Prepared By: Diana Tomoiaga
Checked By: Mark Turner

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FEA Analysis Report

Project: Drain Components
Client: Robert Lawson

APS Reference: RLW7045

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Introduction

APS are working with Rob Lawson to develop a new

Summary of Results and Recommendations

The following results and conclusions presented in this report are based on the information and data available at this point in time.

Mechanical FEA simulations are based on assumptions related to the physical constraints and supports of products as well as the material properties supplied. FEA simulations should be used as a tool to refine designs but should not be used as a substitute for actual physical testing.

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Deflection and Stress Distribution

FEA models were developed from the CAD data of the drain components. The parts were supported along their outer sides on a 1.5 inch wide area from the outer edges.

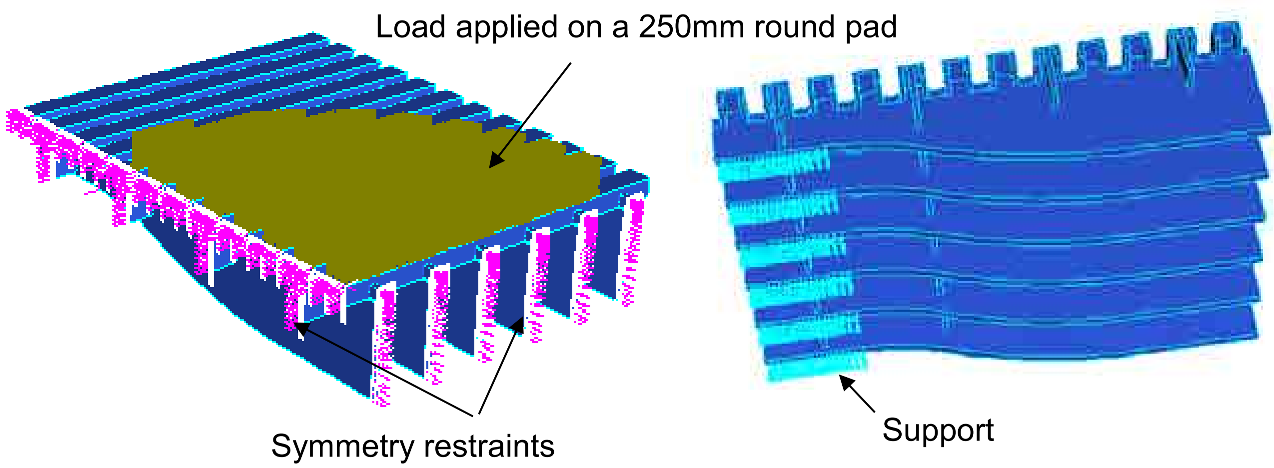
The load was applied on a round pad of 250 mm diameter and deflection and stress of each grate version was investigated at 330 kg, 670 kg and 1000 kg.

The above load requirements correspond to the AS3996-2006 requirements for a class A product.

The results of deflection and stress for each grate version are shown next in this report.

Parallel Straight Grate

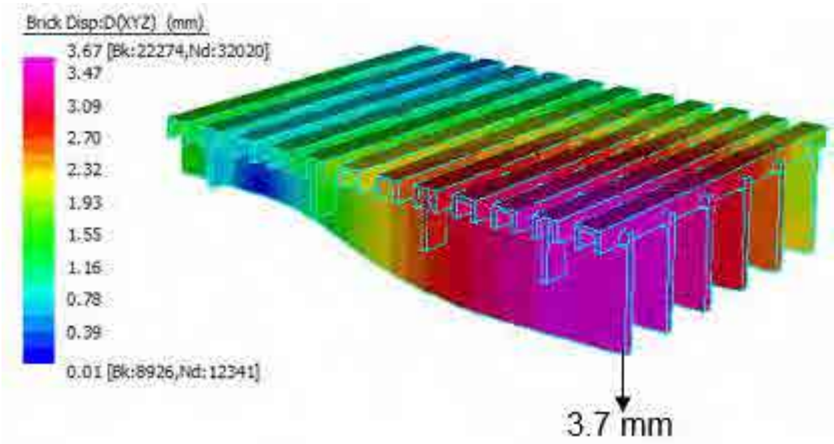
This grate is symmetrical on two perpendicular planes and therefore a quarter model with symmetry restraints on these planes was created for analysis.



FEA Model with load and restraints

330 kg nominal wheel loading

The analysis has indicated a deflection of approximately 4 mm at this load.

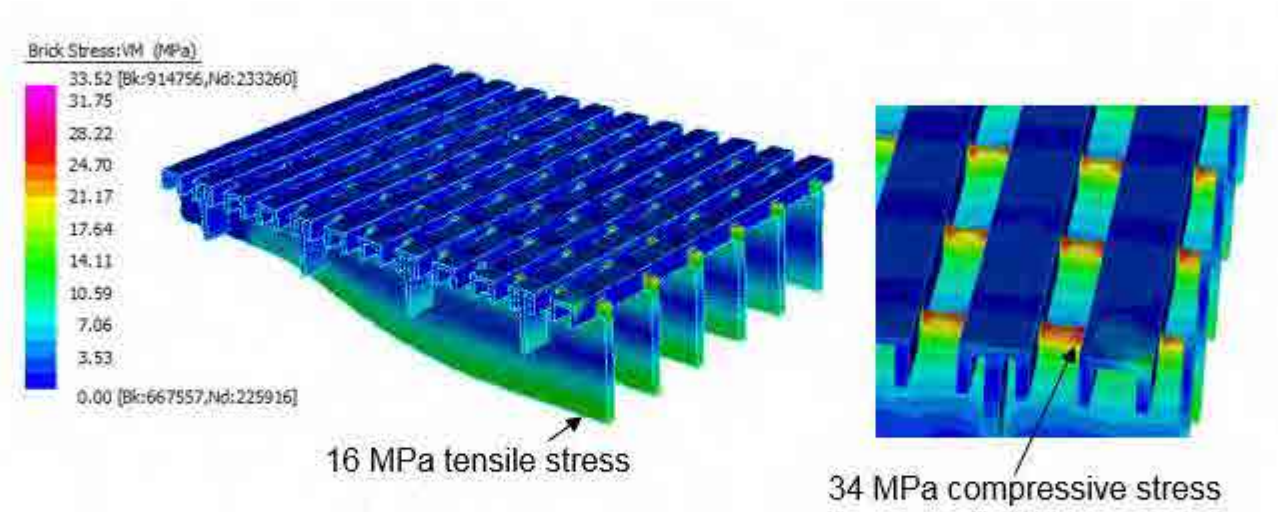


Deflection at 330 kg load

The following plot shows the stress distribution on this grate version at 330 kg top load. The maximum stress indicated on this part is on top of the ribs, between each pair of parallel strips. However, this stress is envisaged to be mostly compressive stress and it is not expected to cause the breaking of the part.

The area that is in tension is the bottom surface of the ribs and therefore the stress in this area should remain below the tensile stress of the material. If the stress here exceeds the tensile limit of the material yielding and/or breaking on the material would be expected.

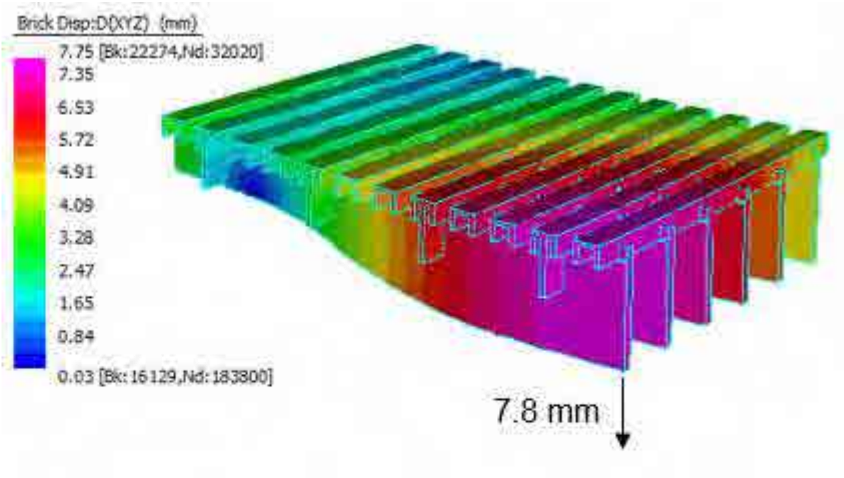
At 330 kg load the analysis has calculated a stress of 16 MPa at the bottom of the ribs which is well below the material limit of 45 MPa.



VonMises stress distribution at 330 kg load

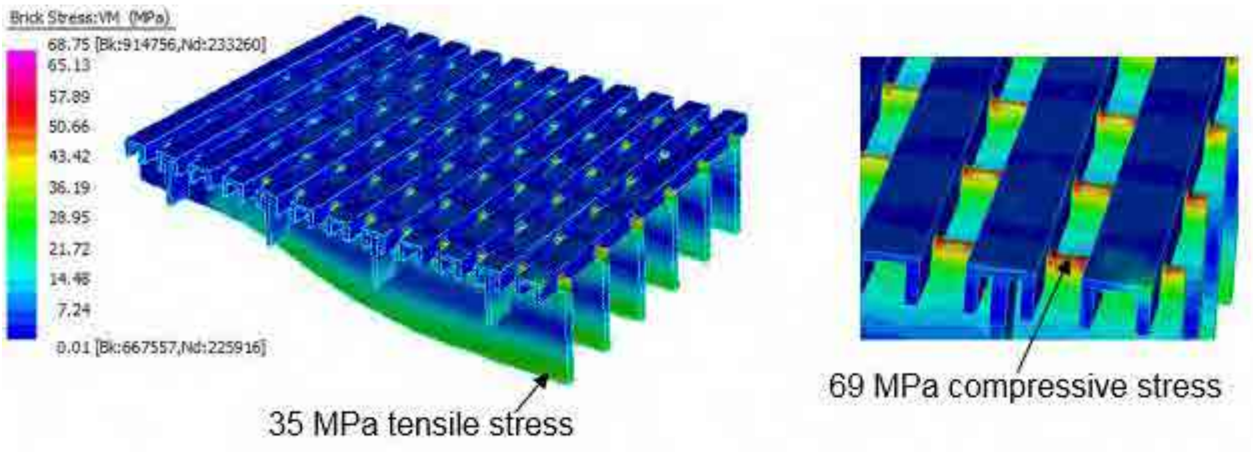
670 kg (6.7kN) Serviceability design load

At 670 kg load the analysis has calculated a deflection of 7.8 mm in the centre of the grate.



Deflection at 670 kg load

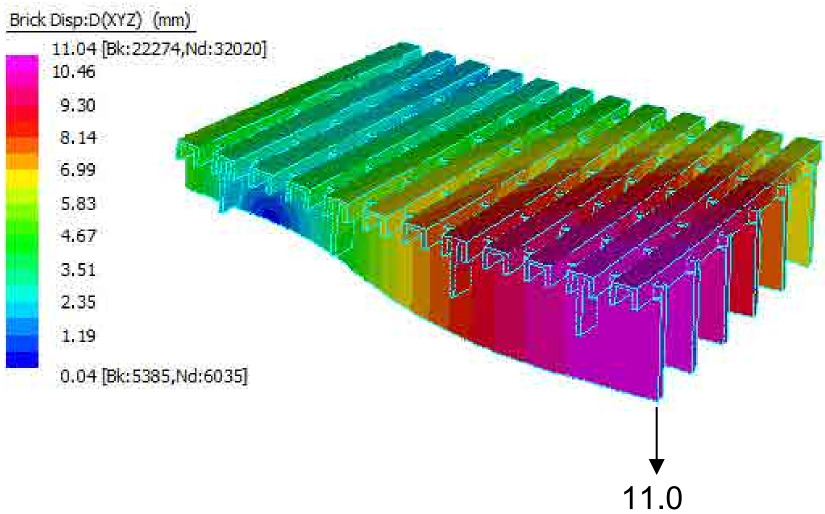
The compressive tress at the top of the ribs increased to 69 MPa. Some local permanent deformation is possible in these areas due to this higher stress. However, the tensile stress at the bottom of the ribs remains below the tensile strength of the material.



Von Mises stress at 670 MPa

1000 kg (10kN) Ultimate limit state design load

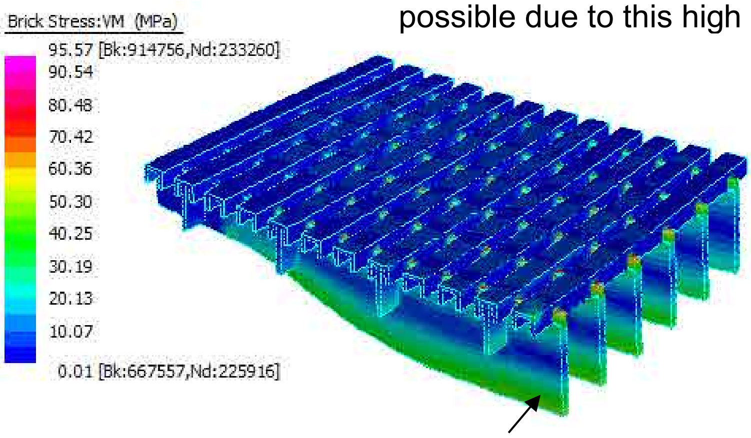
At 1000 kg it is expected that the deflection of the grate will increase to approximately 11 mm.

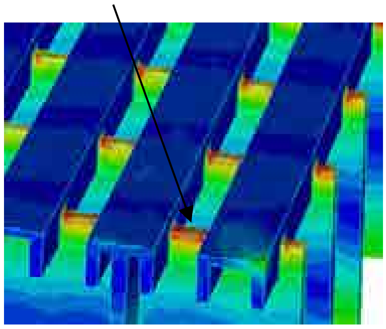


Deflection at 1000 kg

The stress has also increased accordingly with the load increase and the analysis has indicated that both the compressive stress at the top and the tensile stress at the bottom may exceed the tensile strength of the material of 45 MPa.

Approximately 96 MPa compressive stress was indicated on this side of the ribs in the red areas. Some permanent deformation is possible due to this high stress at 10 kN load.

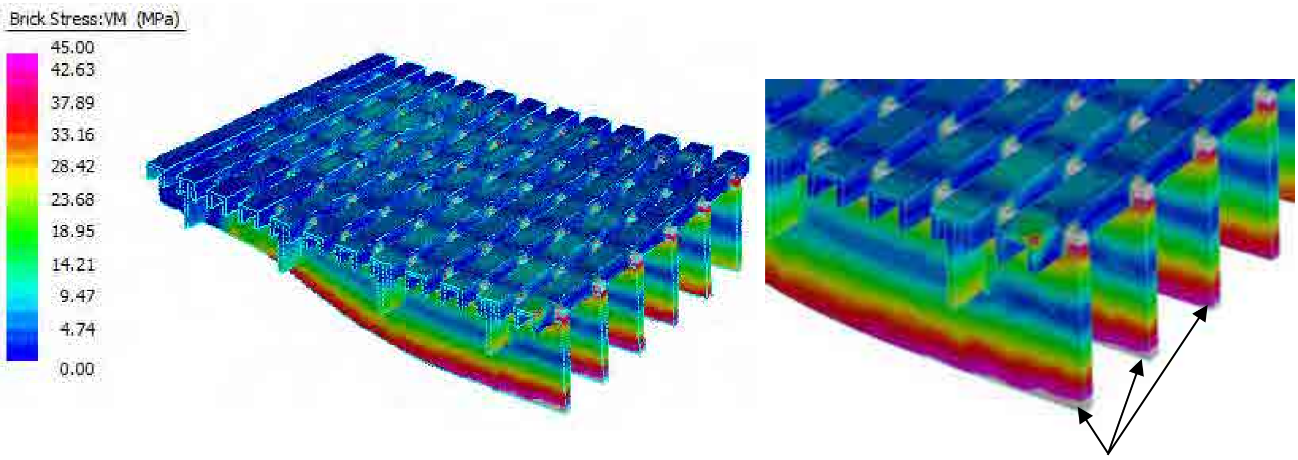




50 MP tensile stress in the centre. This stress exceeds the tensile strength of the material of 45 MPa

Von Mises stress distribution at 1000 kg

The stress was capped at the tensile limit of the material in the next picture. The areas where the stress exceeds the tensile strength of the material are shown in grey.



The tensile stress exceeds the tensile strength in these areas.

Von Mises stress distribution capped at 45 MPa

The vertical ribs used in this analysis were 4 mm thick less draft. To provide additional strength to combat these high stress areas, the rib thickness was increased to 5mm less draft for the CAD models released for tooling.

