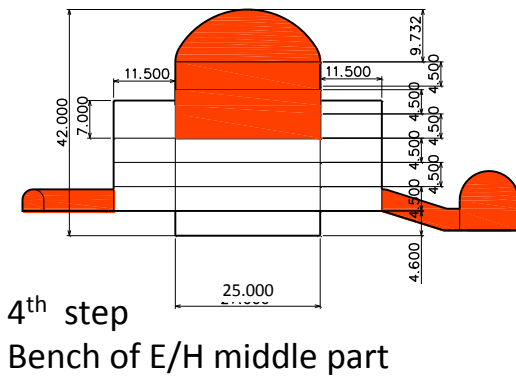
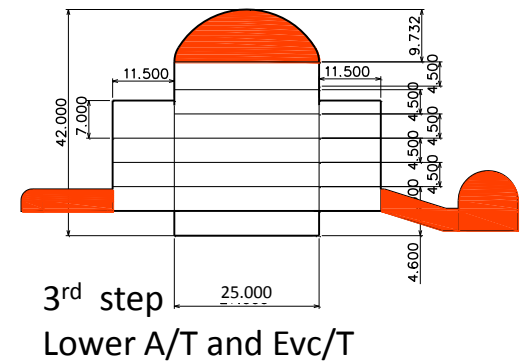
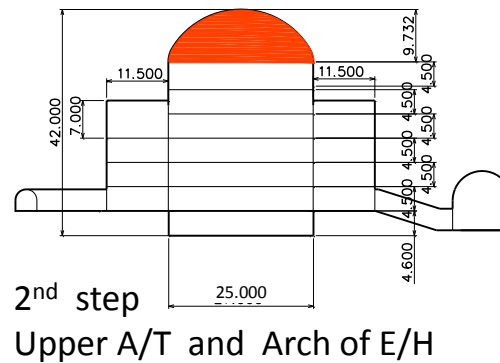
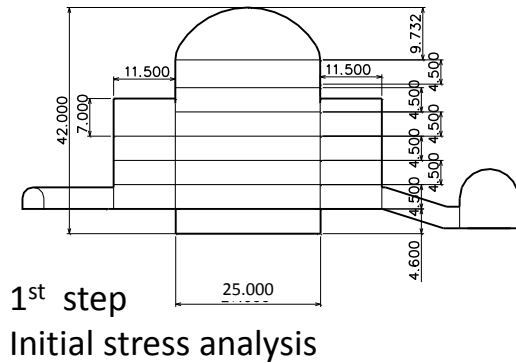
notes	
Blasting	Usually 1-2m from cavern surface Controlled blasting methods <ul style="list-style-type: none"> <li>- Presplit blasting</li> <li>- Smooth blasting</li> <li>- Cushion blasting</li> </ul>
Stress releasing	Depend on <ul style="list-style-type: none"> <li>- Cavern size</li> <li>- Rock properties</li> <li>- Initial stress</li> </ul>

In case of large cavern, loosened area by stress releasing is wider.

Definition of loosened zone by stress releasing  
 Loosened zone  $1.0 < sf. < 1.2$   
 plastic not elastic  
 Fractured zone  $Sf. < 1.0$



# Excavation procedure (Bench program)

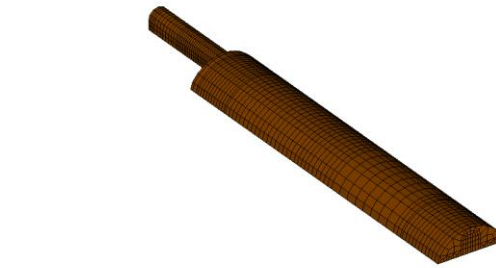


Excavation analysis is by six steps as shown on a figure, to roughly understand the variation of stress and deformation on each step.

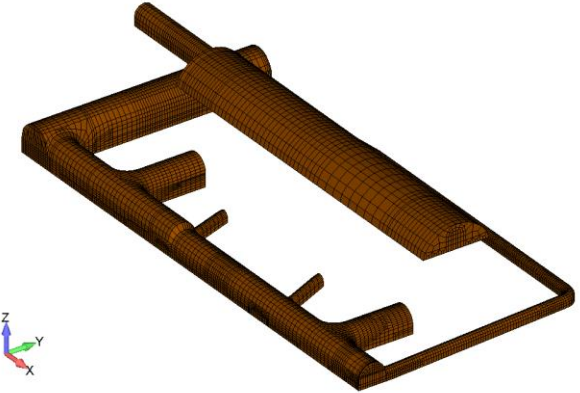
Actual excavation procedure will be more complicated.

# Excavation procedure (Bench program)

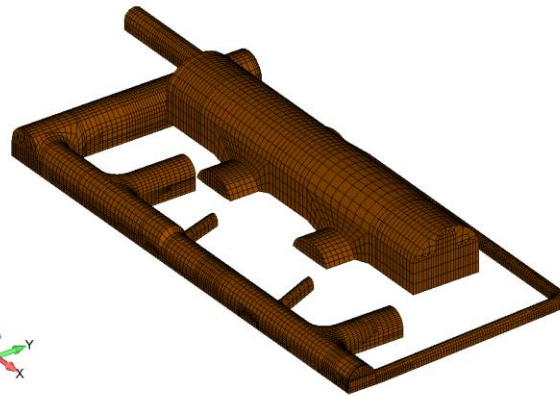
1<sup>st</sup> step  
Initial stress analysis



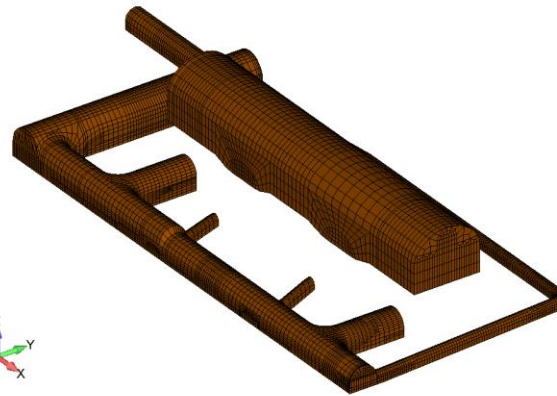
2<sup>nd</sup> step  
Upper A/T and Arch of E/H



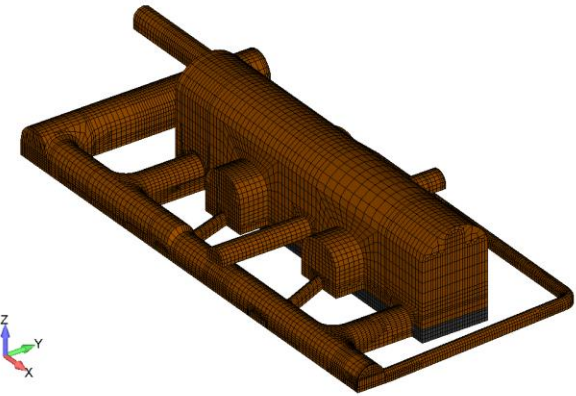
3<sup>rd</sup> step  
Lower A/T and Evc/T



4<sup>th</sup> step  
Bench of E/H middle part

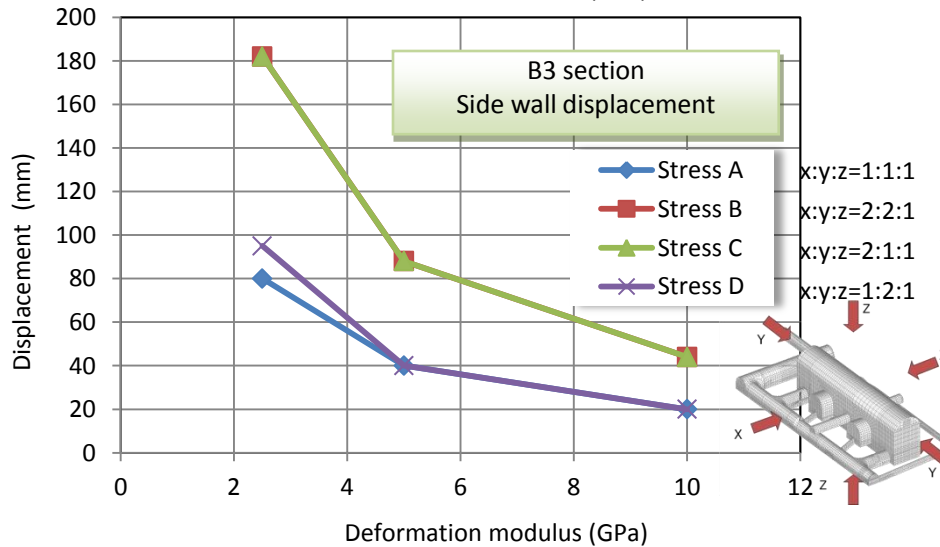
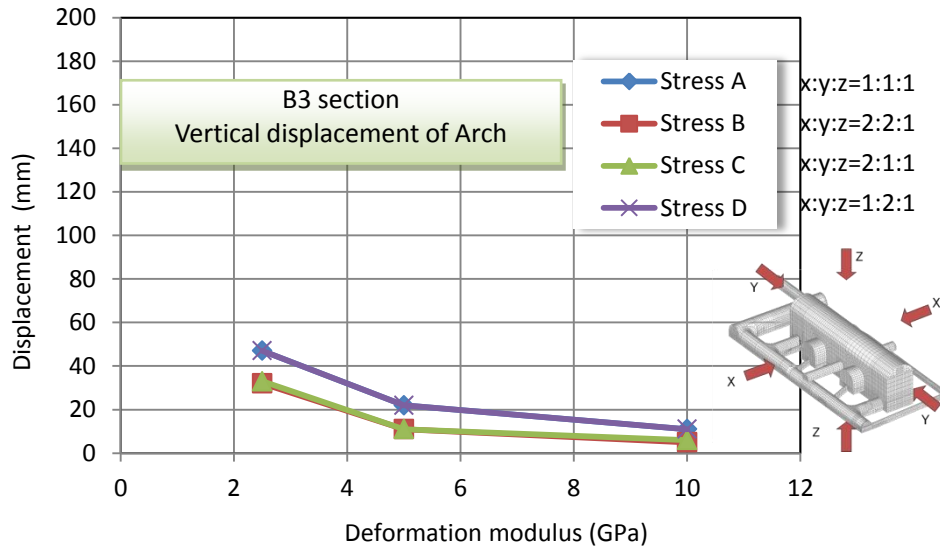


