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Structural Simulation Models

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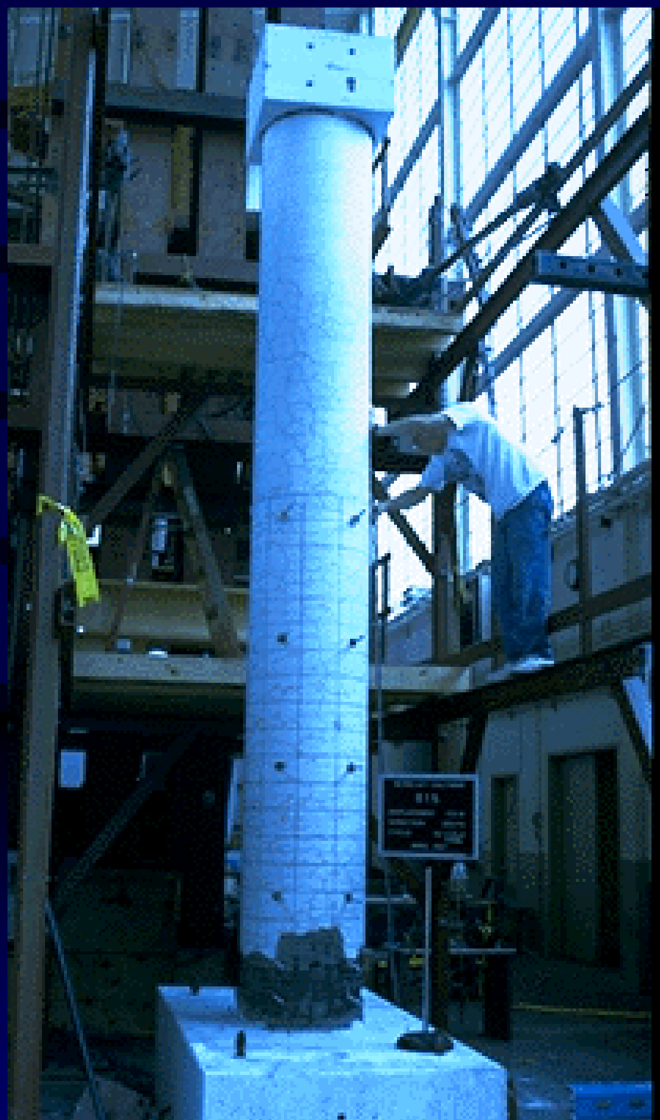
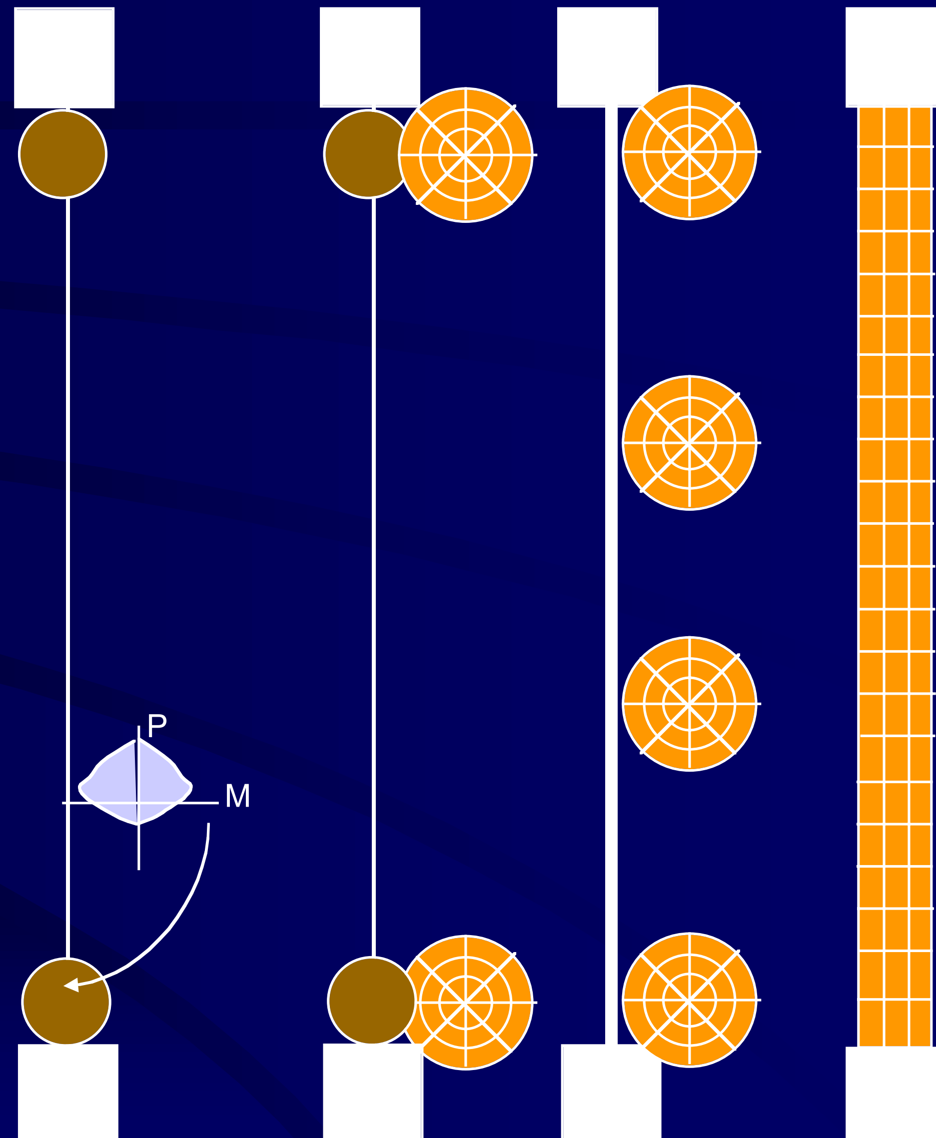
PEER OpenSees Framework

- Software framework for integrating
  - Material and component models. Emphasize degradation and failure behaviors
  - Solution strategies: Static and dynamic for degrading and collapsing systems
  - Performance evaluation based on simulated behavior
- Utilize new computing resources
  - Engineering desktop workstations (SMP, distributed)
  - High-performance computing
  - Computational grids
- Provide network communication mechanisms with scientific visualization methods and databases

Structural Beam-Column Models





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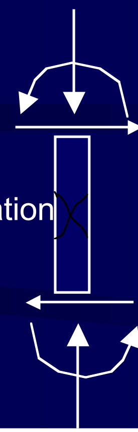
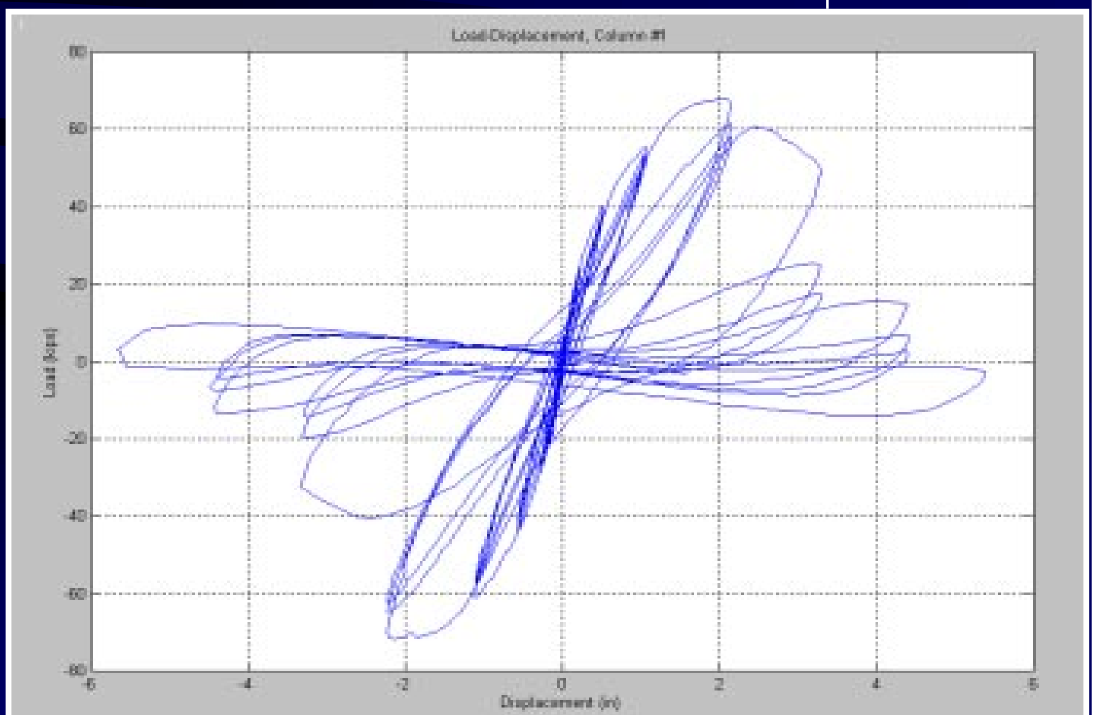
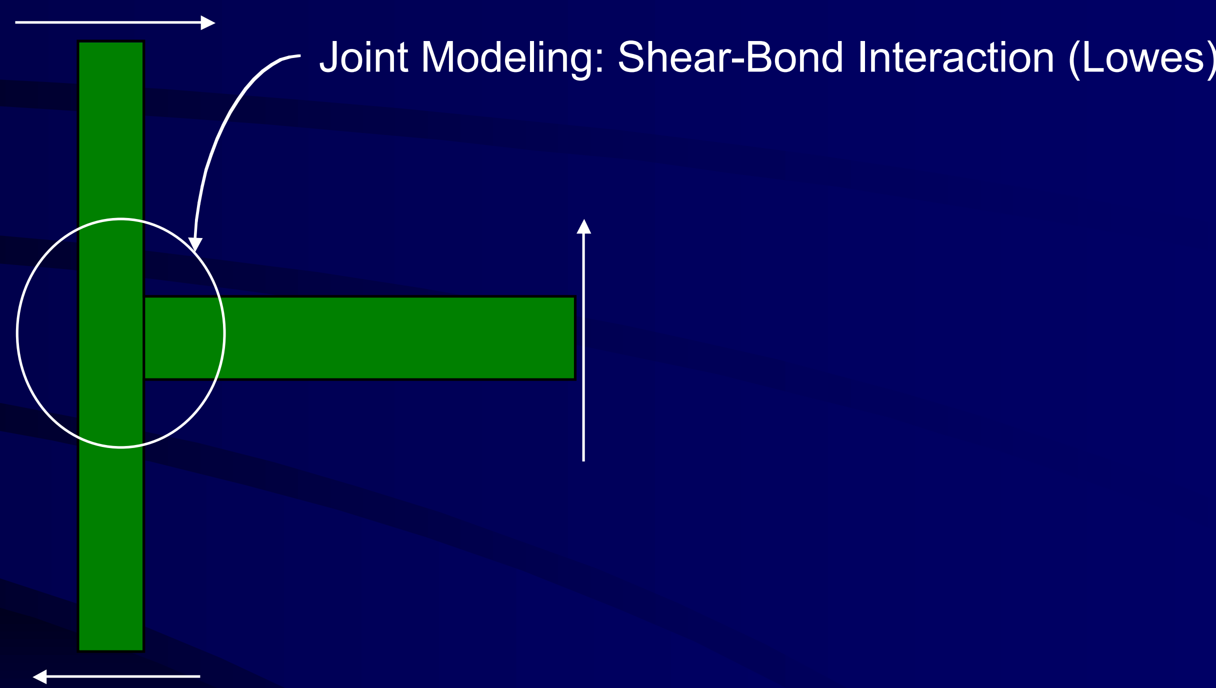
Axial Force-Flexure-Shear Behavior





Beam-Column Joints



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Other issues

- Parameter uncertainty - Sensitivity (DerKiureghian, Conte)
- Shear Wall Models
- Solution Strategies
- Pull-out, bond deterioration

