

**19th International Conference on
Structural Mechanics
in Reactor Technology
Toronto, 12-17 August 2007**

Special session

**The IAEA Coordinated
Research Project on
Safety Significance of
Near Field Earthquakes**

Analytical Study of the CAMUS Benchmark Model subjected by Near Field Earthquake

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Analytical Study of the CAMUS Benchmark Model subjected by Near Field Earthquake

OVERVIEW:

Criteria for selecting the modeling assumptions

Difficulties encountered

Lessons learnt

Evolution of the engineering practice

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Selection of Software:

SOLVIA Finite Element System
(www.solvvia.com)

To resolve non-linear equations a Full Newton method of equilibrium iterations with line search procedure was used in frame of both: static and dynamic analyses.

For transient Time History Analyses an implicit Newmark time integration scheme was employed.

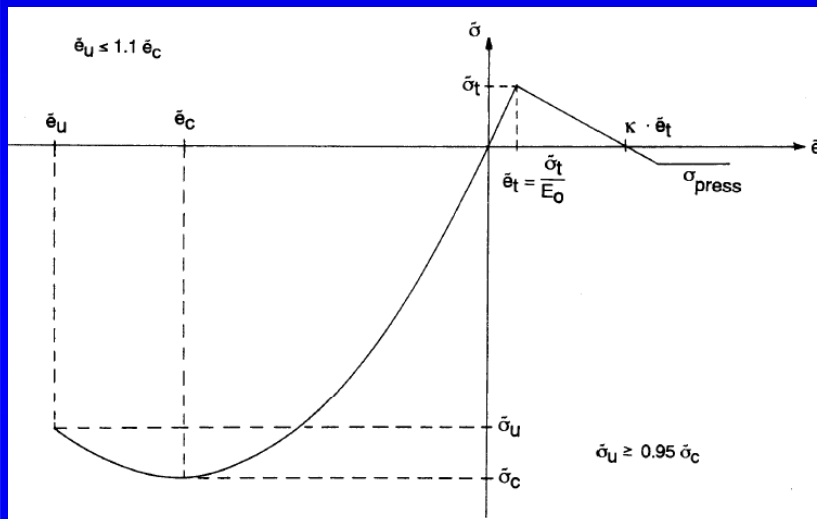
Structural Damping for Time History Analyses was introduced in the model by means of Rayleigh-type damping matrix to reproduce 2 % damping for the first natural frequency of Mock-up.

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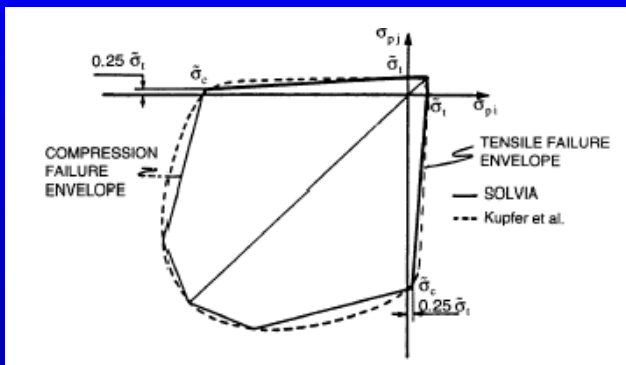
Criteria for selecting the modeling assumptions:

Material Models:

Concrete:

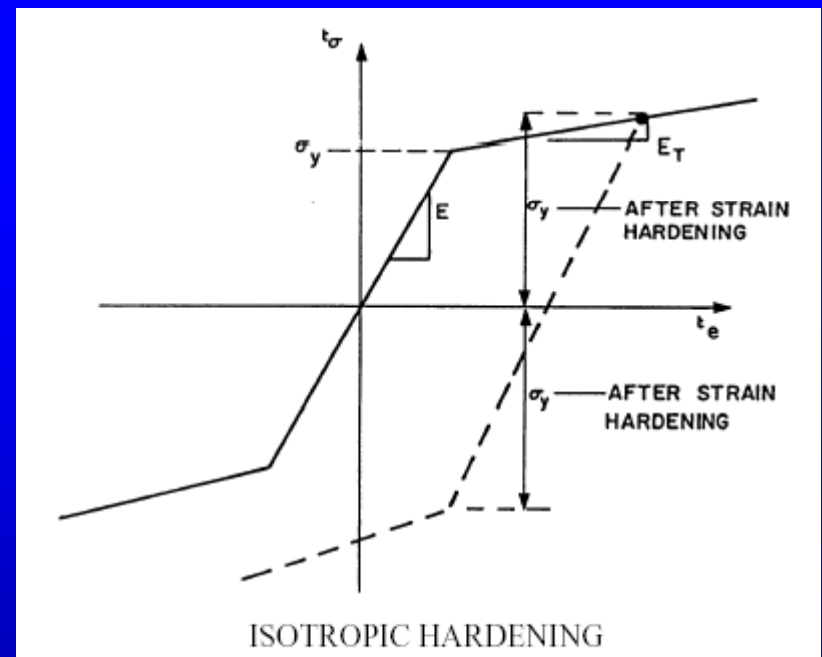


Uniaxial stress-strain law



Biaxial failure envelopes

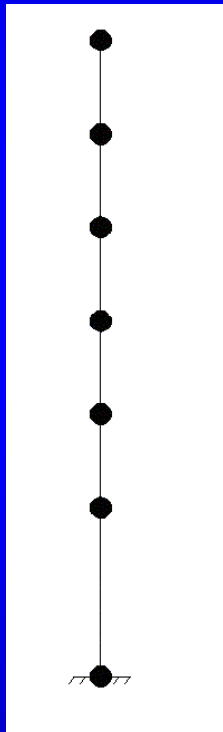
Reinforcement:



