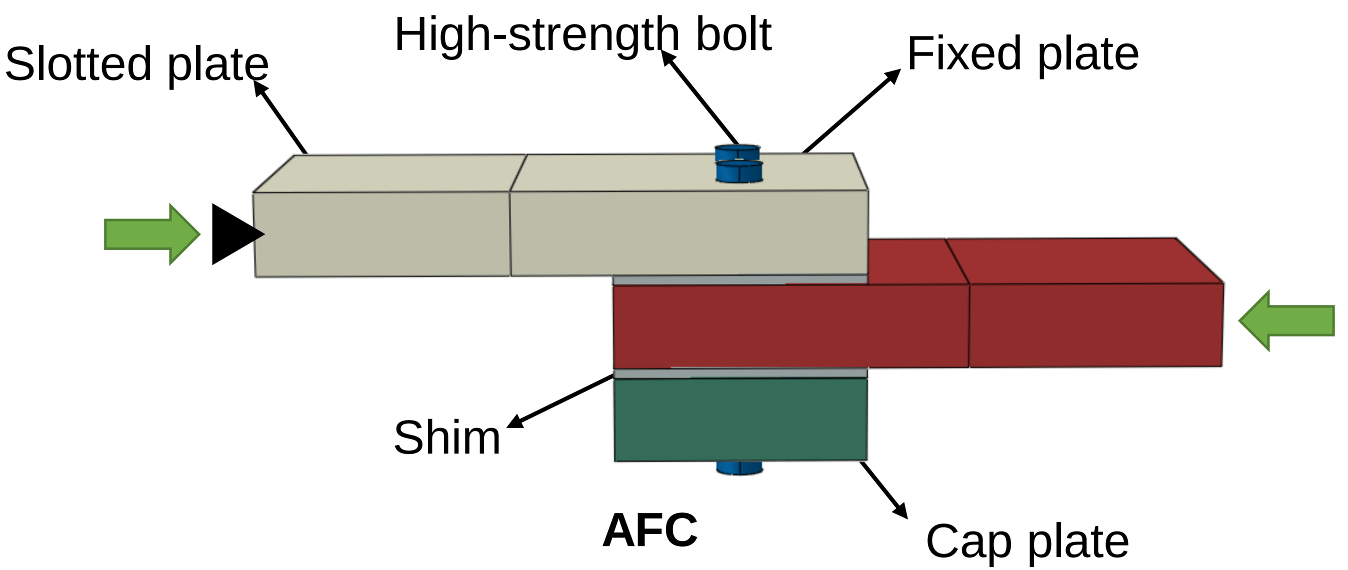
LARGE FRICTION CONNECTIONS PERFORMANCE & REPARABILITY

Why Friction connections?

- Cheap construction cost
- Low damage performance
- Perceived reparability



Issues:

Remained gaps include the lack of:

- Large scale tests on friction connections with big bolt size/different bolt configurations
- Bolt tightening and bolt relaxation effects on the variation in the sliding strengths
- Testing bolts with different lubrication degrees/torque effects
- Different methods of repairing after a major event
- Differences between AFC and SFC

Objectives:

- Determining the effects of **big bolt size** and number of bolt rows in the performance of friction connections.
- Defining a range of required **turn angle** for tightening the bolts.
- Defining acceptable **lubrication** for the large bolts.
- Determining how a connection may be **reinstated** after an event.
- Seeking a unified theory for friction coefficients for **AFC and SFC** bolts.

This project

Experimentally investigates the below items of large friction connections:

- The performance,
- Post-test performance,
- Reparability

And

Numerically investigate:

Explicit behaviour of different parts, deformation, plasticity.

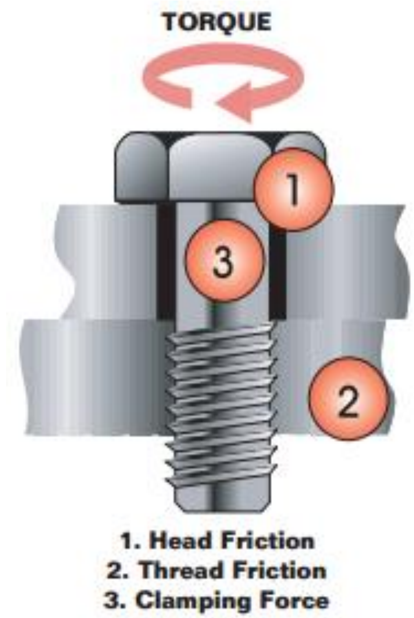
Experimental tests methodology:

1. Tightening tests
2. Sliding test
3. Testing the examined specimens
   (Retesting cooled and damaged specimens)
4. Reparability tests

1. Tightening tests

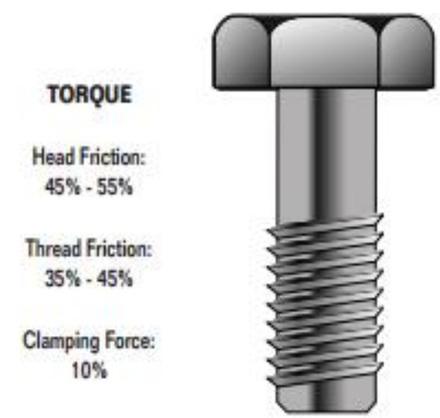
Where does the torque go?

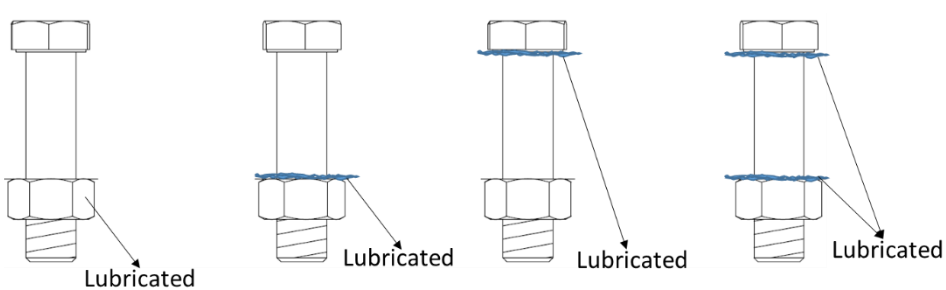
- The torque applied to a bolt is absorbed in three main areas.
- An **increase** in either friction component of **5%** can **reduce** tension **by half**.



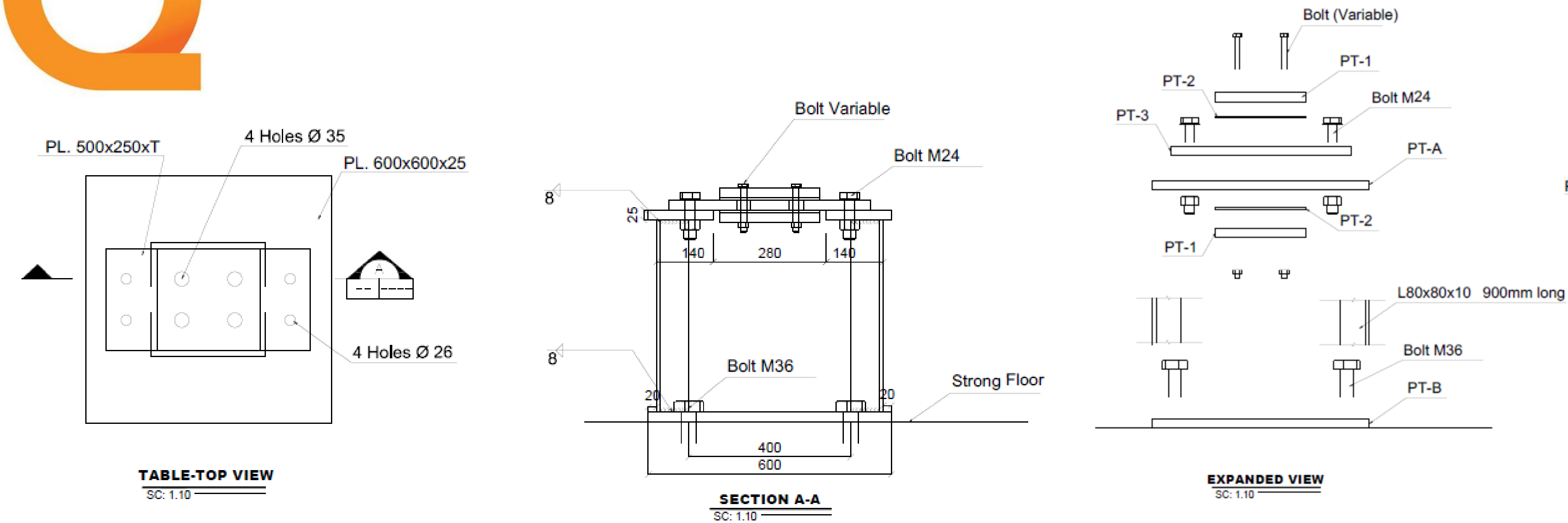
Different lubrication degrees and material effects on tightening

