



Enforcement of a research reactor facility under earthquake conditions

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PSI

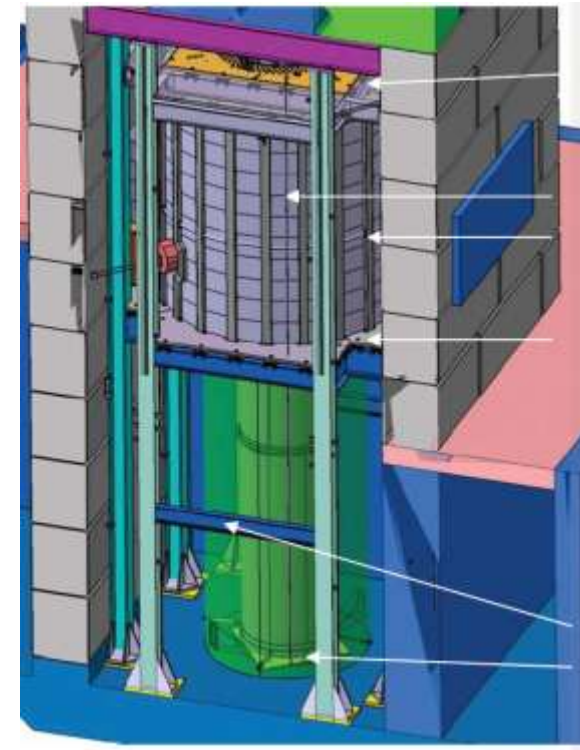


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Introduction

Overview

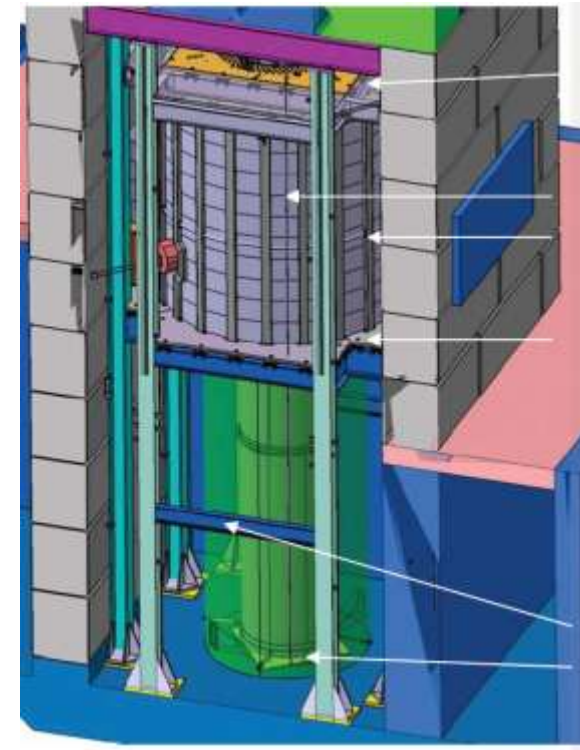
- A research reactor facility has to withstand an earthquake
 - No damage to radiation shielding
 - Built-in components do not fail
 - No deformation to guide bushes of control rods
 - Acceleration at the fuel elements below critical value
- RADIOSS calculation
 - Estimation of the damage to an intended facility design
 - Computation of necessary enforcement



Introduction

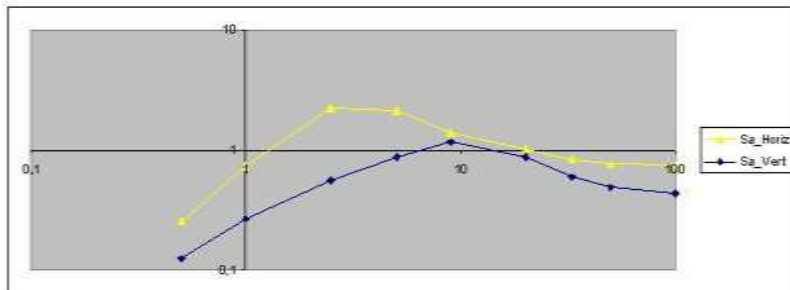
Outline

- Introduction
- Earthquake design spectrum
- Initial geometry model
- Damage analysis of the *initial* model
- Proposed modifications
- Damage analysis of the *modified* model
- Conclusion

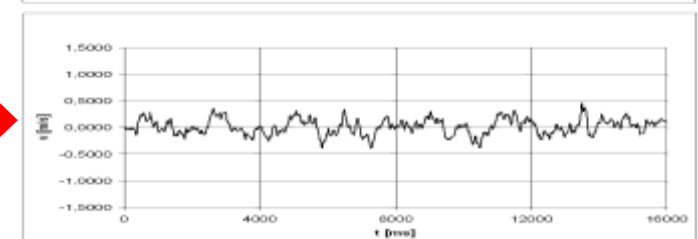
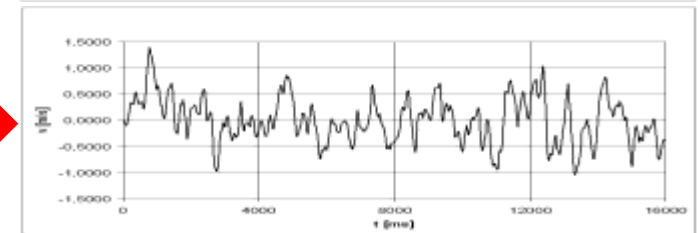
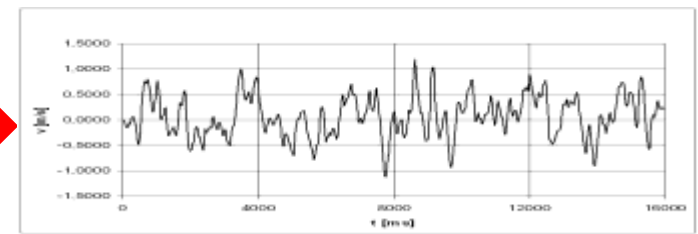
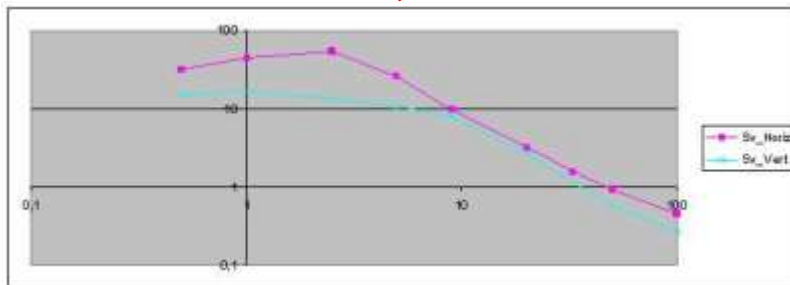


