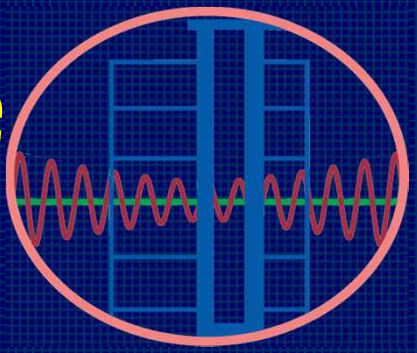
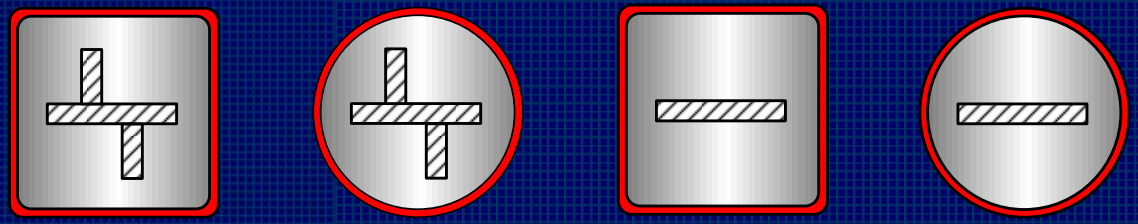
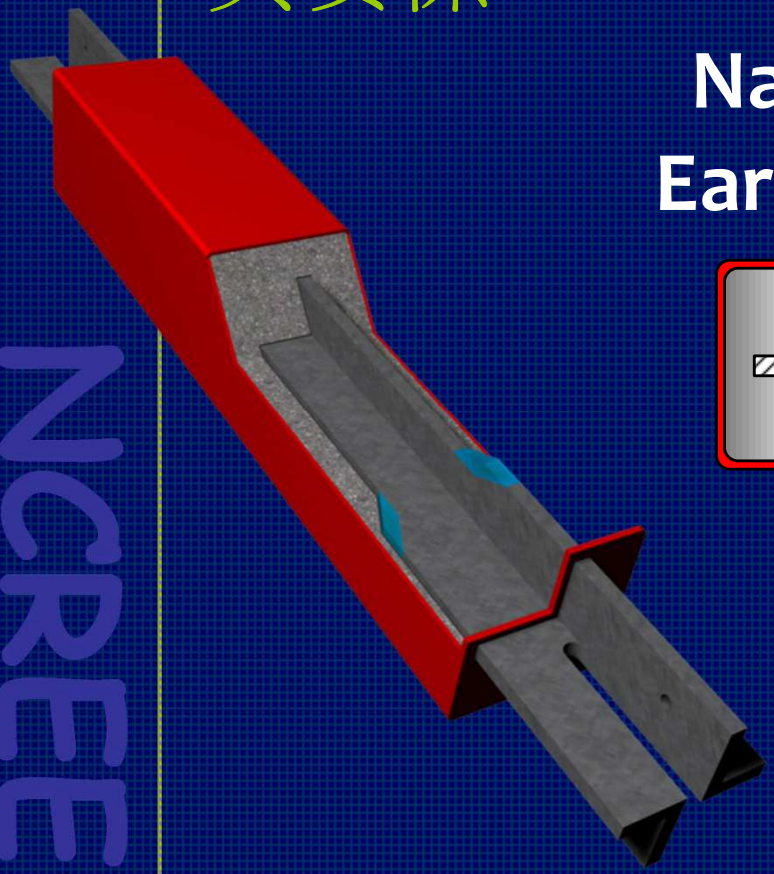
Experimental performance of welded end-slot BRBs



吳安傑 An-Chien Wu

National Center for Research on Earthquake Engineering (NCREE)



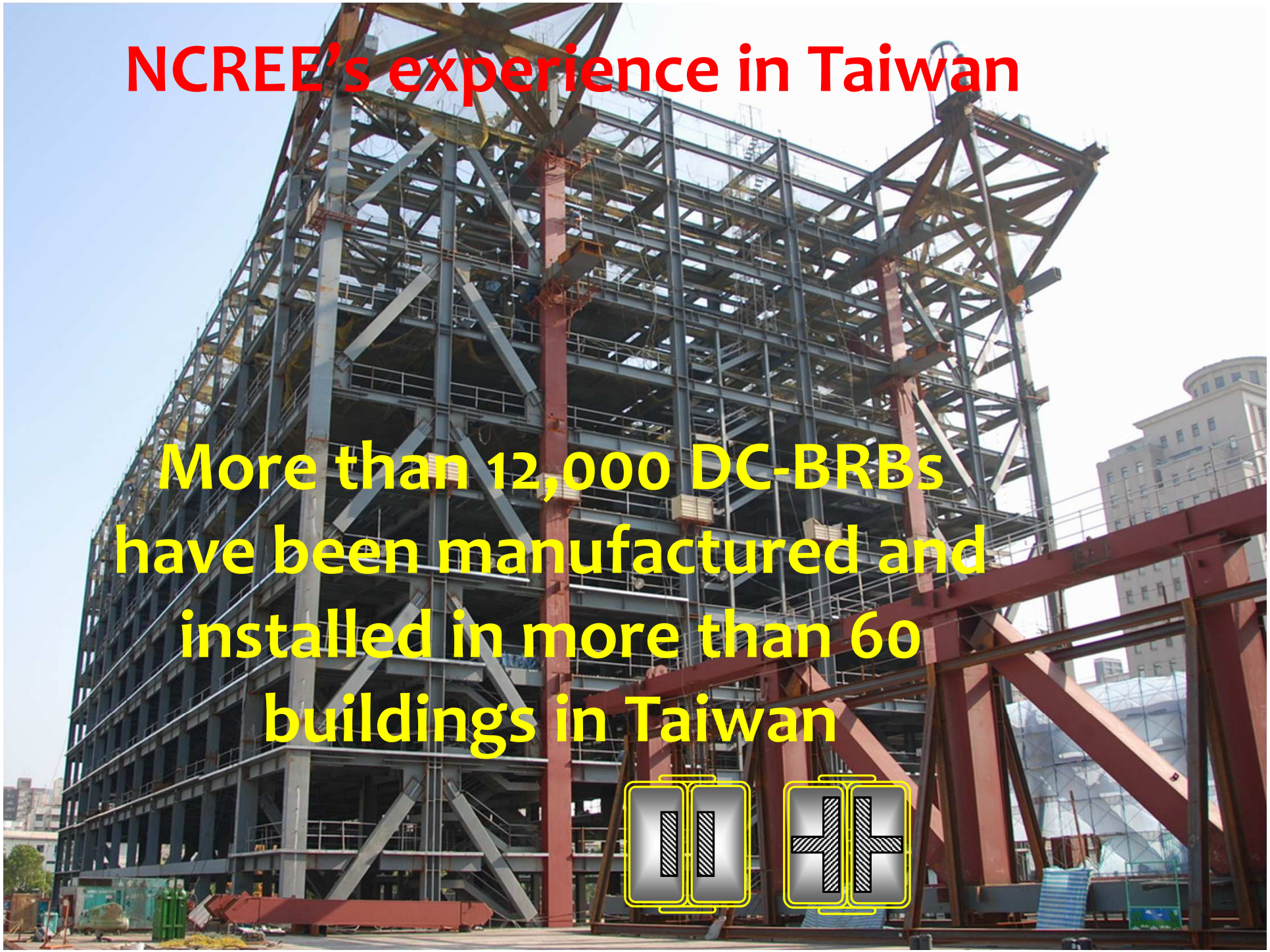


NCREE

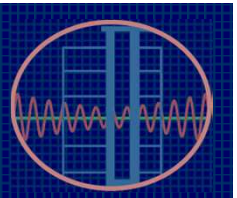
Using WES-BRBs for An Improved Seismic Resisting Performance of Buildings

November 12-14, 2013, New Zealand

NCREE's experience in Taiwan



NCREE attempted to



- reduce the BRB steel material u
- achieve a compact BR connection
- achieve a reliable unbonding mechanism
- ensure the BRB seismic performance
- assist engineers to design BR connections

WES-BRB

BOD

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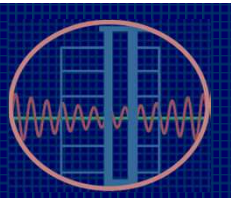
Overview



- Requirements for BRB performance
- Experiments of WES-BRBs
- Experiments of WES-BRB frames
- Applications of WES-BRBs in Taiwan
- Qualifying tests of WES-BRBs
- Conclusions

