Hybrid experimentation for soil pipeline systems

Bristol University. Aug 31st 2016

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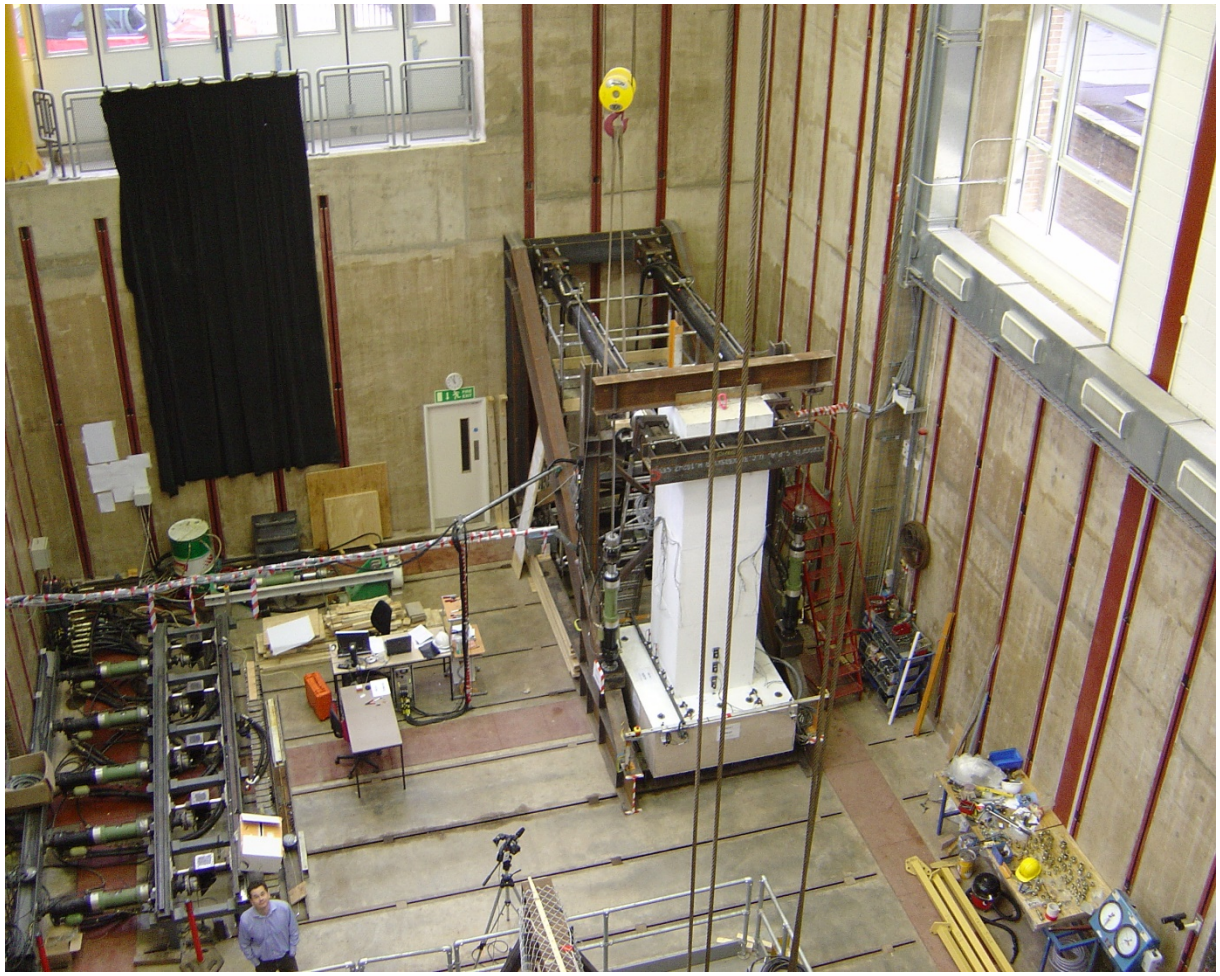
Earthquake Engineering

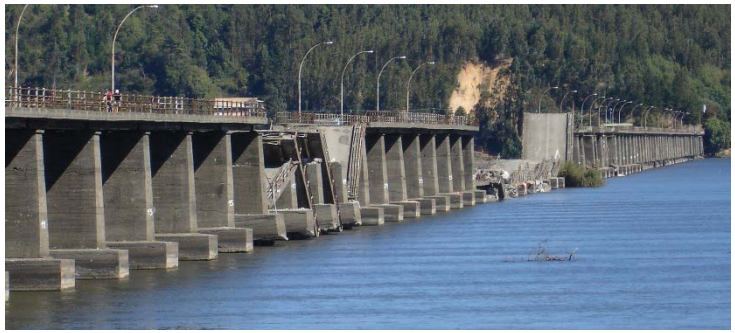
- Main features
  - Research activity since 1958
  - Interdisciplinary
  - Integration of analysis, laboratory experiments and prototype monitoring
  - Largest facilities in UK (£18.5m)
  - Coordinator of EU large facilities since 1990
  - Current research contract portfolio £1.9m
  - Own company, BEELAB Ltd.
- Research themes
  - Non-linear dynamics
  - Systems view of performance
  - Suspension and cable-stayed bridges
  - Advanced laboratory test control
  - Geotechnical modelling and testing
  - Dams and appurtenant works
  - New materials, health monitoring
- Output and Implementation
  - c. 200 publications in earthquake engineering area in last 5 years.
  - Research has strong UK industry focus, e.g.
    - British Energy
    - Second Severn Crossing
    - Scottish & Southern Electric
    - Halliburton KBR
    - Clifton Suspension Bridge
    - MoD
    - Babtie, Halcrow, Flint & Neil
    - BEELAB – many clients, seismic qualification, product development

Experimental Facilities - Bristol

EQUALS test facility



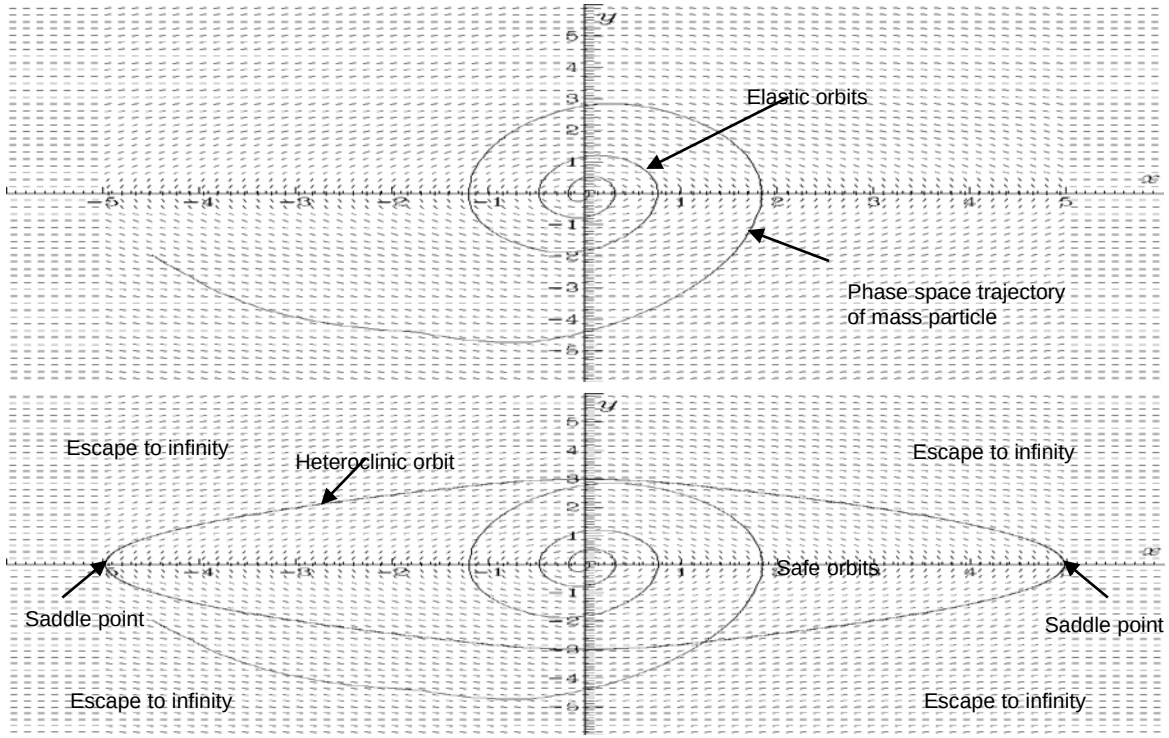
Earthquake Engineering

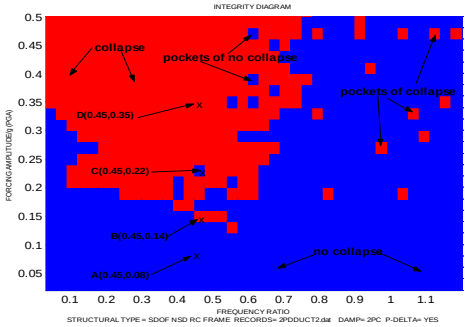


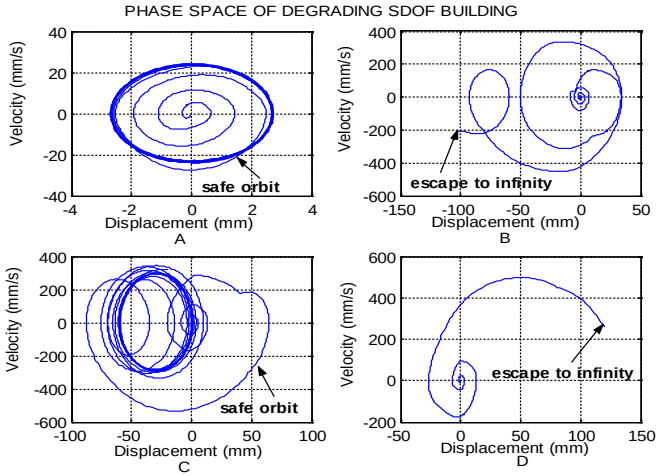
- Analysis and modelling
- Foundations
- Dams / Intake towers
- Masonry infills
- Bridges
- Dynamic substructuring/control
- Protection systems
- UKNEES
- Systems Engineering
- EEFIT
- Outreach - IDEERS, WISER, Dynamic Designs
- Industry

Nonlinear dynamics

- Non-linear potential wells as models of dynamic collapse





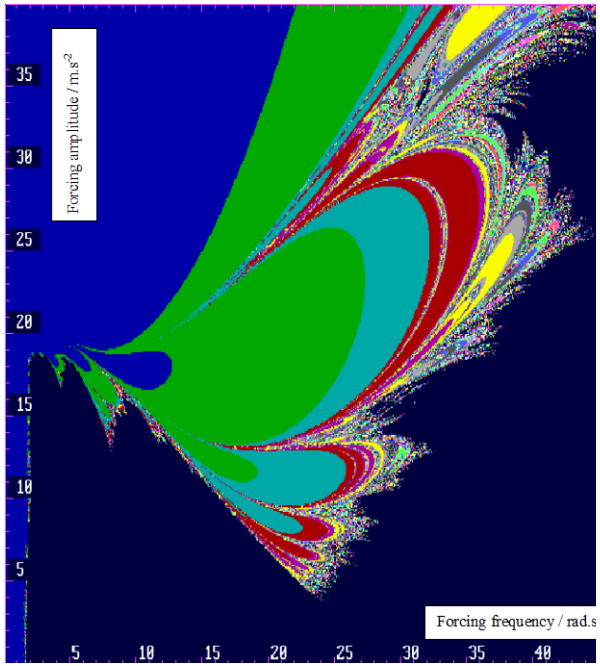


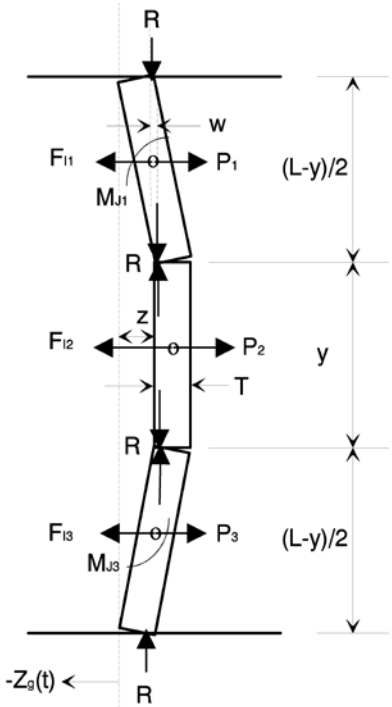
Discrete element modelling

- Modelling of complex nuclear reactor cores

Masonry panels

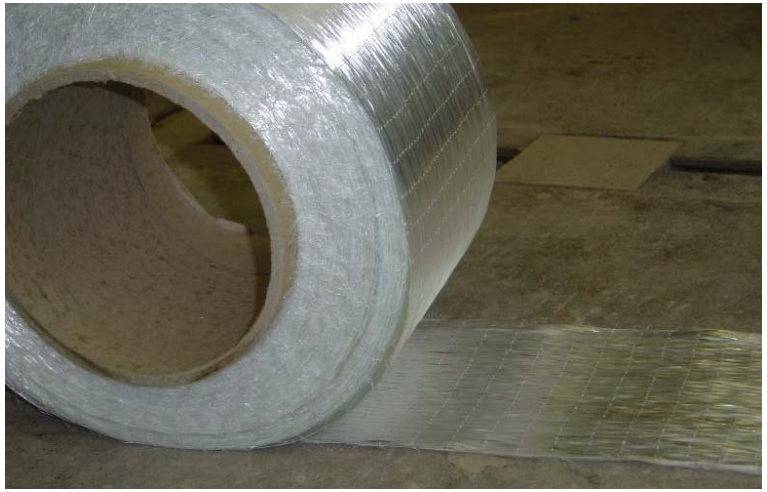
- Out-of-plane behaviour
- Unreinforced masonry panels

