April 3, 2006

# Javelin Analysis Services

Prepared for:
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## Objective

Based on the result of applied Finite Element principles to the EMSEAL assembly, this report will provide detailed engineering information on the following components;

- The cover plate of the EMSEAL Joint System
- The Spine plate and pin of the EMSEAL Joint System
- The Stainless Steel screws fastening the cover plate into place

## Approach

Two studies are used to compute the required results. In the first, a non-linear study is created to compute the displacement of the cover plate and the stresses that will be developed from the applied loads in the cover plate. This is controlled by the characteristics of the "impregnated expanding foam" (a hyper-elastic material). This study is simplified to eliminate contact conditions that would complicate results. The non-linear study only considers one section of the cover plate and spine with the "impregnated expanding foam". The screw fasteners and spine pin were not included in this study.

Once the displacement of the plate is computed from the interaction of the foam against the spine, a second study (using Linear Analysis) was used to calculate the stresses in the spine pin, shear and axial loads on the screws fastening the cover plate to the spine.

### *Assumptions*

1. The hyper-elastic material behaves as non-linear elastic material. The stress strain curve of the material was provided by the Client and simplified to the curve shown in Figure 1 (symmetrical in tension and compression).
2. The screws are not under any preload.
3. There is no friction preventing the cover plate from sliding against the elastomeric concrete.
4. The spine and "impregnated expanding foam" resist the applied shear loads; in other words, the spin and the interaction of the spine to the hyper elastic material will control the sliding of the cover plate.
5. Screw spacing is 4 screws per 5 feet.

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6. Length of spine and cover are both 64 inches.
7. Pin to spine fit were size-on-size.

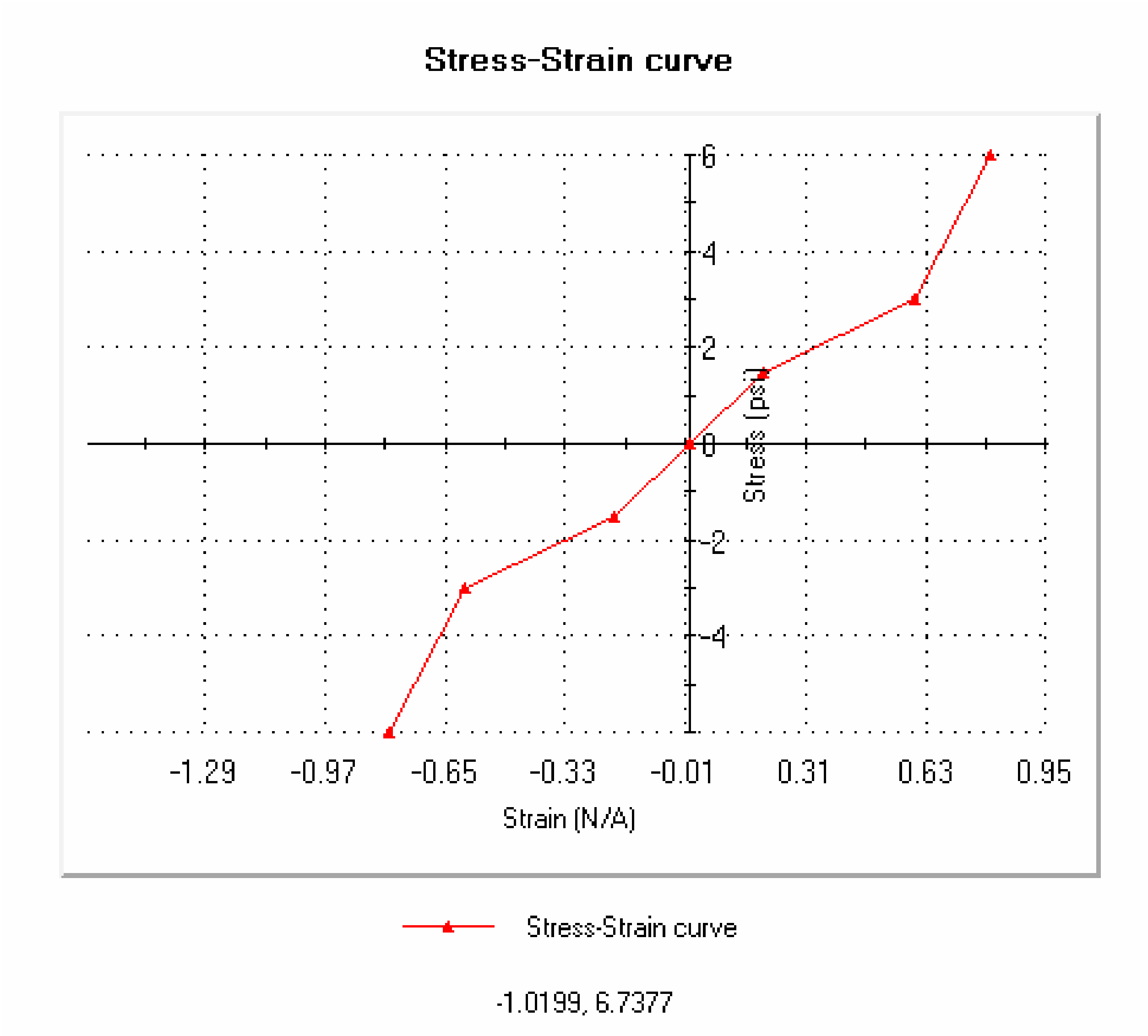


**Figure 1, Stress –Strain Curve**

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### *Given Parameters*

1. The heaviest normal load to the cover plate is 4000 lb (represents the weight of an average vehicle).
2. Using a conservative approach to the normal force created by a traversing vehicle, a friction factor of .2 was used resulting in an 800 lb tangential load (this load works in shear against the screws.