5<sup>th</sup> step  
Arch of alcoves

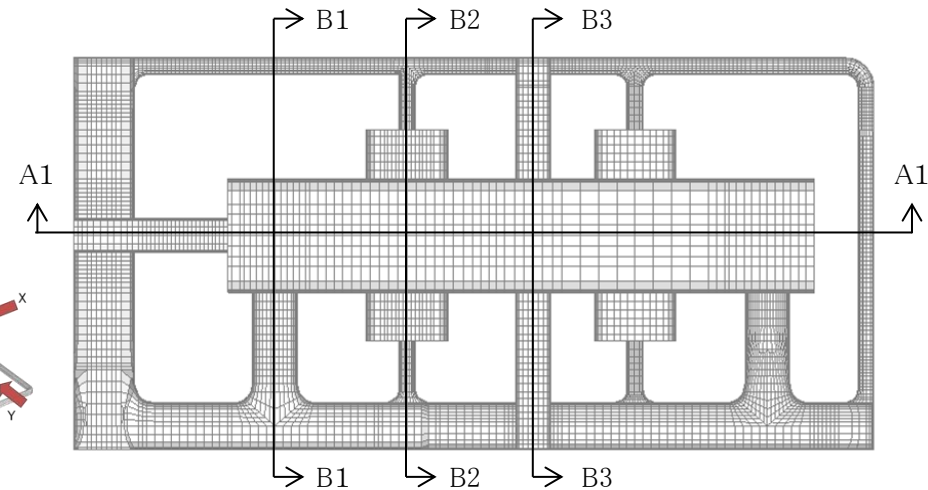


6<sup>th</sup> step  
Bench of E/H bottom part

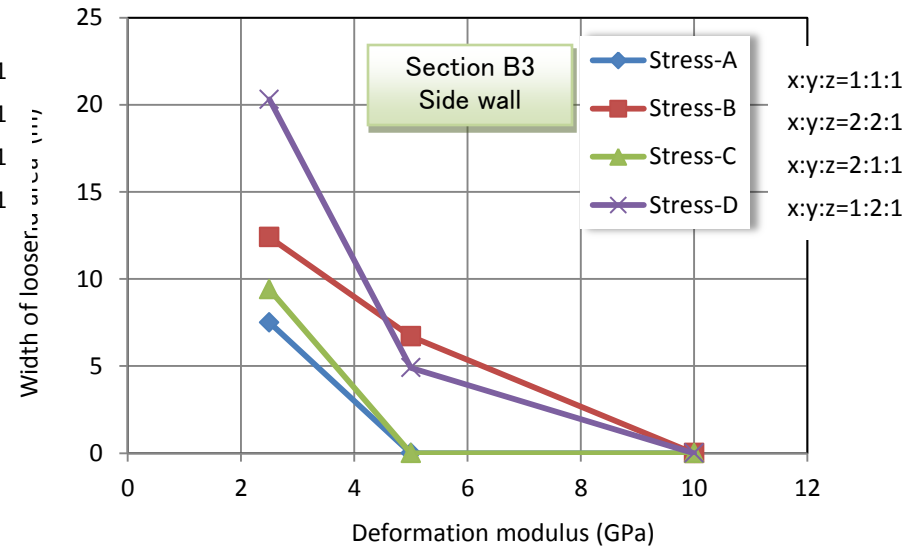
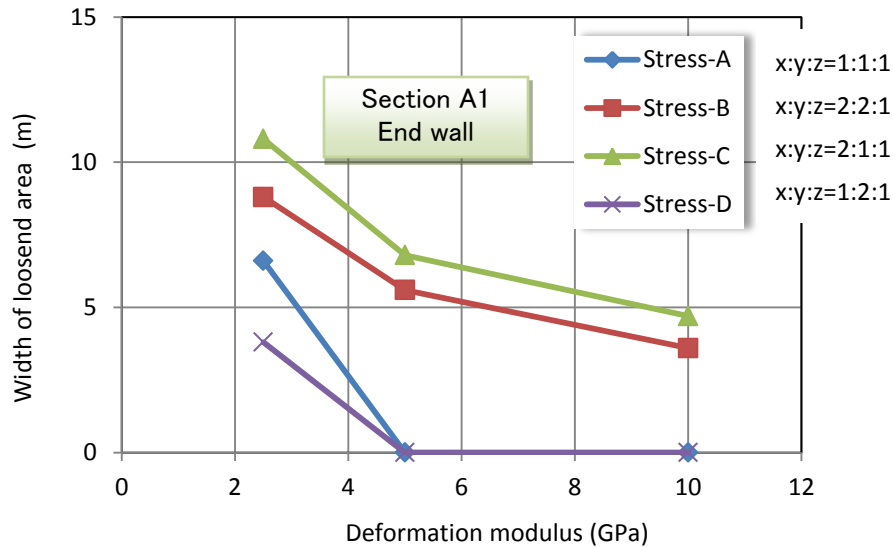
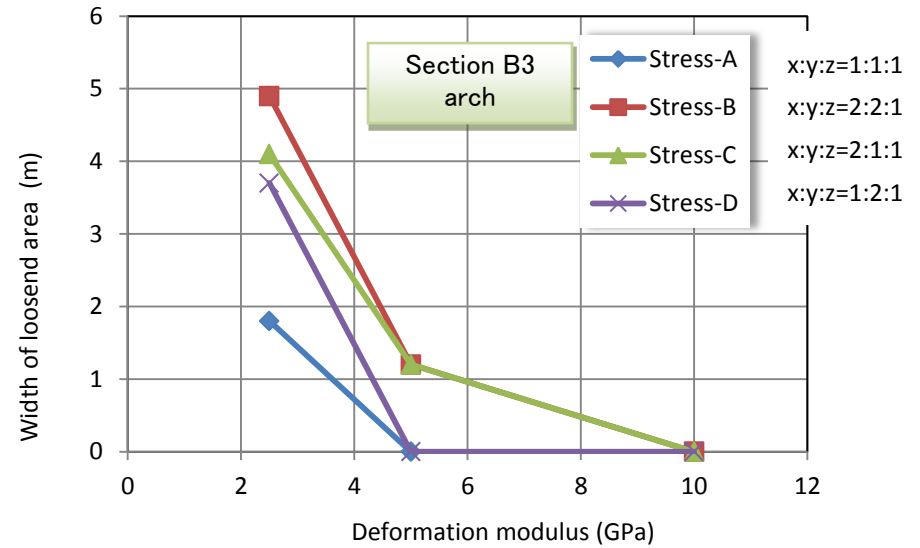
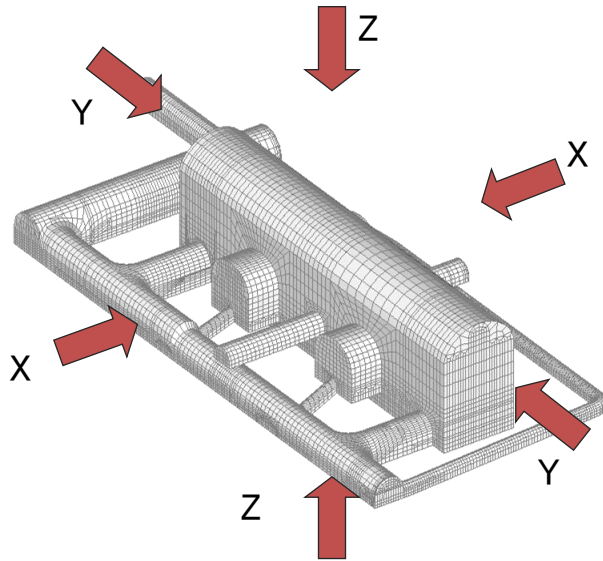
# Displacement