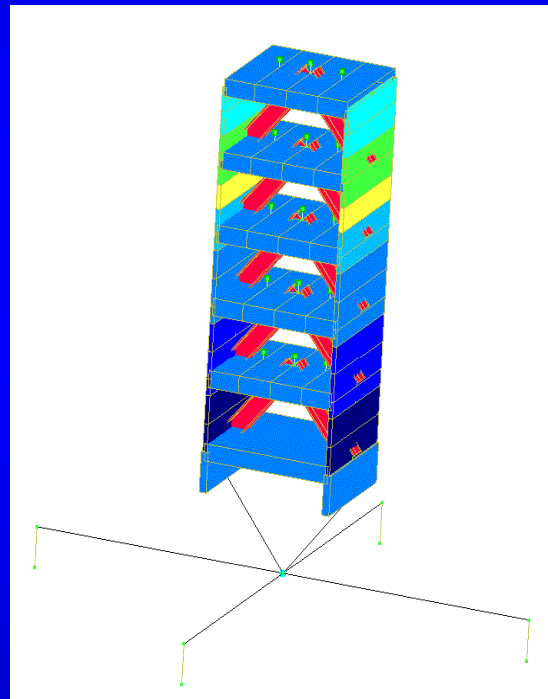
Model bilinear of PLASTIC material

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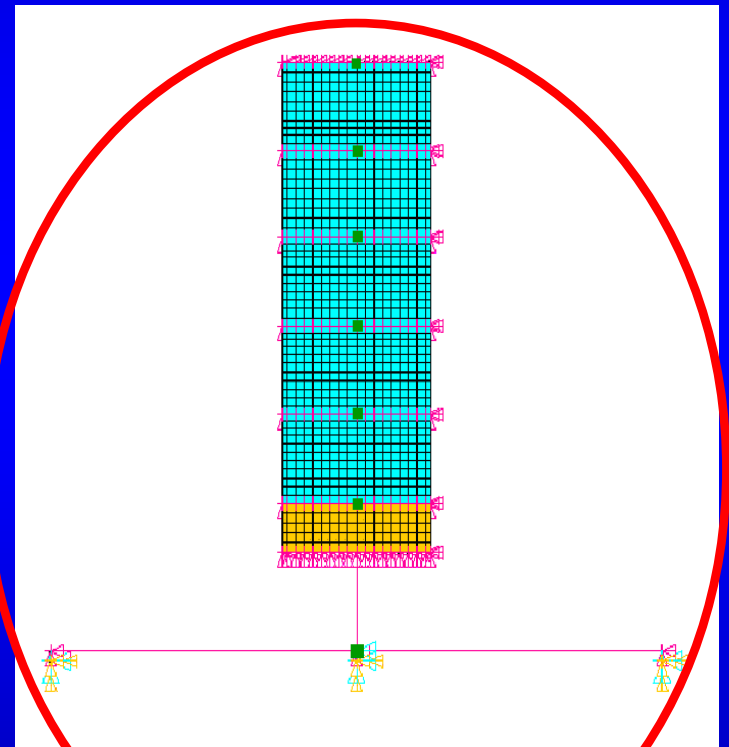
Criteria for selecting the modeling assumptions: Choose of FE Type for Modeling



