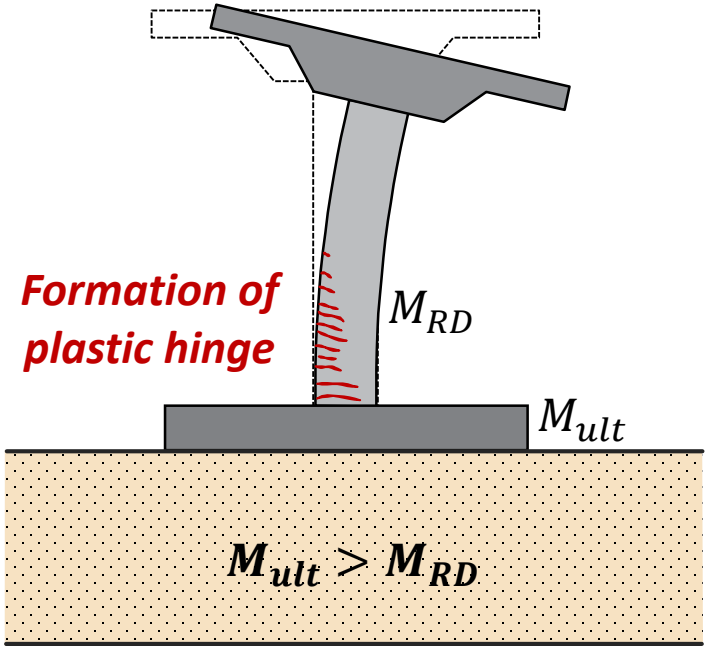
Rocking Isolation

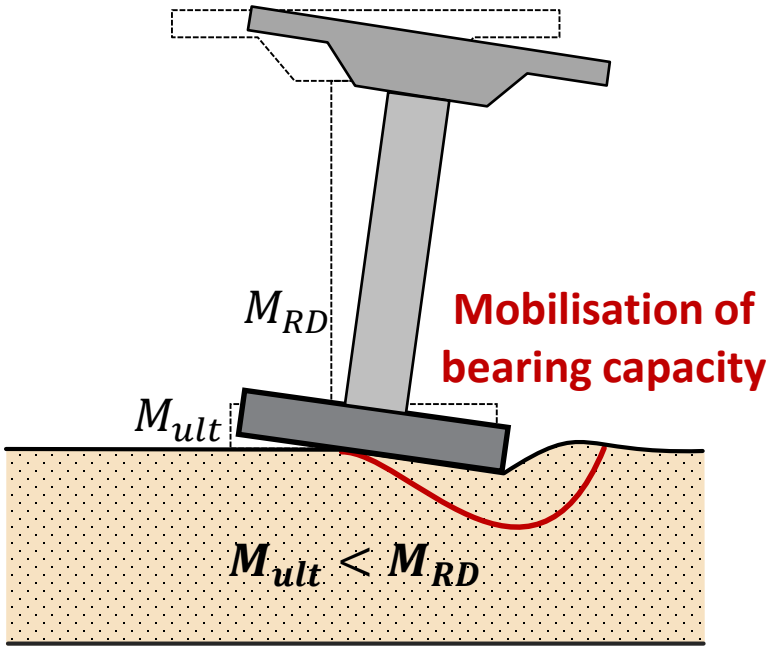
Prof. Dr. Ioannis Anastasopoulos

The concept of Rocking Isolation

Conventional Design



Rocking Isolation



Examples of Accidental Rocking Isolation

Real Examples of Accidental Rocking Isolation

Adapazari, Kocaeli 1999 (Turkey)

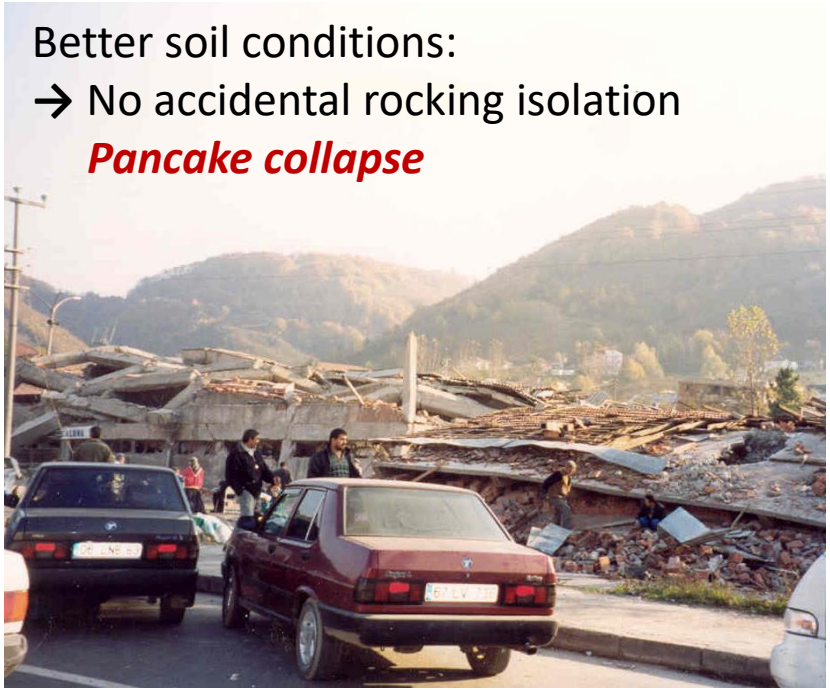
Real Examples of Accidental Rocking Isolation

Adapazari, Kocaeli 1999 (Turkey)

Better soil conditions:

→ No accidental rocking isolation

Pancake collapse



Example Problem: Motorway Bridge

Example problem: motorway bridge

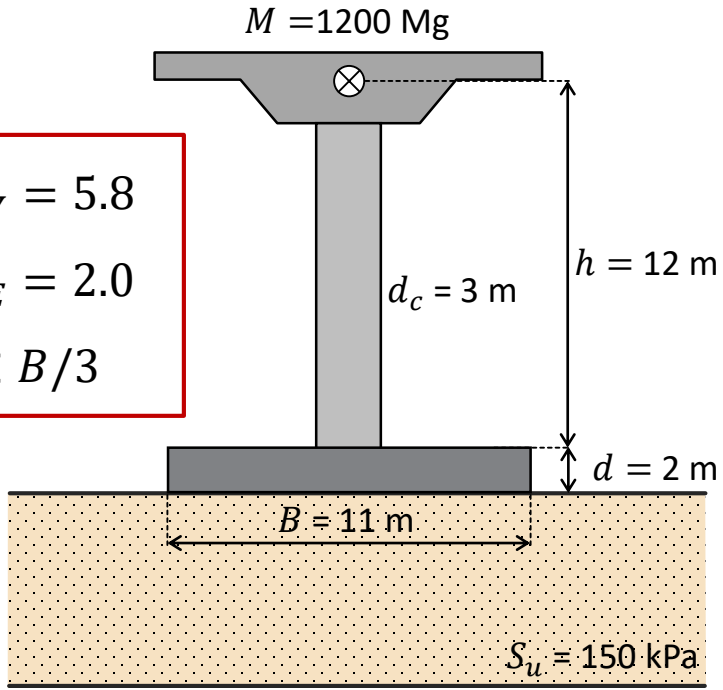
(Anastasopoulos et al., 2009)

