

Our Ref 847004/23-LO-115: dlb

Contact David Beneke

28 April 2005

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Via email : info@rackarmour.com.au

Dear Alex

**RE: RACK ARMOUR
PALLET RACKING UPRIGHT PROTECTION SYSTEM ANALYSIS**

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1 INTRODUCTION

Cardno has undertaken a finite element analysis (FEA) of the Rack Armour pallet racking upright protection system. The purpose of this analysis is to determine if the 106 mm Rack Armour assembly can provide enhanced protection to 90 mm pallet racking uprights for impact loads as specified by FEM 10.2.02 Racking Design Code.

2 REFERENCE INFORMATION

This report has been based on the following standards and reference documents provided by Rack Armour:

- AS/NZS1170.0:2002, Structural Design Actions, Part 0: General Principles ;
- AS4100-1998, Steel Structures ;
- AS4840-1993, Steel Storage Racking ;
- Federation Europeenne De La Manutention FEM 10.2.02 Racking Design Code, April 2001 Version 1.02 ;
- Material data of the Rack Armour received from Rack Armour dated 4 April 2005 ;
- Additional information of the Rack Armour which includes a cross-sectional diagram of the Rack Armour received via email dated 7 April 2005 and
- AutoCAD drawings of the Rack Armour outer (with pre- and post-cut details) and foam insert received via email dated 7 April 2005.

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3 ANALYSIS METHODOLOGY

A three-stage process was used for the analysis of the Rack Armour assembly. Stage 1 examined the stresses on the rack upright for the ultimate impact load in the cross- and down-aisle directions without the Rack Armour installed. Stage 2 examined the hoop stresses in the Rack Armour outer when snap-fitted onto the rack upright. Stage 3 examined the stresses on the rack upright with the Rack Armour installed for ultimate impact loads in the cross- and down-aisle directions. Comparison between the results from Stage 1 and 3 incorporating the results of Stage 2 was then undertaken.

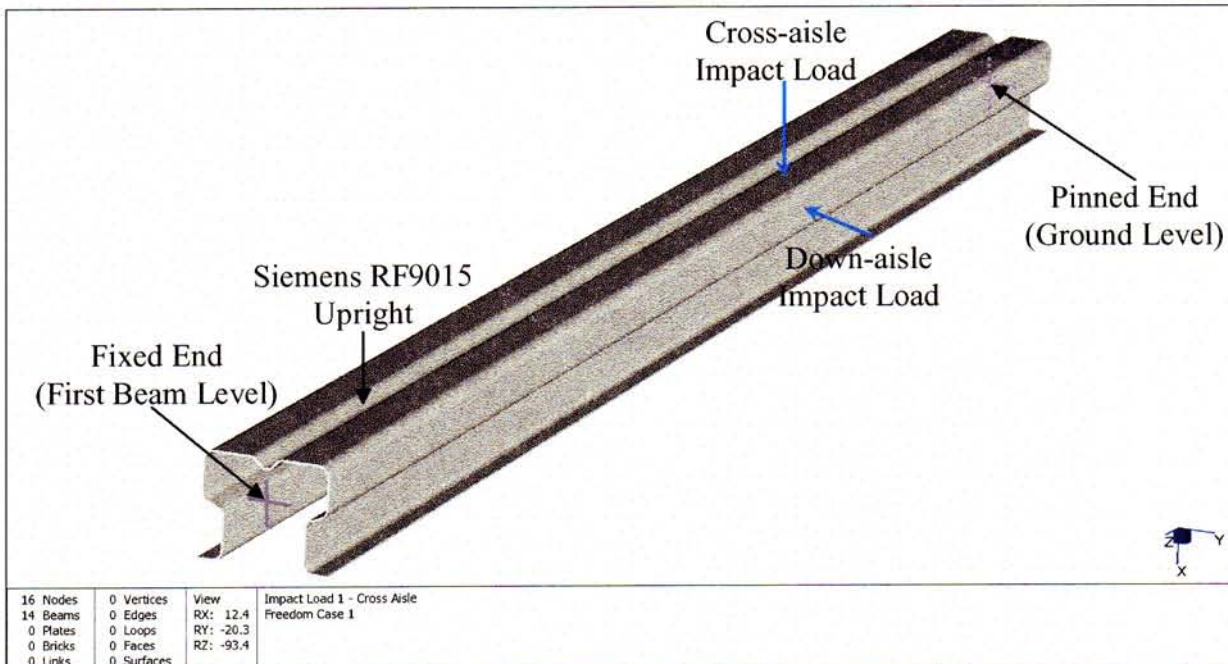
4 STAGE 1 – RACK UPRIGHT WITHOUT RACK ARMOUR FOR IMPACT LOADS

An FEA model of the rack upright was created. The FEA software used was Strand 7 R2.3.5, 2004. The upright geometries were based on the standard Siemens RF9015 upright. The applied equivalent static impact load is consistent with Federation Europeenne De La Manutention FEM 10.2.02 Racking Design Code, April 2001 Version 1.02. This code is typically adopted in Australia for the design of pallet racking systems for impact loads as it is considered state of art compared to AS4084-1993, Steel Storage Racking. In accordance to AS/NZS 1170.0:2002, Structural Design Actions, Part 0: General Principles, a load factor of 1.5 was used to determine ultimate impact forces. An image of the geometry of the Stage 1 FEA model is shown in *Figure 1*.

The total length of the Stage 1 FEA model was 1.5 m which is generally consistent with the height of the first beam level for a standard pallet.



Title: Geometry	
Project: Rack Armour	
Author: Daniel Lai	Reference: 847004/23



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19 April 2005 10:56:00

Figure 1. FEA model of the rack upright without Rack Armour installed for impact loads

4.1 Element Types

The rack upright was modelled based on the geometry of a standard Siemens RF9015 upright section. The Stage 1 FEA model consisted of a series of 4 noded linear plate/shell elements. Rigid links were used at the ends of the model to connect the nodes around the cross section of the upright into a single point at the upright centroid.

4.2 Restraints

The rack upright was rigidly fixed (all translational and rotational movements were fixed) at the end of the model corresponding to the first beam level and pin-supported (all translational movements were fixed) at the end corresponding to ground level.

Aside from the restraints just mentioned, no other restraints were adopted for this analysis. This situation is considered realistic for the purposes of comparison in the down-aisle direction where generally the only restraint to uprights is the pallet beams. However in the cross-aisle direction the FEA model is considered conservative as it neglects the additional horizontal restraint provided by the frame bracing.

4.3 Material Properties

In accordance to AS4100 – 1998, Steel Structures

Siemens Colby RF9015		
Properties	Magnitude	Remarks
Young's Modulus, E	200 GPa	Typical value for structural steel
Poisson's Ratio, μ	0.3	

Table 1. Material Properties of rack upright

4.4 Loading

To determine the peak stresses in the rack upright due to ultimate impact loads, a linear elastic analysis was undertaken with following loading conditions.

4.4.1 Ultimate Impact Loads

Ultimate impact loads were applied on the rack upright as shown in *Table 2*. These loads were based on clause 2.6.2 of the Federation Europeenne De La Manutention FEM 10.2.02 Racking Design Code, April 2001 Version 1.02 and clause 4.2 of AS/NZS 1170.0:2002, Structural Design Actions, Part 0 : General Principles. The ultimate impact loads were converted to face pressures which were then applied to elements on the upright. The reason why this was done was to minimize any local effects due to the application of a concentrated load.

Ultimate Load Case	Orientation	Load Magnitude, L (kN)	Load Factor	Ultimate Load Magnitude, $UL = L \times E_d$ (kN)	Pressure Applied (MPa)	Load Height above ground, h (m)
1	Down-aisle	1.25	1.5	1.875	4.03	0.4
2	Cross-aisle	2.5	1.5	3.75	3.14	0.4

Table 2. Magnitude and location of the ultimate loads applied on the rack upright

4.5 Results

The peak vertical stresses in the rack upright for ultimate impact loads are tabulated in Table 3.

Ultimate Load Case	Orientation	Load Height above ground, h (m)	Stress Magnitude (MPa)	
			Tension (+)	Compression (-)
1	Cross-aisle	0.4	148.5	169.4
		0.6	109.0	48.1
		1.5	70.7	115.6
2	Down-aisle	0.4	62.8	134.7
		0.6	57.5	45.0
		1.5	49.2	49.3

Table 3. Principal stresses of the rack upright for ultimate impact loads

Based on the results above, the peak vertical stresses occurred in the upright at a height of 0.4 m. This is generally consistent with pallet racking designs that we have undertaken in the past. It is noted that the peak vertical stresses at a height of 0.6 m is also referenced above as it corresponds to the height of the Rack Armour assembly for the purposes of comparison to further analyses.

