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Pioneering Futures Since 1898

Bolted and hybrid beam-column joints between I-shaped FRP profiles

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OUTLINE

- Background
- Test arrangement
- Test results
- Failure modes
- Conclusions

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Background

FRP profiles

FRP rebars

FRP strengthening

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Background

Dawlish bridge Davon UK

All composite FRP footbridge spanning a coastal railway line

Old rusty steel bridge reconstructed in 1937

New All-FRP bridge 2011 – **no corrosion**

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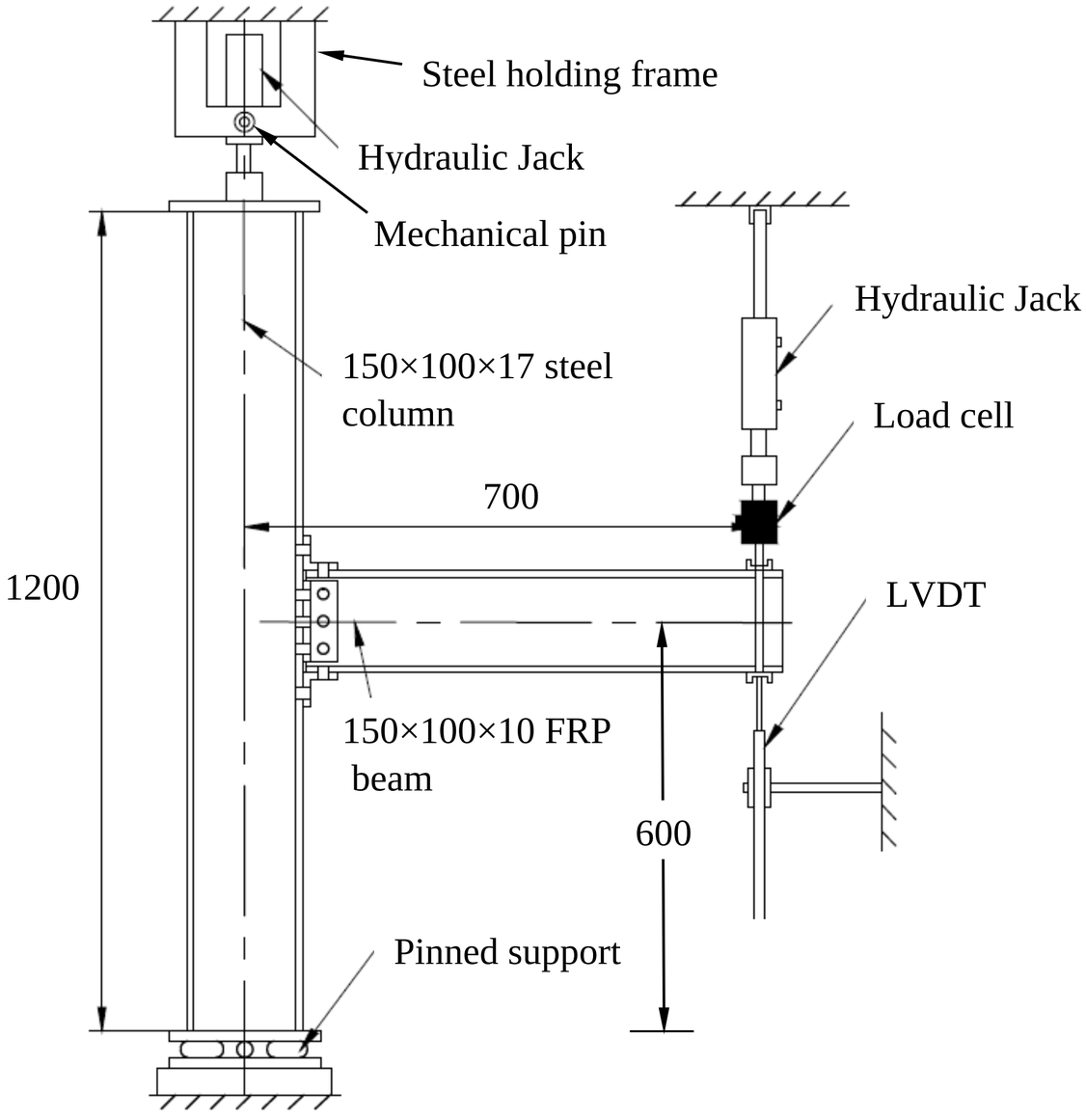
Test arrangement