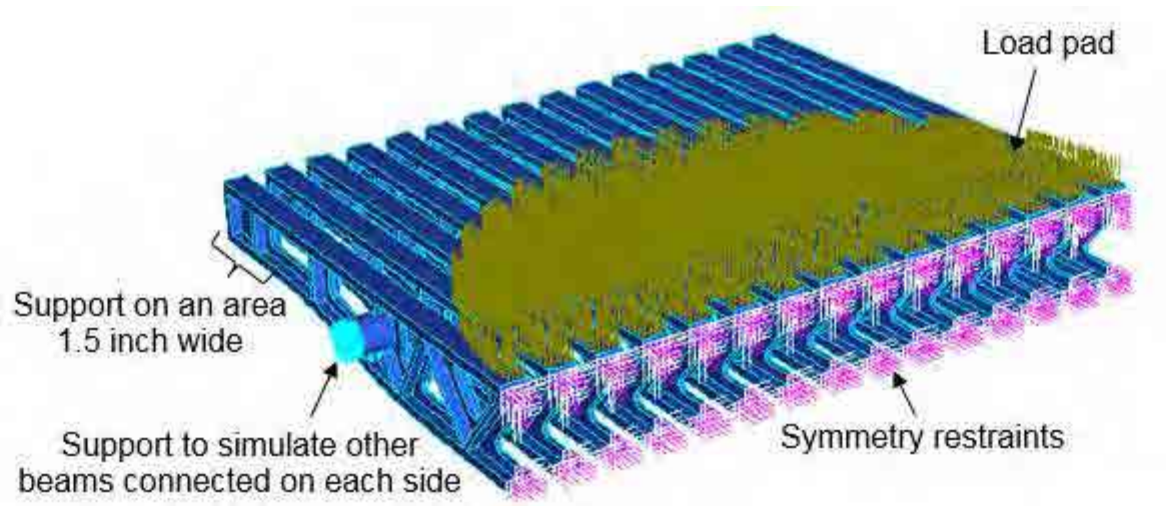
Perpendicular

The next version that was analysed was the parallel crate version.

15 beams were connected for analysis using gap elements. This configuration of 15 beams create a grate sufficiantly wide to for a load pad of 250 mm diameter.

The grate was supported at the end bosses to simualte them being connected to more beams on each side.

Support was also provided along the outer sides of the grate onan area 1.5 inch wide. Because the grate is simetrycal on its mid plane, one half of the beams was modelled for analysis and symmetry restraints were applied of the symmetry plane.

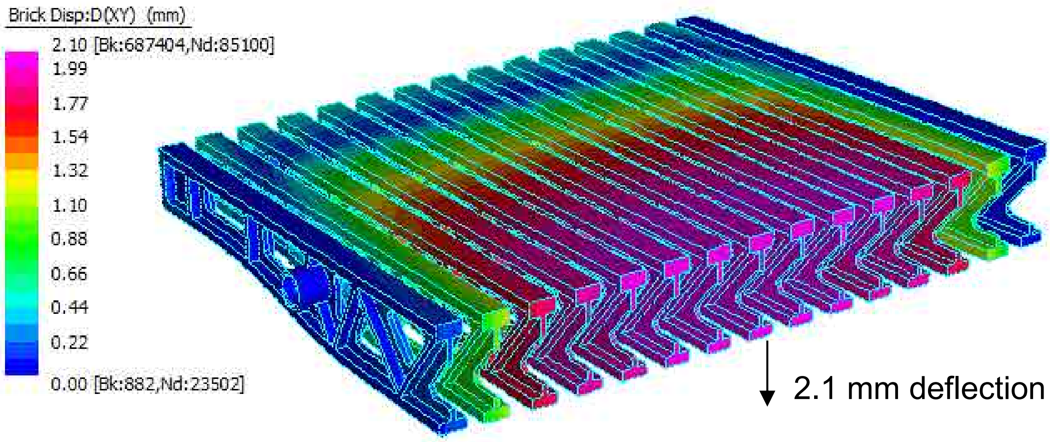


FEA Model with load and restraints

The next plots show the deflection and stress distribution for this version of the grate.

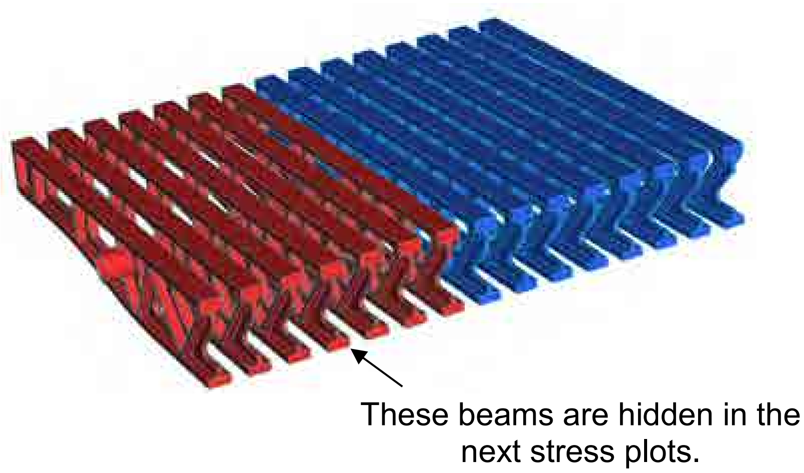
330 kg nominal wheel loading

Approximately 2.1 mm deflection was indicated at 330 kg top load on this grate.



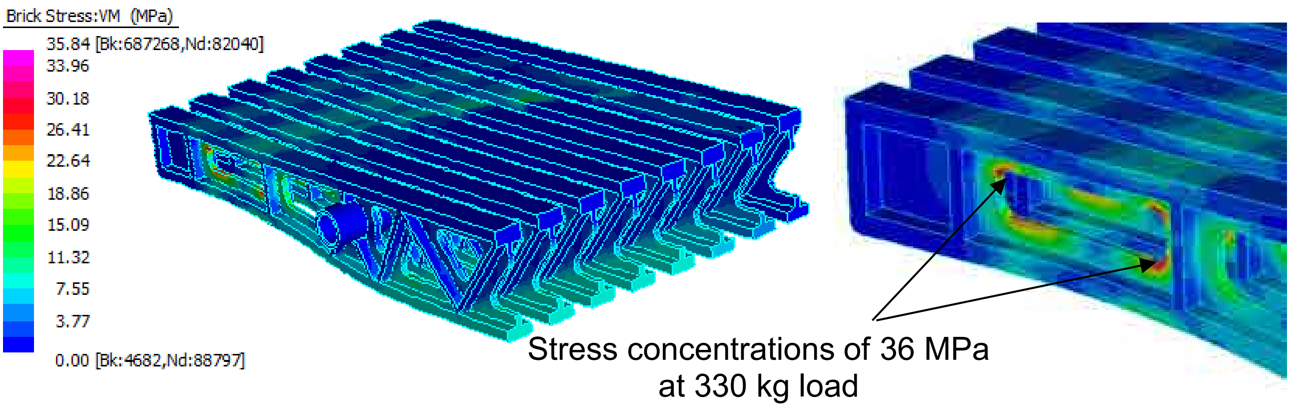
Deflection at 330 kg

The maximum deformation and stress was indicated on the beam positioned in the centre of the group. Therefore, seven beams from the left were hidden in the stress images to show the distribution in areas of maximum stress.



Model setting for stress observations

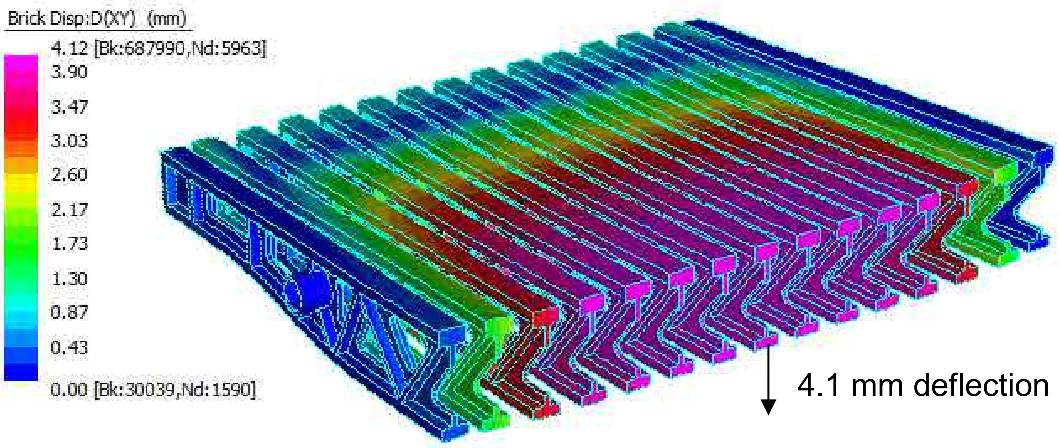
The analysis has indicated stress concentrations at the end holes. These stress concentrations are expected to exceed the tensile strength of the material at a load of approximately 450 kg.



Von Mises stress at 330 kg

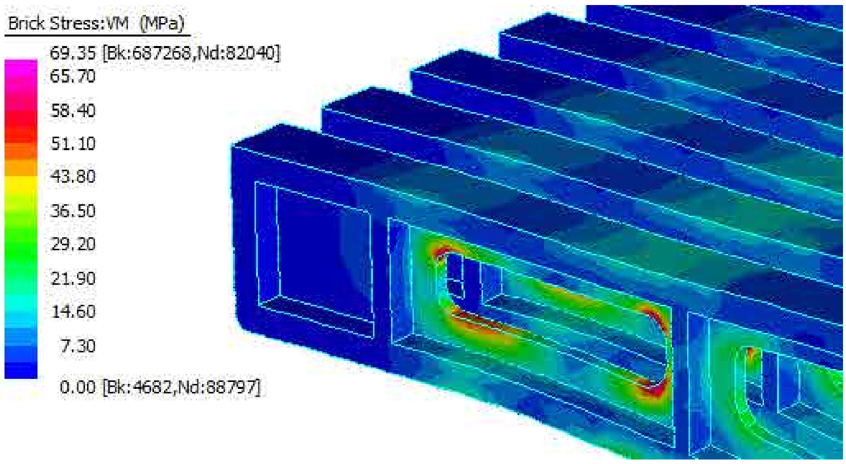
670 kg (6.7kN) Serviceability design load

At 670 kg top load the deflection increased to 4.1 mm.



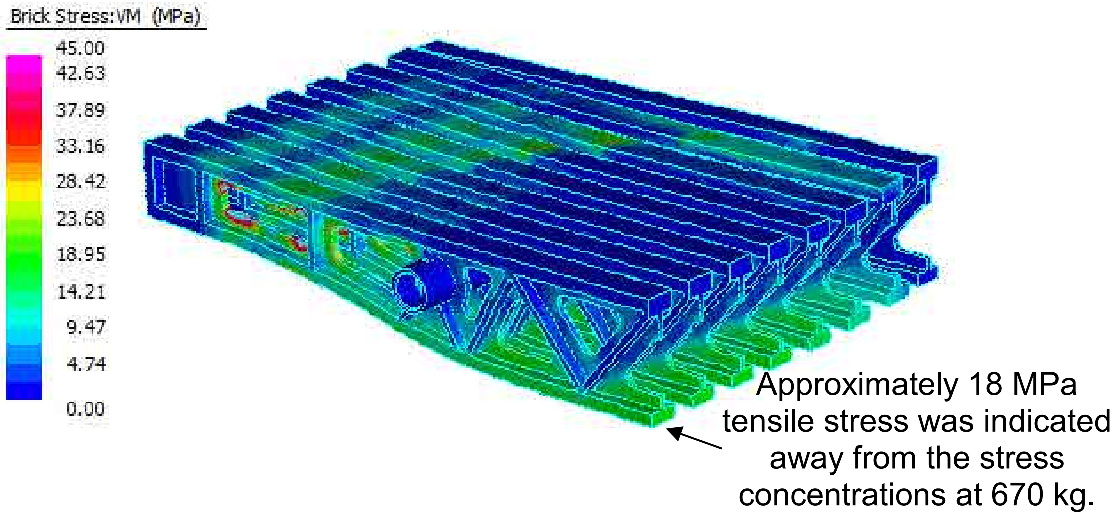
Deflection at 670 kg

The stress also increased accordingly to the load increase and is exceeding the tensile limit of the material of 45 MPa in the areas of stress concentrations.



Von Mises stress- concentrations in the side holes

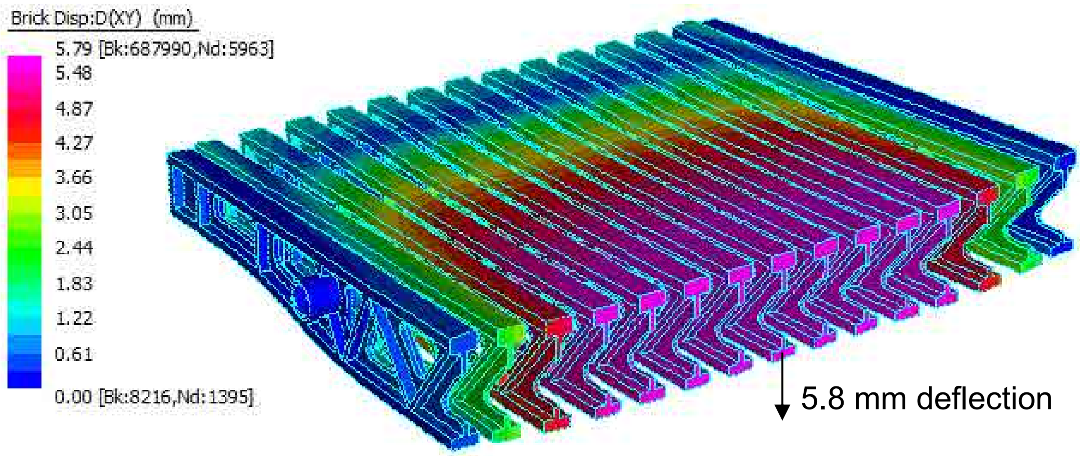
Except for the stress concentration the stress on the rest of the part remains lower than the tensile strength of the material at 670 kg.The next plot shows the stress distribution capped at the tensile limit of the material of 45 MPa.



Von Mises stress distribution capped at 45 MPa

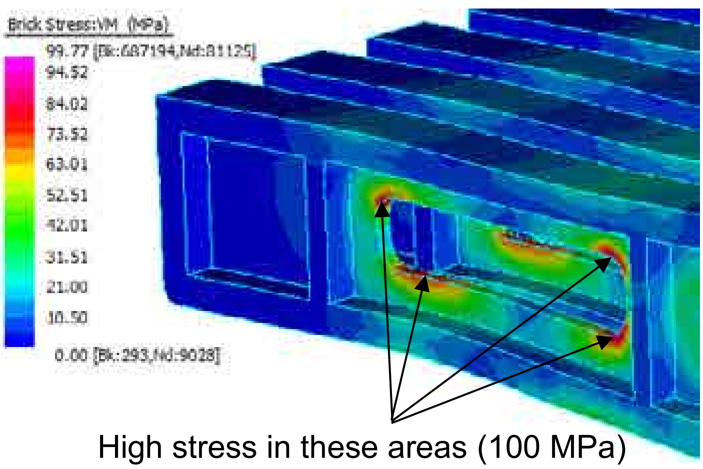
1000 kg (10kN) Ultimate limit state design load

Further increase of deflection was indicated at 1000 kg. The analysis has indicated approximately 6 mm deflection in the centre of this grate at this load.



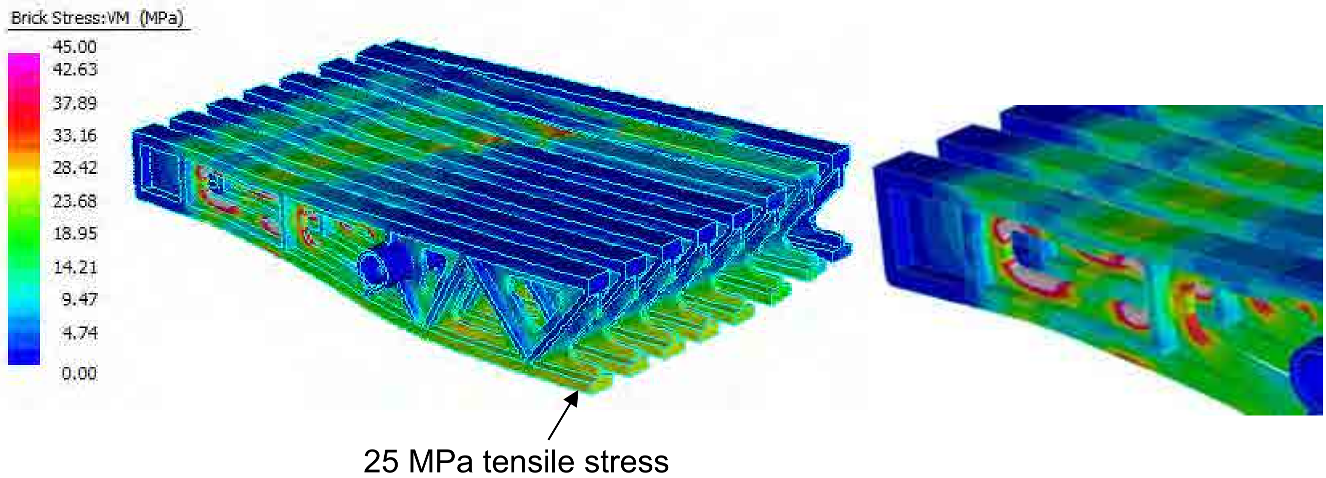
Deflection at 1000 kg

As expected the stress continues to grow with the load increase and greatly exceeds the tensile limit of the material in the stress concentrations. It is highly recommended to fill the holes at the ends of the part to eliminate these concentrations of stress.



