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**Date:** 27.11.15

## Engineers Report FSM-250 Roof Anchor

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### Overview

BVT Engineering Professional Services has been requested by Brian Woods of Innovative Ceiling Systems to review the adequacy of using a Collins Corporation Ltd FSM-250 roof anchor with eight 14g x 25mm Tek screws, into a 25mm wood fibre panel. The system is illustrated below in figure 1.

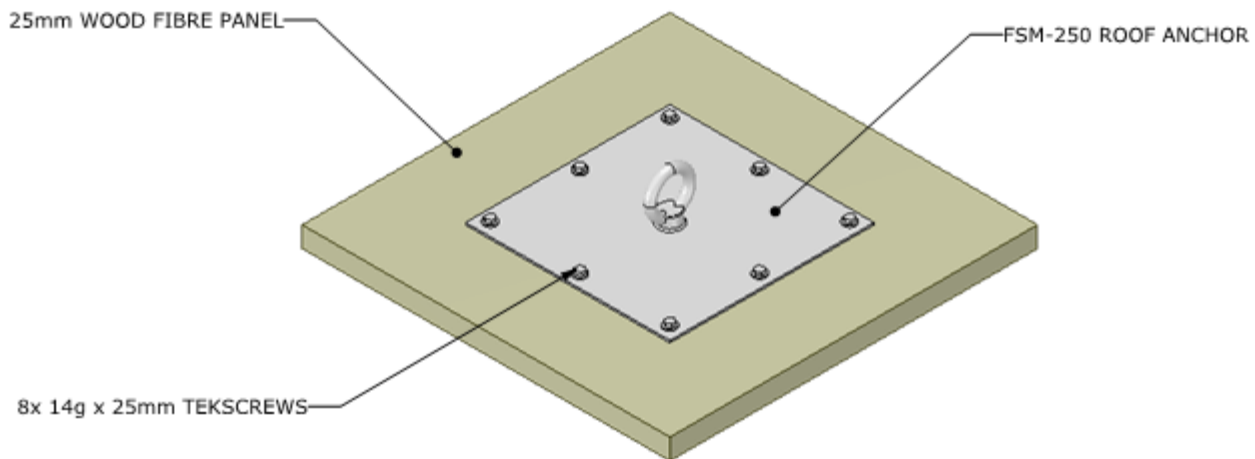


Figure 1 - FSM-250 roof anchor system

The FSM-250 roof anchor is only to be treated as a Total Restraint anchor as defined by AS/NZS 1891.4:2009, as per the manufacturer's specification. The manufacturer also gives two attachment systems, which are:

1. 7.70 Olympic Bulb-Tite Rivets
2. Sikaflex 11FC Adhesive

The purpose of this report is to determine the adequacy of using eight 14g x 25mm Tek screws, as opposed to either of the above arrangements.

## Methodology

### AS/NZS 1891.4:2009 Loading

As per Appendix F of AS/NZS 1891.4:2009, Total Restraint is defined as the control on a person's movement by means of a connection to an anchorage in such a way that it will physically prevent the person from reaching any position at which there is risk of a fall, either over an edge, through a surface or due to a failed moveable platform.

Total Restraint loading is omitted from the AS/NZS 1891 series, and does not provide any advice on strengths needed for Total Restraint anchorages. It is therefore up to the user to ensure the suitability of equipment used for Total Restraint.

The minimum loading requirements for fall arrest anchors are defined as follows:

Limited Free Fall:                12 kN

Free Fall:                            15 kN

### Anchorage Application

The manufacturer does not give a rating for the FSM-250, as it is specifically used for Total Restraint. Therefore the anchorage system must be used on roofs with a pitch less than 25 degrees, as per Best Practice Guidelines for Working on Roofs 2012. An illustration of a Total Restraint system is outlined in figure 2.