Lubrication degrees	Surface treatment		
	Brushed steel		
	Lubrication material		
	Oil	Grease	Molybdenum
Thread-Nut lubricated	3	3	3
Nut Lubricated	3	3	3
Bolt under head lubricated	3	3	3
Full lubricated	3	3	3





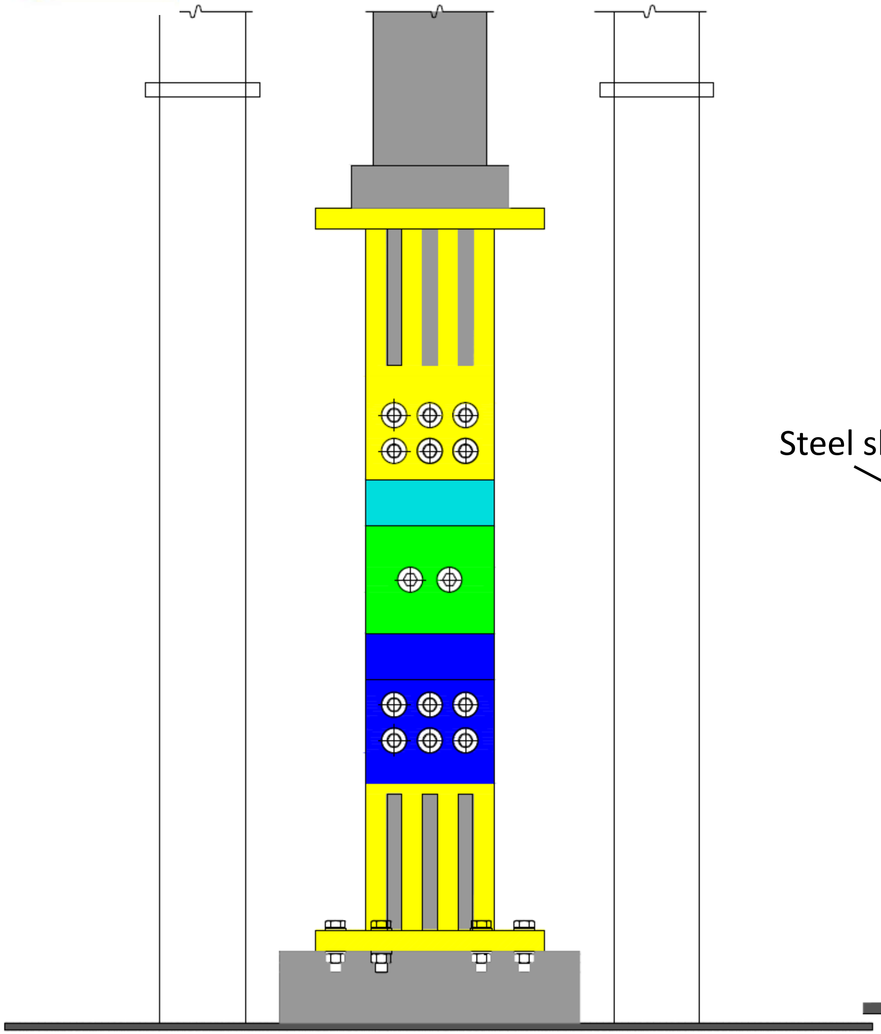
1. Tightening tests



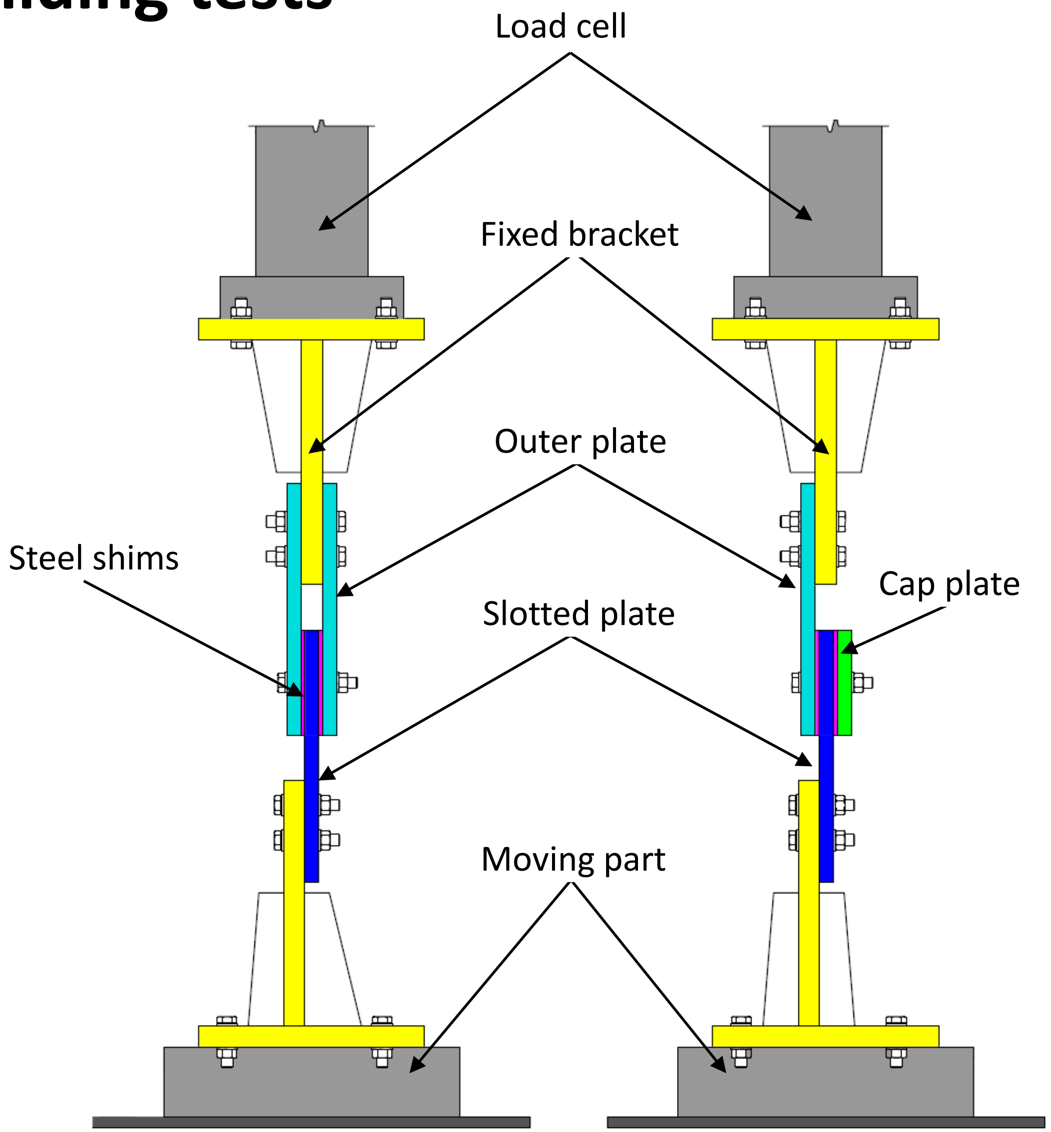
Tests on the bolt size and length effect on tightening

Bolt length mm	Proof load			
	Bolt size			
	M16	M20	M24	M30
85	3	3	3	3
95	3	3	3	3
110	3	3	3	3
125	3	3	3	3
150	3	3	3	3
250	3	3	3	3