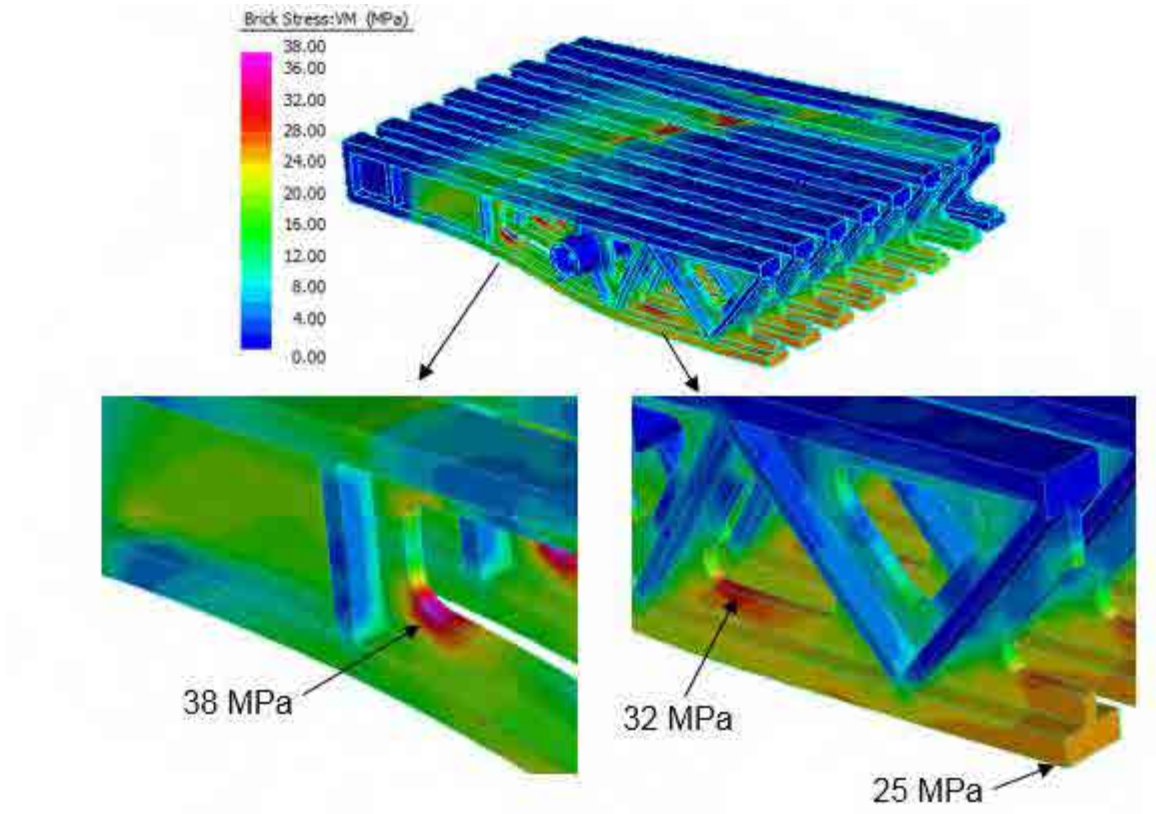
Von Mises stress concentrations in the side holes

Apart from the stress concentrations at the end holes, the stress indicated in the rest of the part remains below the tensile strength of the material as shown in the next plot. It is therefore expected that this product would pass the requirements of the AS 3996-2006 for a class A product if the stress concentrations are addressed.



Von Misses stress distribution at 1000 kg, capped at 45 MPa

In the next analysis iteration, the end holes were filled and the stress at 1000 kg (10 kN) was recalculated. While some stress concentrations were still indicated at the remaining holes, the stress in these concentrations and throughout the part was below the tensile limit of the material.



Von Mises stress distribution at 1000 kg after the side holes were removed

Parallel Radius Support and Strip

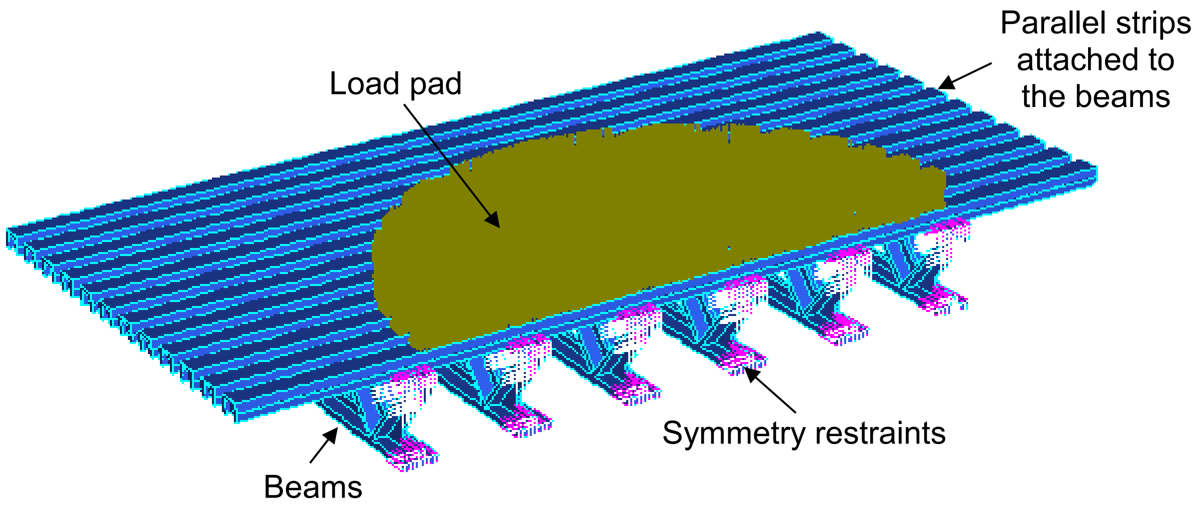
A third version of the crate, the Parallel Radius Support and Strip, was investigated in the next part of the analysis.

This version uses beams to support long, parallel strips place on top. The strips are kept in place via clips on the beams.

For the scope of this analysis it was assumed that a tight, strong attachment is provided by the clips and therefore the strips cannot get away from the beam under load.

This grate is also symmetrical around its central plane and therefore half of the model was used in the analysis with symmetry restraints on the symmetry plane.

Support was provided on an area 1.5 inch wide at the end of the beams.

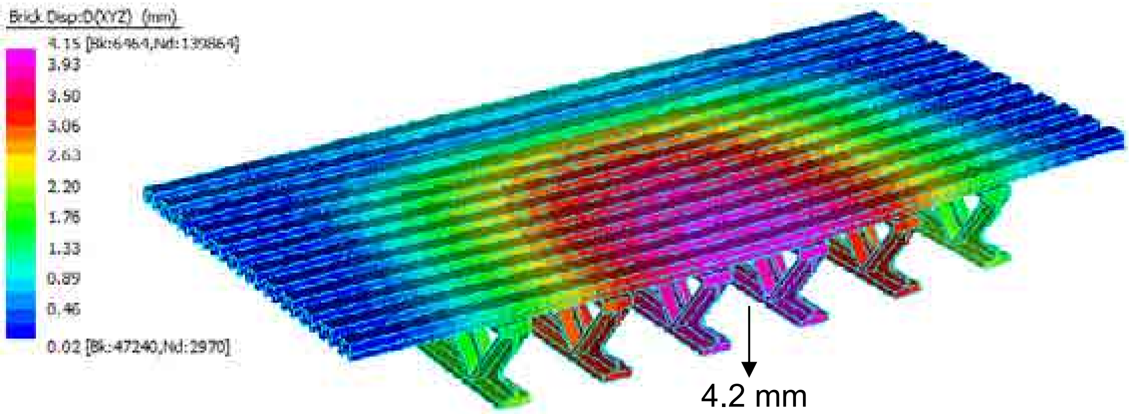


FEA Model with load and restraints

The plots of deflection and stress for this version of the grate are shown in the next part of this report.

330 kg nominal wheel loading

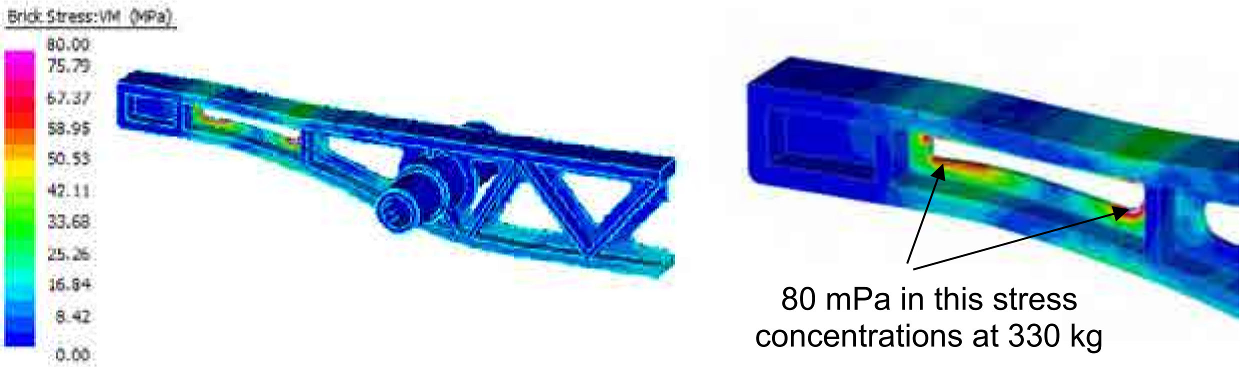
The analysis has indicated approximately 4 mm deflection for this grate version at 330 kg .



Deflection at 330 kg

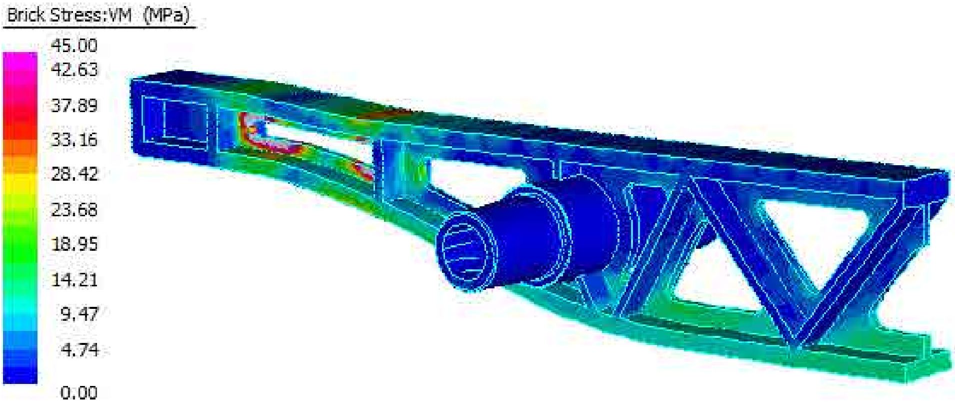
The stress indicated for this grate version also shows stress concentrations in at the outer hole. However, on this design and configuration (ie. number of beams to share the load), these stress concentrations exceed the tensile limit of the material at the nominal wheel loading of 330 kg.

It is envisaged that by filling this hole this issue may be alleviated however, at higher loads the stress may remain high as indicated in the iterations described further in this report.



Von Mises stress distribution at 330 kg

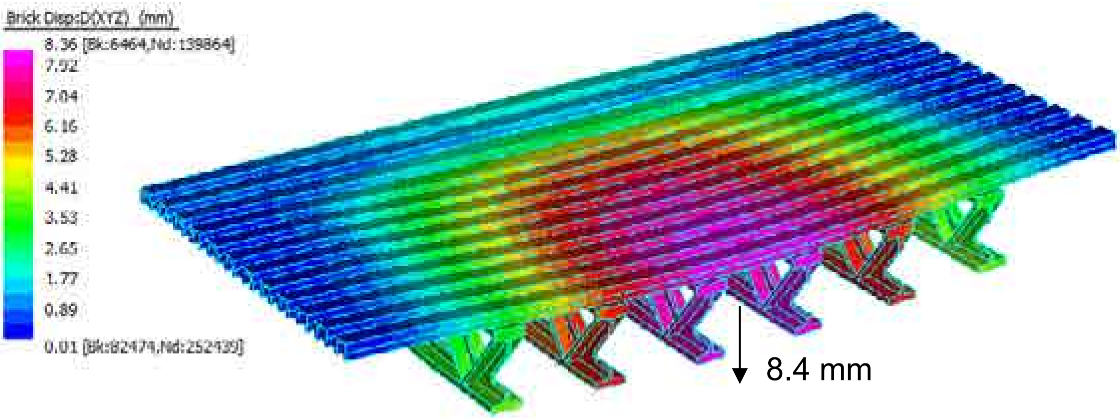
Appart for these concentratioons, the stress in below the tensile strength of the material in the rest of the part.



Von Mises stress capped at 45 MPa at 330 kg

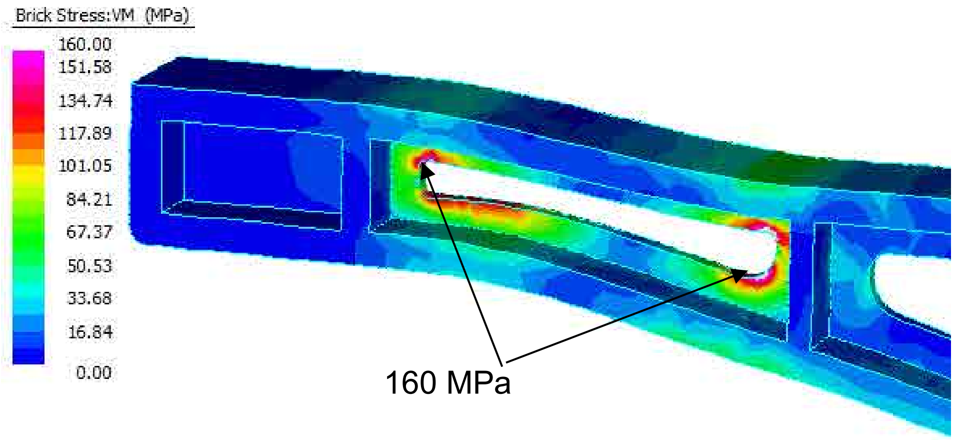
670 kg (6.7kN) Serviceability design load

The deflection increases with the increase in load to approximately 8 mm at 670 kg.

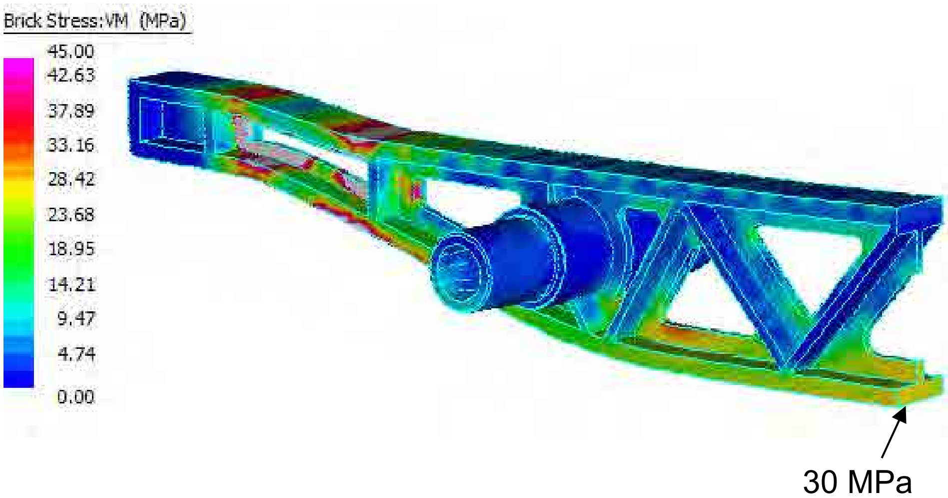


Deflection at 670 kg

The stress greatly exceeds the tensile limit of the material in the stress concentrations at this load. However, it remains within the limits in the rest of the part away from this problematic area.