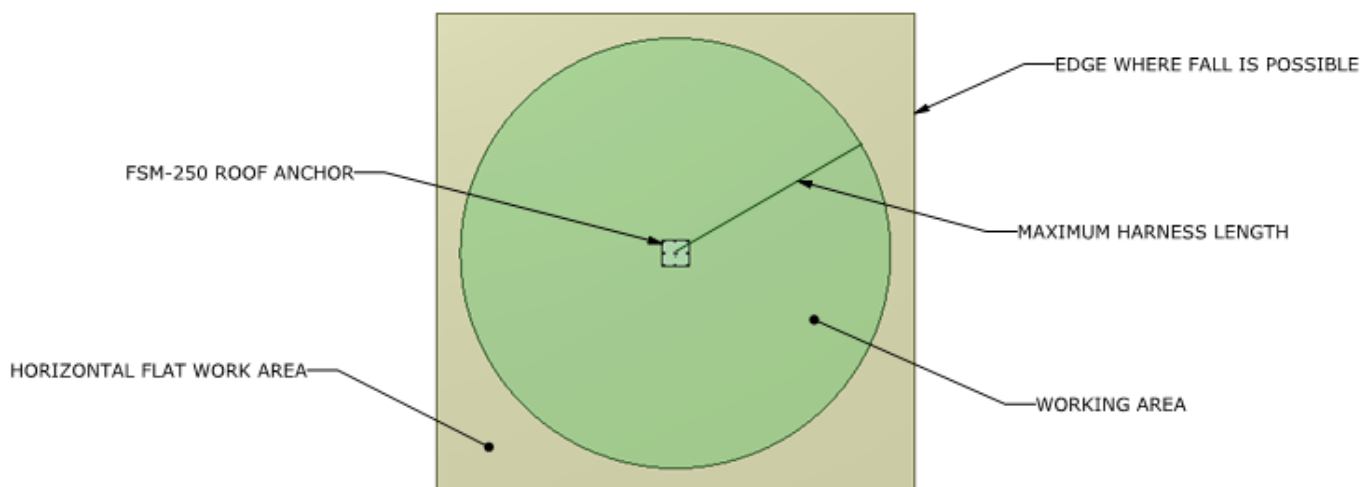


Figure 2 - Illustration of Total Restraint system

### Analysis Parameters

Since there are no specific loading requirements for Total Restraint anchors as per AS/NZS 1891.4, a representative system will be modelled using Finite Element Analysis (FEA) to determine the loading the system can withstand. This will be the basis for determining the adequacy of the anchor strength.

ANSYS 15.0 Mechanical Application has been used for FEA with the following parameters:

Finite Element Model:	ANSYS 15.0 Static Structural
Analysis Type:	Solid Elements, Large Deformation
Material Model:	Stainless Steel (NL)
Yield Strength:	$F_y = 210 \text{ MPa}$
Young's Modulus:	$E = 193 \text{ GPa}$
Tangent Modulus:	$E_t = 1.8 \text{ GPa}$
Poisson's Ratio:	$\nu = 0.31$
Material Model:	Wood Panel
Young's Modulus:	$E = 6.0 \text{ GPa}$
Poisson's Ratio:	$\nu = 0.35$
Contact Model:	Frictionless contact between anchor and panel

The ANSYS model setup and results can be found in the Appendices.

### Acceptance Criteria

Since the FSM-250 roof anchor is an OEM component, the acceptance criteria will focus on the validation of the anchorage fixings. NZS 3603:1993 - Timber Structures has been used for guidance of fixing validation. The following limits for the Tek screws were determined using guidance from NZS 3603:

Single Shear Limit:  $V_f = 1,500 \text{ N}$

Pullout Limit:  $N_f = 1,900 \text{ N}$

Note that these limits are consistent with the Tek screw catalogue, however to confirm these limits it is highly recommended that physical testing of the system is conducted.

## Results

It was calculated that the roof anchorage system was **inadequate for fall arrest loading** in accordance with AS/NZS 1891.4:2009. Excessive stress was present in the FSM-250 roof anchor, and the Tek screws were well above the allowable limits.

Based upon the limits of the Tek screws outlined in this report, the roof anchorage system was found to be adequate for an unfactored ultimate load of 2,600 N. Slight yielding within the baseplate of the FSM-250 roof anchor was present, however this was not deemed to cause catastrophic failure in the system.

It was apparent that the FSM-250 roof anchor had a flexible baseplate design. Figure 3 shows the stress path which tends to load only three Tek screws within the system. It is expected that using a stiffer baseplate design, the load will be transferred across more Tek screws. Table 1 below outlines the calculated Tek screw loads for two load cases.