5 STAGE 2 – RACK ARMOUR OUTER – SNAP FIT INVESTIGATION

A FEA model of the Rack Armour outer was created using half model symmetry conditions. The FEA software used was Strand 7 R2.3.5, 2004. The model was used to investigate the effects of a snap fit connection between the Rack Armour outer and the rack upright. Given that one has to open up the outer to fit the Rack Armour assembly on the upright, it is envisaged that this snap fit connection will introduce residual stresses on the outer which could affect its performance under impact loading. The Rack Armour geometries were based on the actual component sample provided as it was considered the worst case minimal opening in the Rack Armour outer. An image of the geometry of the FEA model is shown in *Figure 2*.

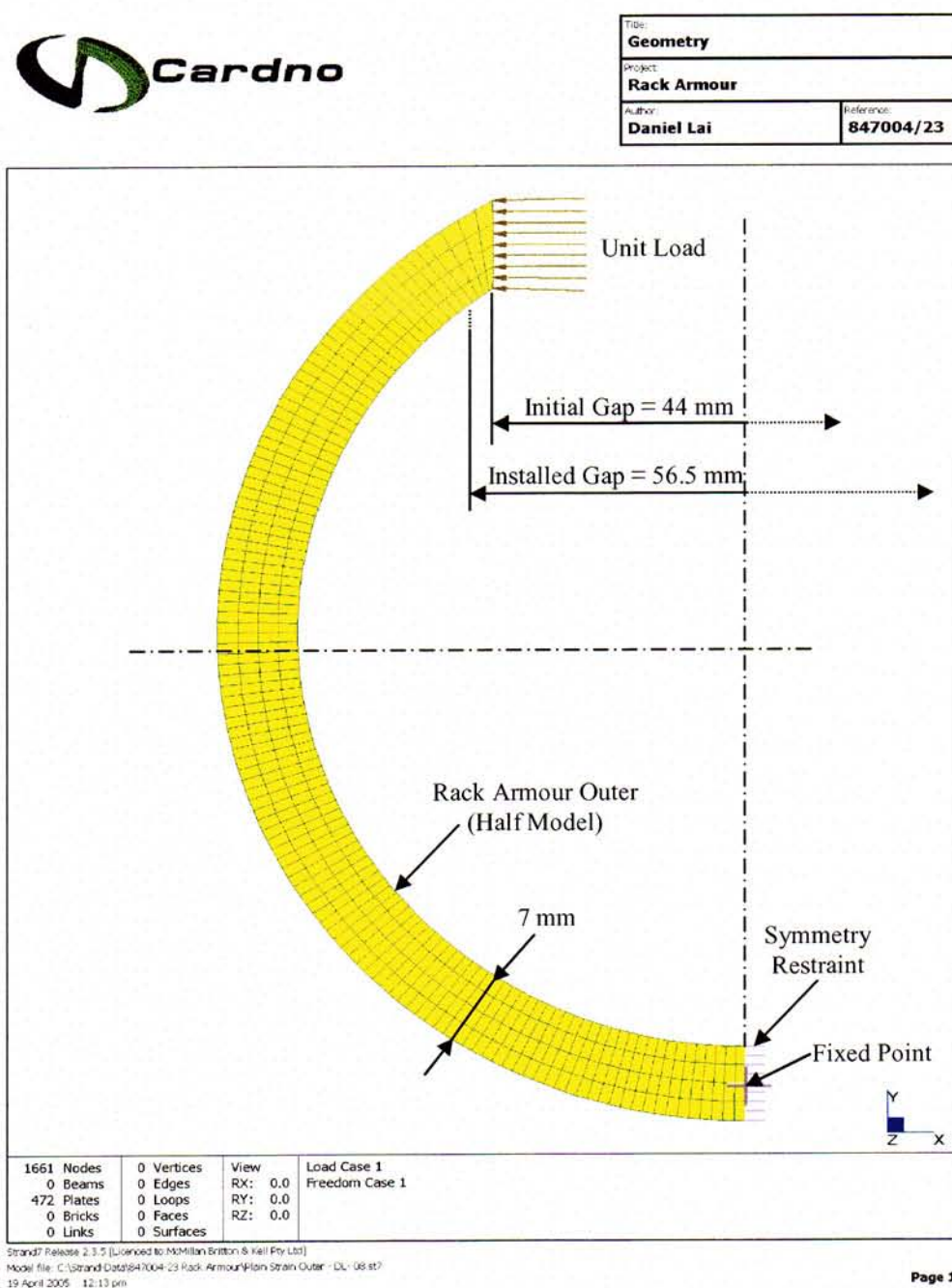


Figure 2. FEA model of the half-sectional Rack Armour outer

5.1 Element Types

The Rack Armour outer was modelled using 4 noded linear plane strain elements.

5.2 Restraints

The Rack Armour outer was provided with symmetry restraint along its symmetry line as well as a fixed point half way through the thickness of the material as shown in *Figure 2* (all translational and rotational movements were fixed). To represent plane strain behaviour, the global freedoms for this model only allowed translation along the X- and Y-direction and rotation about the Z-axis.

5.3 Material Properties

In accordance to material properties information courtesy from Rack Armour received via email on 4 April 2005

Rack Armour Outer (HDPE Plastic)		
Properties	Magnitude	Remarks
Young's Modulus, E	400 – 1000 MPa	Lower and Upper Bound
Tensile Strength	24.8 MPa	Yield D638
Poisson's Ratio, μ	0.35	For short term loading
Section Thickness	7 mm	

Table 4. Material Properties of Rack Armour outer

5.4 Loading

A unit uniformly distributed load was applied on the Rack Armour outer on the inside face of the contact zone with rack upright. The magnitude of this unit load was varied so that the gap between the aforementioned contact zones increased from an original 44 mm to 56.5 mm when installed on the upright.

5.5 Results

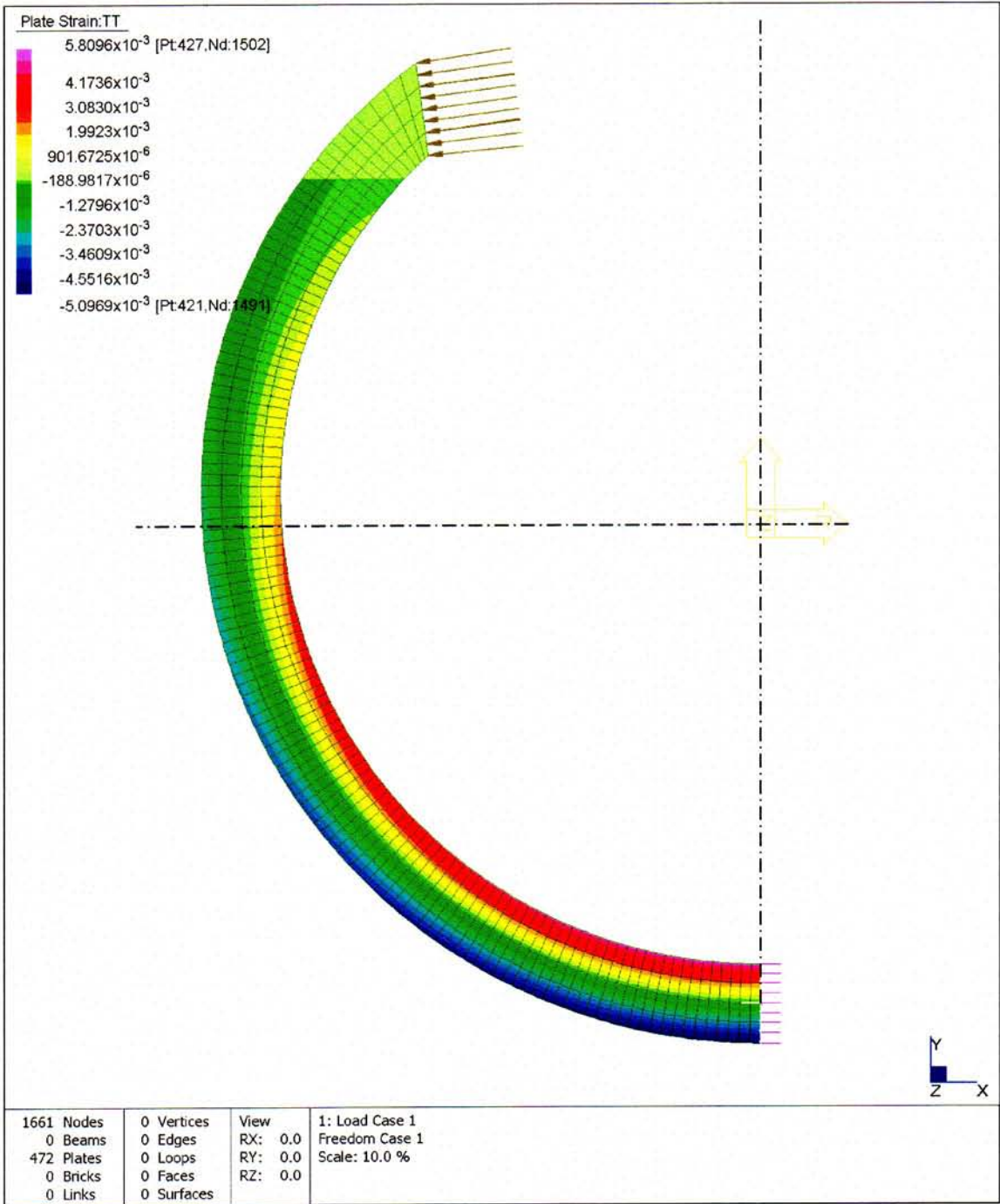
The hoop stresses for the Rack Armour outer for extension to a gap of 56.5 mm are tabulated in *Table 5*. It is noted that given there is a range of Young's Modulus values for the HDPE material, an upper and lower bound was investigated. *Figure 3* shows an image of the deformed Rack Armour outer due to snap fitting on to the rack upright.