Conventional Design

$FS_V = 5.8$

$FS_E = 2.0$

$e < B/3$

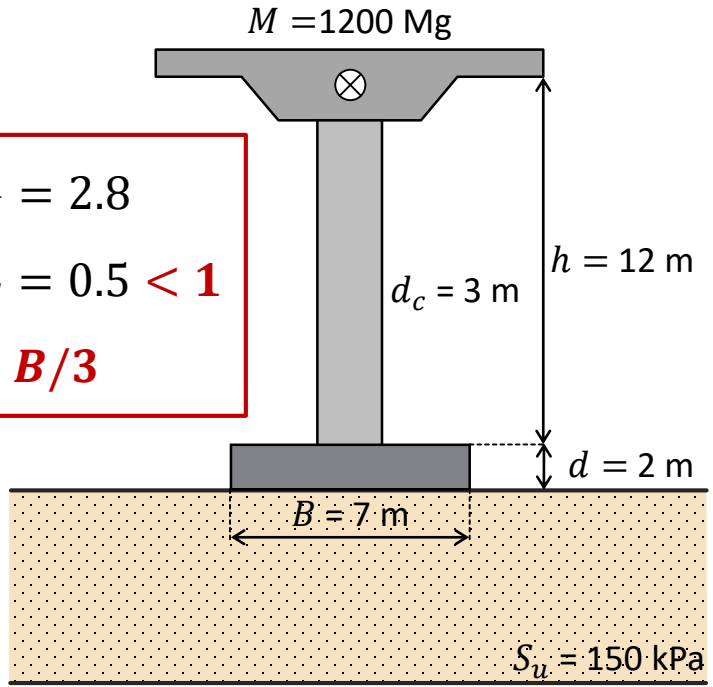


Rocking Isolation

$FS_V = 2.8$

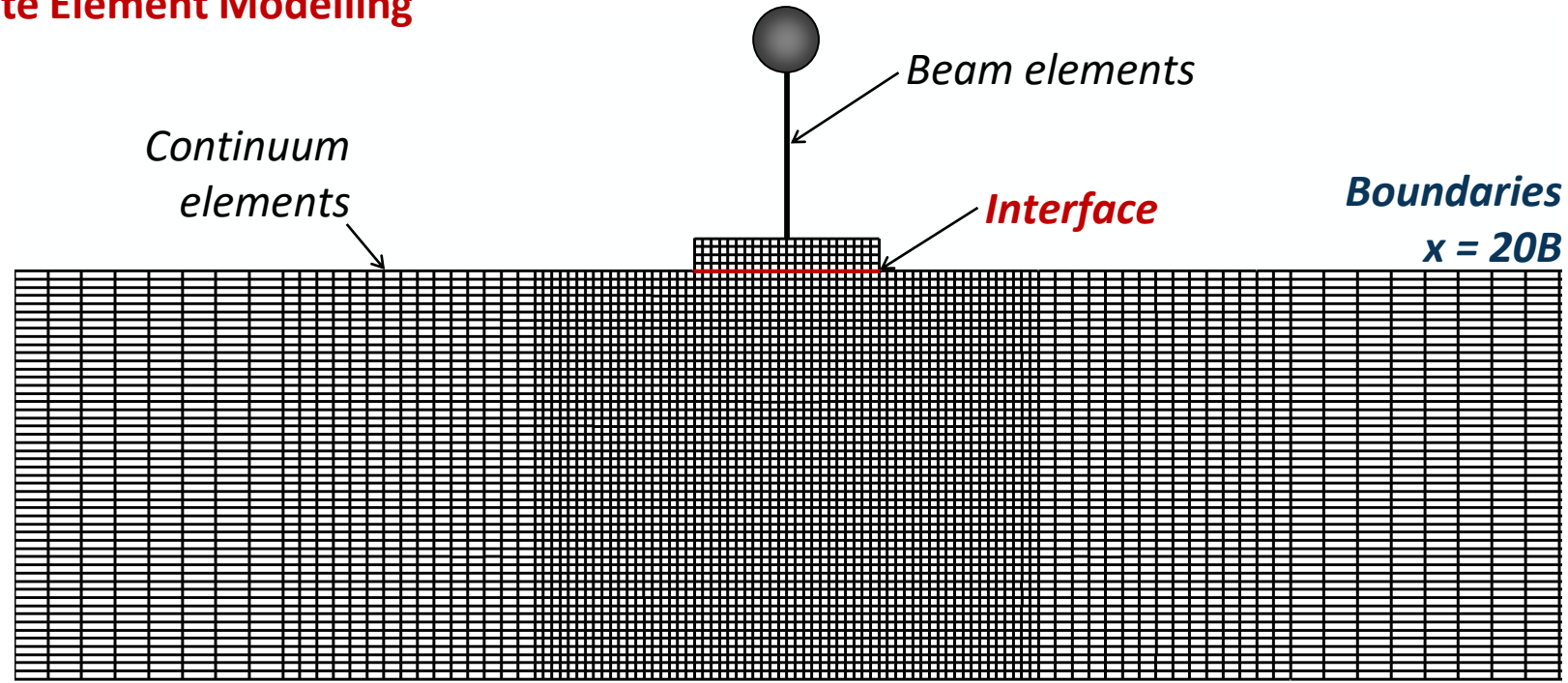
$FS_E = 0.5 < \mathbf{1}$

$e > \boldsymbol{B/3}$



Example problem: motorway bridge

Finite Element Modelling



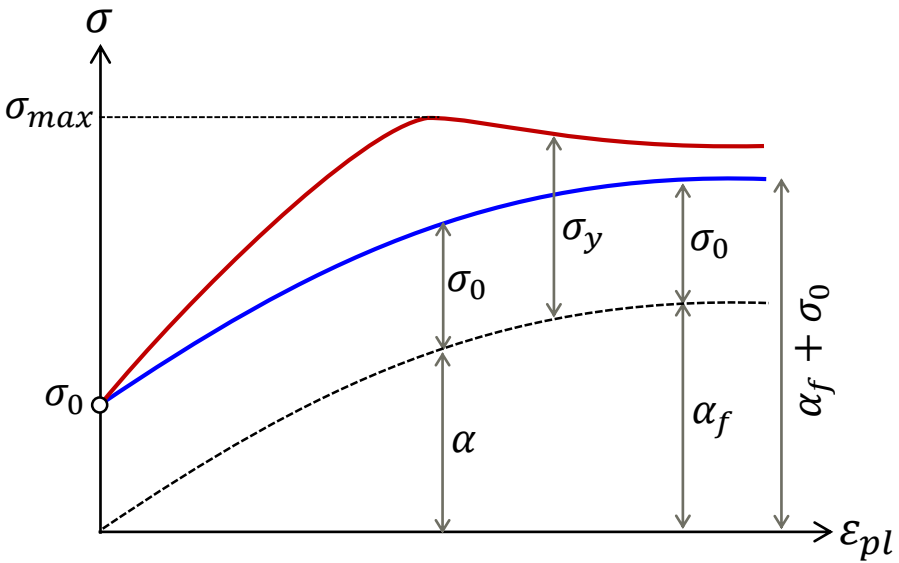
Soil and **Pier** : **Inelastic**

Example problem: motorway bridge

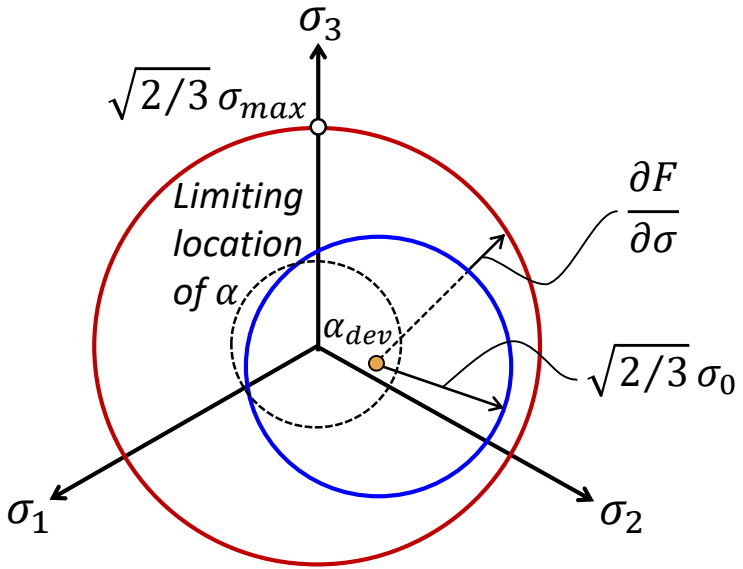
(Anastasopoulos et al., 2011)

Soil Constitutive Model

- Von-Mises Failure Criterion, Isotropic–Kinematic Hardening, Associative Flow Rule



1D Representation



3D Representation

Example problem: motorway bridge

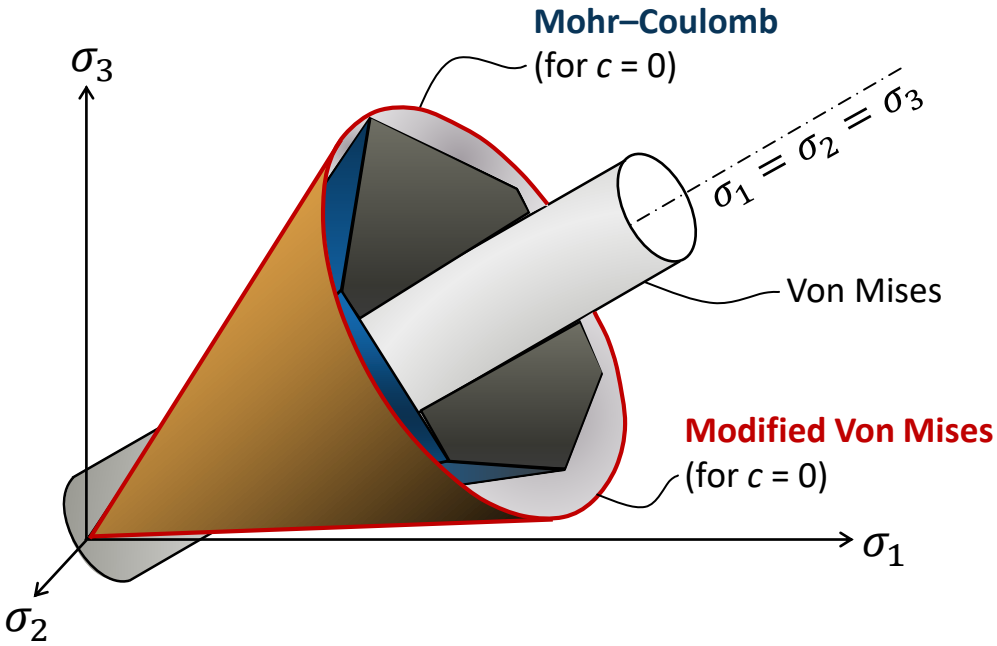
Soil Constitutive Model

- Modification to account for confinement

  (user subroutine in ABAQUS):

$$\sigma_y = \frac{\sqrt{3}(\sigma_1+\sigma_2+\sigma_3)}{3}\sin\varphi$$

- The key advantage of the model is its straight–forward calibration based on few parameters only.



Example problem: motorway bridge

Soil Constitutive Model

- Strength:

$$\sigma_y = \begin{cases} S_u \text{ , for clay} \\ \frac{\sqrt{3}(\sigma_1+\sigma_2+\sigma_3)}{3} \sin\varphi \text{ , for sand} \end{cases}$$

- Initial Elasticity Modulus $C = \kappa\, \sigma_y$

$$\kappa = \begin{cases} 100 \div 1000 \text{ , for clay} \\ 4000 \div 12000 \text{ , for sand} \end{cases} \quad \rightarrow \quad v_s \text{ , } G_0 \text{ , or empirical}$$

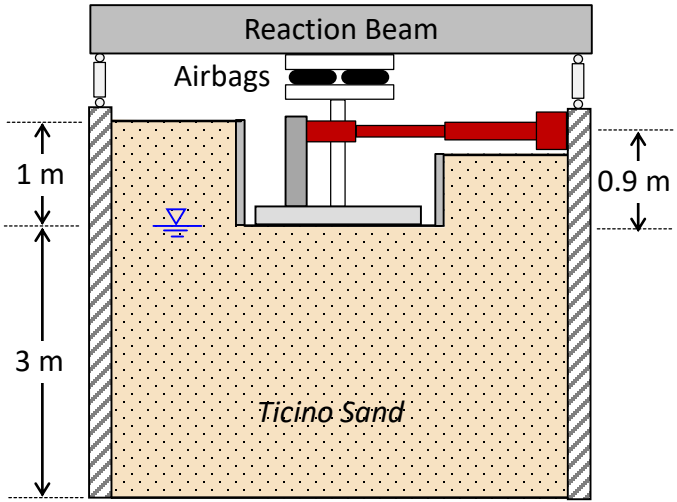
- Hardening Parameters:

$\sigma_0 = \frac{\sigma_y}{\lambda}$, λ ranging from 1 to 10 $\rightarrow$ Calibration against $G - \gamma$ curves

Example problem: motorway bridge

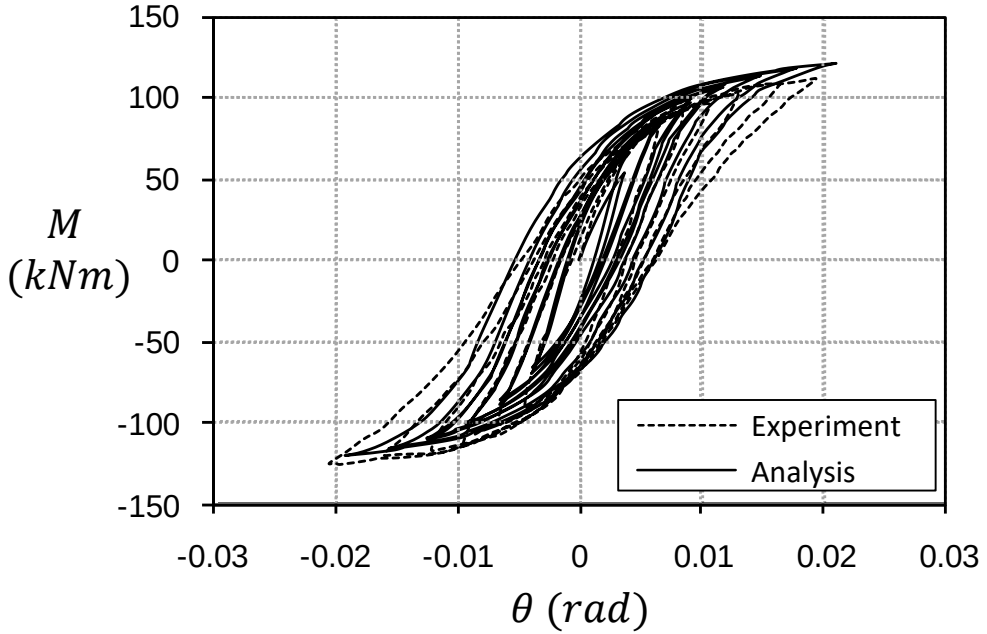
Validation against physical model tests:

- UC Davis centrifuge model tests
- TRISEE large scale-tests



(after Faccioli et al., 1999)