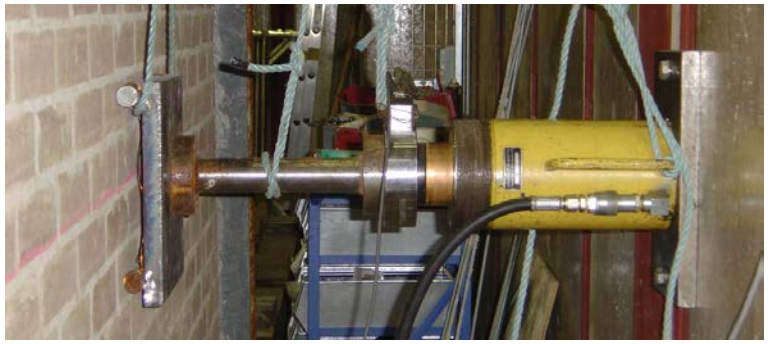




Masonry panels

- Strengthening techniques with GRP fabric

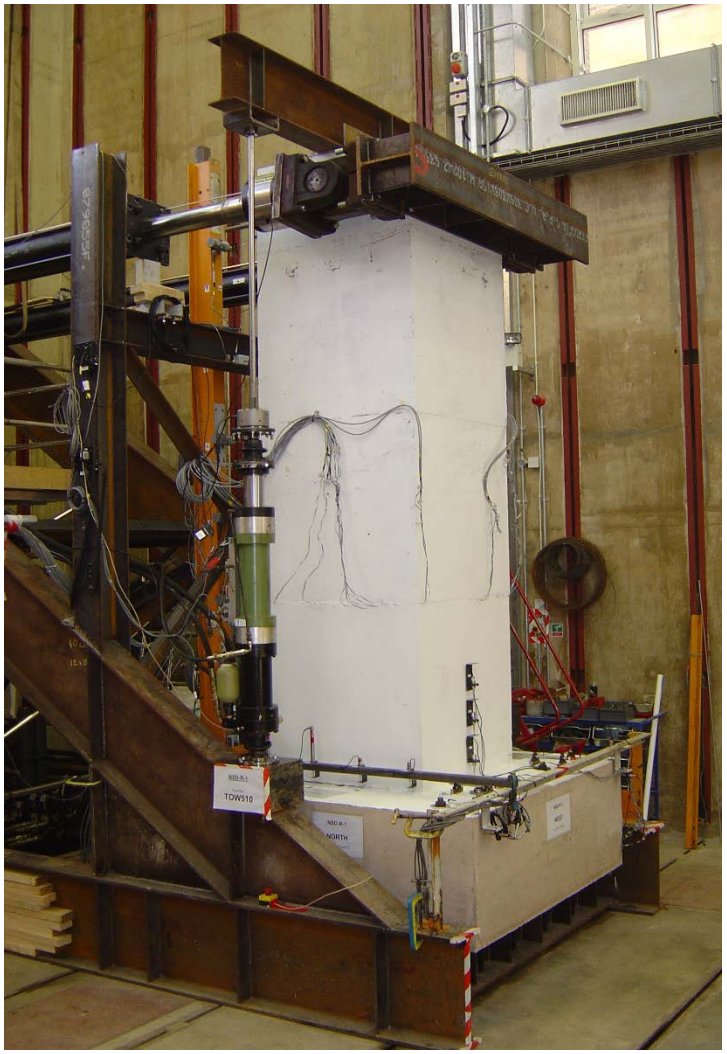




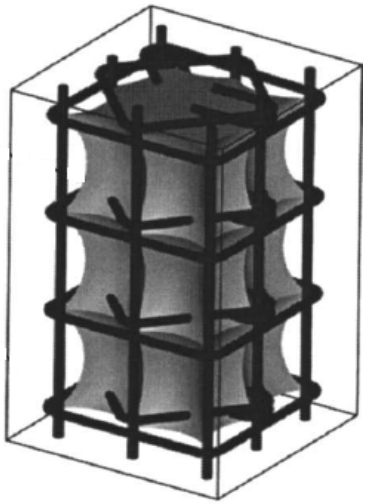
Dams

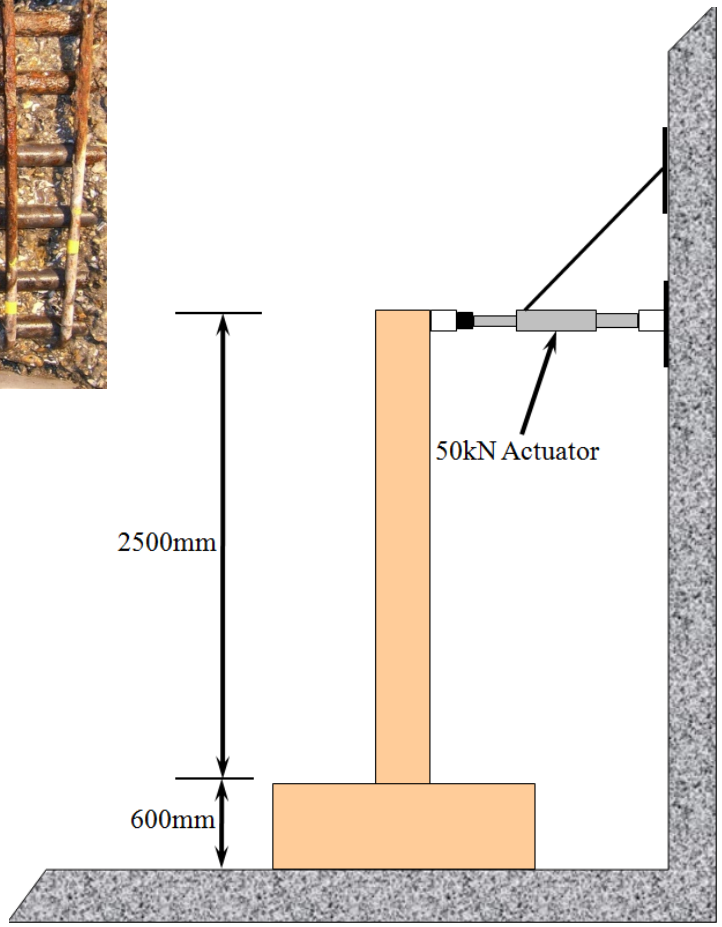
- Performance of Intake towers

Intake and outlet towers regulate reservoir water release



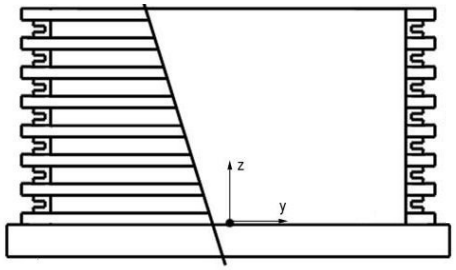
Corrosion of Bridge Piers



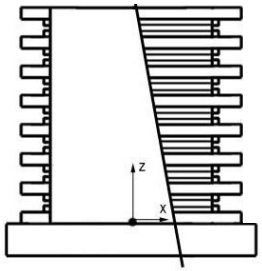


Large Laminar Shear Box

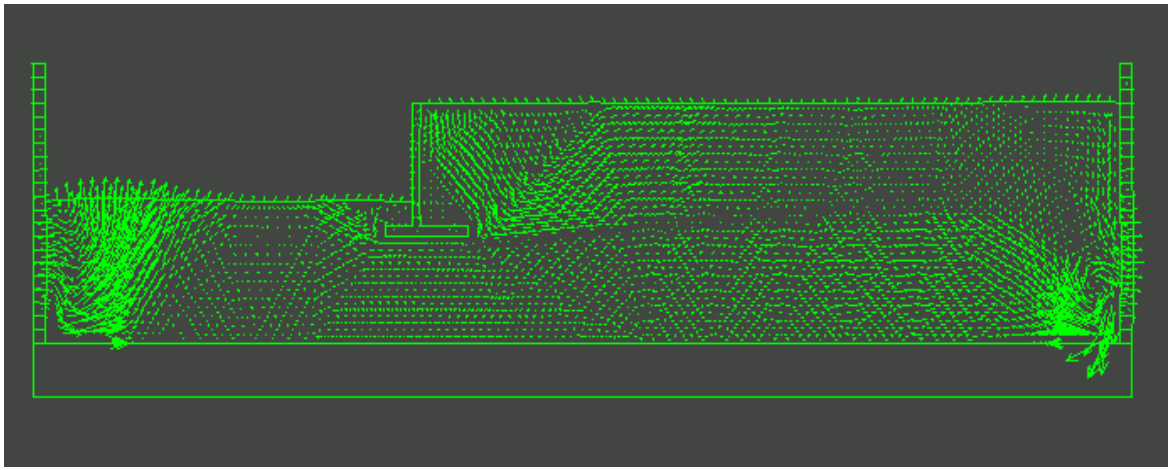
- For large scale testing of retaining walls and foundations

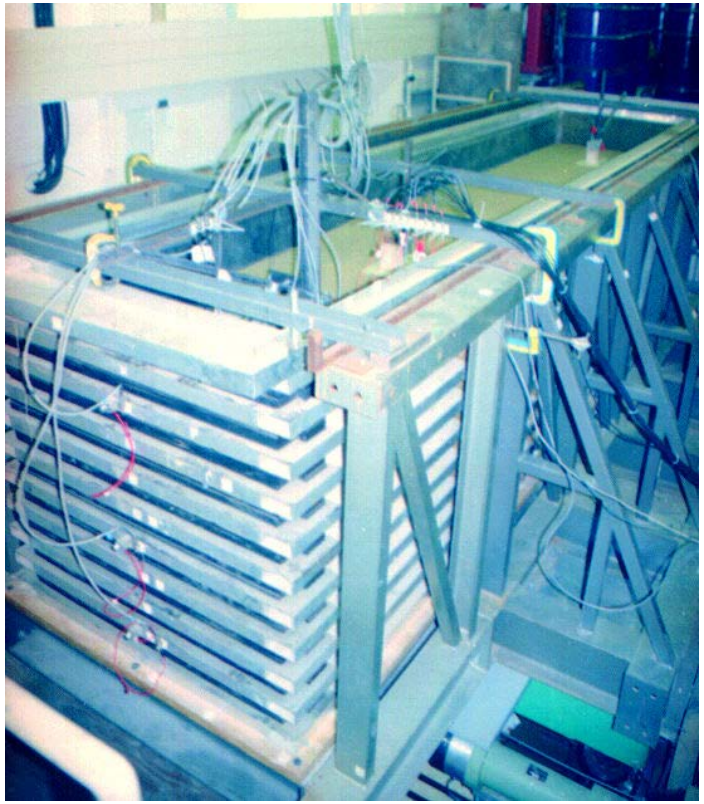


Long section (in direction of shaking)