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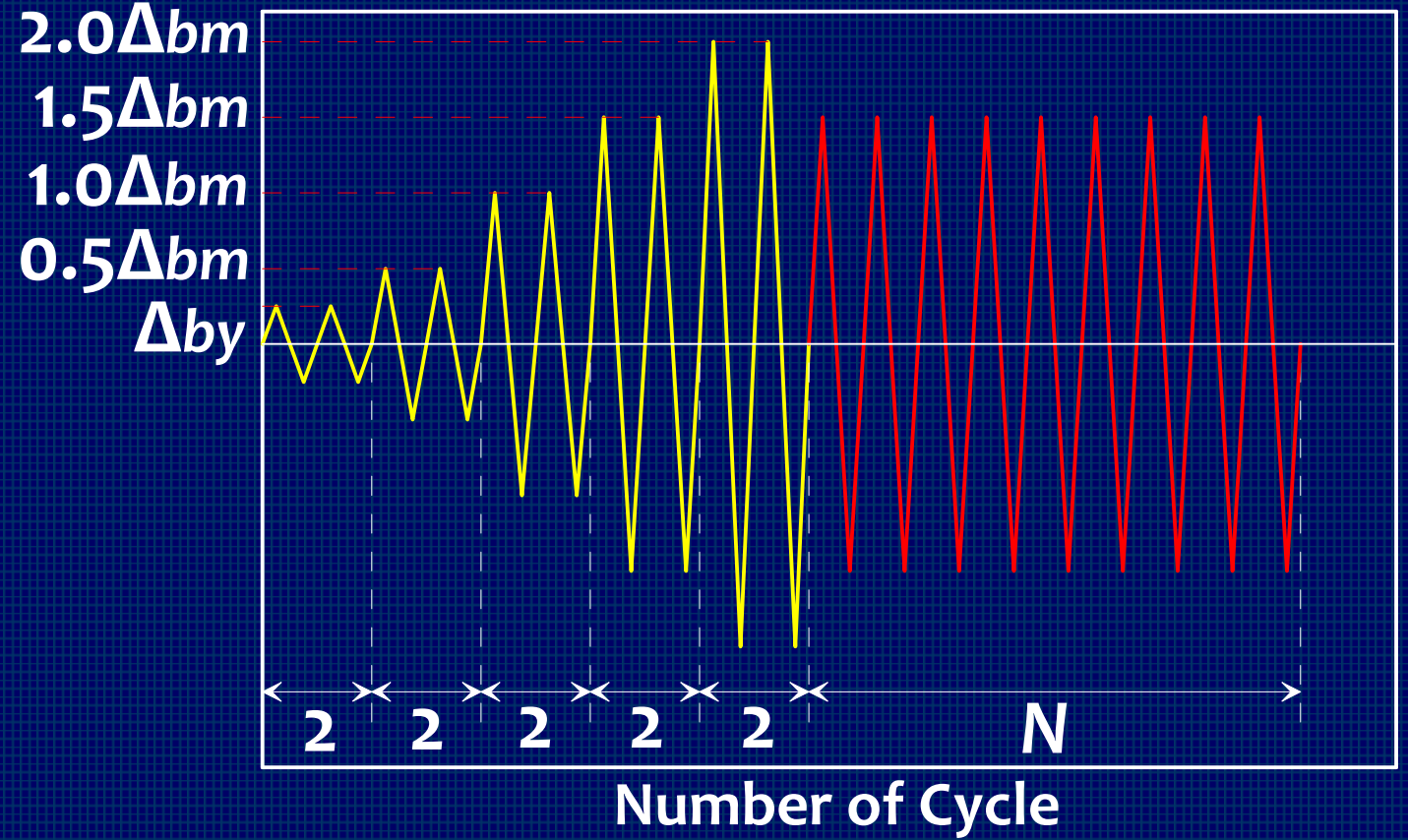
Loading protocol (AISC 2010)



Δ_{by}=deformation at the BRB yield

Δ_{bm}=deformation corresponding to the design story drift Δ_D ($\geqq$1.0%)

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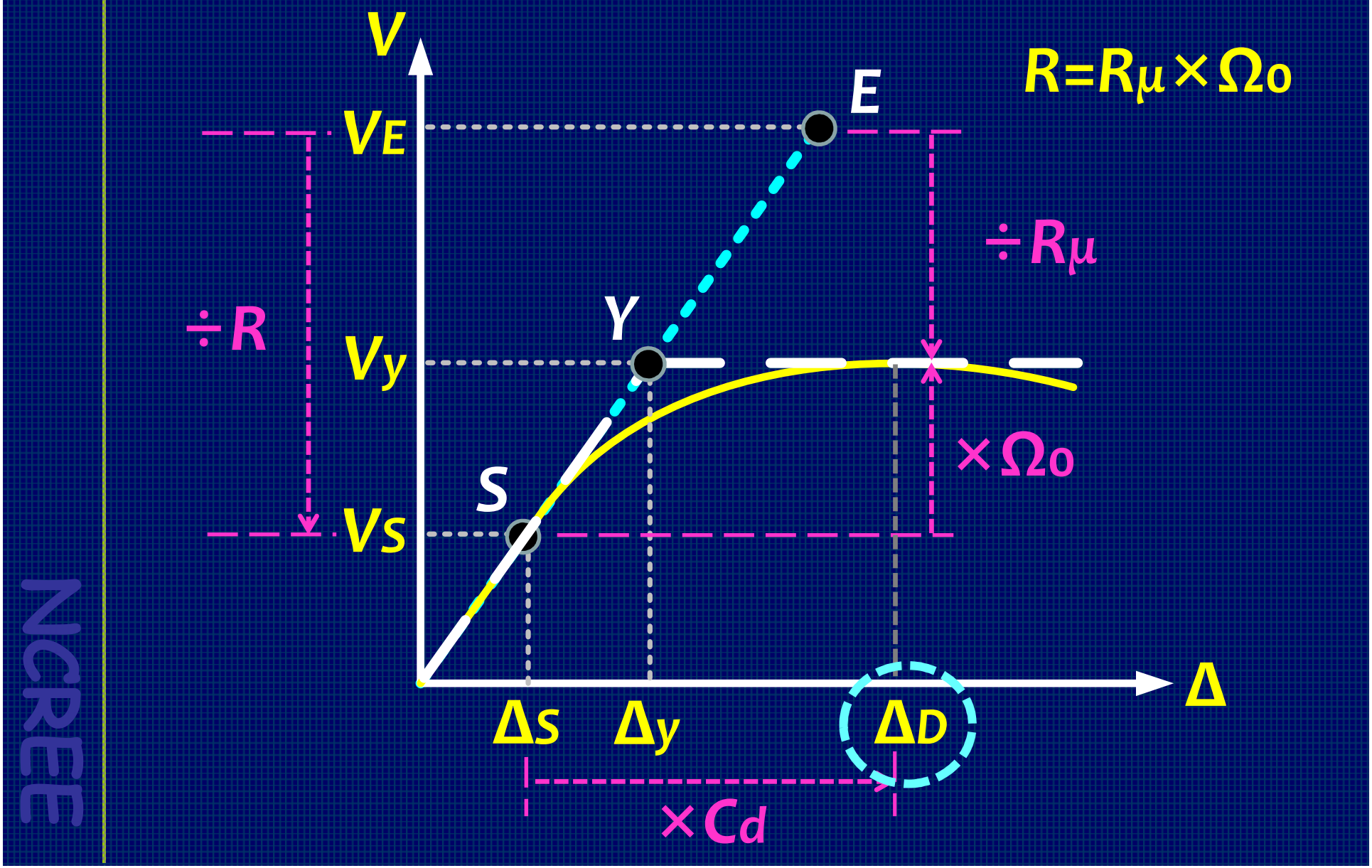
Design story drift $\Delta_D \geqq 1.0\%$ for BRB tests



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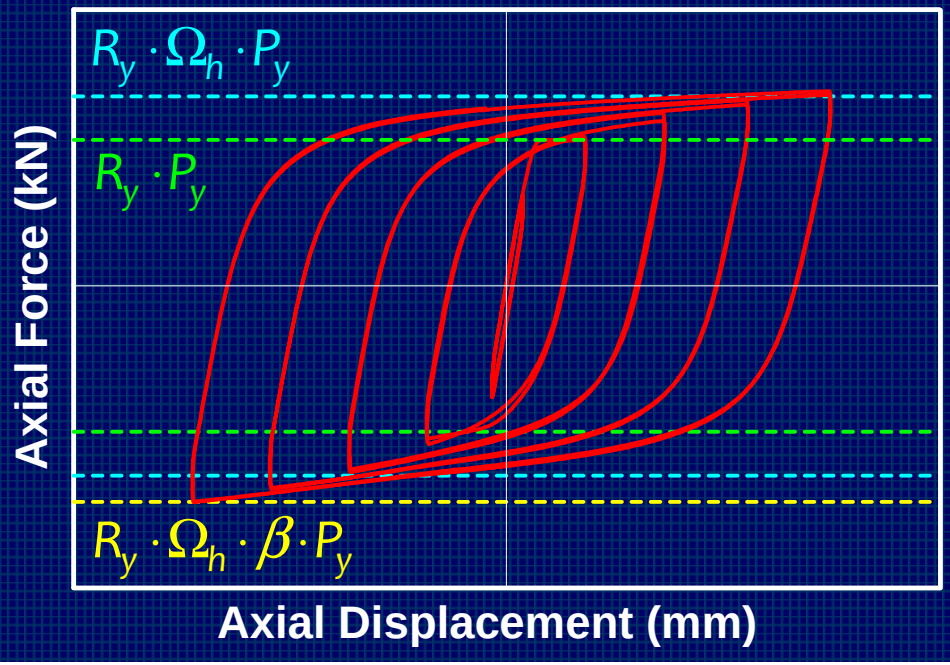
AISC 2010 acceptance criteria