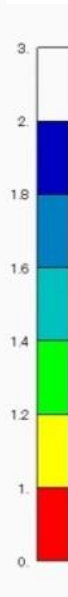
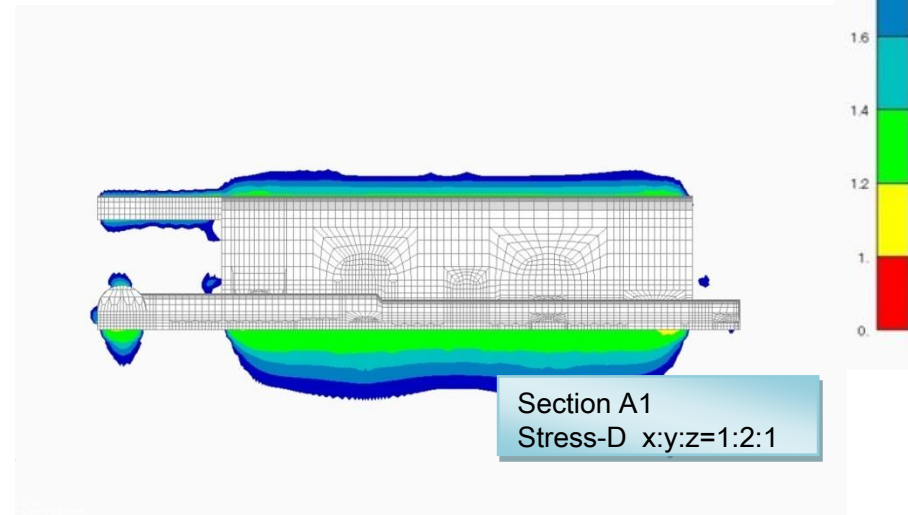
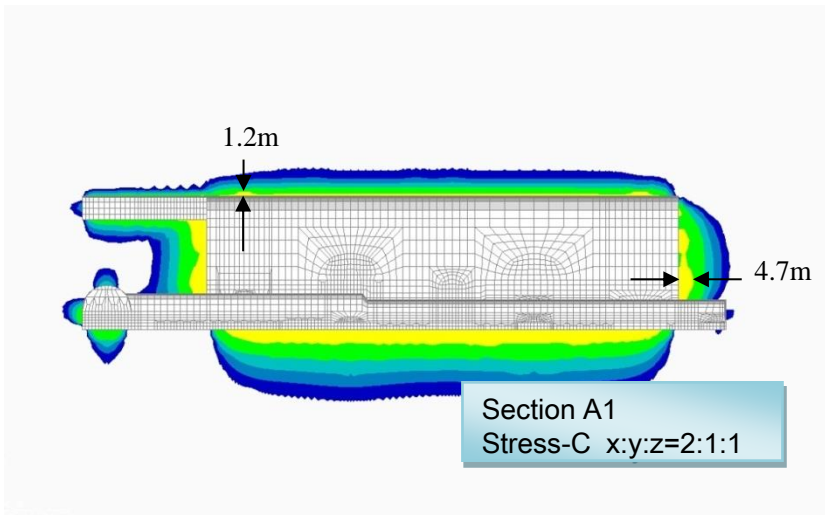
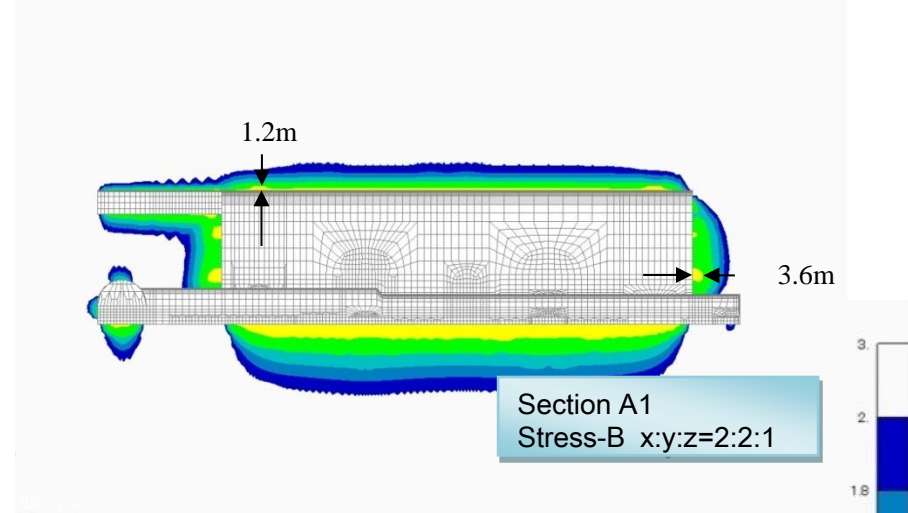
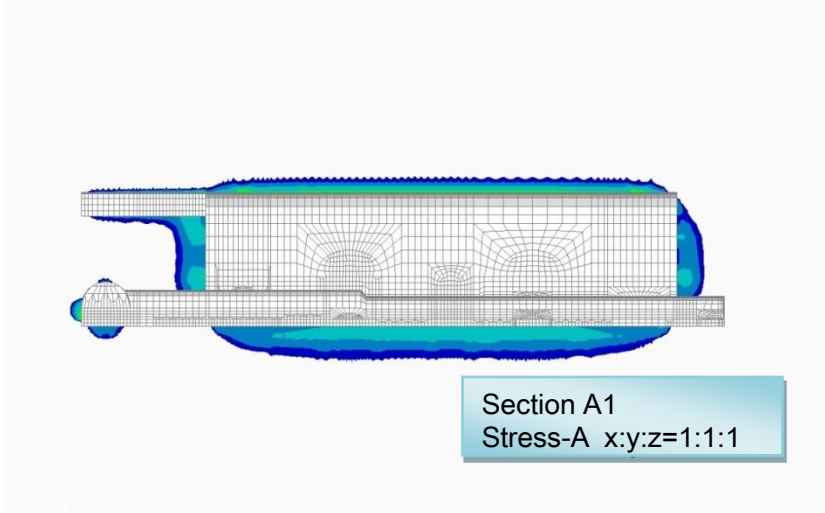
- In case of stress B and C, side wall displacement will be larger relatively.
- Because ground stress of cross section direction is larger.
- But displacements in good rock condition are absolutely small in each case.



# Distribution of loosened zone

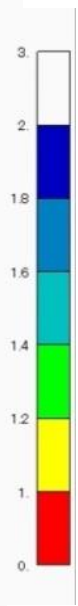
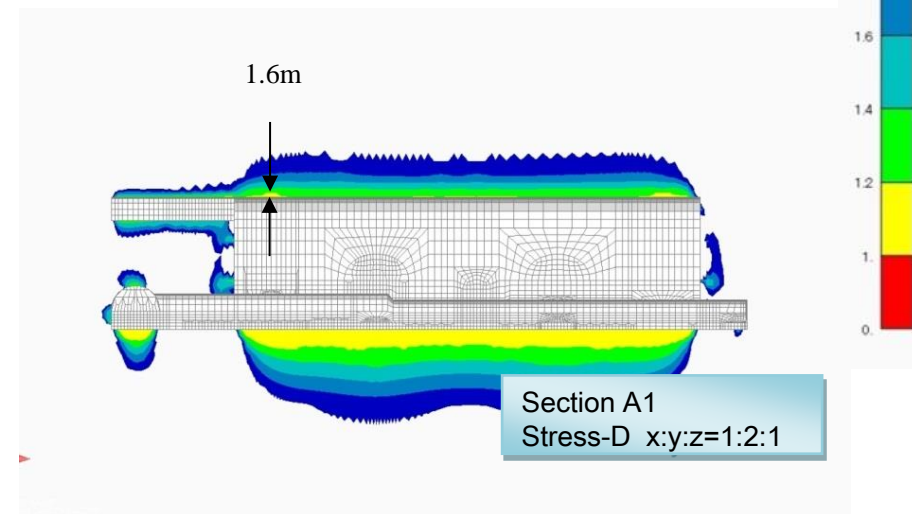
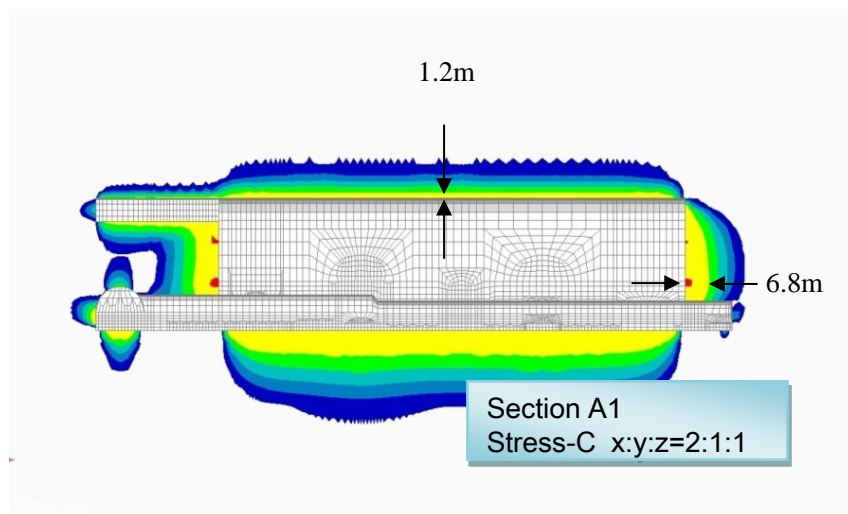
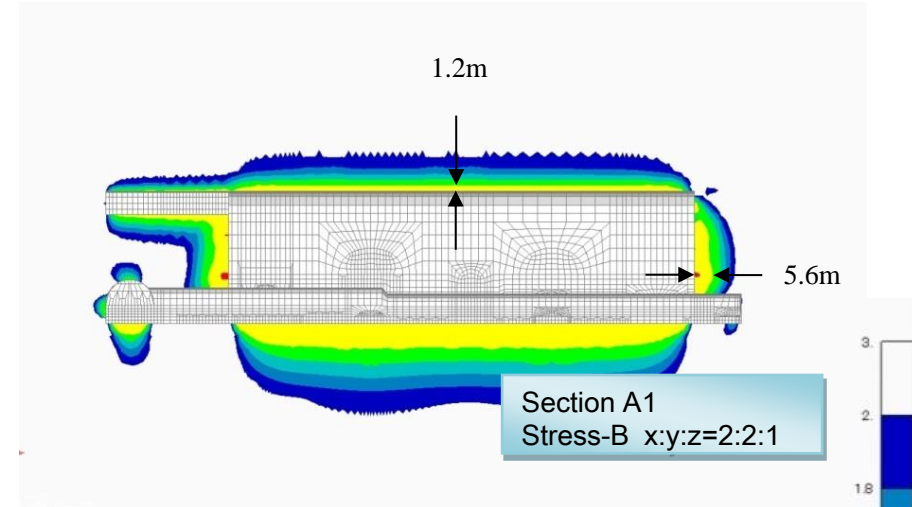
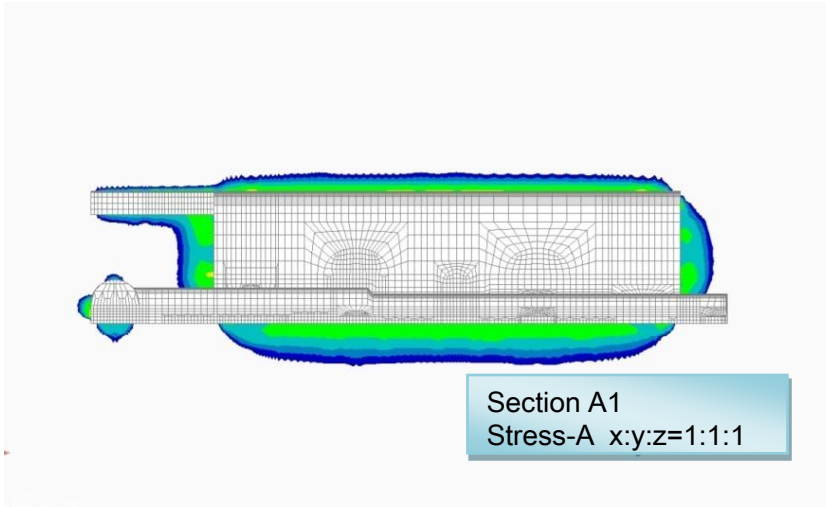