Schematic diagram – single cantilever test set up

Photograph of beam-column sub-assembly

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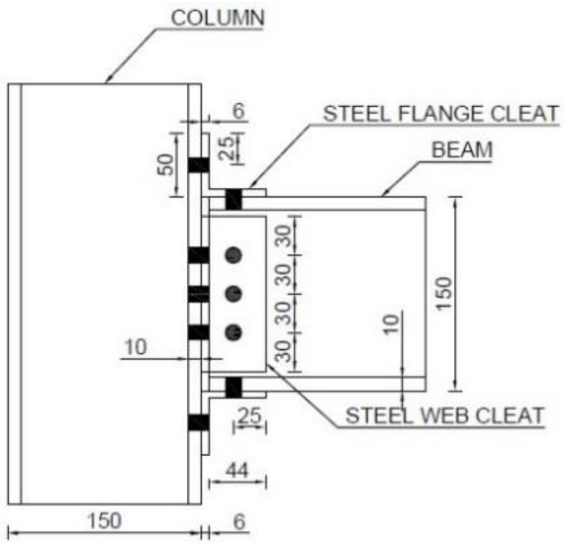
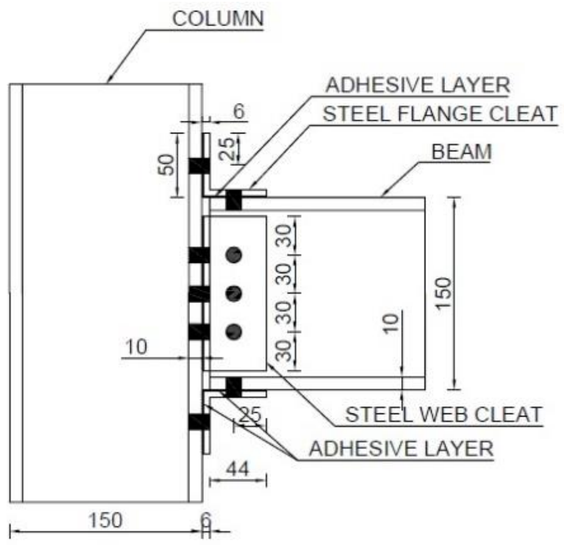
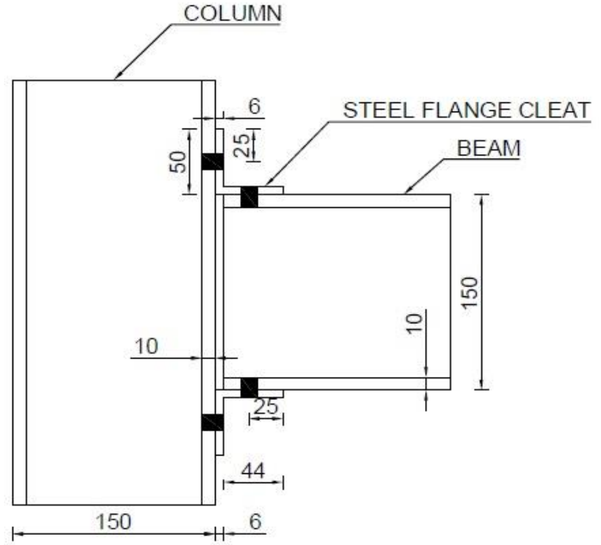
Test arrangement – joint detailing



