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QuakeCoRE low-damage workshop: State-of-art research, guidelines and standards on the SHJ (steel)

QuakeCoRE low-damage workshop 2017
Presentation by Charles Clifton

The University of Auckland

UC University of Canterbury · The University of Auckland New Zealand · Resilient Organisations · GNS Science Te Pū Ao · Massey University · Te Whare Wānanga o te Ūpoko o te Ika a Māui Victoria University of Wellington · The University of Waikato Te Whare Wānanga o Waikato · BRANZ

Scope of Presentation

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- Sliding Hinge Joint connection (SHJ) and its seismic behaviour.
- Asymmetric Friction Connection (AFC).
- Recent developments in the AFSHJ.
- Further established findings and ongoing research.

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The Sliding Hinge Joint Connection (SHJ)

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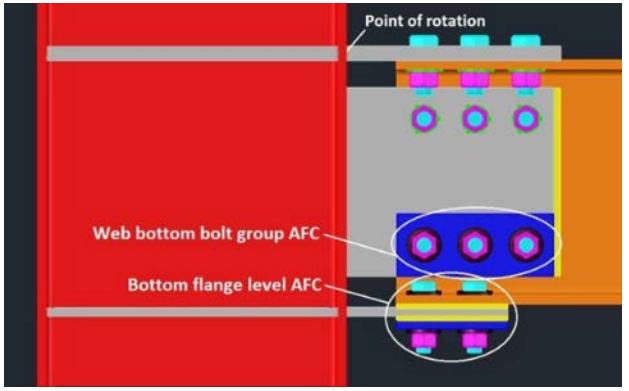
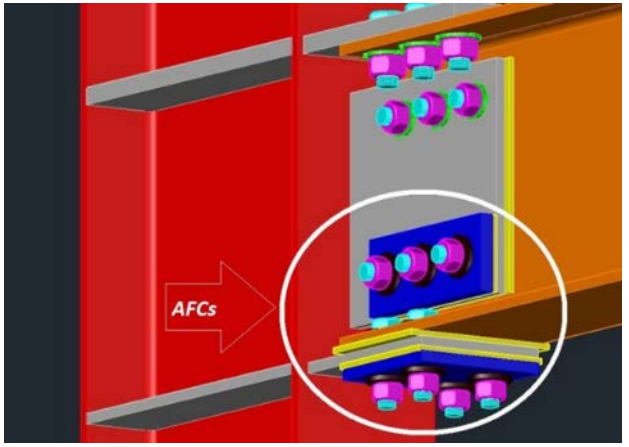
- Developed by Clifton at UoA (1998-2005);
- Further development at the UoA and UoC;
- Widely used in New Zealand;
- Rigid under ULS and sliding under severe events with minimal damage through dissipating energy by the Asymmetric Friction Connections (AFCs).



- **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*"



- Current research to develop true low damage system

The Asymmetric Friction Connection

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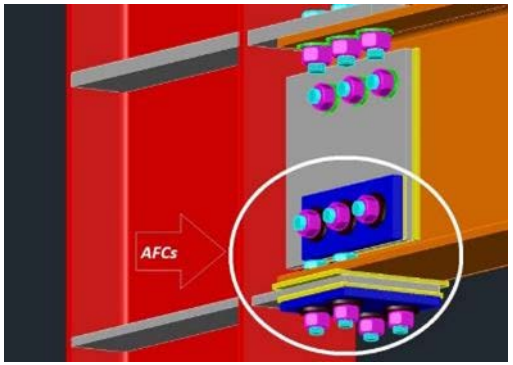
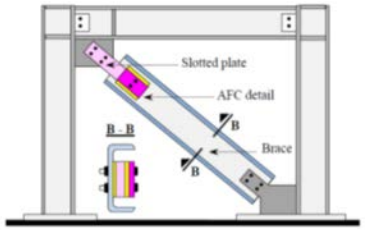
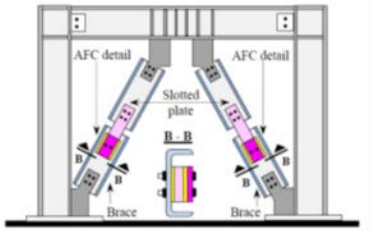
- Rigid in service, slides during severe earthquake, ideally becomes rigid again afterwards.