Earthquake design spectrum

- Earthquake with an occurrence probability of **10^{-6} per year**
- Maximum acceleration in the ground response spectrum is around **2 g**
- Earthquake duration is **20 s**
- Design spectrum transformed into velocity time history by SIMQKE

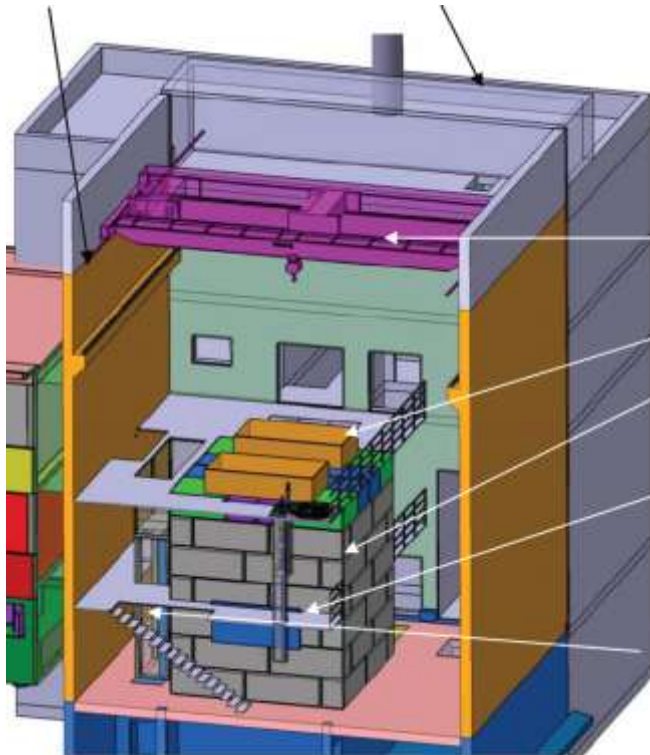


$$S_v = S_a / \omega$$

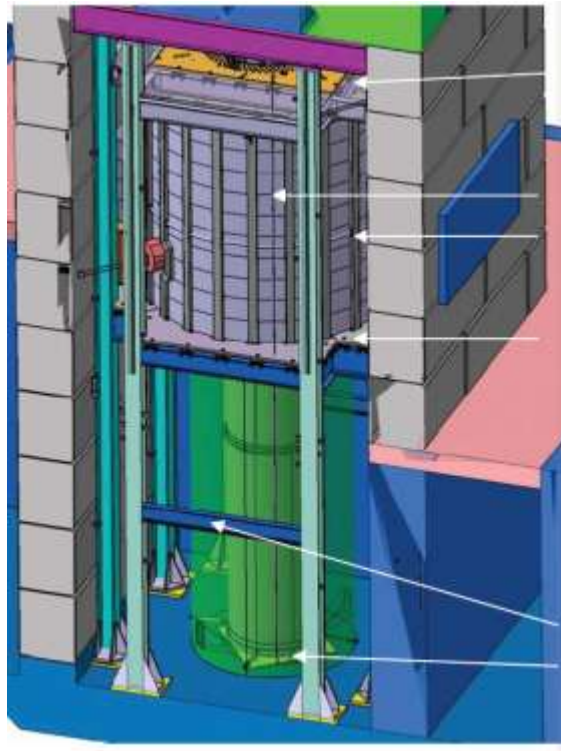


Initial geometry model

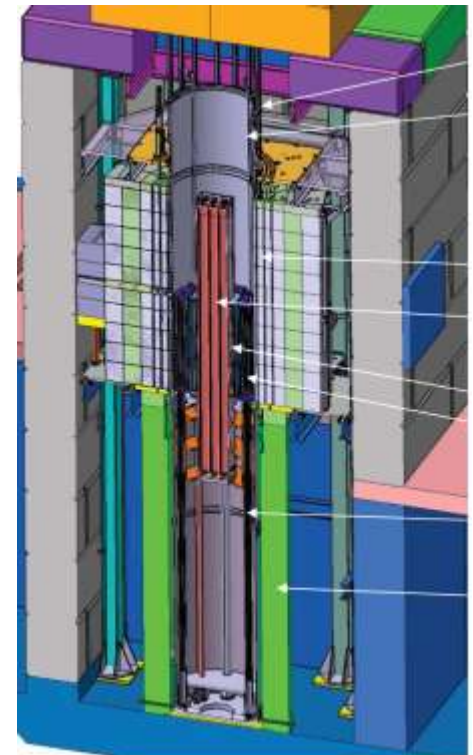
- The initial reactor geometry is as follows:



Reactor building



Reactor shielding

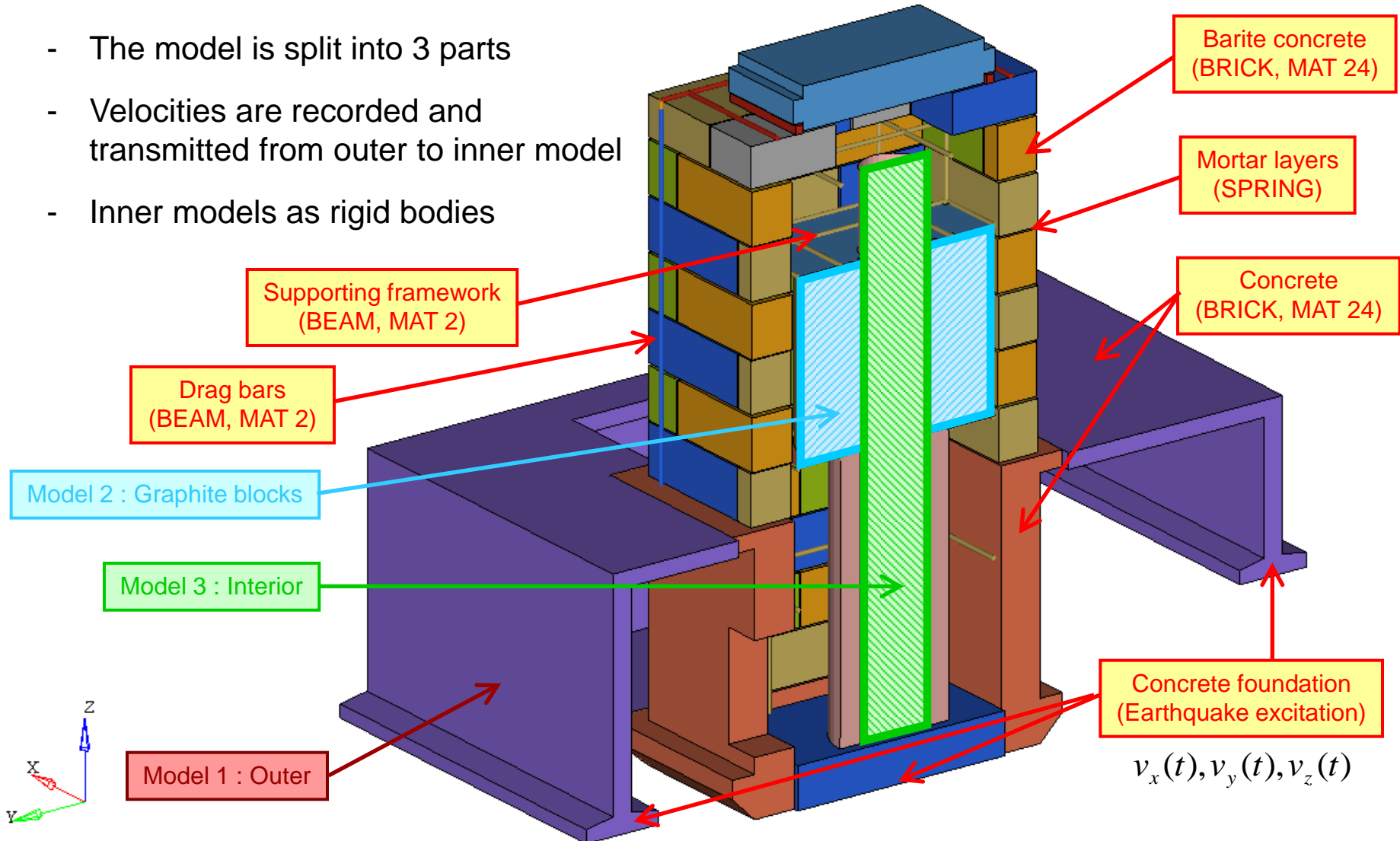


Interior

Initial geometry model

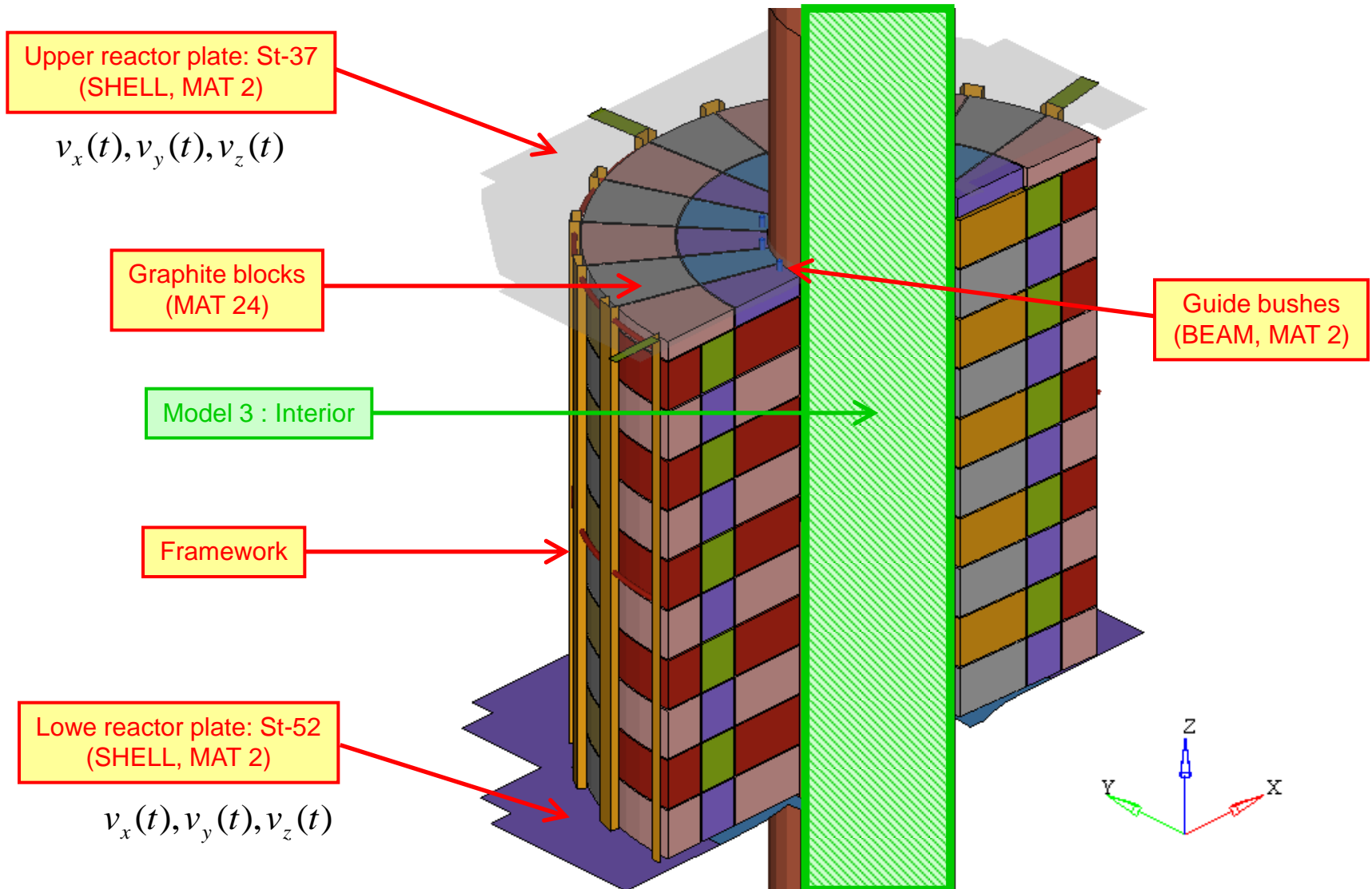
Building & Shielding

- The model is split into 3 parts
- Velocities are recorded and transmitted from outer to inner model
- Inner models as rigid bodies