Rack Armour Outer Young's Modulus (MPa)	Residual Hoop Stress (MPa)	
	Inside Face	Outside Face
400	2.77	- 2.55
1000	7.36	- 6.37

Table 5. Residual hoop stresses of the Rack Armour outer for extension to a gap of 56.5 mm (Tension positive)



Title: Deformed Rack Armour Outer	
Project: Rack Armour	
Author: Daniel Lai	Reference: 847004/23



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Model file: C:\Strand-Data\847004-23 Rack Armour\Plain Strain Outer - DL- 08.st7
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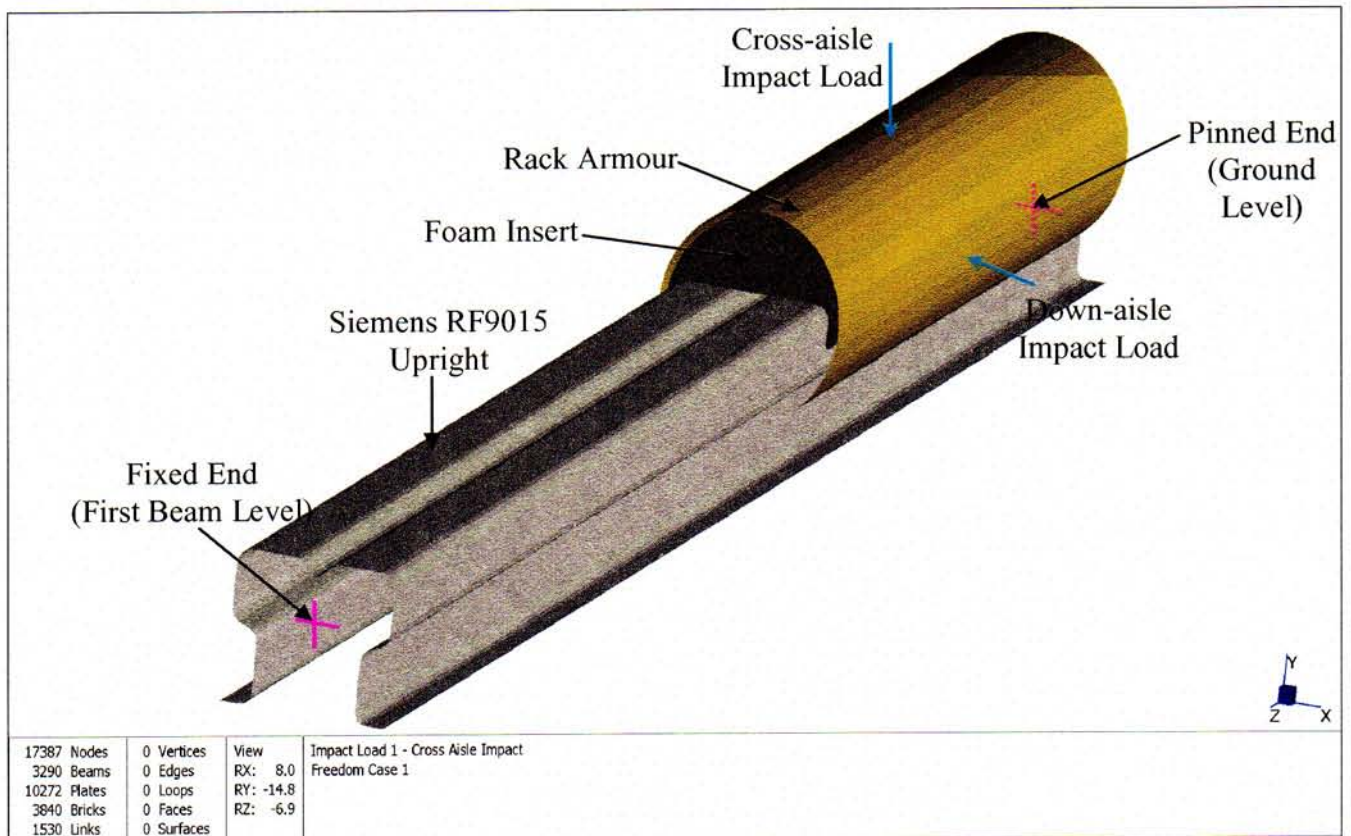
Figure 3. Deformed Rack Armour outer due to snap fitting onto the rack upright

6 STAGE 3 – RACK UPRIGHT WITH RACK ARMOUR INSTALLED

A FEA model of the Rack Armour assembly fitted onto the rack upright was created. The FEA software used was Strand 7 R2.3.5, 2004. The Rack Armour geometries were based on the CAD geometry provided and the upright geometries were based on a standard Siemens RF9015 upright. An image of the geometry of the FEA model is shown in *Figure 4*. The rack upright in this model is essentially the same as that adopted in Stage 1 of this report (refer *Section 4*).



Title: Geometry	
Project: Rack Armour	
Author: Daniel Lai	Reference: 847004/23



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Page 1

Figure 4. FEA model of the rack upright with Rack Armour for ultimate impact loads

6.1 Element Types

The Siemens RF9015 rack upright and the Rack Armour outer were modelled using 4 noded linear plate/shell elements whilst the foam insert was created using 8 noded linear brick elements. Point contact elements from foam-to-outer, foam-to-upright and upright-to-outer were created to simulate the contact zones between each of these components. Images of all the point contact elements used are shown in *Figure 5*. It is important to note that in order to investigate the worst case scenario for the Rack Armour, the friction associated with all of the point contact elements was set at zero