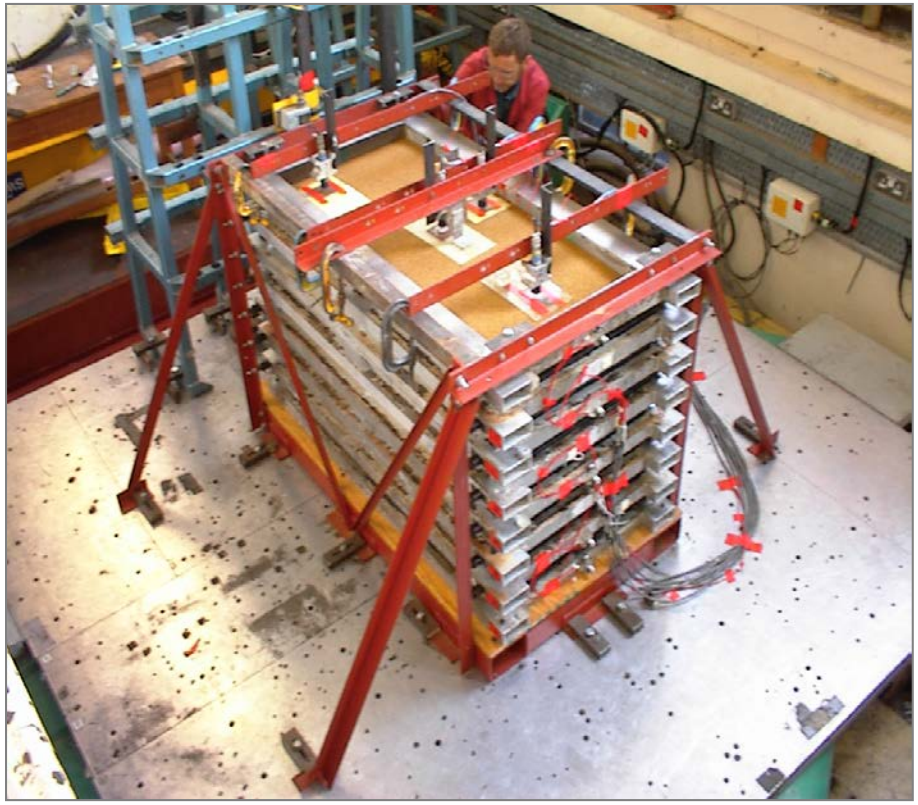
Cross section

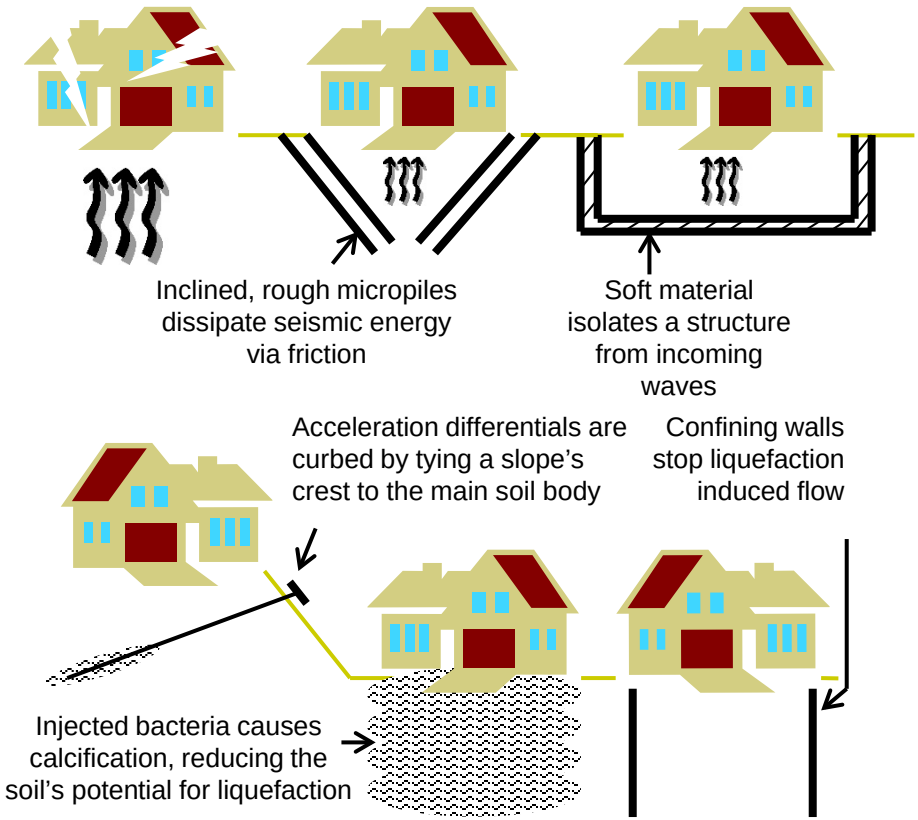




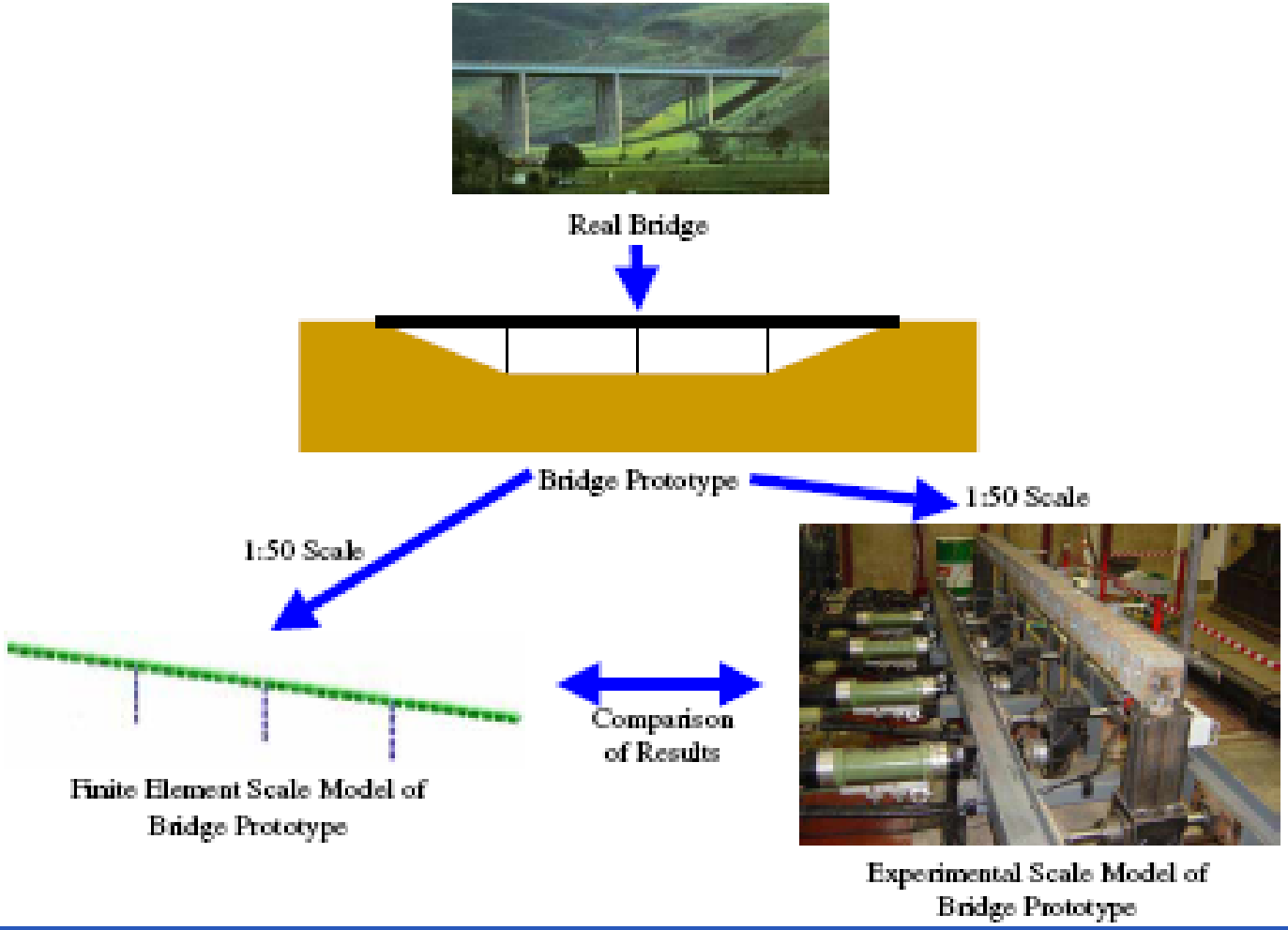
Foundations

- Novel methods to protect existing foundations



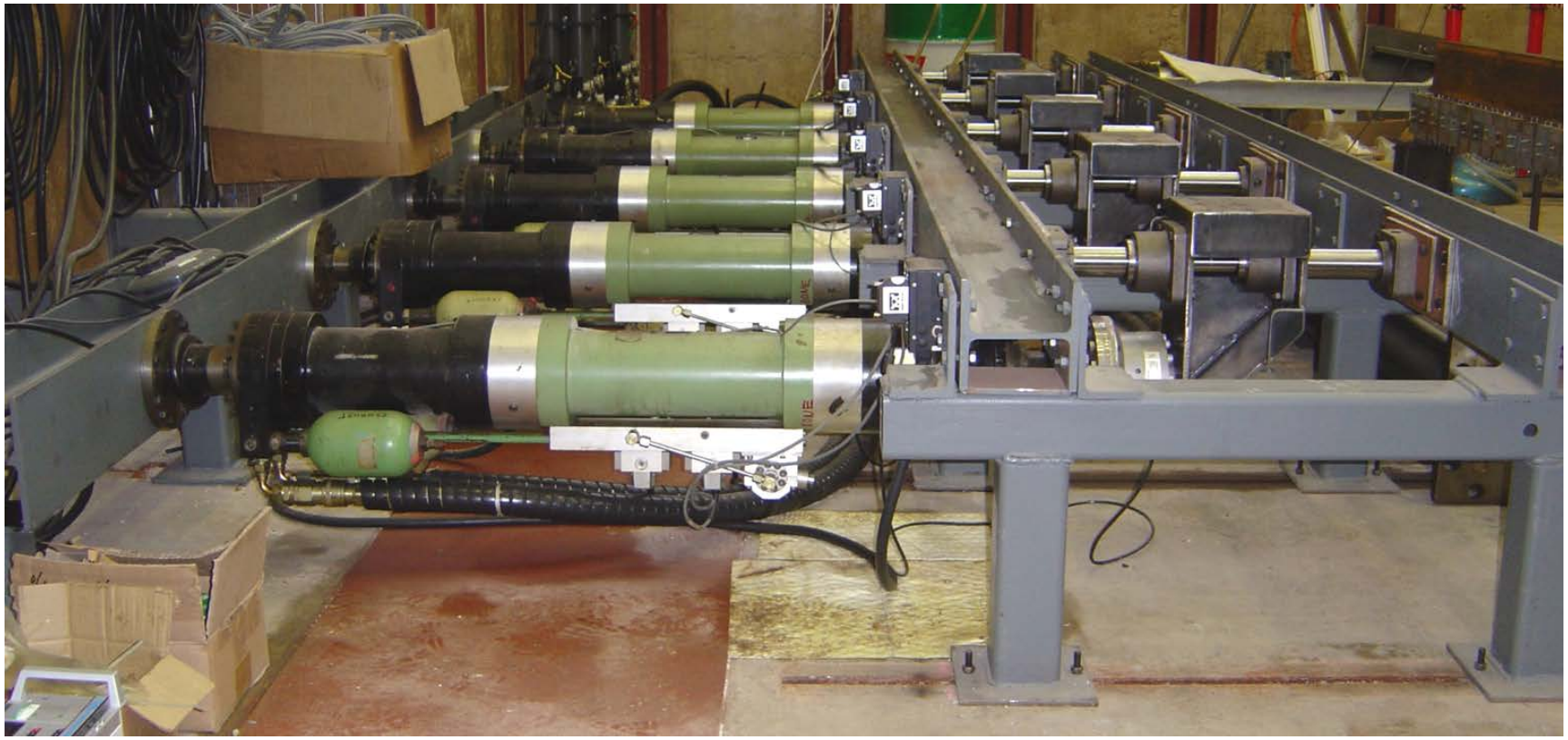


Multiple Support Excitation

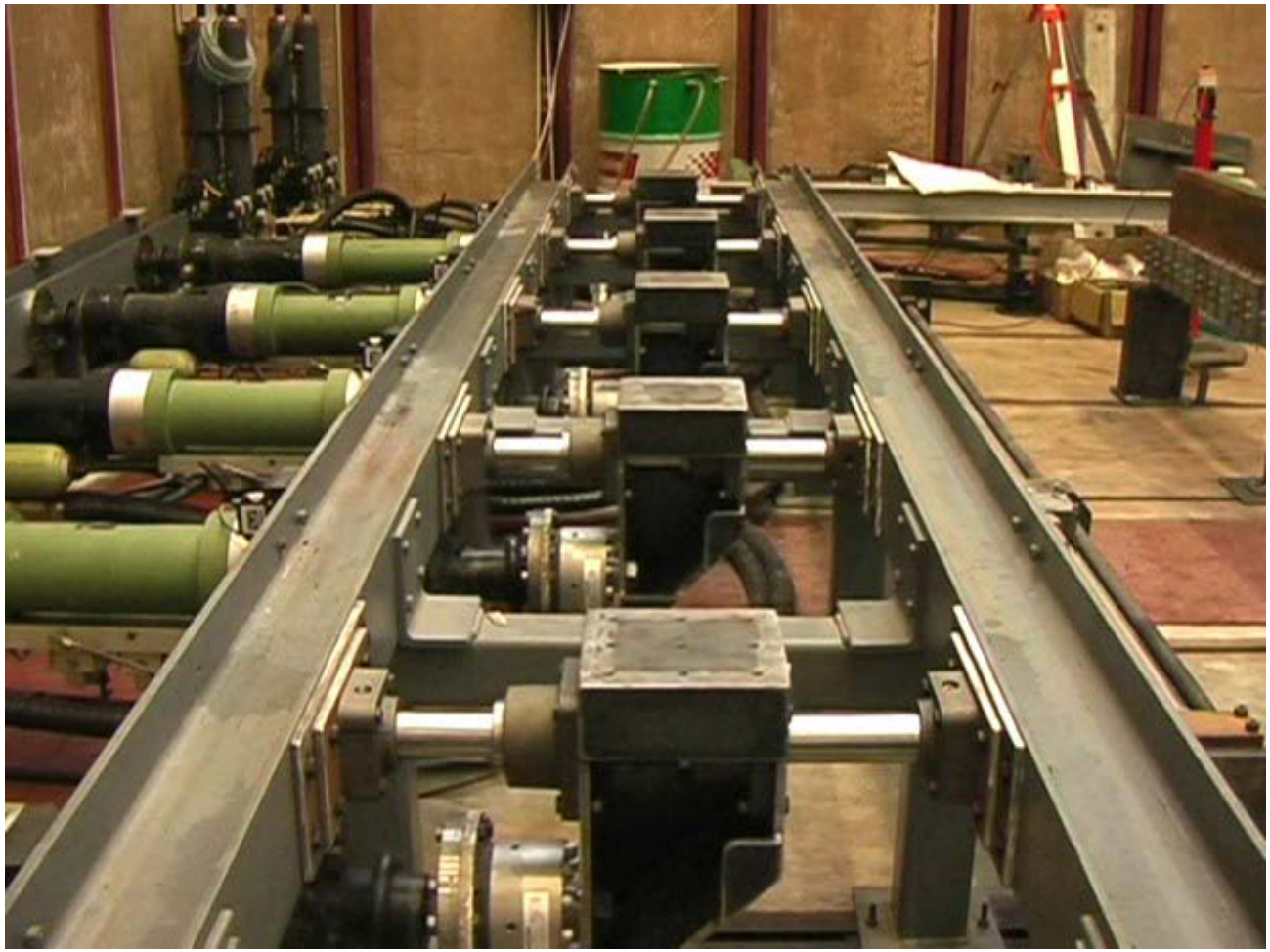


Custom test rig for long structures

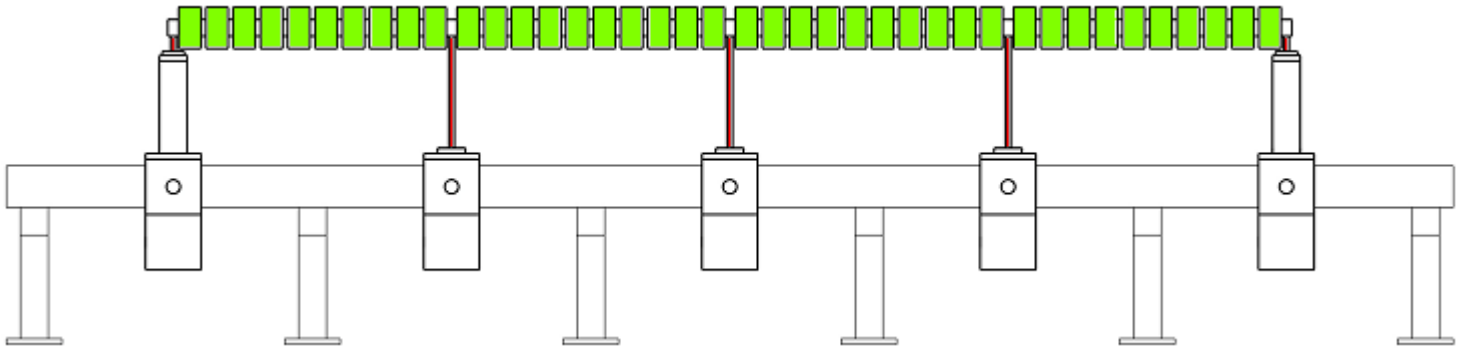
- Multiple support excitation (5 shaking tables)