Stick Model



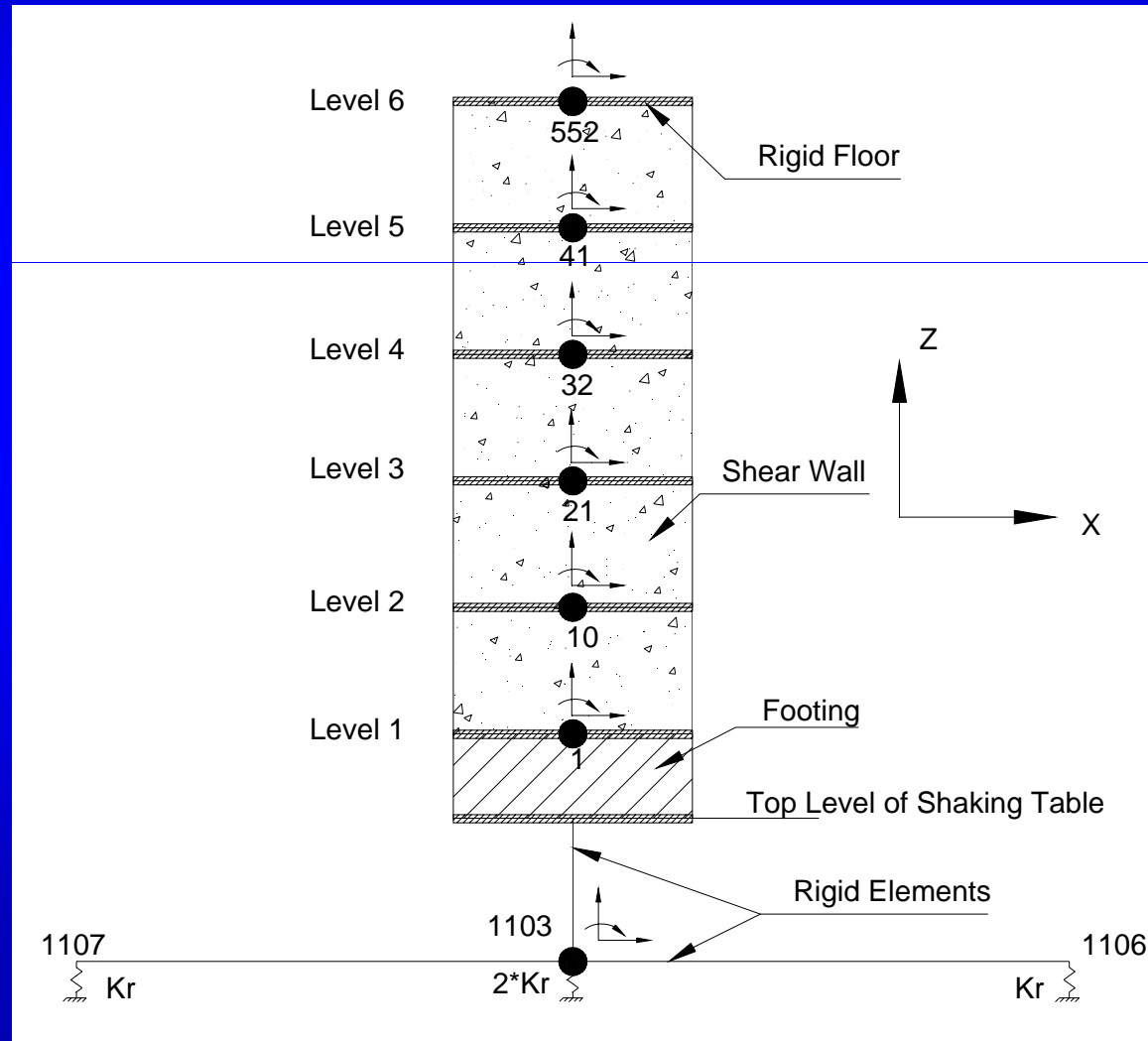
3D Beam Model



2D Plane Model

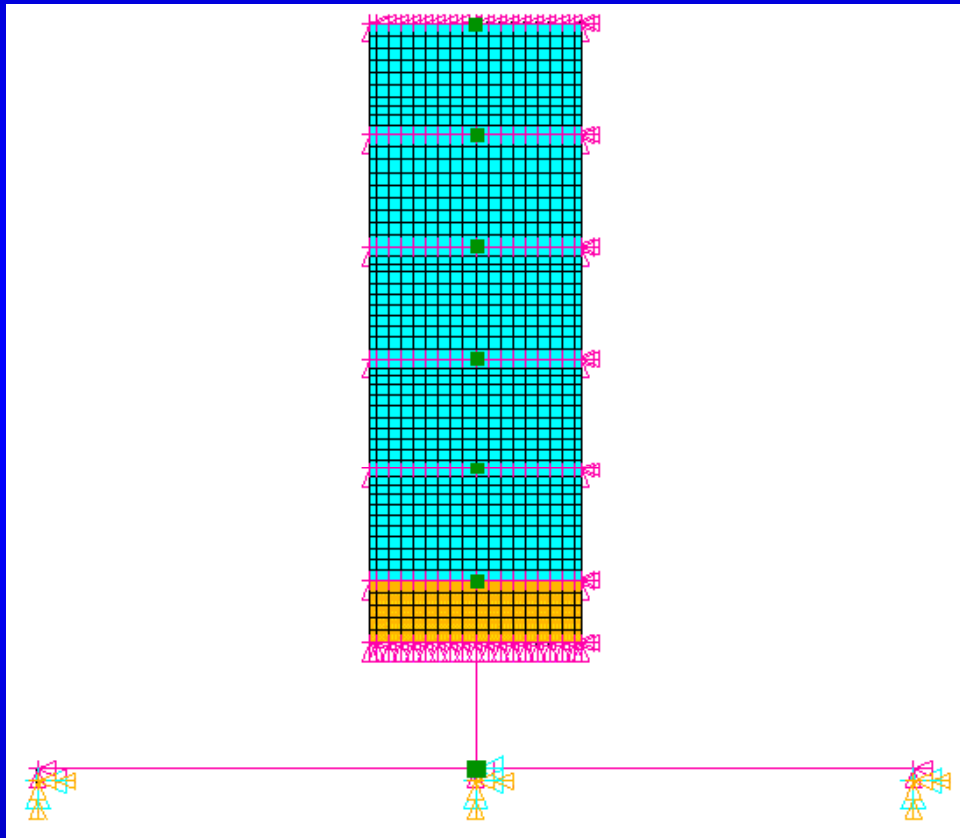
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Criteria for selecting the modeling assumptions: FE MODEL