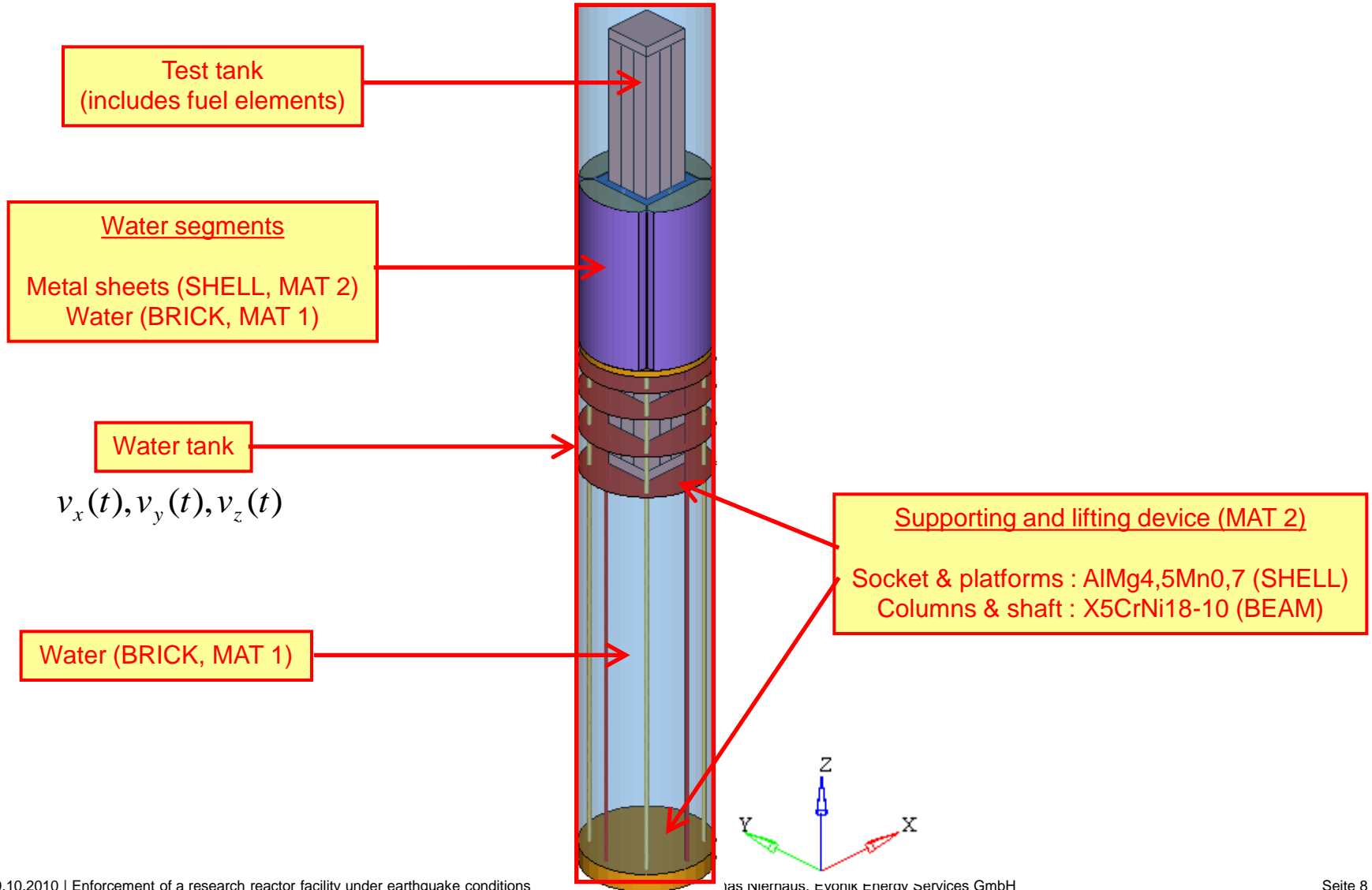
Initial geometry model

Graphite blocks



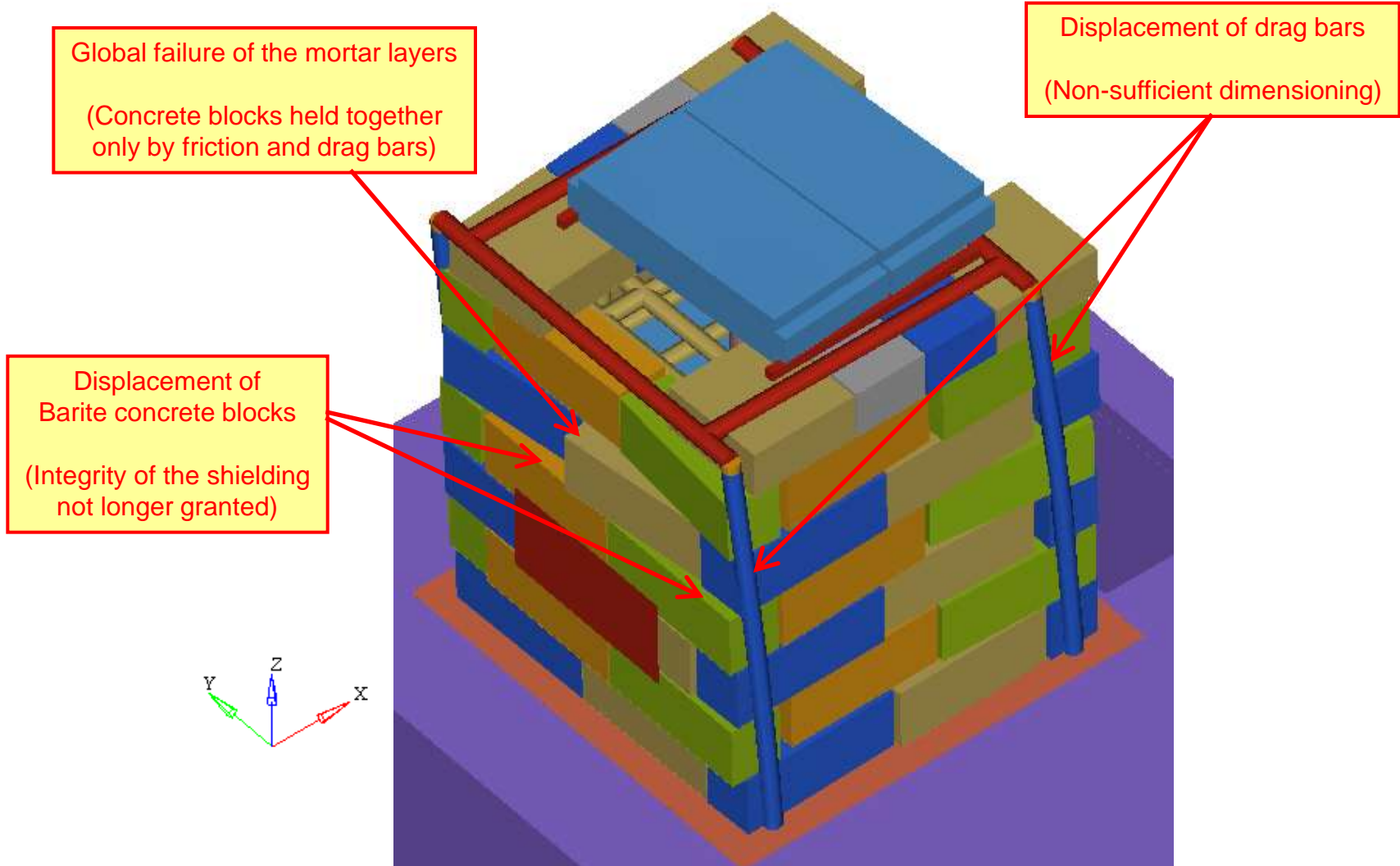
Initial geometry model

Interior



Damage analysis (Initial model)