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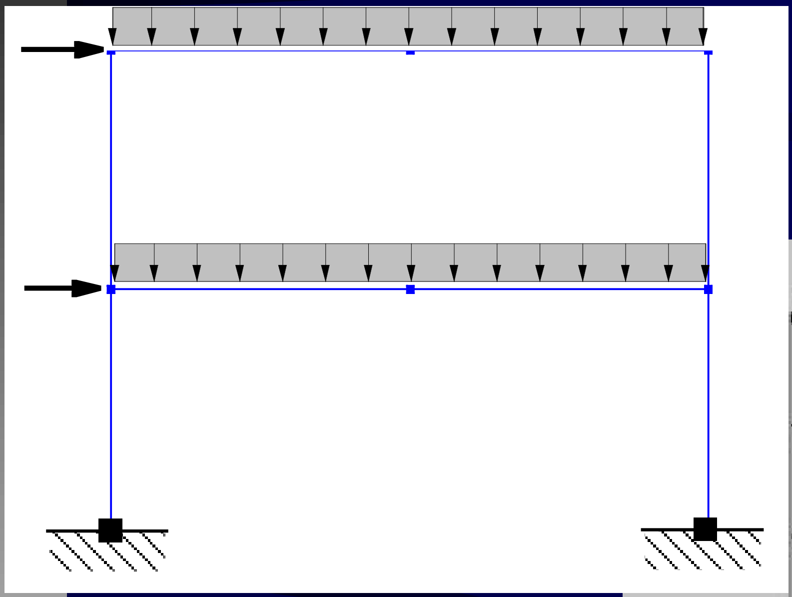
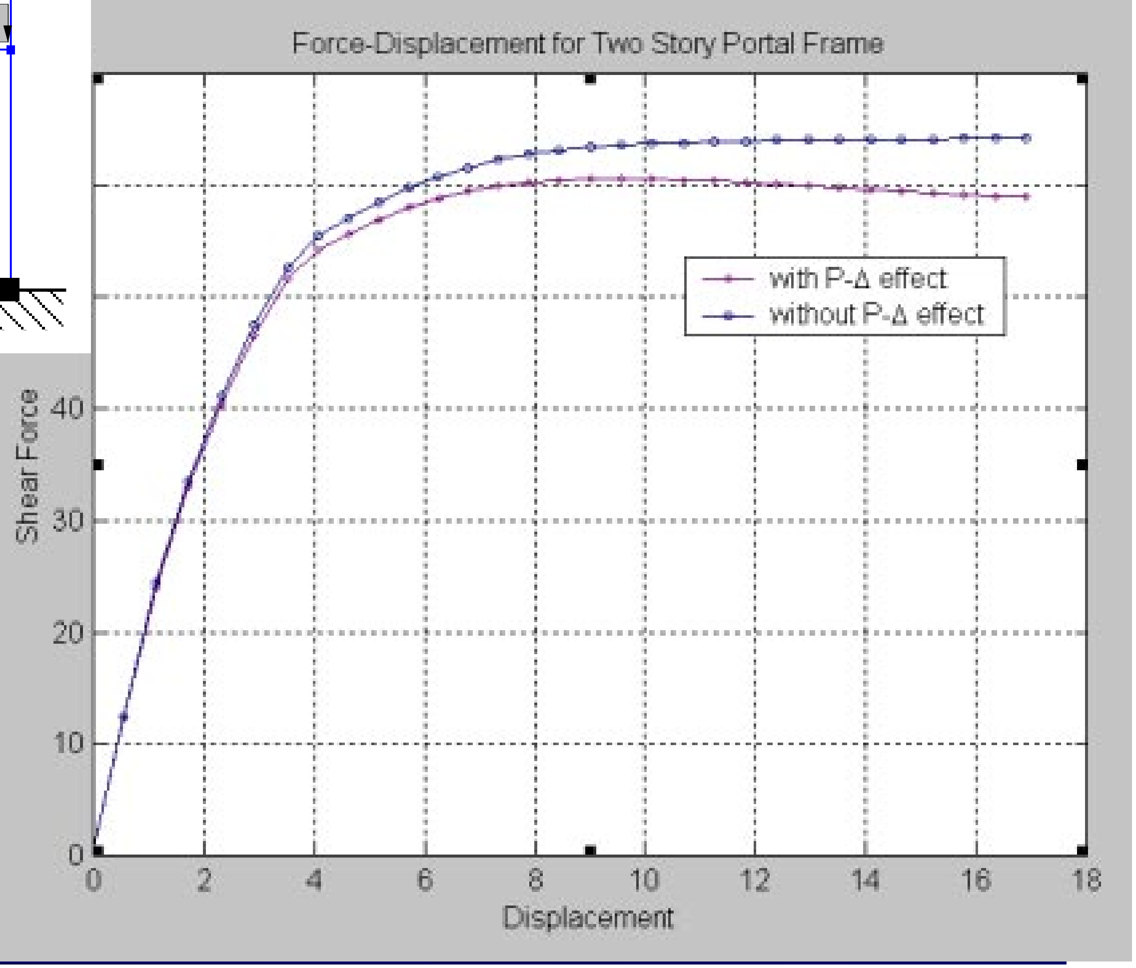
Advances in Frame Element Formulations

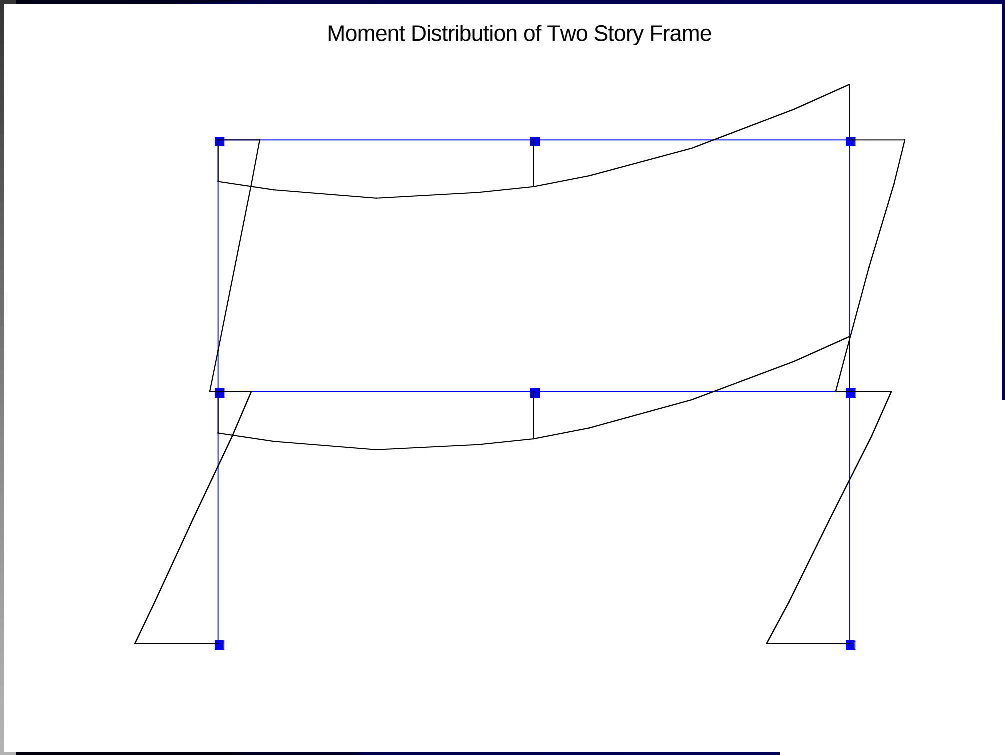
- Force based formulation for 1rst and 2nd order theory (exact internal force distribution)
- Large displacements with corotational formulation
- Mixed force-displacement formulation for frame elements with complex interactions (composite action, pile-soil interaction)
- Robust algorithms of state determination

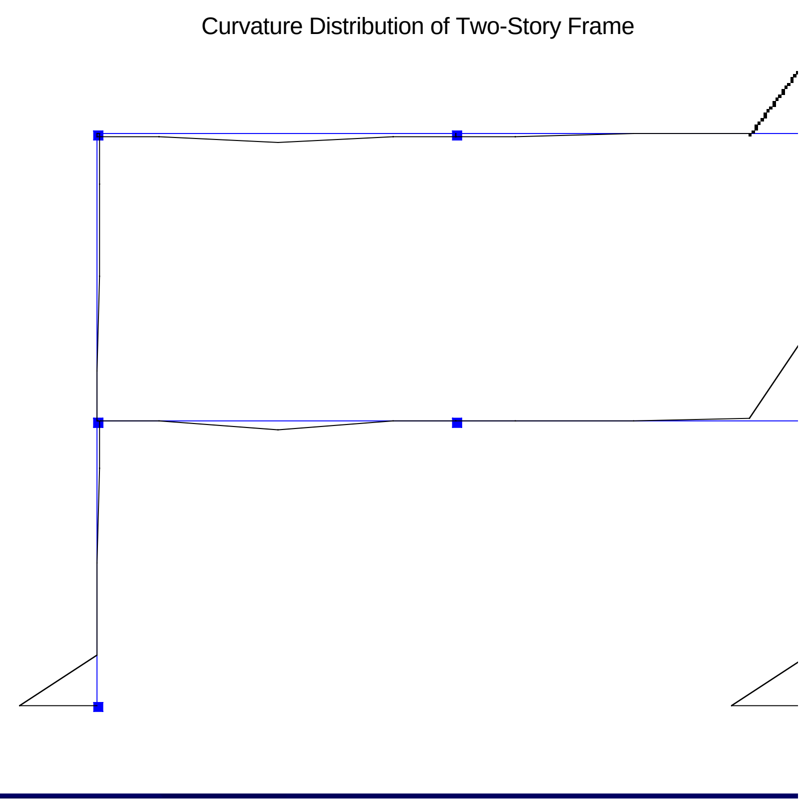
Push-Over of Two Story Frame





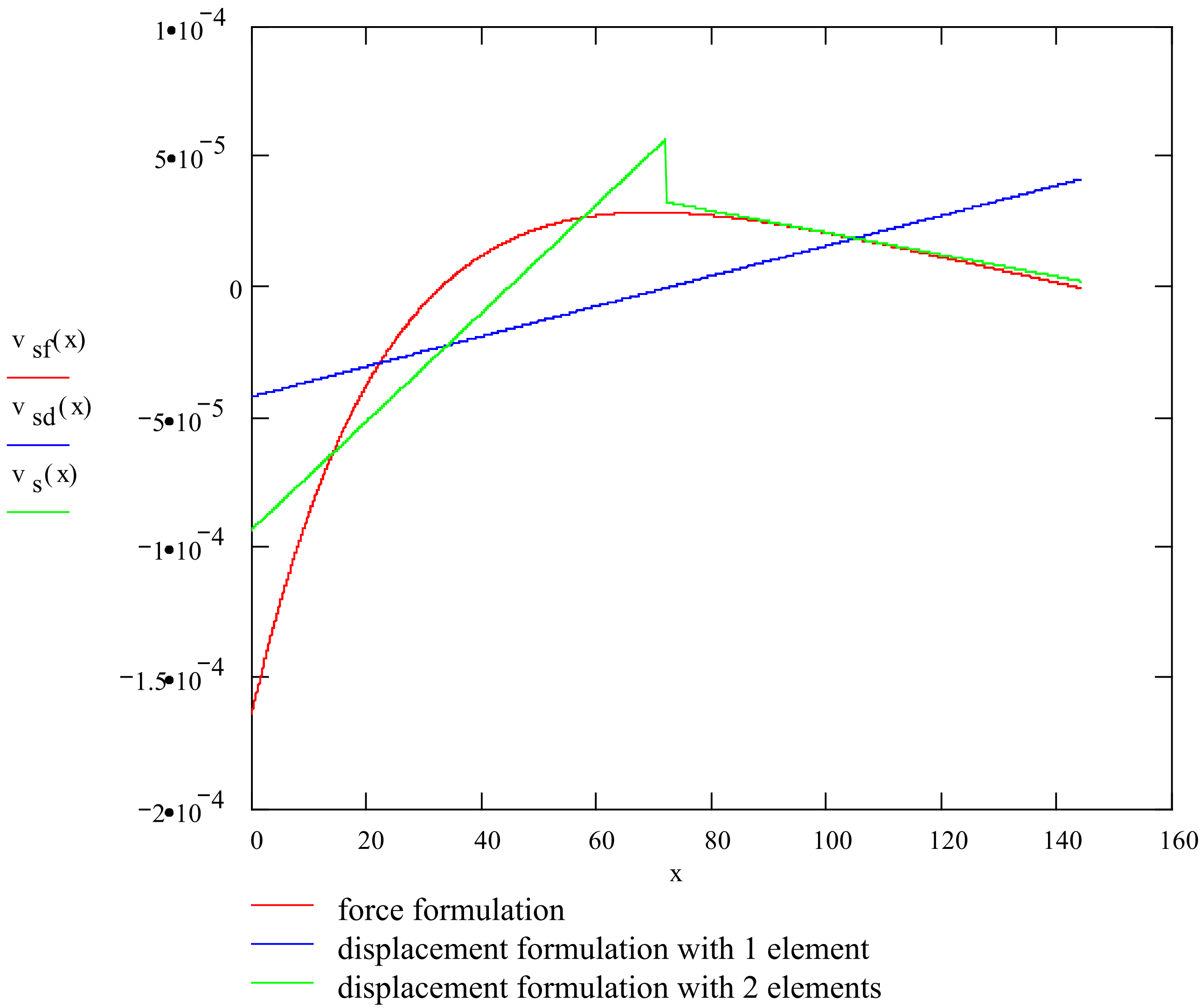
Push-Over of Two Story Frame (Distributions)