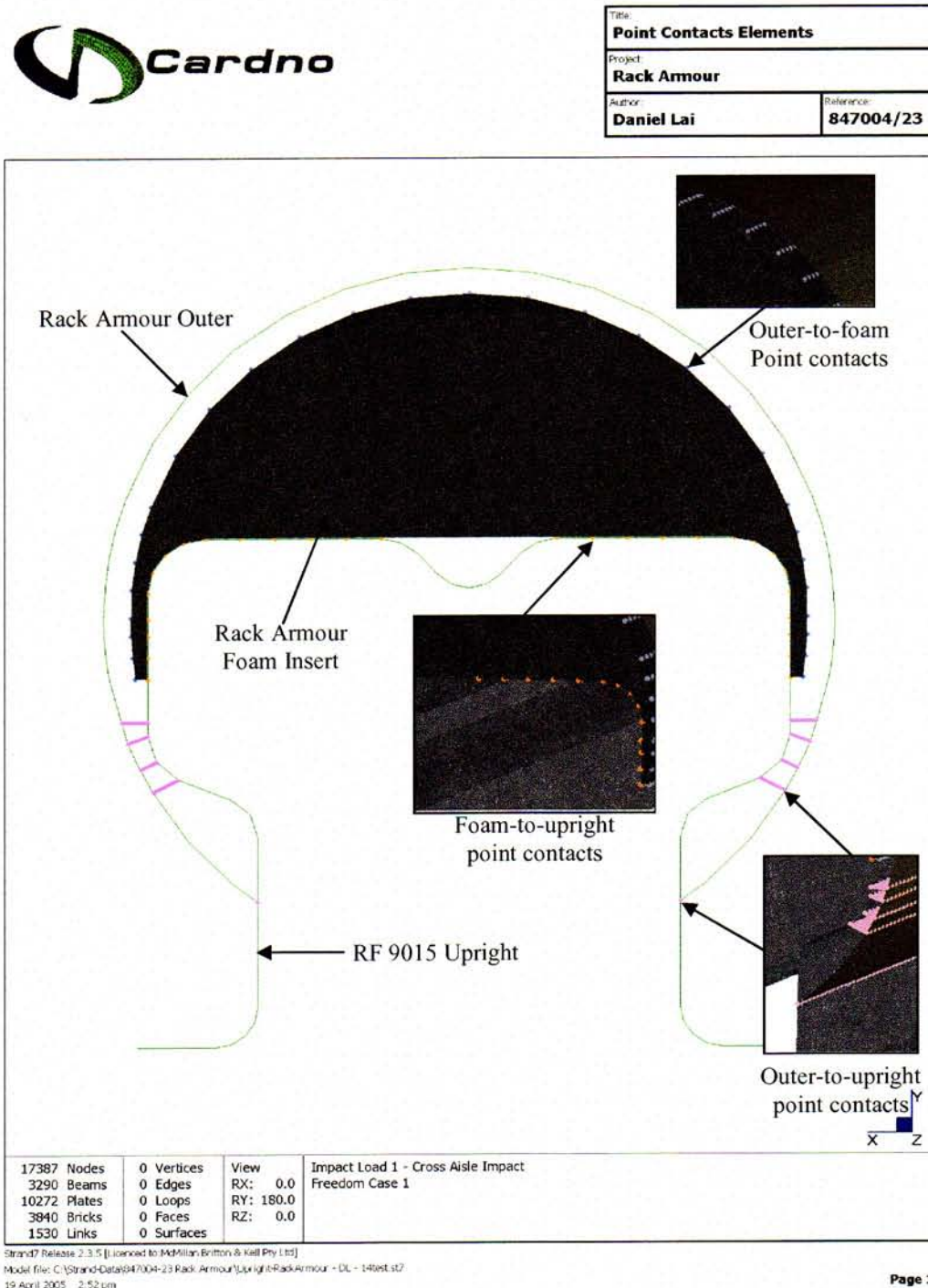


Figure 5. Point contact elements in the FEA model

6.2 Restraints

Restraints and rigid links for the rack upright were the same as for Stage 1 analysis (refer *Section 4*). In addition, given that the Rack Armour outer has a finite thickness, rigid links were used to connect the centreline of the outer to its inner contact surface. *Figure 6* shows an image of both types of rigid links of the FEA model.

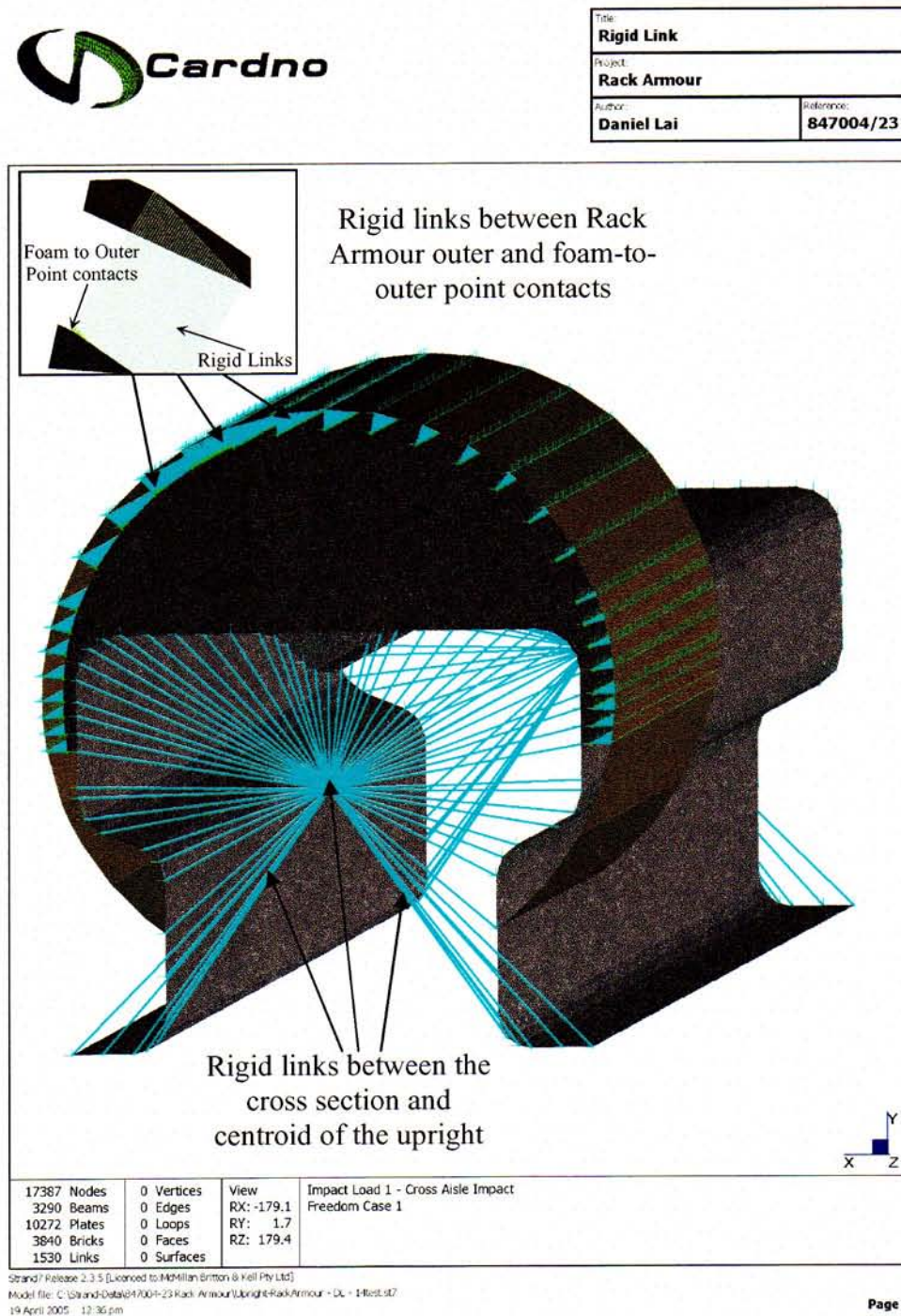


Figure 6. Rigid links of the model

Apart from the aforementioned rigid links, allowance had to be made to vertically restrain the Rack Armour outer and foam insert. If this restraint was not provided then a converged analysis solution would be difficult to obtain given that the friction for each of the point contact elements was zero. Accordingly a series of rigid beams was used to connect the restrained node at the base of the upright to all the nodes at the base of the Rack Armour outer and foam insert. It is noted that initially, rigid links were used in this application however the effect that these rigid links had was to over-restraint the base of the Rack Armour assembly. Hence rigid beams were used instead. The stiffness of these elements calibrated to ensure a converged solution yet not over restraint the base. *Figure 7* shows an image of rigid beams of the FEA model.