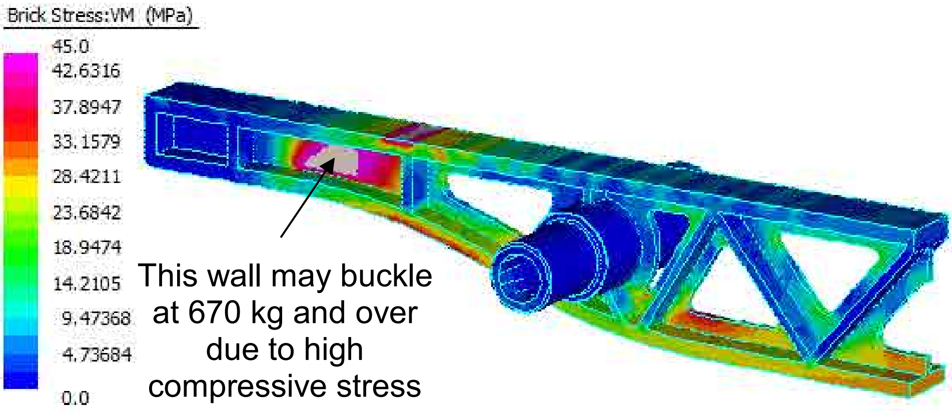
Von Mises stress concentration on the outer hole



Von Mises stress distribution capped at 45 MPa

The outer hole was filled in the next iteration and the stress was recalculated.

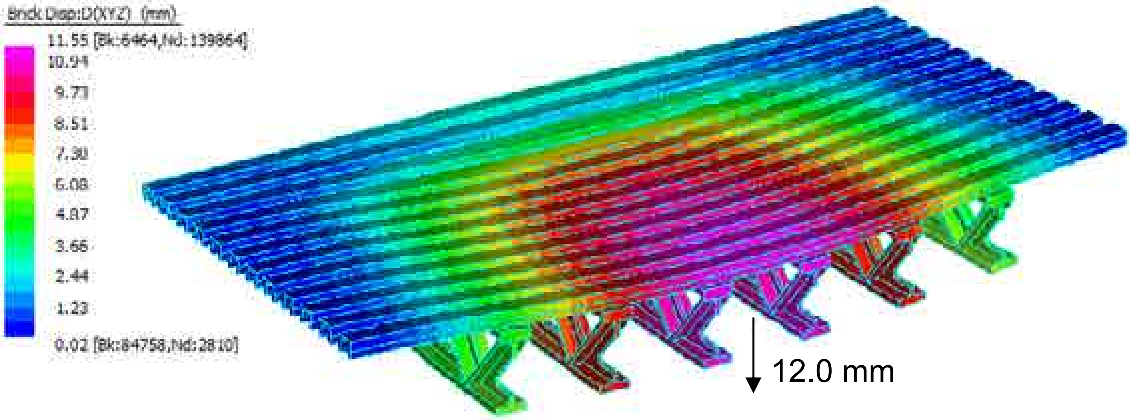
The analysis still shows stresses that execeed 45 MPa on the wall above the support. This high stress may cause the vertical wall to buckle since it is a compressive stress.



Von Mises stress at 670 kg, after removal of outer hole

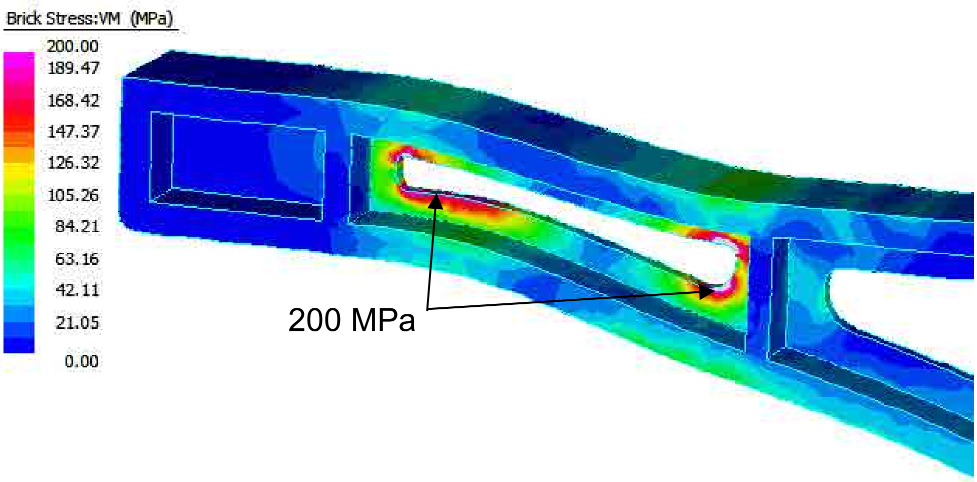
1000 kg (10kN) Ultimate limit state design load

The deflection continues to increase as the load goes up to approximately 12 mm at 1000 kg.

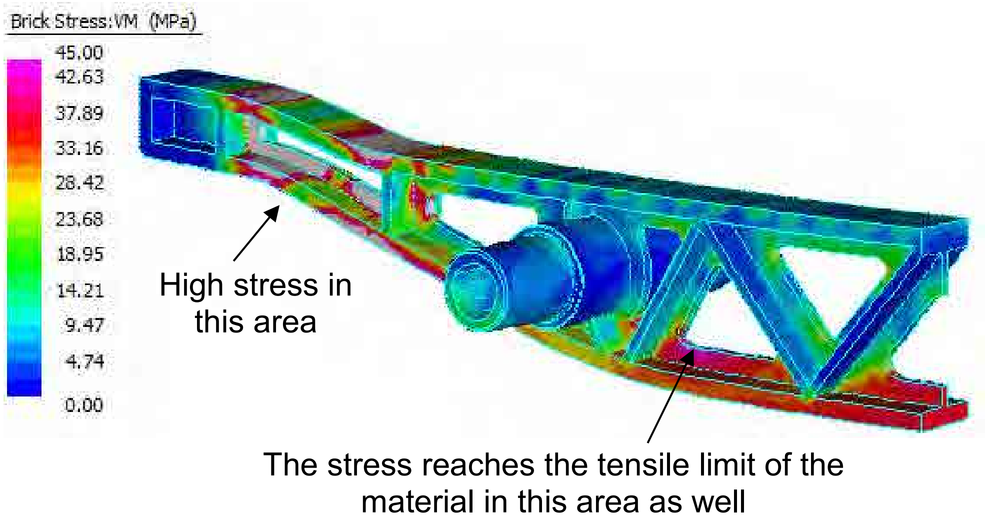


Deflection at 1000 kg

At 1000 kg the analysis has indicated very high stress at the outer hole and the surrounding walls. The stress also reaches the tensile limit of the material in other areas away from the end of the beam.



Von Mises stress concentrations at the outer hole

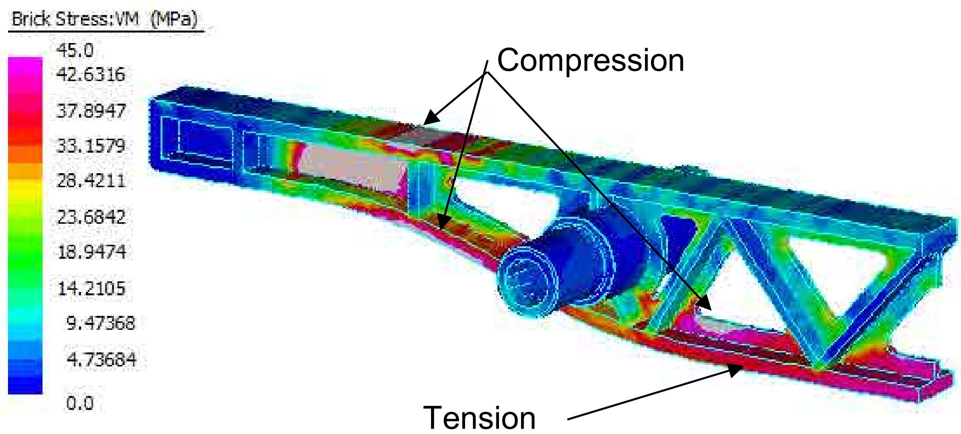


Von Mises stress at 1000 kg, capped at 45 MPa

The stress was reduced in the problematic area after the outer hole was filled. The stress remains high particularly on the wall directly over the support and may cause this wall to buckle.

In compression, there are some areas highlighted, where the stress is also at or slightly exceeds the tensile strength on the material. More importantly, there is a large area bottom of the beam where the tensile stress is at the 45MPa limit of the material.

As the FEA calculations are theoretical, and this 10kN test is an ultimate limit test, it is recommended that the parts actually be tested prior to increasing wall thickness in this bottom beam or reducing the size of the openings as this may introduce unnecessary part weight.



Von Mises stress at 1000 kg after the removal of the hole

DMD 18x18 Flat Grate

The FEA simulations presented in this chapter of the report were performed to simulate the testing from clause 3.3, 3.5 and 3.8 of the ANSI/APSP-16 2011 standard.

The material data used in all simulations presented in this report is the data quoted by the material supplier in the datasheet. All stress results were therefore compared to the quoted tensile limit of the material.

However, if the material is likely to be affected by UV exposure it is recommended to apply an appropriate factor of safety to the results presented in this report to ensure compliance with clause 3.2.2.3.

For example, if the intensification factor, K, of this material is 1.25 (80% of the tensile strength of the virgin material is retained after exposure to UV), the results presented in this chapter shall be multiplied by 1.25.

The following load cases were simulated for the DMD 18x18 Flat Grate:

- Vertical load: The load was applied on the top area of the fitting at various locations. The stress and deformation of the grate was calculated at a load of 1350 N and at a load of 2700N. At 1350 N the grate shall not permanently deform or break. Permanent deformation but no break is permitted at 2700 N
- Pull test: a pull analysis was also performed with 700 N load applied on the underside of the grate. The load was applied each side of a screw and at two points between screws. No permanent deformation of crack of the grate is permitted.

A summary of the results for the DMD 18x18 Flat Grate is shown in the next table. The tensile strength of the material is 45 MPa. If the stress on the part exceeds this value yielding(permanent deformation) and possible cracking of the material in that area is expected .

Table 1: Summary of Results for the DMD 18x18 Flat Grate

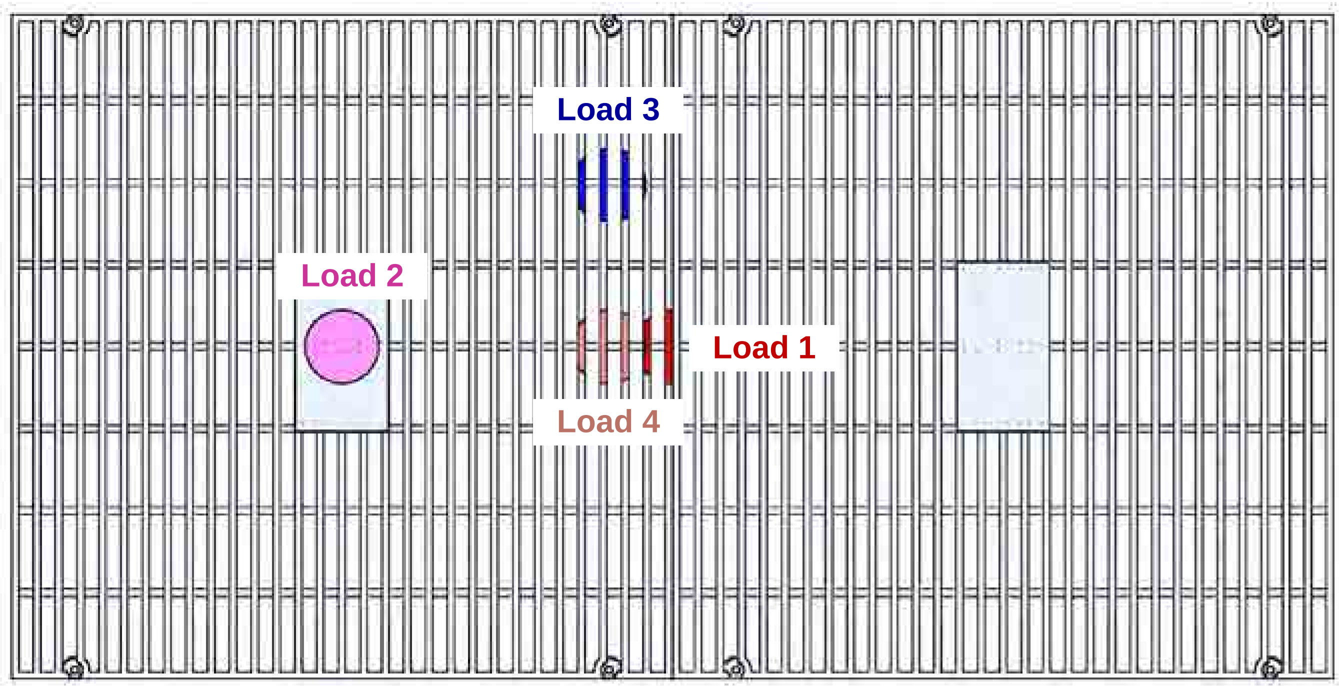
		Deflection		Stress				Comments
				Body		Screws		
Load		**1350 N**	**2700 N**	**1350 N**	**2700 N**	**1350 N**	**2700 N**	
Vertical Load	LC 1	2.34 mm	4.71 mm	13.0 MPa	27.0 MPa	16.5 MPa	36.4 MPa	
	LC 2	2.37 mm	4.75 mm	12.0 MPa	24.0 MPa	5.0 MPa	12.0 MPa	
	LC 3	1.48 mm	2.95 mm	10.0 MPa	21.0 MPa	26.0 MPa	55.0 MPa	
	LC 4	2.82 mm	5.57 mm	15.0 MPa	31.0 MPa	28.0 MPa	58.0 MPa	
Load		**700 N**						**Comments**
Pull Load	LC 1	0.62 mm		9.0 MPa		18.0 MPa		
	LC 2	5.35 mm		23.0 MPa		57.0 MPa		
	LC 3	2.81 mm		22.0 MPa		22.0 MPa		

Vertical Load and Deformation Test (clause 3.3 and 3.5)

The DMD fitting consists of two grates placed next two each other and fixed in place by screws.

The load was applied at 5 locations on one grate as shown in the next picture:

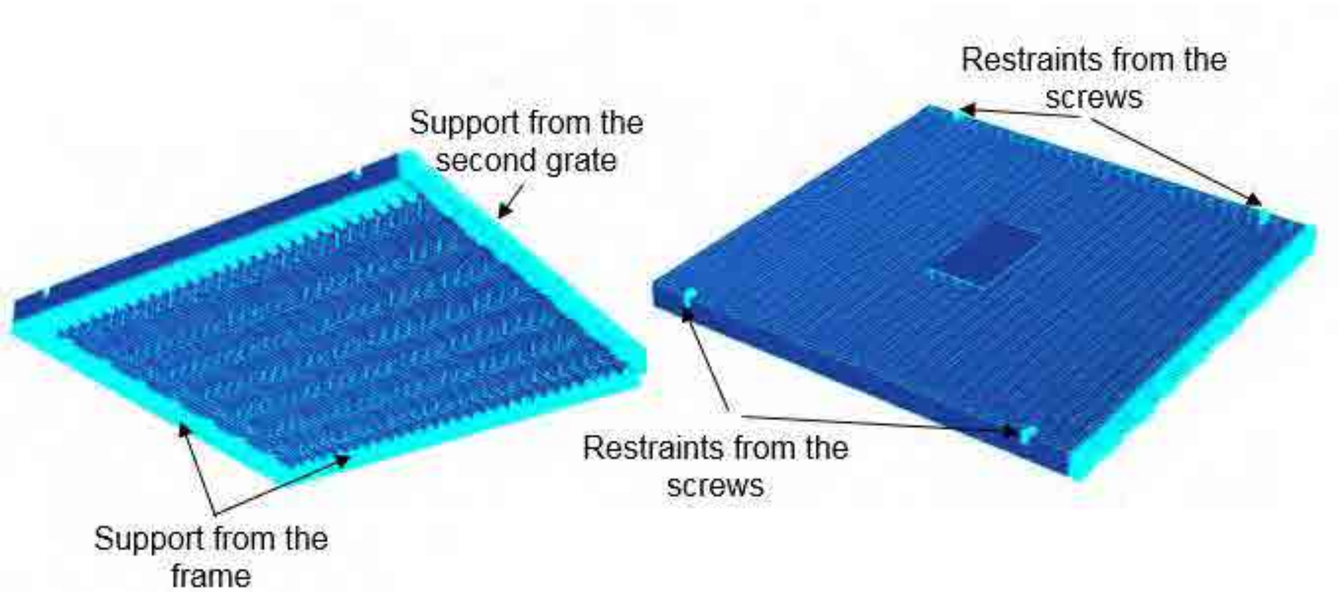
- on the fitting face, in the centre of the 2 grates fitting equally distributed on each of the grates (Load Case 1)
- at two points midway between the centre of the fitting and edge (Load Case 2 and 3)
- between stiffeners (Load case 4)
-



DMD Fitting with Load Cases

An FEA model of one grate was developed from the CAD data. Support was added on the underside on three sides to simulate the contact with the frame and also on the vertical side in contact with the second grate.