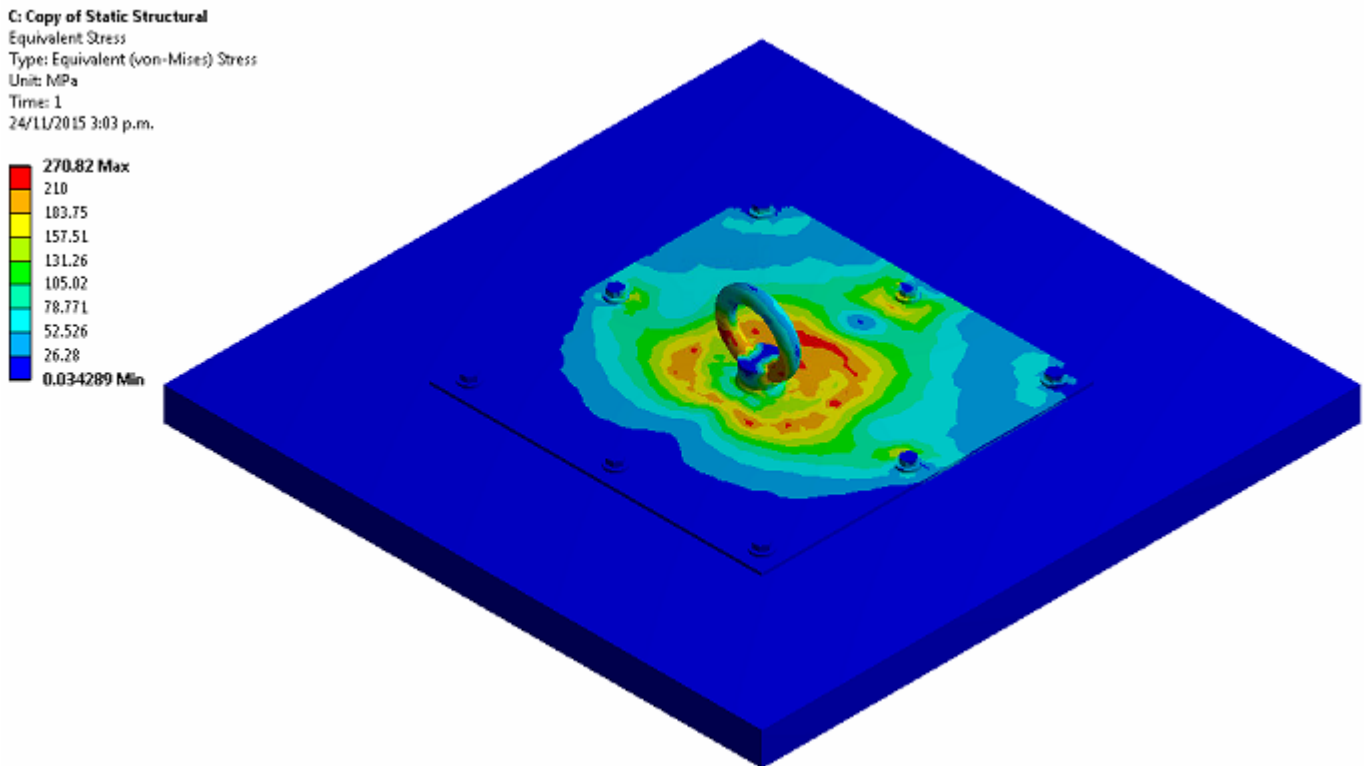


Figure 3 - Von-Mises stress path for FSM-250 roof anchor (@ 2,600 N)

**Table 1 - Tek screw Shear & Pullout Loads**

Load Scenario	Tek screw Shear, V*	Tek screw Pullout, N*
2,600 N	1,423 N	1,868 N
15,000 N	5,841 N	3,370 N

## Conclusions

The FSM-250 roof anchor shall be used only as a **Total Restraint System**, as shown in figure 2. It is therefore not suitable for pitched smooth roofs exceeding 25 degrees as per the Best Practice Guidelines for Working on Roofs:2012. It can be concluded that the system shown in figure 1 is **inadequate for fall arrest loading** as per AS/NZS 1891.4:2009.

AS/NZS 1891.4:2009 does not give strength requirements for a Total Restraint anchor, however AS/NZS 1891.4:2000 has a 6 kN requirement for Total Restraint. The 6 kN load requirement has been omitted from the latest standard, and it is up to the user to define an appropriate level on strength for a Total Restraint anchor.

It is expected that the system outlined in figure 1 will withstand an unfactored ultimate load of 2,600 N. This load equates to a pulling force of 260 kg, which is deemed to be acceptable for use as a single person Total Restraint system.

Compliance with the definition outlined Appendix F of AS/NZS 1891.4:2009 is required for the anchorage to be classed as a Total Restraint system.

## Recommendations

The following is strongly recommended:

- Physically test the system shown in figure 1 to confirm the shear and pullout values of the Tek screws
- Increase the baseplate thickness of the FSM-250 roof anchor if fall arrest compliance is required
- Introduce a circular bolt pattern for even load distribution and additional Tek screws if fall arrest compliance is required
- Working on pitched roofs must have anchors rated for fall arrest loading

## Report Completed By

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## Report Approved By

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## Appendix A - Analysis Results

### 2,600 N Anchor Load

C: Copy of Static Structural  
Static Structural 2  
Time: 1 s  
24/11/2015 3:25 p.m.