- **Nominal yield strength**

$$P_y = F_y \times A_c$$

- **Max. compressive strength**

$$P_{max} = P_y \times R_y \times \Omega_h \times \beta$$



R_y : *overstrength factor*

Ω_h : *strain hardening factor*

β : *compression strength adjustment factor*

(β factor)

AISC 2010 acceptance criteria:

$$\beta_i = P_C^i / P_T^i < 1.3$$

$$CPD > 200\Delta_{by}$$

Cumulative Plastic Deformation

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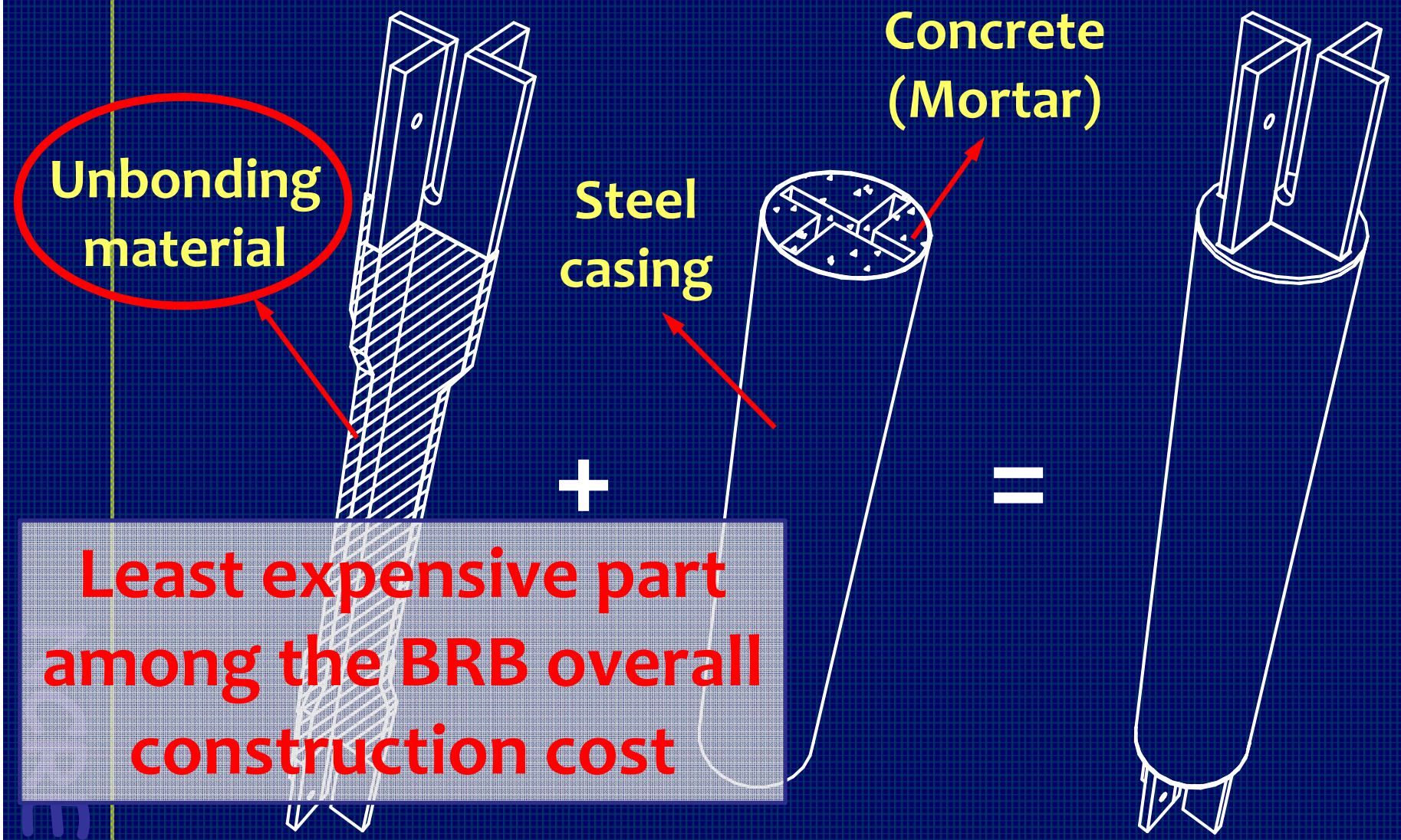
Unbonding mechanism is most critical



Unbonding mechanism is most critical

Unbonding material

Core member

Significant effects on BRB performance:

- ✓ Reflect fabrication quality
- ✓ Affect peak compressive strength (β factor)
- ✓ Affect BRB fatigue life

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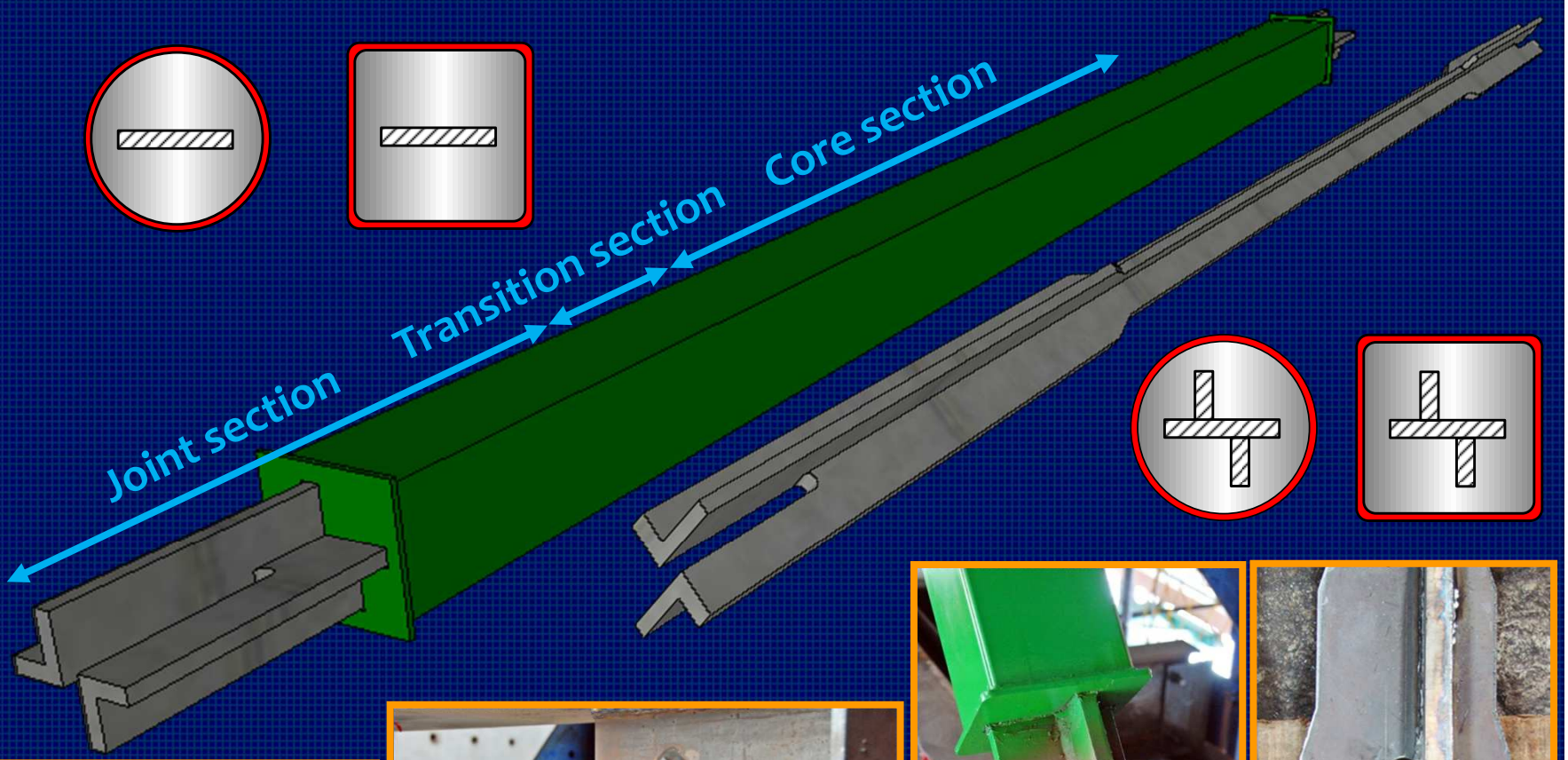
Welded end-slot BRB (WES-BRB)



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Perform well and predictable