Example comparison: dense sand



Example problem: motorway bridge

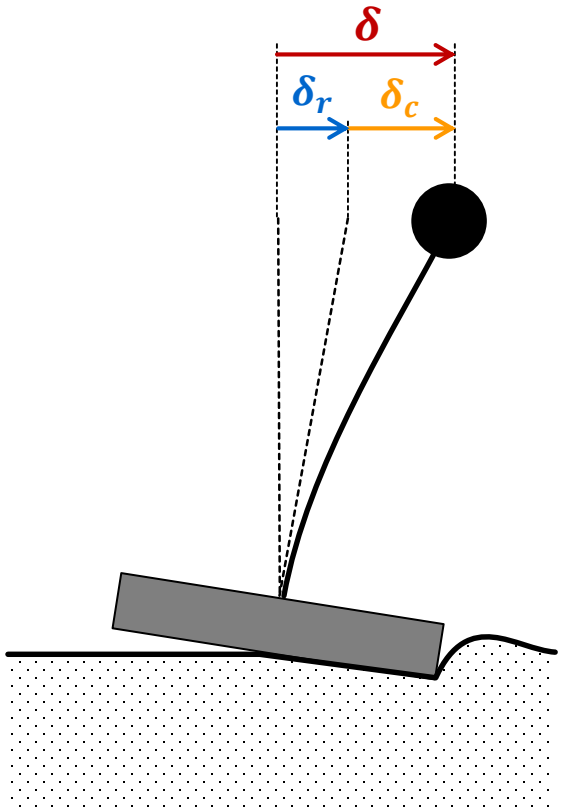
Nonlinear dynamic time history analysis

- A total of 29 seismic records were used to cover a wide range of possible seismic excitations.
- Indicative results are shown here for the devastating ***Takatori*** record from the ***Kobe 1995*** earthquake.
- Conventional design is compared to the rocking isolation design alternative in terms of:

  (a) Deck drift $\boldsymbol{\delta}$ (due to rotation $\boldsymbol{\delta_r}$, flexural $\boldsymbol{\delta_c}$)

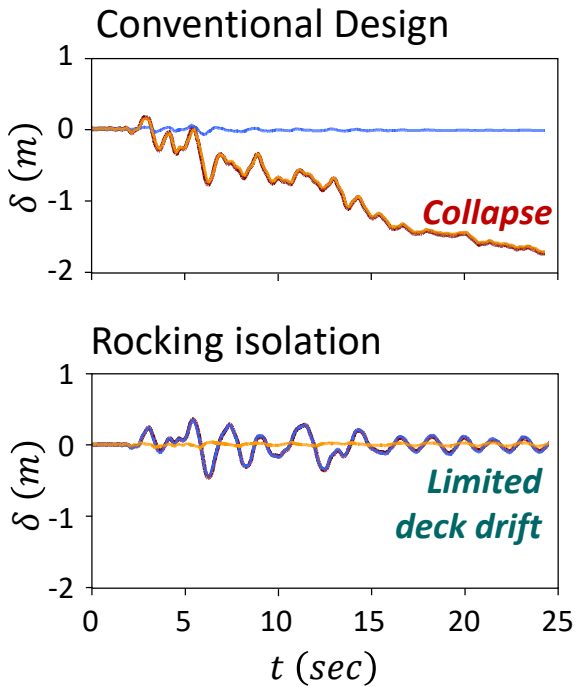
  (b) Foundation moment-rotation response

  (c) Foundation settlement

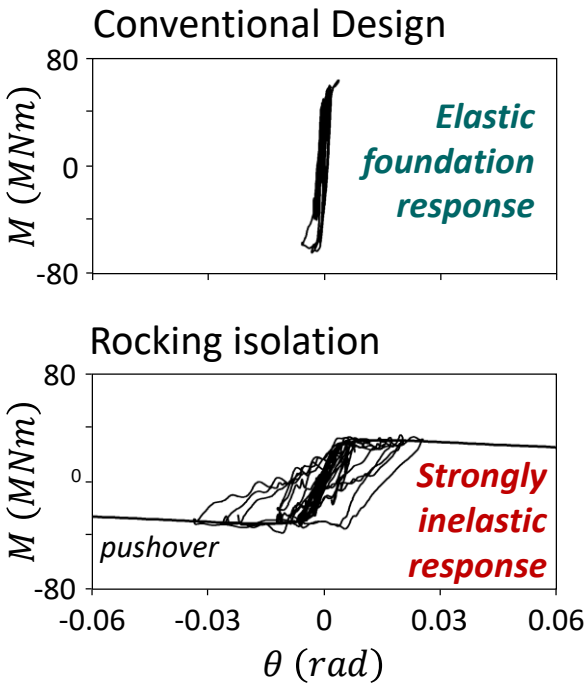


Example problem: motorway bridge

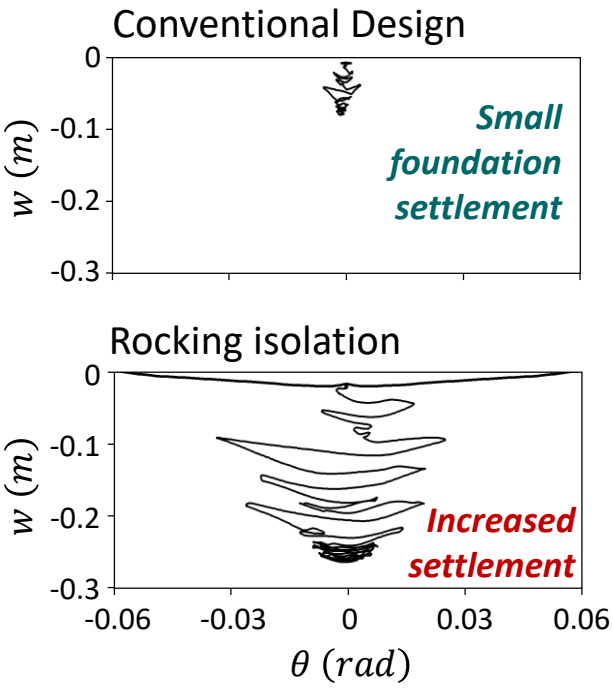
Deck drift



Foundation *M–ϑ*



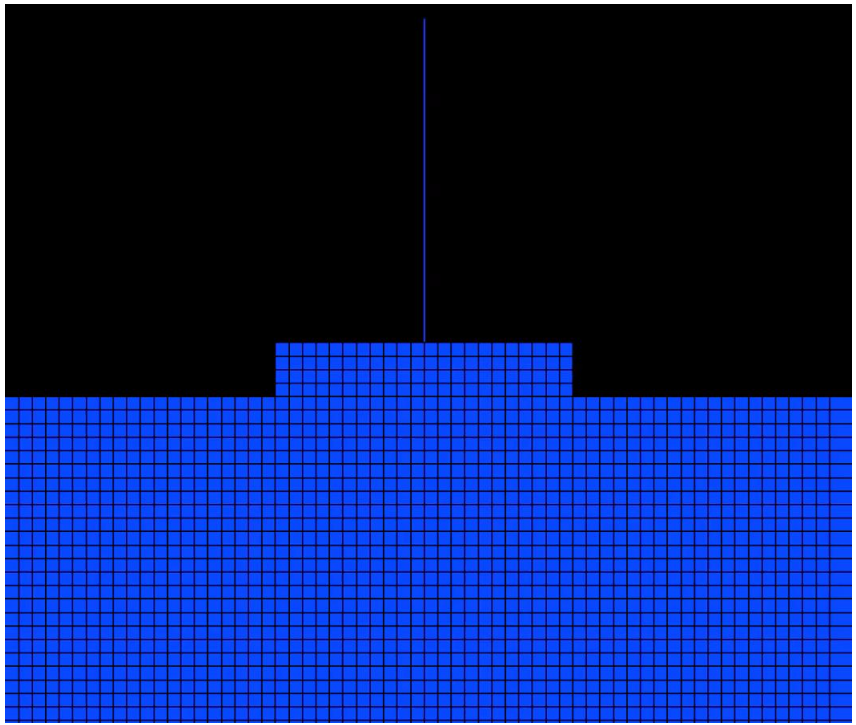
Foundation Settlement



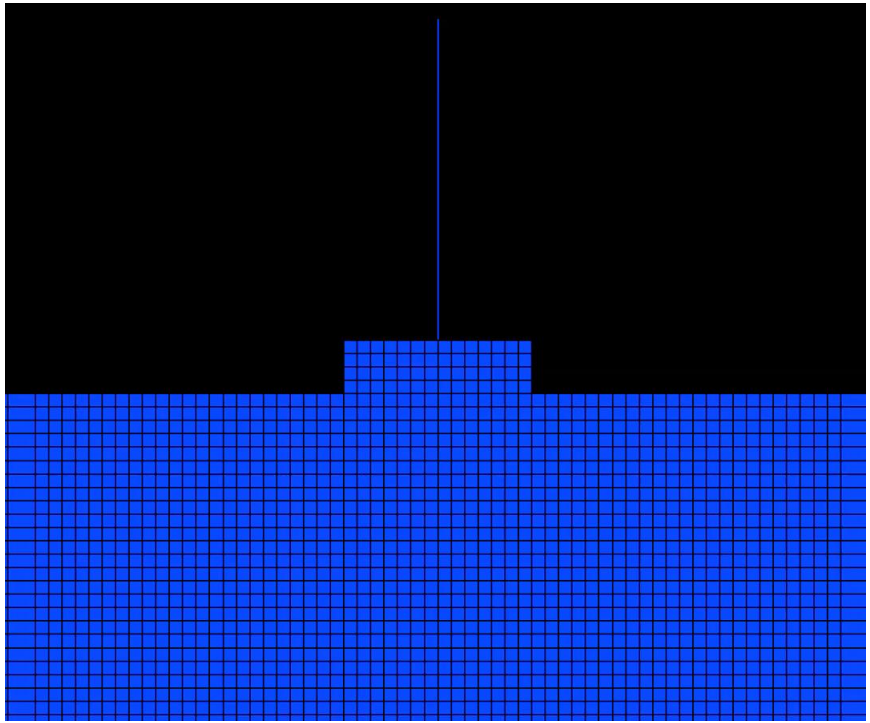
Example problem: motorway bridge

Takatori (Kobe, 1995)

Conventional Design



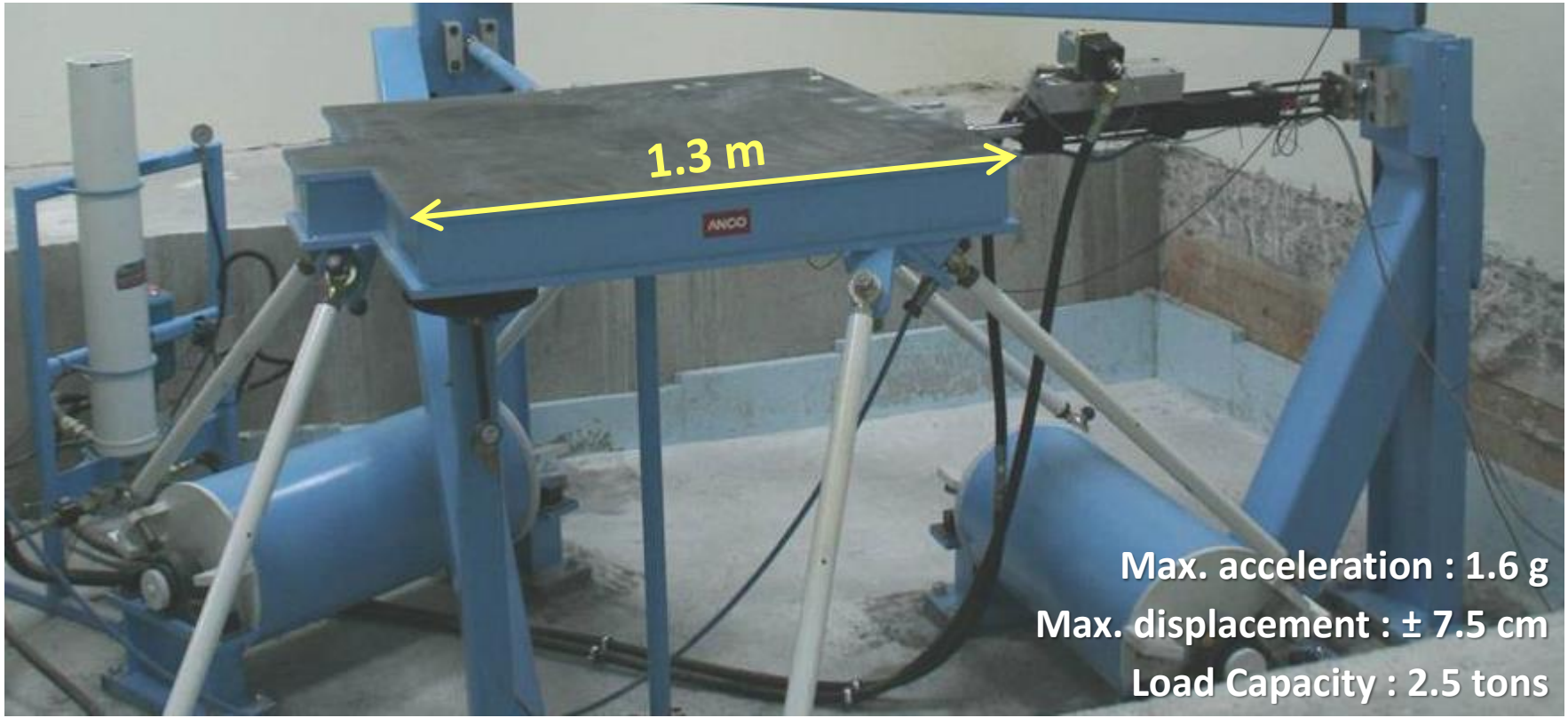
Rocking isolation



Experimental Proof of Concept

Shaking table testing @ NTUA (Greece)