## Defined Loads and Constraints

Two mathematical models had to be developed to meet the computational requirements. The first was a non-linear model to produce the displacements that would be used in the second linear study. The two load cases are as follows;

1. Non linear load case

For the non-linear load case the "impregnated expanding foam" must initially be in compression (2 psi). This required a time step approach. In the first time step the foam was compressed to the point indicated on the stress-strain curve (2 psi). The loads were applied in a second time step once the compression was stabilized. This procedure did not duplicate the foam behavior exactly according to the stress-strain curve, however, results are believed accurate enough for the purposes of this study.

This mathematical model is shown below.

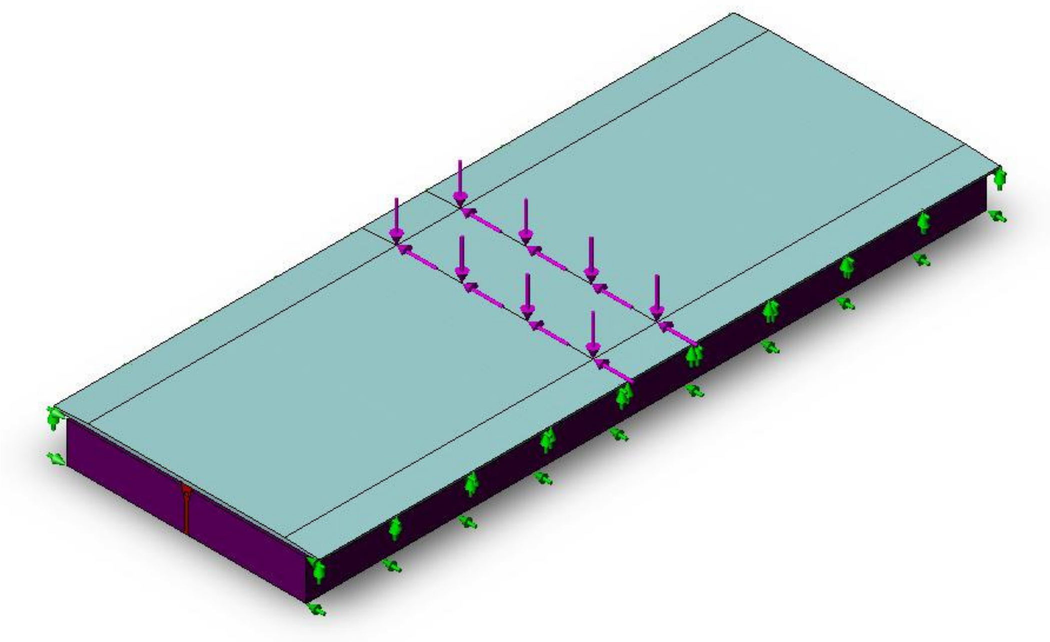

**Figure 2, Non Linear Model, Applied Loads and Constraints**

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2. Linear load case

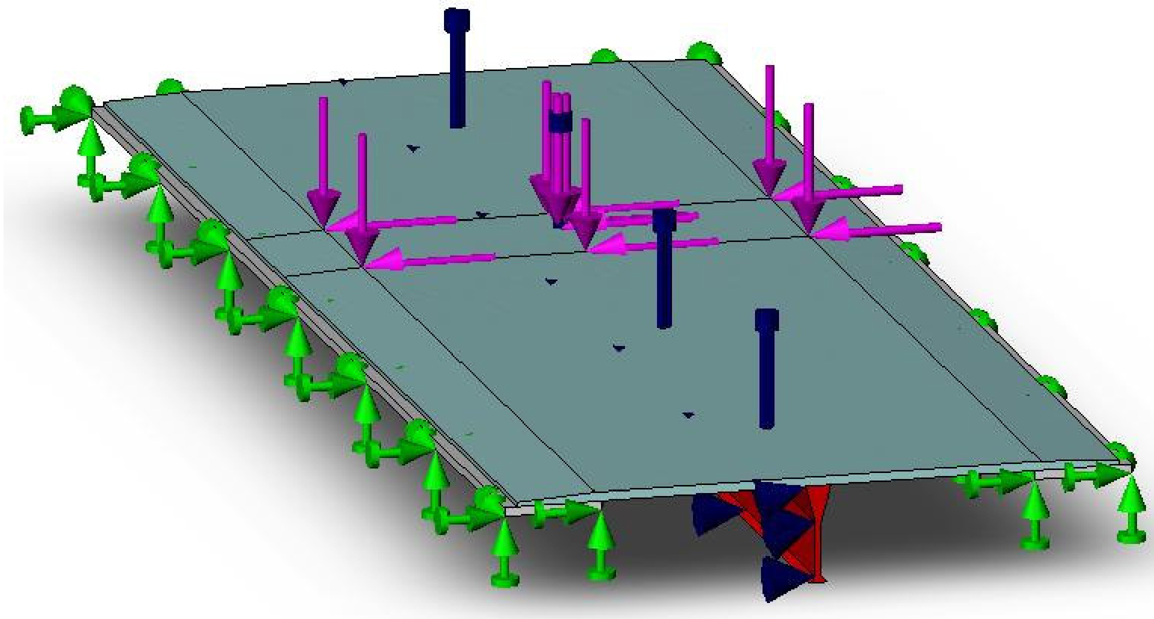

**Figure 3, Linear Model, Applied Loads and Constraints**

| | |
|---|---|
| Green Arrows | -Restraints applied to the elastomeric supporting concrete in all directions. |
| Magenta Arrows | -Loads as defined above (Given Parameters). |
| Blue Bolts | -Bolted connections representing the stainless steel screws without preload. |
| Blue Cones | -Applied Linear Springs to simulate the “impregnated expanding foam”. |