WES-R

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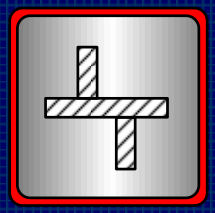
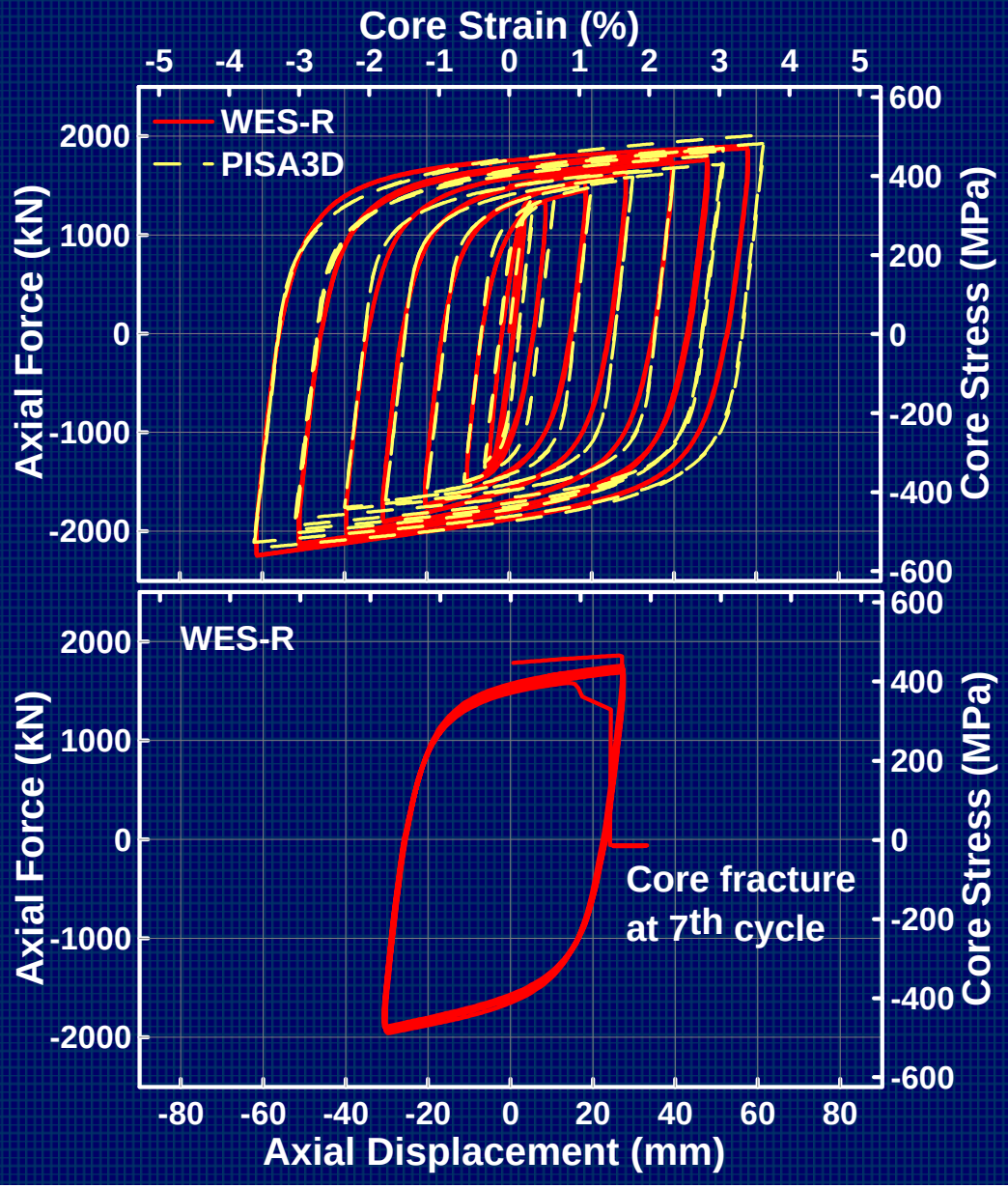
L_{BRB}=2.5m