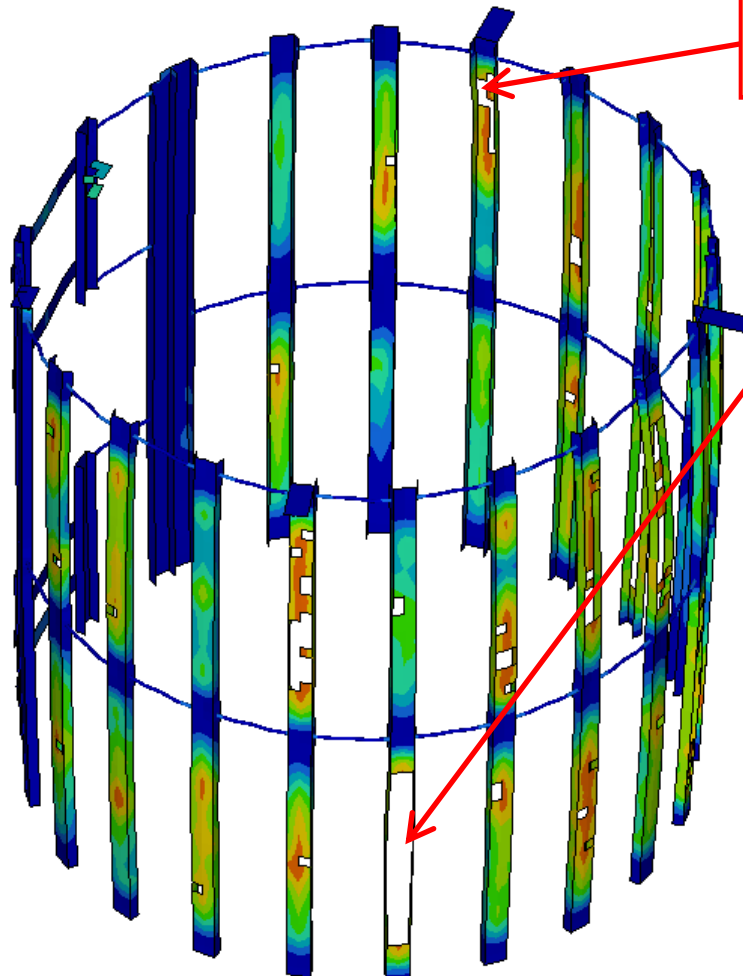
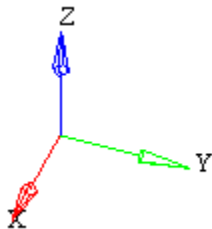
Shielding



Damage analysis (Initial model)

Graphite block enforcement

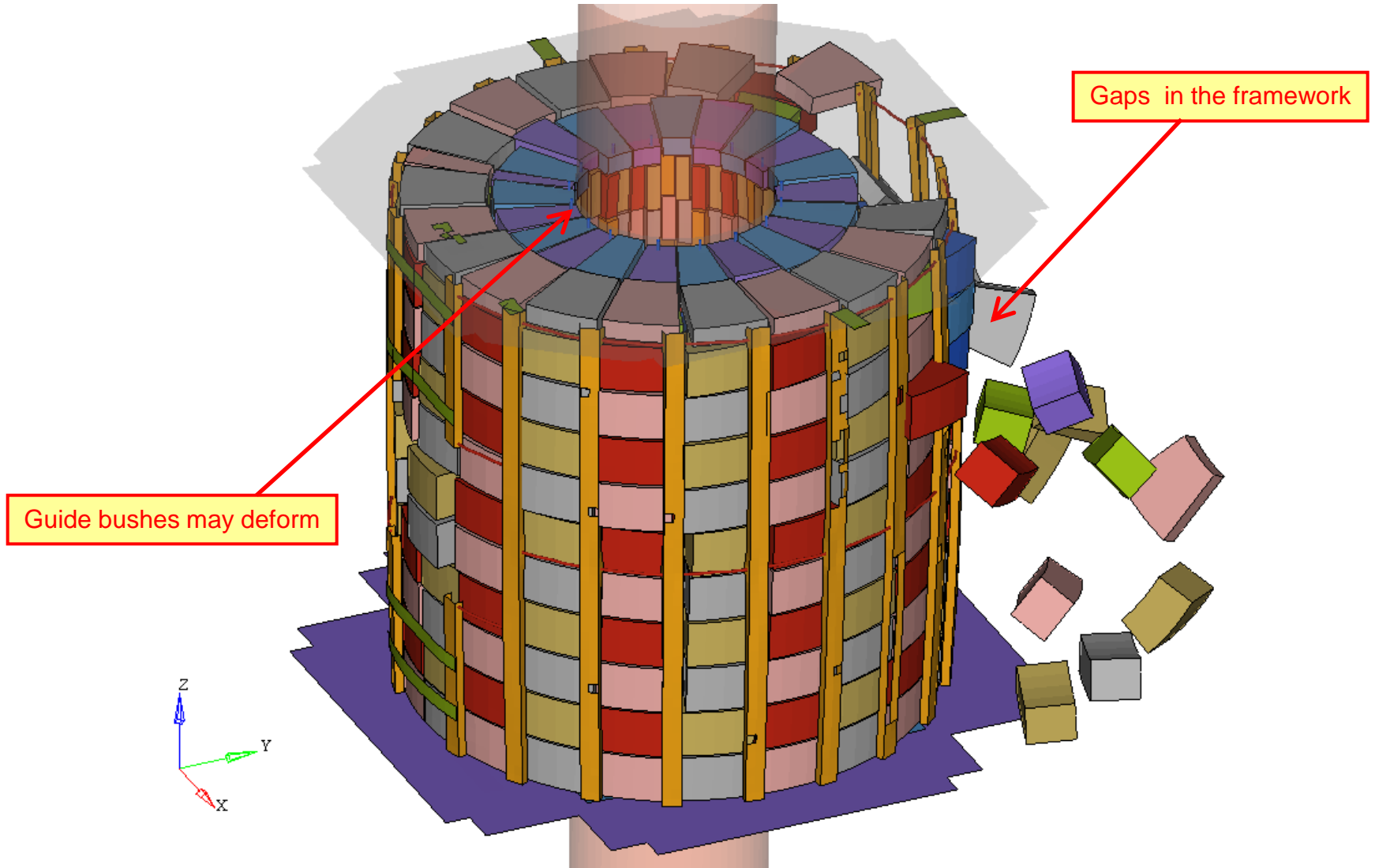
Contour Plot
Plastic Strain(Scalar value, Mid)
Simple Average [%]