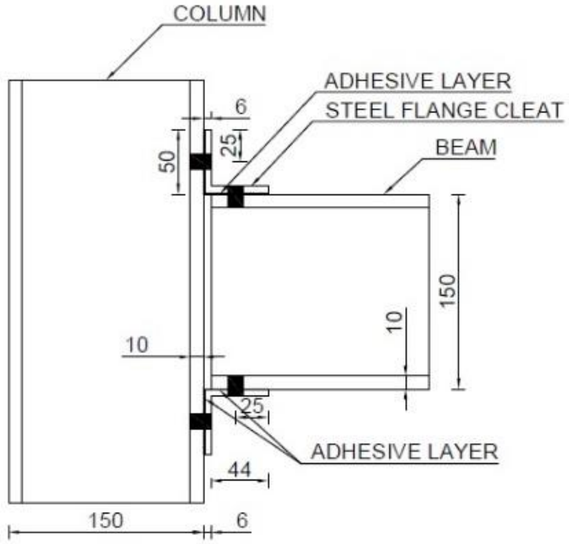
1. SFSc2: Bolted steel cleats



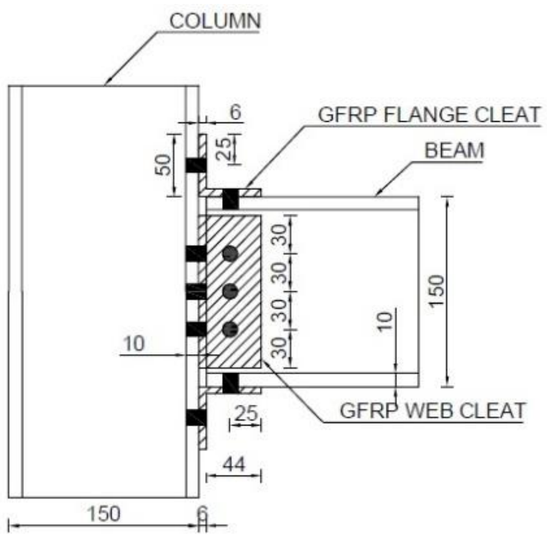
2. SFSc2A: Hybrid steel cleats



3. SFStc2: Bolted steel flange cleats



4. SFStc2A: Hybrid steel flange cleats



5. SFFc2: Bolted FRP cleats

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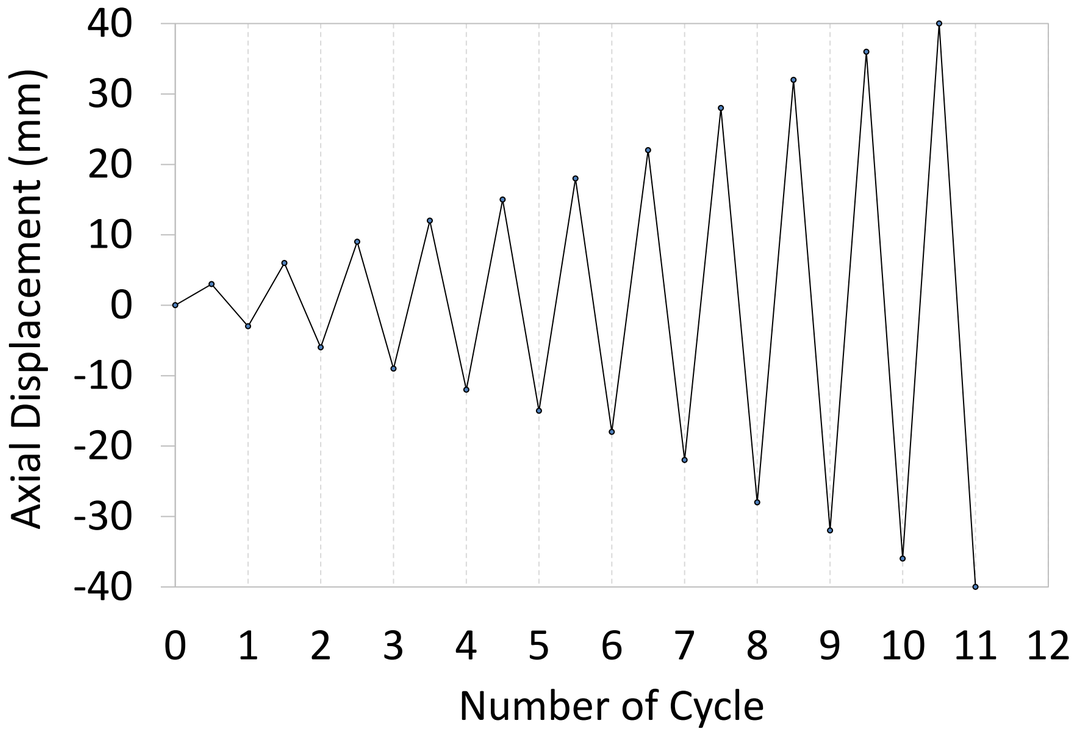
Test arrangement – Loading protocol

Cyclic loading history



Reviewed loading protocols (Filiatrault *et al*. 2018)

- ATC-24 and SAC for steel structures
- ISO and CUREE for wooden structures
- FEMA-461 and FM-1950 for non-structural elements