# Loosened zone / Section A1 / H-class



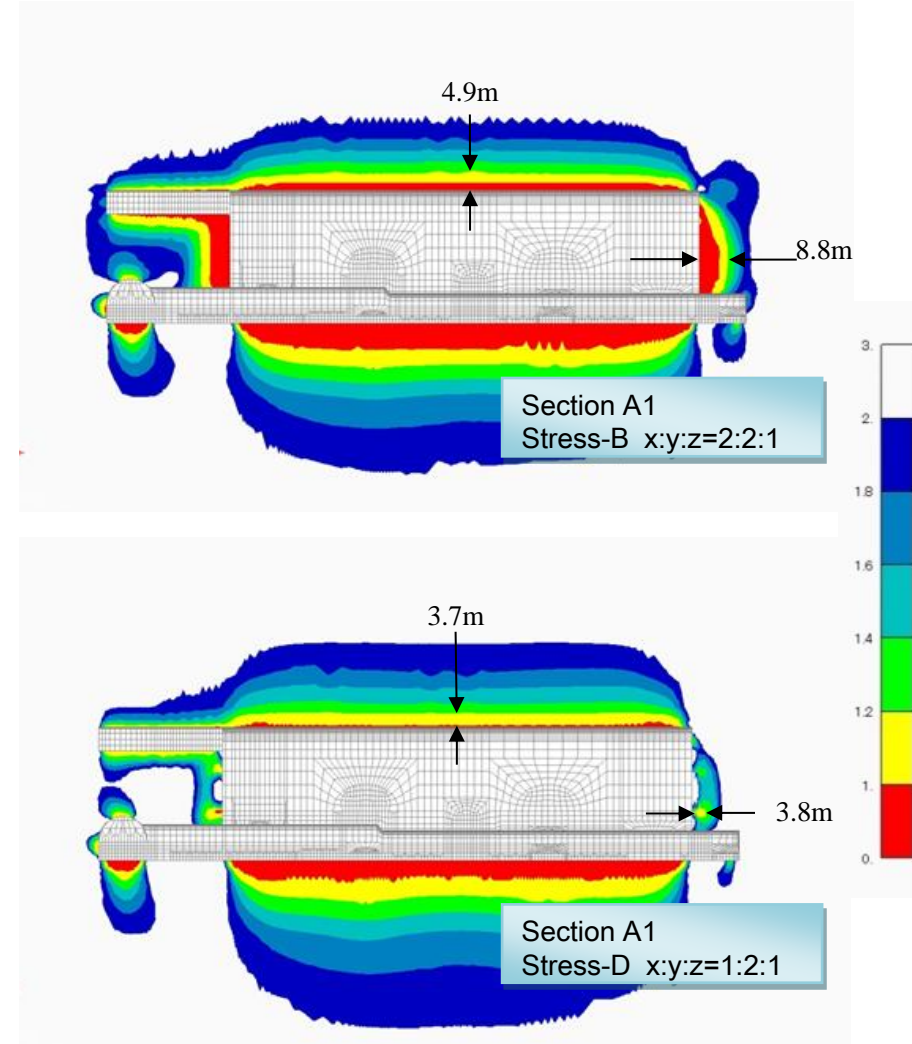
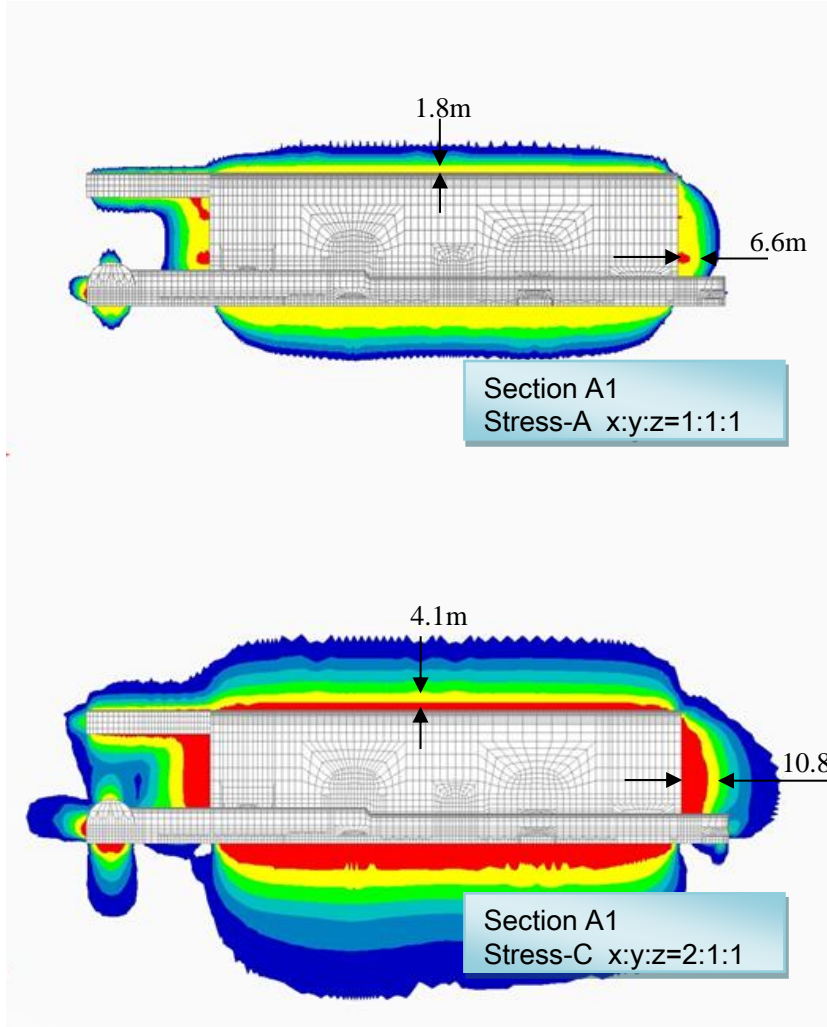


# Loosened zone / Section A1 / M-class

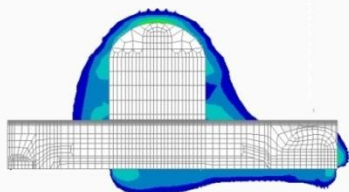




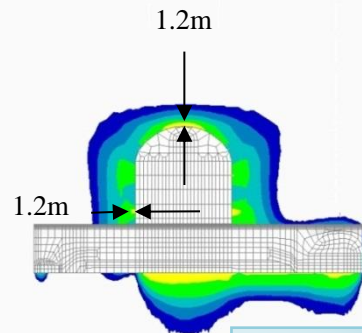
# Loosened zone / Section A1 / L-class



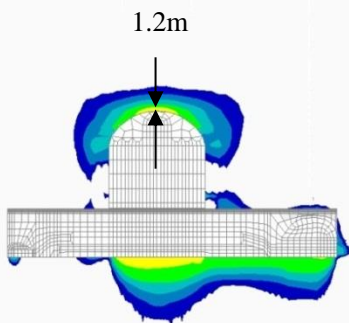
# Loosened zone / Section B1 / H-class



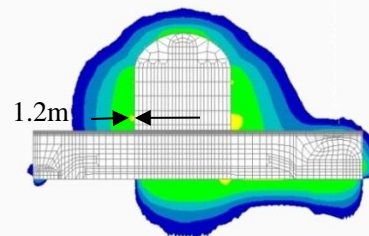
Section B1  
Stress A x:y:z=1:1:1



Section B1  
Stress B x:y:z=2:2:1



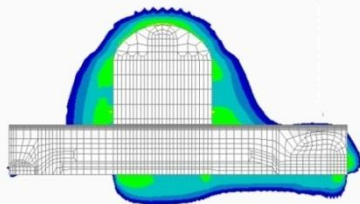
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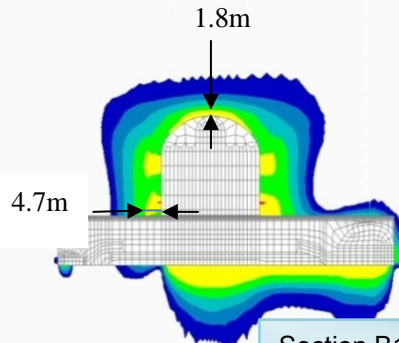
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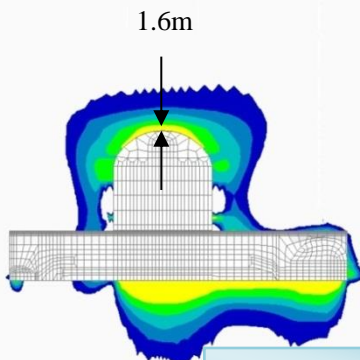
# Loosened zone / Section B1 / M-class



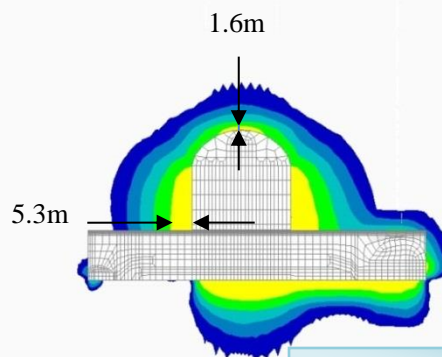
Section B1  
Stress A x:y:z=1:1:1



Section B1  
Stress B x:y:z=2:2:1



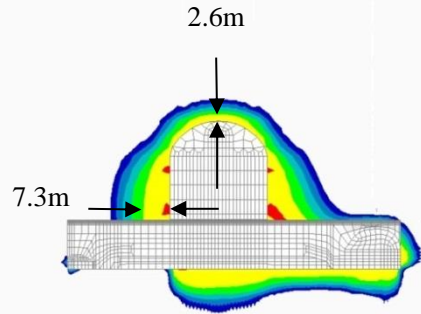
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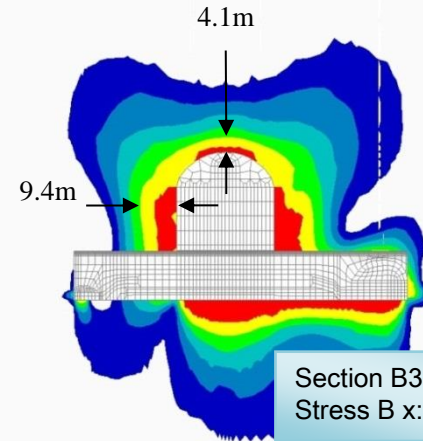
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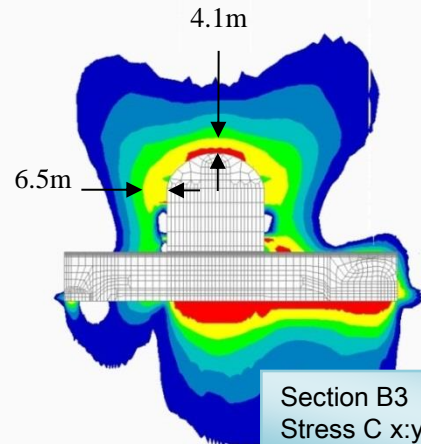
# Loosened zone / Section B1 / L-class