The NTUA–Soil Mechanics Laboratory Shaking table



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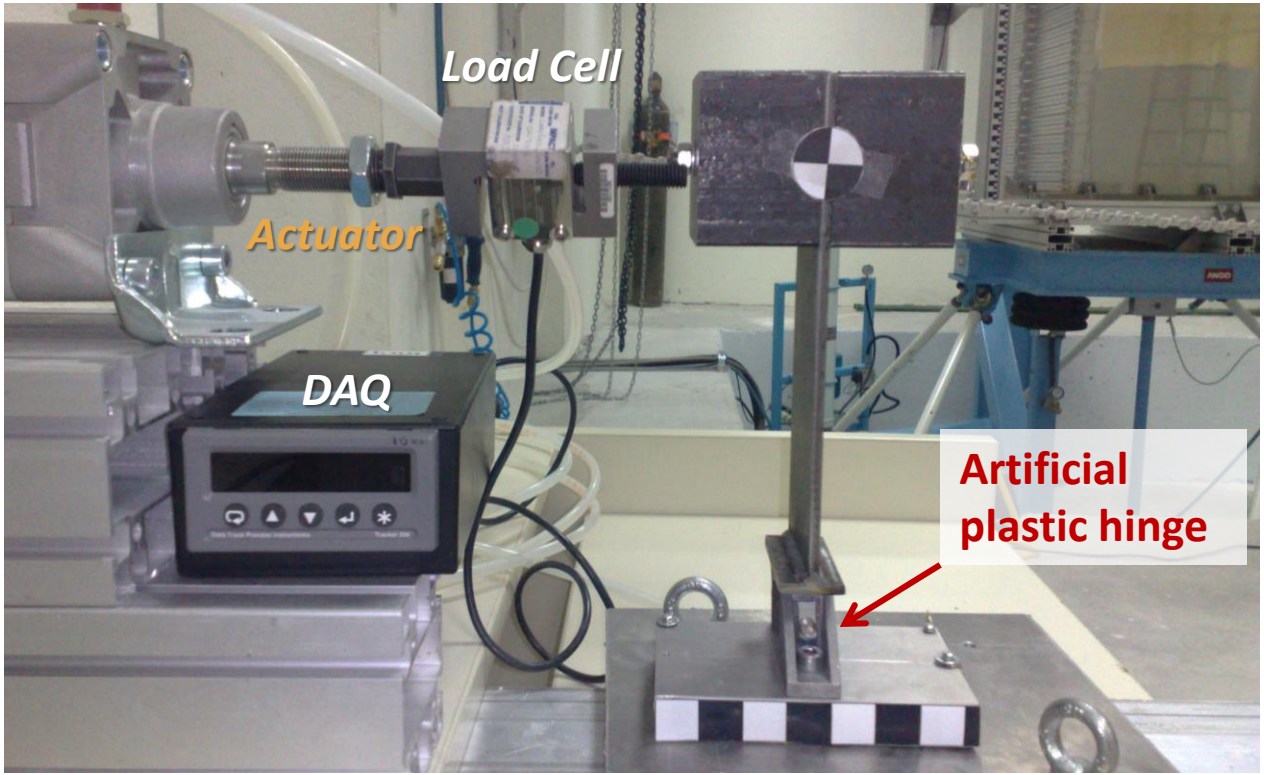

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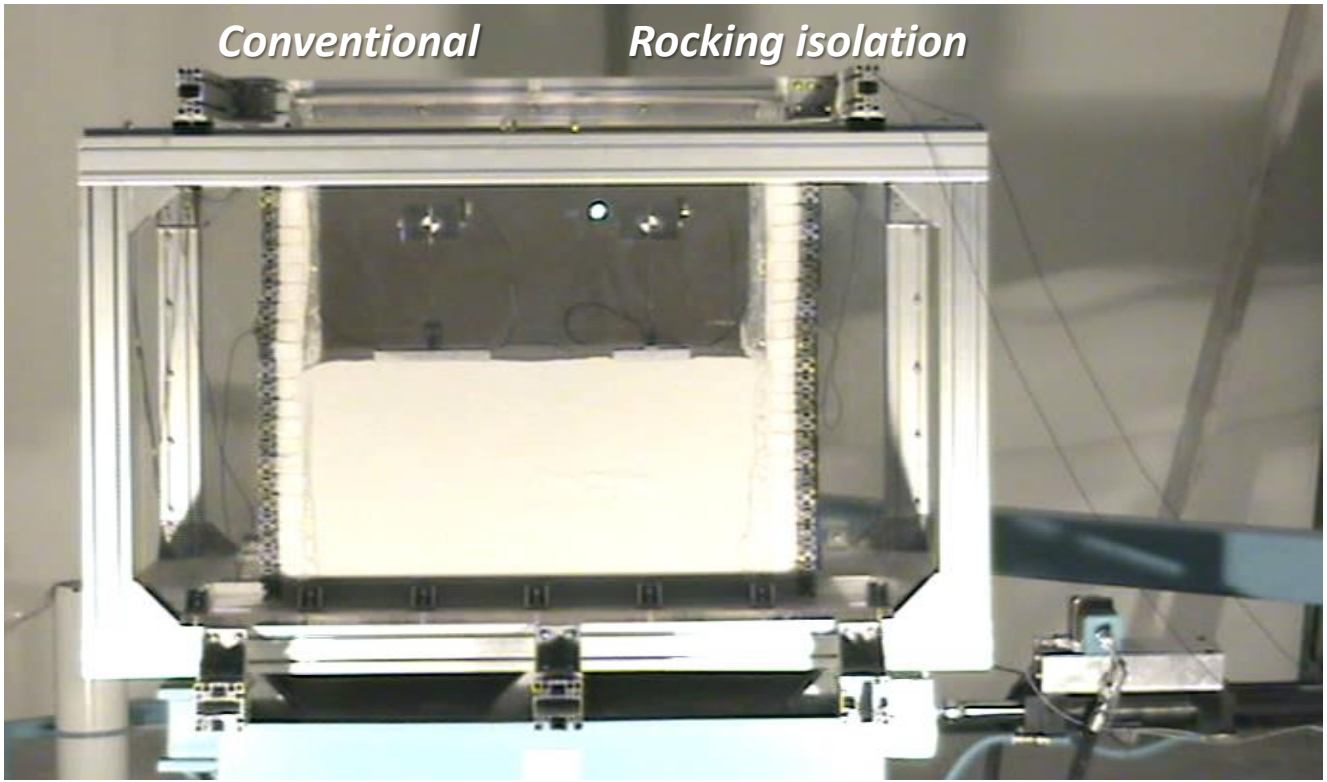


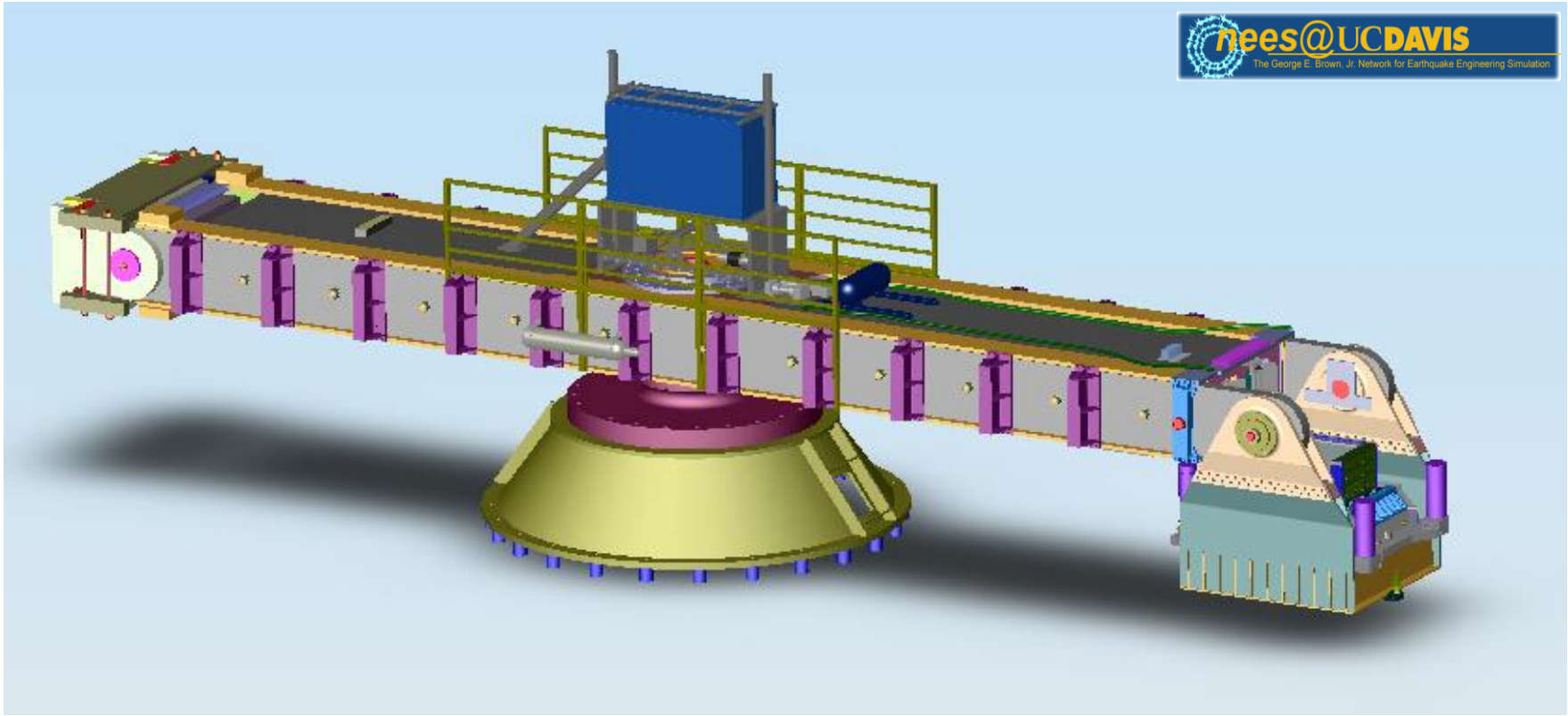
Sin 1 Hz, 0.4 g

Experimental Proof of Concept

Centrifuge model testing @ the University of Dundee (UK)