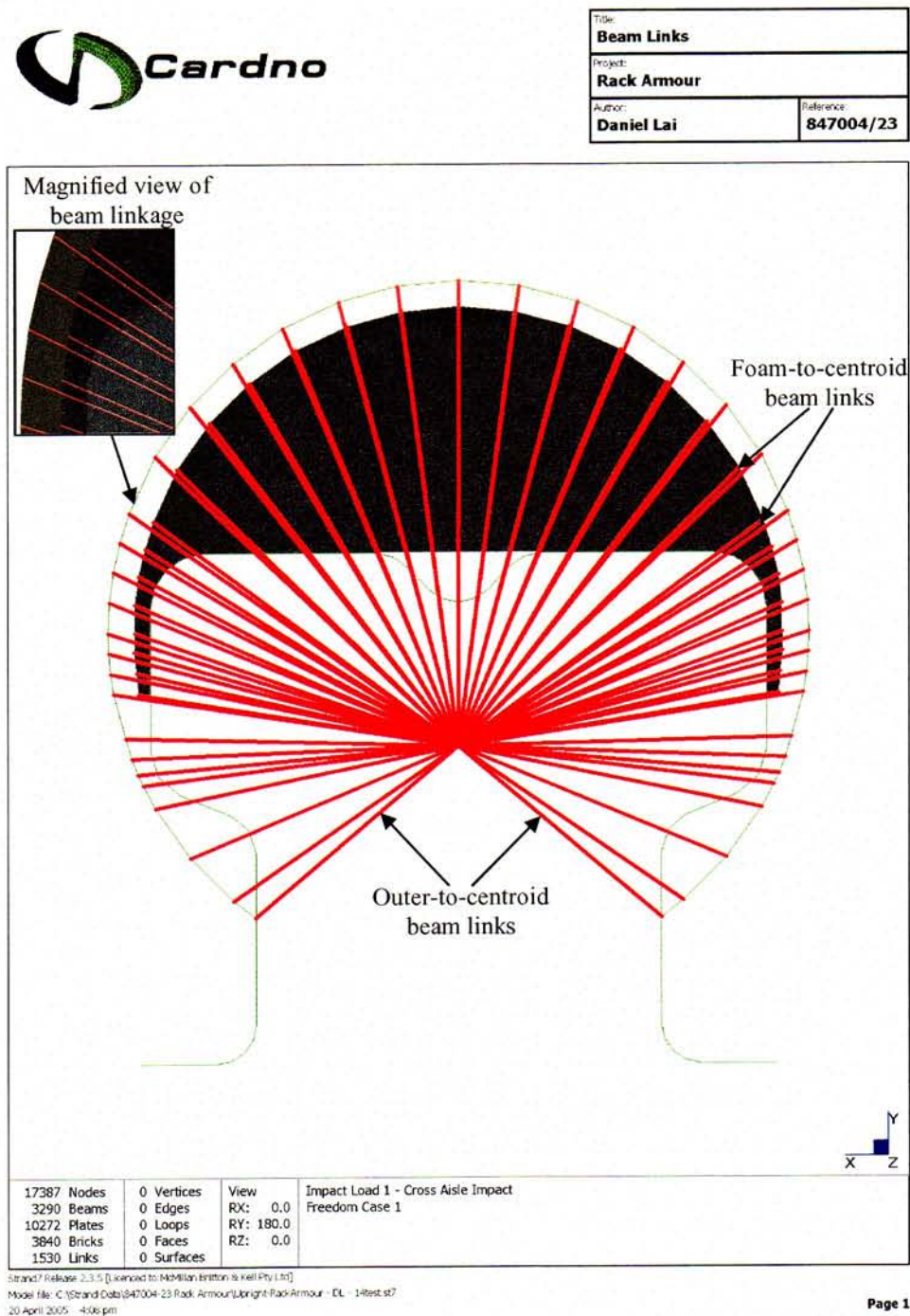


Figure 7. Rigid beams of the FEA model

6.3 Material Properties

In accordance to AS4100 – 1998, Steel Structures and material properties information courtesy from Rack Armour received via email on 4 April 2005

Siemens Colby RF9015 (Structural Steel)		
Properties	Magnitude	Remarks
Young's Modulus, E	200 GPa	Typical value for structural steel
Poisson's Ratio, μ	0.3	Typical value for structural steel
Beam Length	1.5 m	
Beam Thickness	0.0015 m	
Rack Armour Outer (HDPE Plastic)		
Properties	Magnitude	Remarks
Young's Modulus, E	400 – 1000 MPa	
Tensile Strength	24.8 MPa	Yield D638
Poisson's Ratio, μ	0.35	For short term loading
Section Length	0.6 m	
Section Thickness	0.007 m	
Foam Insert (Crossed-linked Polyethylene Foam)		
Properties	Magnitude	Remarks
Young's Modulus, E	0.26 MPa	Non-linear material characteristic
Tensile Strength	0.25 MPa	
Poisson's Ratio, μ	0.4	

Table 6. Material properties of the rack upright, Rack Armour outer and foam insert

Point Contact Elements	Contact Length (mm)	Average Contact Area (m^2)	Initial Stiffness (MN/m)	Remarks
Foam-to-Outer	0.1	0.101	29.0	Normal contact elements, Zero Friction
Foam-to-Upright	0.1	0.058	85.7	
Upright-to-Outer	0.13	0.009	29.3	

Table 7. Contact Stiffness of the non-linear point contact elements

Beam Links	Young's Modulus, E (GPa)	Poisson's Ratio, μ	Diameter (mm)	Remarks
Foam-to-Centroid	200	0.3	0.5	Circular cross section
Outer-to-Centroid	200	0.3	0.5	

Table 8. Properties of the beam links

It is noted that the Rack Armour foam insert exhibits non-linear material properties as shown in *Figure 8*. Given the potential for variation in this material is high, it was decided to investigate linear elastic material properties yet vary the elastic modulus up and down by one order of magnitude which is considered appropriate in this circumstance as the upper and lower bounds cover for the non-linearity in this material

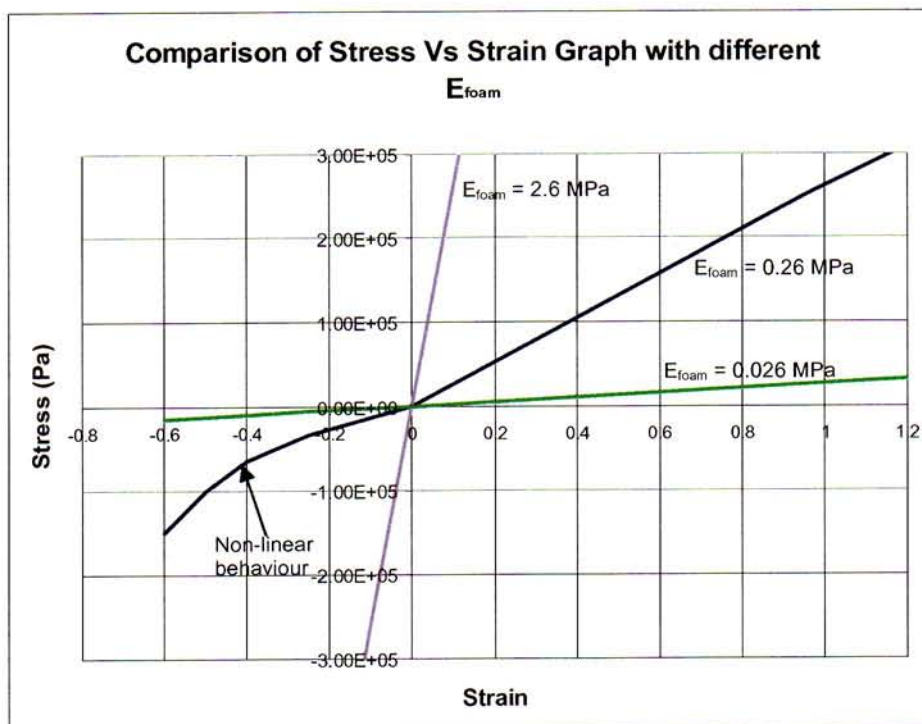


Figure 8. Stress against Strain Graph with different foam modulus of elasticity

6.4 Loading

To determine the effect on the rack upright with the Rack Armour assembly installed, non-linear point contact analysis (with linear geometry and linear elastic material) were undertaken with the loading conditions as stated in *Table 9*. All values are quoted in accordance with clause 2.6.2 of the Federation Europeenne De La Manutention FEM 10.2.02 Racking Design Code, April 2001 Version 1.02 and clause 4.2 of AS/NZS 1170.0:2002, Structural Design Actions, Part 0 : General Principles.

Ultimate Load Case	Orientation	Load Magnitude, L (kN)	Load Factor	Ultimate Load Magnitude, UL = $L \times E_d$ (kN)	Load Height above ground, h (m)
1	Down-aisle	1.25	1.5	1.875	0.4
2	Cross-aisle	2.5	1.5	3.75	0.4

Table 9. Magnitude and location of the ultimate loads applied on the rack upright with Rack Armour installed

6.5 Results

Comparison of stresses on the rack upright with and without the Rack Armour installed for ultimate impact load in the cross- and down-aisle directions are tabulated in *Table 10* and *11*. Stresses were determined on the rack upright with different Rack Armour outer and foam insert modulus of elasticity. The analysis investigated the Rack Armour outer modulus of elasticity ranging from 400 to 1000 MPa and the foam insert modulus of elasticity ranging from 0.026 to 2.6 MPa. Images of the deformed Rack Armour subjected to ultimate cross- and down-aisle impact loads are shown in *Figure 9* and *10*.