2.Sliding tests

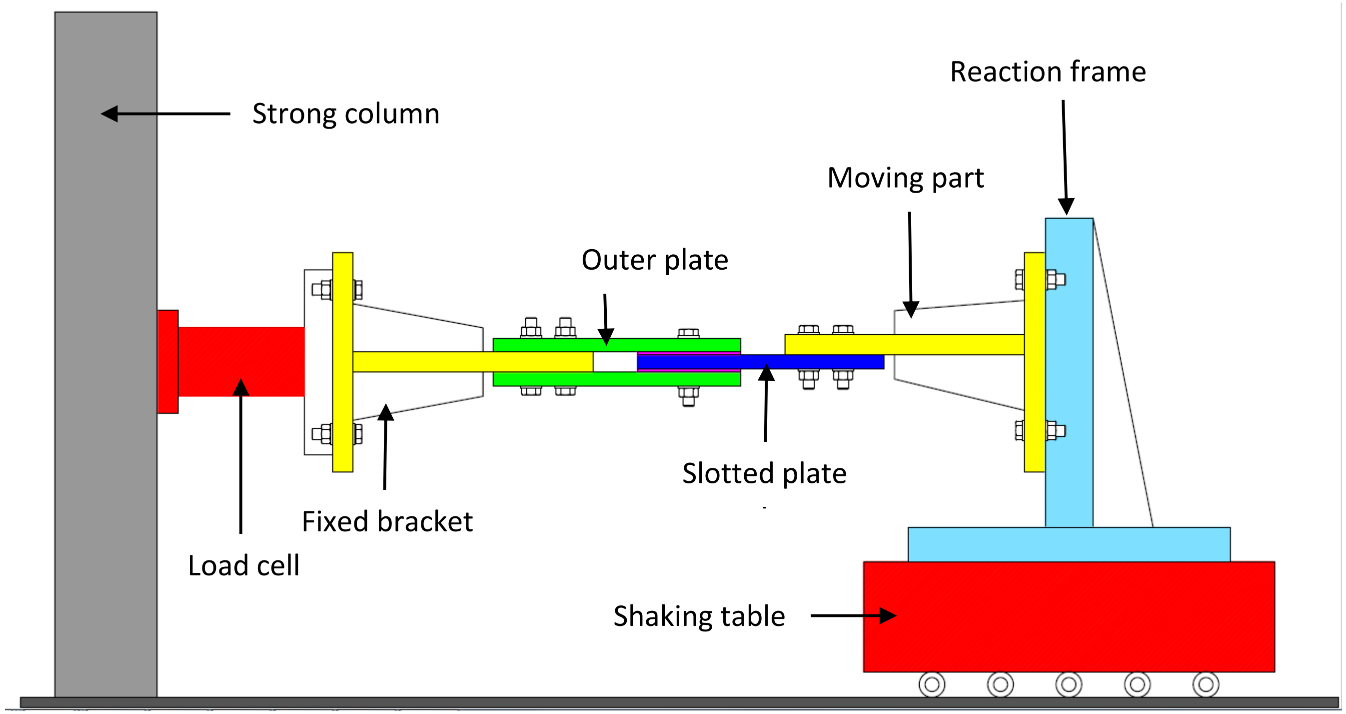


The AFC specimen on DARTEC machine



2.Sliding tests

Tests on high rate loading effect on friction connections



High rate loading test setup on shaking table

2.Sliding tests

Tests on the lubrication and surface treatments effect on friction connections

Lubrication level	Symmetric					Asymmetric
	Surface treatment					Surface treatment
	Mild steel	Flame cleaned	Wire brushed	Sand blasted	Shot blasted	Wire brushed
Dry	-	-	3	-	-	3
Thread-Nut lubricated	3	3	3	3	3	3
Full lubricated	-	-	3	-	-	3

2.Sliding tests

The performance of friction connections considering different clamping forces

Tightening level	Symmetric				
	Surface treatment				
	Mild steel	Flame cleaned	Wire brushed	Sand blasted	Shot blasted
Snug tighten	-	-	3	-	-
0.5 required turn	3	-	3	-	-
Turn to proof load	BM	BM	BM	BM	BM
1.5 required turn			3		

Tests on the bolt configurations effect on friction connections AFC&SFC

Surface treatment	Bolt Size			
	M16	M20	M24	M30
Brushed surface	3	3	Benchmark	3

Numerical study

Detailed finite element models have been developed to obtain accurate and efficient methods for modeling the friction connections in general.

Model development considering:

1) Contact interaction between different surfaces

2) Bolts interaction with plates during sliding

3) Bolt load variability and dependency

4) Dynamic friction coefficient during sliding

Some analyses will be conducted to predict the behavior of the specimens during the experiment based on an existing test results.

Later, the finite element results will be calibrated by the experimental results of this research in order to get numerical models which have strong conformity to the actual condition of large friction connections, AFC and SFC.

Parametric study

This stage consist of the following analysis

1) Different surface treatments

2) Different clamping forces

3) Different bolt sizes/numbers

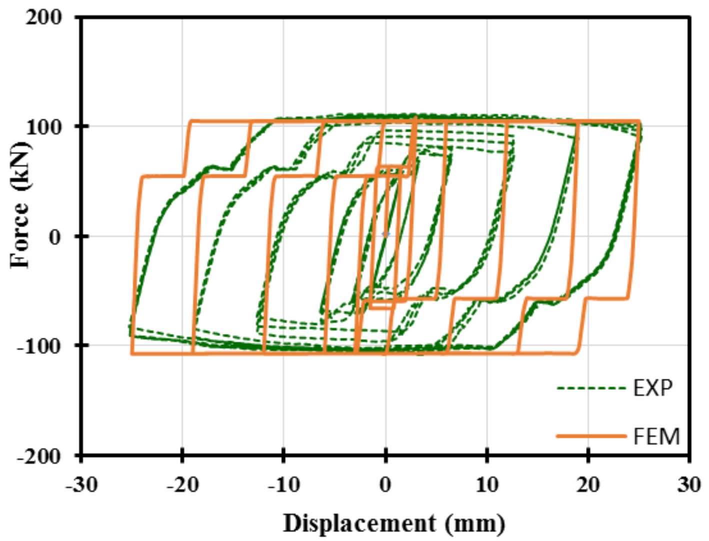
4) Different hole sizes

5) Different sliding distances

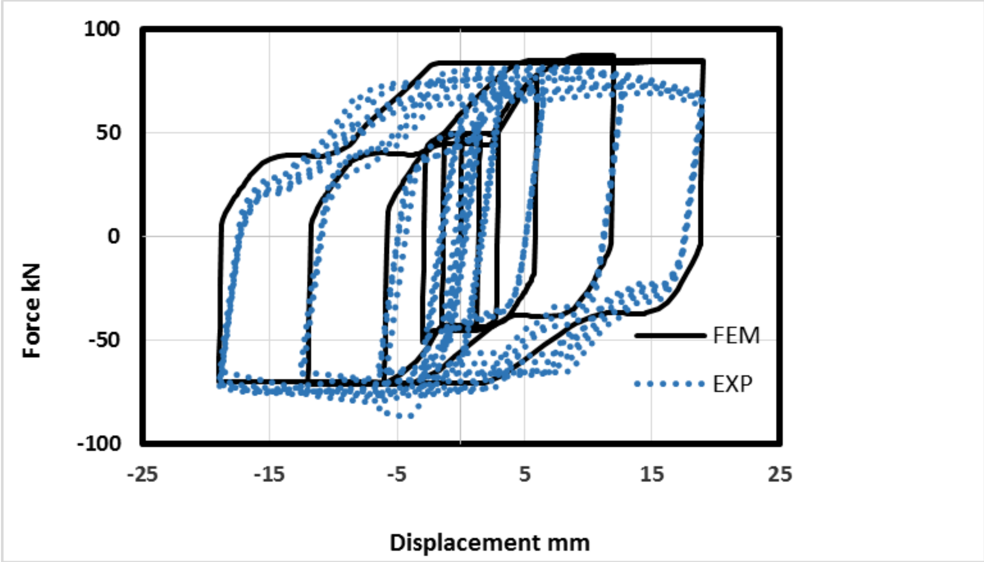
6) Effective bolt lever arm

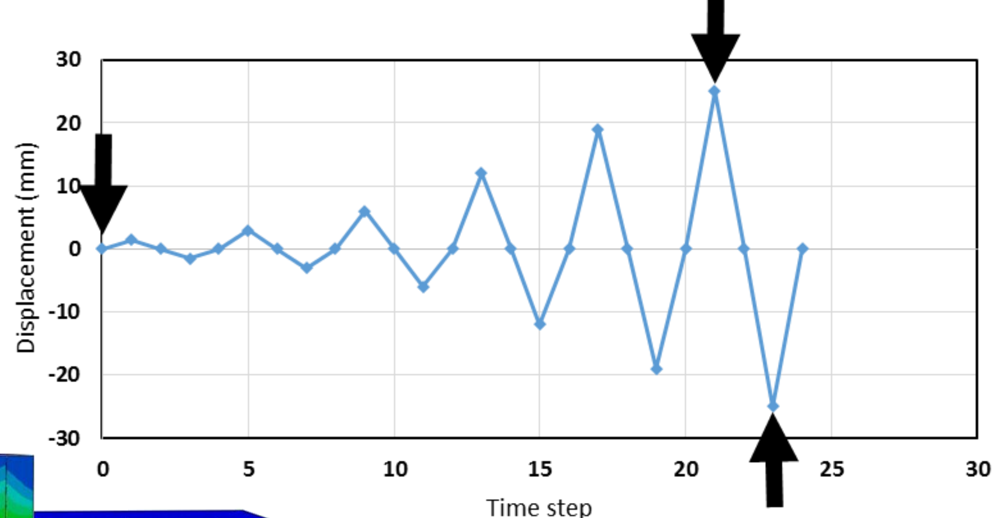
FEM Validation for AFC with M16 bolts- 42mm and 162 mm grip length