P_y=1340kN

β<1.18

CPD=640





Perform well and predictable

WES-C

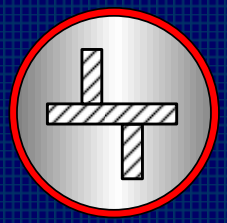
NCREE

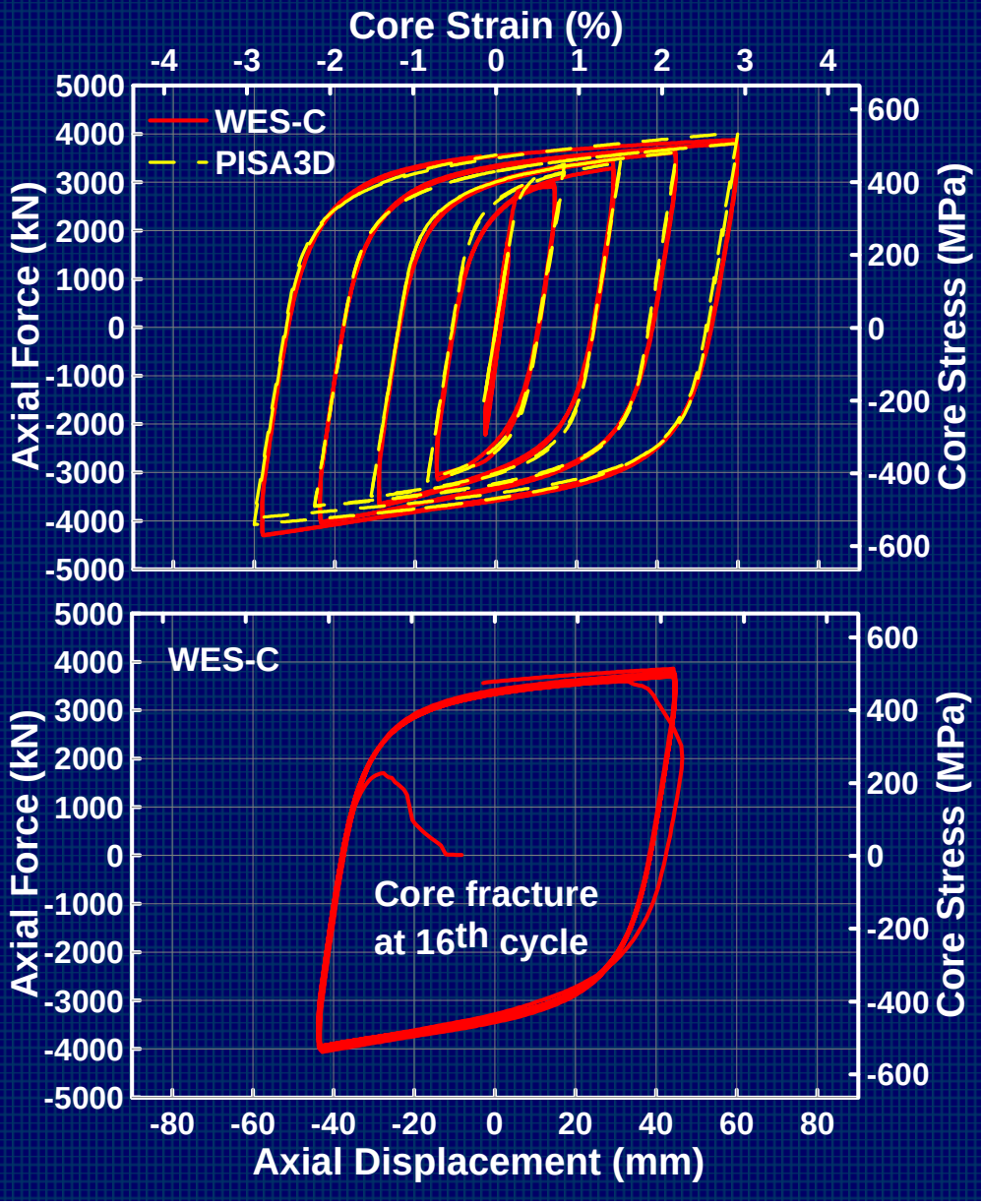
L_{BRB}=3.3m

P_y=3000kN

β<1.11

CPD=834





Perform well and predictable

WES-J

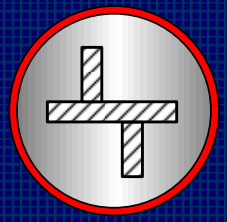
NCREE

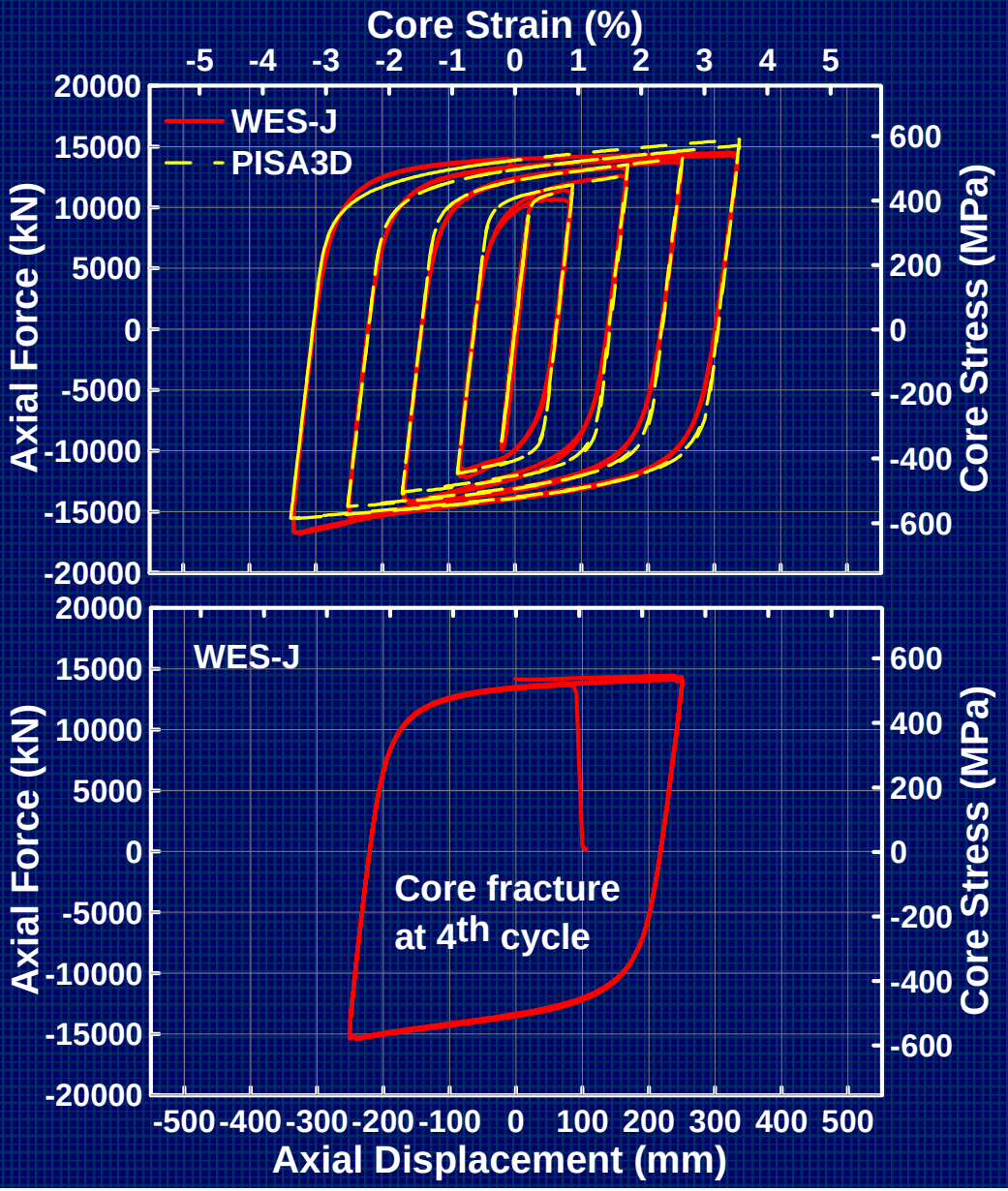
L_{BRB}=12.5m

P_y=10600kN

β<1.16

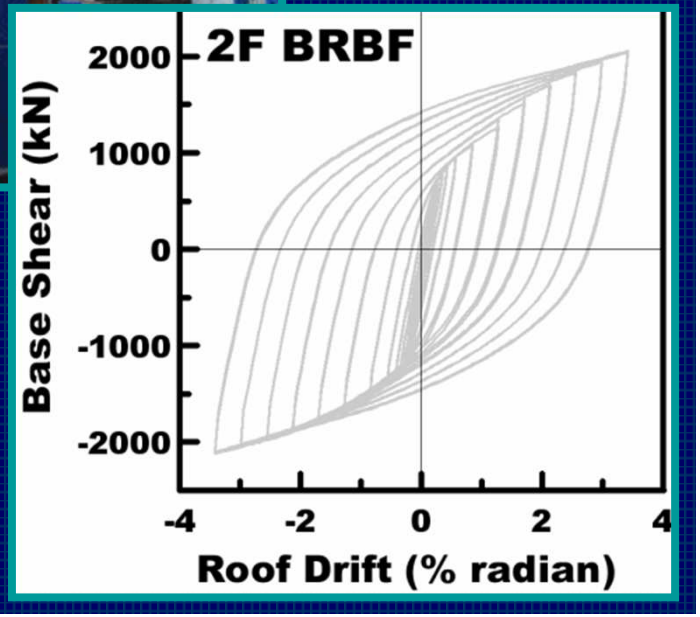
CPD=406



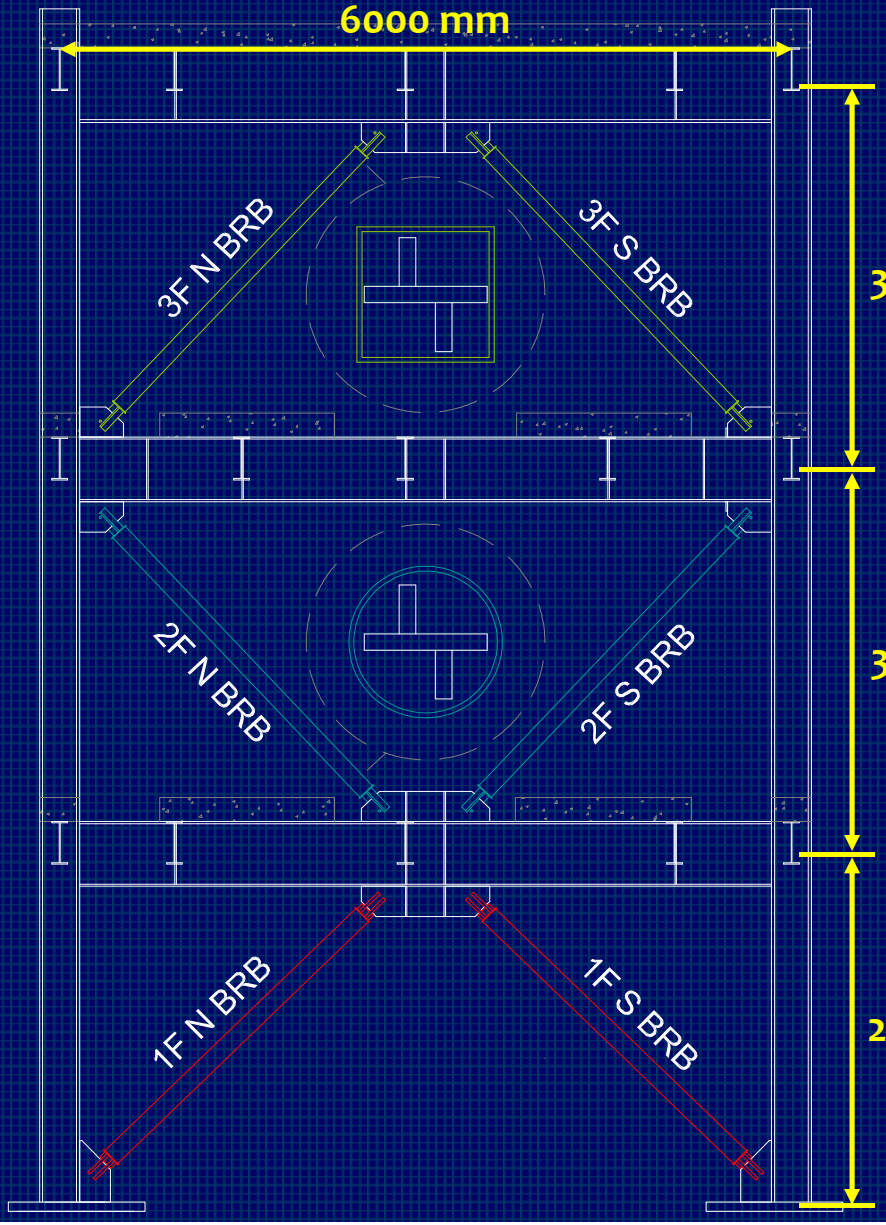


Performed well in the 2-story BRBF

>3.5% rad.