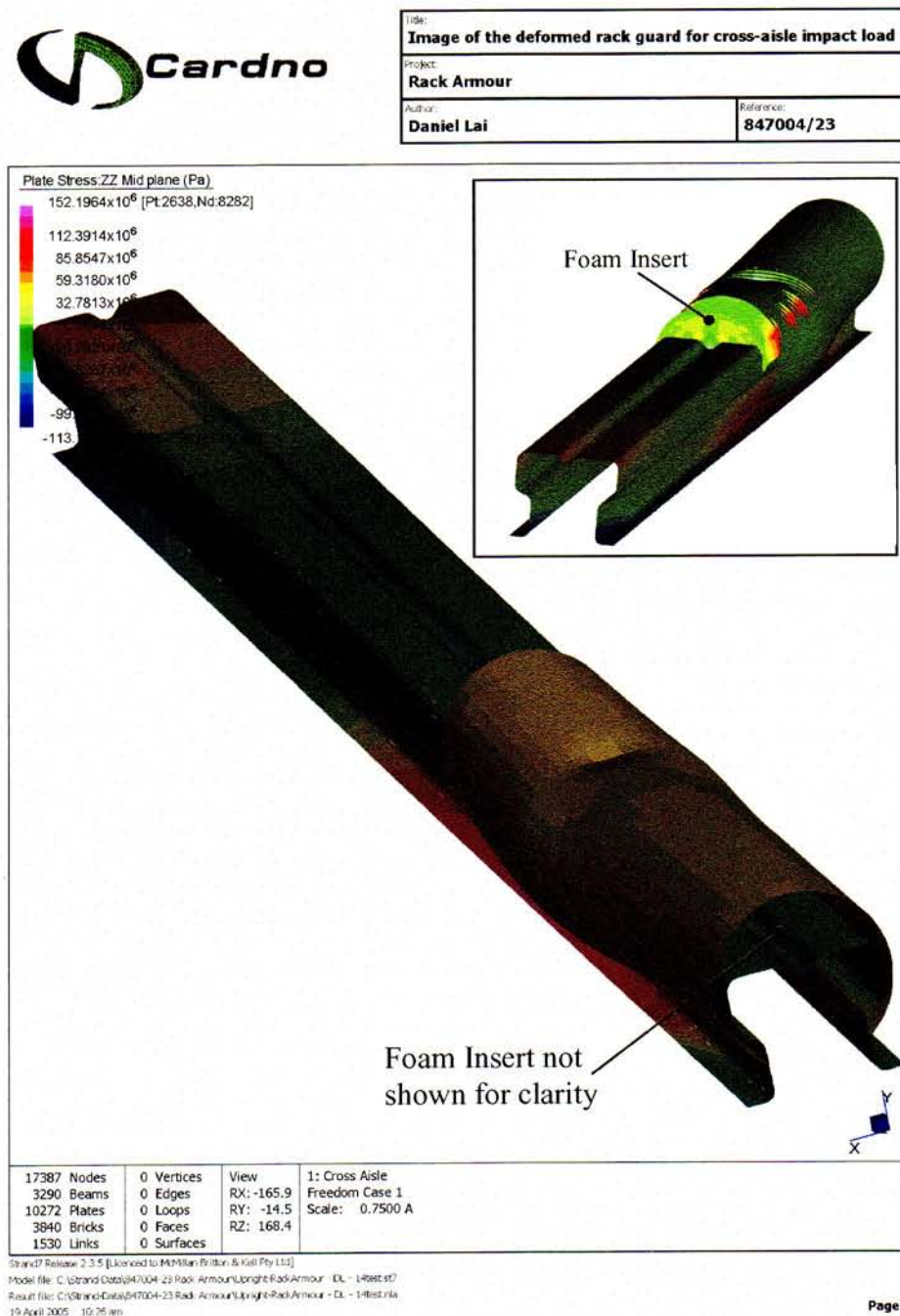


Figure 9. Deformed Rack Armour subjected to ultimate cross-aisle load



Title: Image of the deformed rack guard for down-aisle impact load	
Project: Rack Armour	
Author: Daniel Lai	Reference: 847004/23

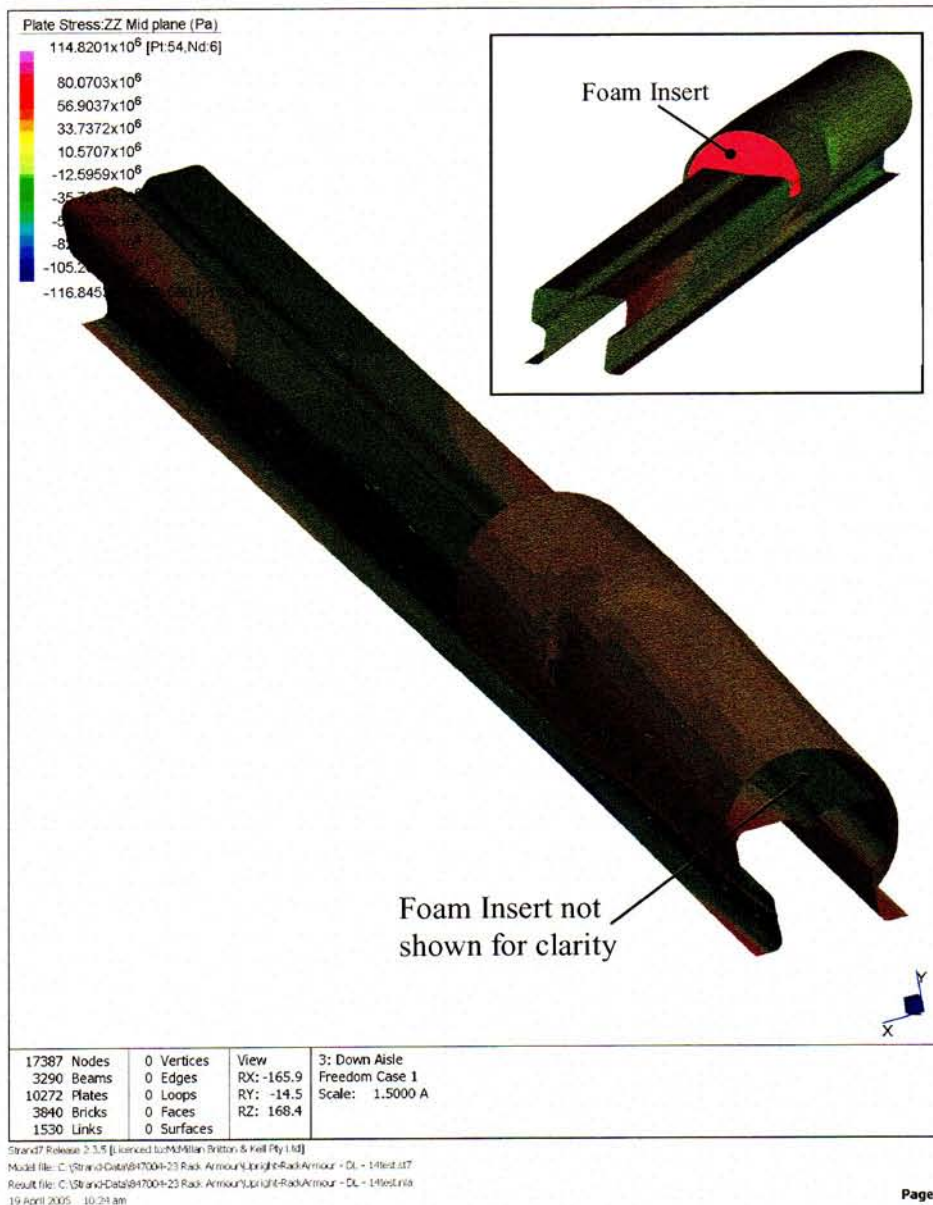


Figure 10. Deformed Rack Armour subjected to ultimate down-aisle load

6.5.1 Upright Vertical Stress Comparison

Examination of *Tables 10* and *11* indicate that when the Rack Armour is installed, the vertical stresses in the upright are equal to (within 2%) or less than the case when the upright is on its own. This is with the exception of the stresses determined at a height of 0.6 m for cross-aisle loading. At this height the vertical stresses on the upright with the Rack Armour installed are up to 33% greater than when the Rack Armour is not installed. The primary reason for this is that the Rack Armour provides additional flexural stiffness to the upright (as the centroid of the Rack Armour outer is eccentric to the upright) unlike the down-aisle case thereby creating a hard point at the location where the Rack Armour terminates. It is noted that this effect is not observed in the down-aisle direction as the centroid of the Rack Armour outer and the upright coincide.