SAC loading protocol is used

SAC protocol (SAC 1997)

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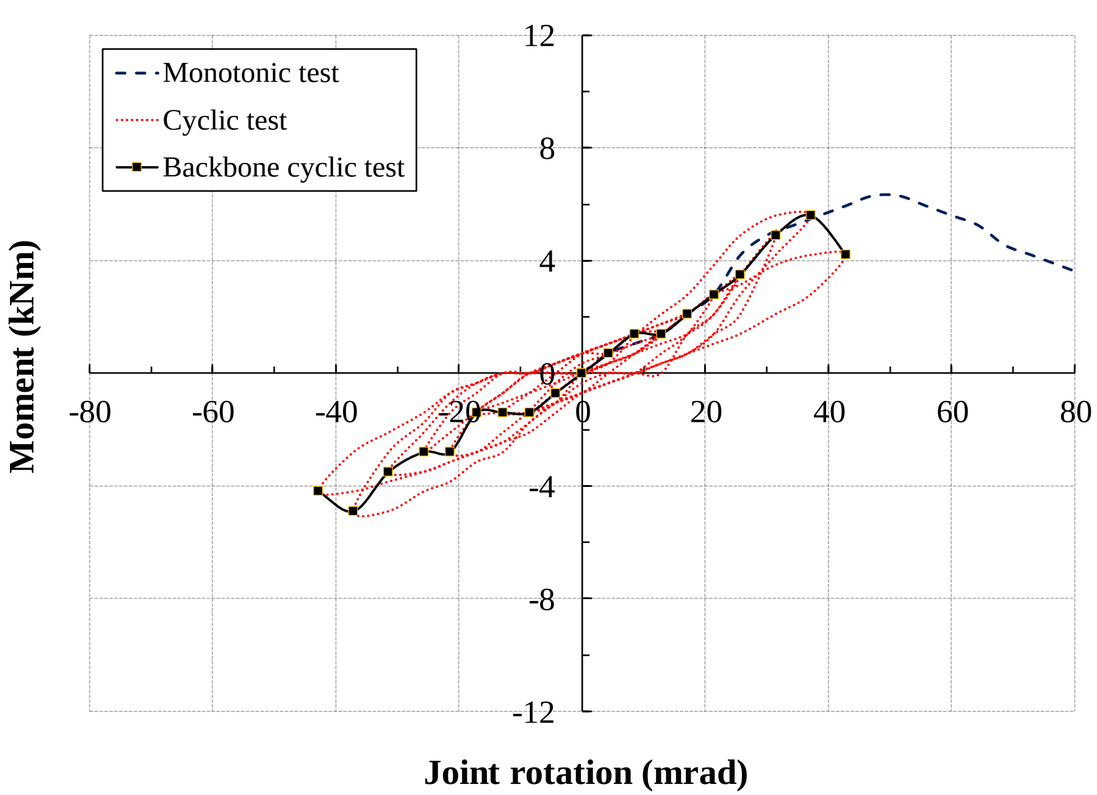
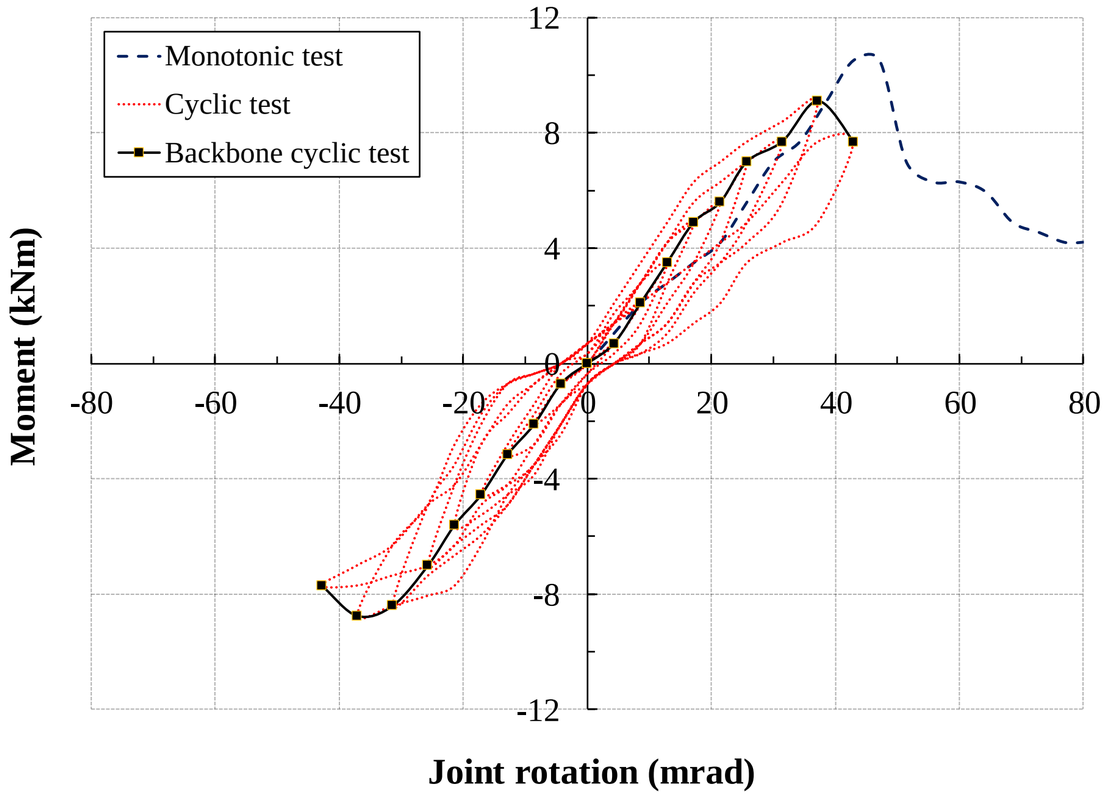
Test results