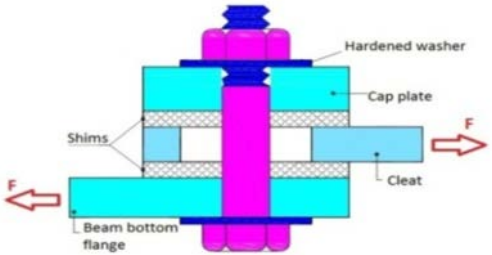
- Located at the beam web bottom bolt and beam bottom flange levels of the SHJ.
- Consists of five components all clamped by the pre tensioned high strength bolts.
- Can be used in the rocking shear wall base, column base, and brace.

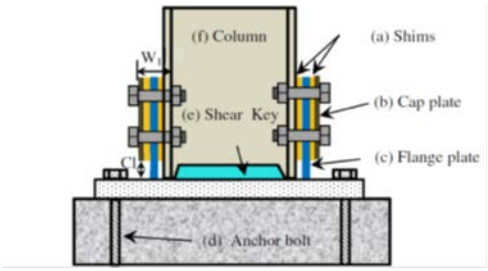
- Floating cap, pushing the bolts into the double curvature, and resulting in a pinched form hysteresis loop.

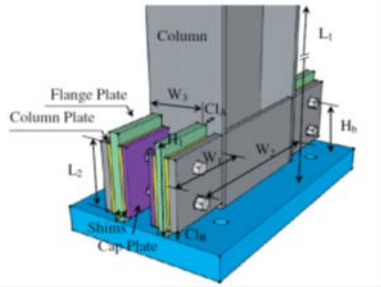












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Using Belleville Springs to retain the post earthquake strength and provide better self-centering

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- Installing the bolts in the elastic range

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- Using partially squashed Belleville springs

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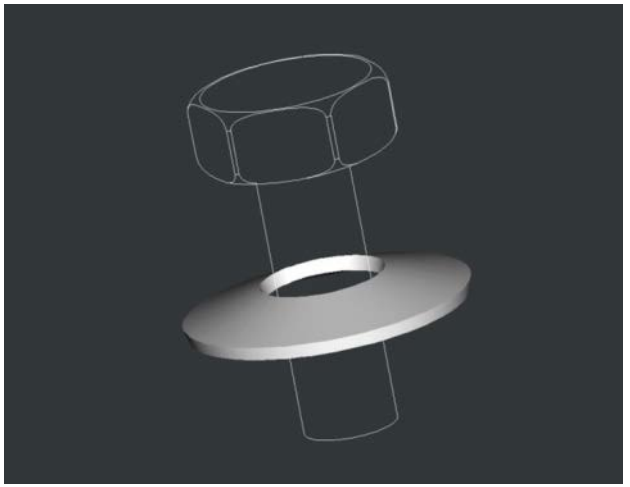
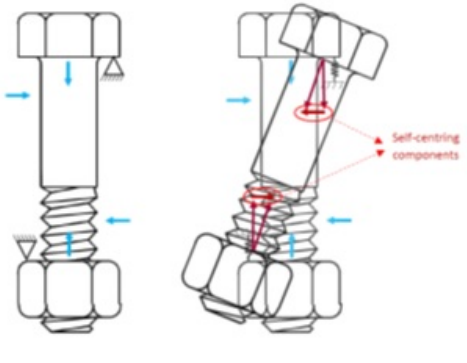
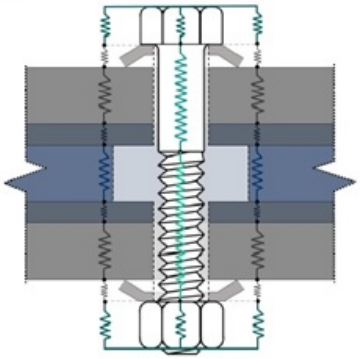
  - *Improved self-centering*
  - *Retaining the clamping force following severe earthquakes*
  - *More stable sliding behaviour*
  - *Eliminating damaging prying effects*
  - *Higher frictional resistance*
  - *Less surface degradation*