Whilst there is an increase in upright vertical stresses at $h = 0.6$ m its impact on overall upright design can be ignored. The reason for this is that the magnitude of the vertical upright stresses induced at $h = 0.6$ m is less than that at $h = 0.4$ m even with the Rack Armour installed. The upright design would be based on the stresses at $h = 0.4$ m combined with whatever vertical loads are placed on the upright at that time.

Load Case 1 - Ultimate Cross Aisle Impact Load

Load height above ground, h (m)			0.4		0.6		1.5		Maximum Vertical Stress (MPa)
Rack upright with Rack Armour	E _{Rack Armour} (MPa)	E _{Foam} (MPa)							
	400	0.026	128.6	-63.7	114.4	-63.6	70.7	-110.0	
		0.26	137.0	-81.5	117.5	-60.2	71.1	-110.8	
		2.6	151.1	-107.7	119.3	-51.0	71.9	-111.6	
	1000	0.026	126.9	-74.0	113.5	-64.0	70.7	-109.9	
		0.26	131.9	-76.8	115.7	-62.5	70.8	-110.4	
		2.6	142.4	-91.8	117.8	-56.6	71.4	-111.1	
Rack upright without Rack Armour	E _{upright} (GPa)		148.5	-169.4	109.0	-48.1	70.7	-115.6	
	200								

Table 10. Comparison of stresses experienced by rack upright with and without Rack Armour for ultimate impact loads in the cross-aisle direction (Tension positive)

Load Case 2 - Ultimate Down Aisle Impact Load

Load height above ground, h (m)			0.4		0.6		1.5		Maximum Vertical Stress (MPa)
Rack upright with Rack Armour	E _{Rack Armour} (MPa)	E _{Foam} (MPa)							
	400	0.026	46.0	-86.7	45.4	-35.1	49.0	-49.2	
		0.26	48.2	-87.3	45.4	-36.5	48.0	-48.1	
		2.6	58.8	-92.8	45.6	-37.2	47.8	-48.0	
	1000	0.026	45.1	-83.5	45.4	-36.1	49.7	-49.8	
		0.26	47.0	-86.1	45.3	-36.4	48.0	-48.2	
		2.6	49.7	-88.0	45.5	-37.4	47.9	-48.0	
Rack upright without Rack Armour	E _{upright} (GPa)		62.8	-134.7	57.5	-45.0	49.2	-49.3	
	200								

Table 11. Comparison of stresses experienced by rack upright with and without Rack Armour for ultimate impact loads in the down-aisle direction (Tension positive)

6.5.2 Rack Armour Outer Stress

In order to appropriately evaluate the results of the FEA analysis for Stage 3, one must consider the results of Stage 2 for the residual stresses introduced by the snap fit connection of the Rack Armour outer to the rack upright.

The limiting yield stress for the Rack Armour outer is defined by $\phi f_y = 0.7 \times 24.8$
= 17.36 MPa

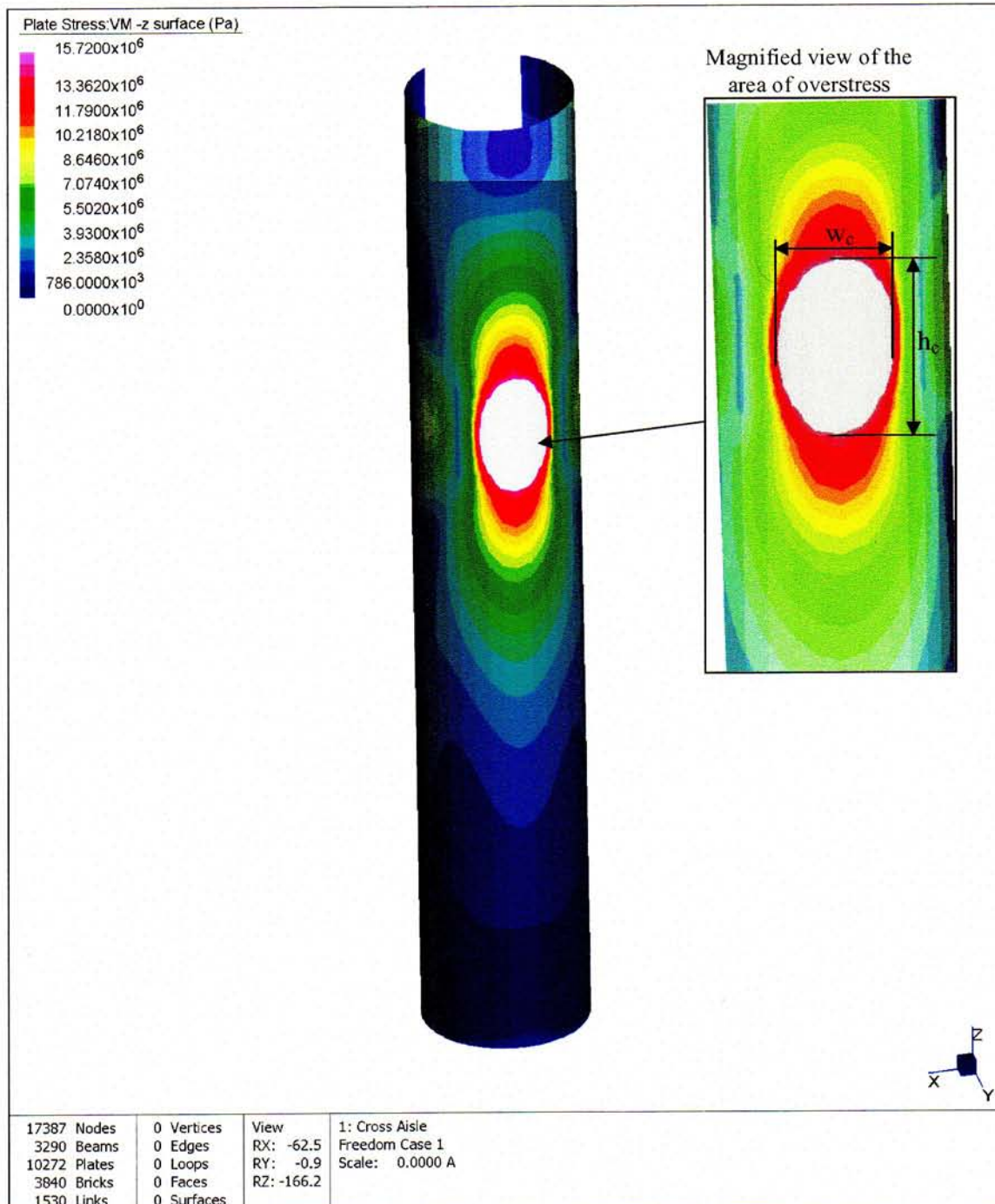
The worst case maximum stress introduced by the snap fit connection = 7.36 MPa

Therefore the limiting combined stress = $(17.36^2 - 7.36^2)^{1/2}$
= 15.72 MPa.

Images of the area of overstress due to cross- and down-aisle impact load is shown in *Figure 11* and *12* respectively. *Table 12* identifies the magnitude of the areas of overstress when compared to the limiting combined stress of 15.72 MPa. Examination of this table indicates that for both load cases irrespective of the material properties used, some form of plastic deformation could potentially occur under the ultimate impact load. Notwithstanding it could be argued that the actual impact load is applied over a defined area different to that in the FEA model when it is applied as a nodal point load to the Rack Armour outer. AS/NZS 1170.0:2002, Structural Design Actions, Part 0: General Principles does provide some guidance in this regard as stated in clause 3.2(b), Point load area of 0.01m^2 however Federation Europeenne De La Manutention FEM 10.2.02 Racking Design Code, April 2001 Version 1.02 does not. If the rules of AS1170.0:2002, Structural Design Actions, Part 0: General Principles are applied then the zones of overstress could essentially be averaged out and peak stresses potentially decreased down to acceptable levels.



