Thursday, 24 May 2018

Optimised Sliding Hinge Joint for Moment Resisting Steel Frames

Presentation by:

Shahab Ramhormozian, UoA and AUT

QuakeCoRE steel-themed meeting

Scope of Talk

- Improvements in Moment Resisting Steel Frame (MRF) seismic performance
- Sliding Hinge Joint connection (SHJ)
- SHJ moment-rotational behaviour
- Asymmetric Friction Connection (AFC)
- SHJAFC dynamic tests (with/without BeSs, optimum bolt tension, surface roughness, etc.)
- Further research/tests and established findings
- Ongoing research

Improvements in steel MRFs

1994 Northridge & 1995 Kobe earthquakes

↓

Unexpected beam-to-column fracture

due to ductile overload of the bottom flange of beam to column welded connections

↓

1) Capacity designed MRFs (e.g. RBS)

Irrecoverable plastic deformation×

Low damage threshold×

Difficult to repair×

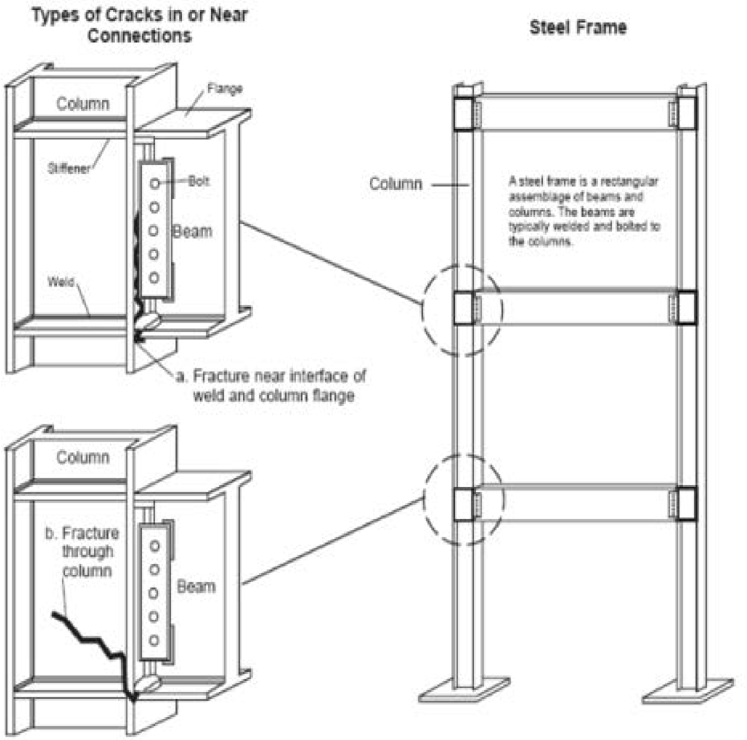
2) Low damage steel MRFs

Rotational slotted bolted connection

Post tensioned systems

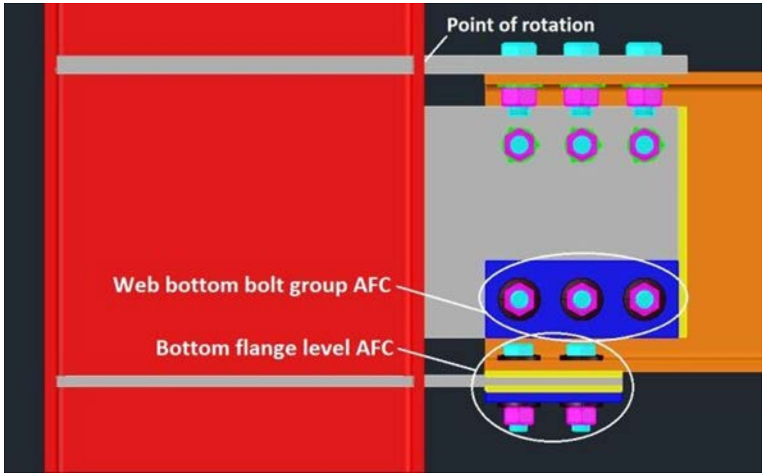
Shape memory alloy systems

Sliding hinge joint connection (SHJ)