Recent Undertaken research

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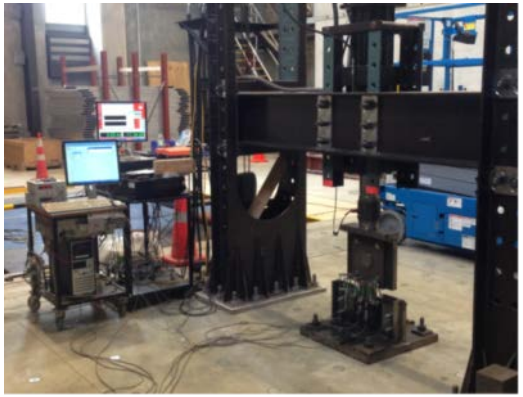
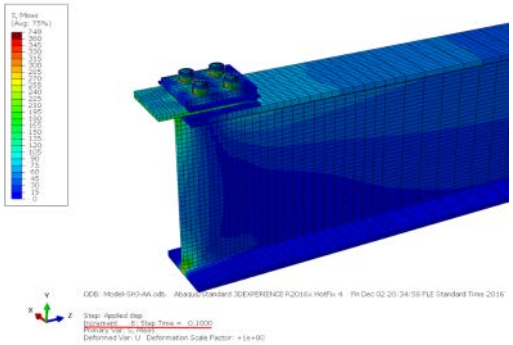
- **Analytical:** based on first principles;

- **Experimental:** using customized high precision tools to reach the highest level of accuracy and completeness in the experiments;
  - *More than 50 AFSHJ real scale component level dynamic tests with and without Belleville springs on two AFSHJ test setups*
  - *More than 200 bolt tightening and direct tensioning tests with and without Belleville springs.*

  - **Numerical:** using ABAQUS and SAP2000 software





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Established findings (to be published in Journals in 2017/18):

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- Developing a practical turn-of-nut-based 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.

- Establishing the optimum surface preparation/roughness level for the AFC plies sliding surfaces. This also removes the CoF variability concerns about the friction sliders.

- Establishing the optimum use of the Belleville springs. This removes the concerns about the post-earthquake elastic strength loss, damaging prying effects, and the variations of the bolt tensions during sliding.

- Establishing the optimum level of installed bolt tension in the AFSHJ. This is presented at the NZSEE2017 conference.

- Proposing required changes on the previous recommended method of bolt tightening. This removes the concerns about the reliability of the HSFG bolts delivered installed tension. These provisions are already in AS/NZS1252 and AS/NZS5131 and will be in NZS3404 next revision.

- 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. This is presented at the NZSEE2017 conference.

- Experimentally investigating the shim-less AFC, AFC with TiN coated shims, and AFC with abrasion resistant cleat and shims.

Ongoing research

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- FEM modelling of the SHJ AFC with and without BeSs to numerically investigate the effect of BeSs, optimum bolt tension, effect of number of bolt rows, effect of prying actions, effect of plies thickness reduction.

- Developing the AFC bolt model to design the AFC.
  - This is based on the first principals, will explain in details the behaviour of the AFC, and gives the modified design procedure.

- Developing a simplified but accurate MDOF building model of the SHJ to research the SHJ dynamic self-centring capability using SAP2000 considering the several parameters such as column base rotational stiffness, type of the friction damper, the additional linear elastic spring between the column and beam, and stepping column base.

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

Thank you and Questions