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## Mesh Results

1. Non–Linear Study

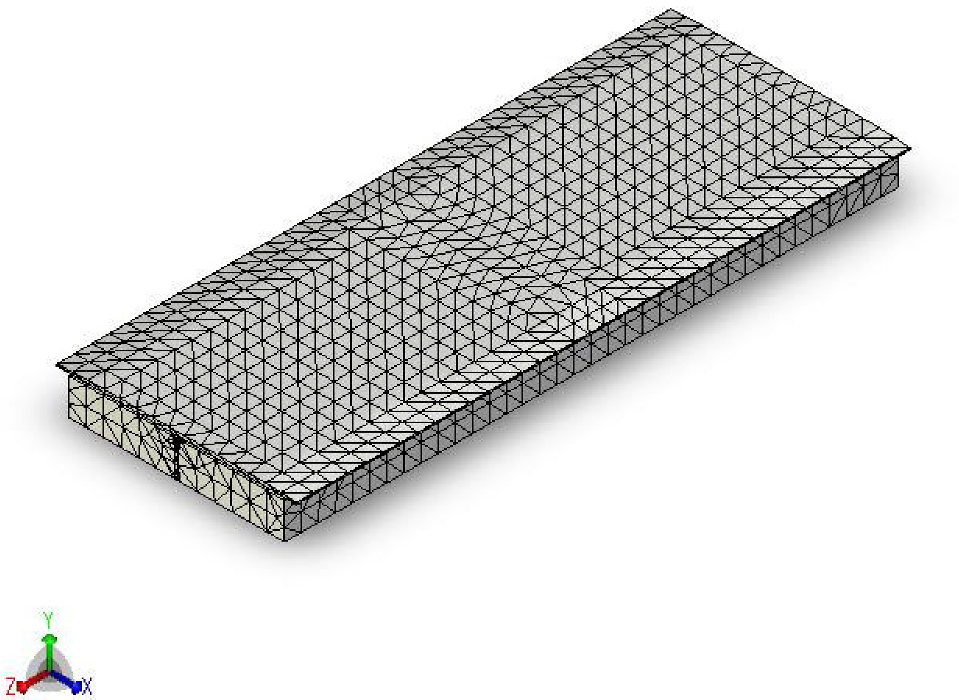


**Figure 4, Non-Linear Study Mesh Geometry**

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2. Linear Study

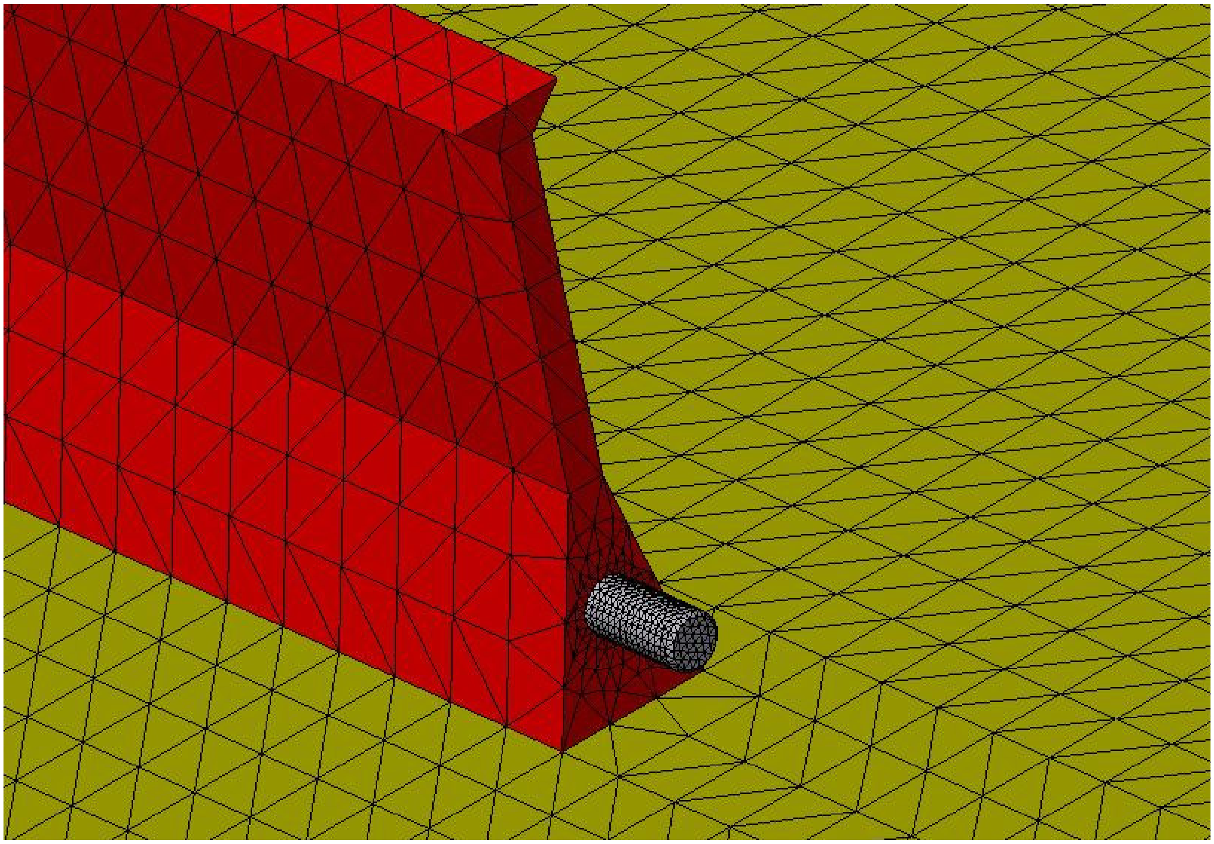

**Figure 5, Mesh Geometry**

1. Cover plate and spine shown in gold and red respectively has a maximum mesh size of .75 inches. The mesh looked very consistent and did not distort part geometry.
2. The spine pin is shown in gray and has a maximum mesh size of .1". Mesh controls had to used here to produce competent mesh geometry.