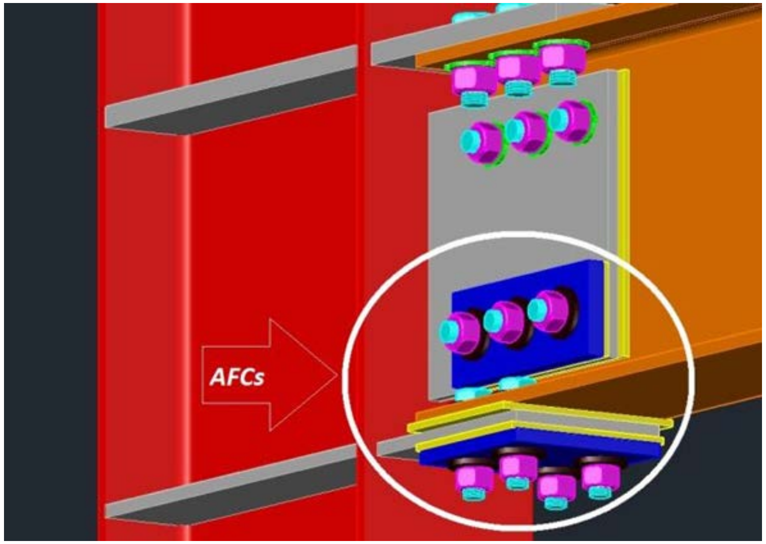
The Sliding Hinge Joint Connection (SHJ)

- Developed by Clifton at UoA (1998-2005);
- Further development at the UoA and UoC;
- Widely used in New Zealand;
- Rigid up to ULS and sliding under severe events with minimal damage through dissipating energy by the Asymmetric Friction Connections (AFCs).



Key benefits:

- Decoupling joint strength and stiffness.
- Isolating the floor slab.
- Confining yielding to the bolts. “Intended to be improved or ideally avoided”
- Pinched hysteresis behaviour. “intended to be improved for the self-centering”



- Current research to develop true low damage system

SHJ practical applications

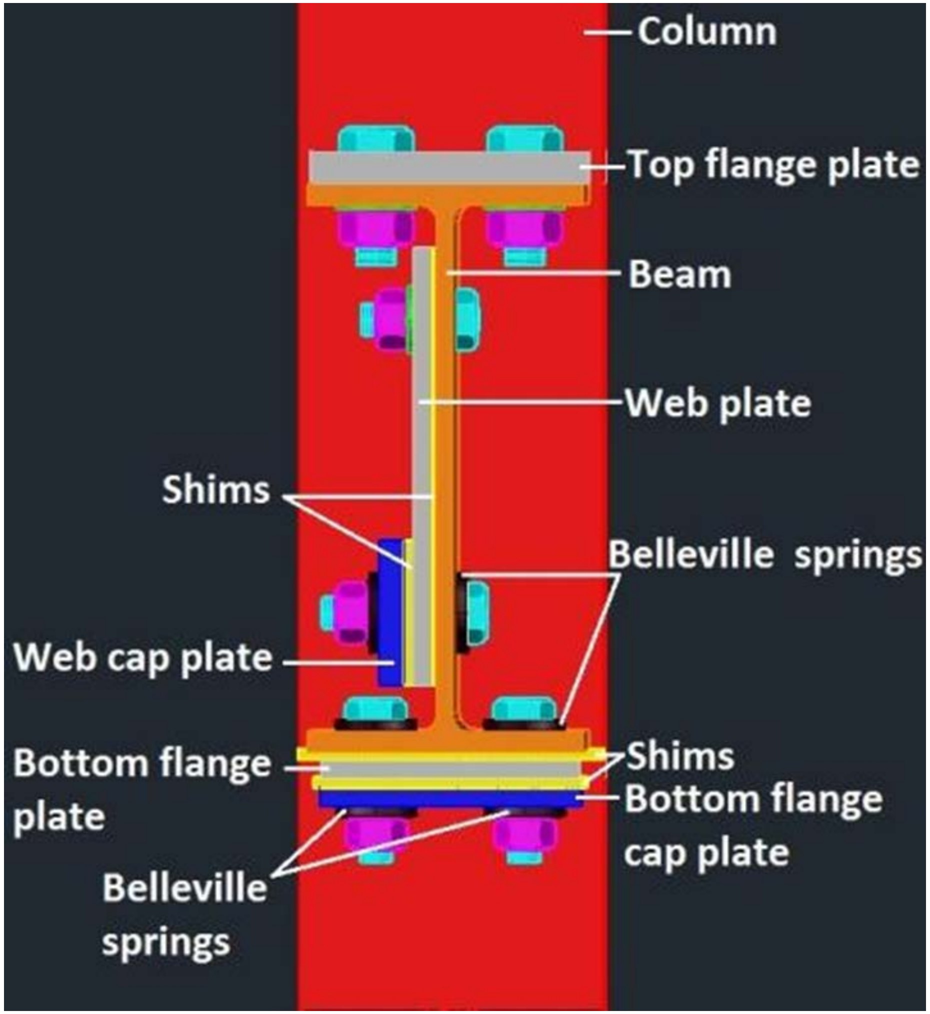
Has been through two earthquakes sufficient to generate sliding; no structural or non-structural damage

The Asymmetric Friction Connection (AFC) in the SHJ

- Located at the beam ***web bottom bolt*** and beam ***bottom flange*** levels.