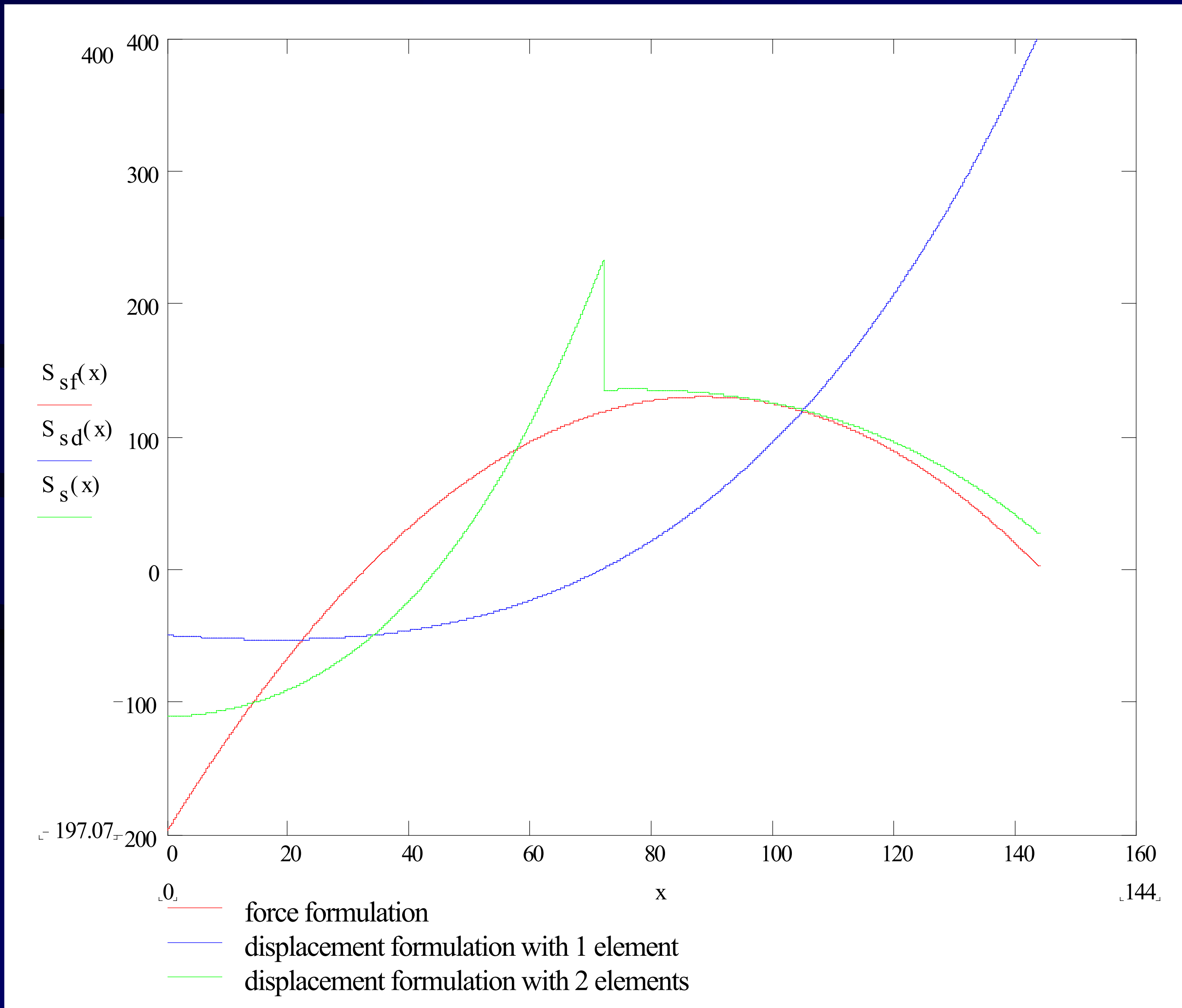


Tapered Beam - Curvature Distribution

Curvature distribution:



Tapered Beam - Bending Moment Distribution



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Advantages of Force Formulation

- equilibrium is satisfied exactly along the element in every iteration; end compatibility is satisfied on convergence
- distributed loads can be readily accommodated
- a single element suffices for the entire member; no mesh refinement is necessary; localization problems are minimized
- formulation is very robust in the presence of strength softening

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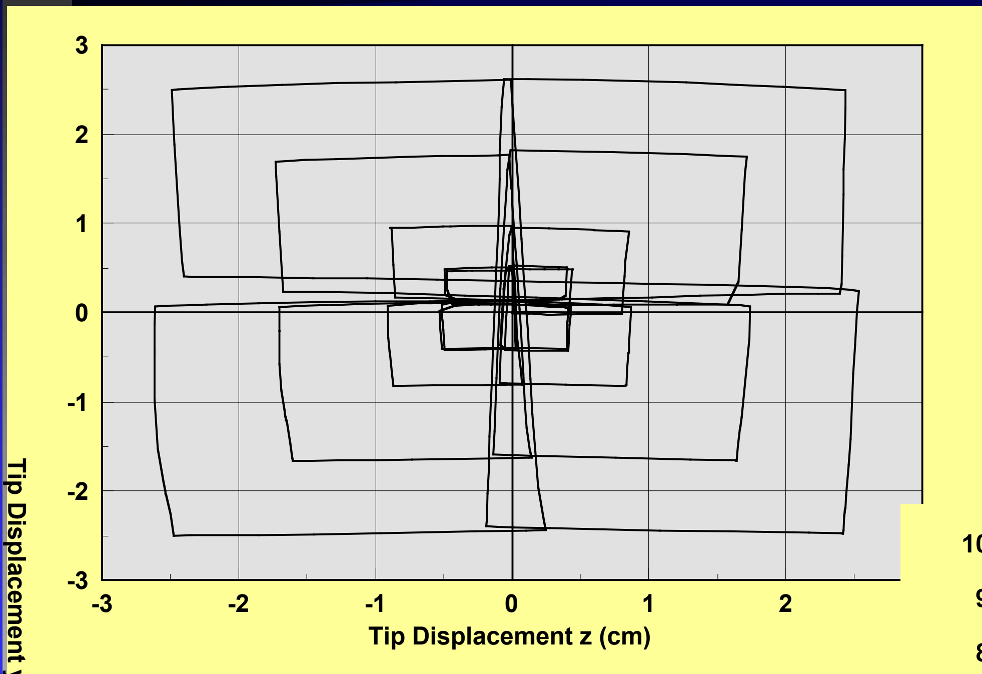
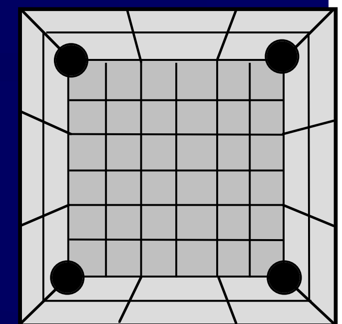
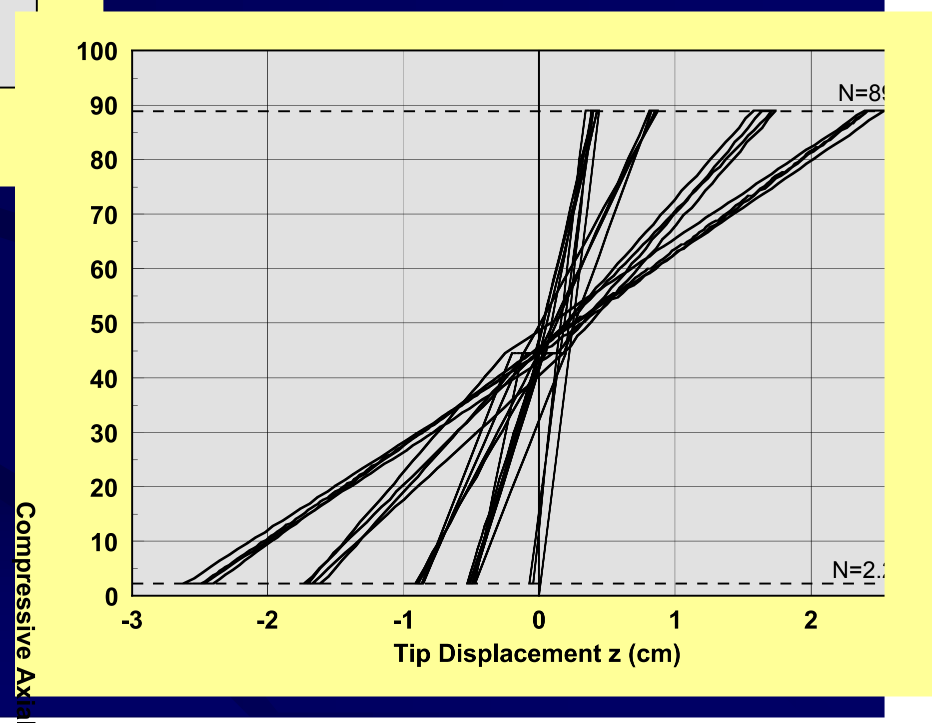
Low-Moehle Specimen No. 5 (EERC Report 1987-14)