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## Results

1. Non-Linear Study
    a. Von Mises Plot of Simplified Assembly

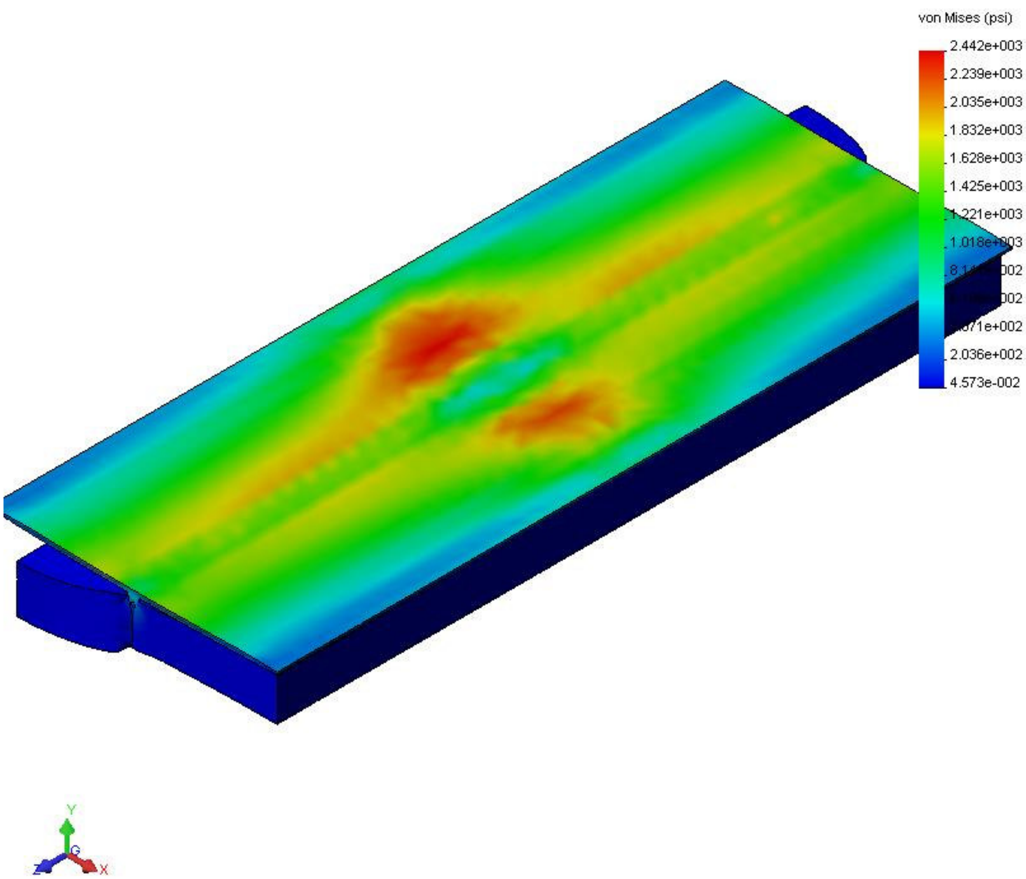


**Figure 6, Non Linear Stress Plot**

b. Von Mises Plot of Spine

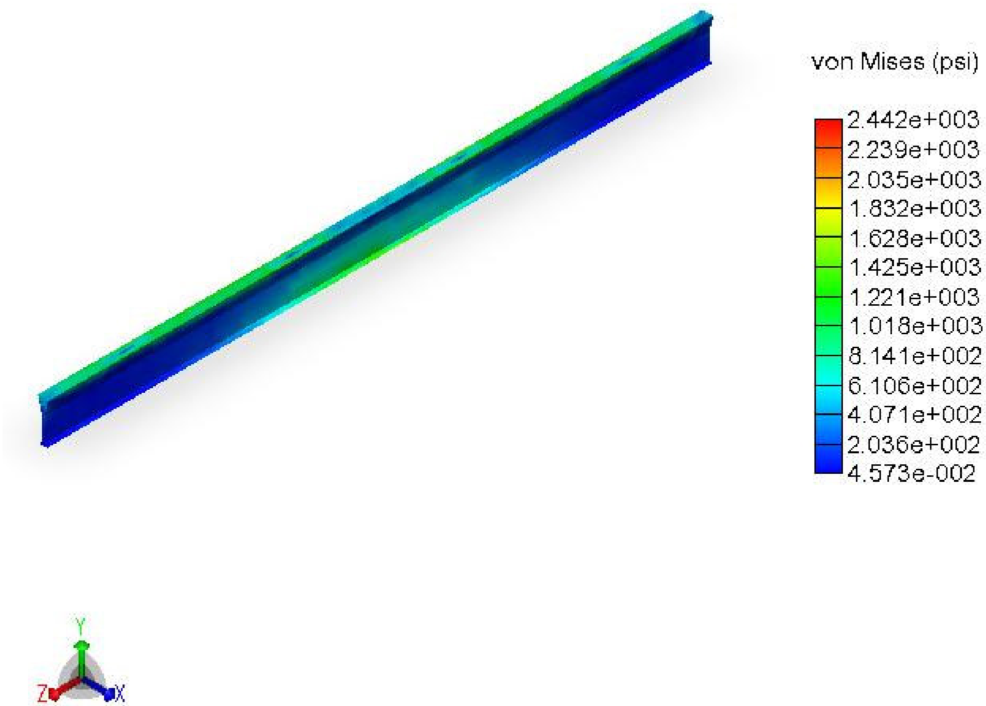