Joints with steel web and flange cleats



1. SFSc2: Bolted joint with steel web and flange cleats



2. SFSc2A: Hybrid joint with steel web and flange cleats

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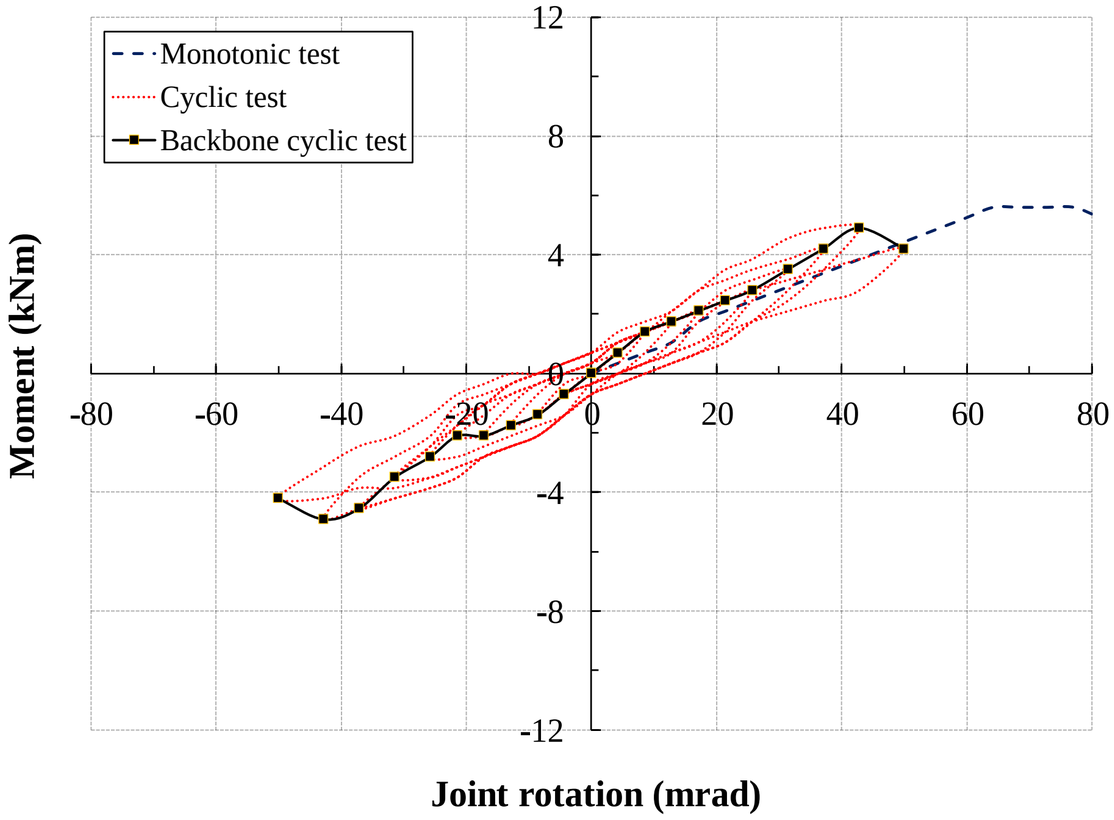
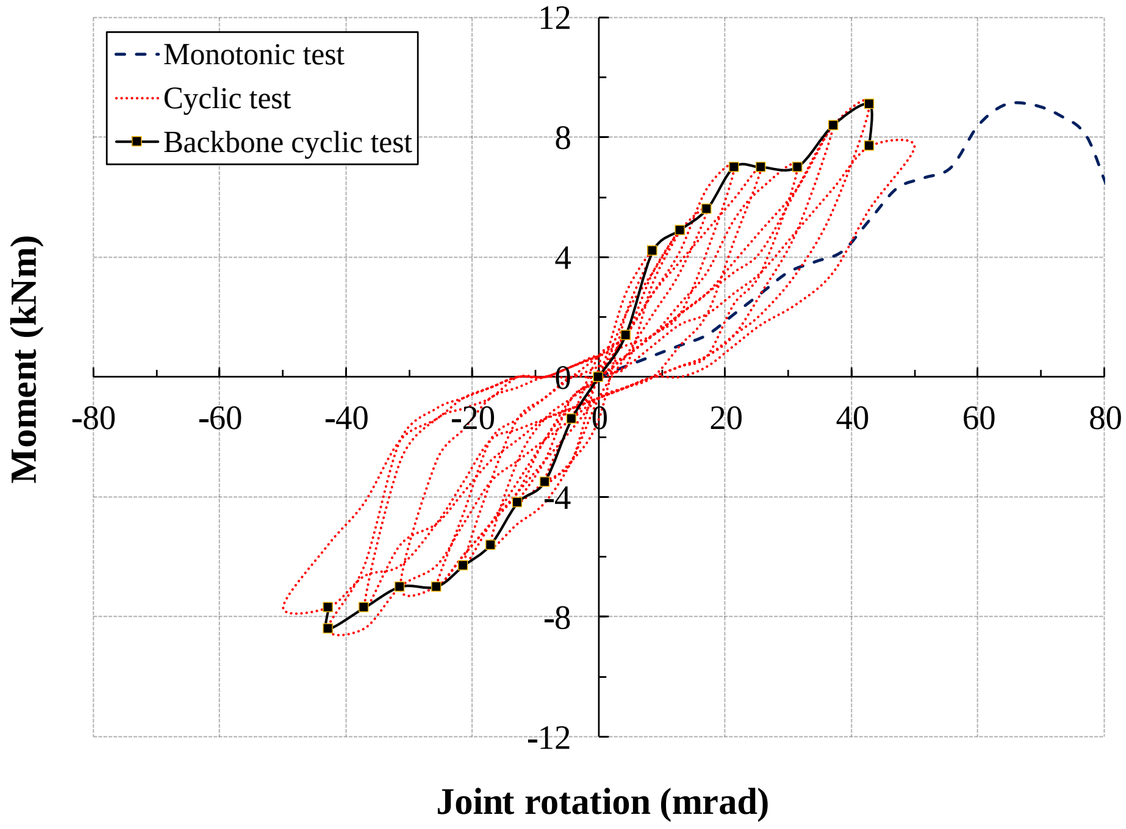
Monotonic test results are from a paper by the authors https://doi.org/10.1016/j.compstruct.2020.112500.