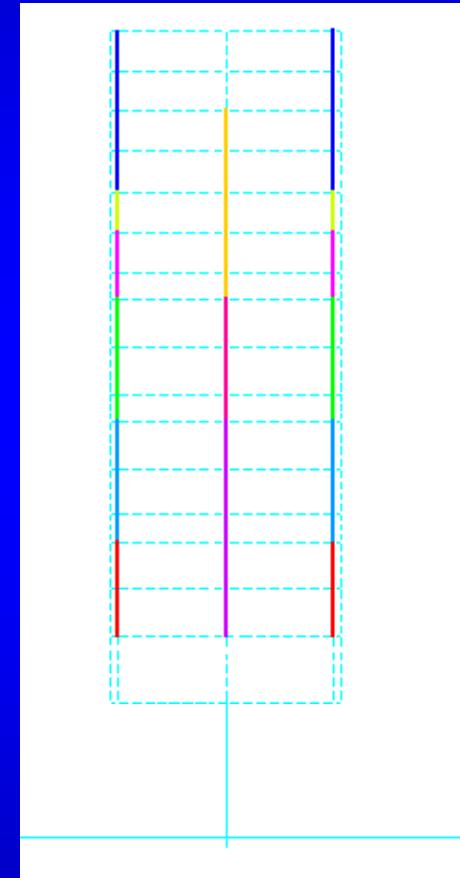


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Criteria for selecting the modeling assumptions: FE MODEL



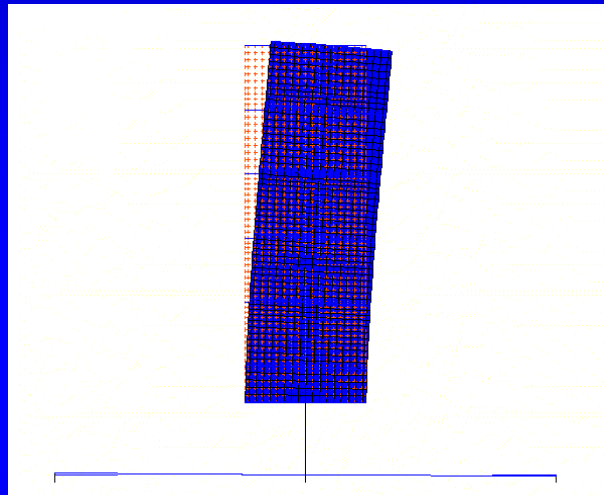
Mock-up Finite Element Model.



Modeling of Mock-up Steel Reinforcement

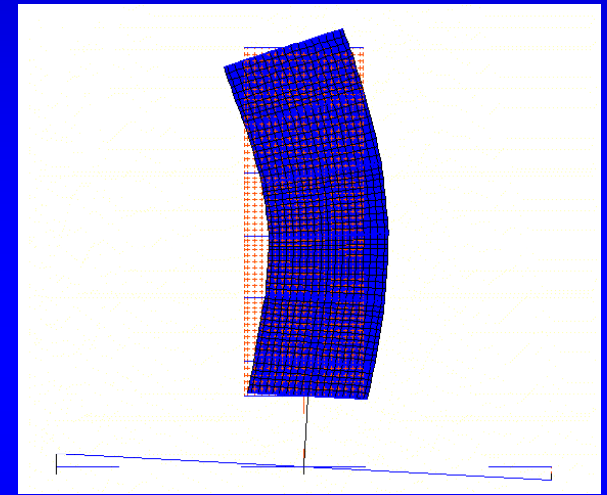
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Criteria for selecting the modeling assumptions: Linear Approach: Eigen Modes & Natural Frequencies