Biaxial Bending



and Variable Axial Load



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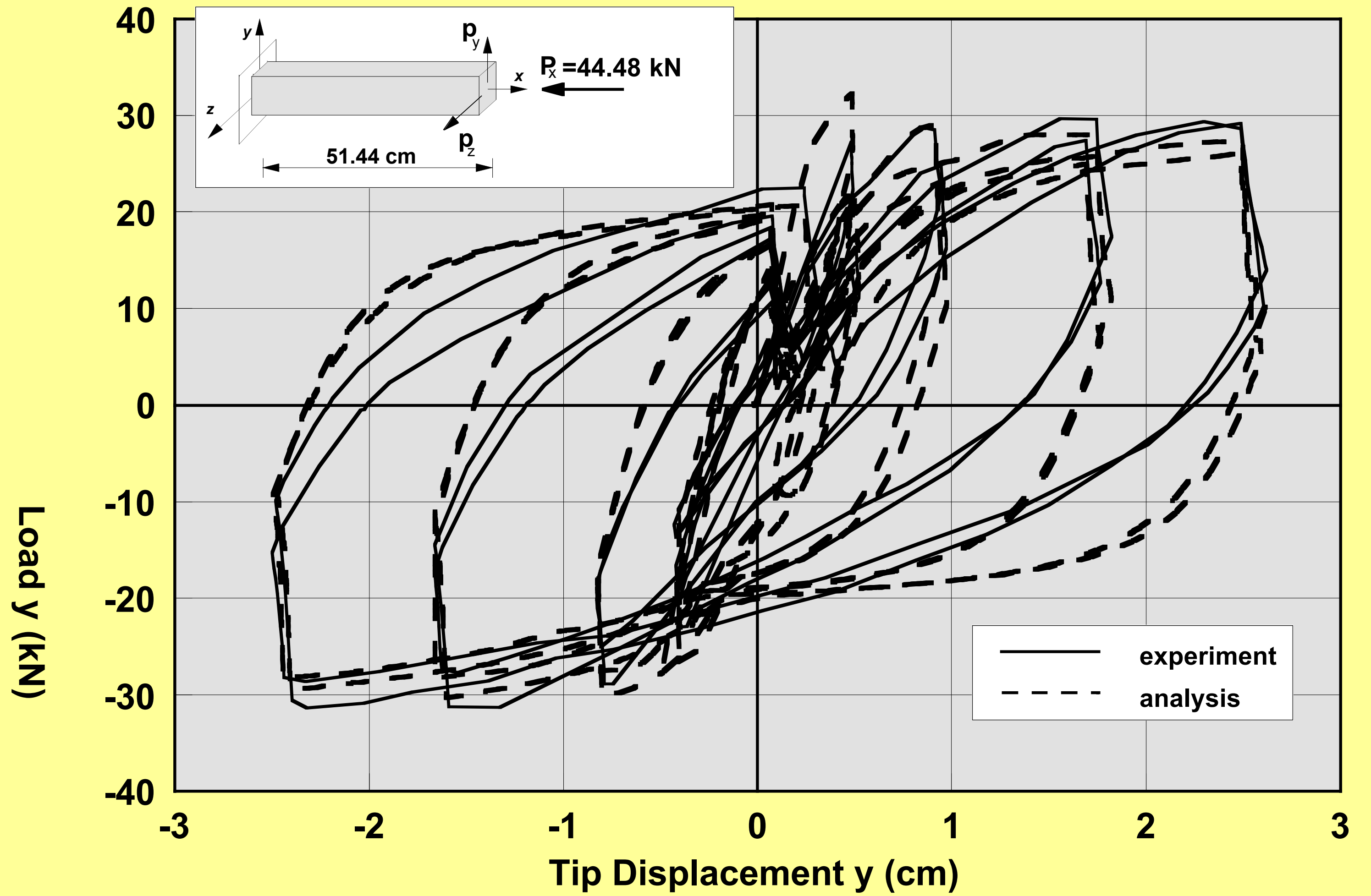
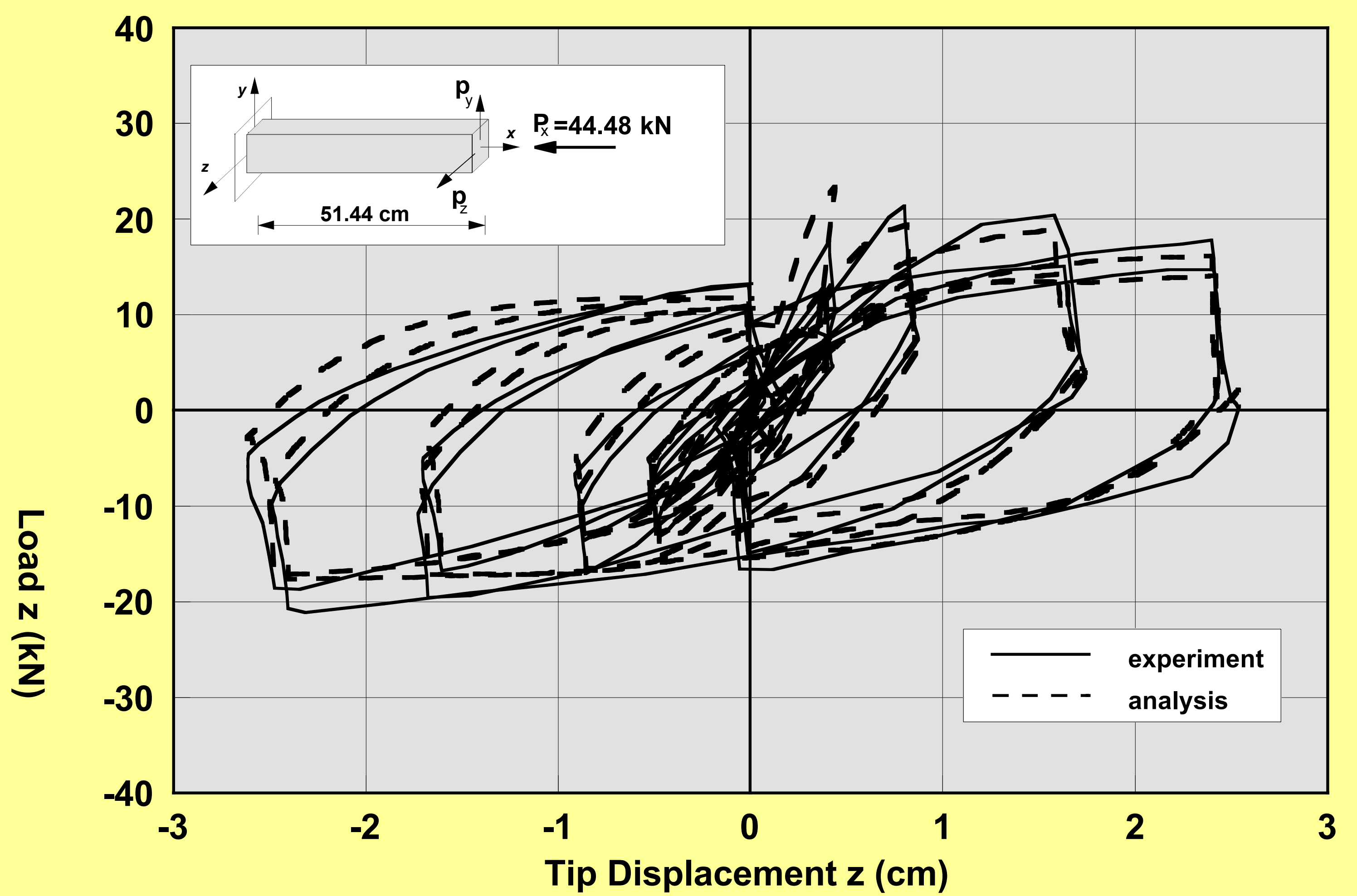
Low-Moehle Specimen 5: Response in y



Low-Moehle Specimen 5: Response in z



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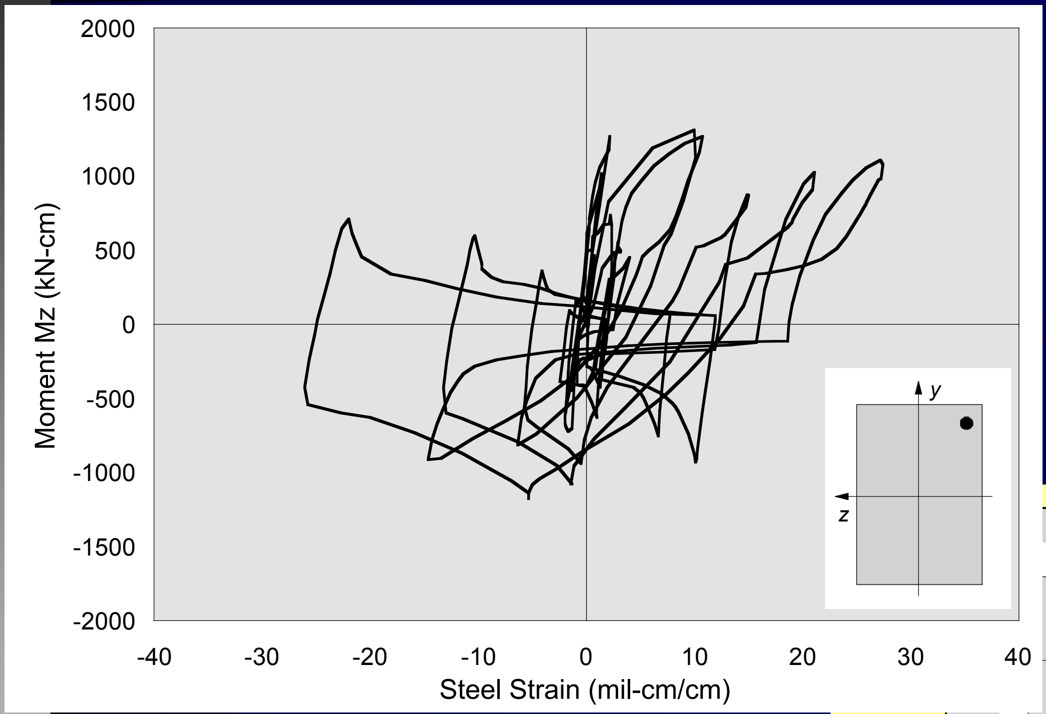
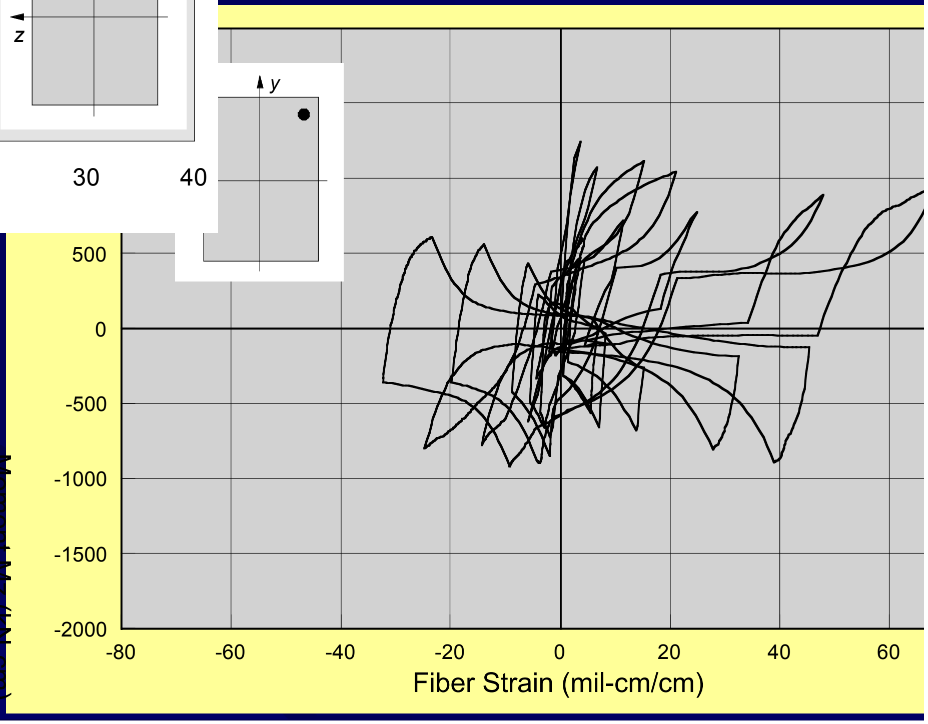
Low-Moehle Specimen 5: Reinforcing Steel Strain History