Test results

Joints with steel flange cleats only



3. SFStc2: Bolted joint with steel flange cleats only



4. SFStc2A: Hybrid joint with steel flange cleats only

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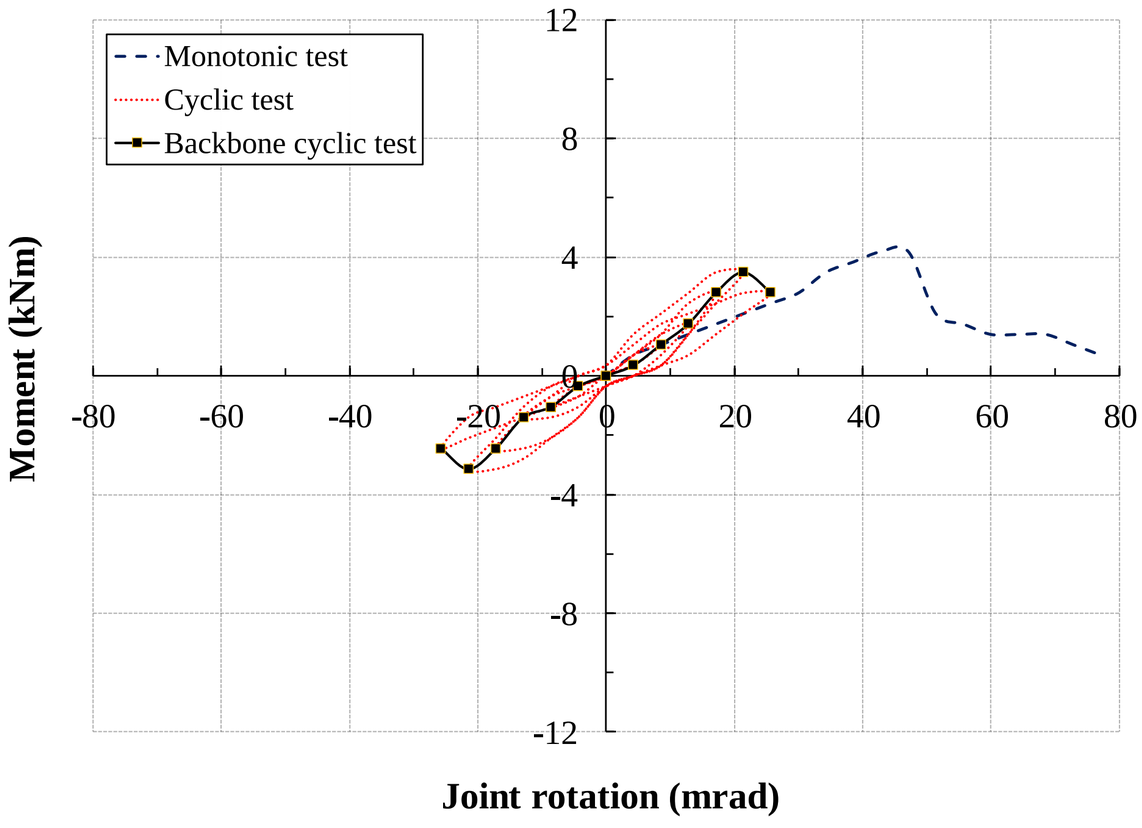
Test results