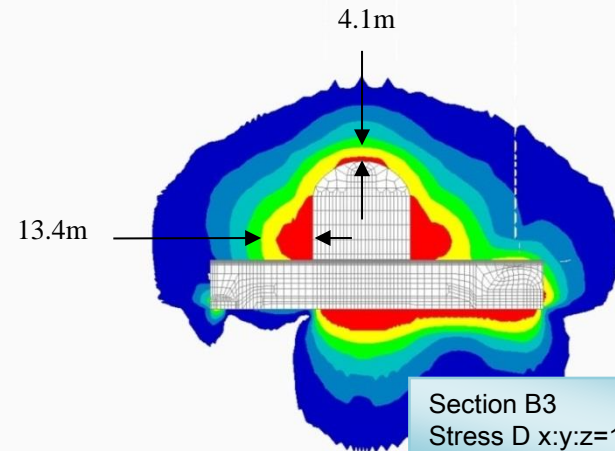
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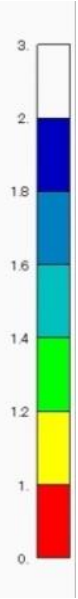
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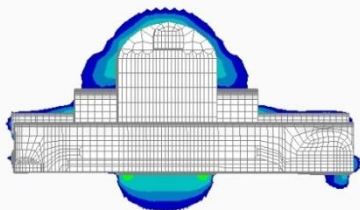
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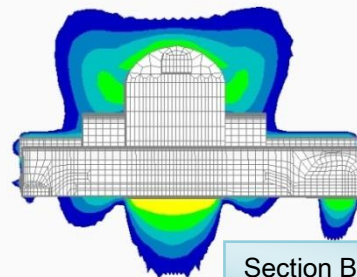
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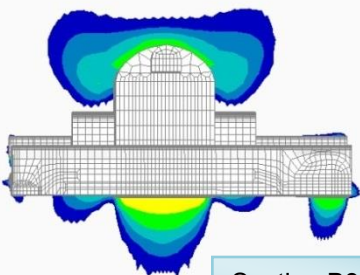
# Loosened zone / Section B3 / H-class



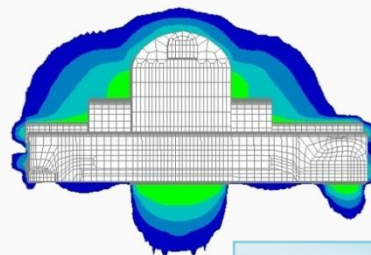
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Section B3  
Stress B x:y:z=2:2:1



Section B3  
Stress C x:y:z=2:1:1

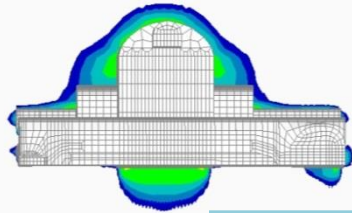


Section B3  
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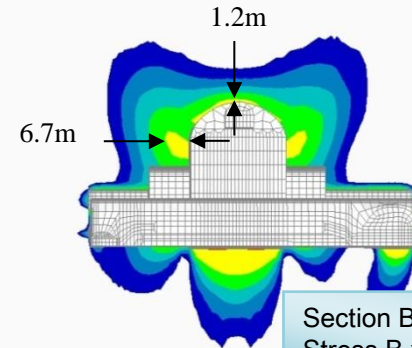




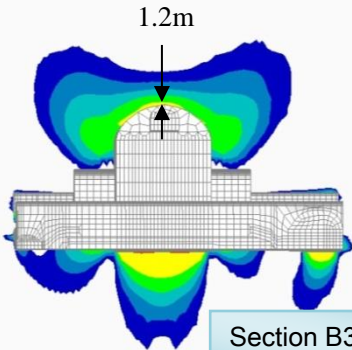
# Loosened zone / Section B3 / M-class



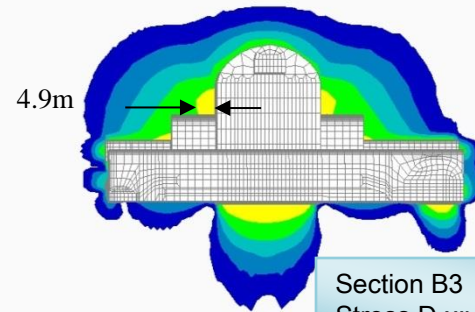
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Section B3  
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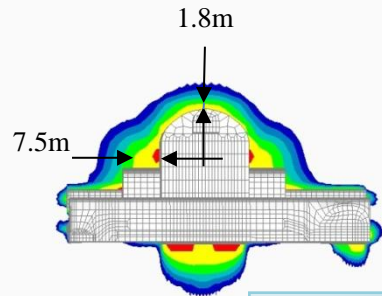
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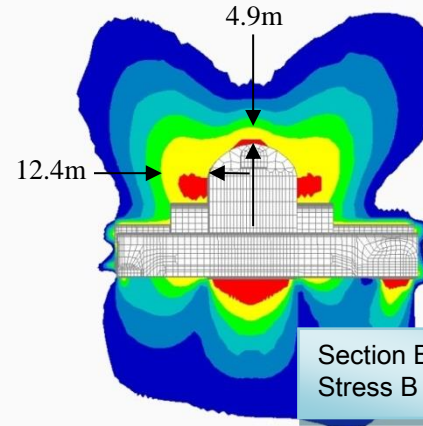
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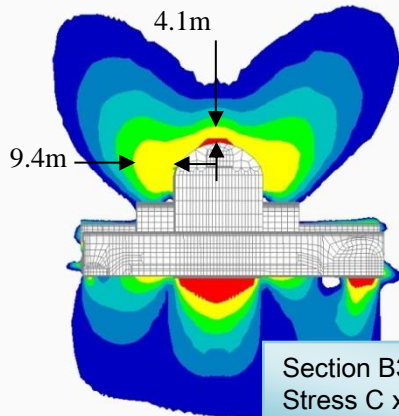
# Loosened zone / Section B3 / L-class



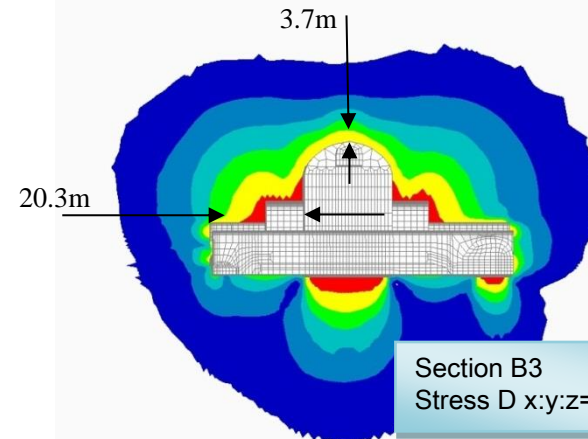
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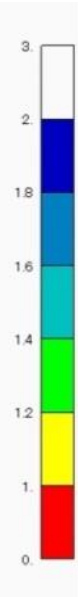
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Section B3  
Stress C x:y:z=2:1:1



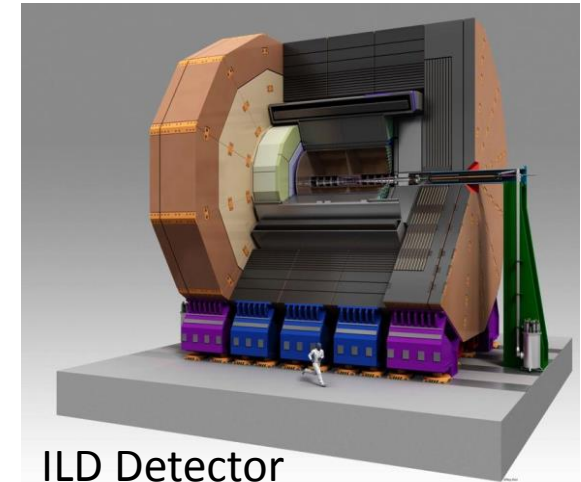
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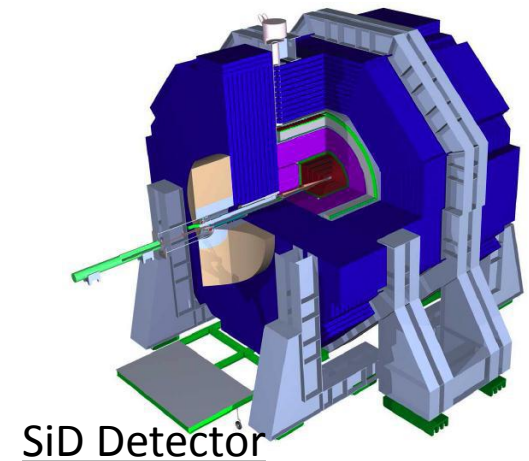