Pseudo-dynamic tests of a full-scale 3-story BRBF



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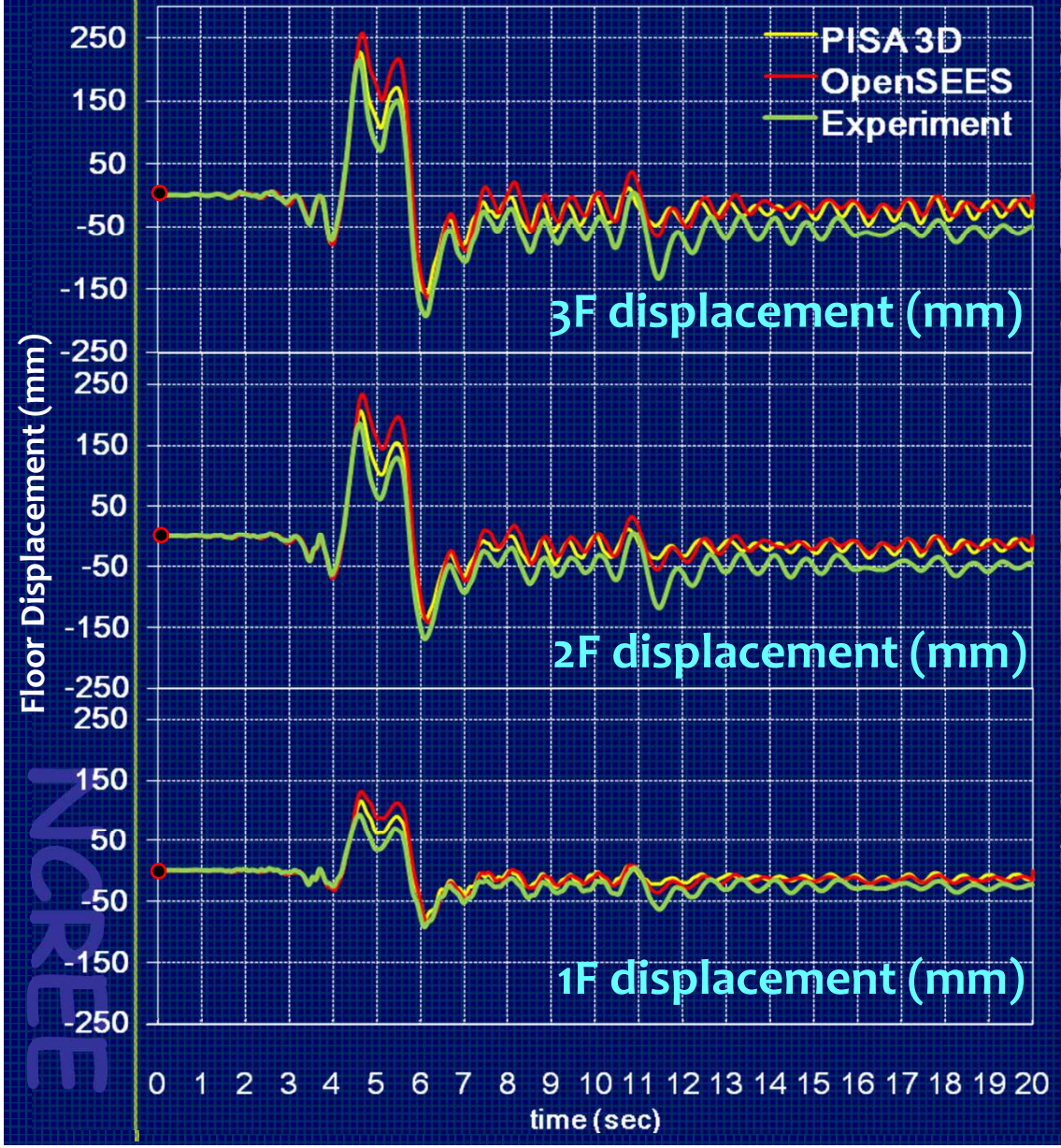
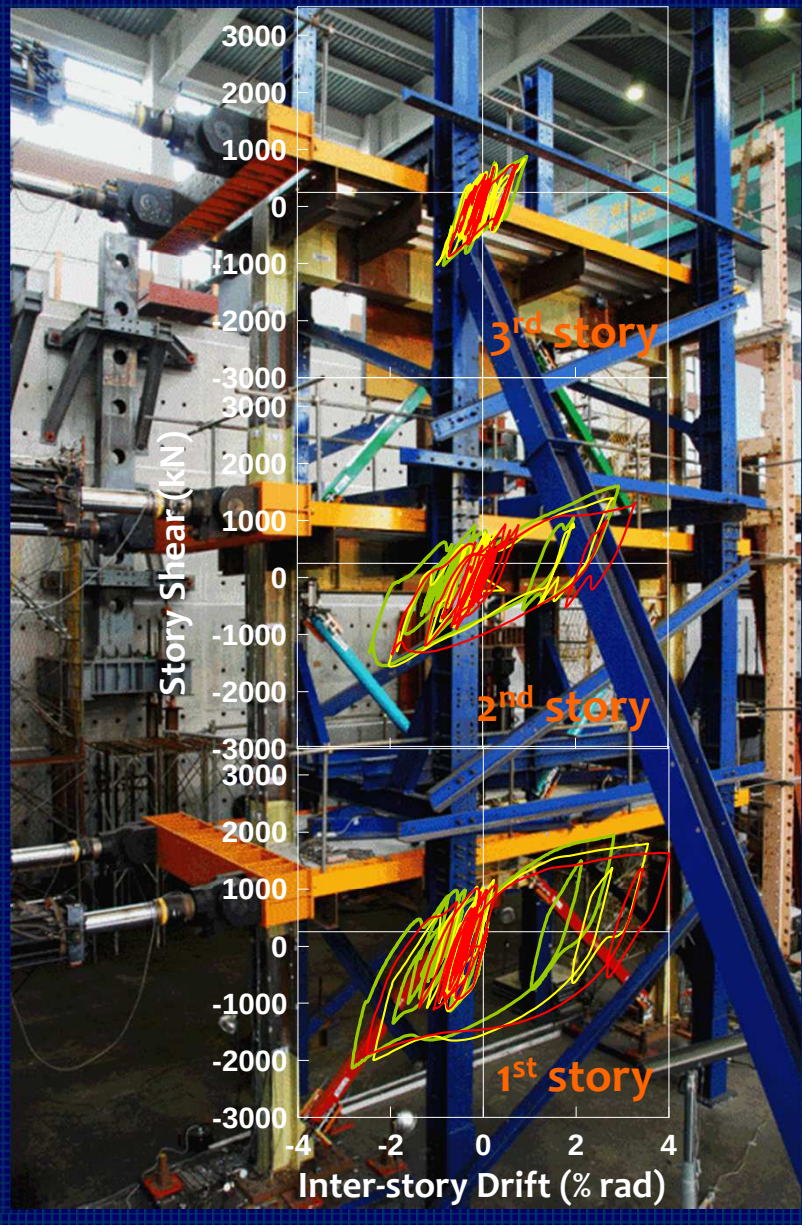
Stable and predictable responses





Excellent performance is confirmed

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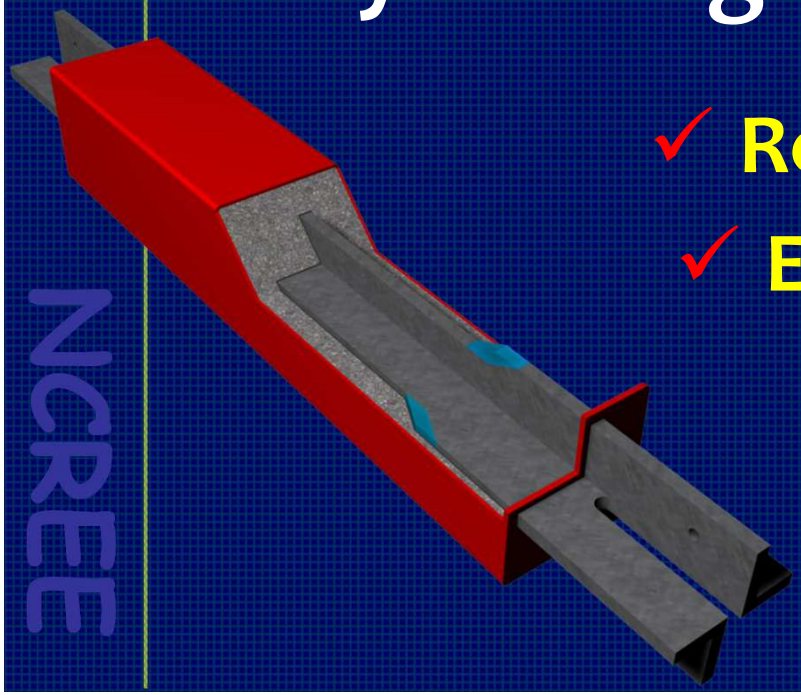
Applications of WES-BRBs

- 5 fabricators licensed in Taiwan
- More than 2,000 WES-BRBs installed in more than 15 buildings
- Grayson Engineering in NZ is licensed



- ✓ Reliable unbonding mechanism
- ✓ Excellent seismic performance
- ✓ Cost-effective fabrication
- ✓ Compact and stable end connection