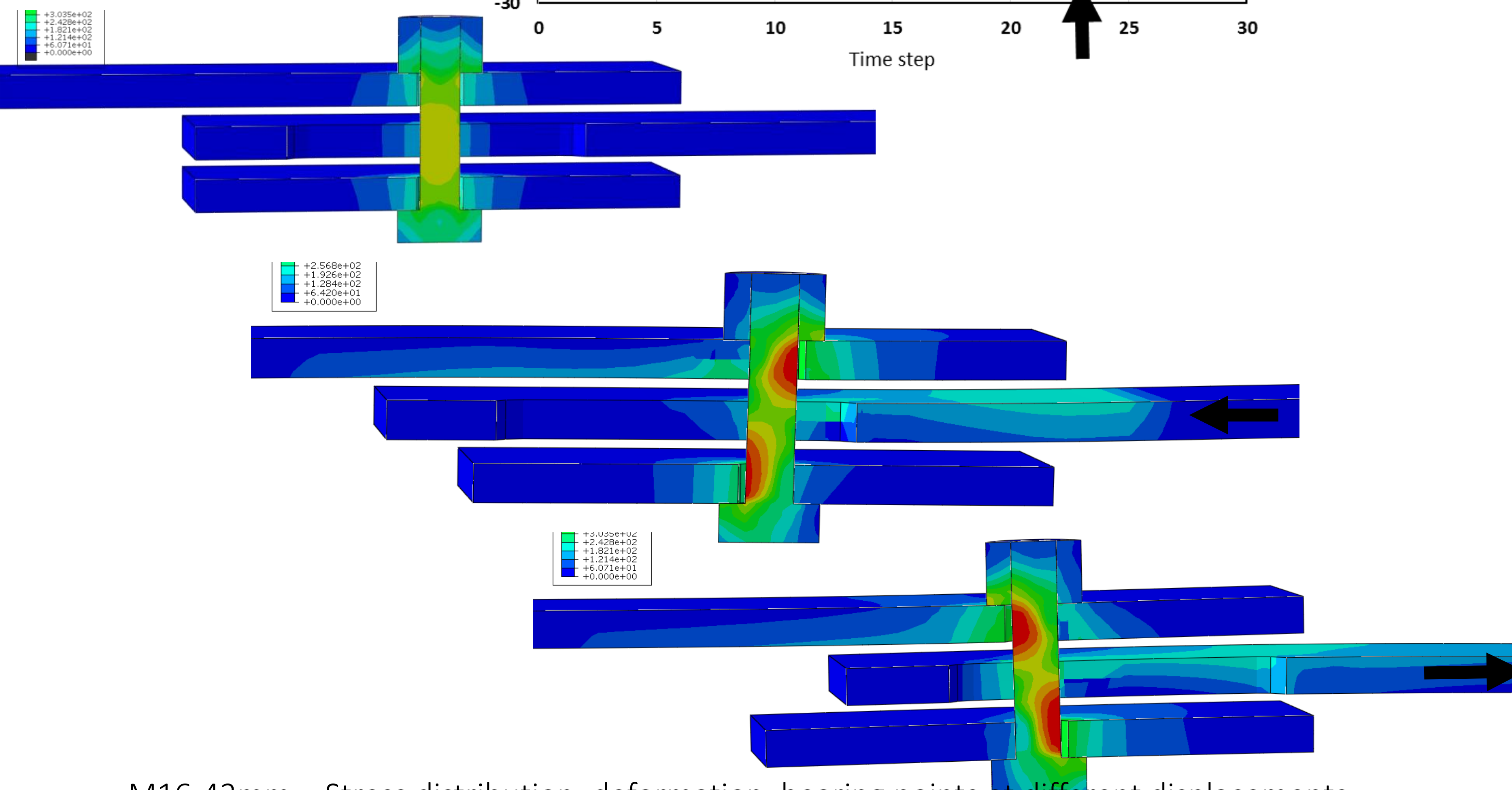
AFC-M16 grip length 42mm



AFC-M16 grip length 162mm

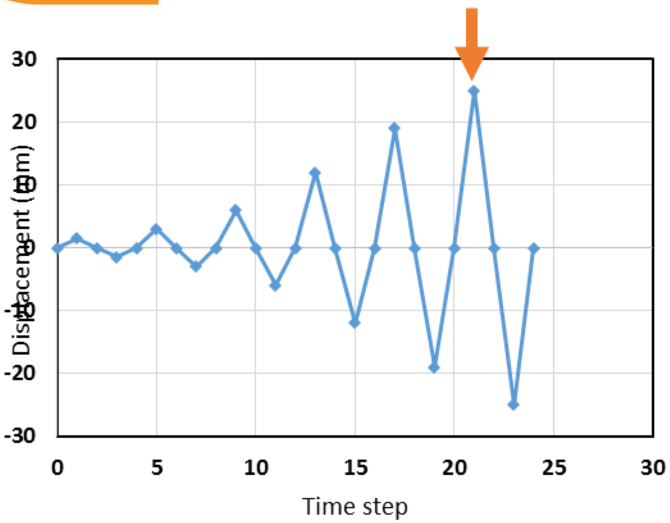


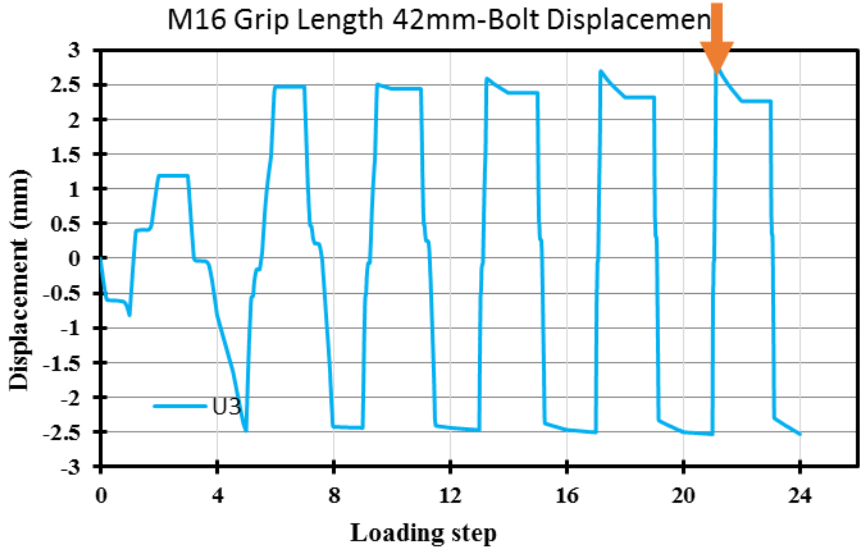


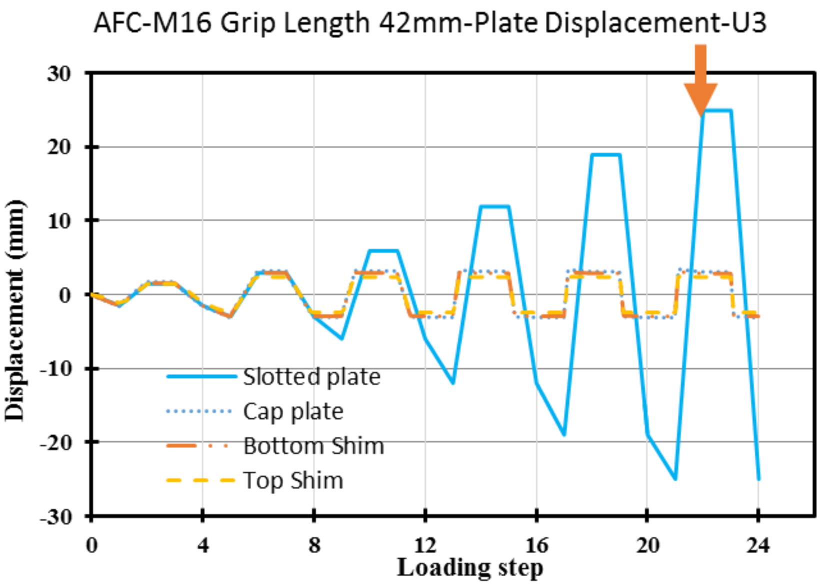


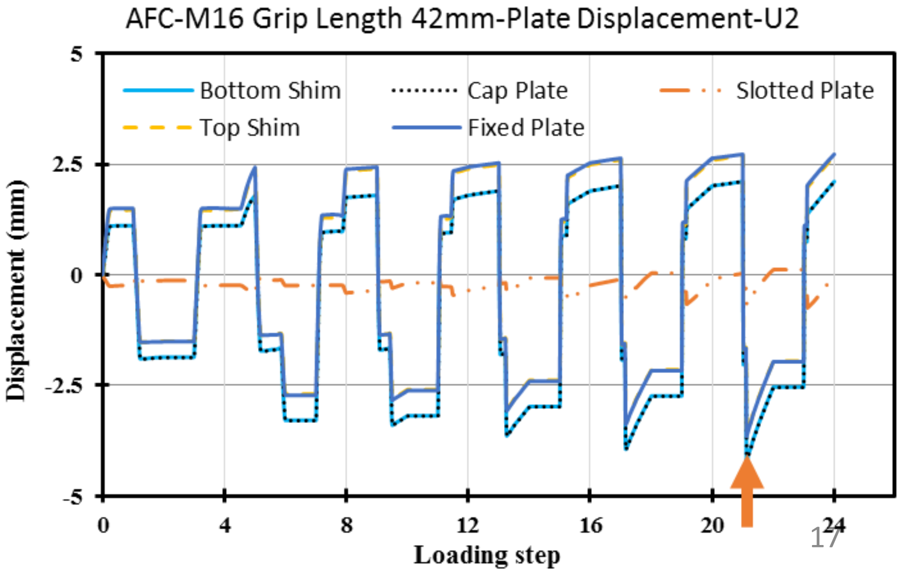
M16-42mm – Stress distribution, deformation, bearing points at different displacements

FEM outputs AFC with M16 bolts- 42mm grip length (Element displacement)