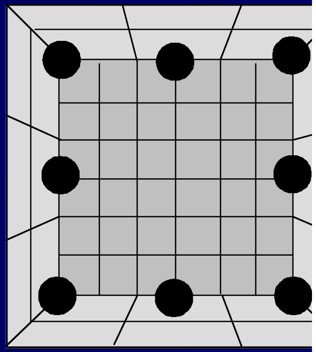




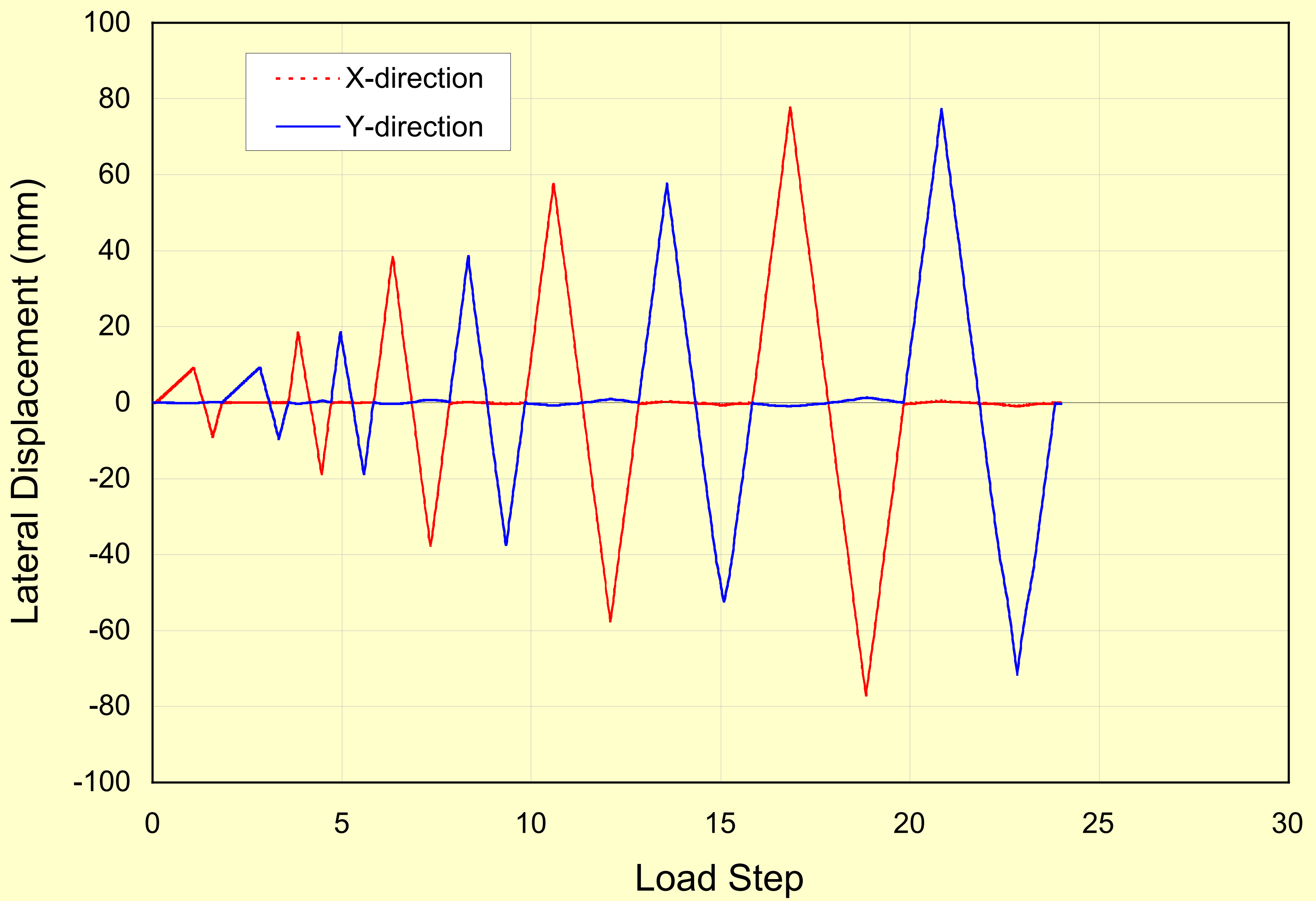
Correlation Studies for ISPRA columns (Bousias et al.)

12 Column Specimens with identical geometry and reinforcing

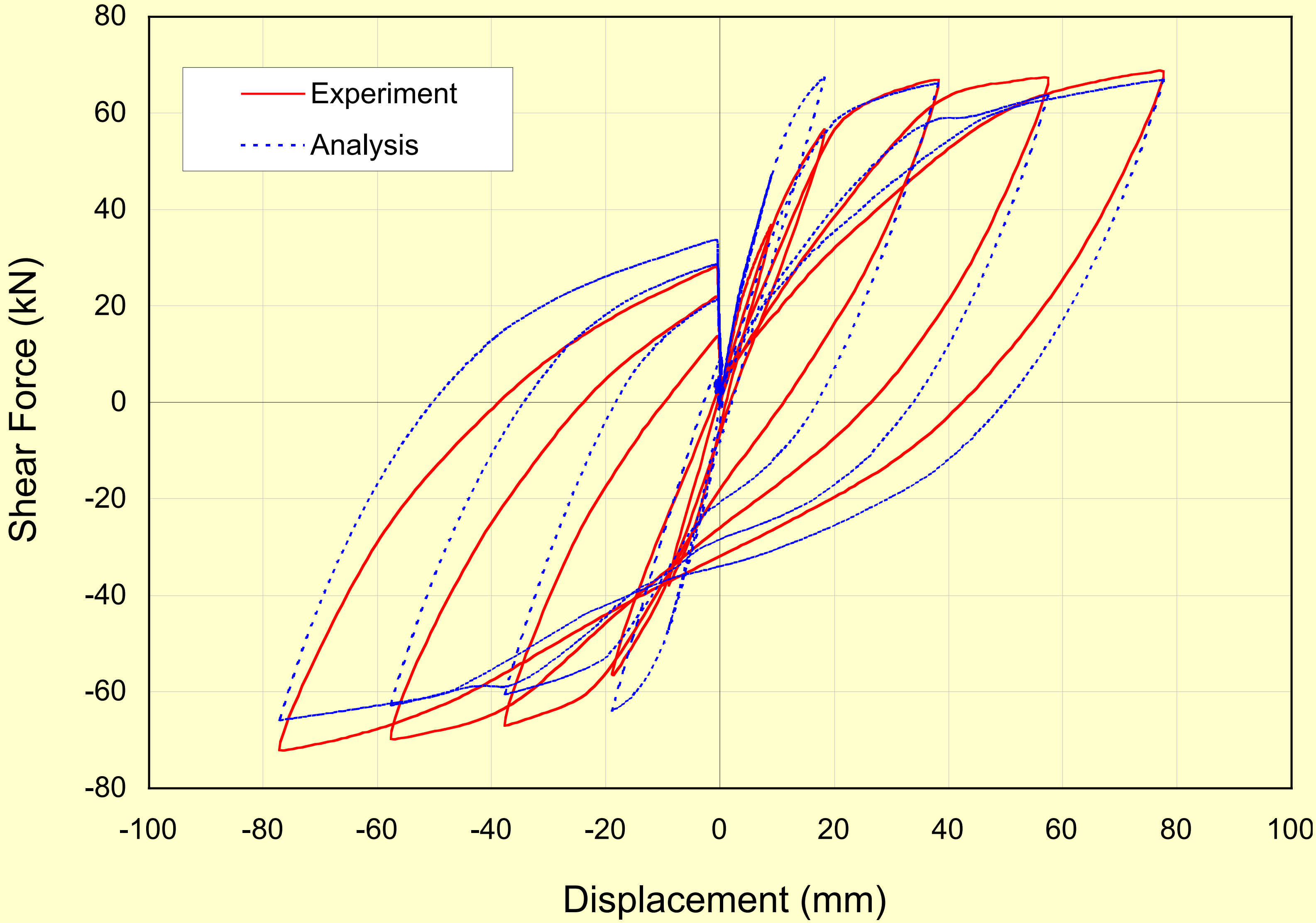
- S0
  - Uniaxial displacement cycles in x
  - constant axial compression ~ 16% of axial capacity (?)
- S1
  - Alternating uniaxial displacement cycles in x and y
  - constant axial compression ~ 10% of axial capacity
- S5, S7
  - Different biaxial displacement histories in x and y;
  - constant axial compression ~ 12% of axial capacity
- S9
  - Biaxial displacement history in x and y;
  - two levels of axial compression ~ 3%->15% of axial capacity
- S4
  - Displacement in x, Force in y
  - constant axial compression



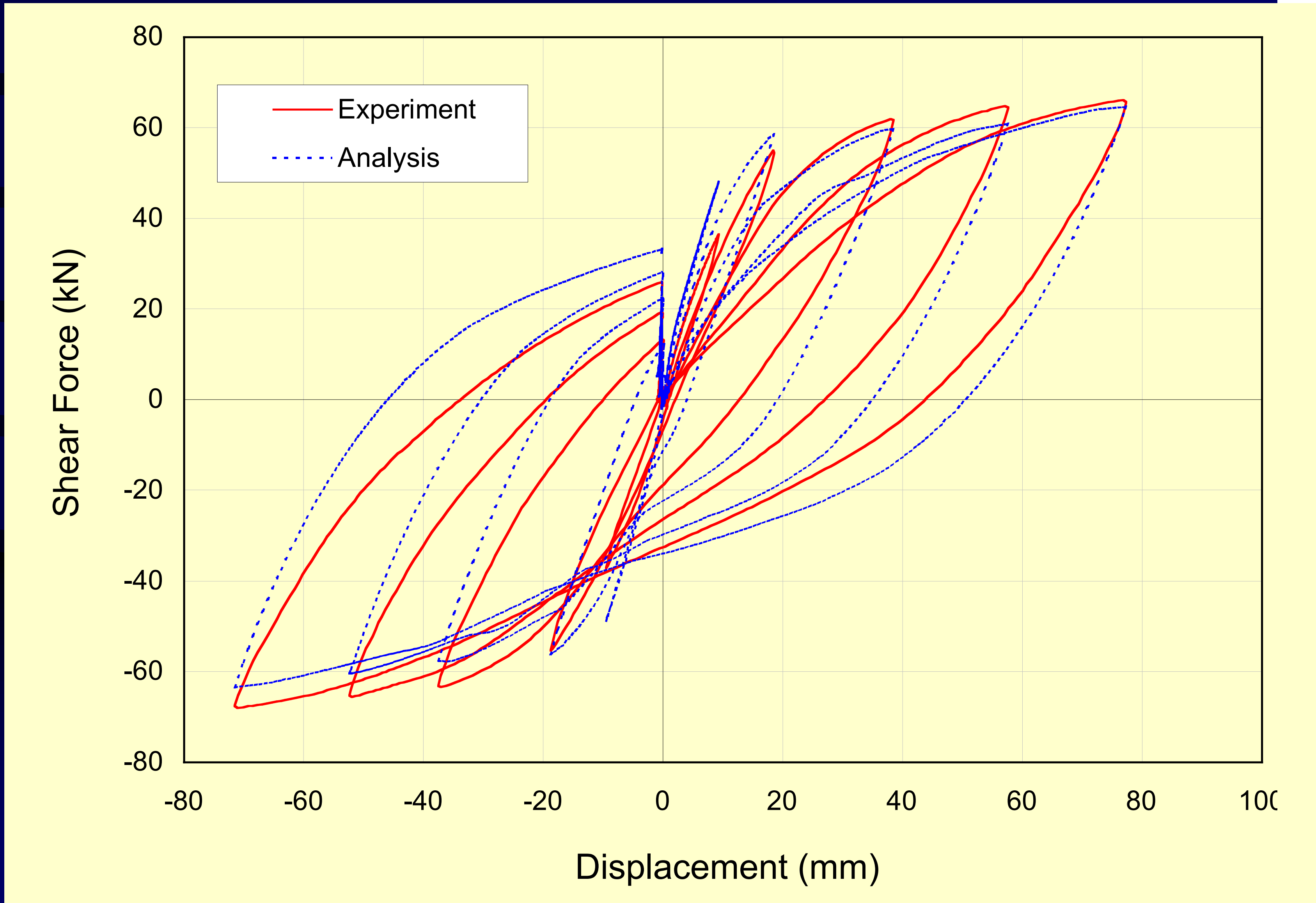
ISPRA Specimen S1 - Lateral Displacement History