**Figure 7, Non-Linear Stress Plot of Spine**

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c. Displacement Plot of Simplified Assembly

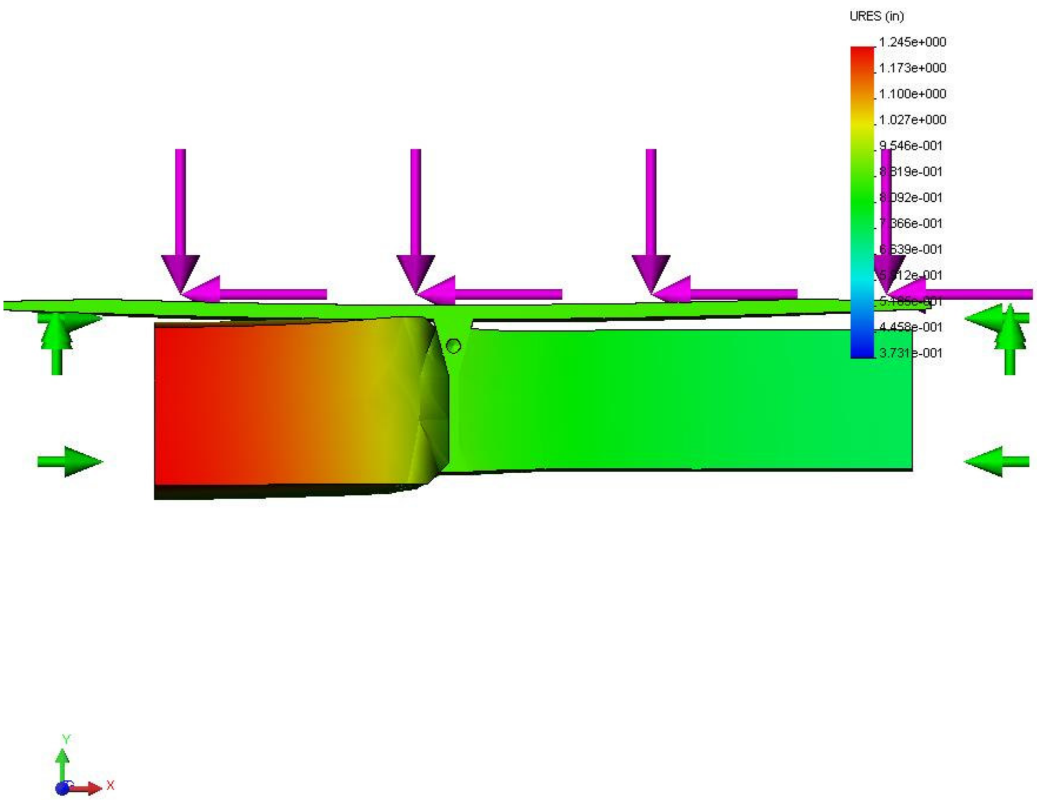


**Figure 8 , Non Linear Displacement Plot**

Maximum displacement of cover plate - .7 inches (assuming no friction)