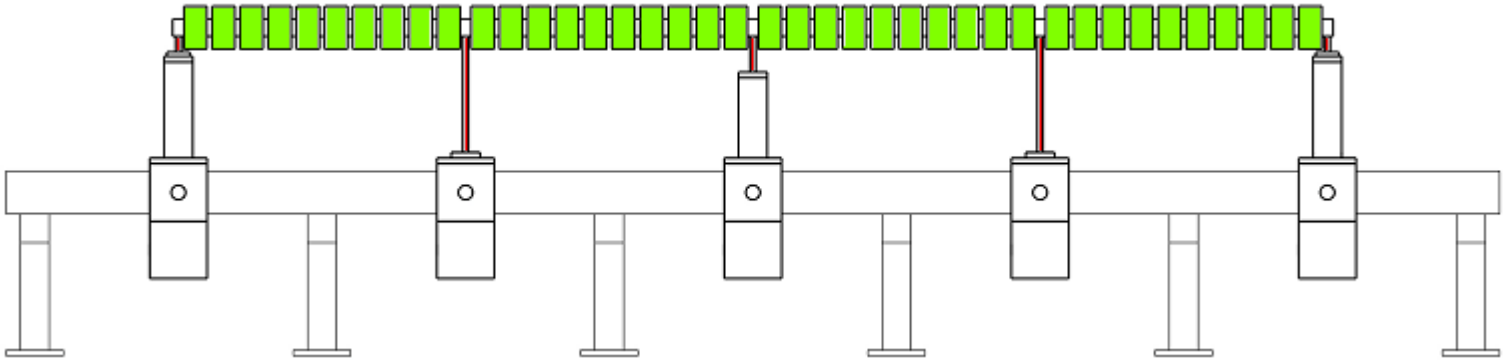
The MSE test bed



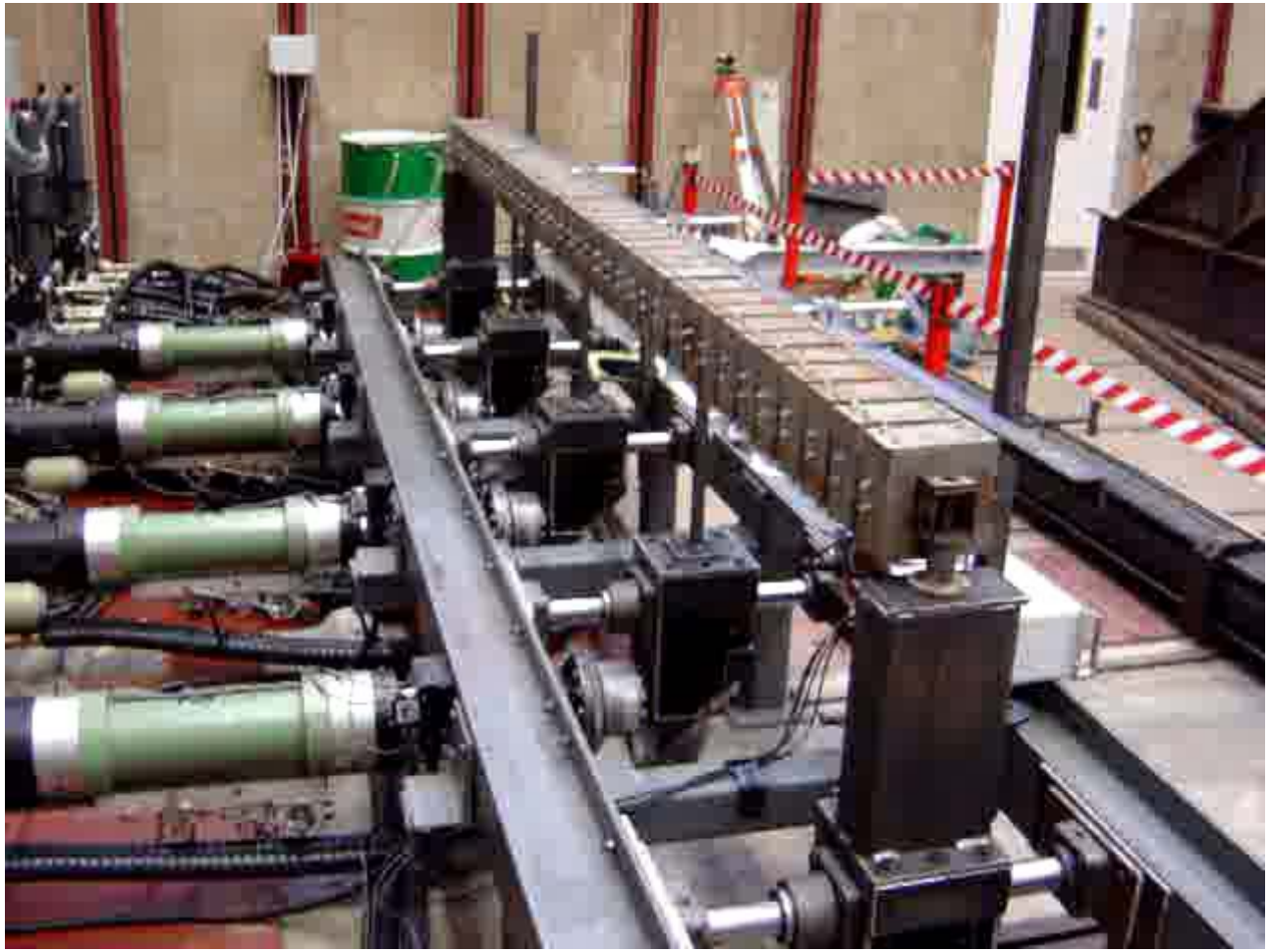
MSE experimental tests



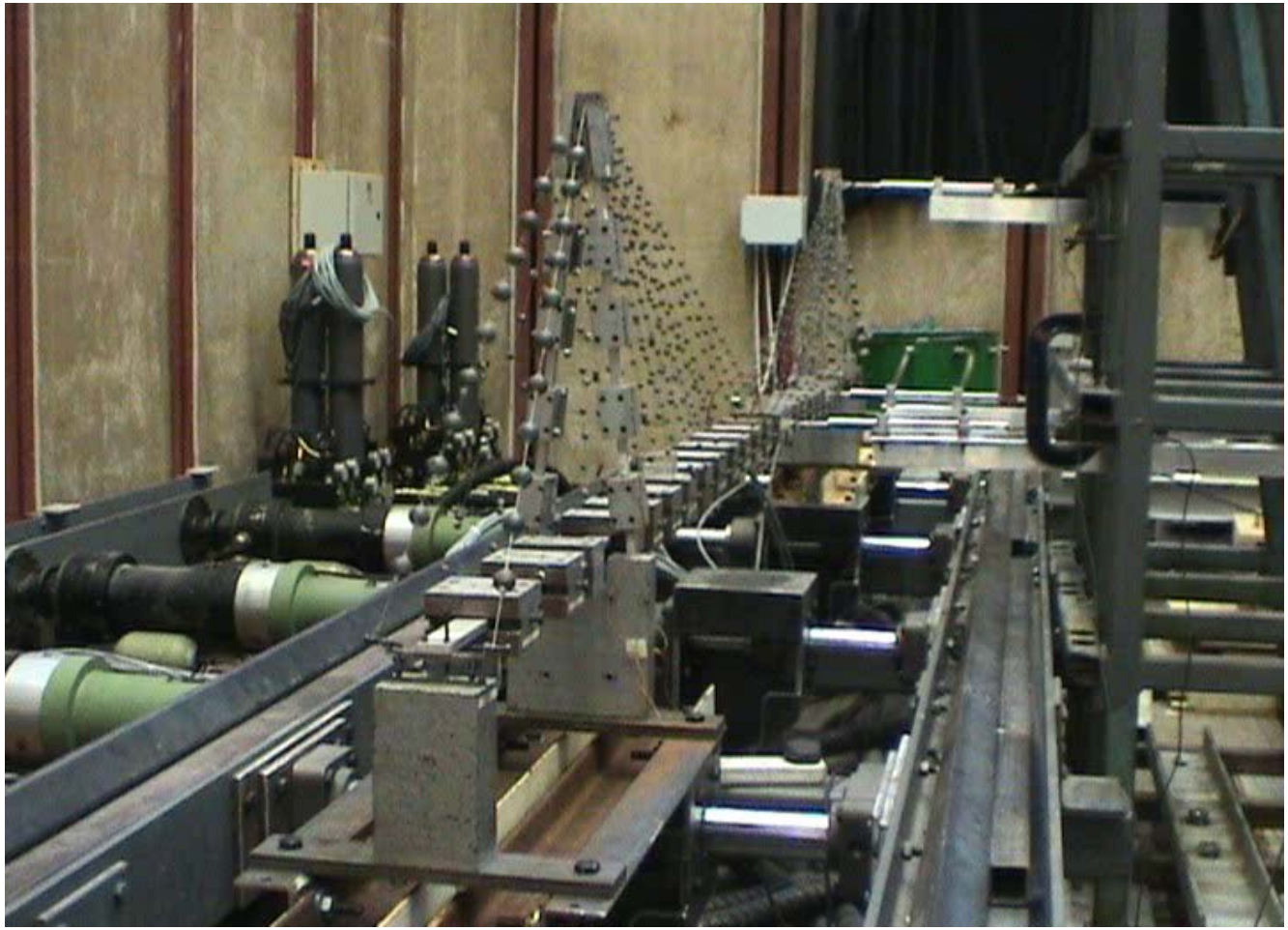
Test bed with the LLL (top) and LSL (bottom) bridges attached