**A** Force: 2600. N  
**B** Fixed Support

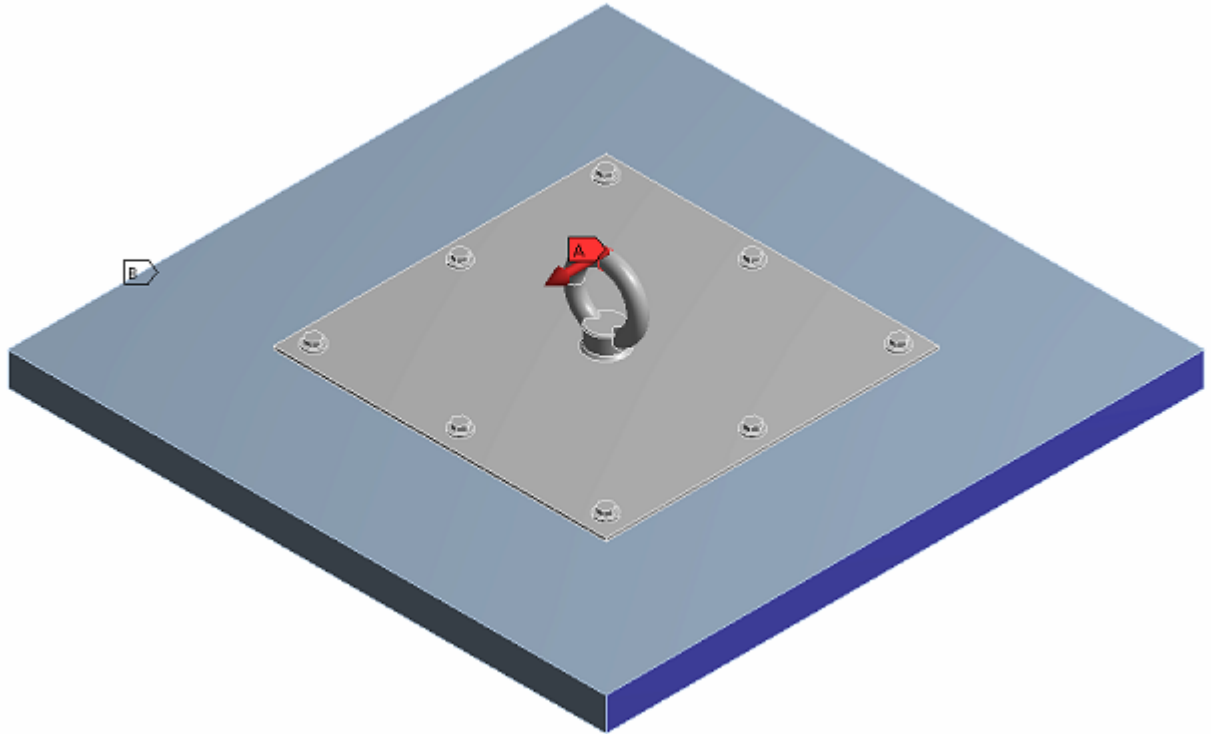


Figure A1 - 2.6 kN load model setup

C: Copy of Static Structural  
Total Deformation  
Type: Total Deformation  
Unit: mm  
Time: 1  
24/11/2015 3:26 p.m.