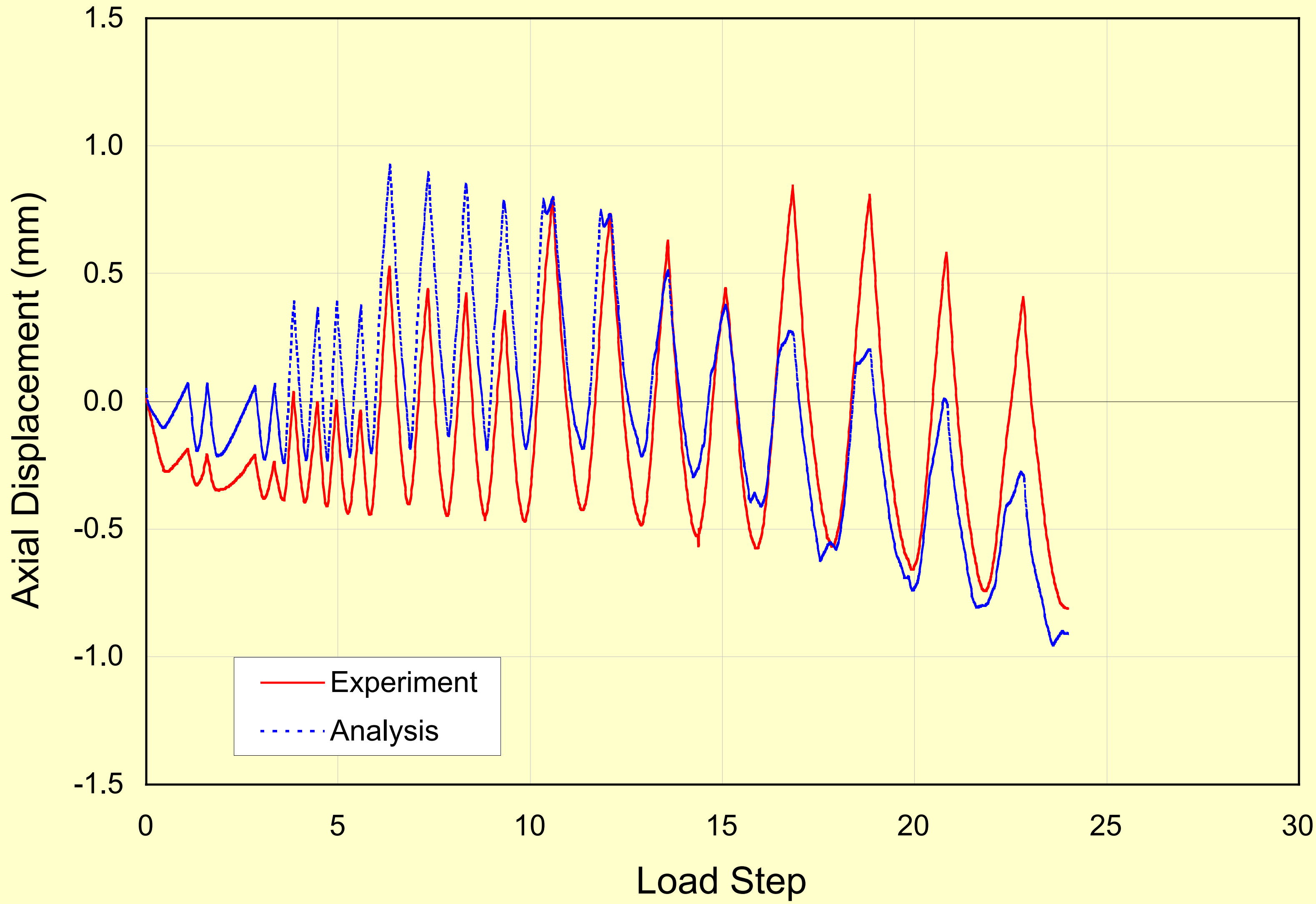
ISPRA Specimen S1 - Flexural Response in x



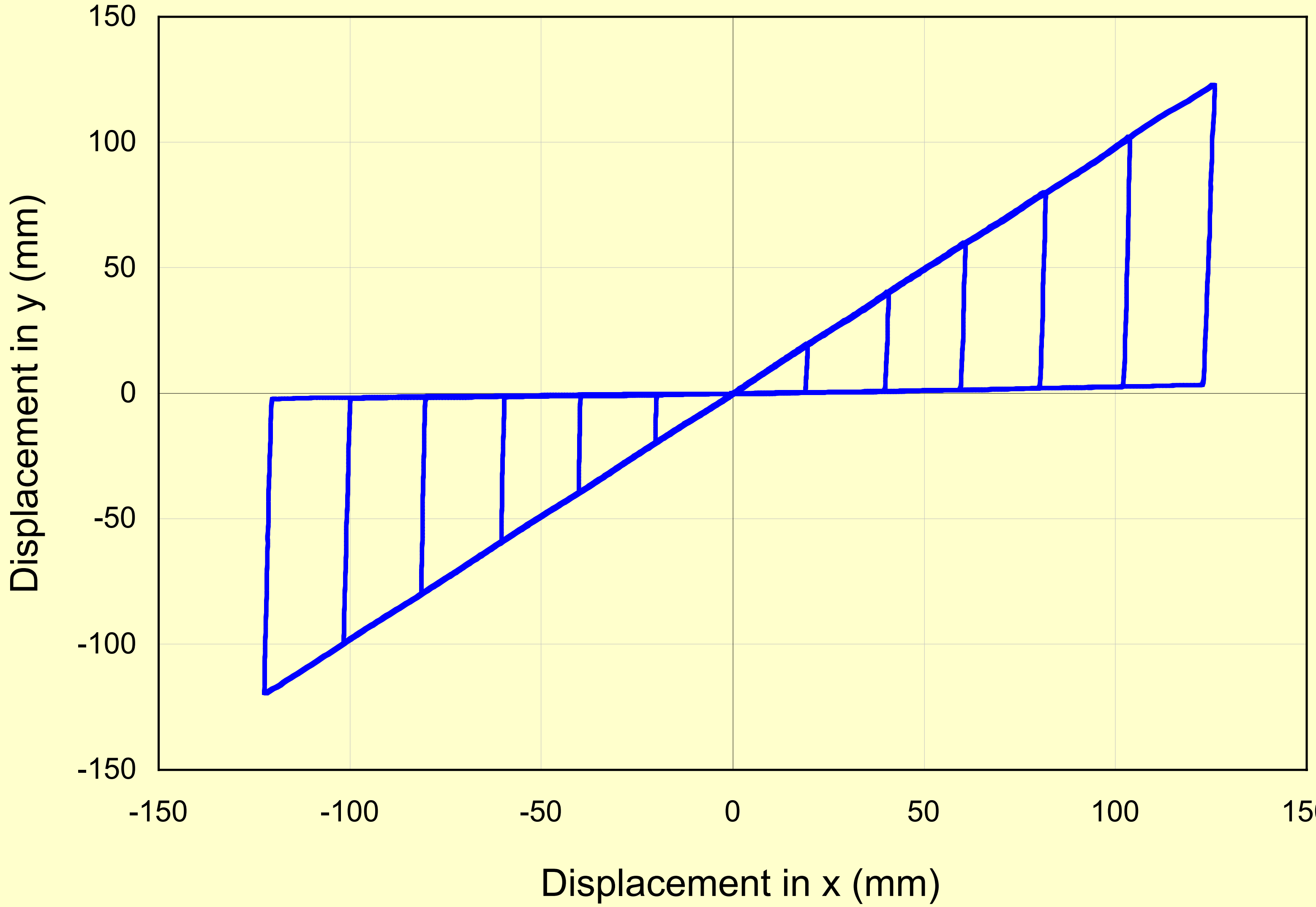
ISPRA Specimen S1 - Flexural Response in y



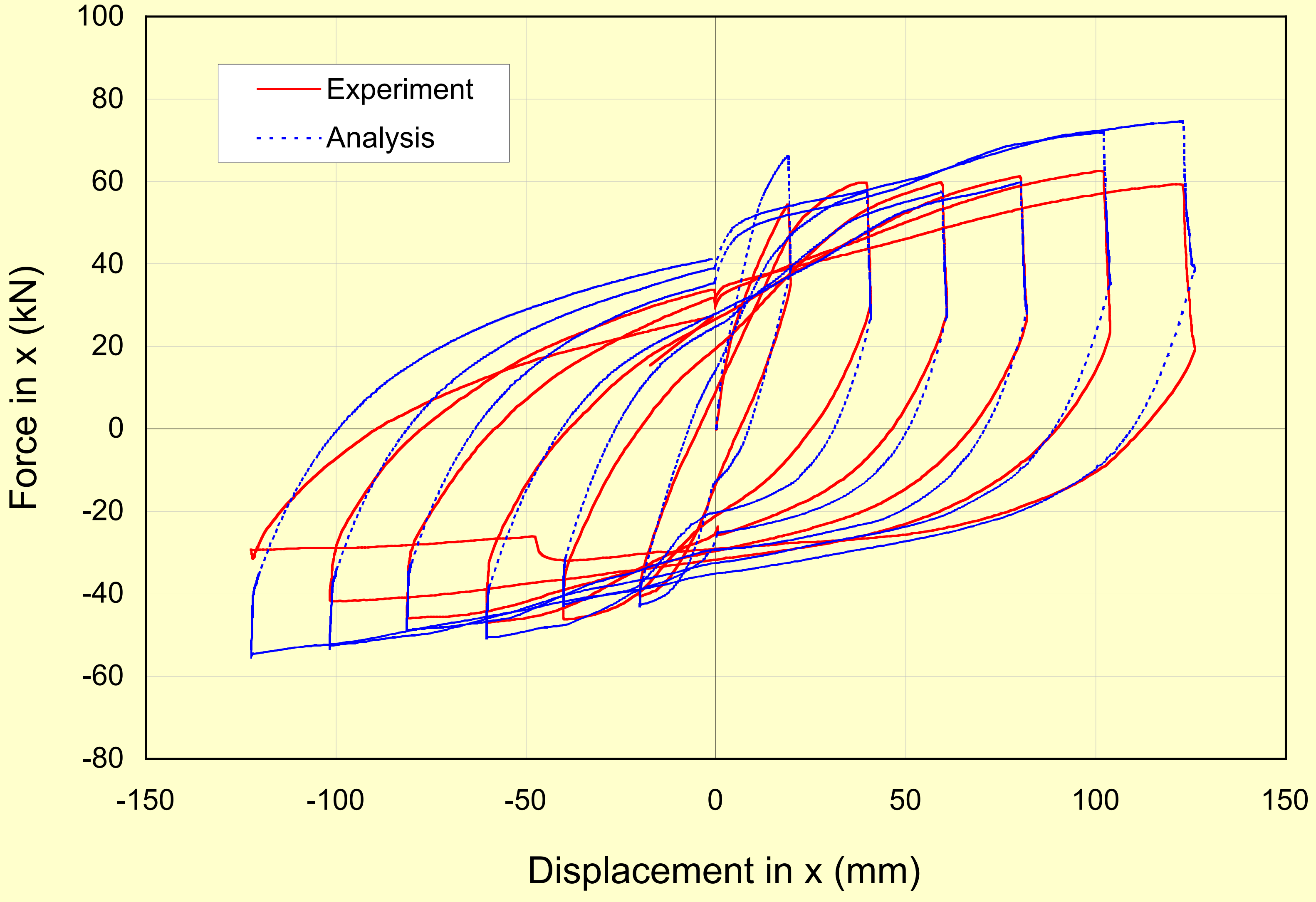
ISPRA Specimen S1 - Axial Displacement History