Centrifuge modeling

Courtesy of Prof. Bruce Kutter



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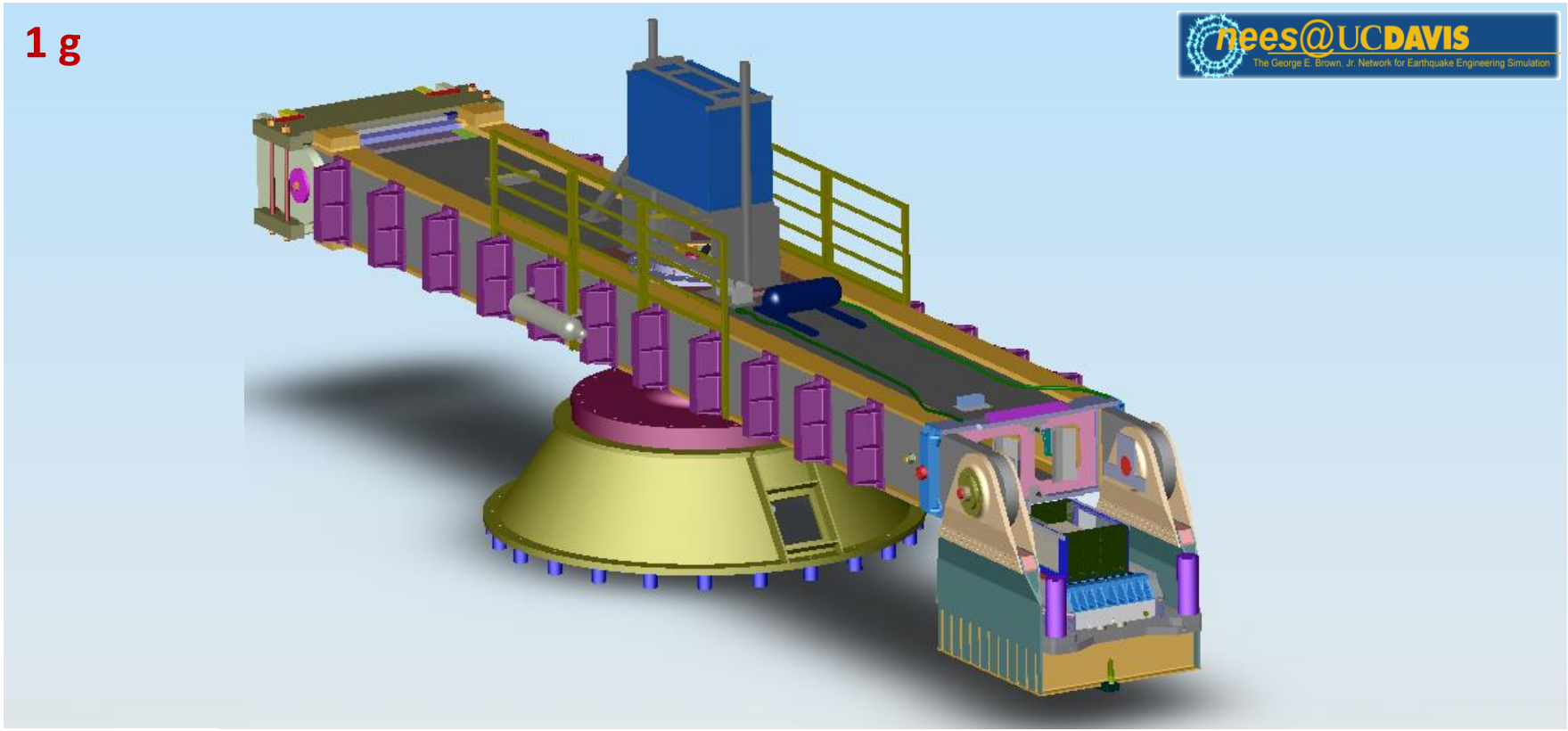
1 g



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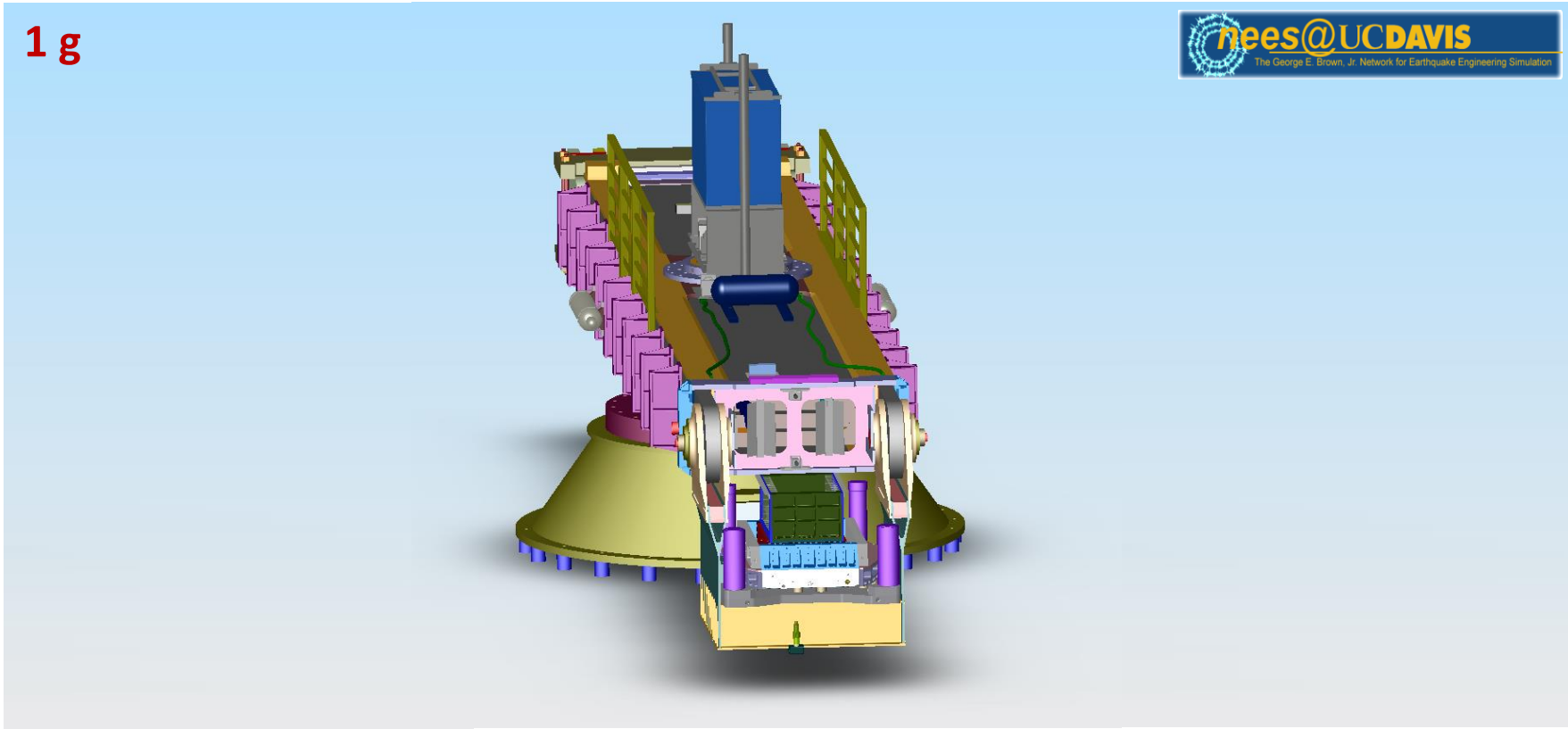
1 g



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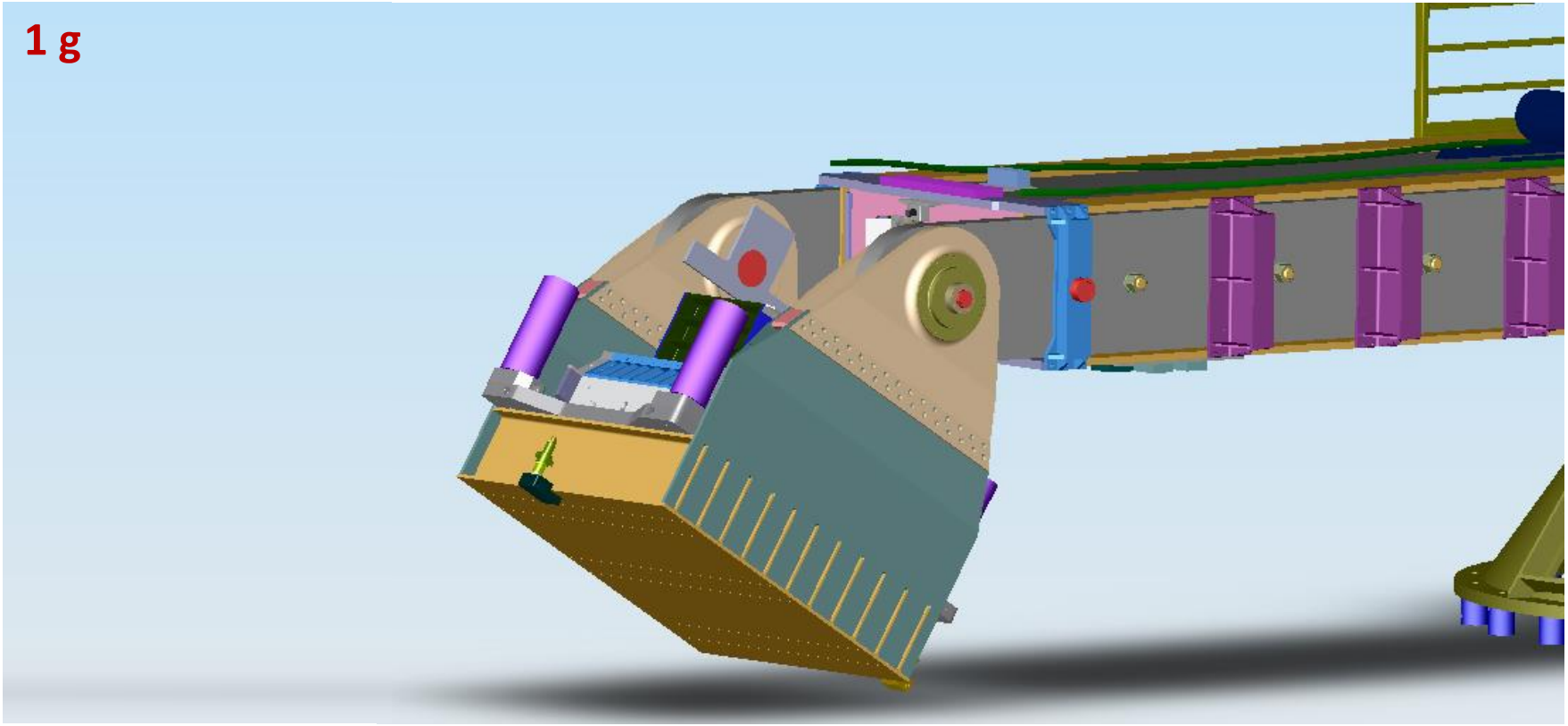