6.4384 Max  
5.723  
5.0076  
4.2923  
3.5769  
2.8615  
2.1461  
1.4308  
0.71538  
0 Min

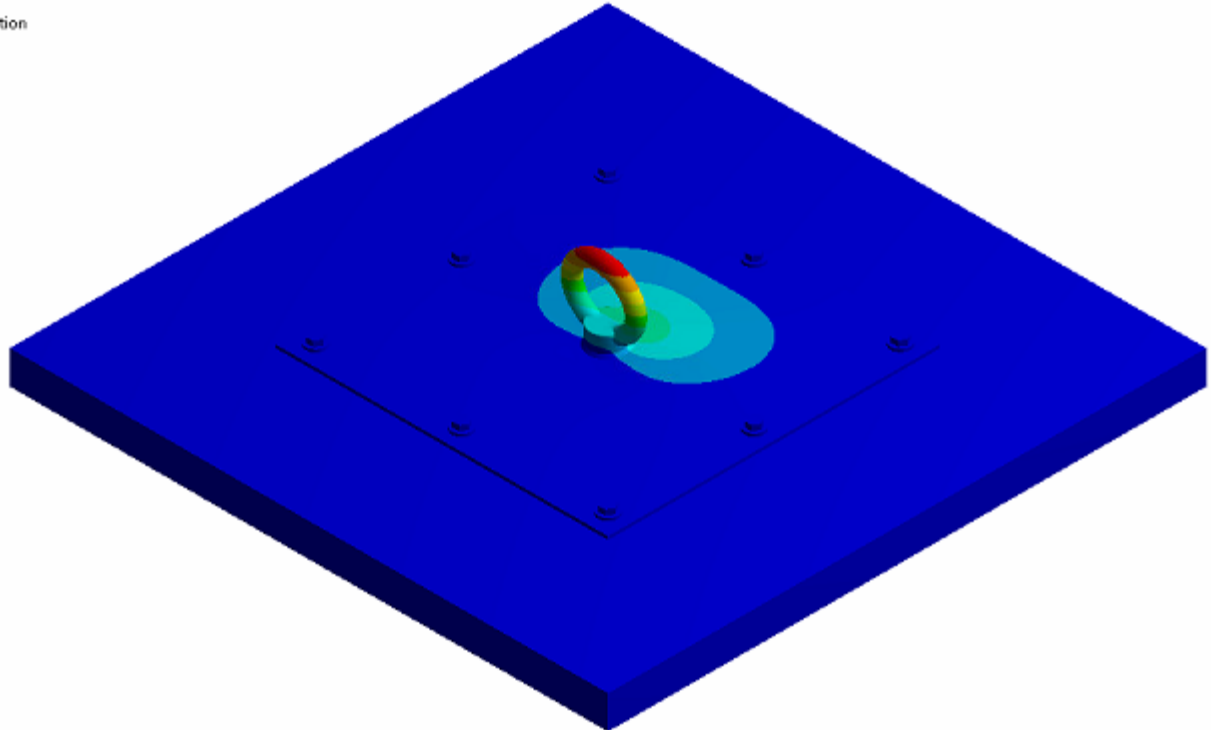


Figure A2 - 2.6 kN load deformation (true scale)

C: Copy of Static Structural  
Equivalent Stress  
Type: Equivalent (von-Mises) Stress  
Unit: MPa  
Time: 1  
24/11/2015 3:27 p.m.