Restraints were also added to the screw areas.



FEA model of DMD grate with restraints

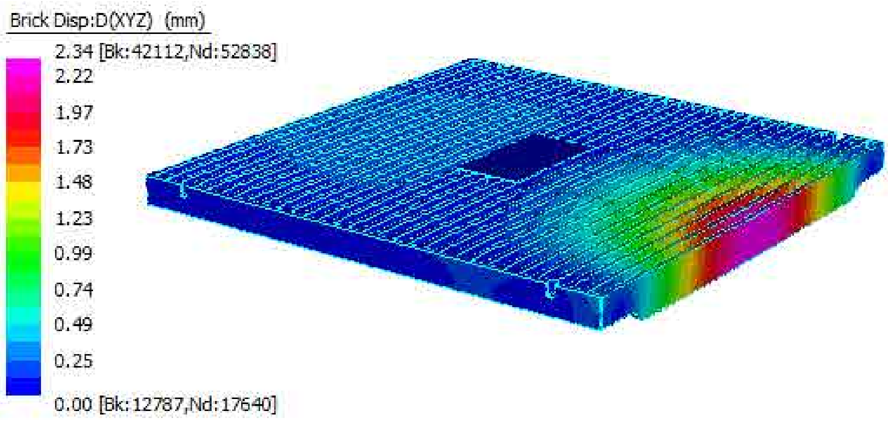
All loads were applied in increments up to 3000 N and the performance of the grate (stress and deflection) was evaluated at 1350 N and 2700 N.

The performance requirements for this grate is not to permanently deform, crack or lose any material at 1350 N load. At 2700N the grate can permanently deform but it shall not break.

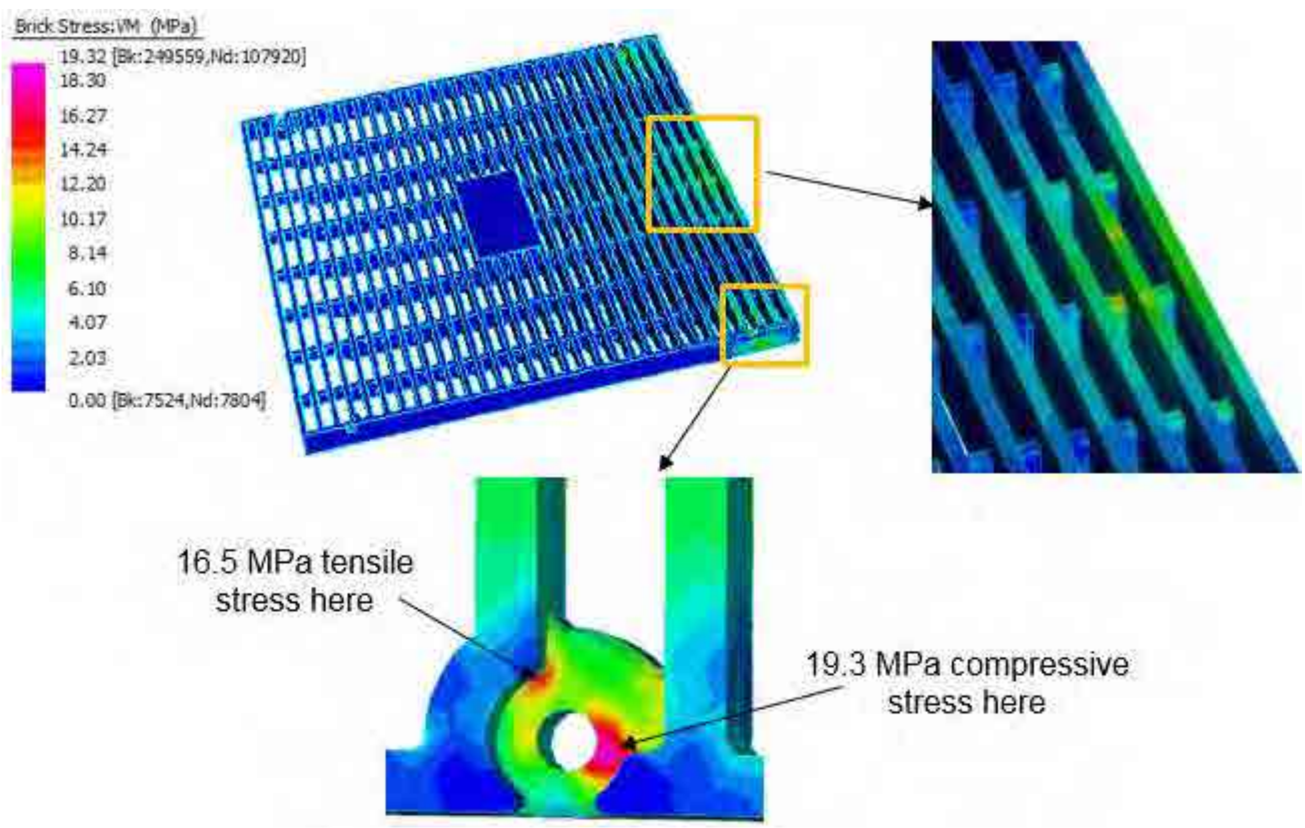
The results of the vertical load analysis for the DMD 18x18 Flate grate are shown next in this report.

Load case 1: on the fitting face

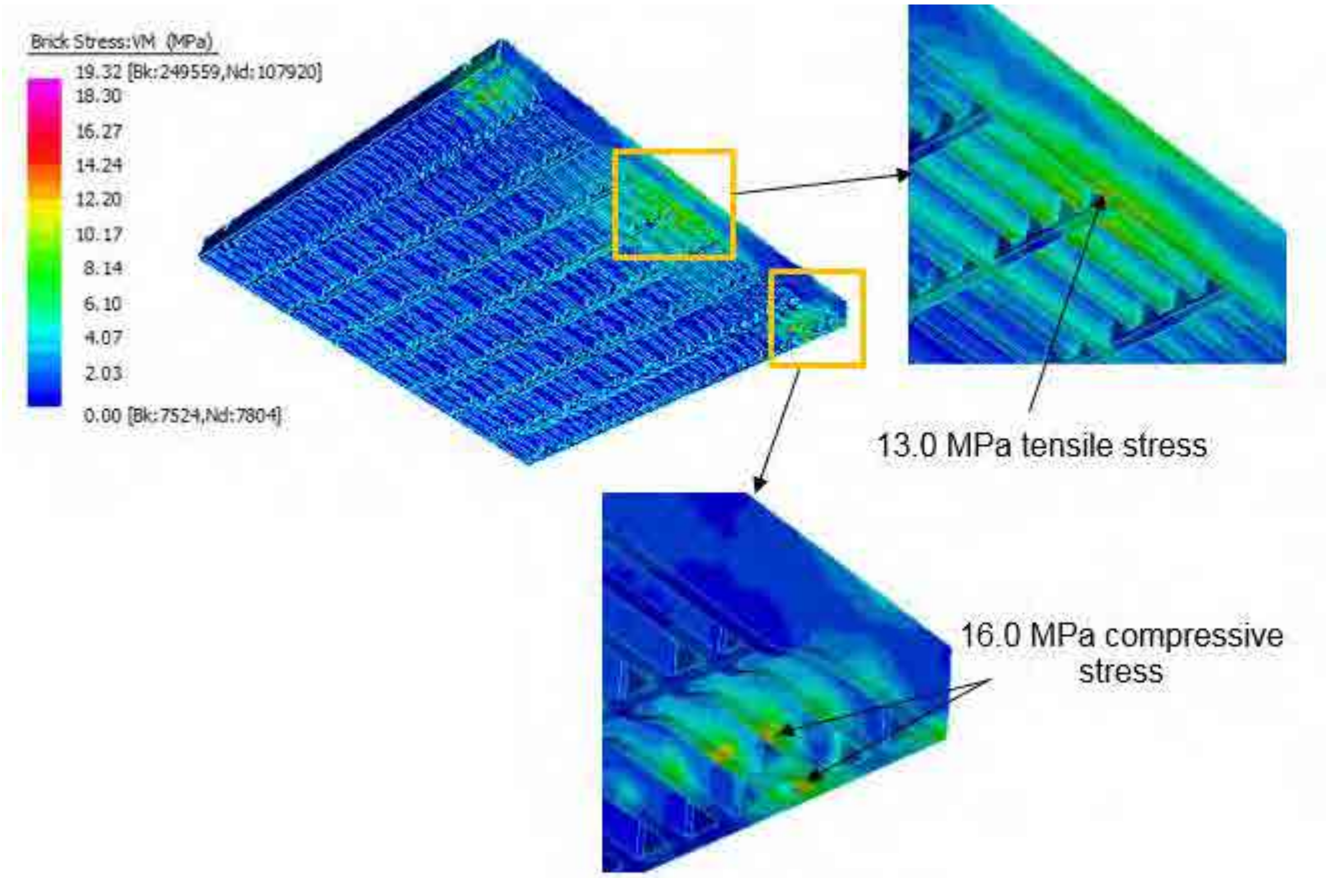
<u>1350 N Force (½ on one grate, ½ on the other grate)</u>



Deflection

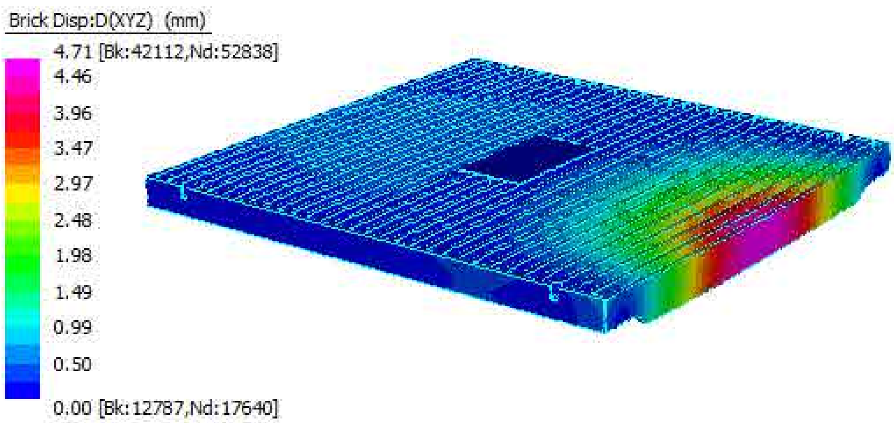


Von Mises Stress- Top view

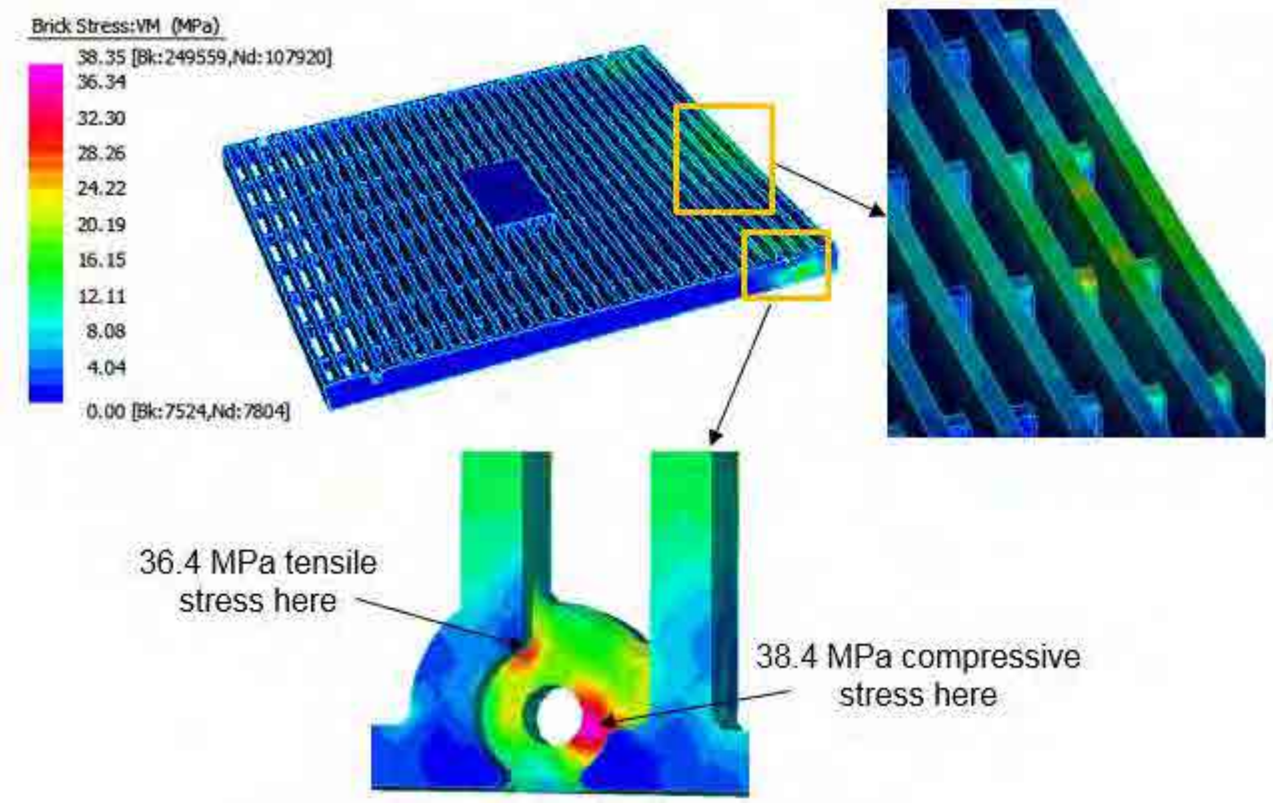


Von Mises Stress- Bottom view

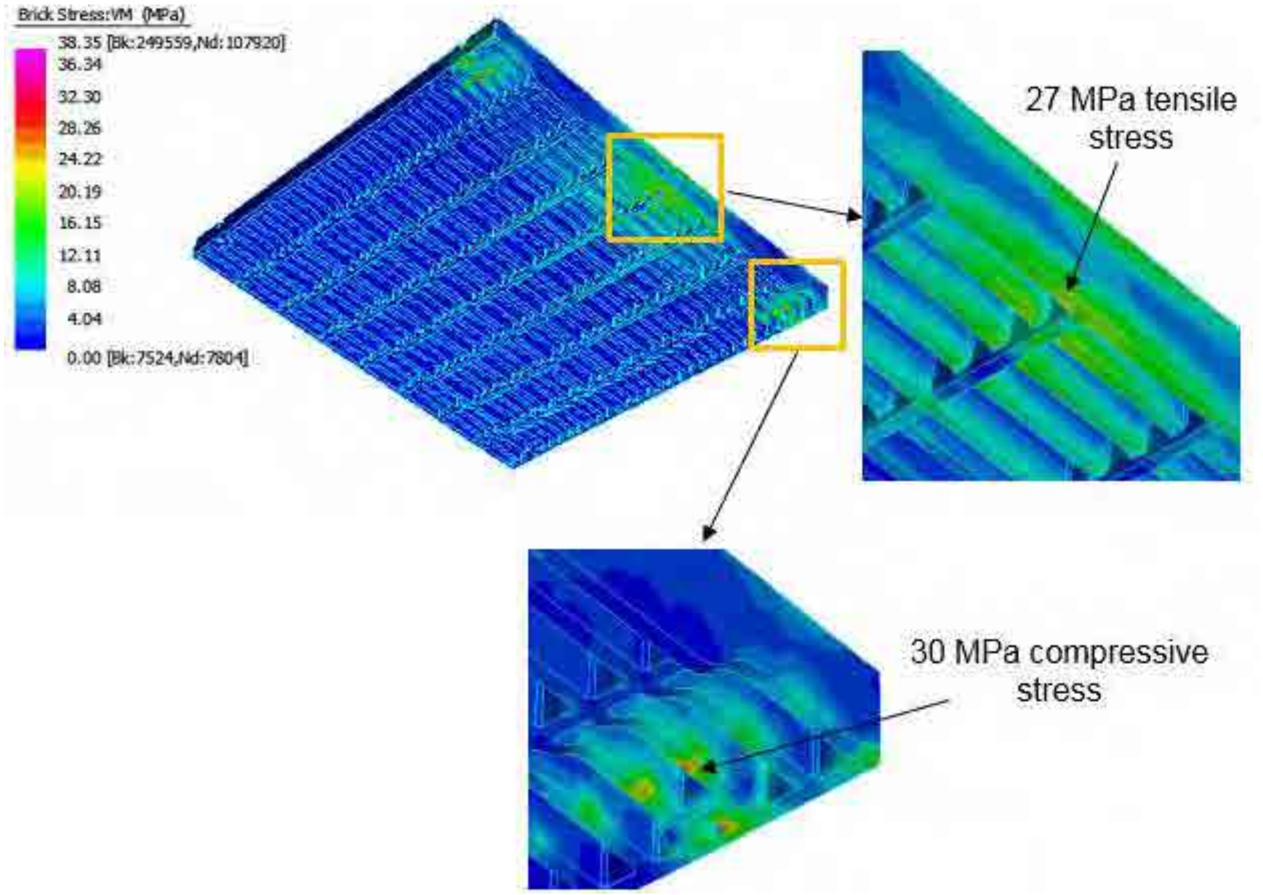
<u>2700 N Force (½ on one grate, ½ on the other grate)</u>