Failure plastic strain exceeded in framwework

Damage analysis (Initial model)

Graphite blocks

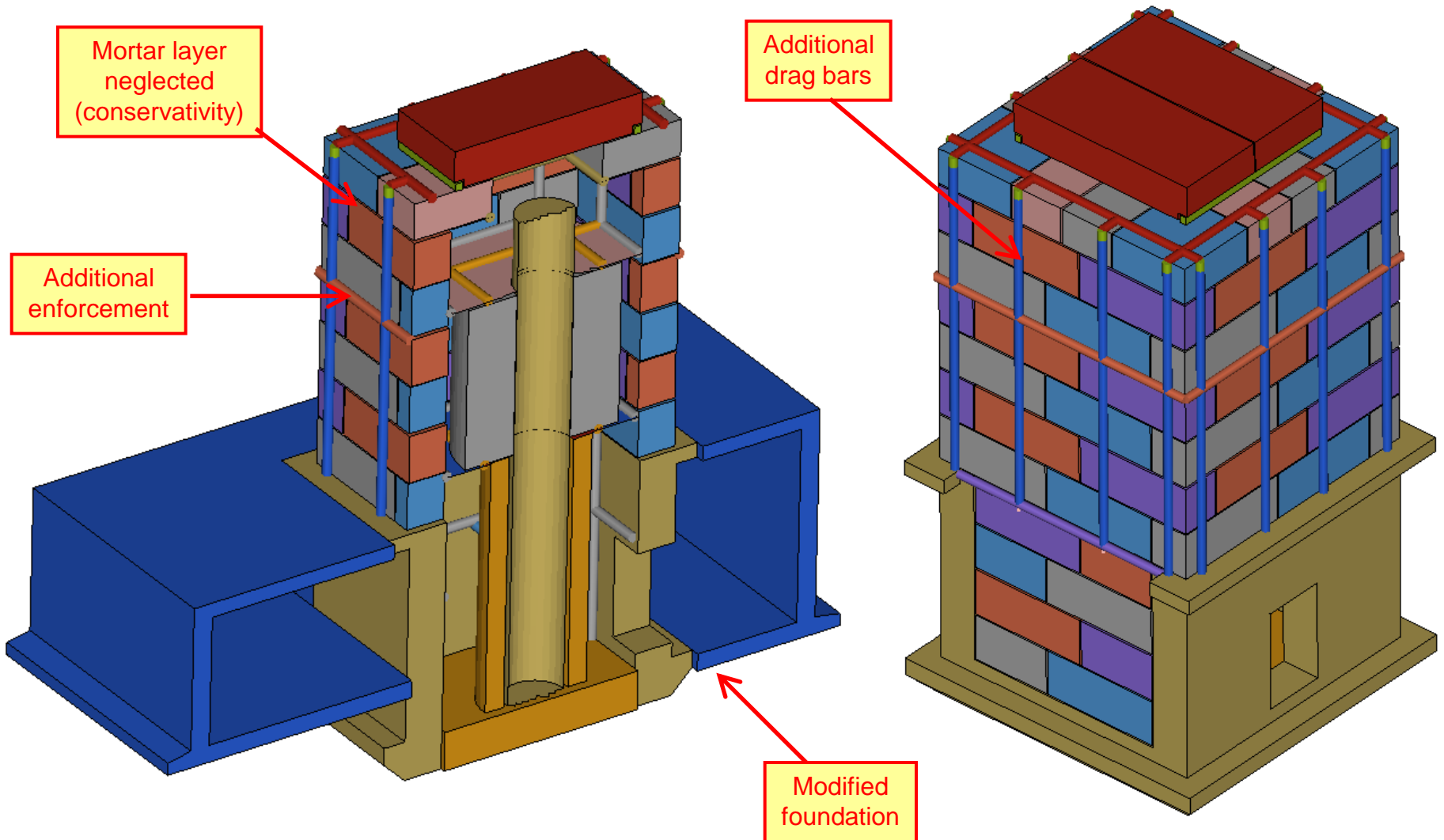


Proposed modifications

- Protection objective not met with initial design
 - Shielding damage
 - Loosening of concrete and graphite blocks

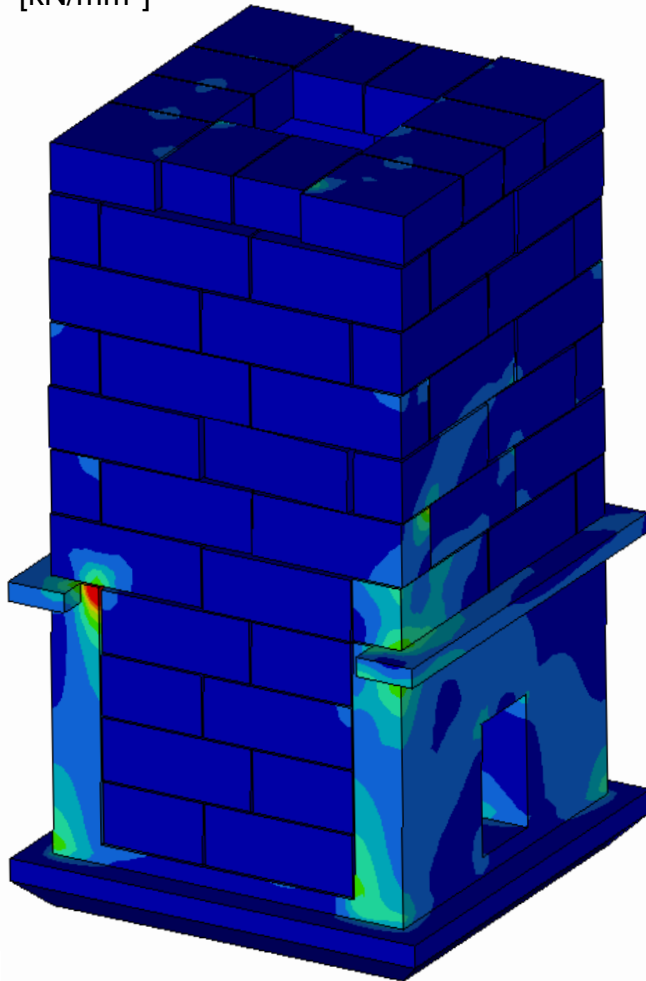
- Need for further enforcement
 - Increased number and diameter of drag bars in outer enforcement
 - Additional support for concrete socket
 - Cover plate to avoid dropping of concrete bricks into the reactor
 - Increased enforcement for the graphite blocks