# Analysis conditions

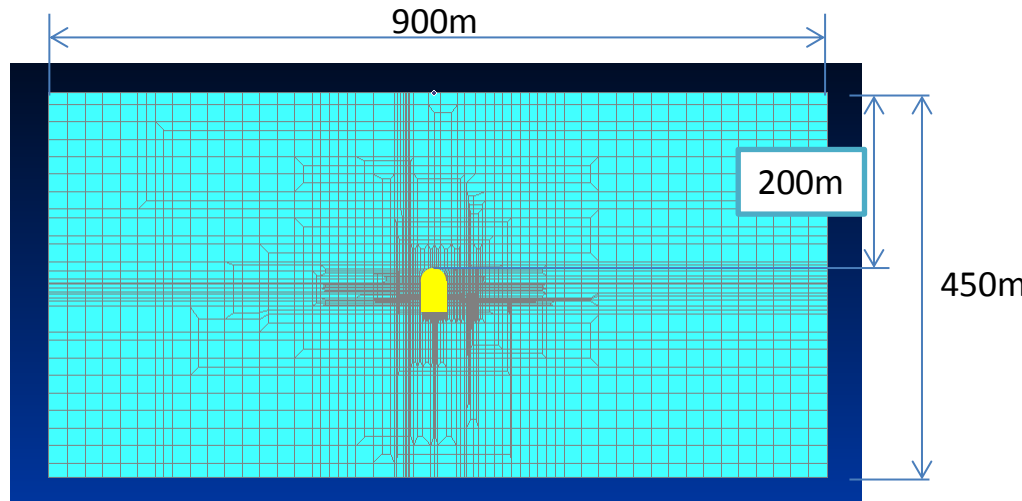
- Estimation of displacement distribution around E/H by installing or push-pulling Detectors.
- Rock mass deformation modulus : 5 GPa
- Analysis method : 3D Elastic FEM analysis
- Displacement is inversely proportional to deformation modulus because of elastic analysis.
- Model size :
  - H450m x W900 x L900m
  - Overburden : 200m



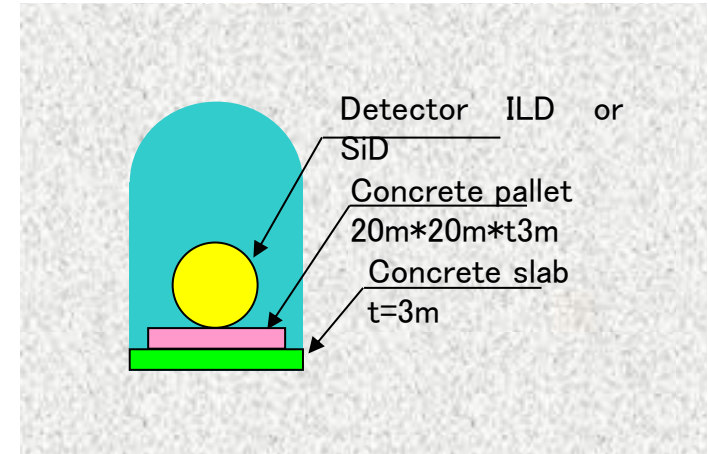
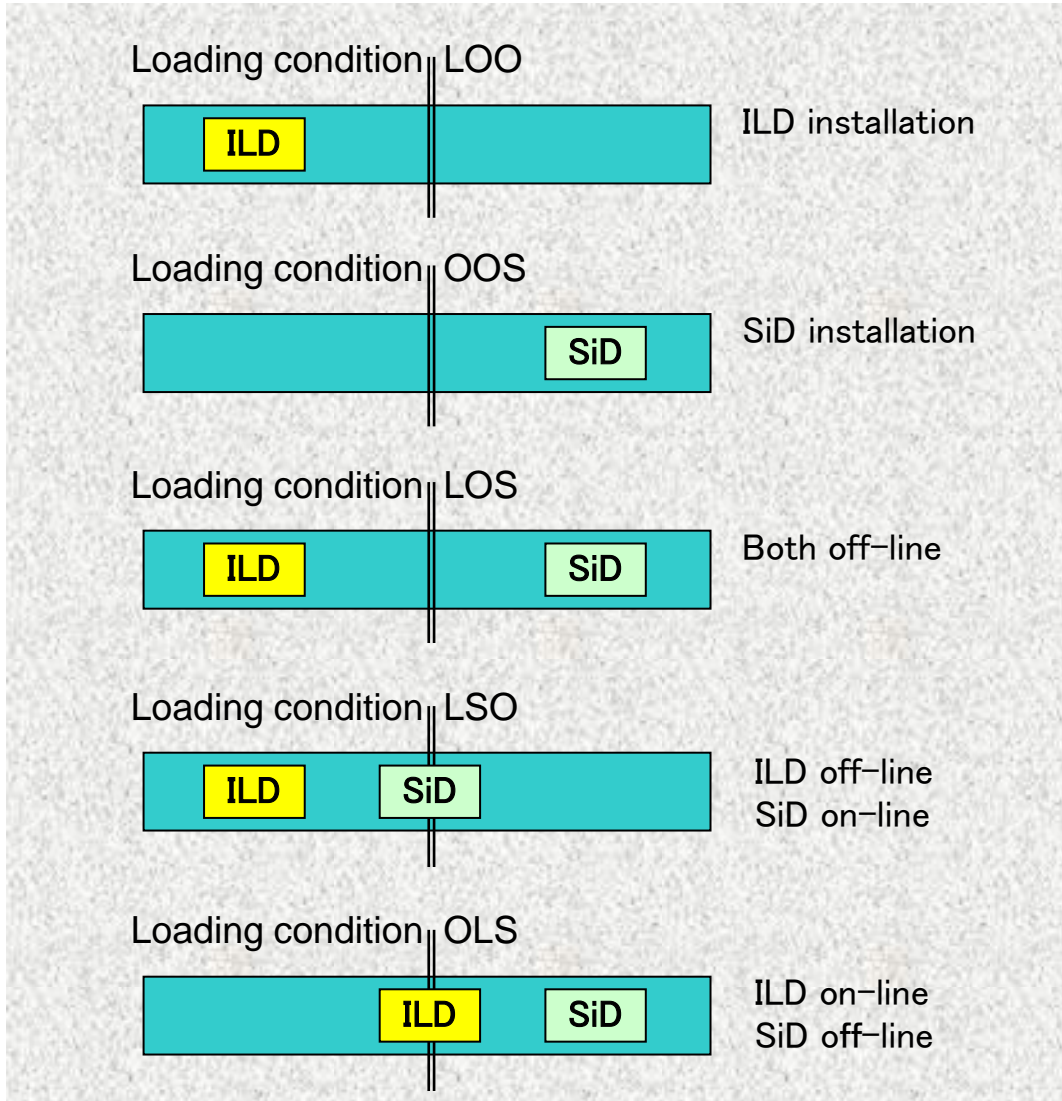
ILD Detector



SiD Detector



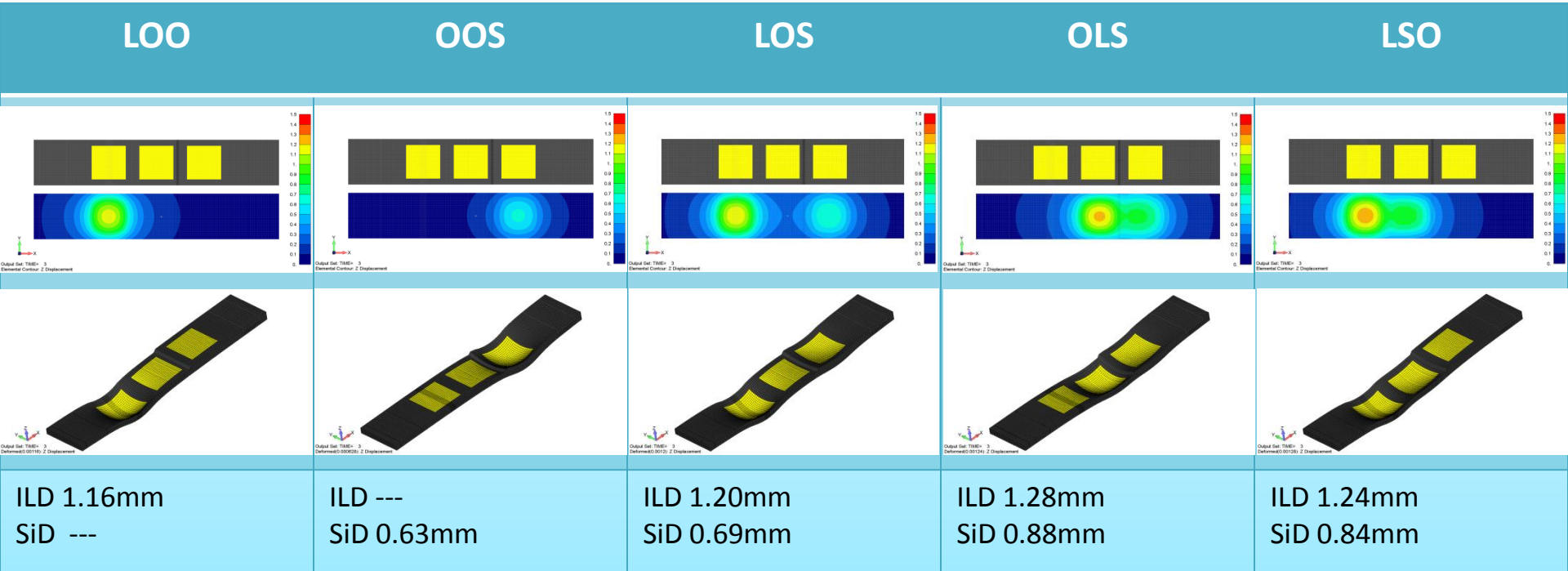
# Subject 2 : Loading condition (Detector position)



ILD weight : 15,000 tons  
 SiD weight : 10,000 tons

- Detectors are installed on concrete pallets.
- Thickness of concrete pallets are assumed as 3m.
- Detector weight are loaded on the pallet as a uniformly-distributed load