Deflection

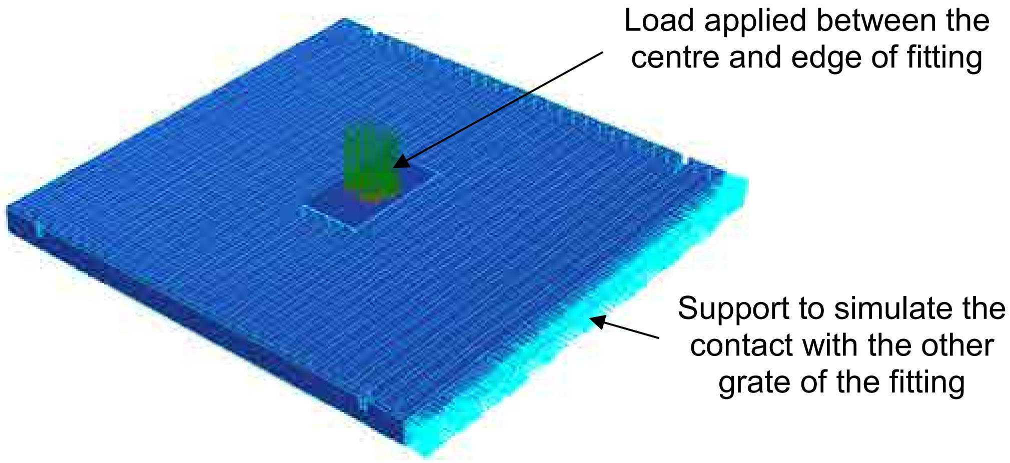


Von Mises Stress- Top view



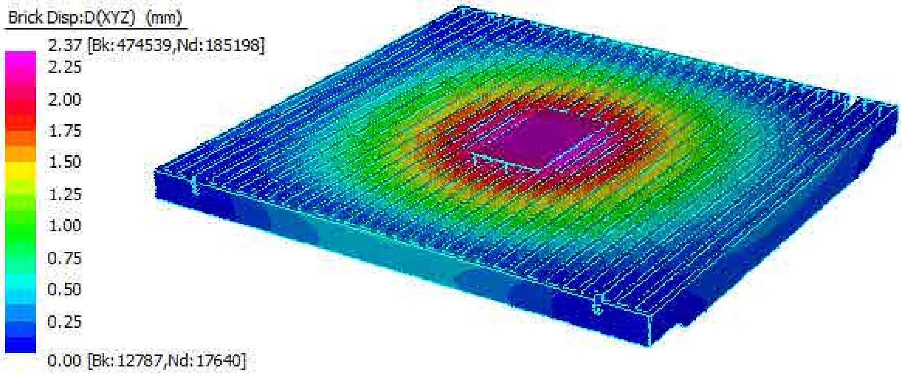
Von Mises Stress- Top view

Load case 2: Midway between centre of fitting and edge-Point 1

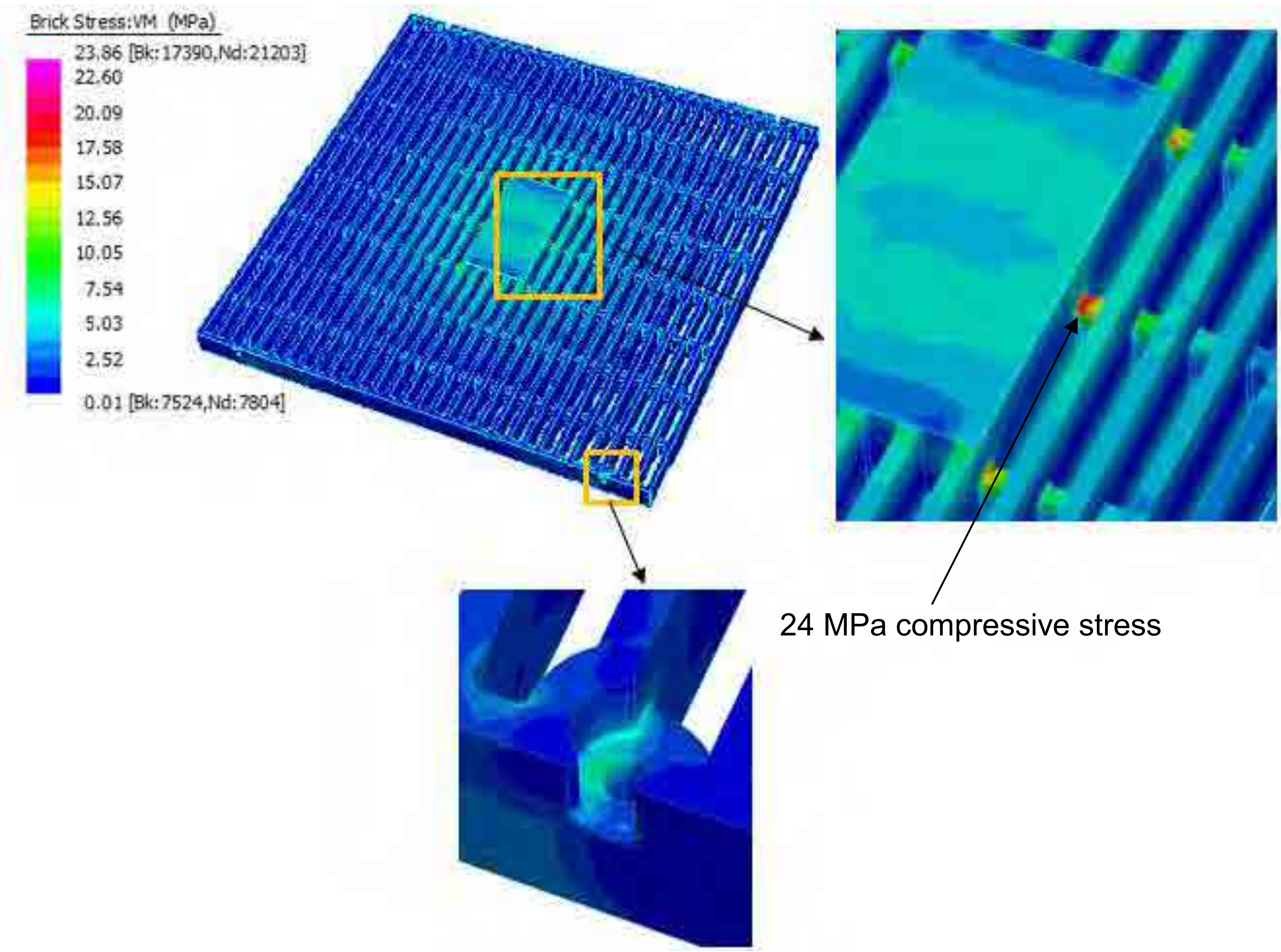


FEA Model -Load case 2

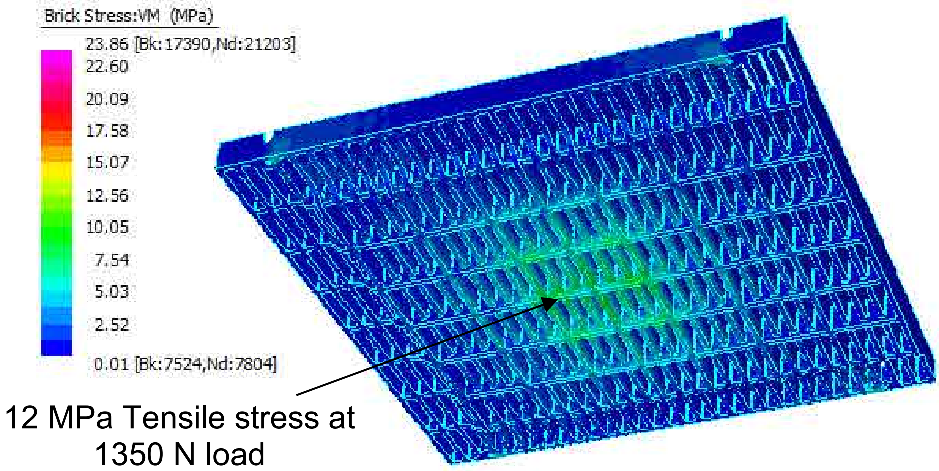
<u>1350 N Force</u>



Deflection

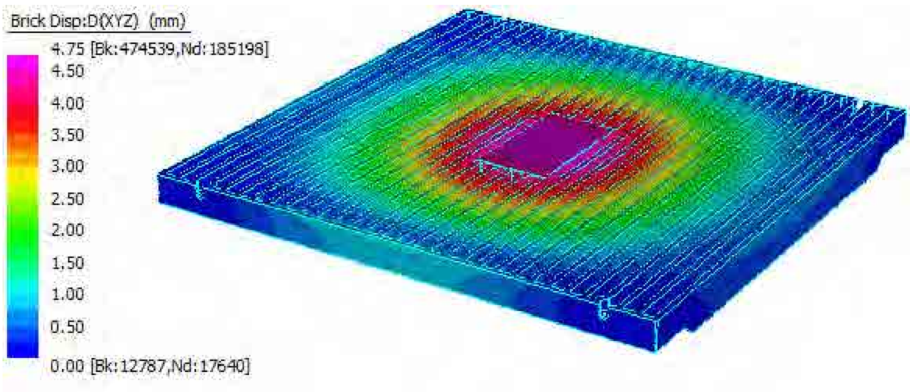


Von Mises Stress- Top view

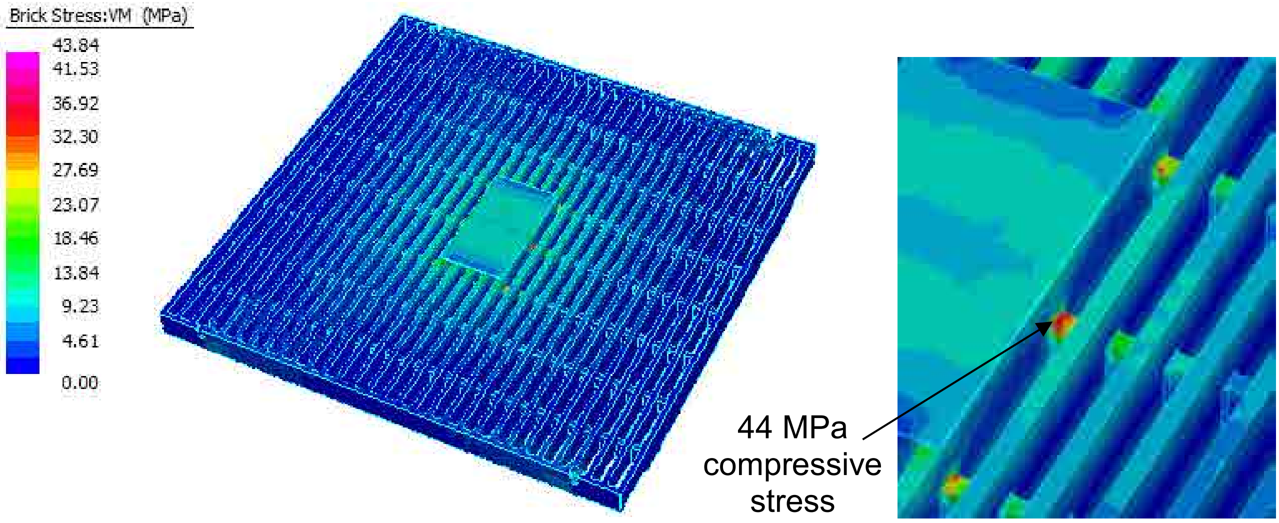


Von Mises Stress- Bottom view

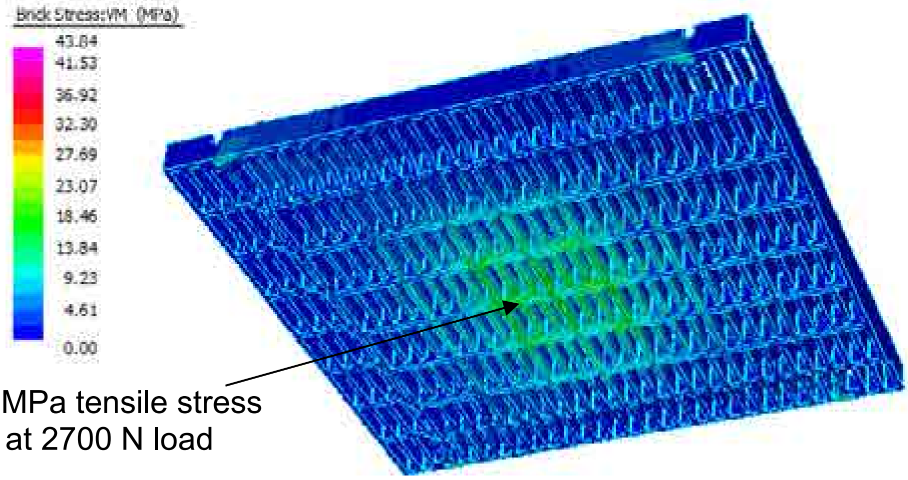
<u>2700 N Force</u>



Deflection

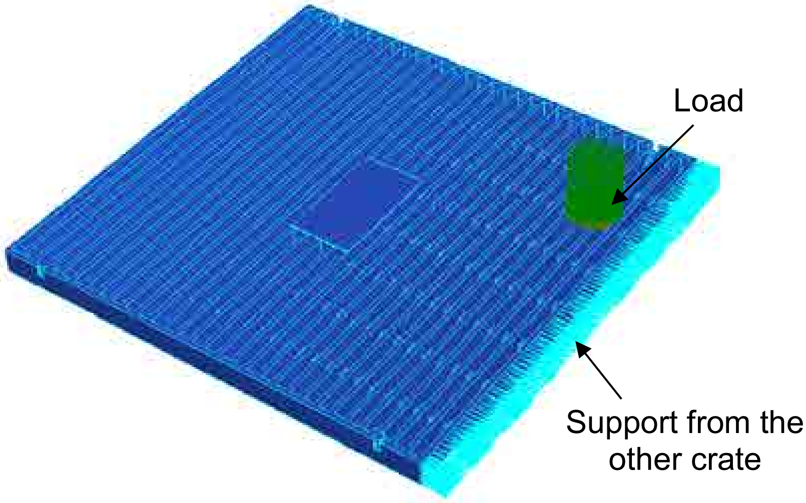


Von Mises Stress- Top view



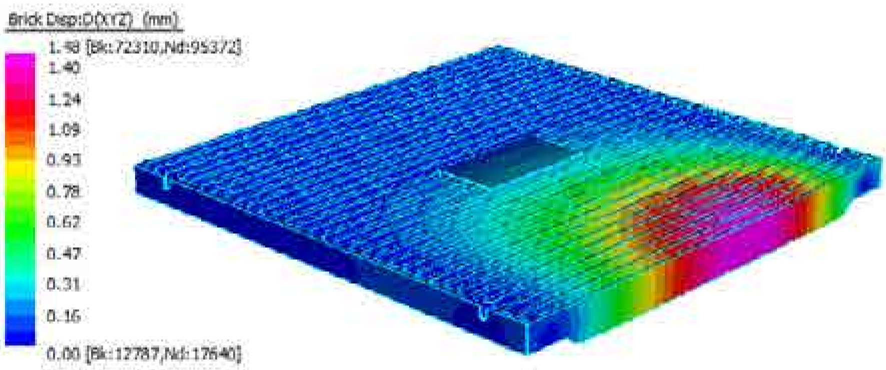
Von Mises Stress- Bottom view

Load case 3: Midway between centre of fitting and edge-Point 2

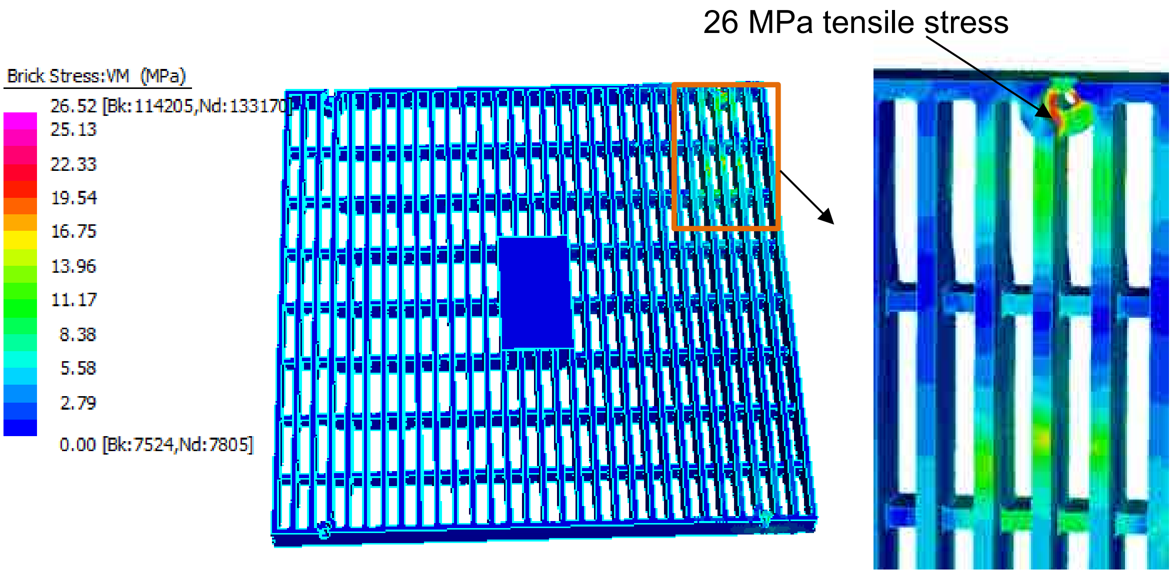


FEA Model -Load case 3

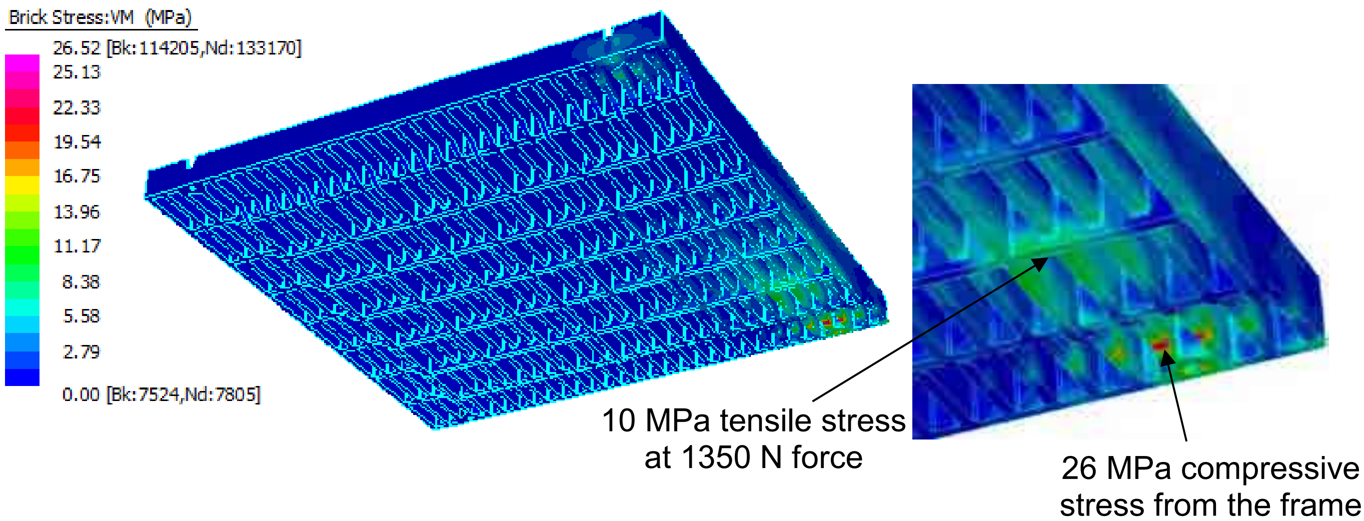
<u>1350 N Force</u>



Deflection