270.82 Max  
210  
183.75  
157.51  
131.26  
105.02  
78.771  
52.526  
26.28  
0.034289 Min

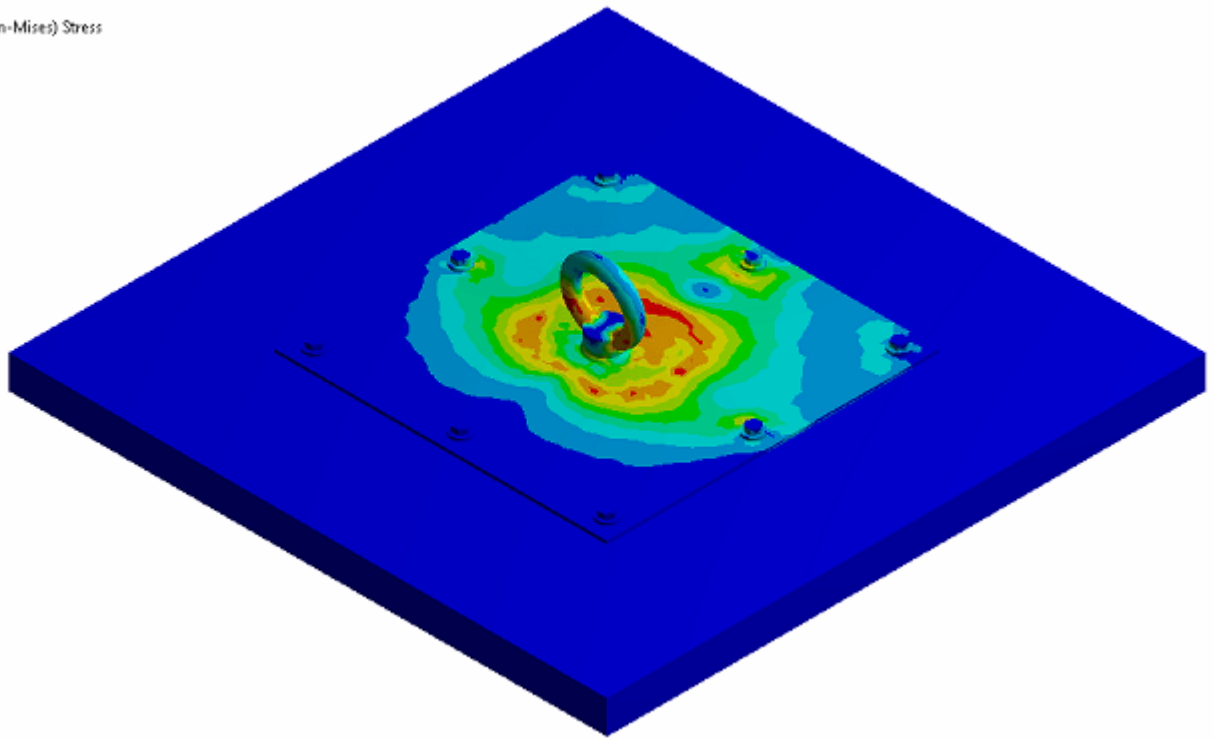


Figure A3 - 2.6 kN load Von-Mises stress (capped at yield strength)

C: Copy of Static Structural  
Equivalent Stress  
Type: Equivalent (von-Mises) Stress  
Unit: MPa  
Time: 1  
24/11/2015 3:28 p.m.

270.82 Max  
210  
183.75  
157.51  
131.26  
105.02  
78.771  
52.526  
26.28  
0.034289 Min

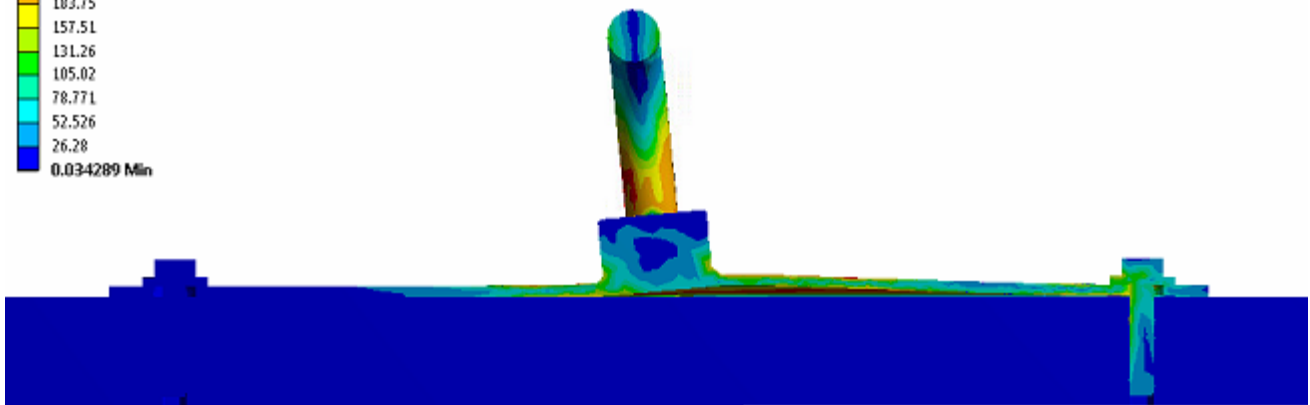


Figure A4 - 2.6 kN load Von-Mises stress (section view)

B: Static Structural  
Static Structural  
Time: 1 s  
24/11/2015 2:26 p.m.