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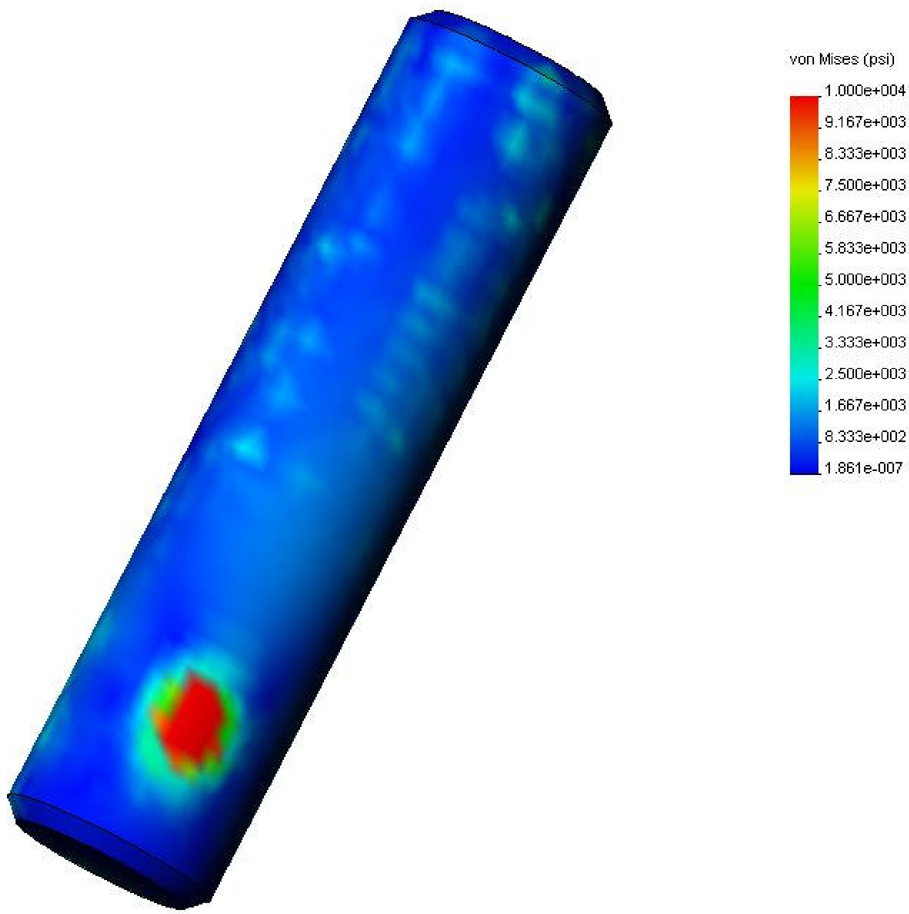
2. Linear Study

   a. Spine Pin

      i. Contact 1




ii.