- Consists of ***five components*** all ***clamped by the pre tensioned high strength bolts***.

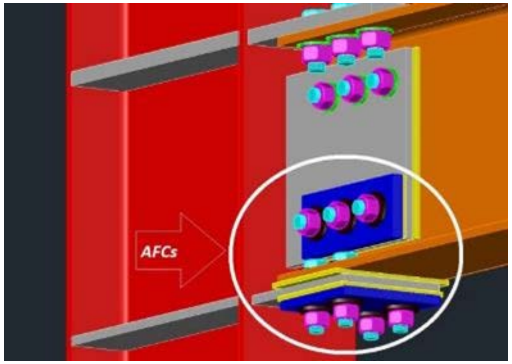
- The ***web top bolts*** carry the ***vertical shear***
- The ***beam top flange plate*** anchors the beam to the column as a "***pin***" connection



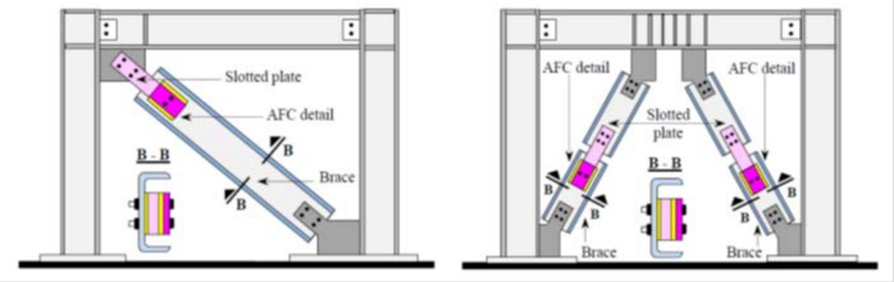
Asymmetric friction connection (AFC):

Applications, benefits, and concerns

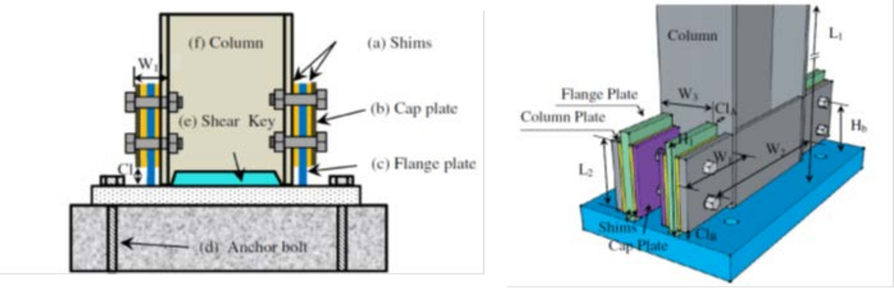
➢Being researched to be used in the shear wall base, column base, and brace,



Sliding Hinge Joint (SHJ) – Clifton (2005)



Chanchi Golondrino et al. (2014)



Borzouie et al. (2015)

➢Benefits:

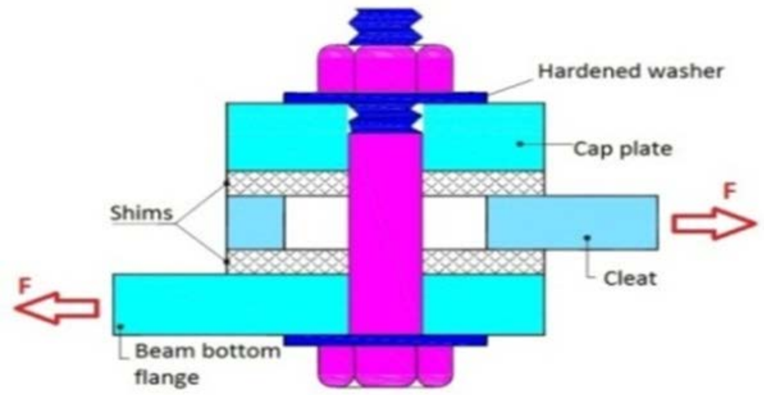
- ➢Simple to build
- ➢Cost effective
- ➢Capable to dissipate energy under the events greater than the ULS earthquake
- ➢Providing a repeatable pinched form hysteresis curve