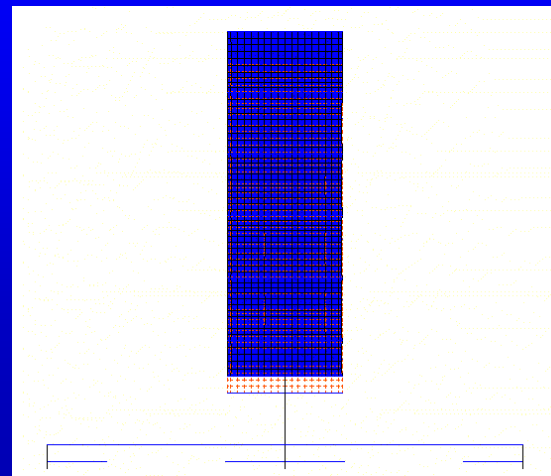


7.25 Hz

23.13 Hz

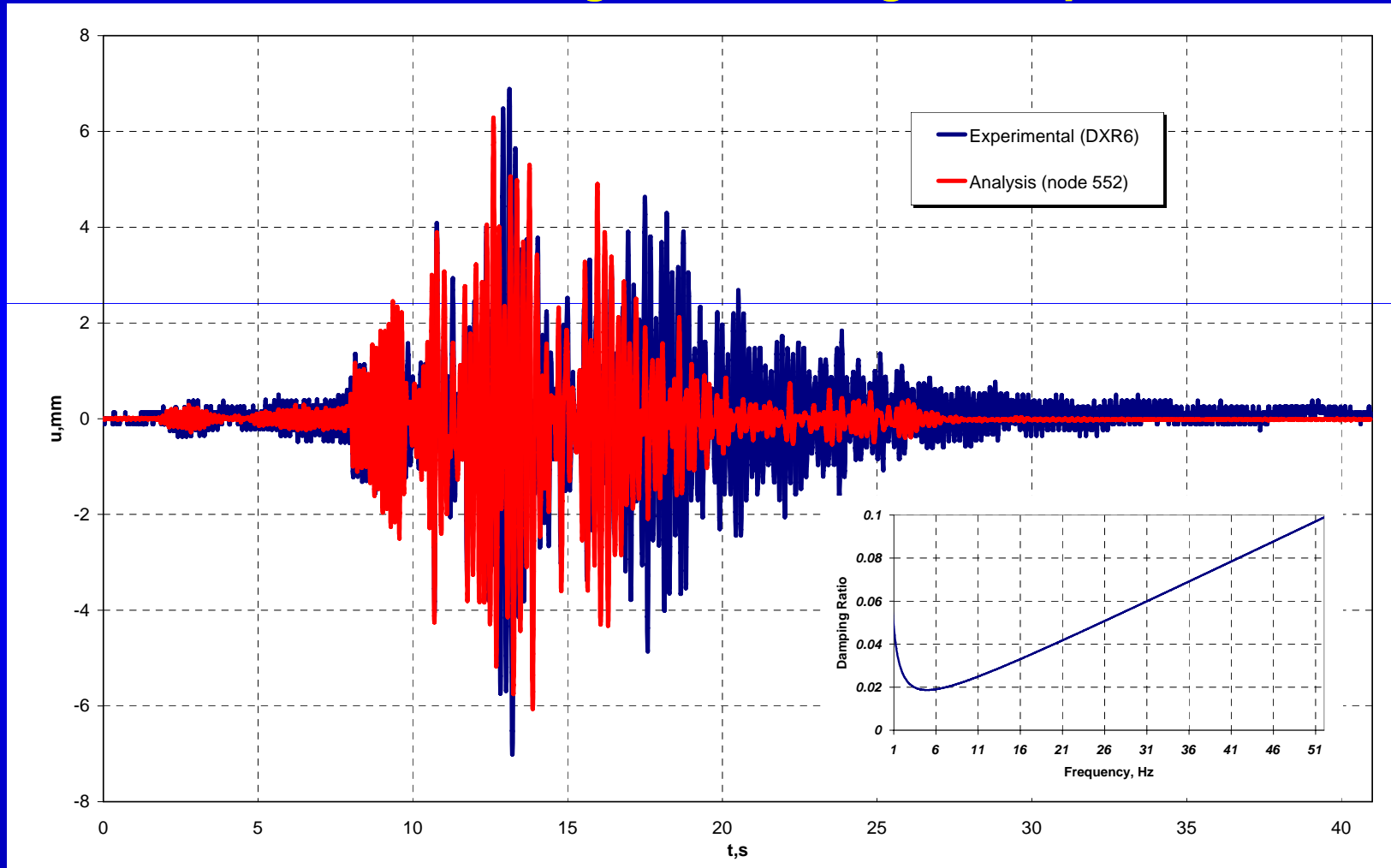


34.8 Hz



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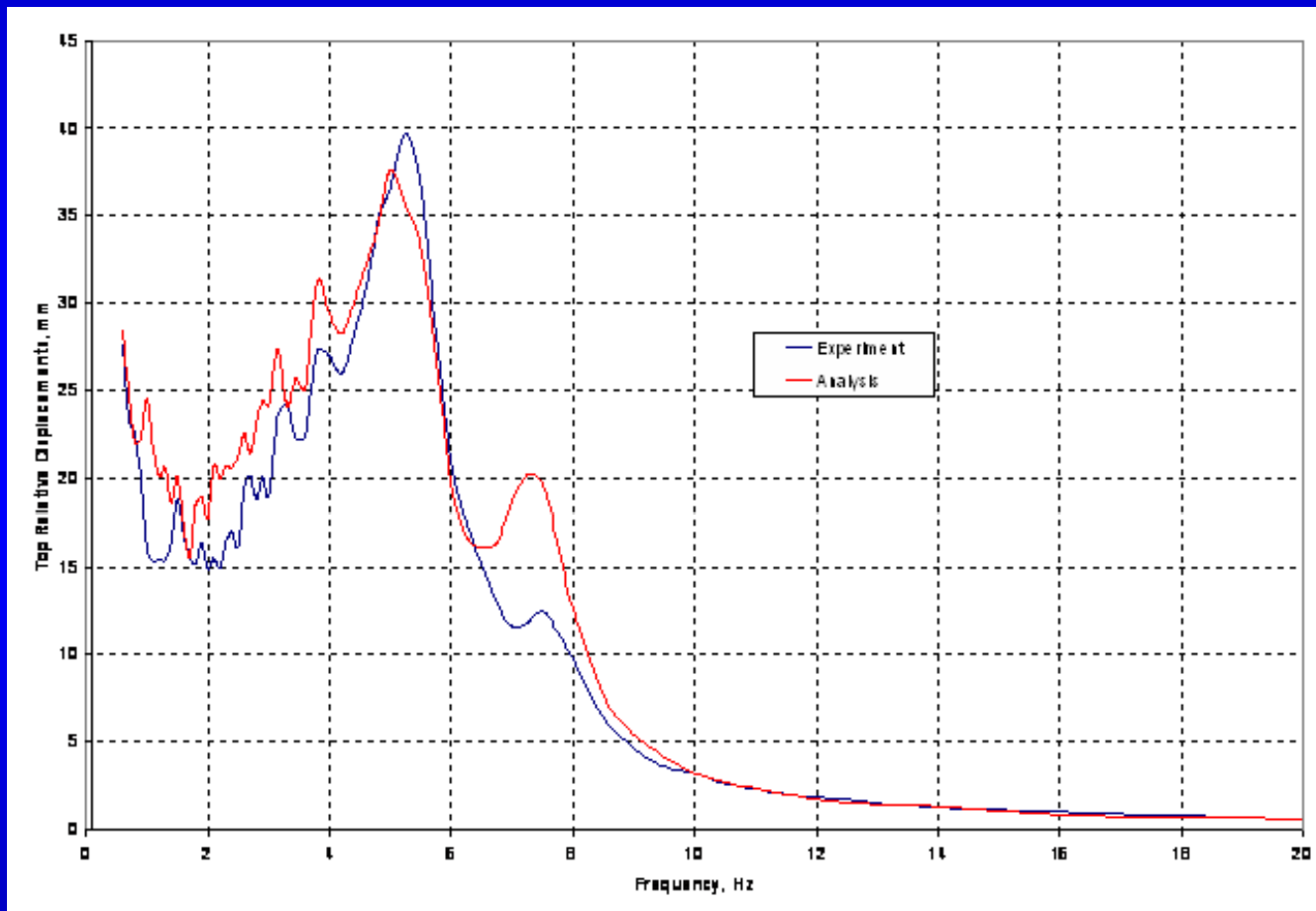
Criteria for selecting the modeling assumptions:



Comparison of relative top displacements (RUN1)

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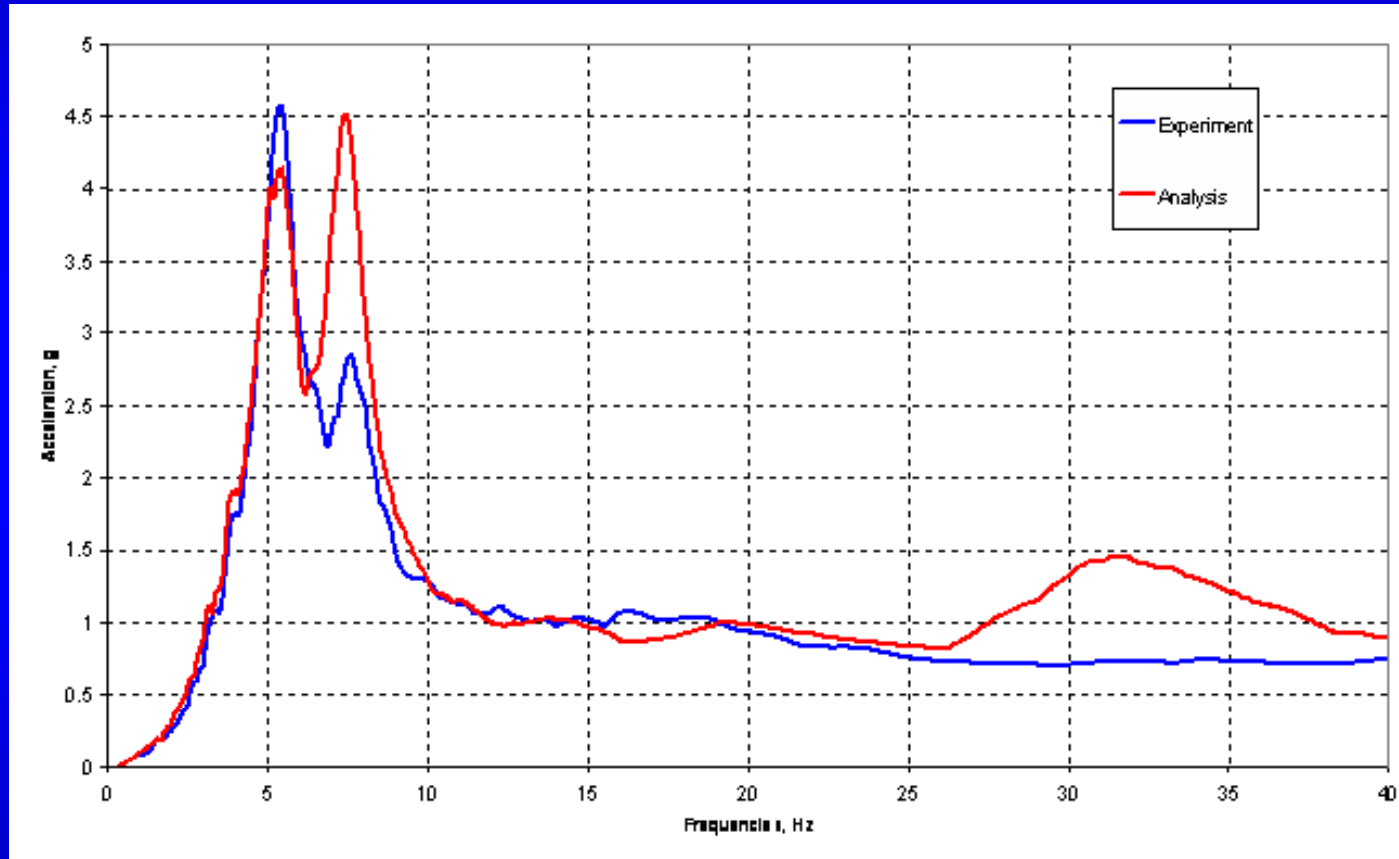
Criteria for selecting the modeling assumptions:



Displacement Response Spectra (Damping – 5 %).