**Figure 9, Spine Pin shown in Von Mises Stress Plot, Contact 1**

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iii. Contact 2

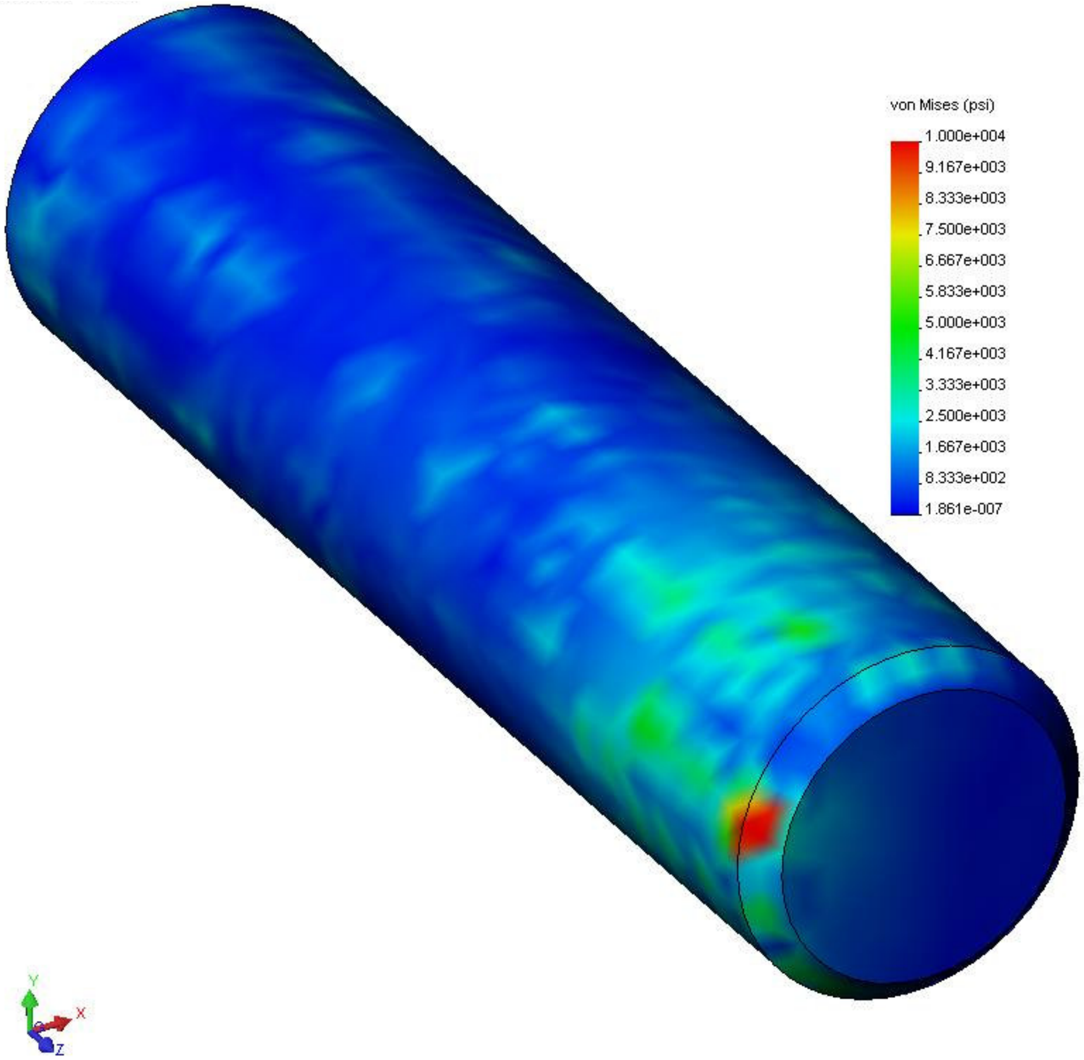


**Figure 10, Spine Pin shown in Von Mises Stress Plot, Contact 2**

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b. Spine Contacts

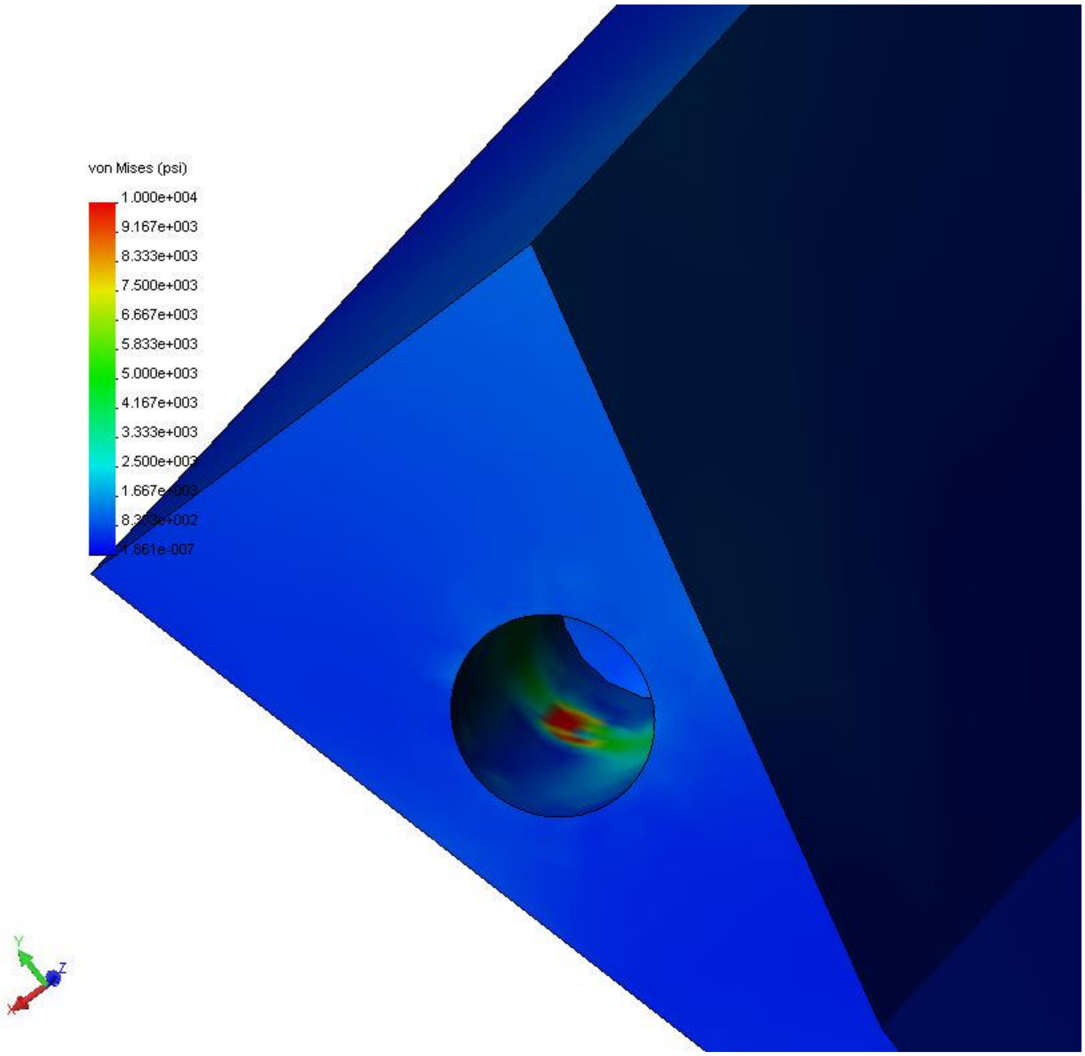


**Figure 11, Resulting contact stresses on spine pin bore**

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## Fastened Connections

| | | | | |
|---|---|---|---|---|
| Study name: Study 4 | | | | |
| Bolt: Bolt Connector-17 | | | | |
| | | | | |
| | | | | |
| Type | X-Component | Y-Component | Z-Component | Resultant |
| Shear Force (lb) | -24.69 | 1.5009 | 41.642 | 48.434 |
| Axial Force (lb) | 8.13E-07 | 129.95 | -4.684 | 130.04 |
| Bending moment (lb-in) | -15.914 | -0.38467 | -10.672 | 19.165 |

| | | | | |
|---|---|---|---|---|
| Study name: Study 4 | | | | |
| Bolt: Bolt Connector-18 | | | | |
| | | | | |
| | | | | |
| Type | X-Component | Y-Component | Z-Component | Resultant |
| Shear Force (lb) | -41.741 | 1.5716 | 43.602 | 60.382 |
| Axial Force (lb) | 7.35E-07 | 199.08 | -7.1756 | 199.21 |
| Bending moment (lb-in) | -16.788 | -0.64627 | -17.93 | 24.571 |

| | | | | |
|---|---|---|---|---|
| Study name: Study 4 | | | | |
| Bolt: Bolt Connector-19 | | | | |
| | | | | |
| | | | | |
| Type | X-Component | Y-Component | Z-Component | Resultant |
| Shear Force (lb) | -55.132 | -0.38285 | -10.622 | 56.147 |
| Axial Force (lb) | 3.45E-07 | 42.74 | -1.5405 | 42.768 |
| Bending moment (lb-in) | 4.1676 | -0.77829 | -21.593 | 22.005 |

| | | | | |
|---|---|---|---|---|
| Study name: Study 4 | | | | |
| Bolt: Bolt Connector-20 | | | | |
| | | | | |
| | | | | |
| Type | X-Component | Y-Component | Z-Component | Resultant |
| Shear Force (lb) | -78.437 | -1.7509 | -48.578 | 92.277 |
| Axial Force (lb) | 1.80E-06 | 350.8 | -12.644 | 351.03 |
| Bending moment (lb-in) | 18.442 | -1.1797 | -32.729 | 37.586 |

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304 Stainless Steel Mechanical properties are as follows:

Yield Stress – 30,000 to 50000 PSI
Ultimate Stress – 75,000 TO 125000PSI

| Size | Major Dia | Minor Dia Area | Tensile Stress Area | Tensile Stress | Bending Stress | Shear Stress | Factor of Safety | Factor of Safety |
|---|---|---|---|---|---|---|---|---|
| inch | inch | sq. inch | sq. inch | PSI | PSI | PSI | Sy=30000 psi | Sy =50000 PSI |
| 1/4 | 0.25 | 0.0269 | 0.0318 | 11038 | - | 3420 | 3.76 | 6.04 |
| **3/8** | **0.375** | **0.0678** | **0.0775** | **4529** | **-** | **1419** | **6.62** | **11.0** |

## Summary and Recommendations

All computed stresses are well within acceptable working levels based on the geometry, assumptions and given parameters. The spine pin does see some high contact stresses and therefore this component should be produced from quality steel that can be surface treated to prevent premature wear. To prevent excessive wear of spine pin bore, a tight-fit tolerance can be considered to reduce this.

Computed Factors of Safety (Approximate)

| | | | |
|---|---|---|---|
| Cover Plate | – | 5 | |
| Spine | – | 7 | (the effects of the contact stresses are not included) |
| Spine Pin | – | 10 | (the effects of the contact stresses are not included) |
| 3/8" Screws | – | 6.6 to 11.0 | |

**The analysis and the technical information presented in this report has been conducted and prepared by:**

**Robert E. Rennie, P. Eng.**

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    a. The limitations of the simulation technology employed.
    b. The customer supplied data and input parameters.
    c. The modeling simplifications agreed upon and used in the simulation to approximate the customer's expectation of the anticipated physical reality.
2. The customer agrees to limit Javelin's complete and total liability with respect to the services performed to the value charged for said services.
3. This proposal is the property of Javelin Technologies and shall not be disclosed to any third party without the prior written consent of Bill McEachern, P.Eng of Javelin.