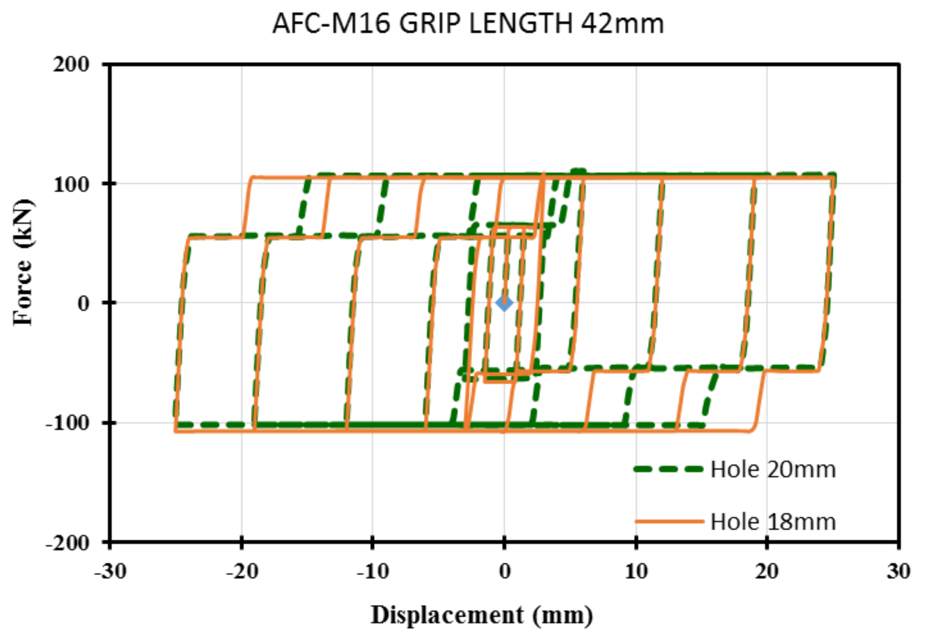


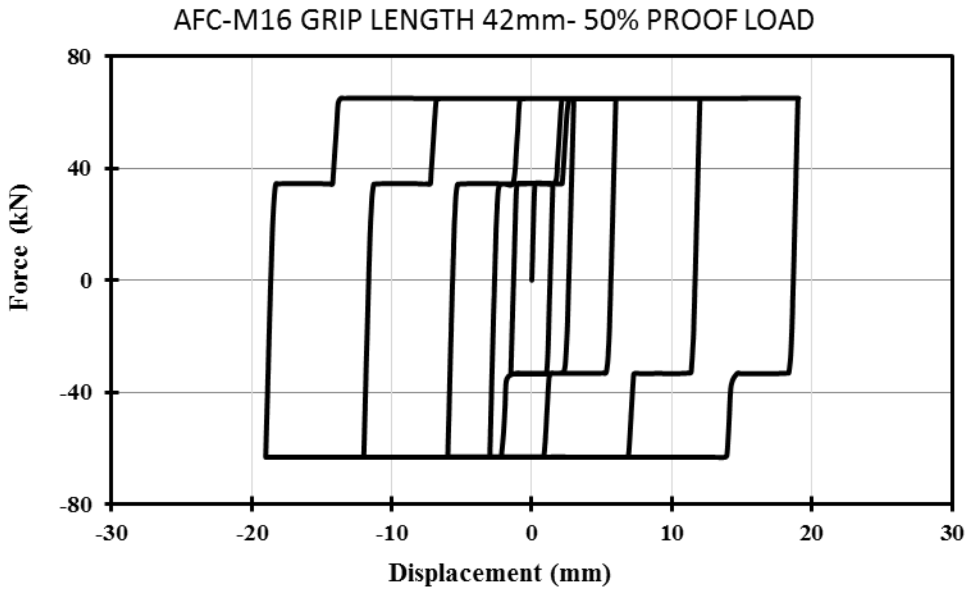




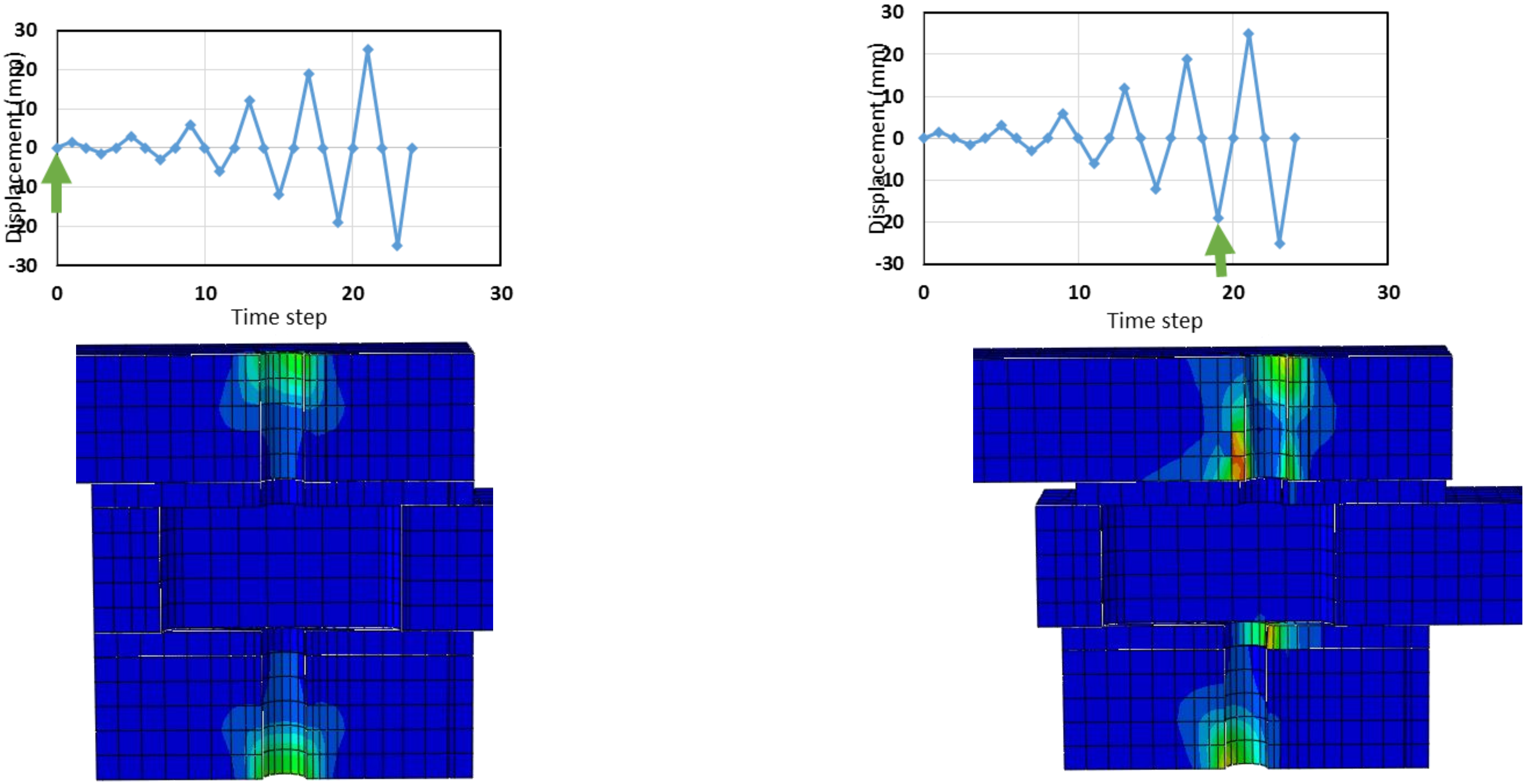


AFC with M16 bolts- 42mm grip length (Hole size, clamping force effect)



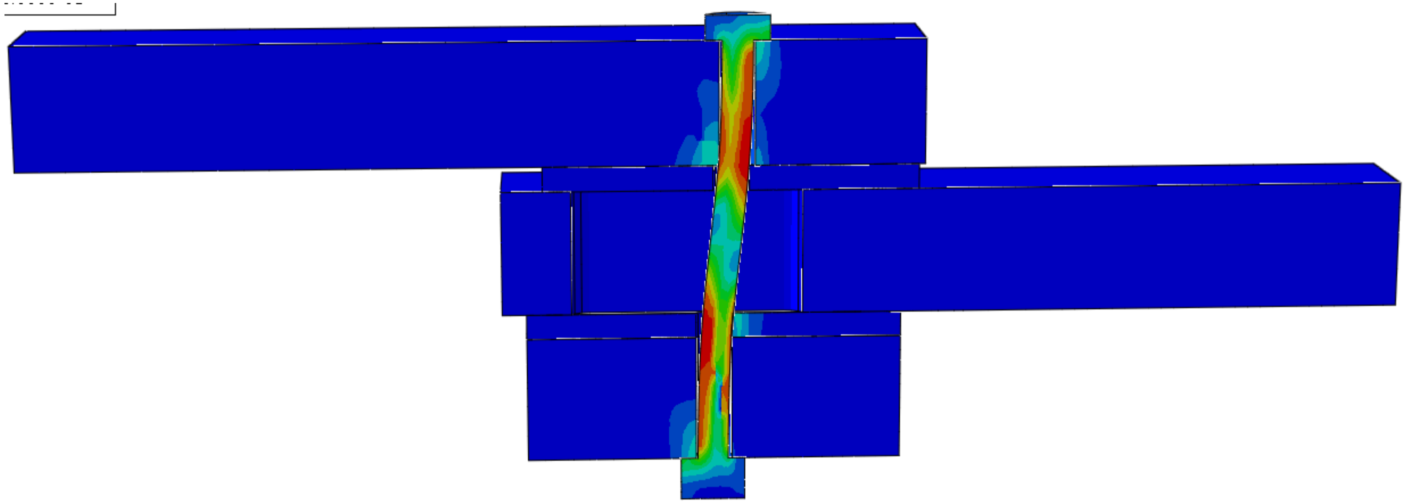