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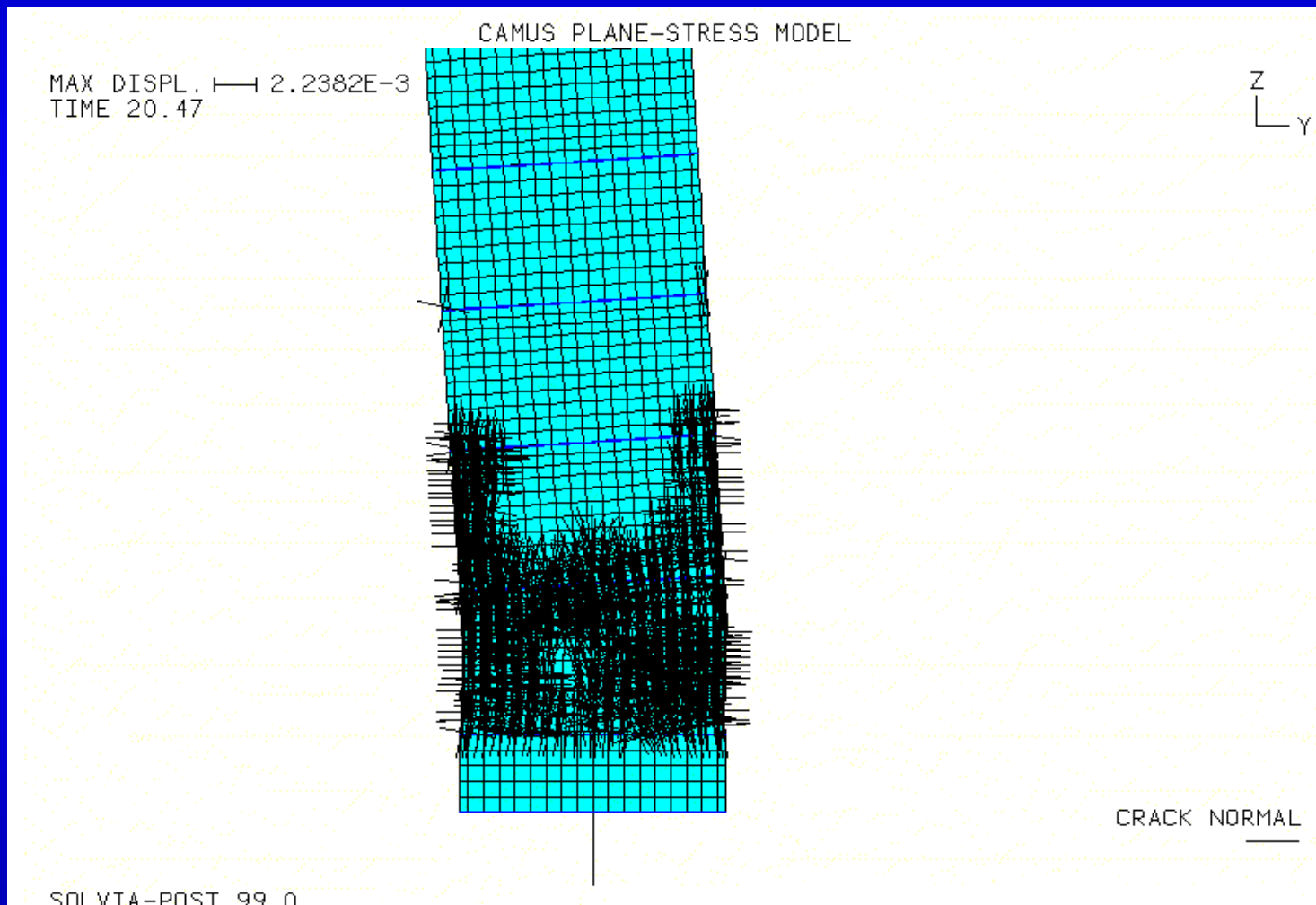
Criteria for selecting the modeling assumptions:



Acceleration Response Spectra

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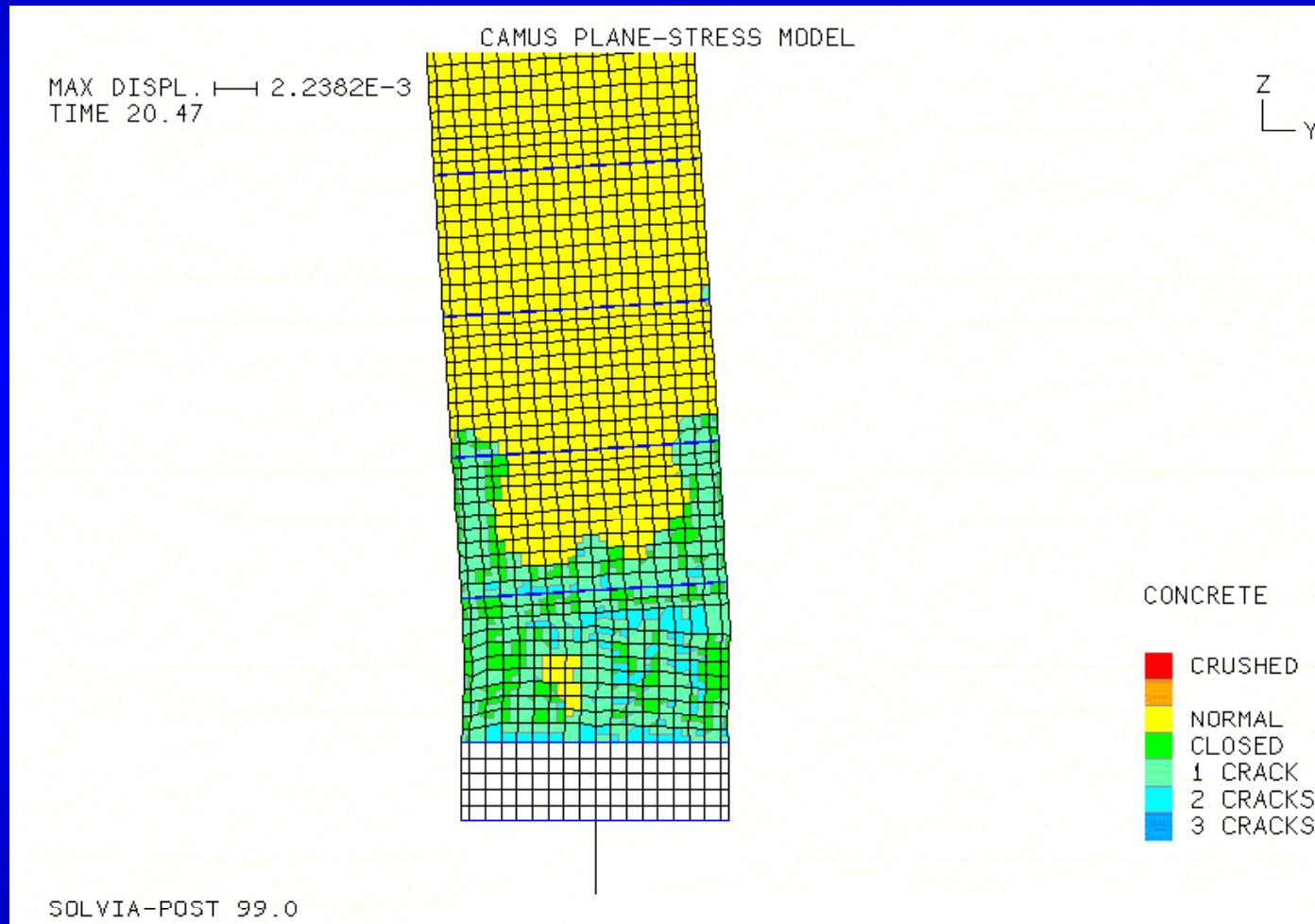
Criteria for selecting the modeling assumptions:



Crack Pattern of Mock-Up Specimen after RUN3

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Criteria for selecting the modeling assumptions:



Damage Pattern of Mock-Up Specimen after RUN3

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Difficulties encountered:

✓ modeling:

- uncertainty of footing – shaking table interaction;
- complexity and number of Concrete Model characteristics needed for Analyses;
- modeling of construction joints;
- applying of boundary conditions for accurate representation of input motion given for the top of shaking table

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Difficulties encountered:



analyses:

- numerical instability & solution' convergence problems;
- lack of experience in Displacement Based Approach



interpretation of results:

- discrepancy between traditional FE results (strains, stresses, element forces) and integral values requested by Benchmark (bending moments, shear forces, curvatures)
- RUN 4 Problem
- Vertical Acceleration

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Lessons learnt:

- ✓ A degree of analysis accuracy is independent from used methodology and approach.
- ✓ A degree of analysis accuracy is independent from used software.
- ✓ Accuracy depends on a judgment and access to the test results only.
- ✓ In case of really blind contest a deviation of analysis results would be terrible: +/- many times to experiment results.

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Lessons learnt:

- ✓ Use of Displacement Based Approach looks very attractive from engineering point of view, but for very limited and certain cases. Implementation of this method for the Design of Nuclear Installations is under a big question due to very strict Regulatory and Code Demands. However it could be considered as acceptable for some types of existing nuclear structures;
- ✓ Conventional Response Spectrum Method leads to a significant overestimation of seismic loads for highly non-linear structures;

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Lessons learnt:

- ✓ **Non-Linear Time History Analysis is a very powerful tool in current Engineering Practice. Modern Software gives a real possibility for modelling of any peculiarities in structures and their behaviour. However, unjustified use of Non-Linear THA could be just a reflection of analyst' concept and accumulated judgement. From this point the actual IAEA RCP Benchmark gives a great opportunity to get an experimental background and gain practical experience in Non-Linear Analysis.**

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Lessons learnt:

- ✓ A definition of NFE is highly appreciated but seems could not be scientifically formulated just now. Using of CAV criterion would be useful.
- ✓ A damaging capacity of high frequency low duration earthquakes is obviously much less than low frequency large duration same PGA seismic excitations.

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Evolution of the engineering practice:

- ✓ **Performing of Sensitivity Analysis for Non-Linear Problem with variation of a number of significant parameters;**
- ✓ **Use of several time histories for evaluation of non-linear behaviour;**
- ✓ **Developing of the main approach to find a reasonable balance for modeling technique (simplification vs complexity)**

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Evolution of the engineering practice:

- ✓ **Approaches used in engineering practice should be different for new-designed and existing structures. To implement new methodologies in coordination with National Authorities engineers need justified background from International Engineering Community;**
- ✓ **Developing of benchmark test models of structures/ components and admittedly committed examples of analyses and results with recommendation on modal combination procedure is highly appreciated and could become one of the goals of future IAEA CRP activity. See as a positive example and experience the classic BNL piping benchmarking study and process.**