“LLL” bridge and MSE

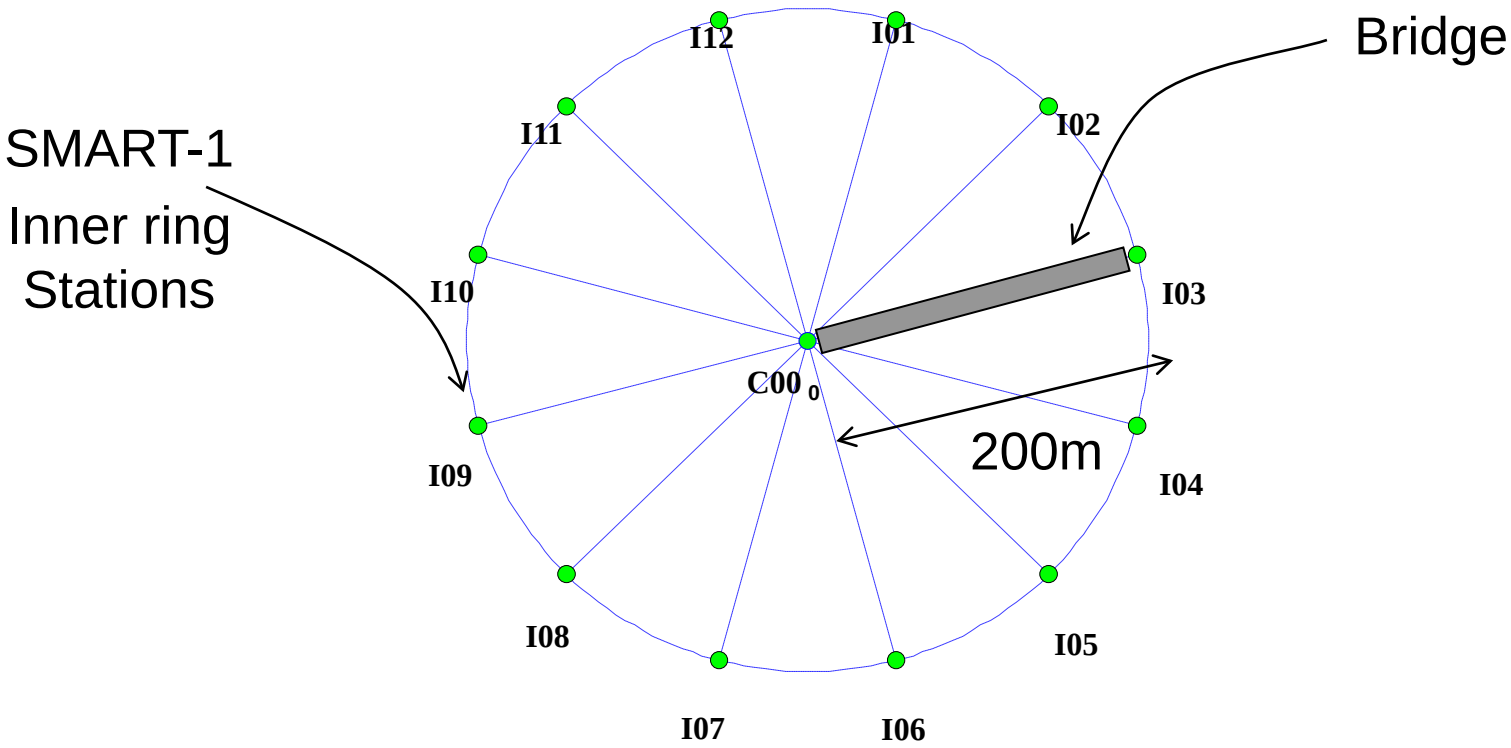


Cable stay bridge and MSE

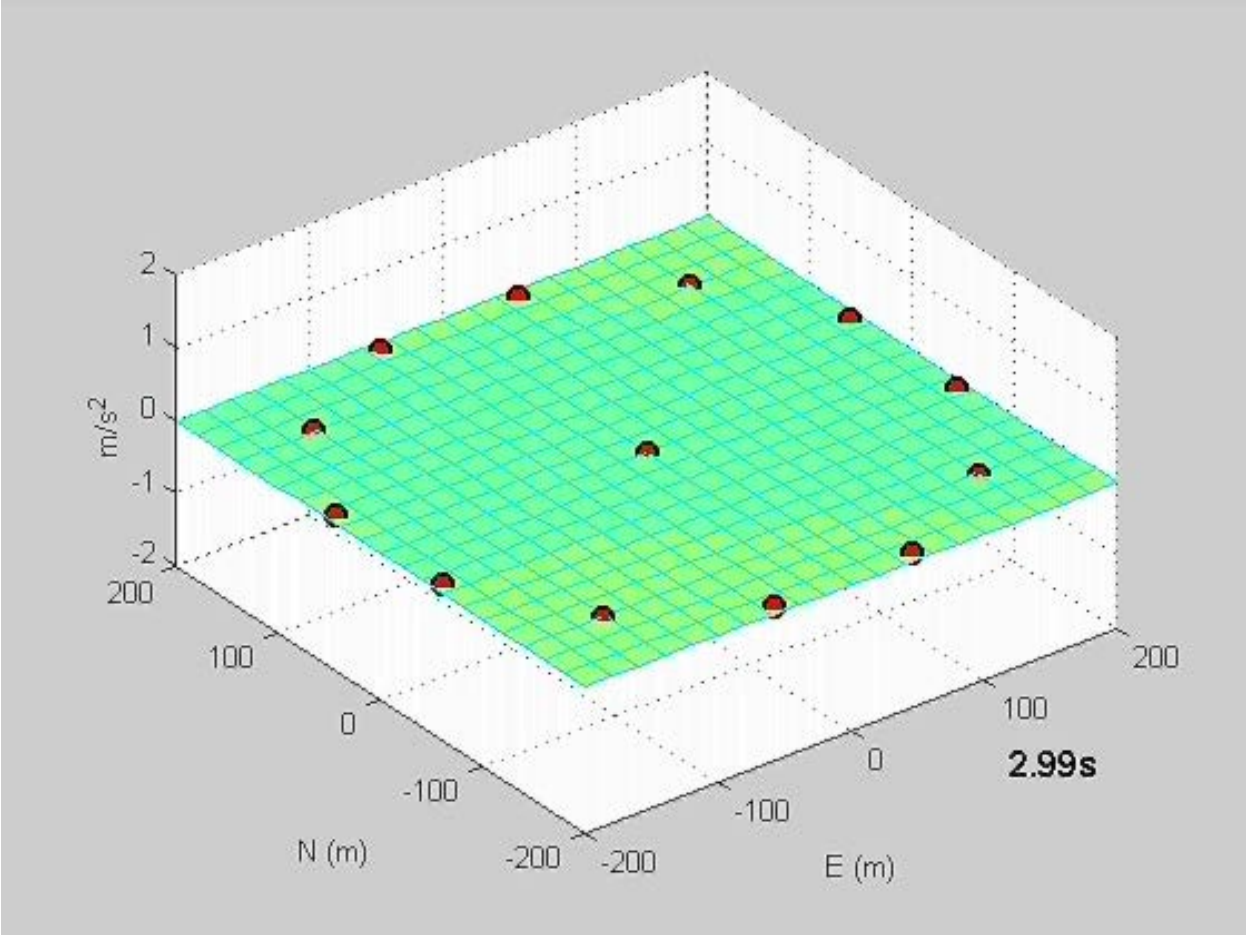


The SMART1 array – inner ring

- Used to study effect of variable ground motions on bridges

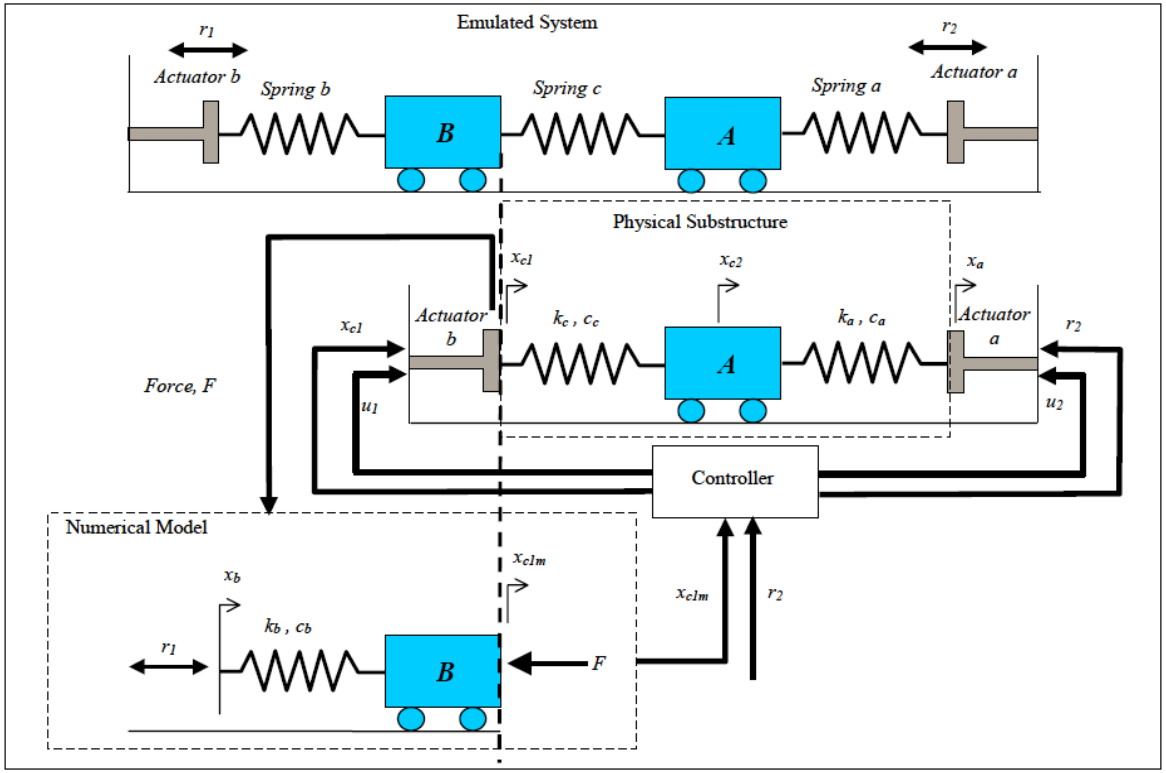


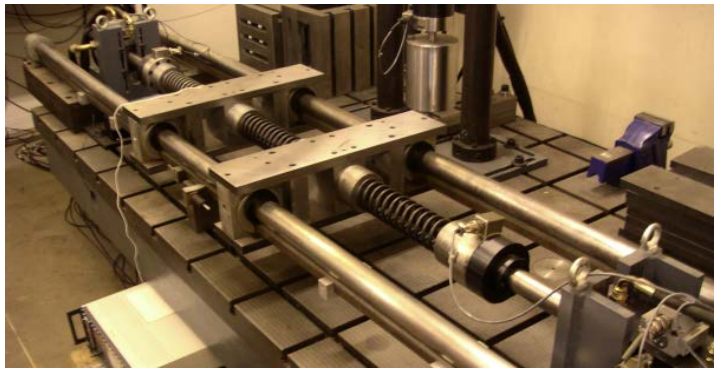
Motion recorded by array