Joint with FRP web and flange cleats



5. SFFc2: Bolted joint with FRP web and flange cleats

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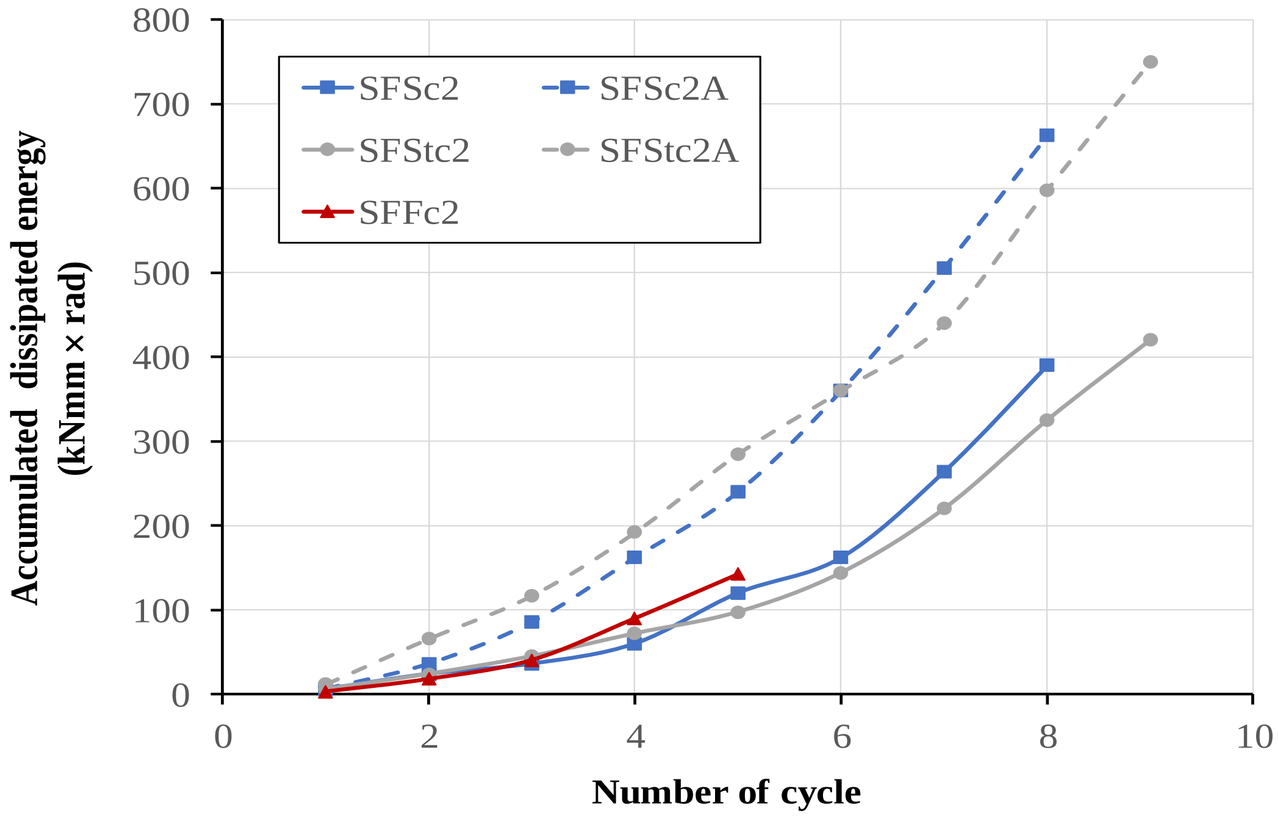
Test results

Cyclic performance



Accumulated dissipated energy of each joint against number of cycles

- Dissipated energy of hybrid joints is 75% higher than bolted joints
- Dissipated energy FRP joints is half of steel joints
- Energy performance of web and flange cleated and flange cleated only joints is similar

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Failure modes

Shear-out failure at beam’s bolted zone

1. SFSc2: Bolted joint with steel web and flange cleats

3. SFStc2: Bolted joint with steel flange cleats only

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Failure modes

Adhesive debonding with shear-out failure

2. SFSc2A: Hybrid joint with steel web and flange cleats

4. SFStc2A: Hybrid joint with steel flange cleats only

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Failure modes

Delamination cracking

5. SFFc2: Bolted joint with FRP web and flange cleats

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Conclusions

- Three failure modes: shear-out, debonding and delamination
- Hybrid joints showed twice as much stiffness as bolted joints
- Dissipated energy of hybrid joints is 75% higher than bolted joints
- Dissipated energy of FRP joints is about half of steel joints
- Adding web cleat to a flange cleated joint offers no benefit
- Bonding delays initiation of damage in FRP cleats and members

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Ongoing work

PFC-RHS and RHS-RHS beam-to-column joints

Courtesy of Access Design and Engineering UK

Cooling Tower system (Courtesy of Creative Composites USA)

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References

Qureshi J, Nadir Y, John SK. 2020. Bolted and bonded FRP beam-column joints with semi-rigid end conditions. Compos Struct. 247:112500.

SAC. 1997. Protocol for Fabrication, Inspection, Testing and Documentation of Beam- column Connections and Other Experimental Specimens. Report No. SAC/BD-97/ 02, SAC Joint Venture Sacramento, CA.

Filiatrault A, Perrone D, Brunesi E, Beiter C, Piccinin R. 2018. Effect of cyclic loading protocols on the experimental seismic performance evaluation of suspended piping restraint installations. Int J Press Vessel Pip. 166:61–71.

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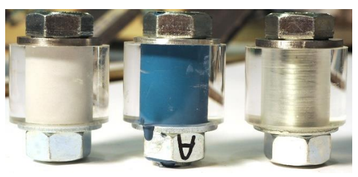
Thanks for listening…..Questions?

A recent review paper:

Qureshi J. 2022. A Review of Fibre Reinforced Polymer Structures. Fibers. 10(3):27.



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