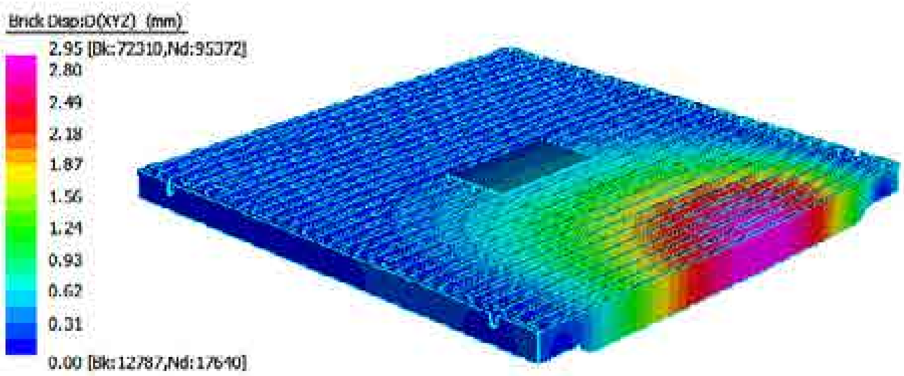


VonMises Stress-Top View

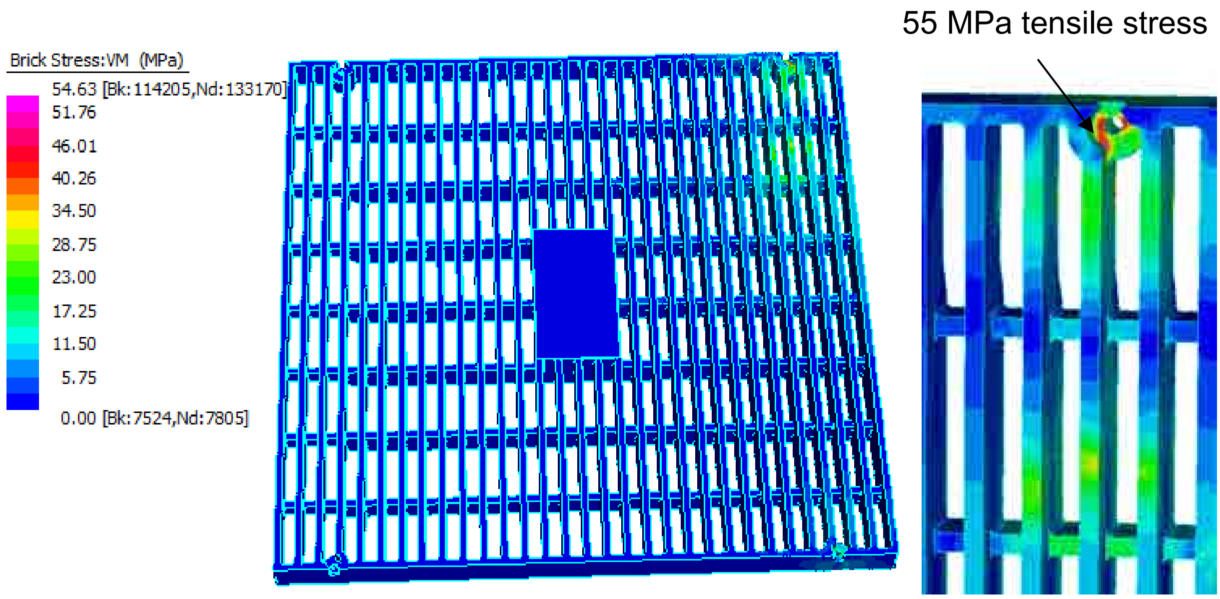


VonMises Stress-Bottom View

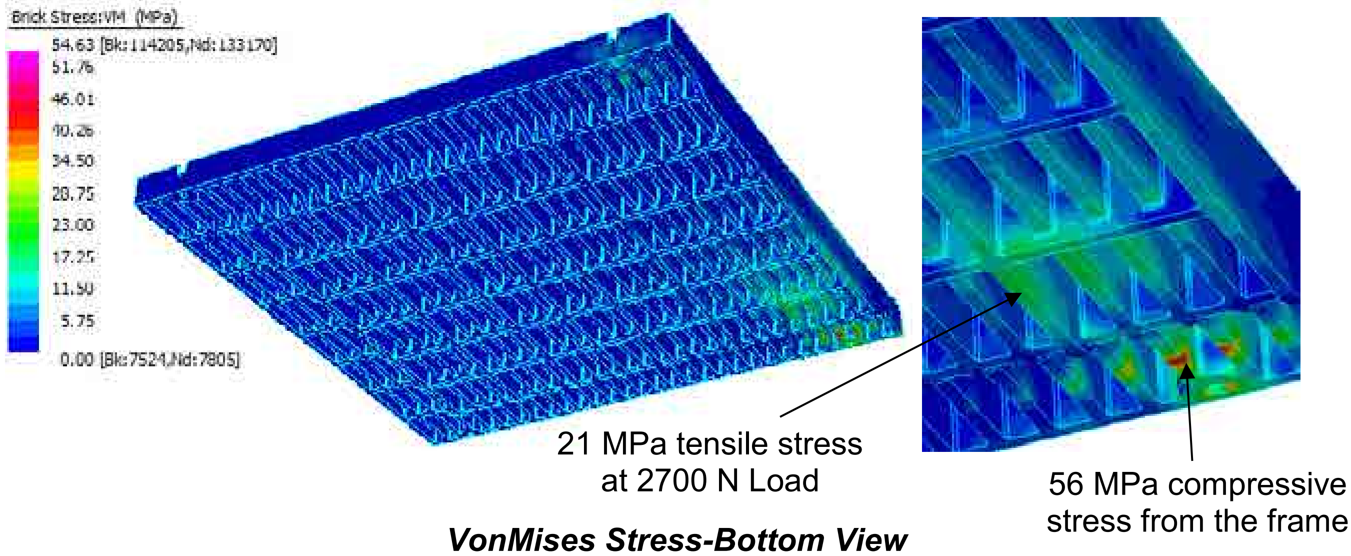
<u>2700 N Force</u>



Deflection

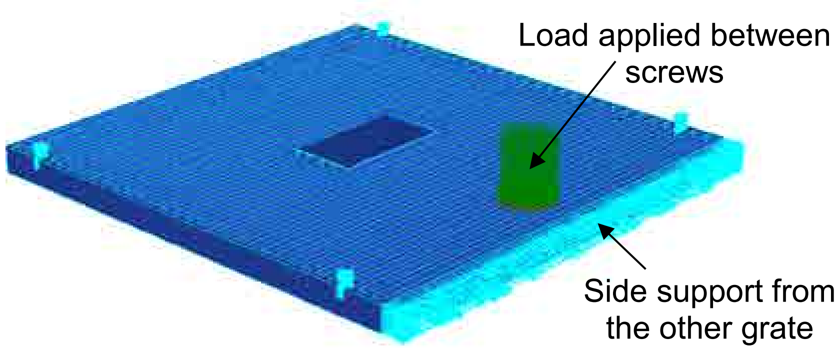


VonMises Stress-Top View



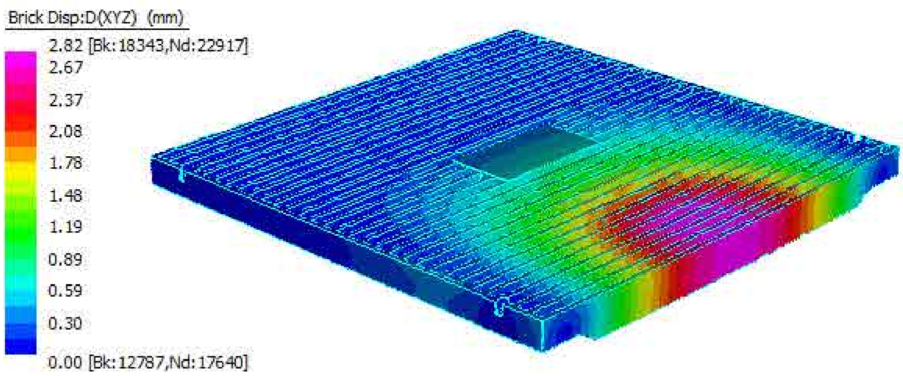
VonMises Stress-Bottom View

Load case 4: Between screws- Grate edge 1

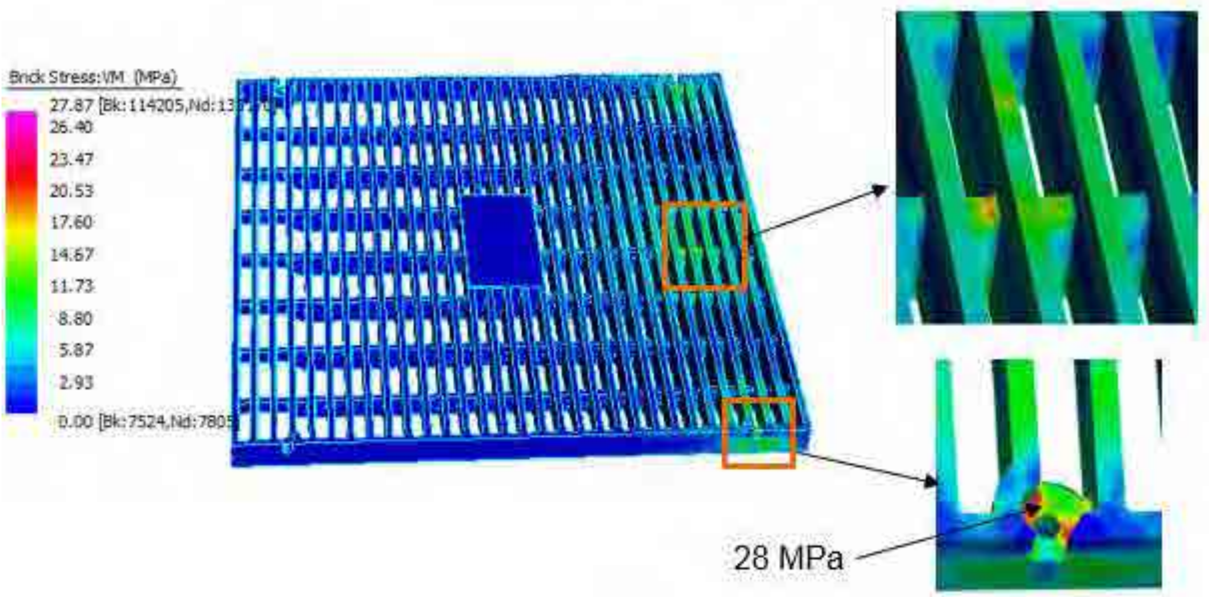


FEA Model -Load case 4

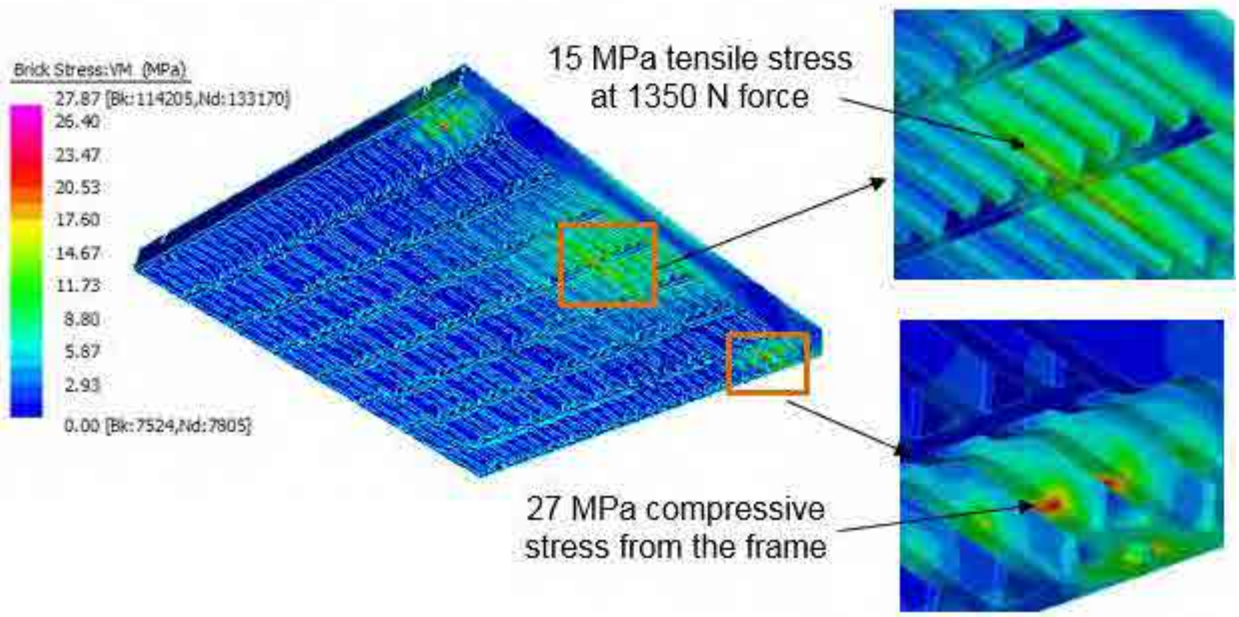
<u>1350 N Force</u>



Deflection

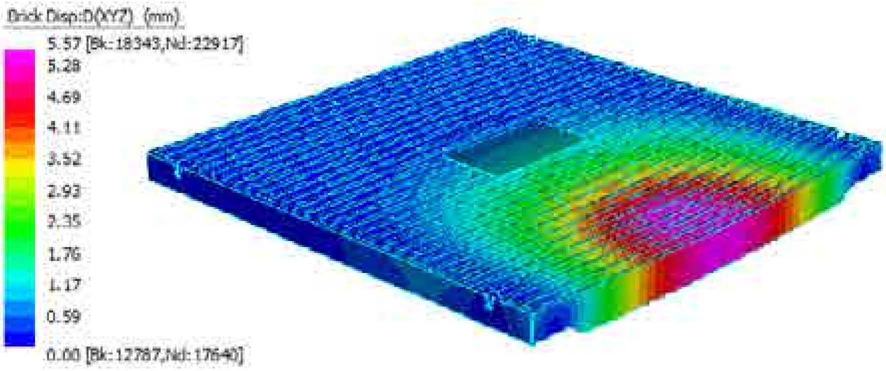


Von Mises Stress- Top View

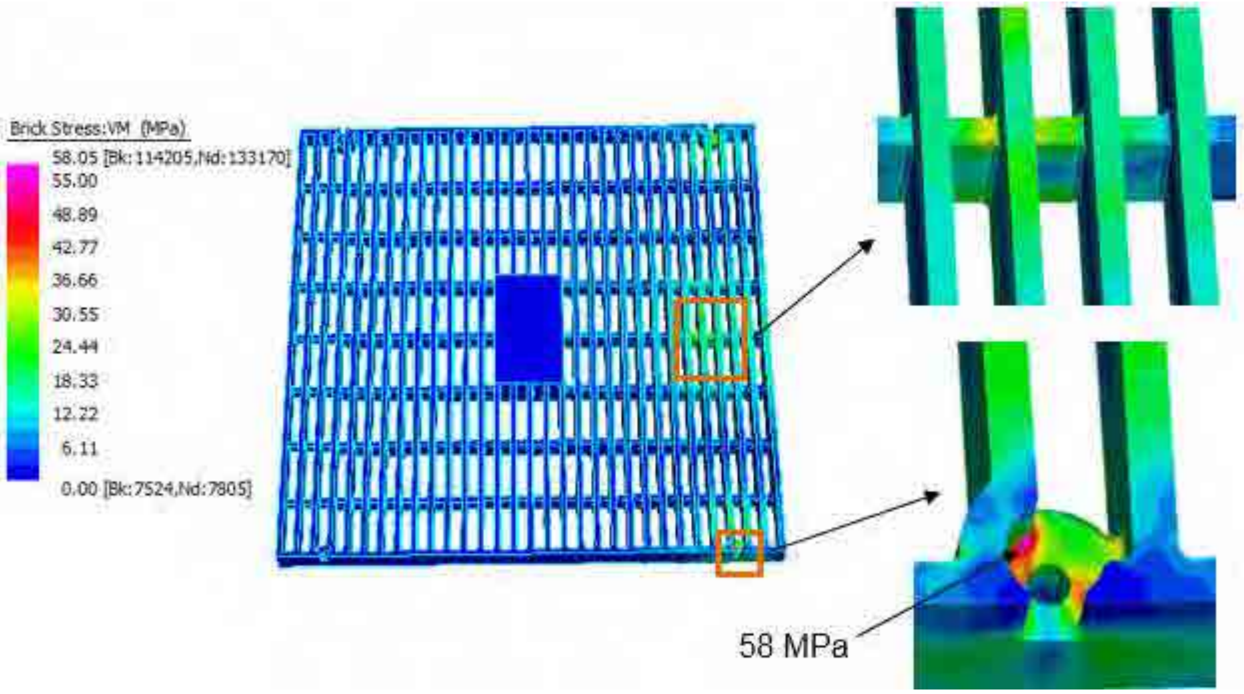


Von Mises Stress- Bottom View

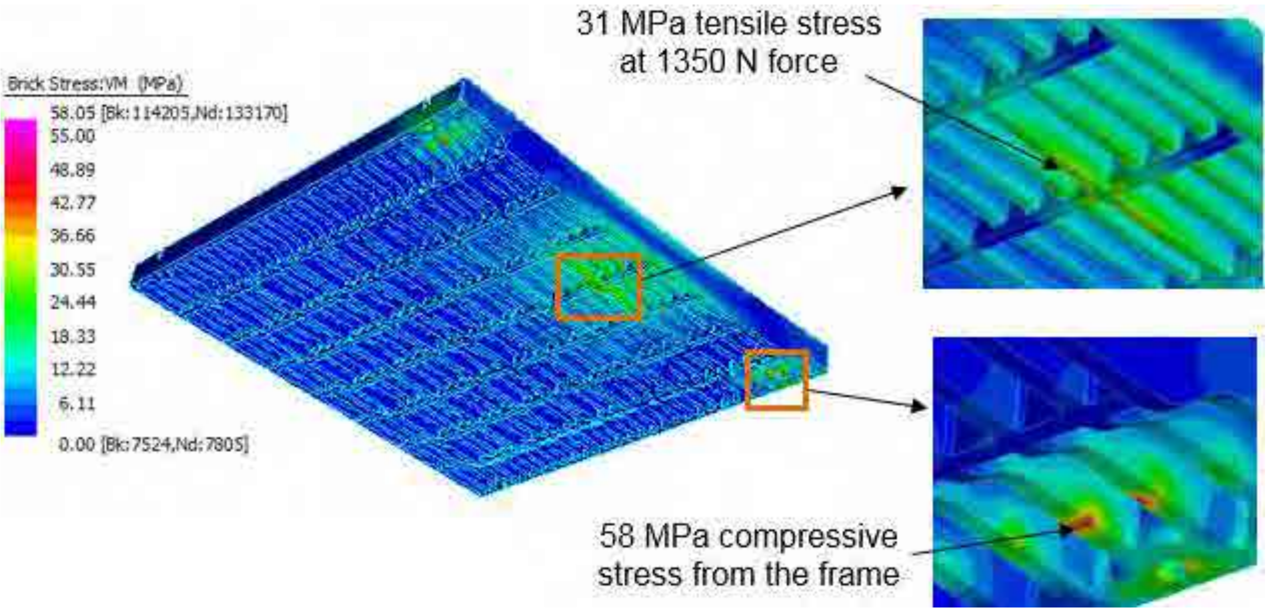
2700 N Force



Deflection



Von Mises Stress- Top View



Von Mises Stress- Bottom View

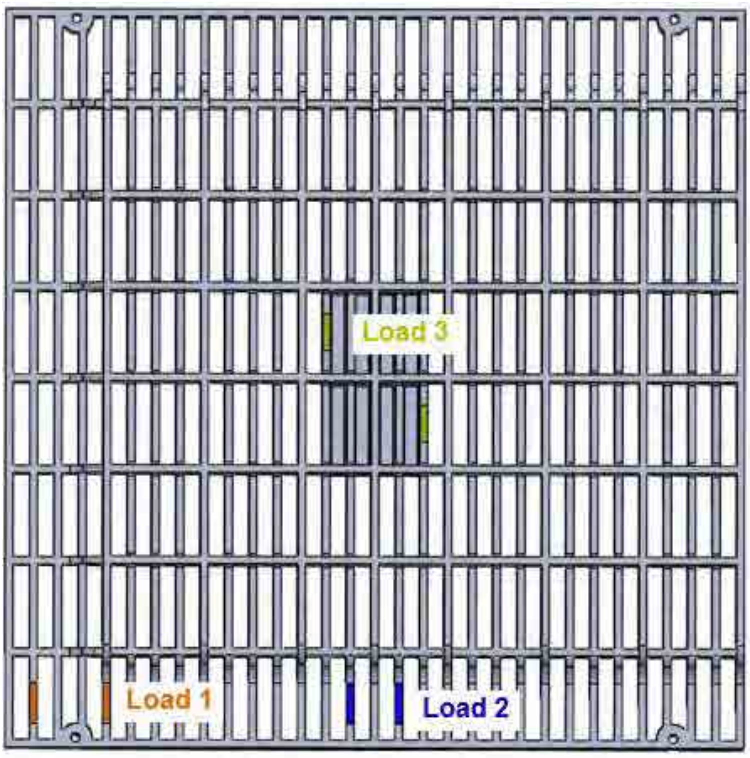
Pull Load Test (clause 3.8)