➢Concerns:

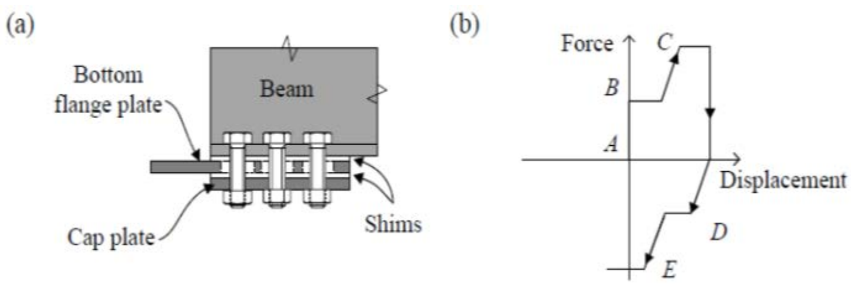
- ➢Post-sliding bolt tension loss, resulting in post-sliding elastic strength reduction
- ➢Post-earthquake bolt inspection to retighten and/or replace the bolts
- ➢Not able to statically self-centre
- ➢Probable change in performance over time other than in dry internal environments

AFC sliding behaviour

- Consists of five plies clamped by HSFG G8.8 fully tensioned "yielded" bolts
  - beam bottom flange,
  - Cleat "with elongated holes"
  - Cap plate "floating ply"
  - Two shims "high hardness steel"

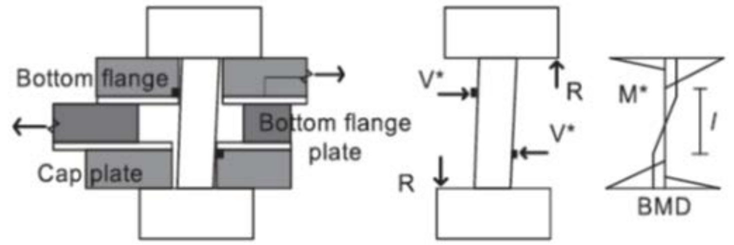


- Having two main sliding surfaces
  - cleat and the upper shim interface
  - cleat and the lower shim interface



- Floating cap, resulting in a pinched form hysteresis

- Pushing the bolts into the double curvature state during stable sliding
  - ***Bending moment-Shear force-Axial force*** interaction in the bolts



Using Belleville Springs to retain the post earthquake strength and provide better self-centering

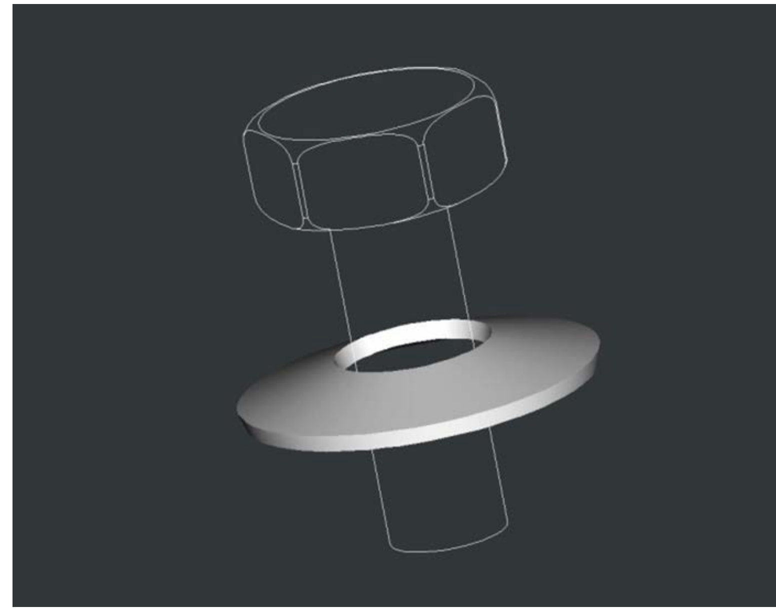
- Installing the bolts in the elastic range