Title: Rack Armour Outer Stresses - Cross-aisle Load	
Project: Rack Armour	
Author: Daniel Lai	Reference: 847004/23



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Result file: C:\Strand-Data\847004-23 Rack Armour\Upright-Rack Armour - DL - 14test.rla
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Figure 11. Area of overstress due to cross-aisle load



Title: Rack Armour Outer Stresses - Down-aisle Load	
Project: Rack Armour	
Author: Daniel Lai	Reference: 847004/23

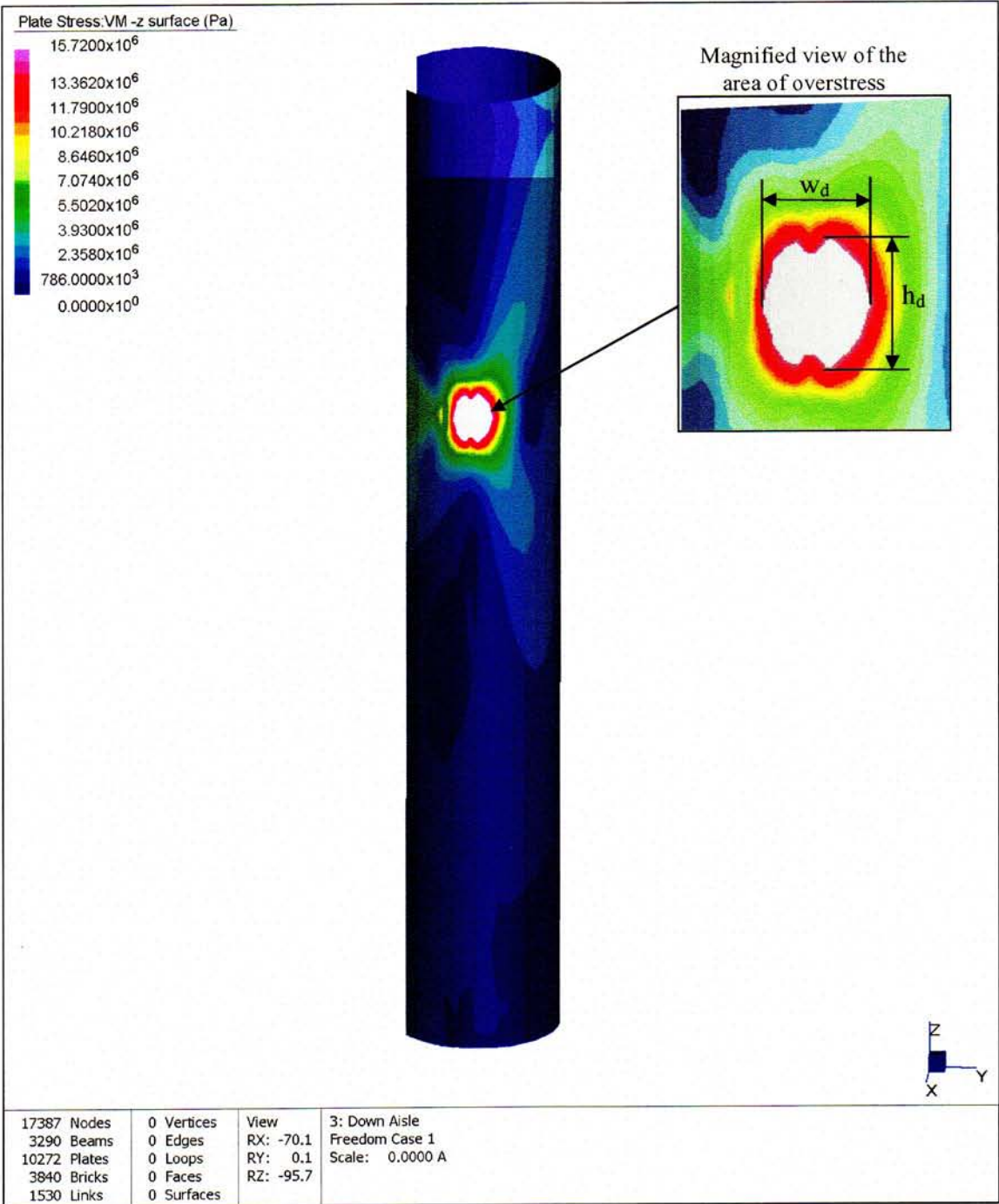


Figure 12. Area of overstress due to down-aisle load

Orientation of ultimate impact load applied			Area of overstress > ϕf_y					
			Cross-aisle			Down-aisle		
Rack Armour	$E_{\text{Rack Armour}}$ (MPa)	E_{Foam} (MPa)	Height, h_c (mm)	Width, w_c (mm)	Area (m^2)	Height, h_d (mm)	Width, w_d (mm)	Area (m^2)
	400	0.026	113	50	0.006	50	29	0.001
		0.26	75	50	0.004	38	26	0.001
		2.6	50	33	0.002	25	17	0.0004
	1000	0.026	138	50	0.007	50	32	0.002
		0.26	100	50	0.005	38	26	0.001
		2.6	63	42	0.003	25	21	0.0005

Table 12. Area of overstress with different Rack Armour and foam modulus of elasticity for ultimate impact load in the cross- and down-aisle directions.

6.5.3 Rack Armour Foam Insert Stresses

Comparison of stresses on the Rack Armour foam insert for ultimate impact load in the cross- and down-aisle directions are tabulated in Table 13. Stresses were determined on the foam insert with different Rack Armour outer and foam insert modulus of elasticity. The analysis investigated the Rack Armour outer modulus of elasticity ranging from 400 to 1000 MPa and the foam insert modulus of elasticity ranging from 0.026 to 2.6 MPa.

Examination of Table 13, the magnitude of the Von Mises stress of the foam insert increased as the Rack Armour outer and foam insert become stiffer. Therefore the degree of stress experienced by the foam insert is dependent on the modulus of elasticity of the Rack Armour outer and foam insert. In addition, as the tensile strength of the foam insert is in the order of 250 kPa, there is the potential that the foam insert will be permanently damaged if the Rack Armour assembly is required to resist the full ultimate impact.

Orientation of ultimate impact load			Cross-aisle	Down-aisle	
Rack Armour Foam Insert	$E_{\text{Rack Armour}}$ (MPa)	E_{Foam} (MPa)			
	400	0.026	0.22	0.16	Von Mises Stress (MPa)
		0.26	0.32	0.73	
		2.6	0.98	2.74	
	1000	0.026	0.25	0.10	
		0.26	0.32	0.42	
		2.6	0.67	1.70	

Table 13. Von Mises stresses of Rack Armour foam insert with different Rack Armour and foam insert modulus of elasticity for ultimate impact loads in the cross- and down-aisle directions

7. Conclusions and Recommendations

Cardno have undertaken a finite element analysis of the Rack Armour pallet racking upright protection system. The purpose of the analysis was to determine if the 106 mm Rack Armour assembly aids in resisting impact loads on 90 mm wide rack uprights as defined by Federation Europeenne De La Manutention FEM 10.2.02 Racking Design Code, April 2001 Version 1.02. Our analysis investigated both cross- and down-aisle impact loads, the effects of snap fit connection between the Rack Armour assembly and the upright as well as variations in material properties for the Rack Armour outer and foam insert. Based on the results of our analysis, we conclude the following:

- The Rack Armour assembly assists the rack upright in resisting the applied ultimate impact loads. For either cross- or down-aisle impact loads the stresses upon which rack uprights are designed are reduced when the Rack Armour assembly is used.
- There is a potential for the Rack Armour outer to become plastically deformed during the application of the impact load. However the extent of plastic deformation (if any) is dependent on the area over which the impact load is applied. Neither AS/NZS1170.0:2002, Structural Design Actions, Part 0: General Principles or Federation Europeenne De La Manutention FEM 10.2.02 Racking Design Code, April 2001 Version 1.02 clearly define this area.
- The magnitude of stress experienced by the Rack Armour foam insert is dependent on the how stiff the Rack Armour outer and foam insert are for either cross- or down-aisle impact loads. There is also a potential for the foam insert to be permanently damaged as a result of the ultimate impact load.

Based on the above conclusions we recommend the following:

- The 106 mm Rack Armour assembly is suitable for use in either selective, pick module or drive-in rack applications to assist in resisting impact loads defined by Federation Europeenne De La Manutention FEM 10.2.02 Racking Design Code, April 2001 Version 1.02 for 90 mm wide uprights.
- Given that there is a potential for plastic deformation of either the Rack Armour outer or foam insert, rack owners should be advised that as a part of their statutory requirement to regularly inspect rack installations and their associated components, should either the Rack Armour outer or foam insert be permanently deformed such that the deformation is easily identifiable by eye or the Rack Armour becomes significantly loose on the upright then the damaged component should be replaced.

We trust that the above information is suitable for you current requirements. Should you have any questions, please do not hesitate to contact the undersigned.

Yours sincerely,

A handwritten signature in black ink, appearing to read 'David Beneke', followed by a horizontal line.

David Beneke
Principal
for Cardno