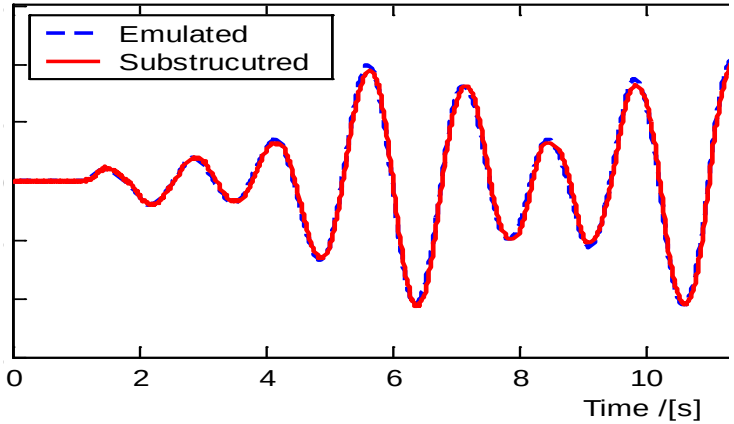


Adaptive Control

- Now regularly used for substructure testing

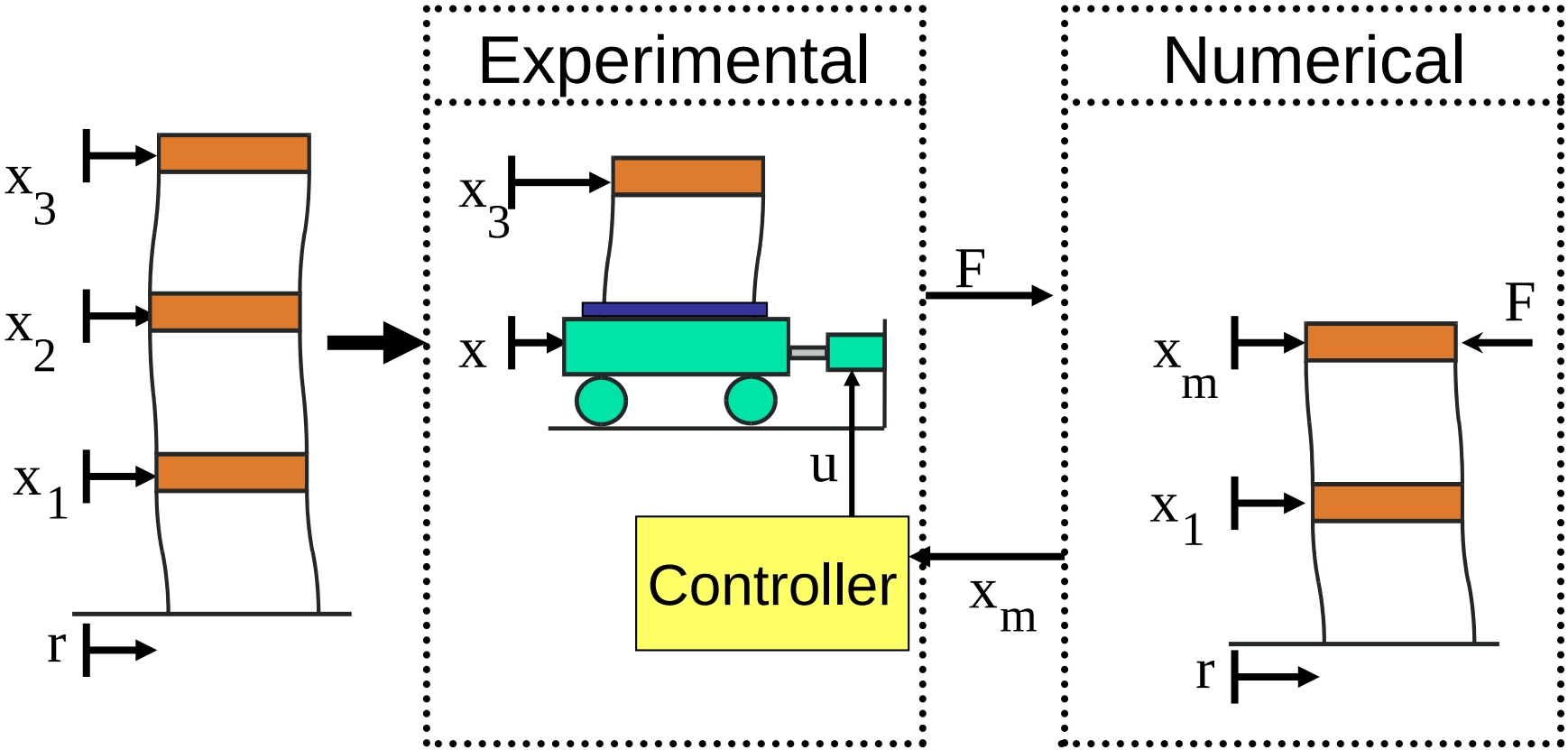




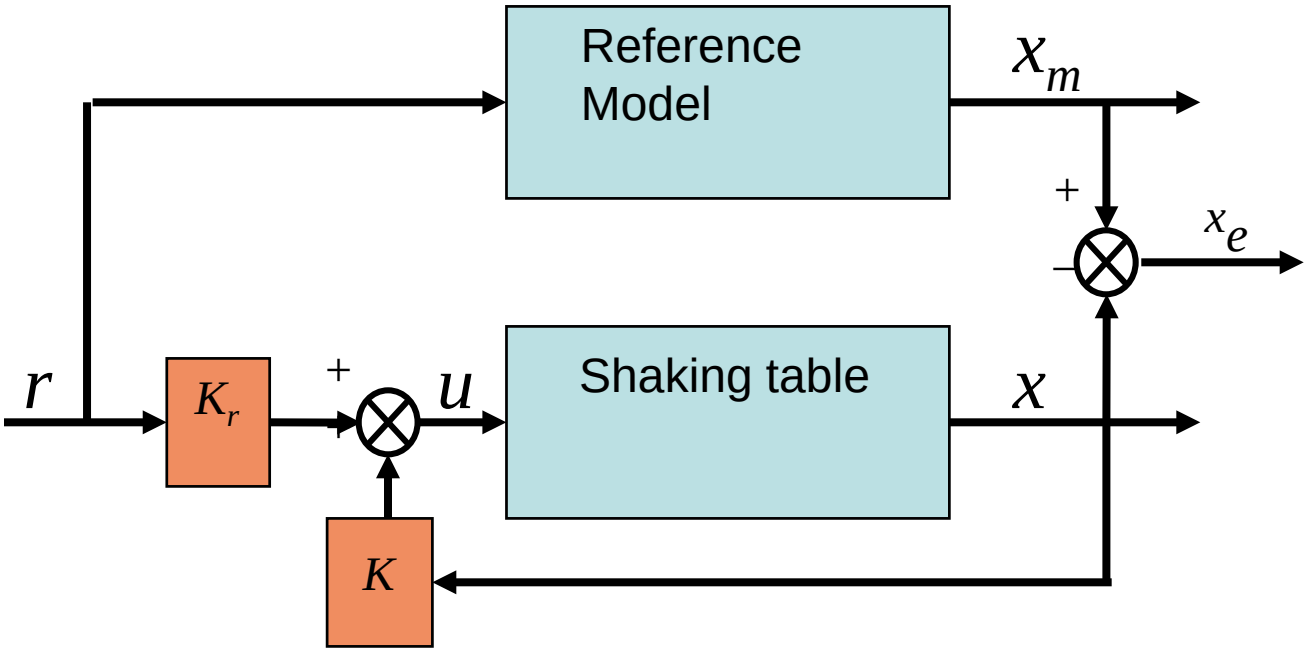


Dynamic Substructuring

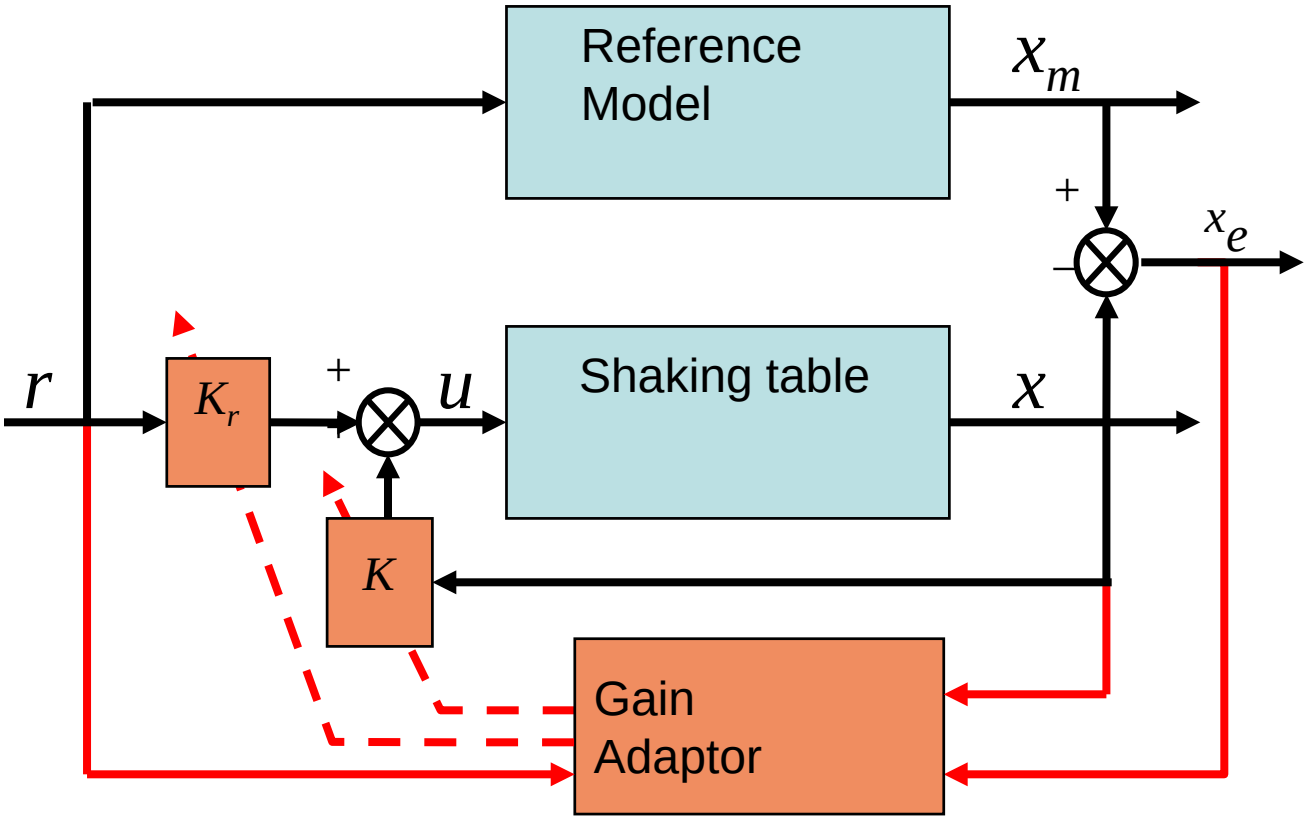
Idealised 3-storey building



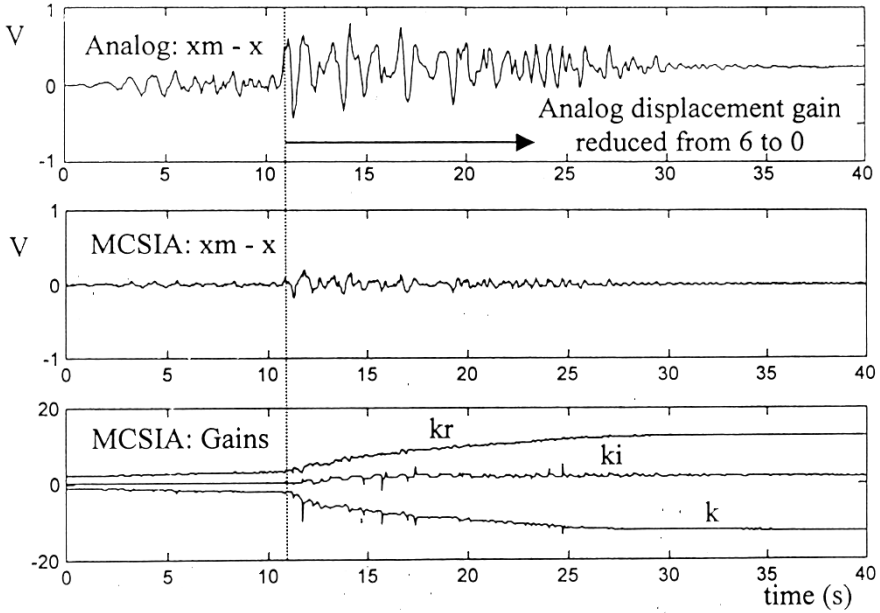
Linear Controller