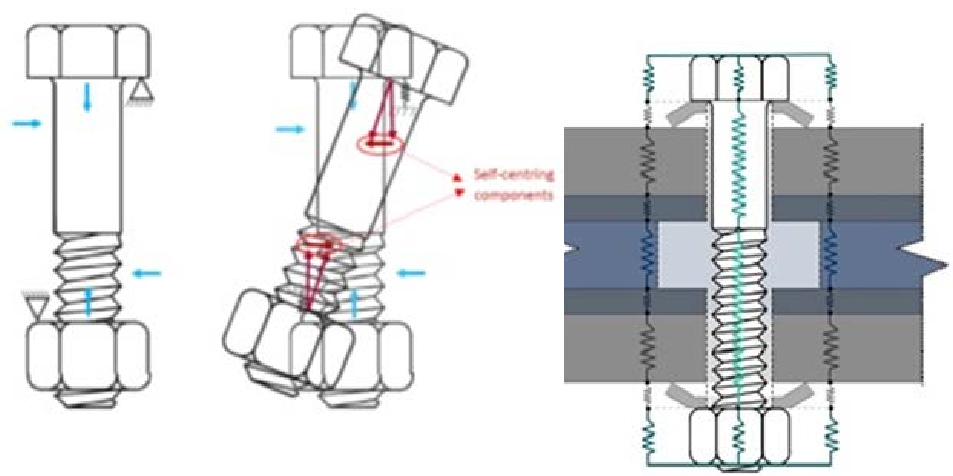
+

- Using partially squashed Belleville springs

=

  - *Improved self-centering*
  - *Retaining the clamping force following severe earthquakes*
  - *More stable sliding behaviour*
  - *Eliminating damaging prying effects*
  - *Higher CoF*
  - *Less surface degradation*

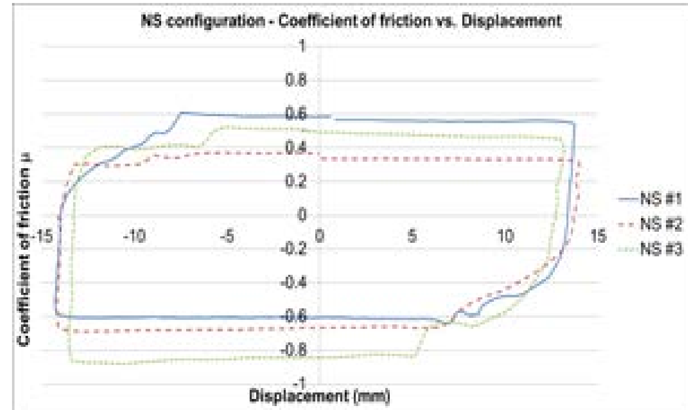


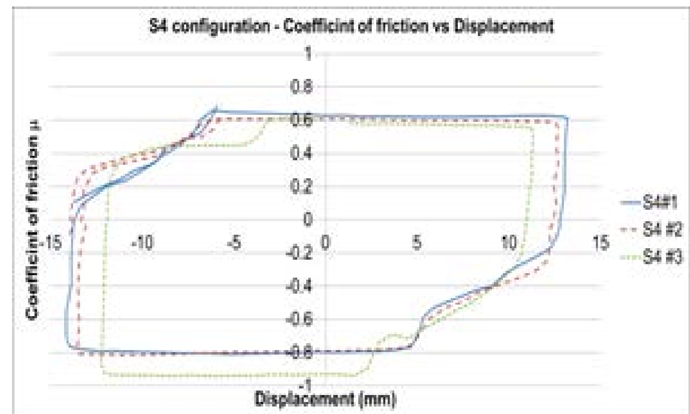


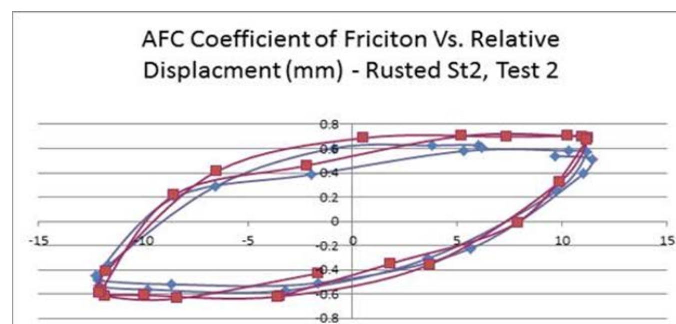
SHJAFC with BeSs dynamic tests results

Introducing Belleville springs can:

- Significantly **reduce the bolt tension loss** after sliding has occurred
- Provide **more stable behaviour** for the AFC and the bolt group
- Increase the **post-earthquake connection slip force**
- Increase the coefficient of friction and the joint sliding shear capacity
- Improve the **joint self centring capability**
- **Eliminate the prying effects** if BeSs are partially compressed







Further research and established findings

- Developing a methodology to tighten the HSFG bolts with BeSs in the bolt's elastic range using an AFC bolt tightening test setup. This removes the concerns about the delivered installed clamping force in the friction sliders.