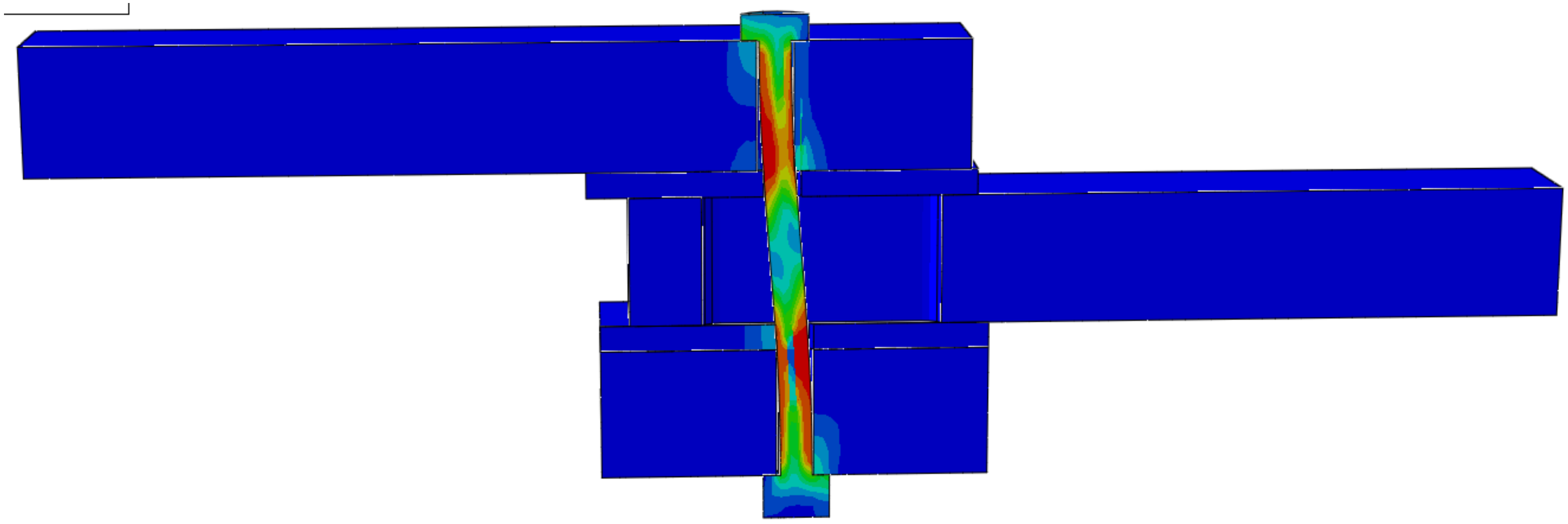
AFC with M16 bolts- 162mm grip length



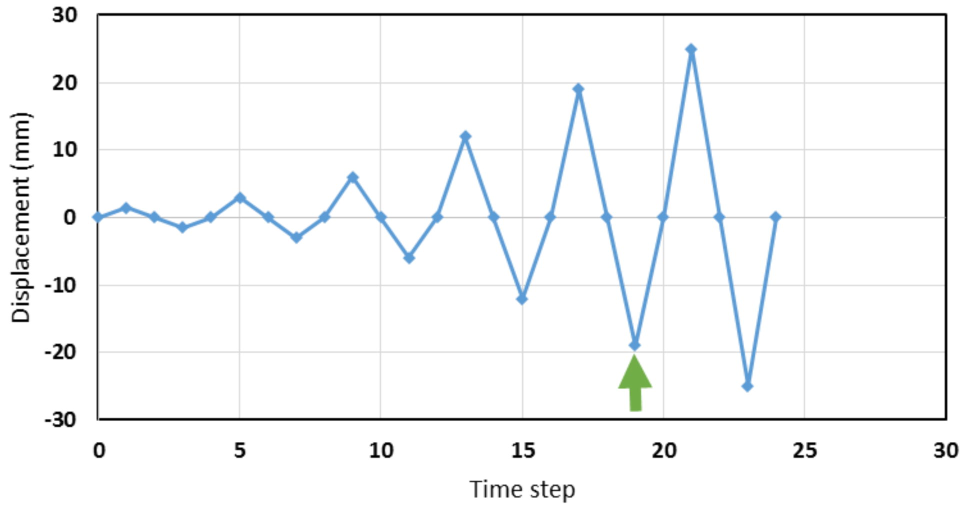
AFC with M16 bolt- Grip length 162mm – Stress distribution in plates before and after sliding