A Force: 15000 N  
B Fixed Support

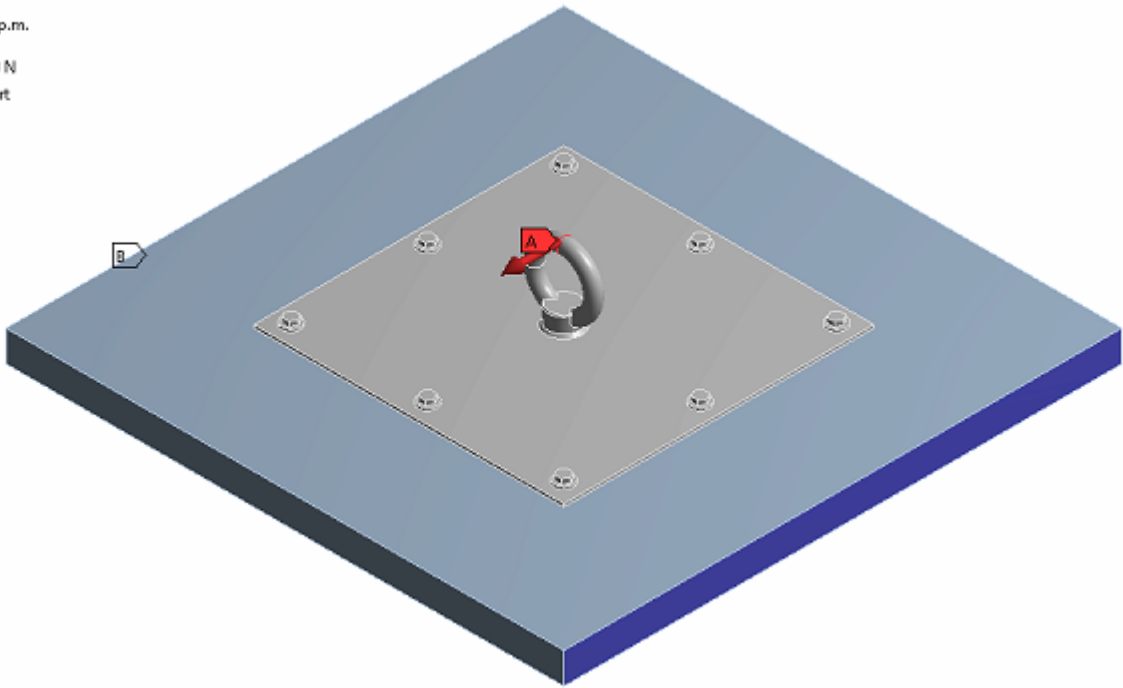


Figure A5 - 15 kN fall arrest load model setup

B: Static Structural  
Total Deformation  
Type: Total Deformation  
Unit: mm  
Time: 1  
24/11/2015 2:28 p.m.

58.416 Max  
51.926  
45.435  
38.944  
32.453  
25.963  
19.472  
12.981  
6.4907  
0 Min

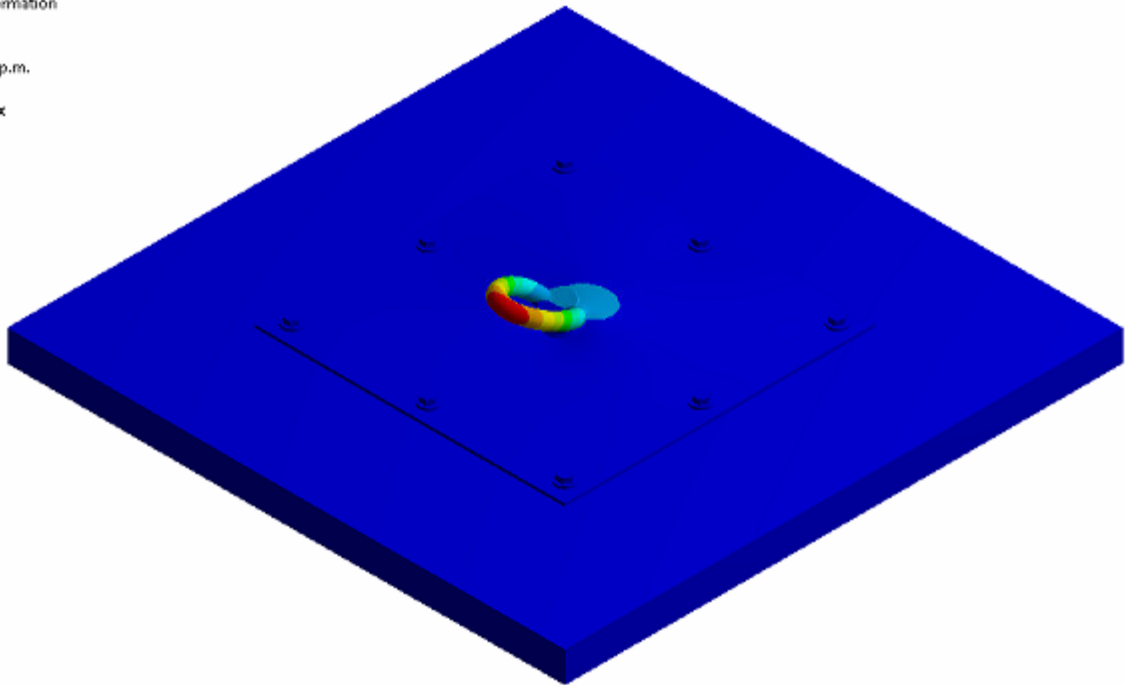


Figure A6 - 15 kN fall arrest load deformation (true scale)



B: Static Structural  
Equivalent Stress  
Type: Equivalent (von-Mises) Stress  
Unit: MPa  
Time: 1  
24/11/2015 2:29 p.m.