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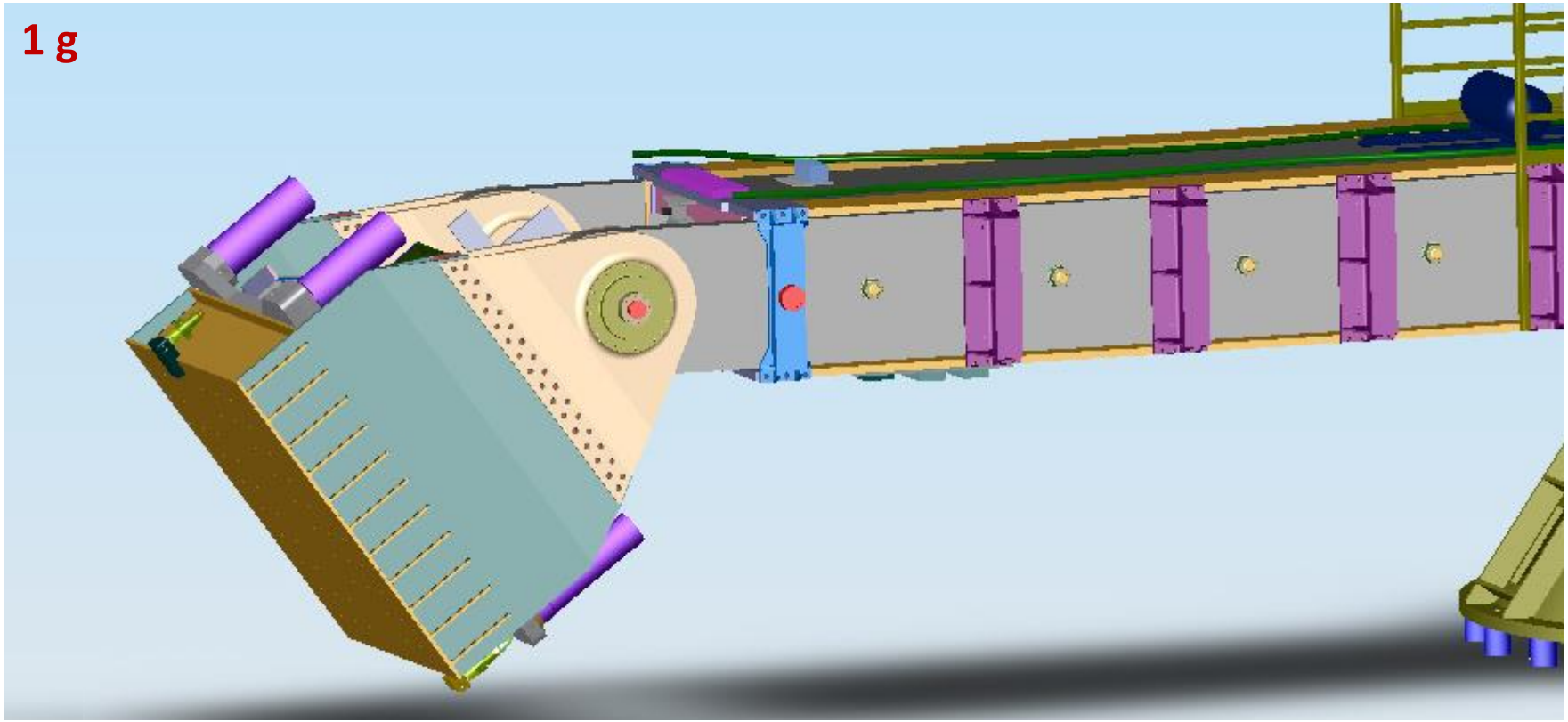

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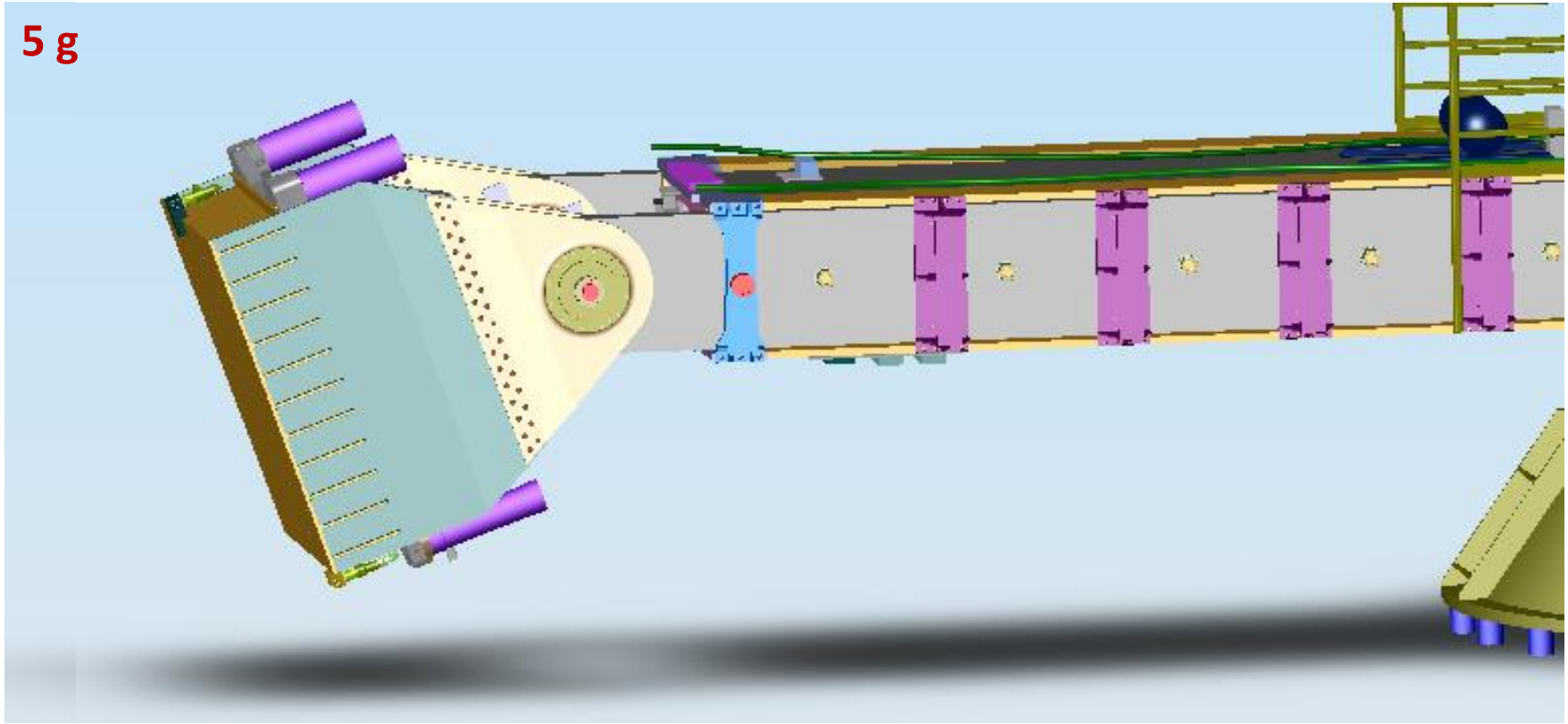

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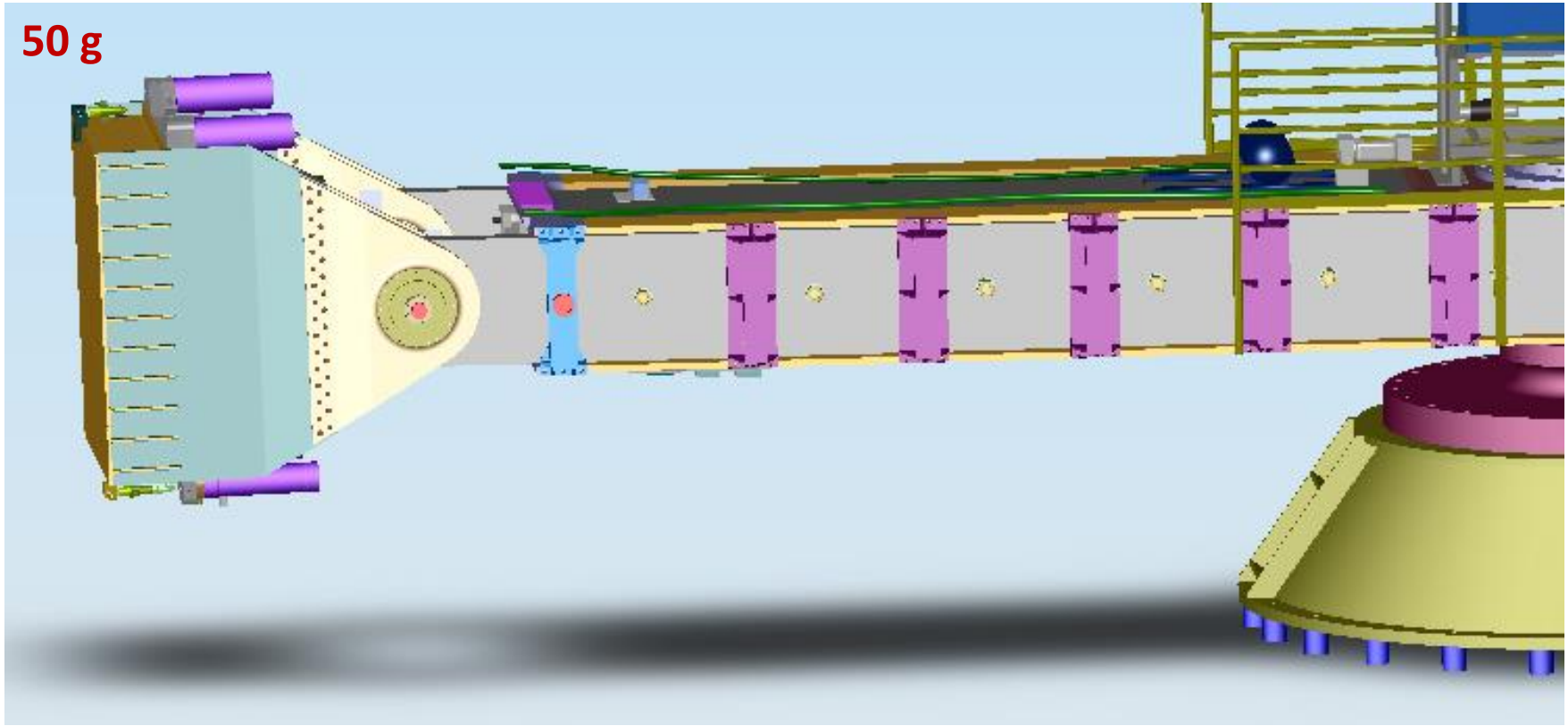
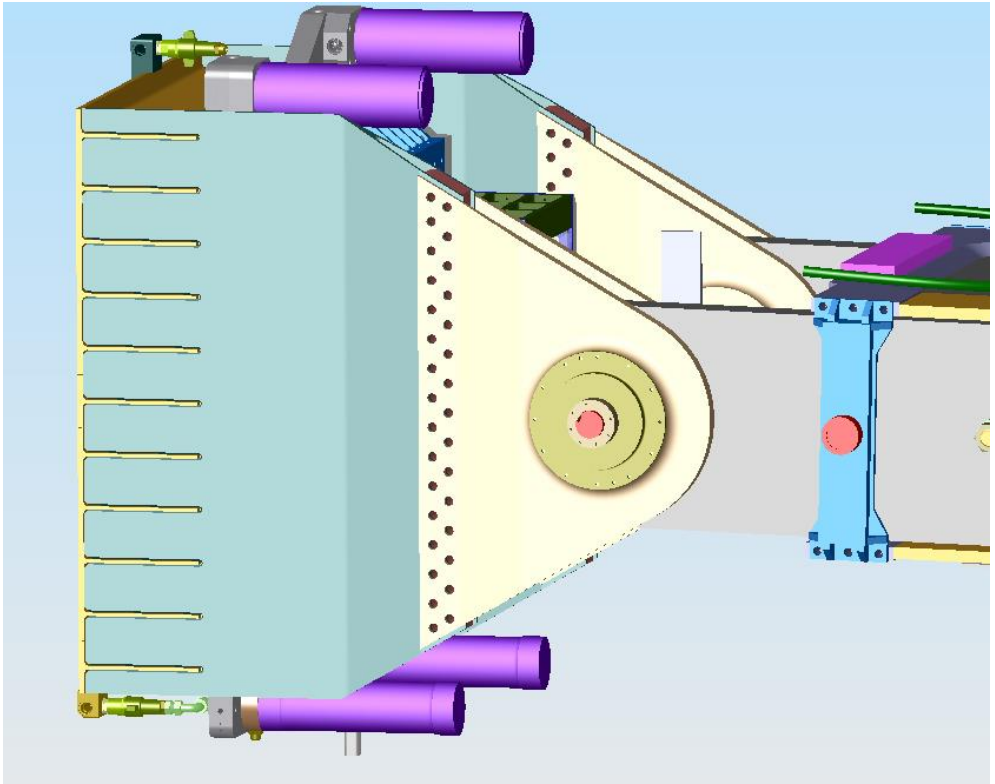