# Base concrete slab displacement by placing detectors

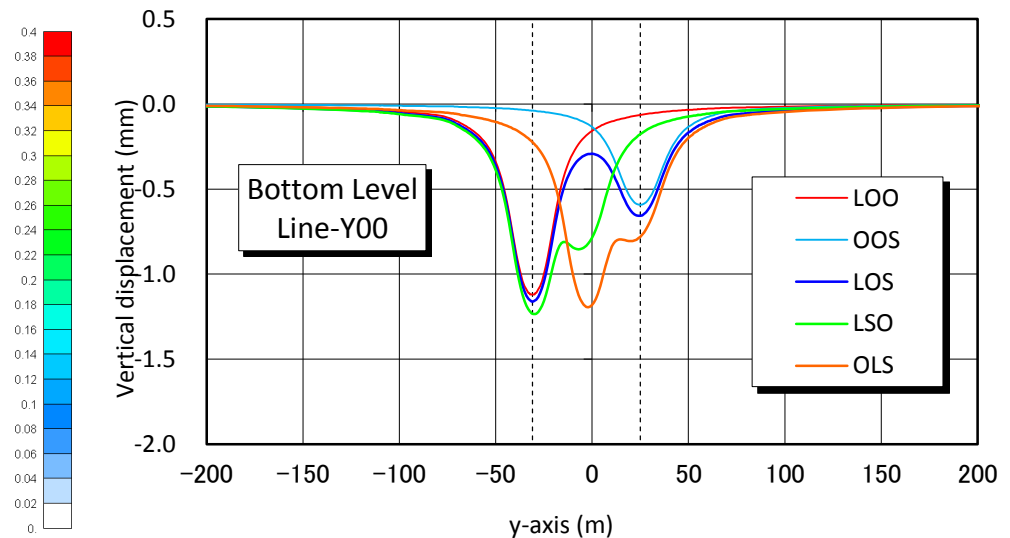
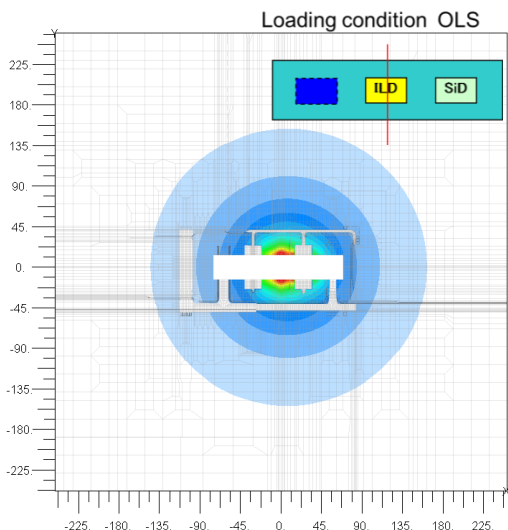
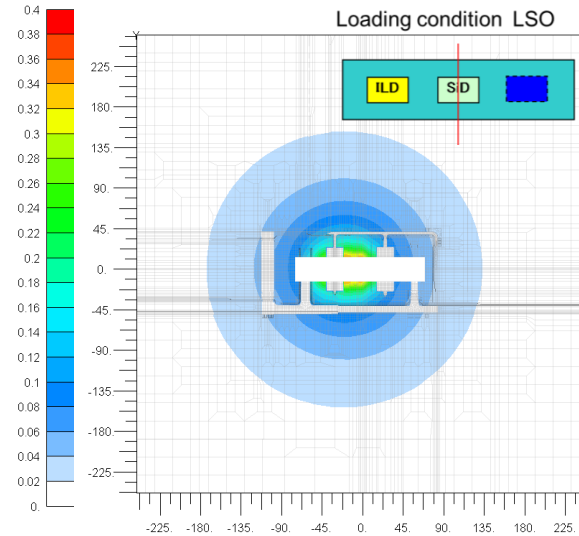
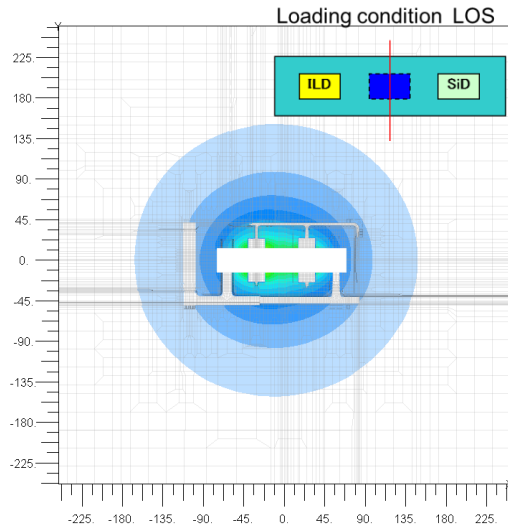


Max displacement of ILD is 1.28mm, “OLS” case : ILD online case

Max displacement of SiD is 0.84mm, “LSO” case : SiD online case

Rock mass Deformation modulus : 5GPa  
Concrete Young’s modulus :25GPa

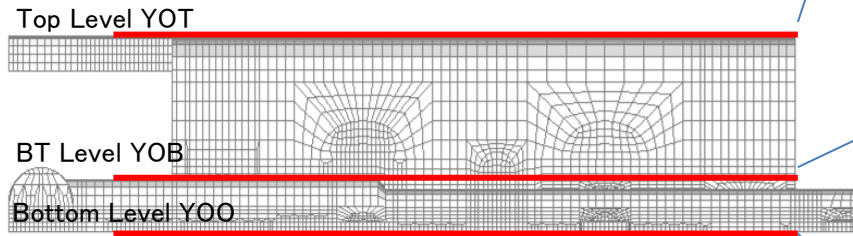
# Displacement distribution of E/H bottom level



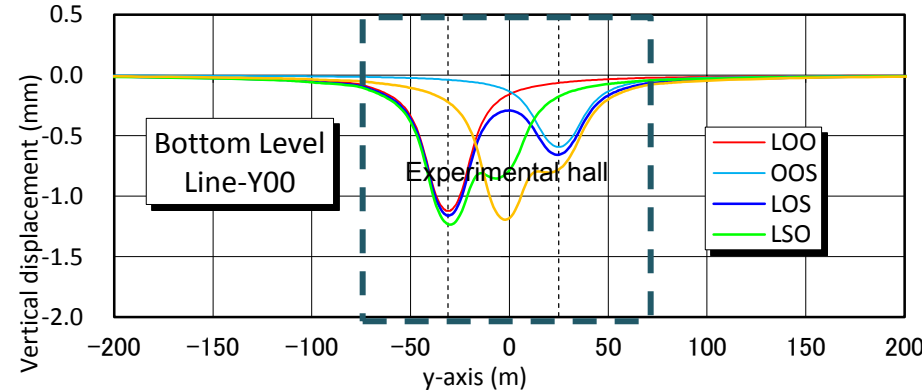
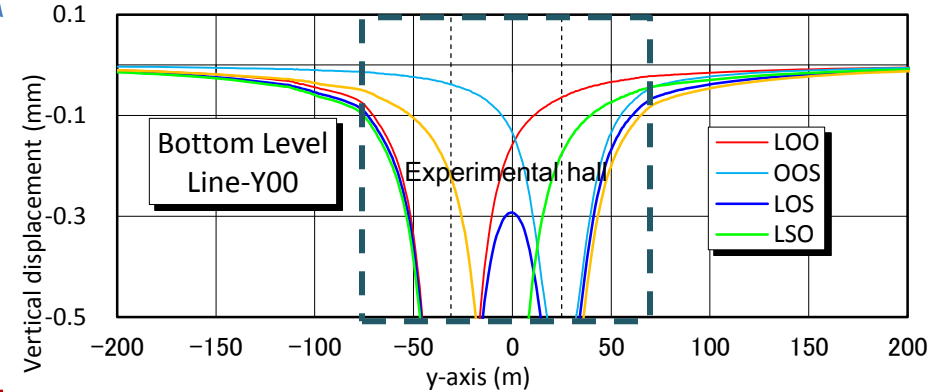
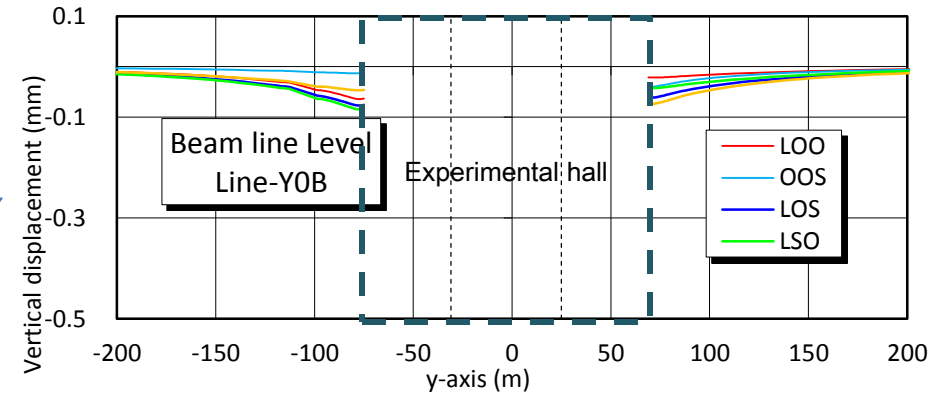
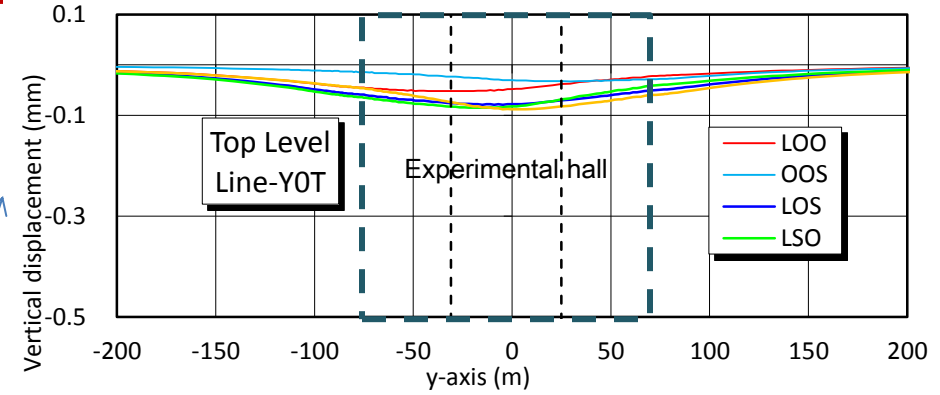
# Vertical displacement distribution at each level