- The AFC component experimental tests on the MTS machine to establish the *optimum level of installed bolt tension*.

- Establishing the optimum surface preparation/roughness level for the AFC plies sliding surfaces using an AFC test rig on the MTS machine. This also removes the CoF variability concerns about the friction sliders.

Further research and established findings

- Experimentally investigating the following AFC configurations:
  - *A shim-less AFC*
  - *AFC with TiN coated shims*
  - *AFC with abrasion resistant cleat and shims*

- Investigating the method of bolt tightening recommended by NZS3404:
  - *Proposing required changes on current Australia/NZ standards recommended method of bolt tightening.*

- Developing a dynamic *SDOF SHJ model* to investigate the effect of dynamic loading frequency, mass, and wind down on the *static* and *dynamic self-centering capability* at component level.

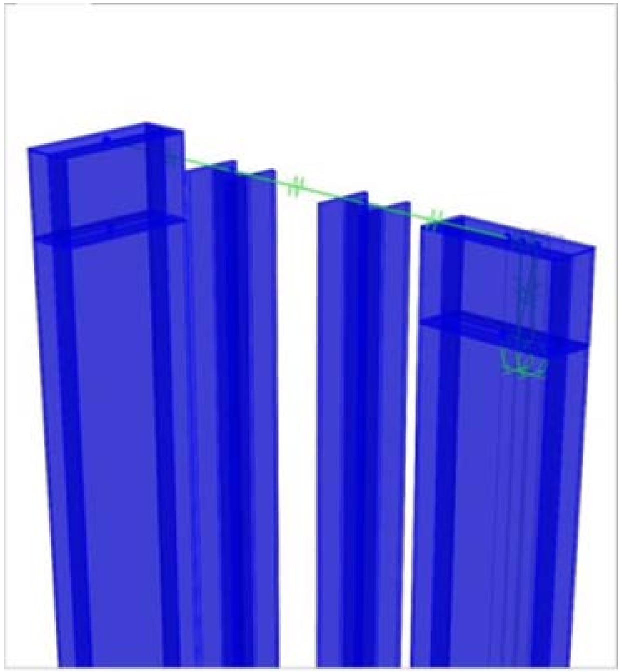
Ongoing research

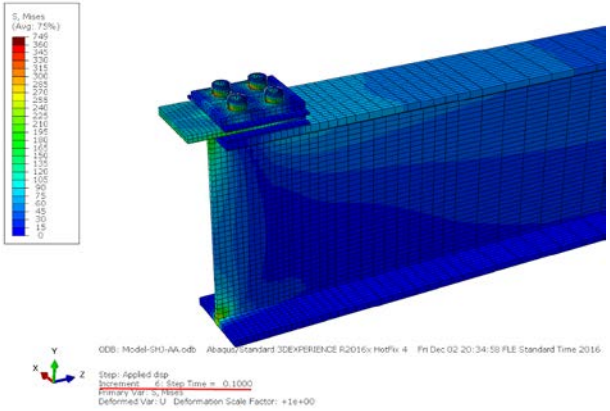
- Developing a MDOF model of the SHJ to research the SHJ dynamic self-centring capability numerically considering the parameters such as column base rotational stiffness, column continuity, type of the friction damper, the additional linear elastic spring between the column and beam, and stepping column base.

- FEM of the SHJ using ABAQUS investigating the influence of:
    - Levels of bolt tension
    - SHJ beam-column gap
    - Presence of BeSs
    - Number of bolt rows
    - Prying effects
    - Ply thickness reduction

- Developing an AFC bolt model and a practical design guide to design the SHJAFC.

- Pre and post earthquake system identification of the Te Puni Village SHJ building using SHM data.





Acknowledgements

- *New Zealand Earthquake Commission (EQC),*
- *New Zealand Center for earthquake resilience (QuakeCoRE),*
- *New Zealand Society for Earthquake Engineering (NZSEE),*
- *The UoA department of Civil and Environmental Engineering,*
- *Steel Construction New Zealand (SCNZ),*
- *All colleagues and friends around the world who kindly helped us*

Many thanks!

Question?