Centrifuge modeling

Courtesy of Prof. Bruce Kutter

- A centrifuge-mounted shaking table can be used to simulate seismic shaking



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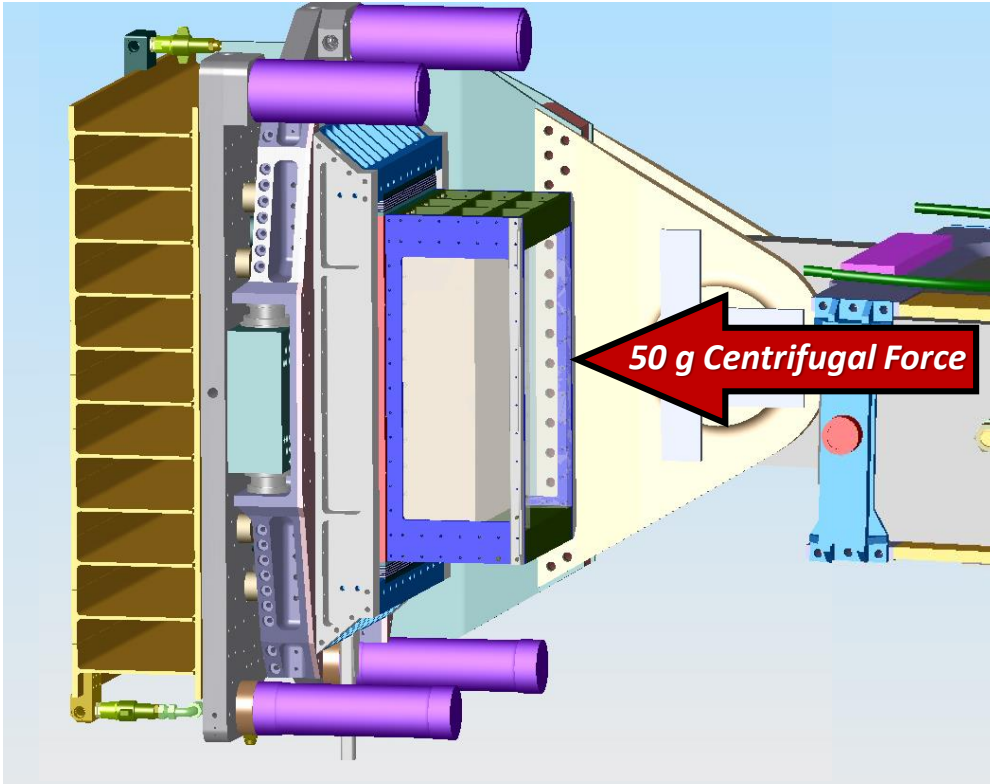

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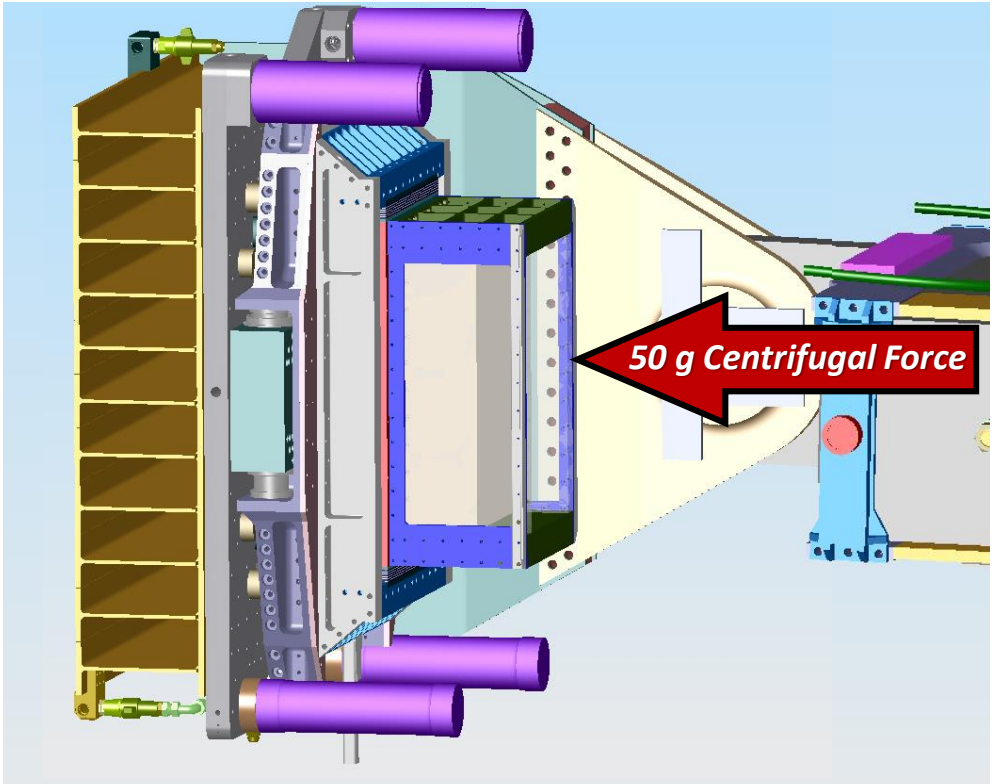

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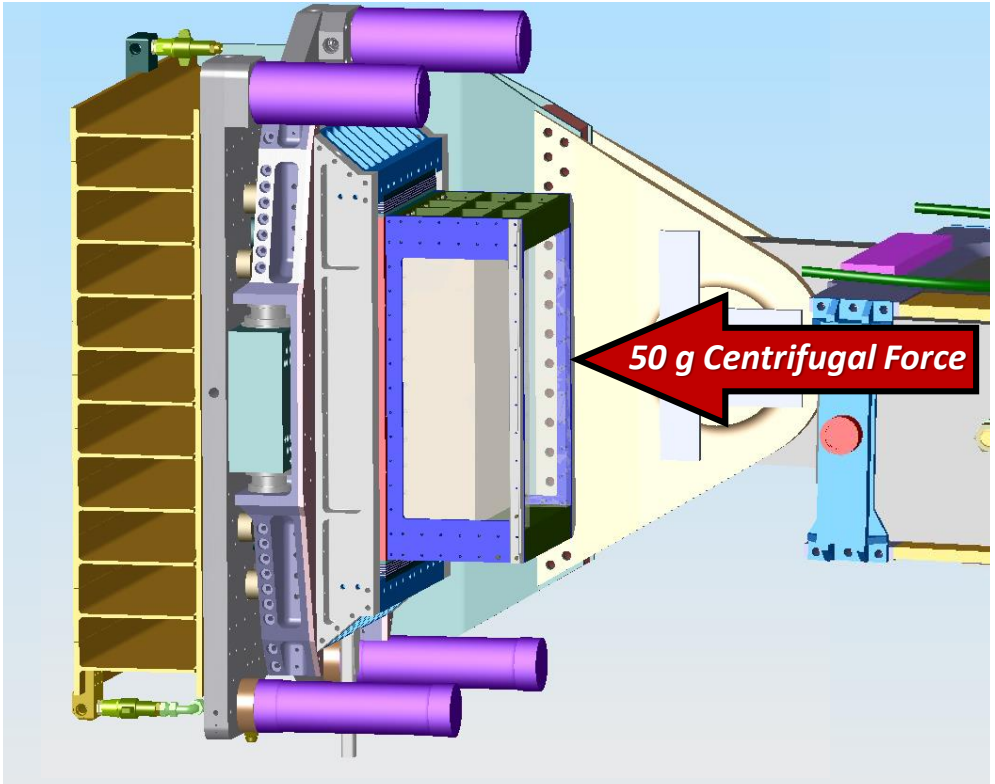
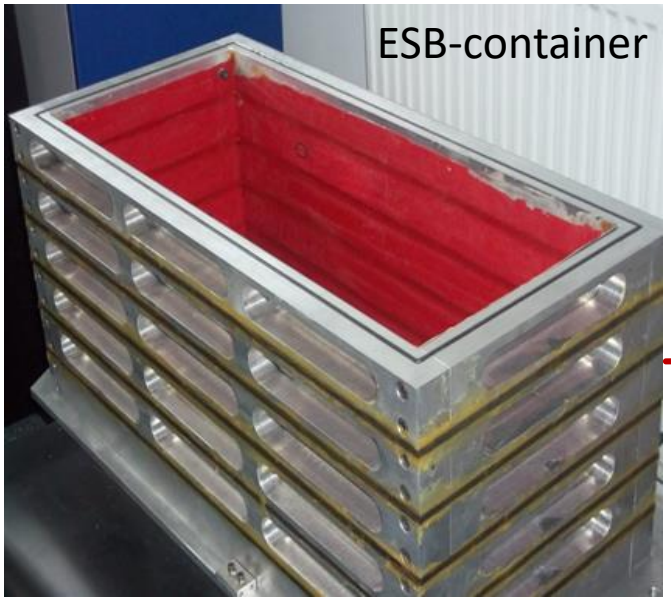


The Dundee Geotechnical Beam Centrifuge

The Dundee Geotechnical Beam Centrifuge

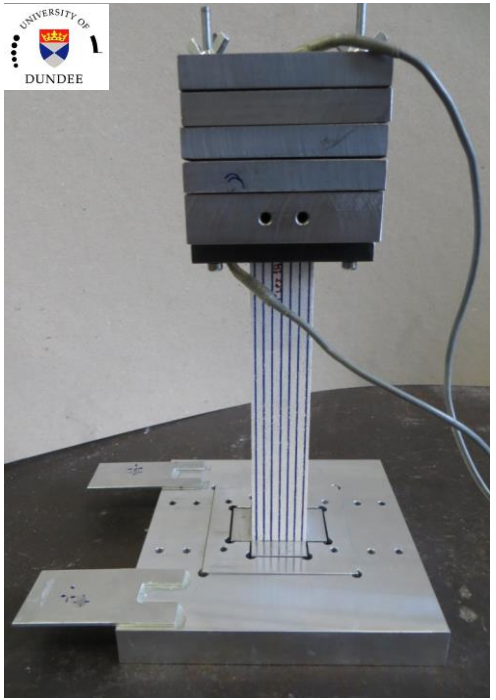
Centrifuge-mounted
earthquake simulator



Experimental Proof of Concept

(Loli et al., 2014)

Centrifuge model testing @ the University of Dundee (UK)