Proposed modifications

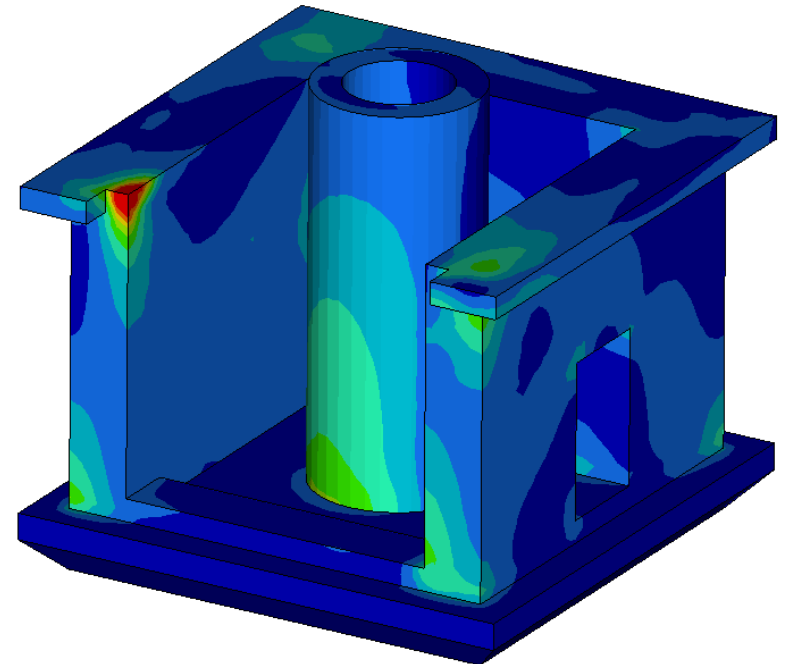


Damage analysis (Modified model)

Contour Plot
Von Mises(Scalar value, Mid)
Simple Average [kN/mm²]



- Maximum stress below compressive strength of barite concrete ($f_c=22 \text{ N/mm}^2$)
- No severe damage to concrete parts
- Only slight displacement of shielding

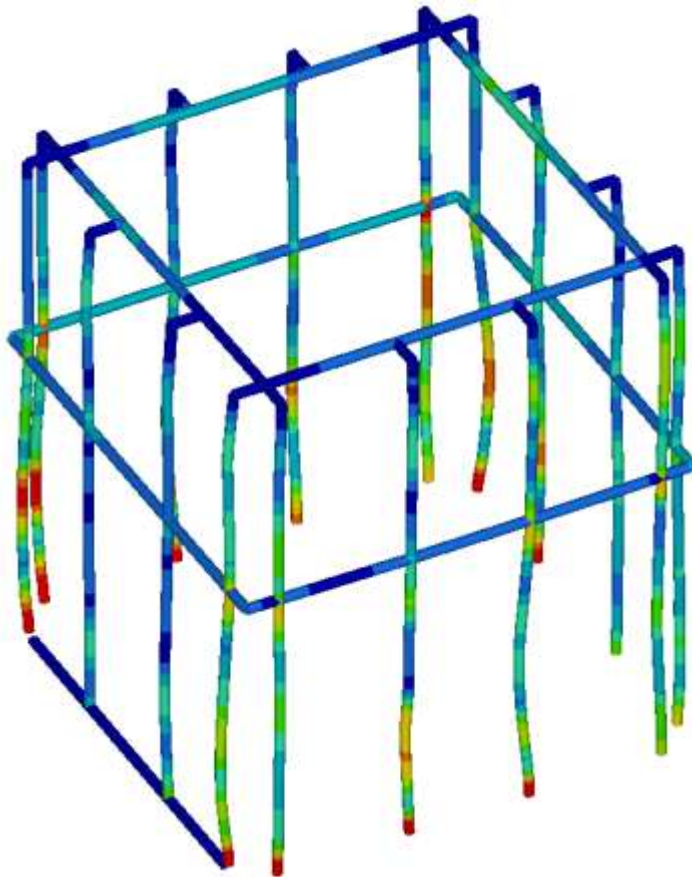


Damage analysis (Modified model)

Contour Plot
Von Mises(Scalar value, Mid)
Simple Average [kN/mm²]



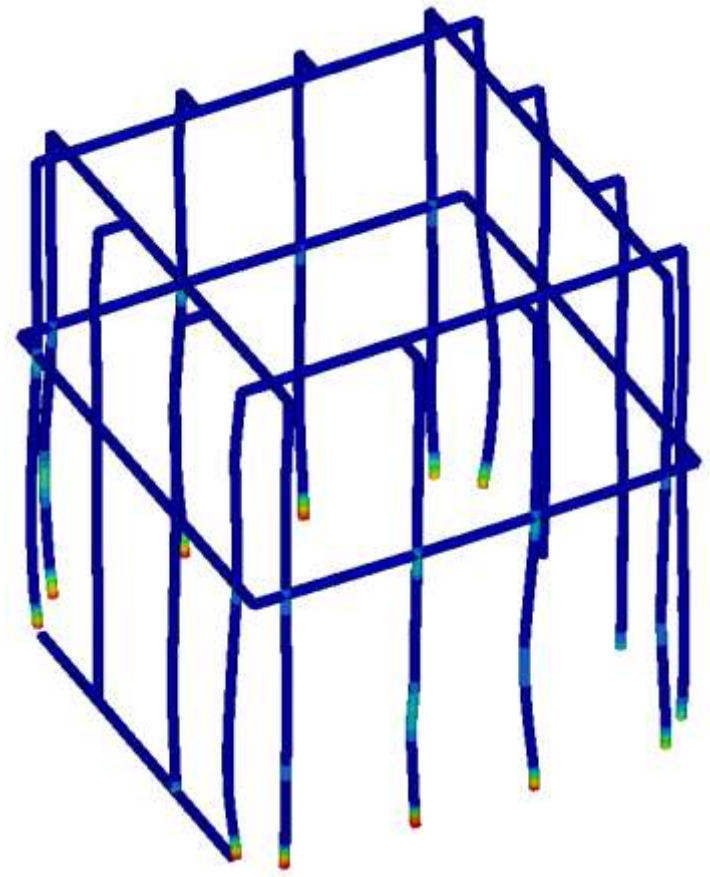
$$R_m = 800 \text{ N/mm}^2$$



Contour Plot
Plastic Strain(Scalar value, Mid)
Simple Average [%]