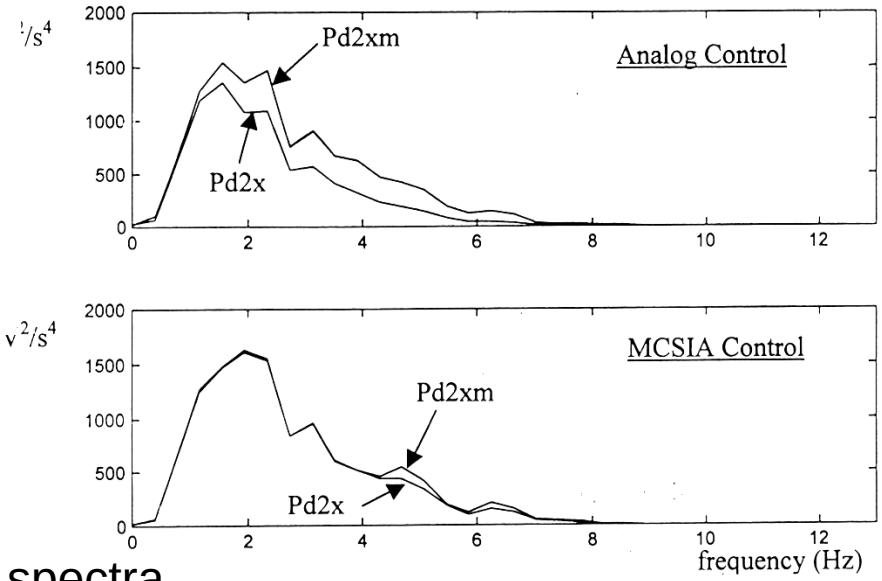
Basic Minimal Control Synthesis



MCS Adaptive Control with parameter change

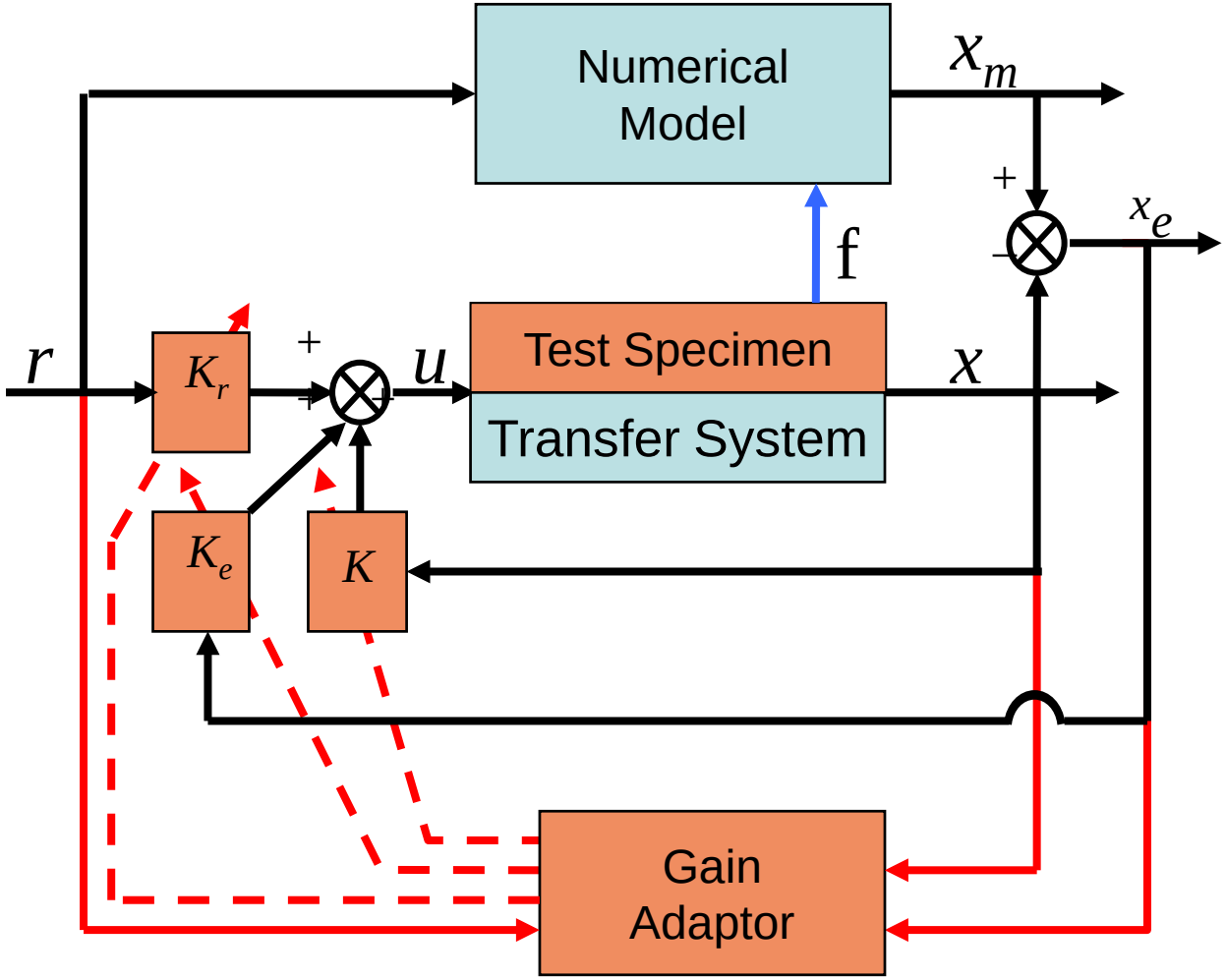


Displacement errors



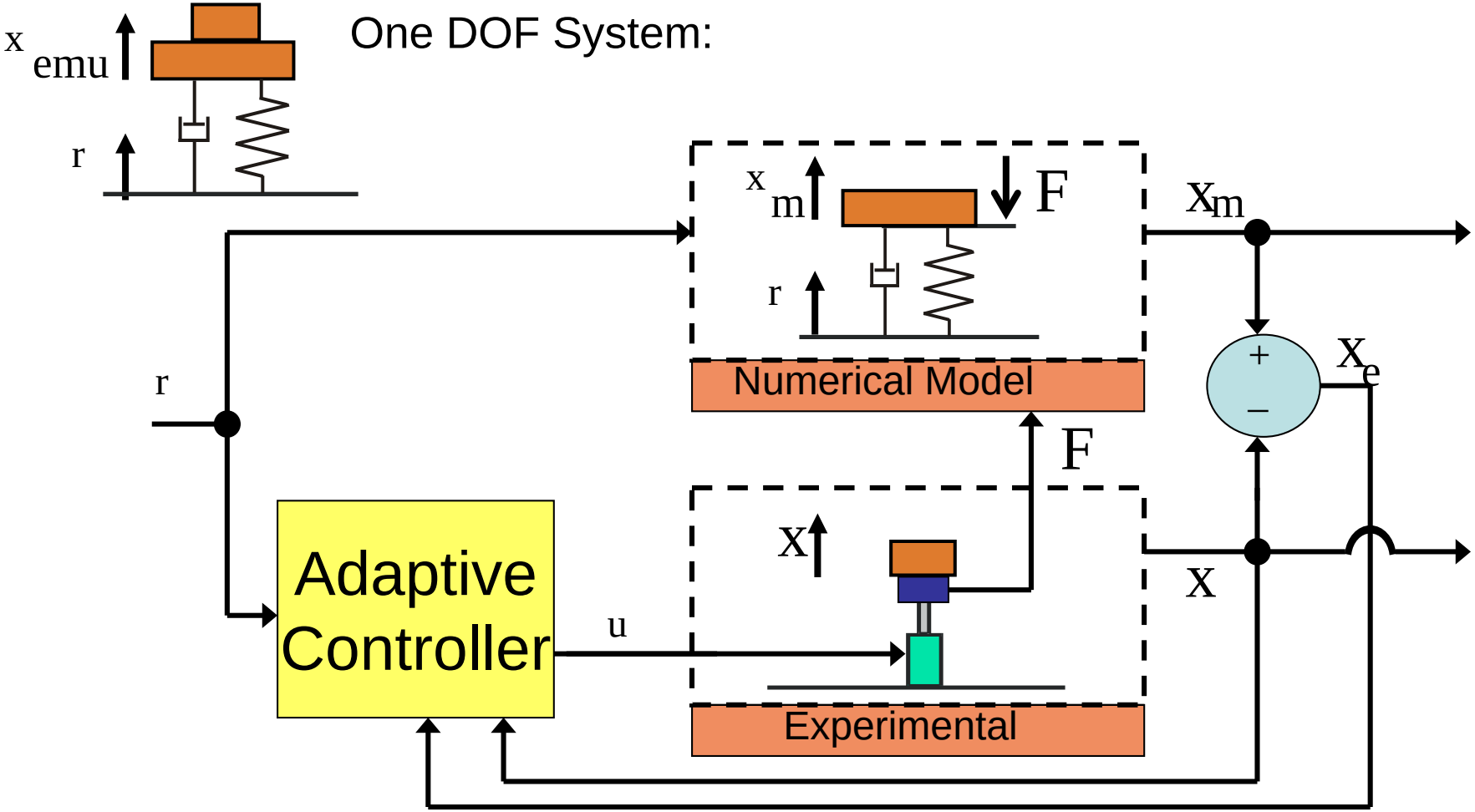
Acceleration spectra

MCS modified for Substructuring



Proof of Concept Experiments

One DOF System:



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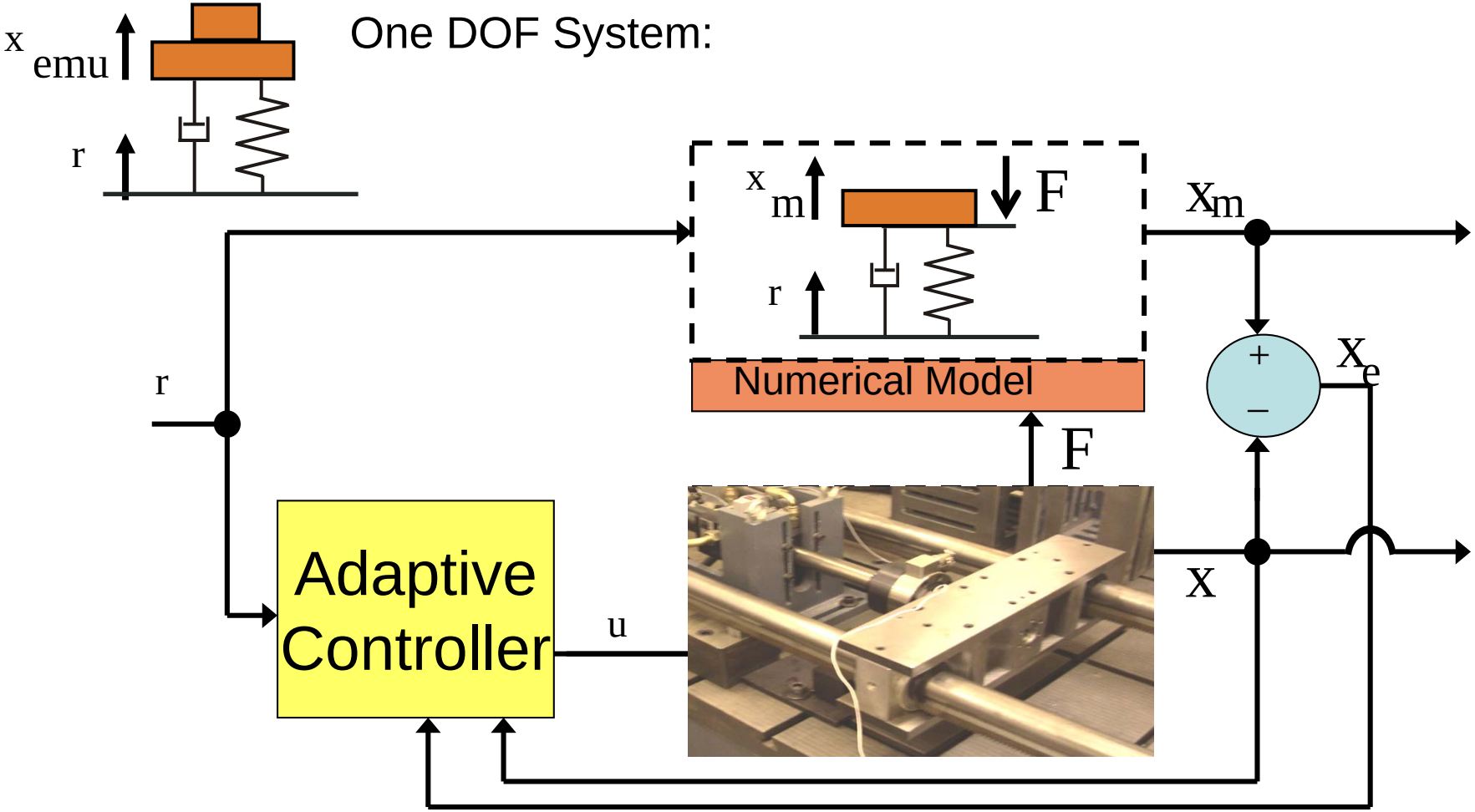
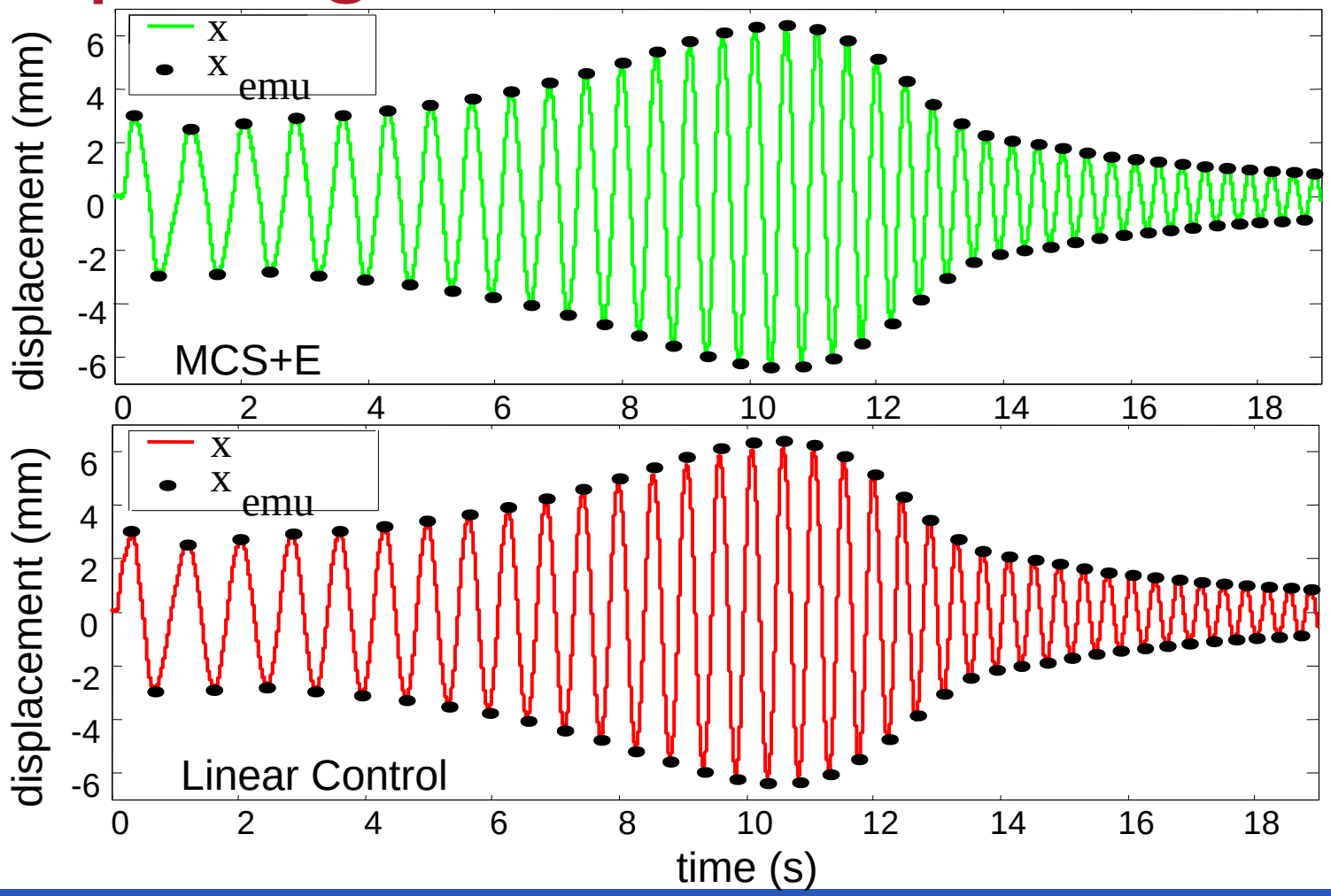


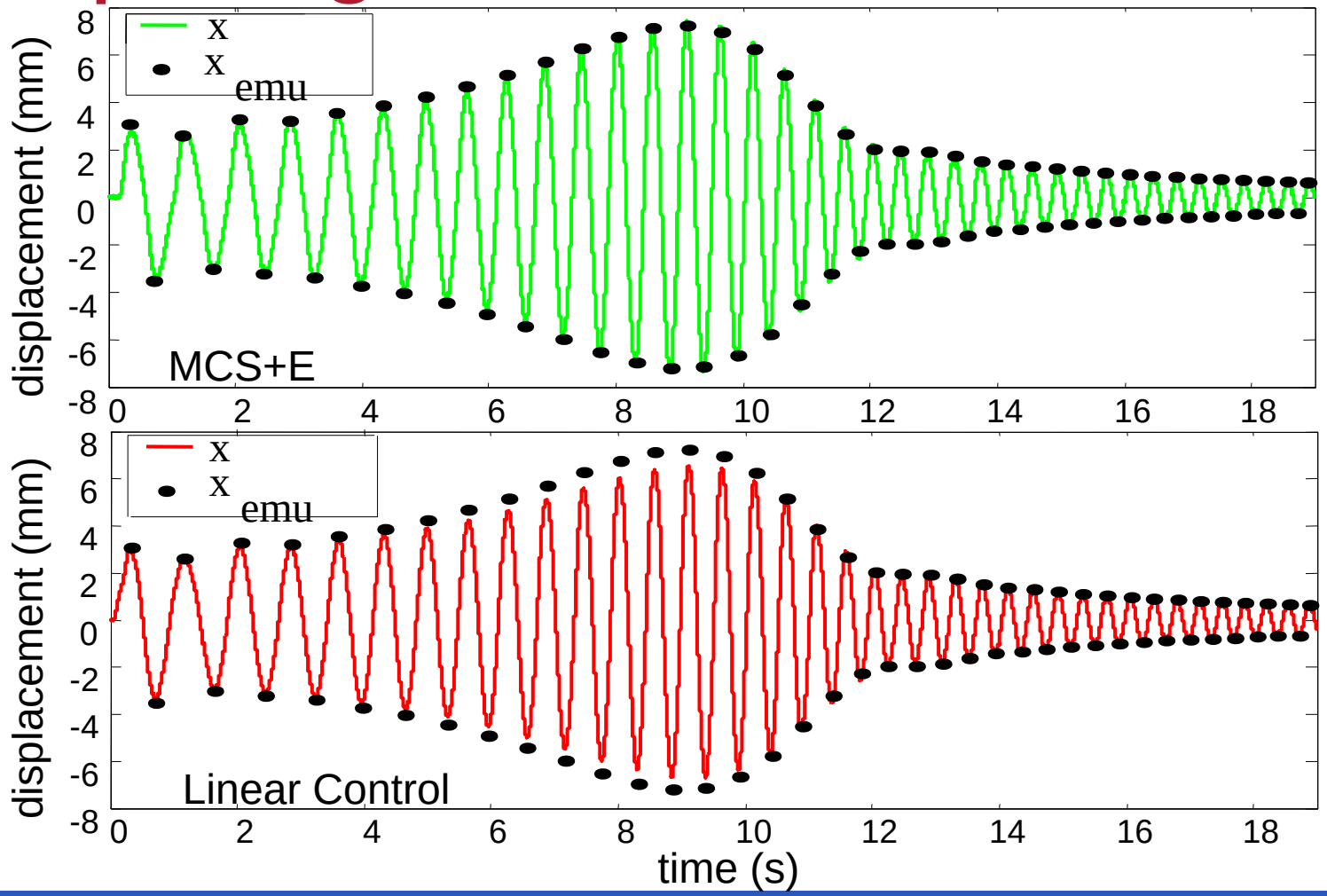
Comparing x to x

whole structure



Comparing x to x

40 kg substructure



Custom test rig for pipelines

- In development (likely to be a modified version of the MSE rig)

- A system using up to 8 actuators is being considered
- A large flexible soil box will run across tops of the tables
- The solid box might be aprox 10m long and 300 x 300mm in cross section with the pipe embedded in the centre
- The model pipeline to be instrumented to measure SSI

Custom test rig for pipelines

- Input motions being considered are lateral and axial motions
- Axial forces in pipeline might be applied by extra actuators at ends of pipe using substructuring
- Active control of shaking tables will be needed to avoid specimen - actuator interaction problems

- Some issues still to be addressed:
  - Failure of the small scale pipeline
  - Instrumentation of the pipeline

Conclusions

- A custom multiple shaking table system is being developed to apply MSE to a soil pipeline system
- Adaptive minimal control synthesis algorithm with demand modification (MCSmd) has proved to be the most suitable controller for dynamic substructuring tests using shaking-tables and will be used for these tests

- Design of the shaking table | soil box | pipeline system has started but there are some significant issues to be resolved