ISPRA Specimen S5 - Lateral Displacement History



ISPRA Specimen S5 - Flexural Response in x



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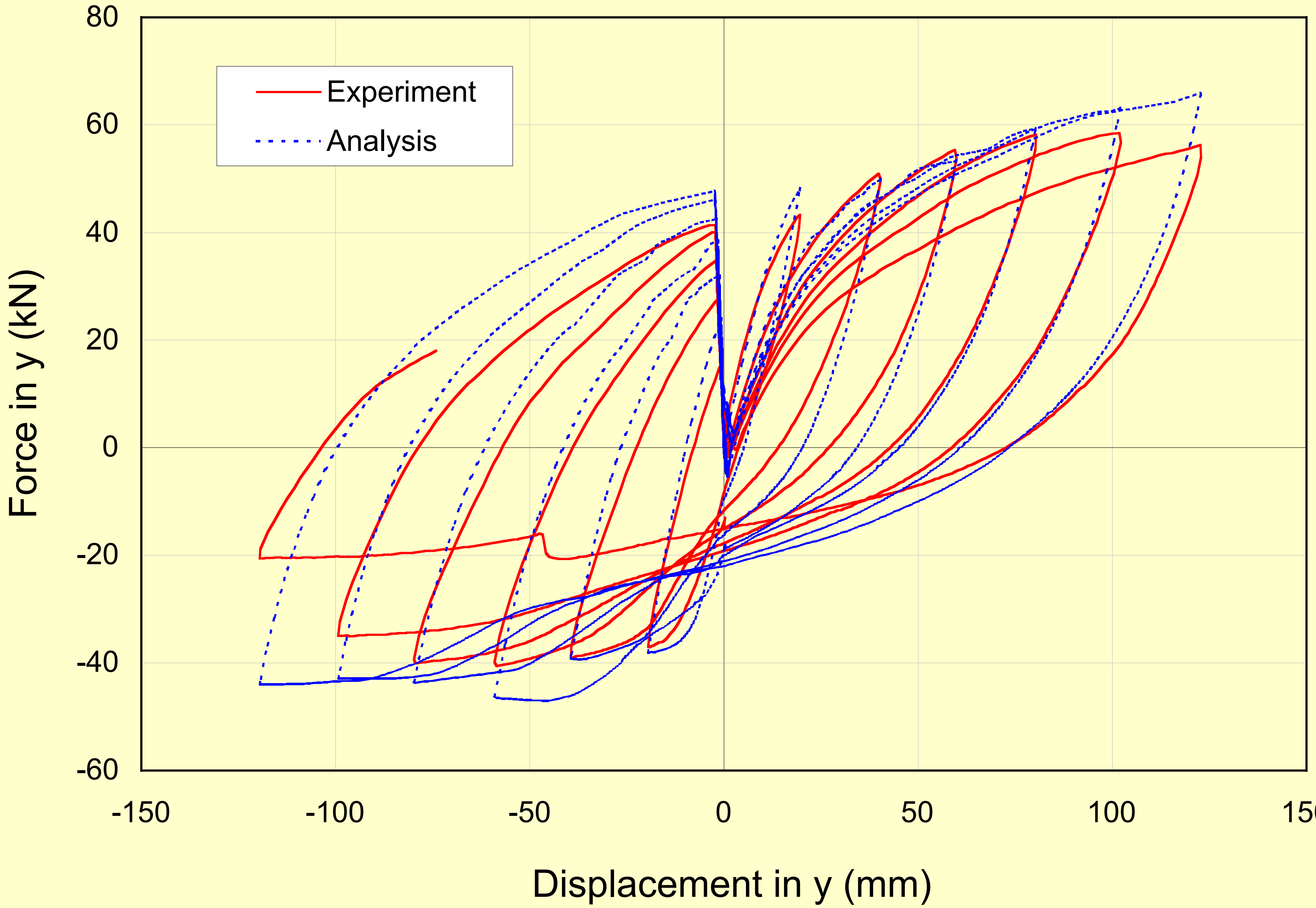
ISPRA Specimen S5 - Flexural Response in y



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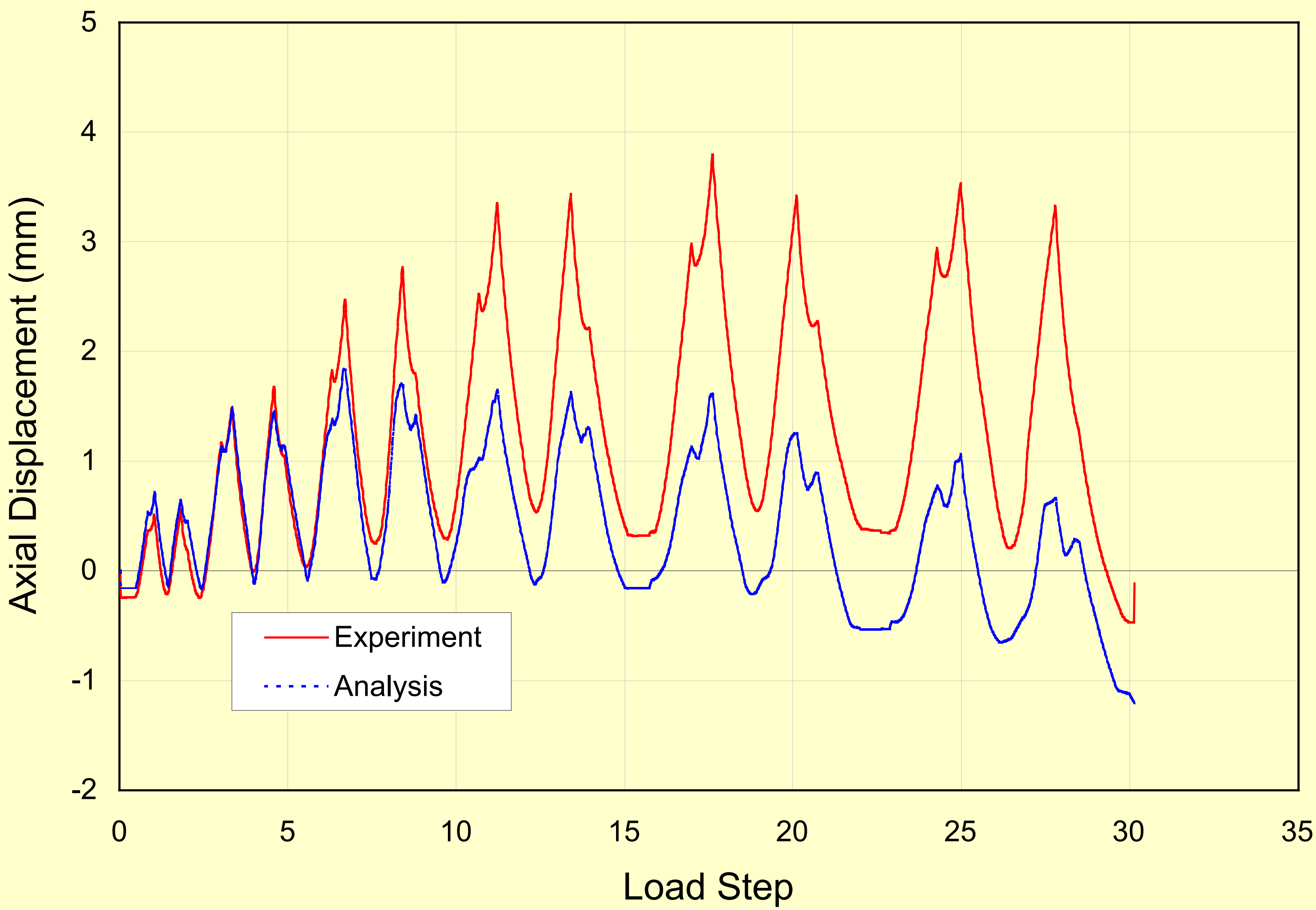
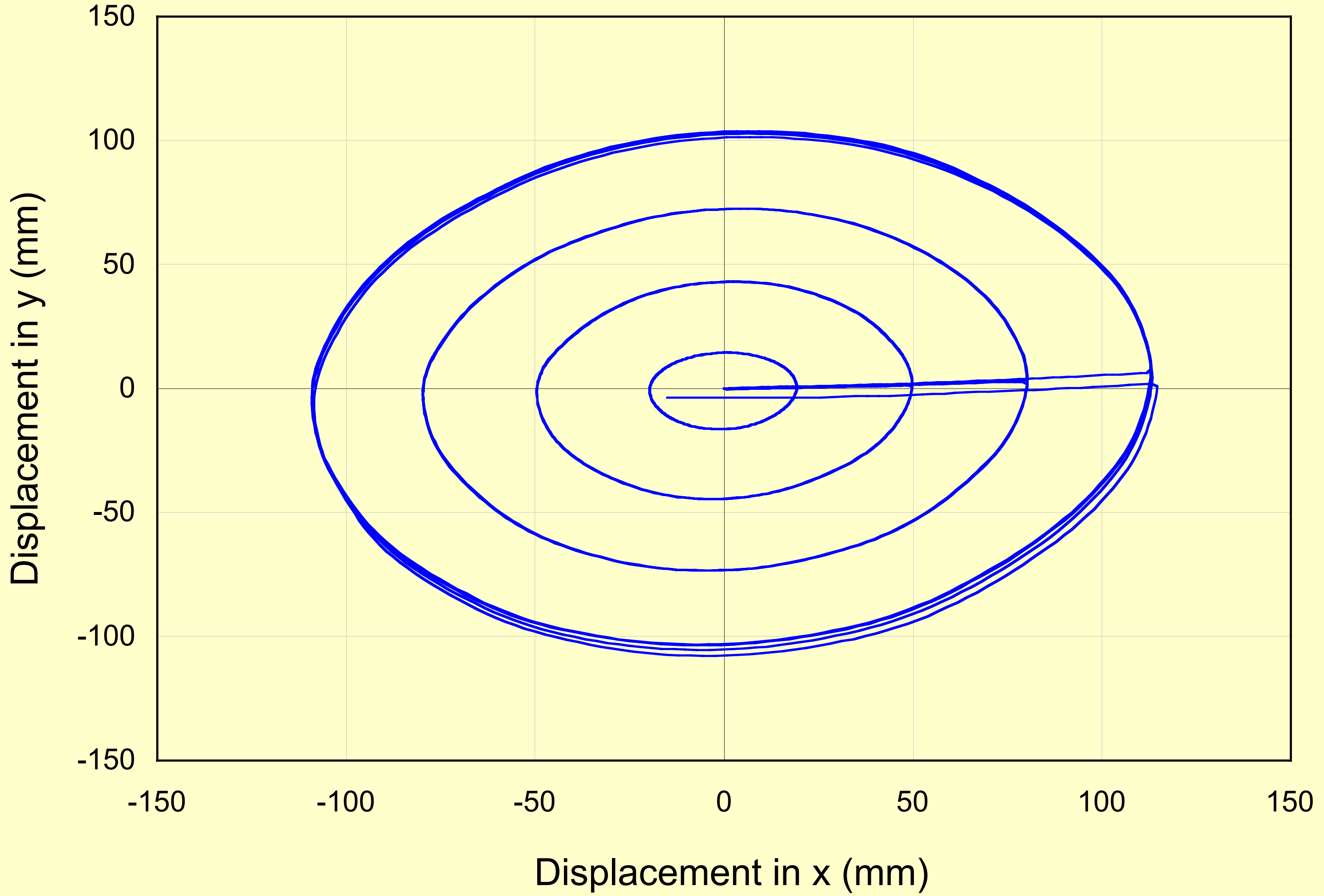
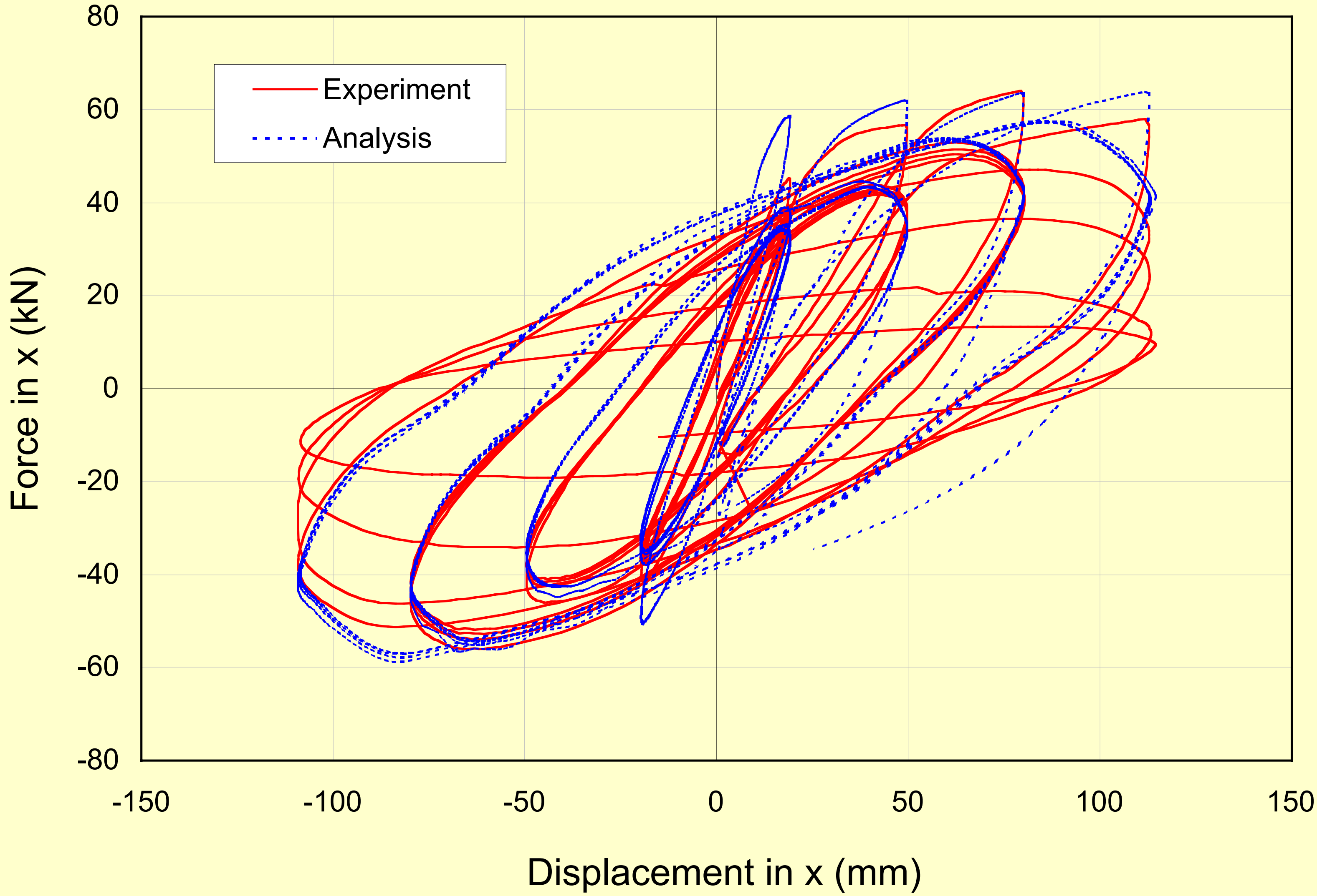
ISPRA Specimen S5 - Axial Displacement History