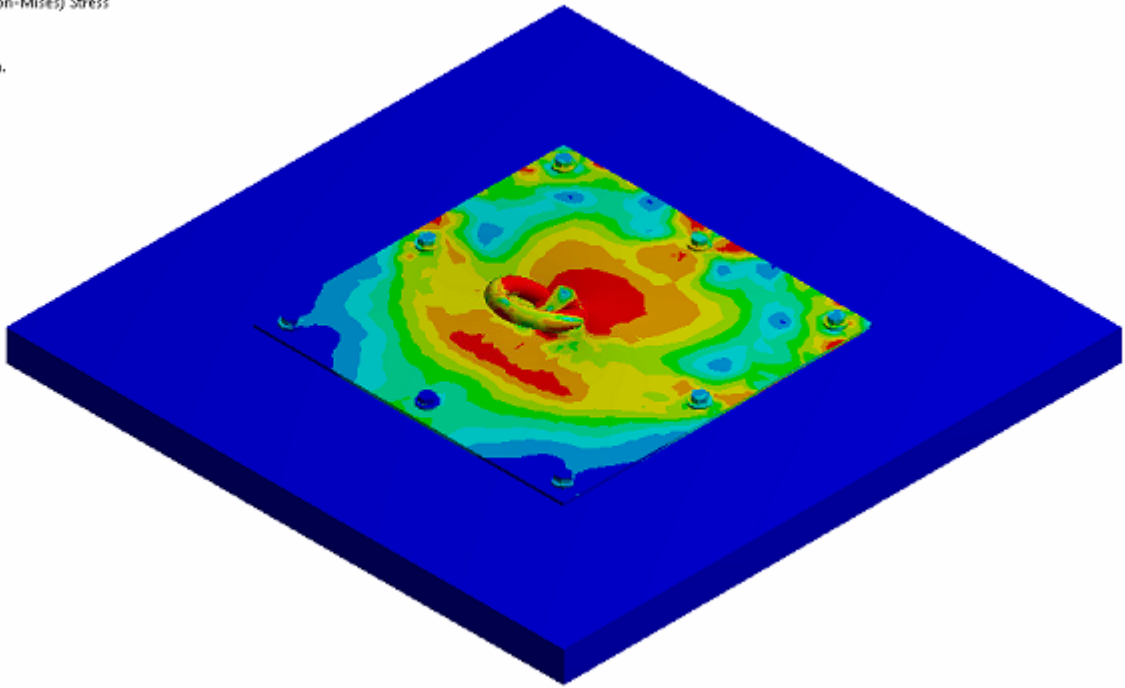
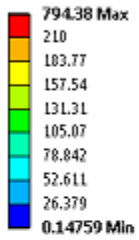


Figure A7 - 15 kN fall arrest load Von-Mises stress (capped at yield strength)

B: Static Structural  
Equivalent Stress  
Type: Equivalent (von-Mises) Stress  
Unit: MPa  
Time: 1  
24/11/2015 2:30 p.m.

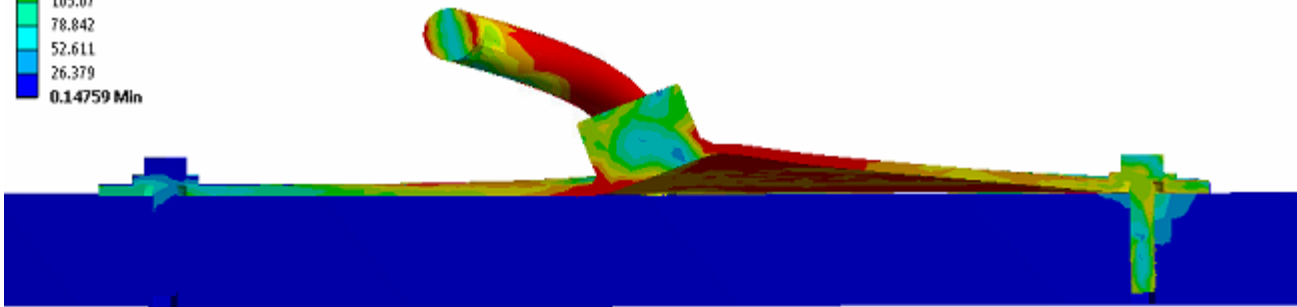
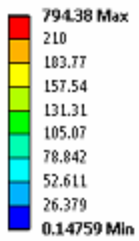


Figure A8 - 15 kN fall arrest load Von-Mises stress (section view)