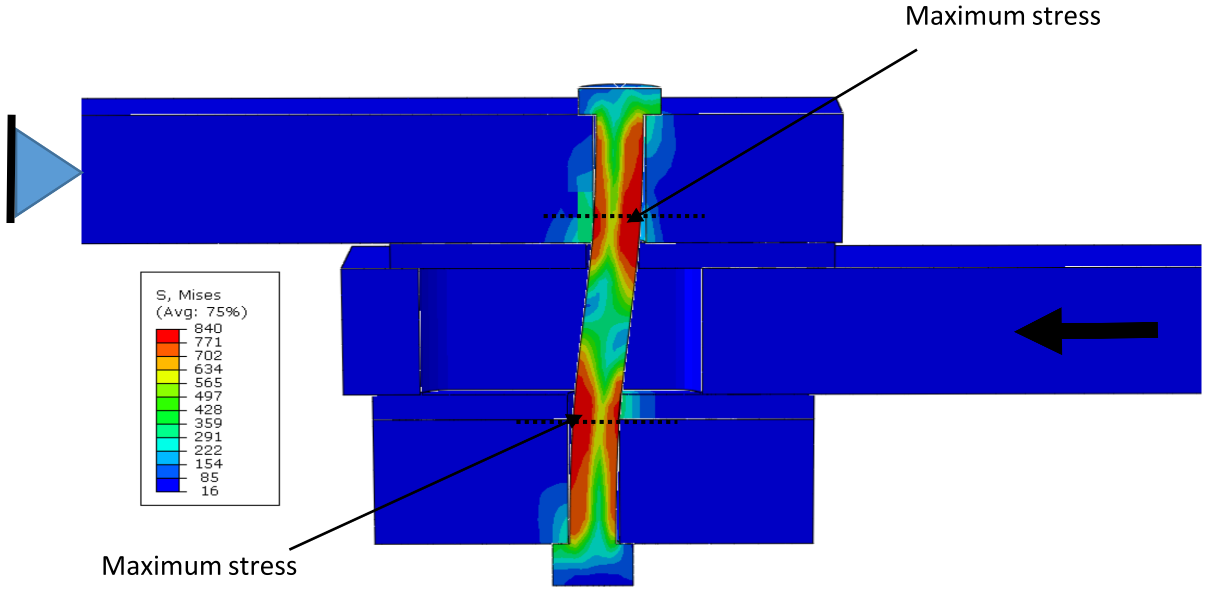
AFC with M16 bolts- 162mm grip length (Bolt behaviour)



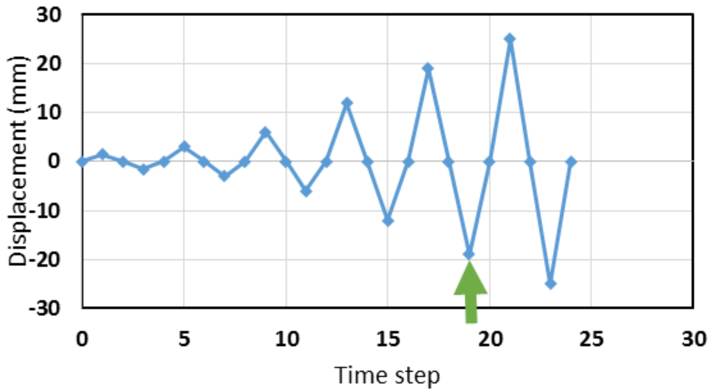


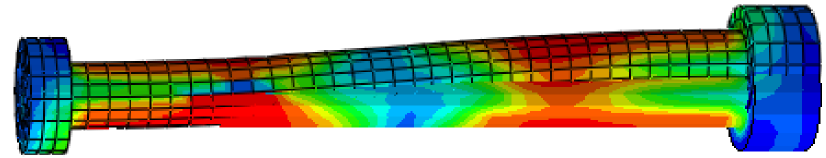
M16- Grip length 162mm – Stress distribution, deformation, bearing points



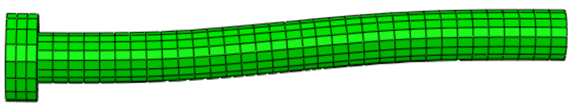


Bolt bearing locations depends on bolt size and bolt length

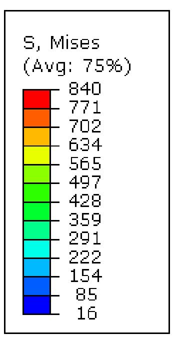


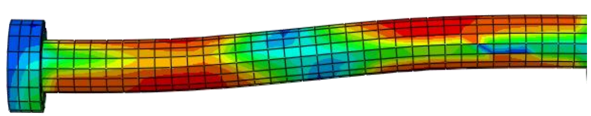


Experimental test (Chanchi 2016)

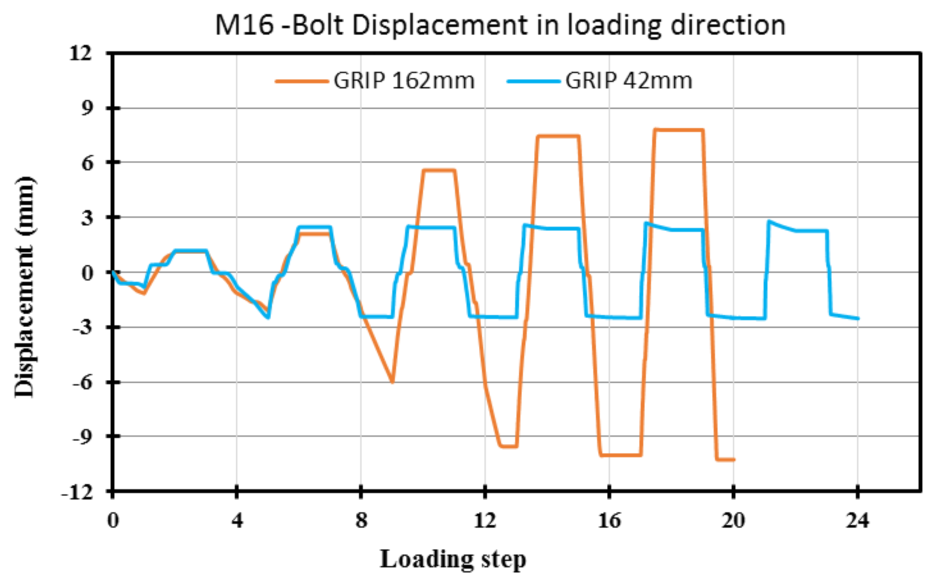


Bolt deformation





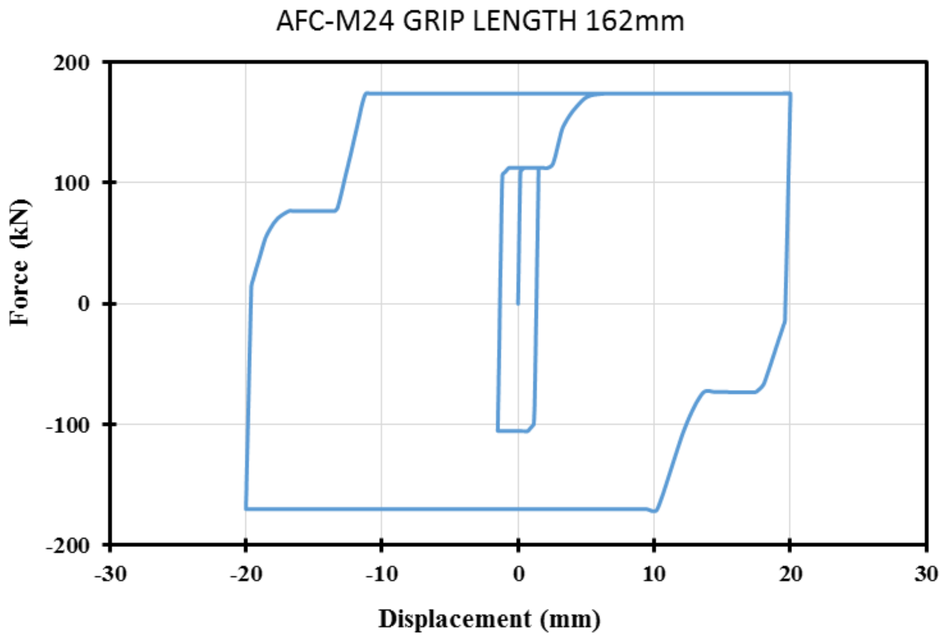
Stress distribution (Mpa)