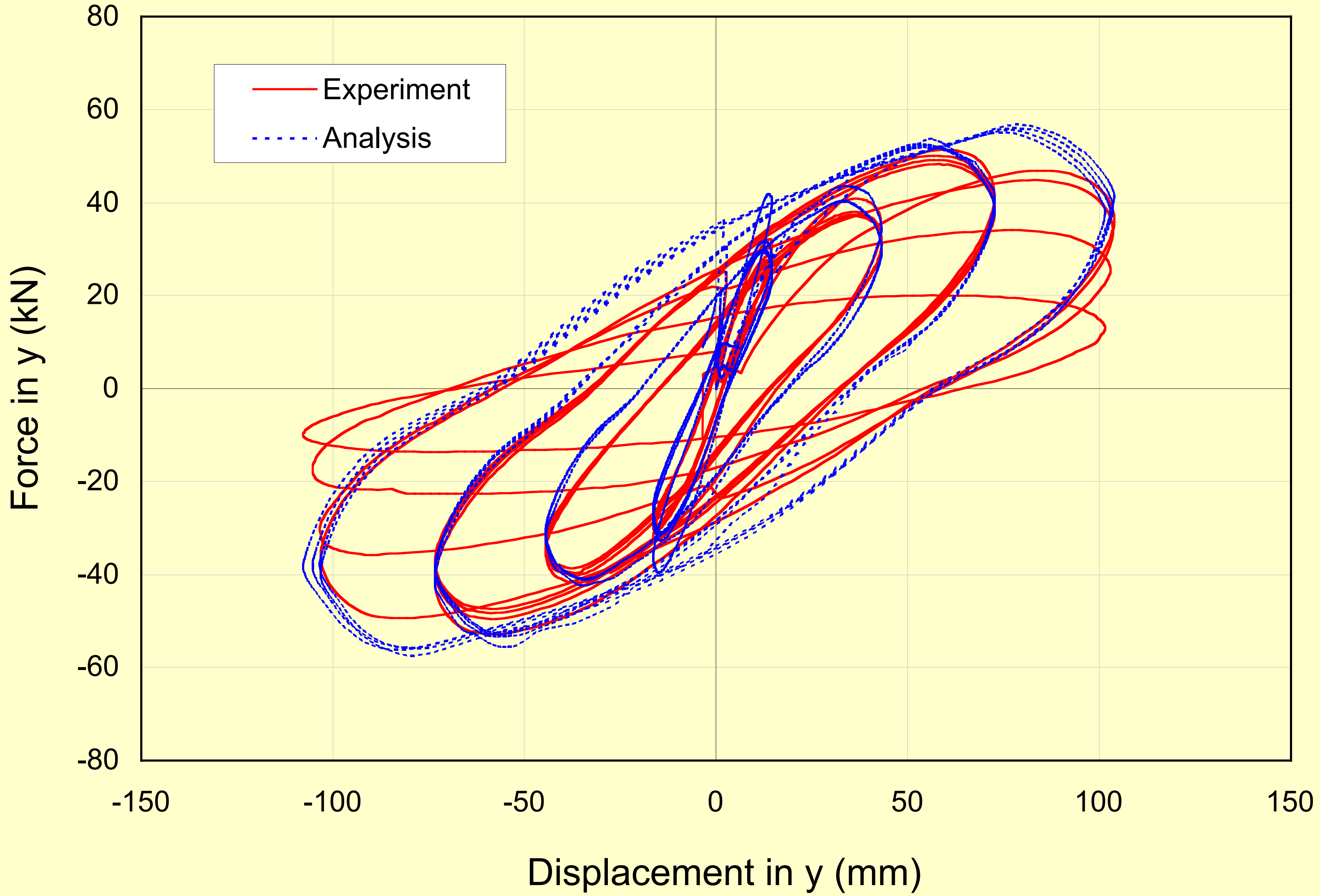
ISPRA Specimen S9 - Lateral Displacement History



ISPRA Specimen S9 - Flexural Response in x



ISPRA Specimen S9 - Flexural Response in y



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ISPRA Specimen S9 - Axial Displacement History

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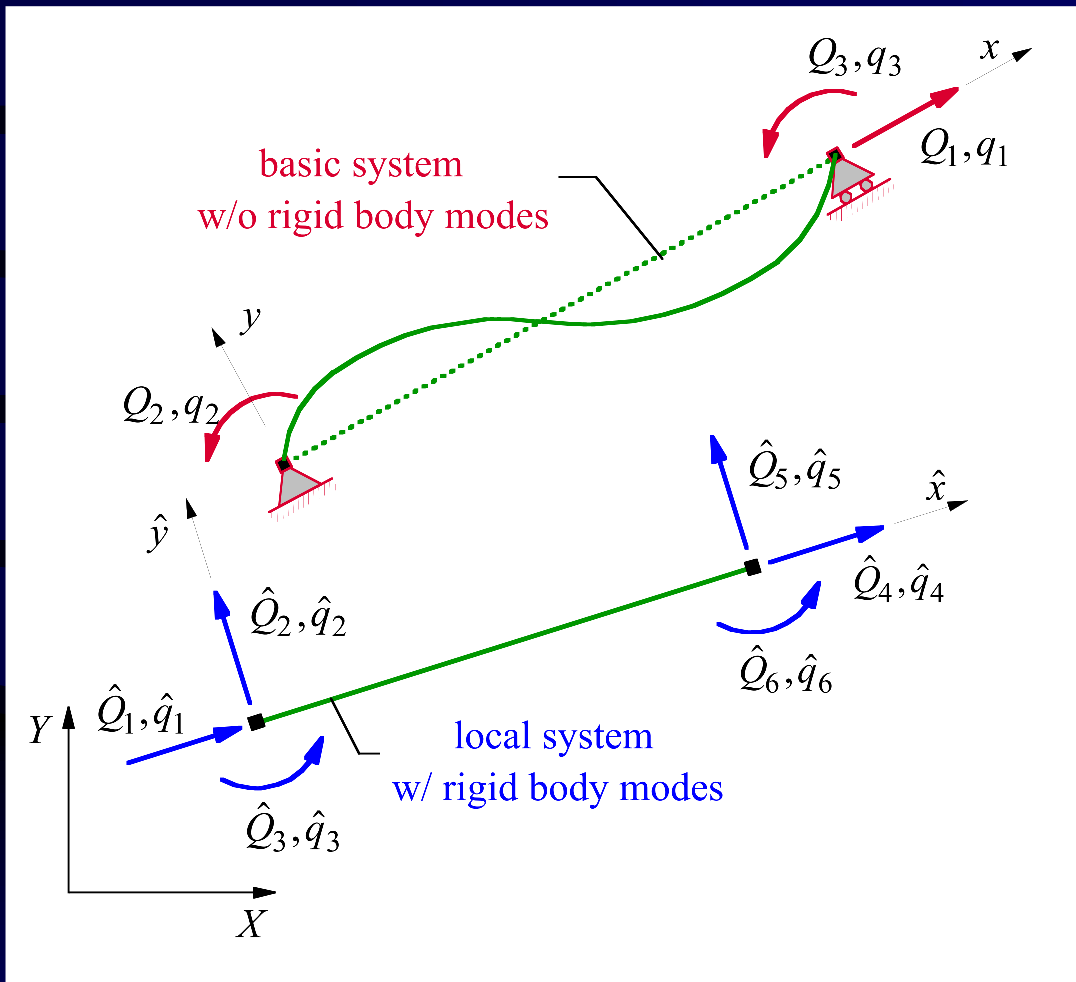
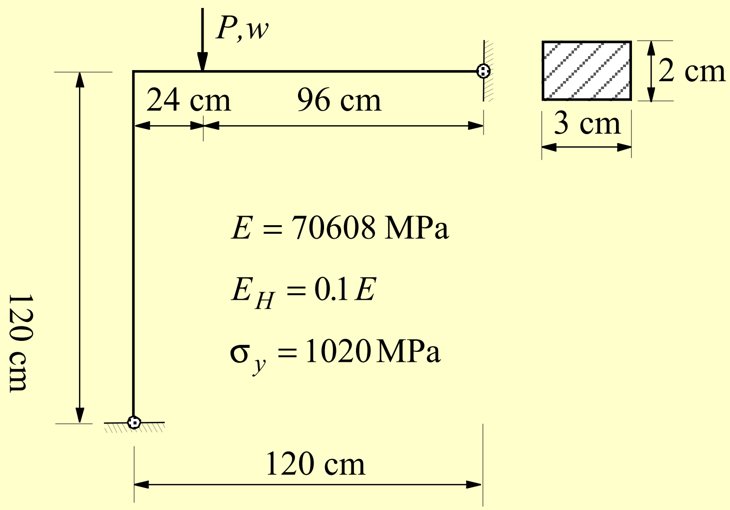
Second order analysis - Large displacements



The co-rotational formulation separates rigid-body modes fr local deformations, using a si coordinate system that continuously translates and ro with the element as the deformation proceeds.

Lee's Frame



$E = 70608$ MPa

$E_H = 0.1\,E$

$\sigma_y = 1020$ MPa

Lee's Frame

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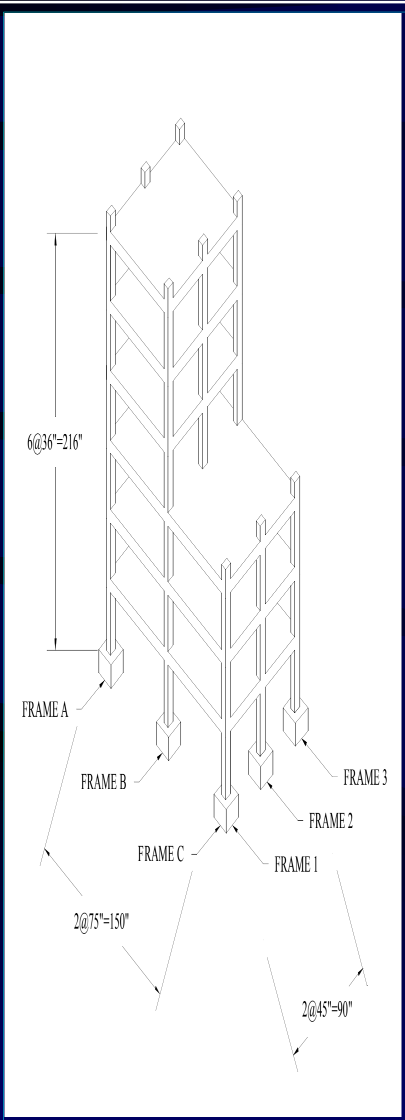
Parking Garage, 1994 Northridge Earthquake

Shaking Table Specimen of Shahrooz-Moehle (1987)



Shaking Table Specimen El Centro 7.7

Shaking Table Specimen El Centro 49.3