Bottom level displacement is larger  
Displacement outside E/H is almost same

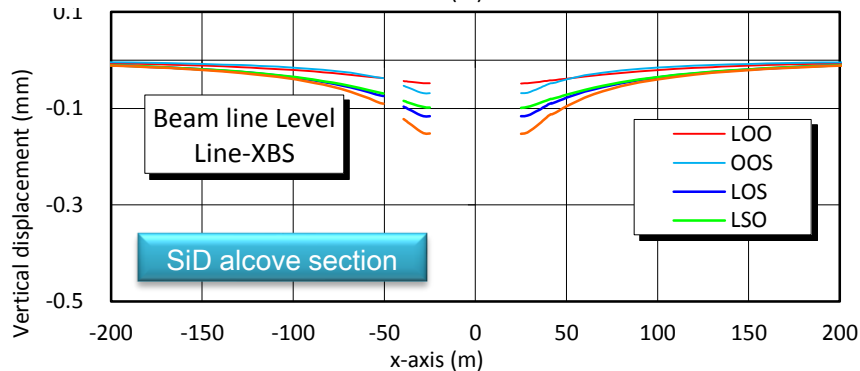
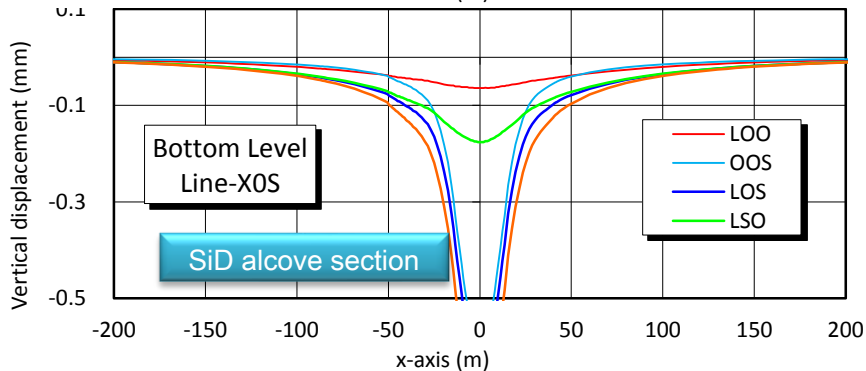
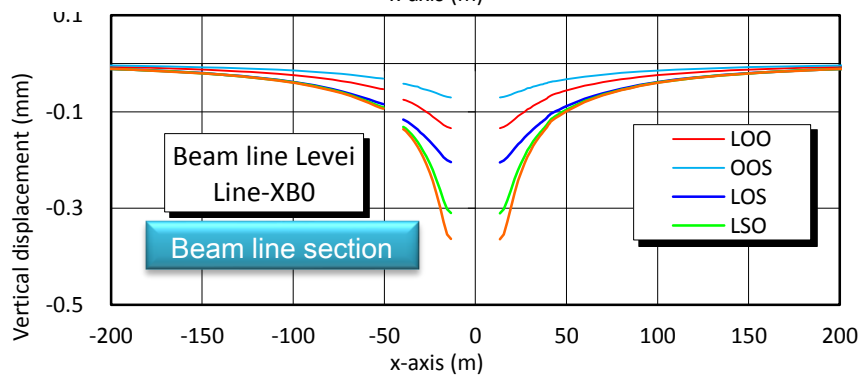
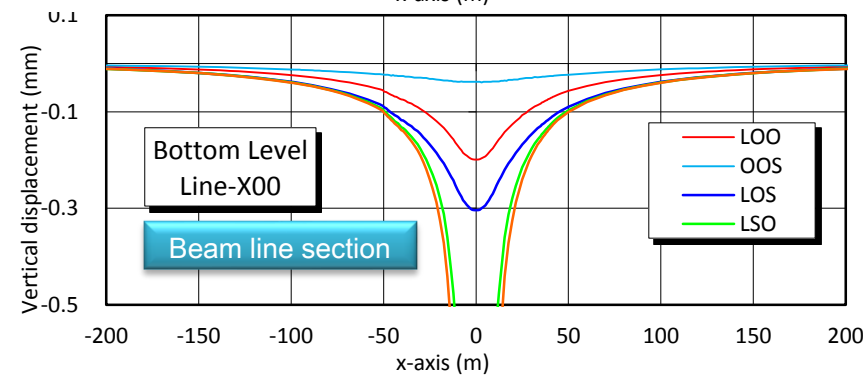
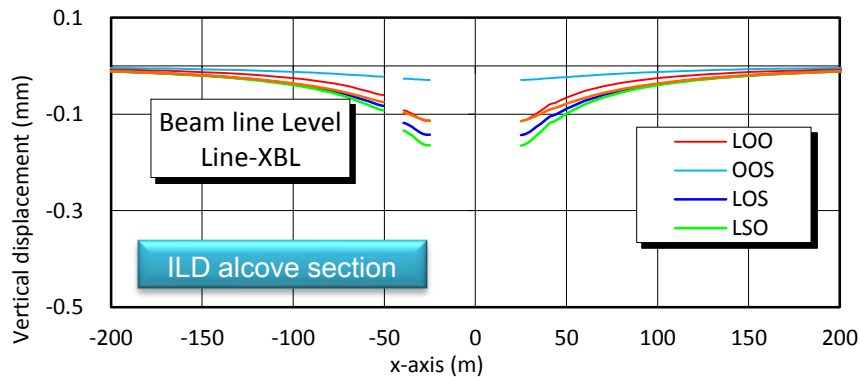
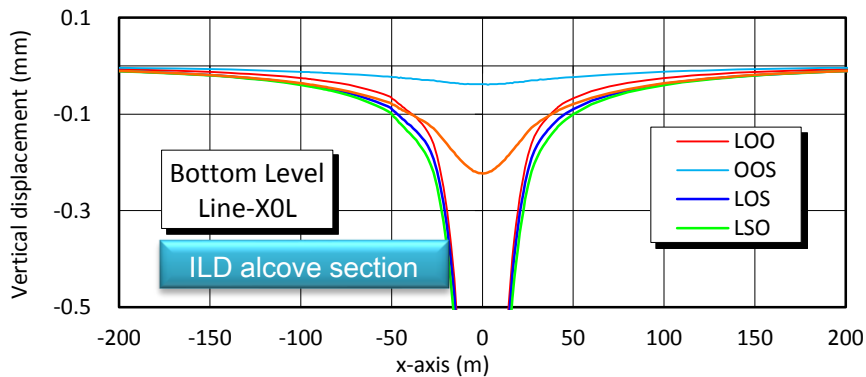
Deformation modulus : 5GPa



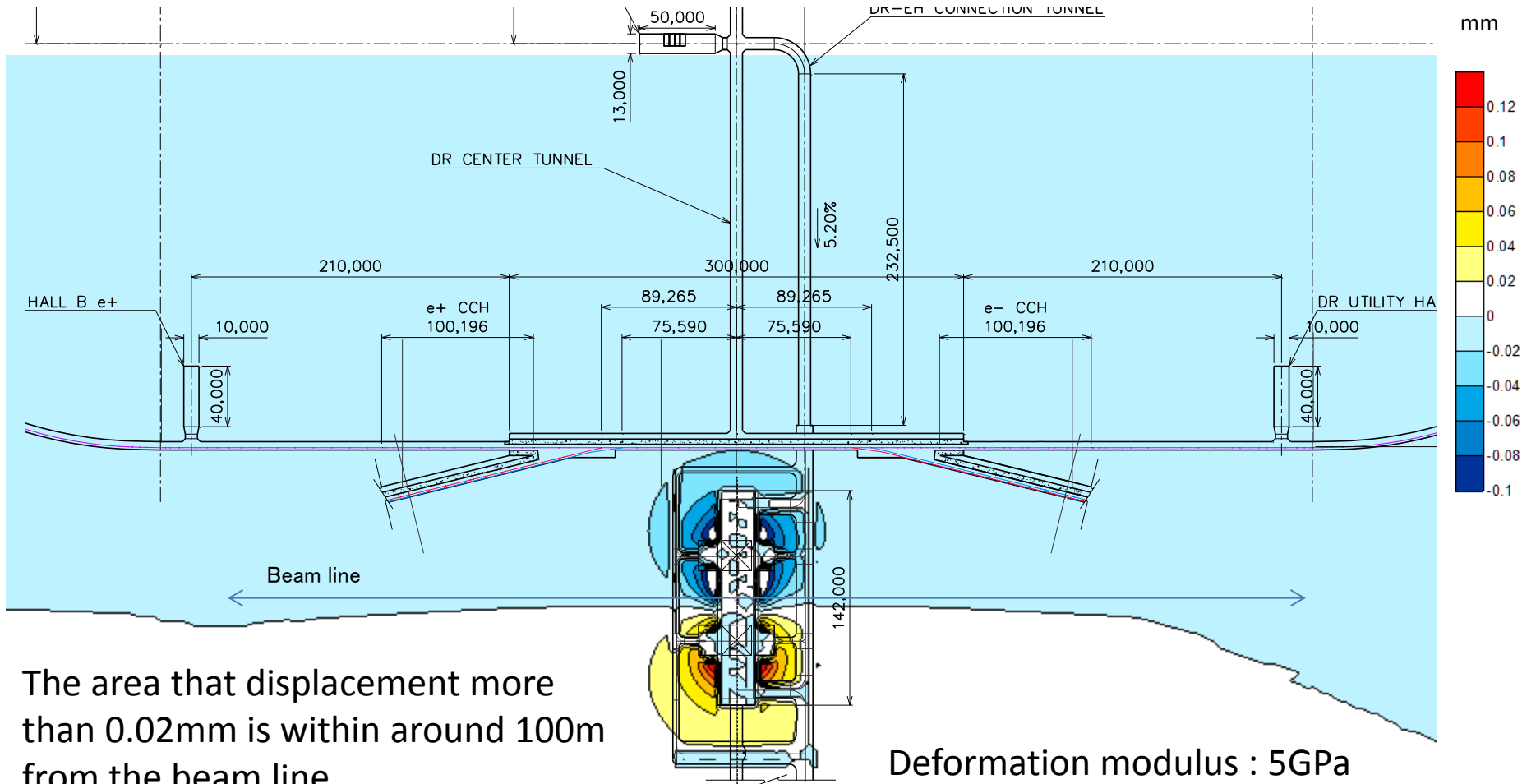
## Study 2 : Displacement by Detectors movement



# Vertical displacement distribution at each cross section



# Relative displacement between "LSO" and "OLS" at Beam line elevation



The area that displacement more than 0.02mm is within around 100m from the beam line.