Clamping force reduction 32%

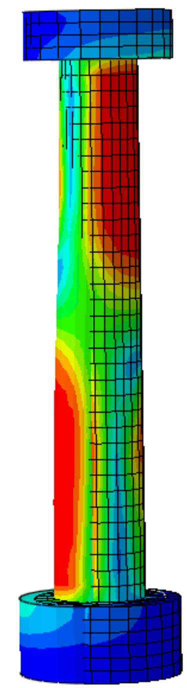
Bolt Dis. 10mm

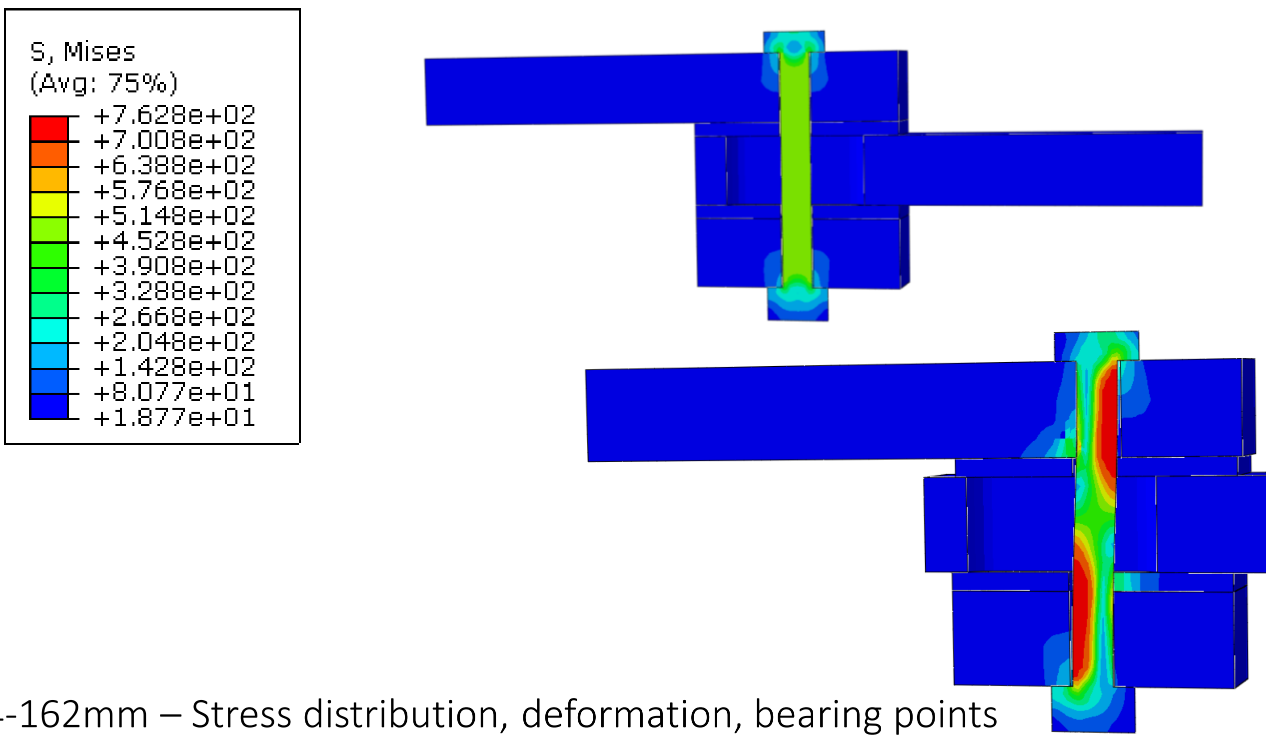
M16-162mm – Stress distribution, deformation



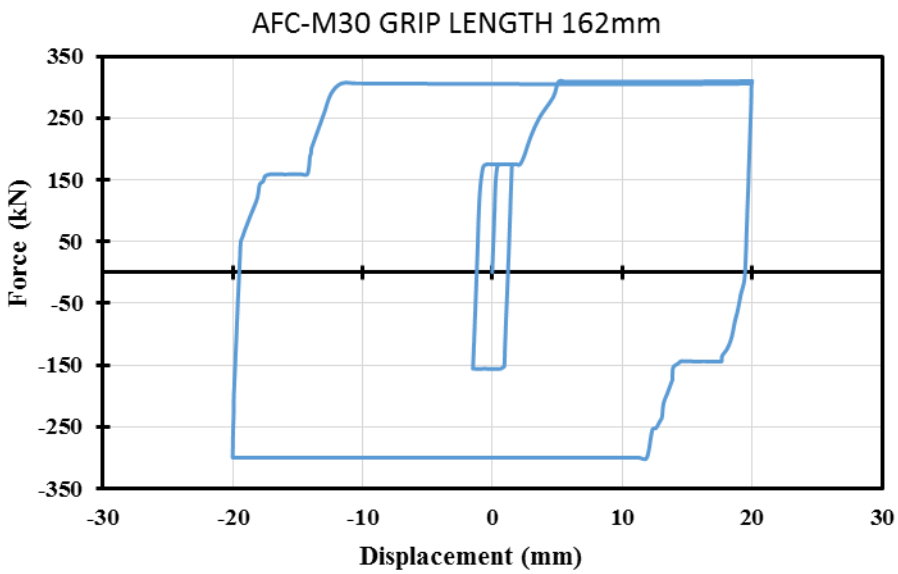
Clamping force reduction 11%

Bolt Dis. 5mm



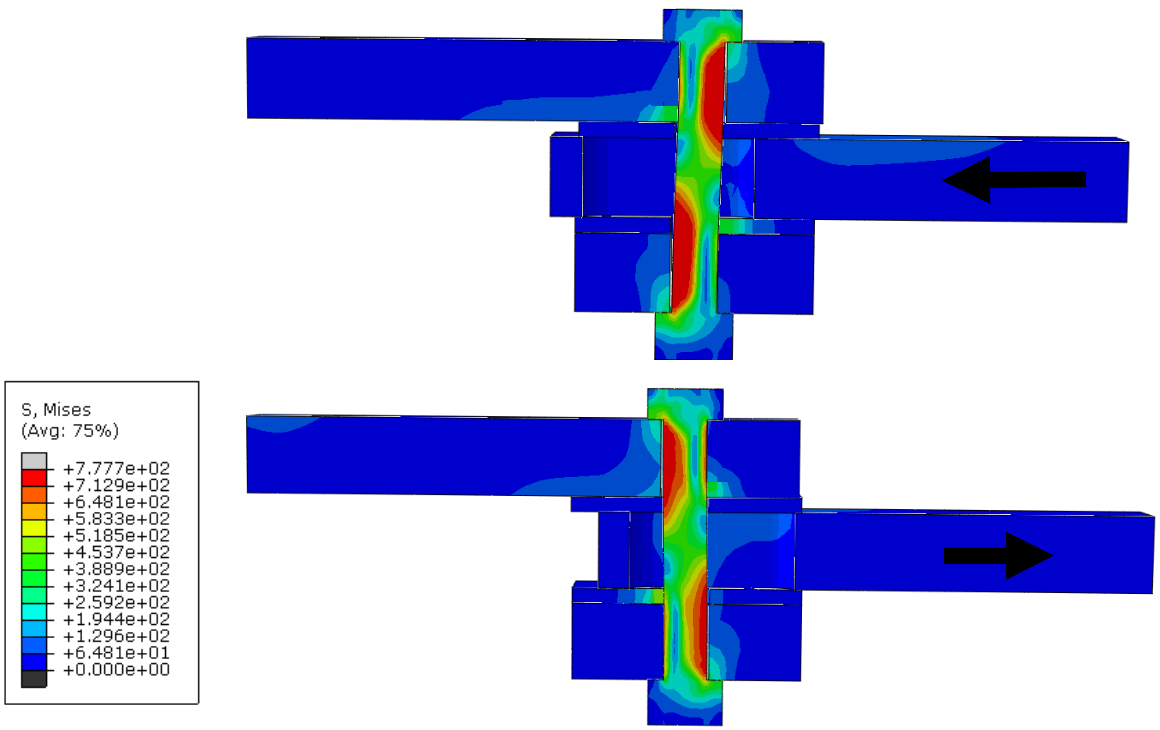


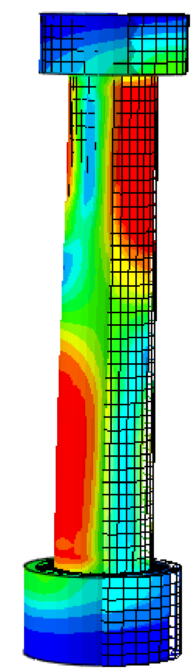
M24-162mm – Stress distribution, deformation, bearing points



Clamping force reduction 5%

Bolt Dis. 4mm





M30-162mm – Stress distribution, deformation, bearing points