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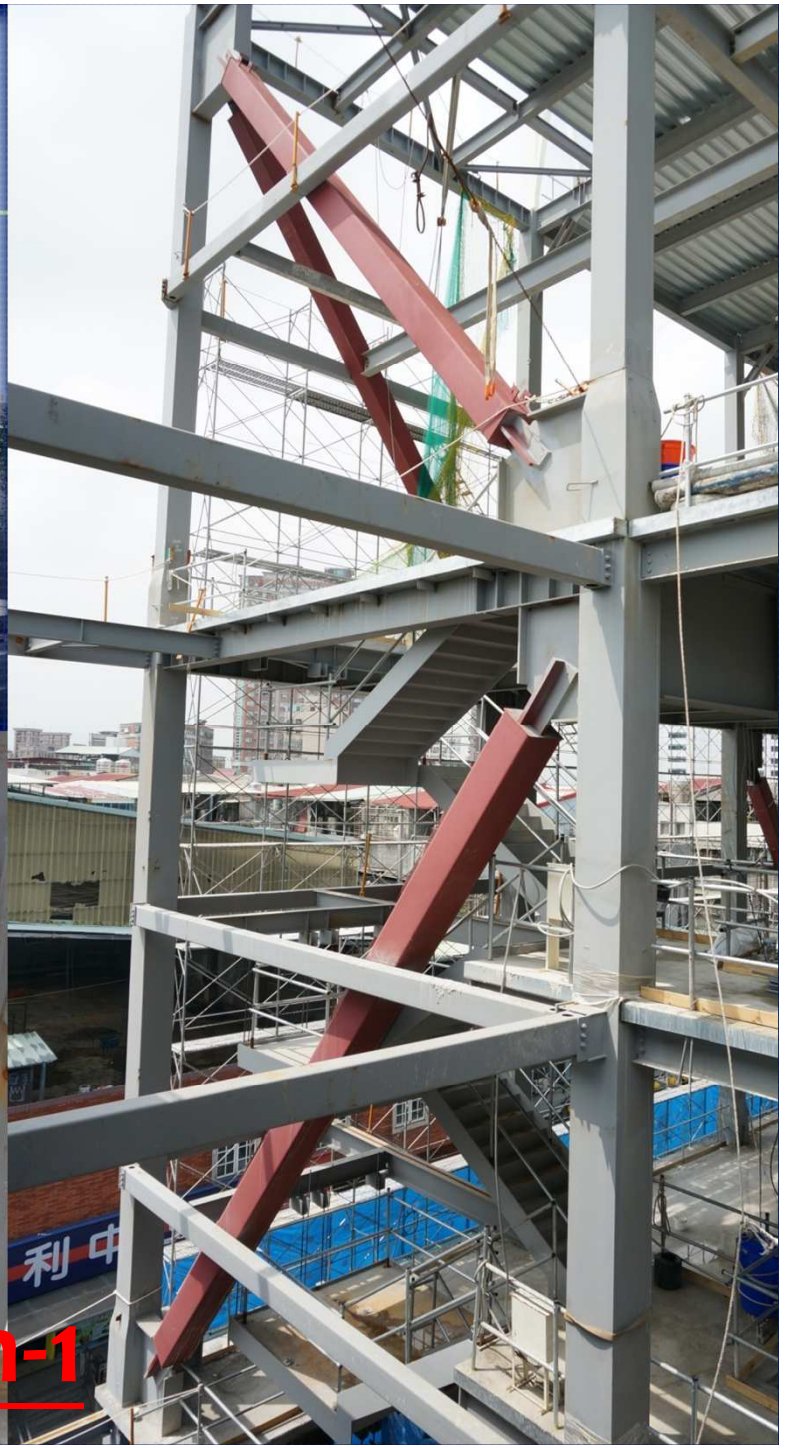


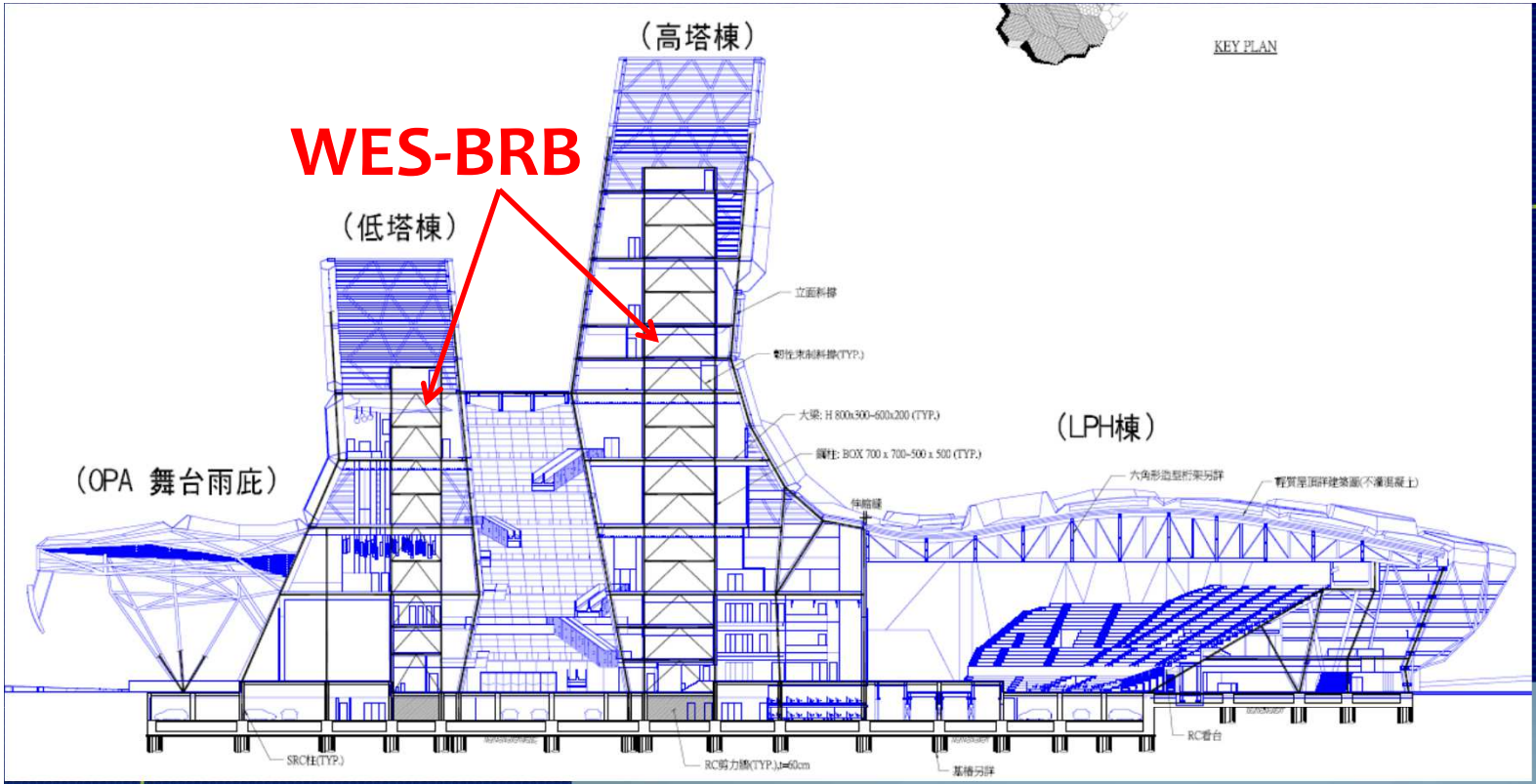
New Taipei City Stadium-1

New Taipei City Stadium-2

NCREE

A 5-star Hotel in Taipei

NCREE



Kaohsiung Maritime Culture and Popular Music Center

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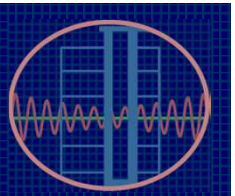
Conduct the quality control



- Inspect the applying material and the fabrication process
- Conduct qualifying tests on randomly selected members in every 100 WES-BRBs manufactured
- Provide certificates for 15-year warranty
- Provide the BOD cloud service for automated design of BRBs and connections

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Qualifying test results of randomly selected BRBs

Member	P_y(kN)	L_{BRB}(mm)	Casing(mm)	Strain	CPD
WES-01	5175	7013	449×449×8	3.0%	478
WES-02	6720	9198	465×465×8	3.0%	606
WES-03	2250	4500	250×250×6	3.0%	518
WES-04	7300	4773	Pipe 500×9	3.0%	1044
WES-05	8300	4700	390×390×8	3.0%	950
WES-06	2510	3700	Pipe 318.5×6	1.8%	1101
WES-07	3200	3708	Pipe 406.4×9	2.1%	756
WES-08	3750	4250	Pipe 406.4×6	2.2%	819
WES-09	6940	4110	Pipe 500×9	2.7%	887
WES-10	8800	3285	485×485×10	1.9%	1106