$$\epsilon_{\max} = 10\%$$

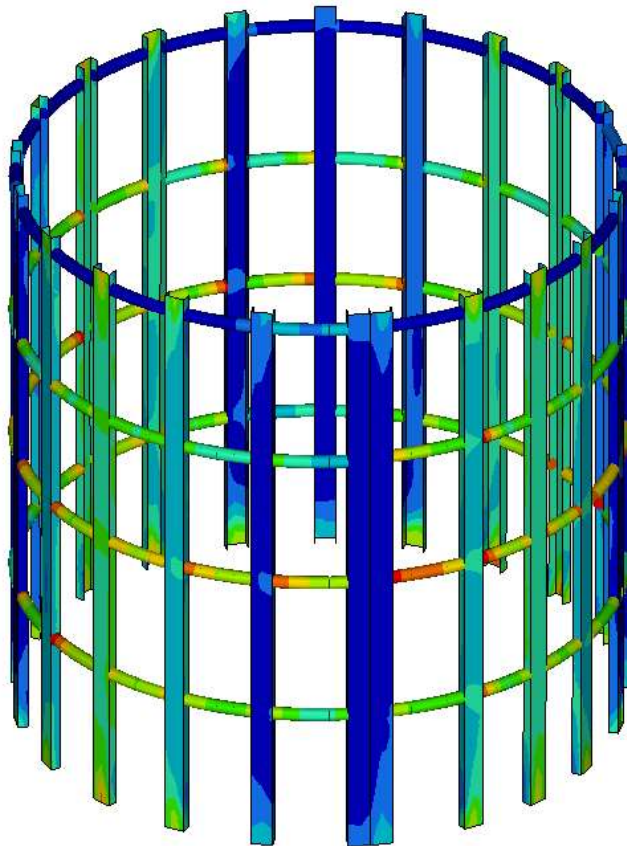


Damage analysis (Modified model)

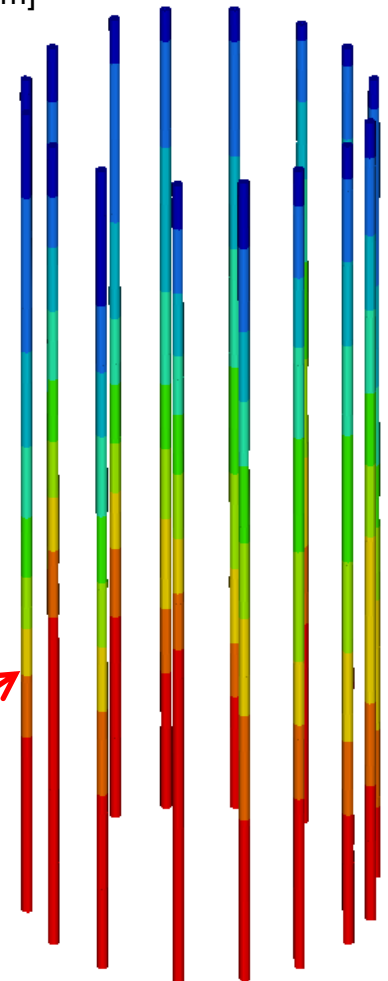
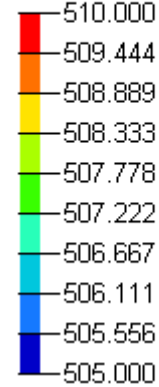
Contour Plot
Von Mises(Scalar value, Mid)
Simple Average [kN/mm²]



$$R_p = 235 \text{ N/mm}^2$$



Contour Plot
Displacement(X)
Analysis system [mm]

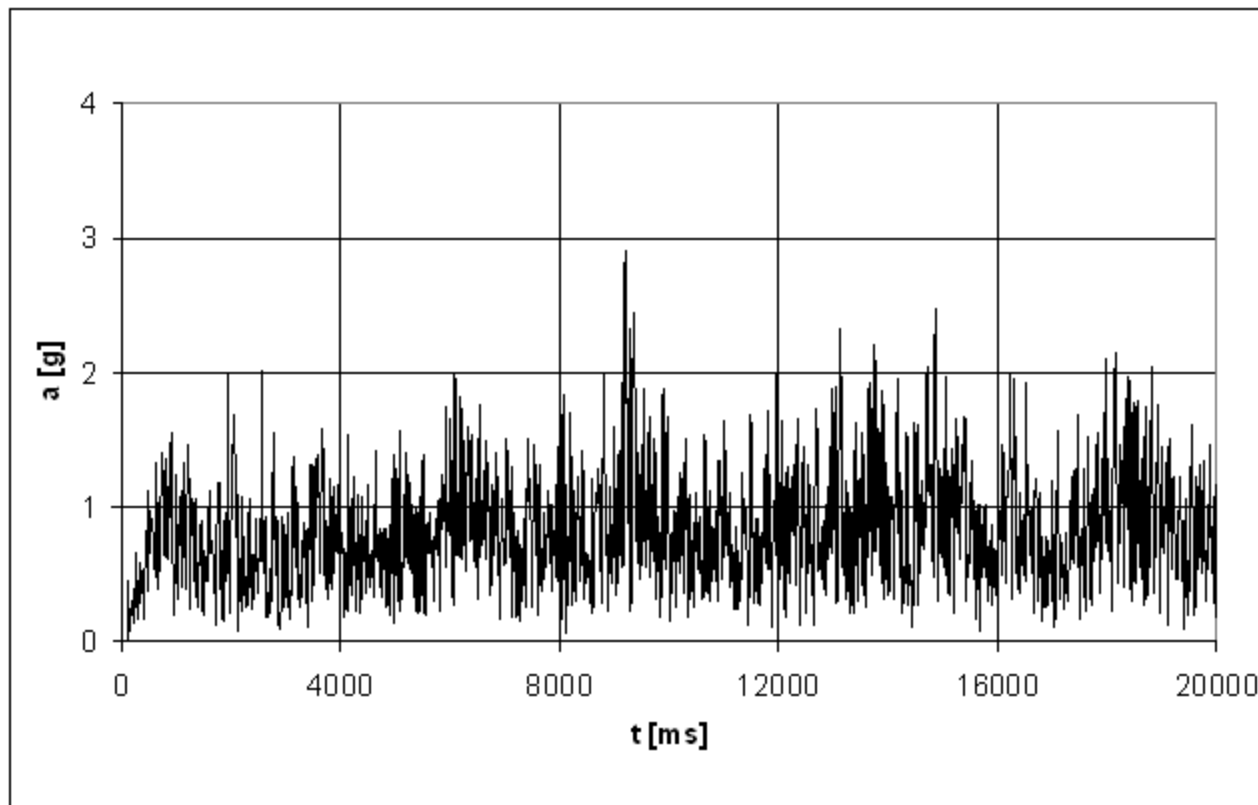


No bending,
tilt angle 0.07°



Damage analysis (Modified model)

- Absolute value for acceleration at fuel element does not exceed critical value



Conclusion

- RADIOSS explicit simulation of a research reactor facility including built-in components has been performed
- Proof that the research reactor does not experience damage in case of an earthquake following a given design spectrum
 - Radiation shielding does not fail
 - No damage of built-in components
 - Guide bushes do not deform, control rods operatable
 - Acceleration on fuel element does not exceed critical value



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