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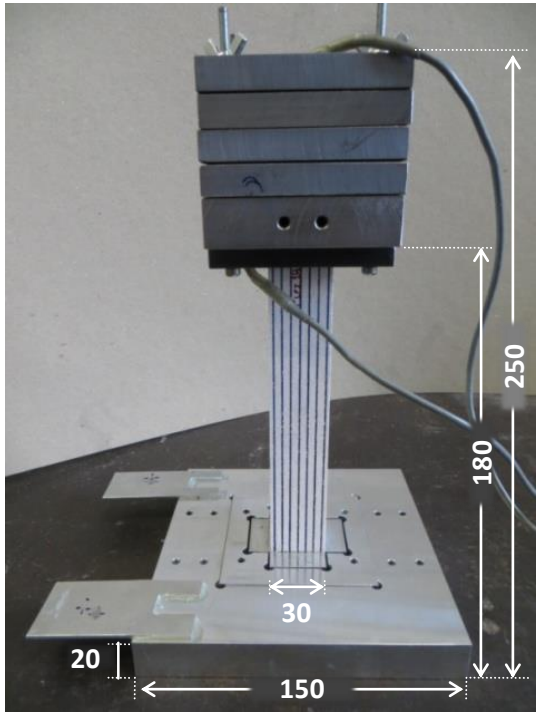

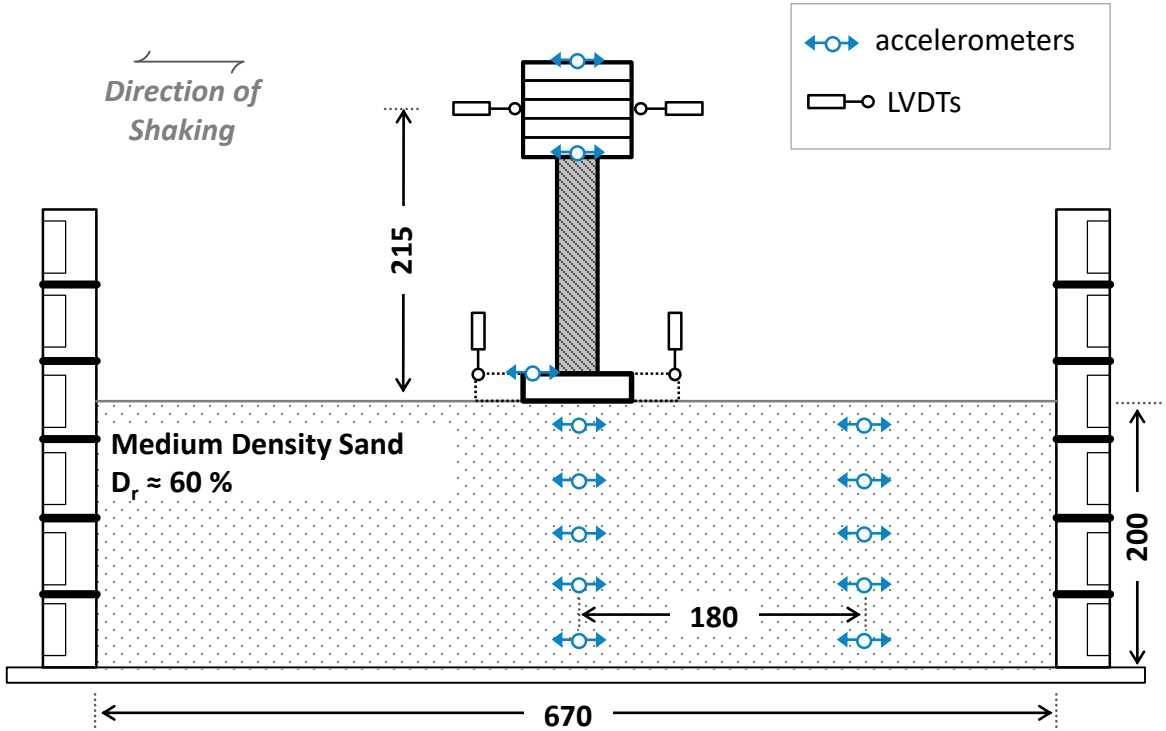

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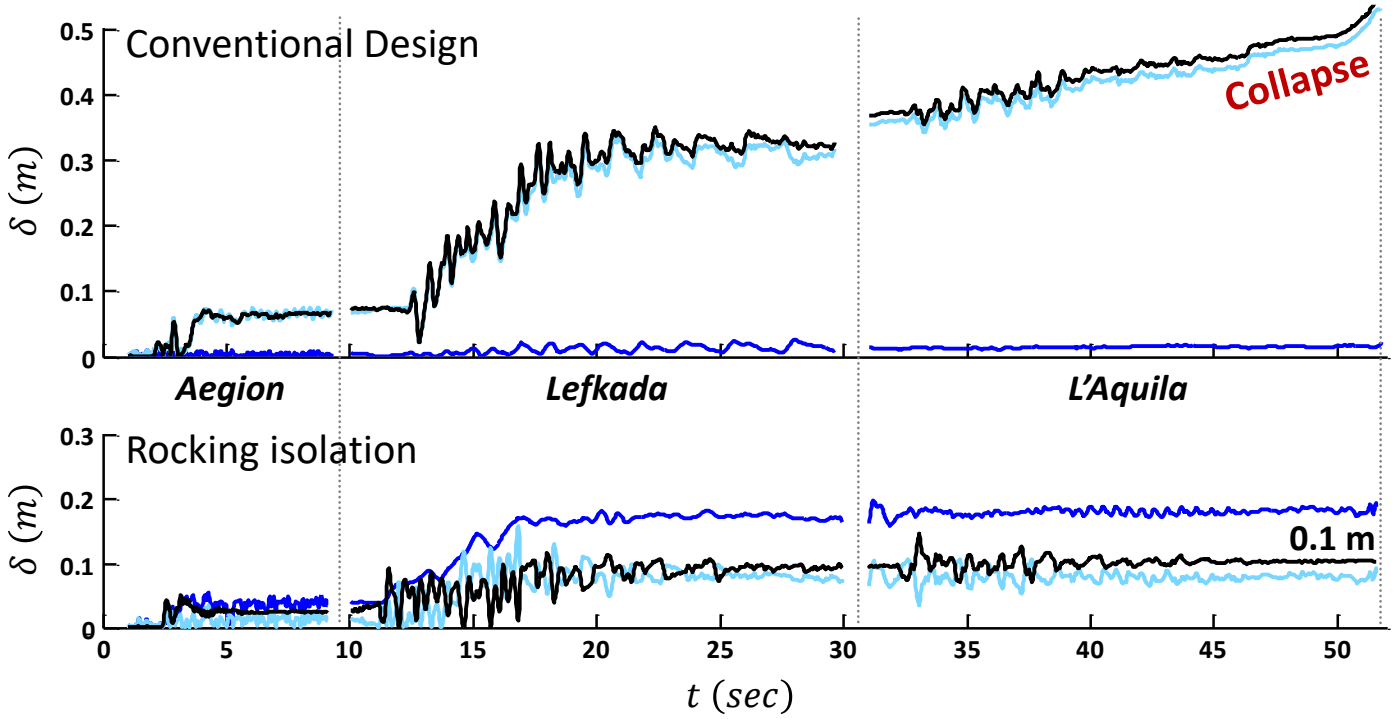

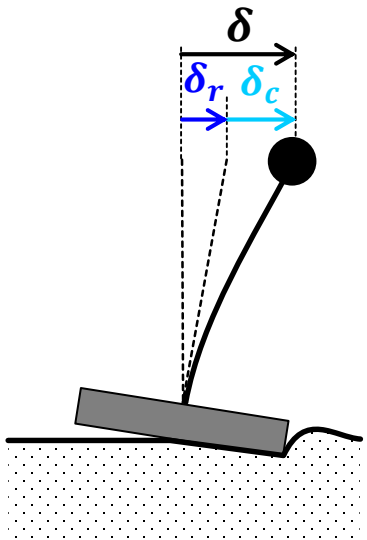

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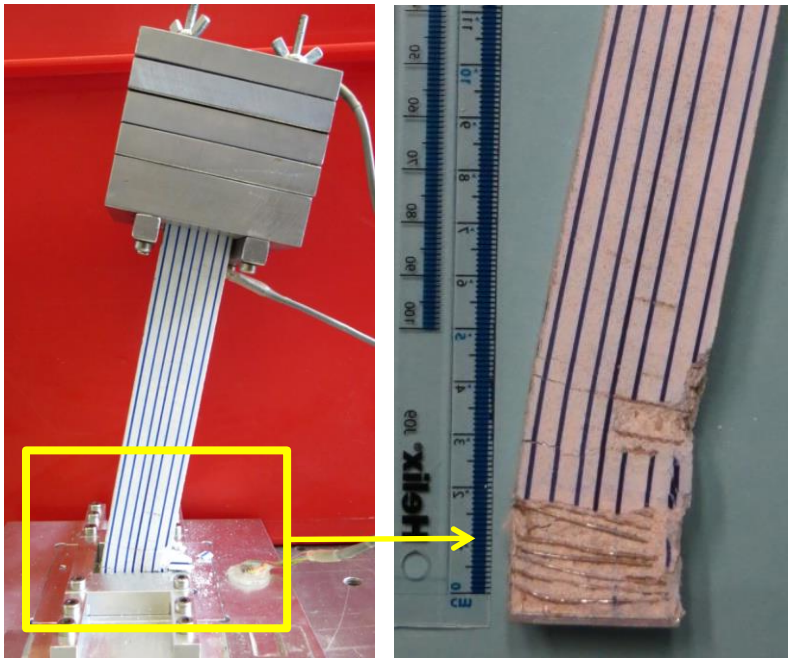
Conventional Design



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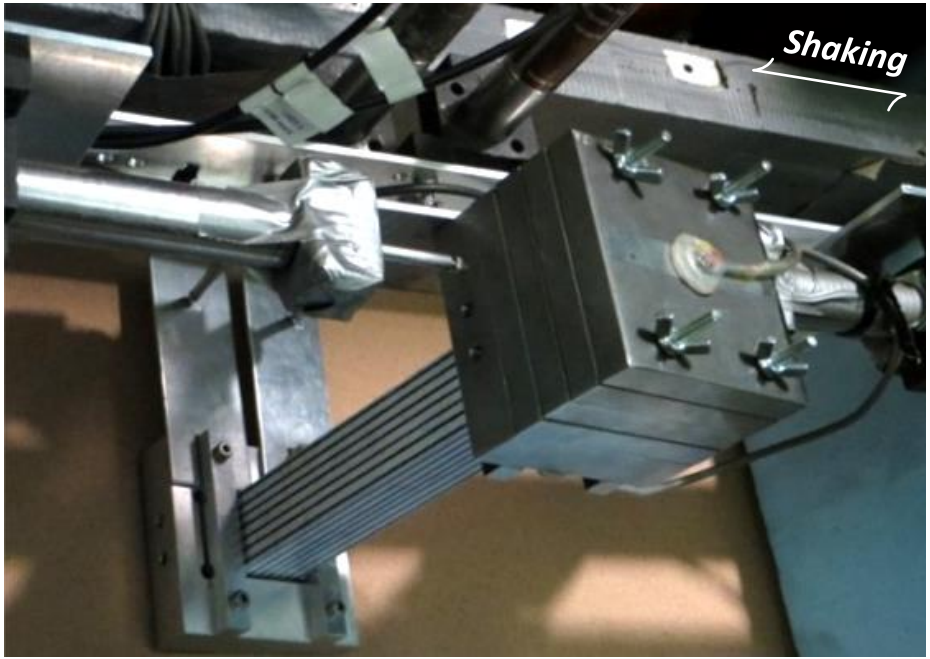

Thank you for your attention!