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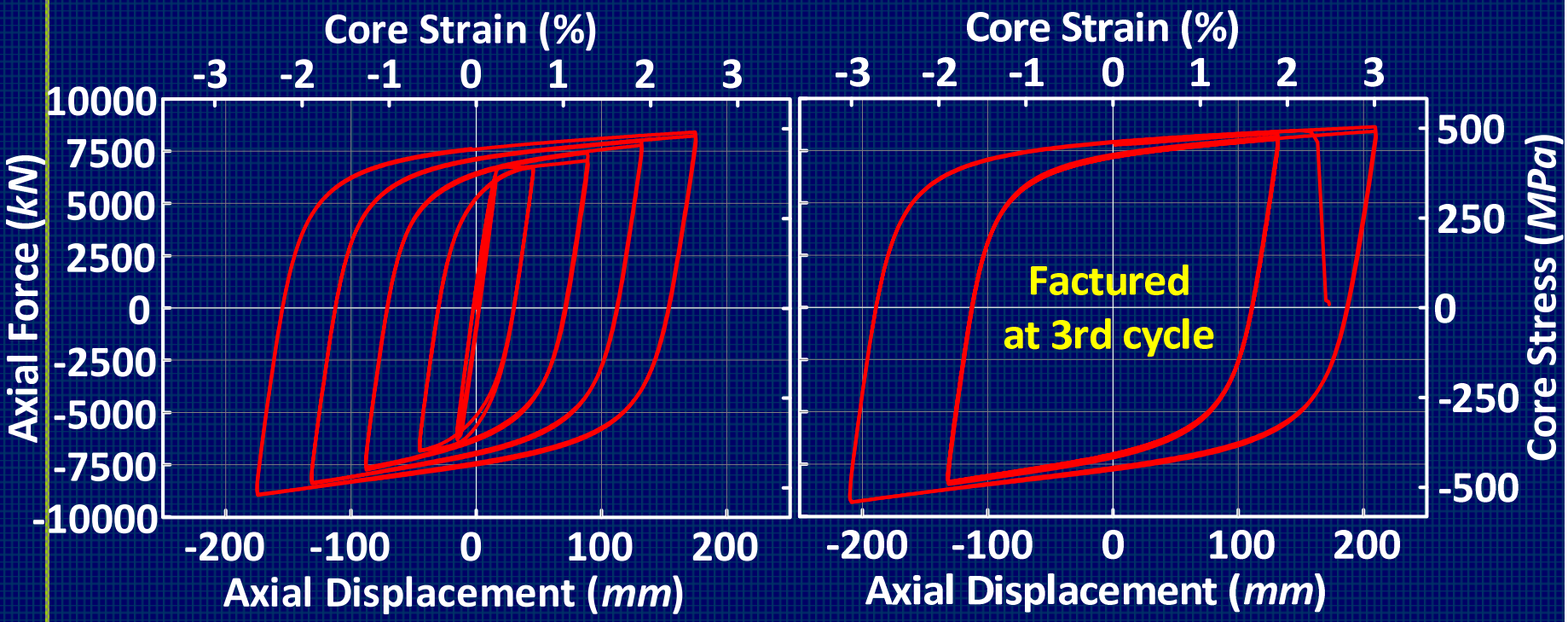
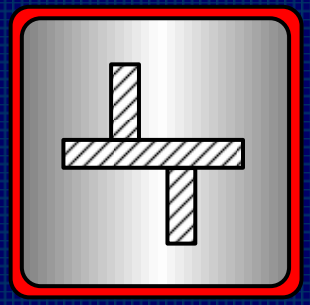
A typical one in randomly selected WES-BRBs





WES-02, A572 GR50

Py=6720kN, LBRB=9198mm

CPD=606, β<1.08

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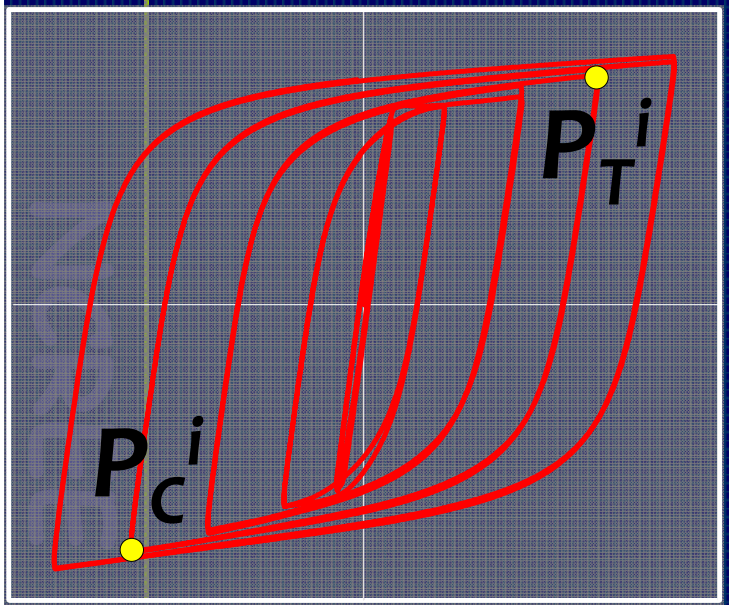
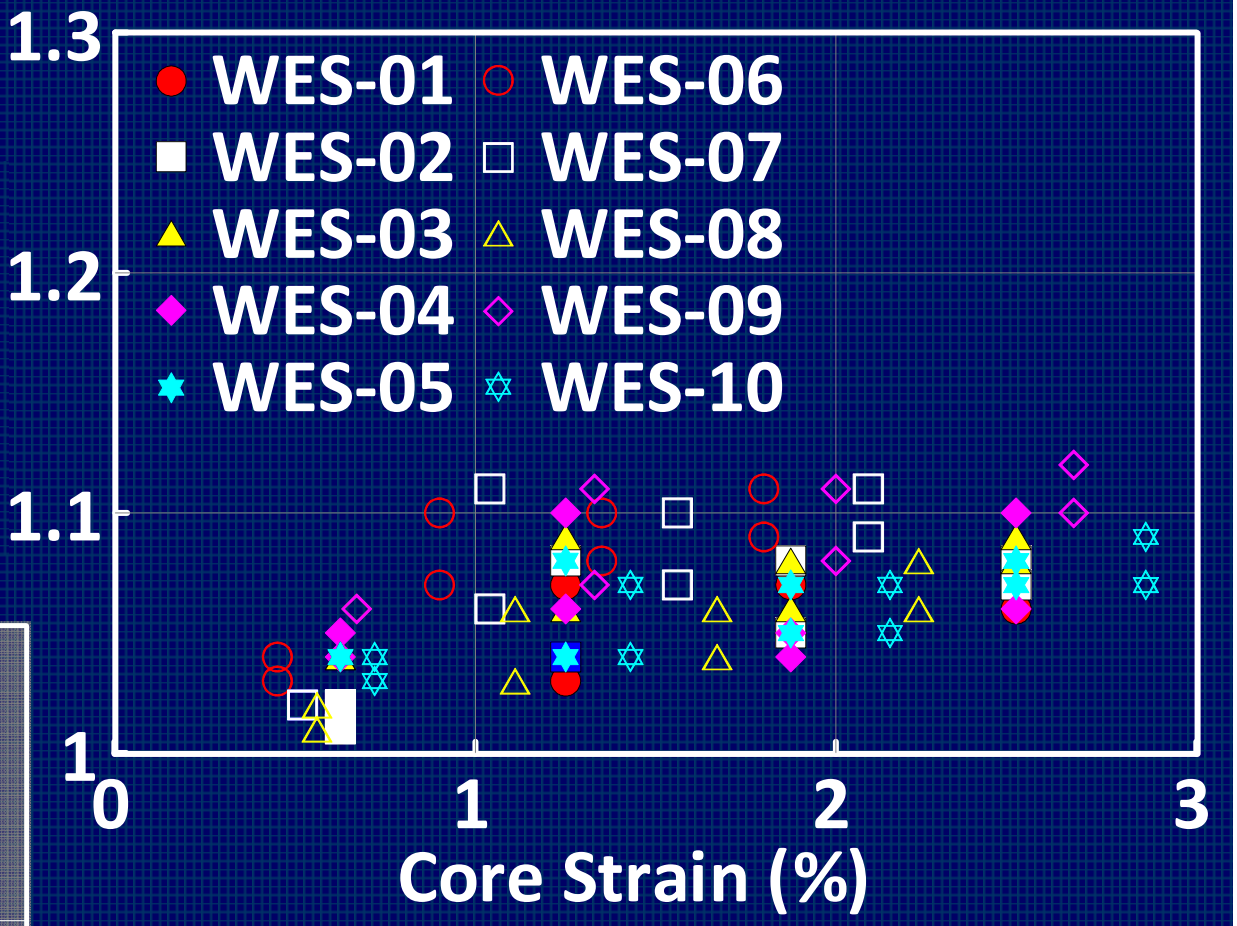
High quality of the ten WES-BRBs

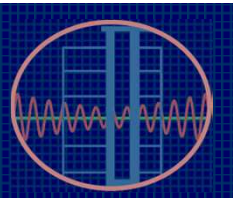
$$\beta_i = \frac{P_C^{\,i}}{P_T^{\,i}}$$





All the β values < 1.12

Conclusions



- Excellent performance of the WES-BRB is confirmed by full-scale component and frame tests.
- Seismic responses of WES-BRB members and frames can be satisfactorily predicated.
- Management of the WES-BRB license, quality control and design-aid is established by NCREE.

http://BOD.ncree.org.tw

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