The pull test is required of all fitting with openings of 9.53 mm or more, affording a finger grip.

The opening of the DMD grade is 10.22 mm x 51.5 mm and therefore this test was simulated in the FEA analysis.

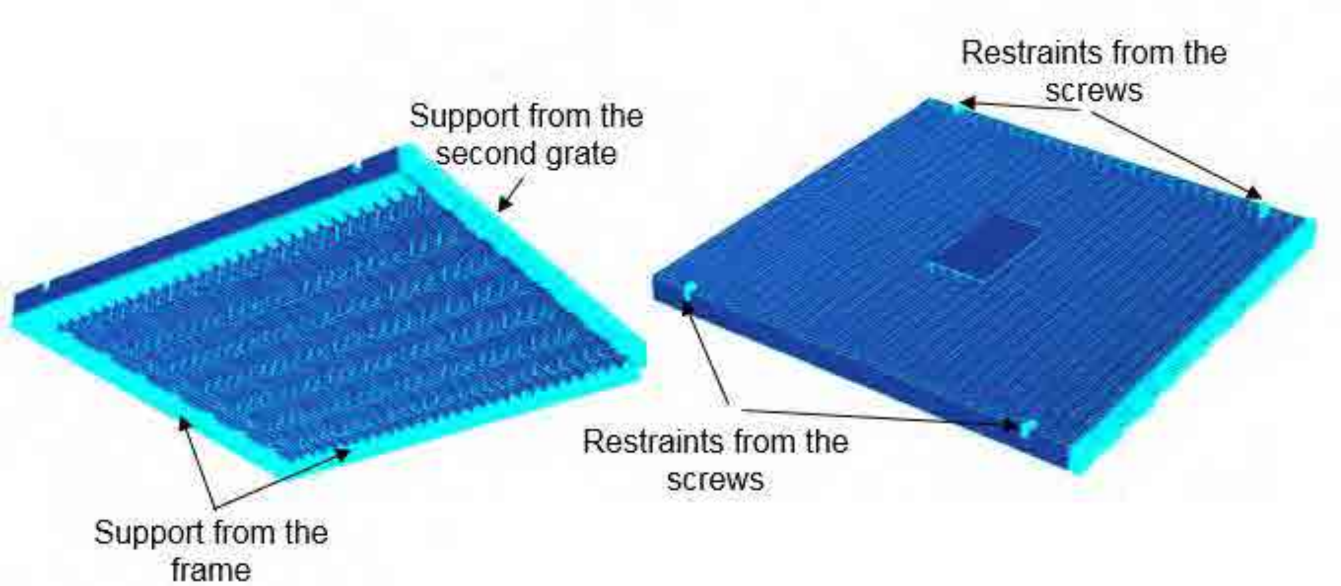
A load of 700 N was applied on the underside of the grate to approximate a bather's three fingers directly adjacent to the screws and midway between screws.

Three load cases were simulated for this test as shown in the diagram below:



Load diagram for pull tests

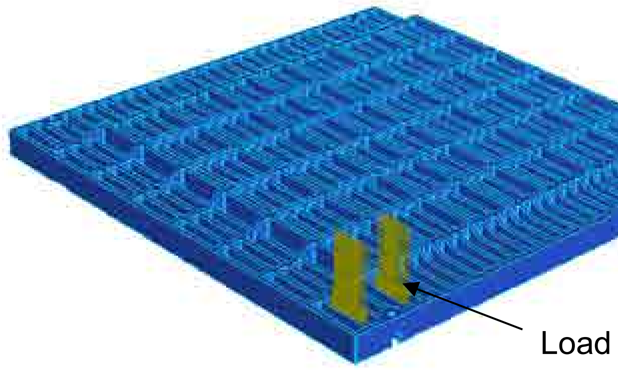
The same support and restraints were used in this part of analysis:



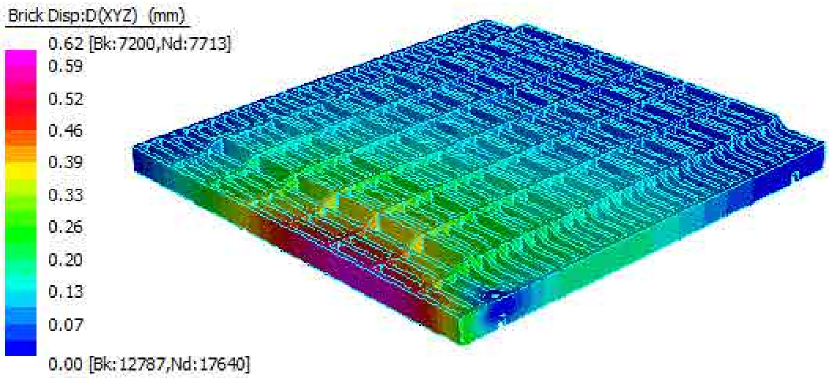
Support and restraints for the pull test analysis

The results for the pull load tests simulations are shown next in the report.

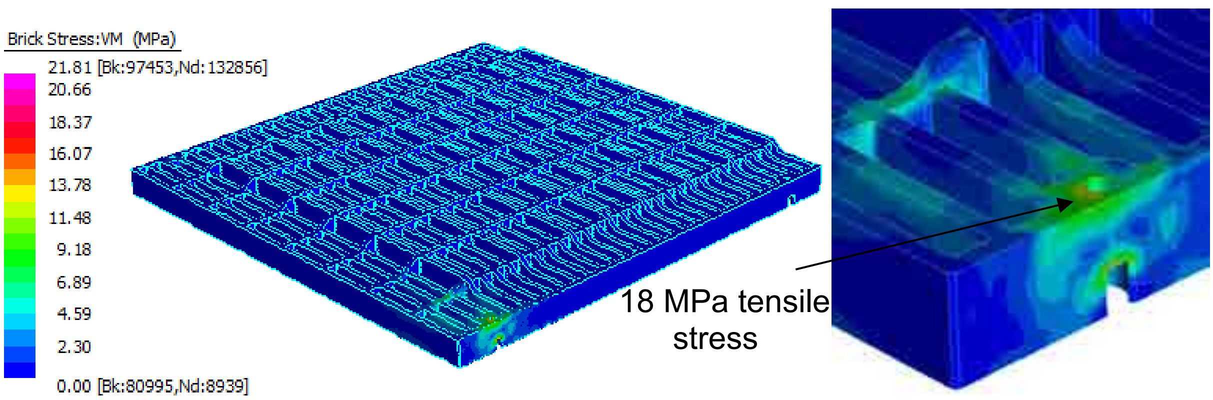
Load case 1: Pull test adjacent to screws



FEA Model -Pull test-Load case 1

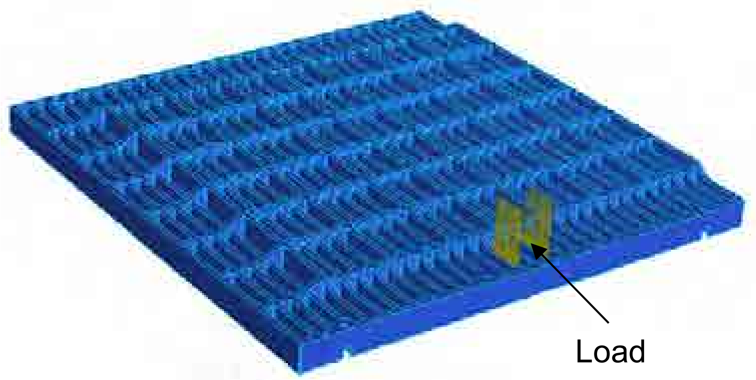


Deflection

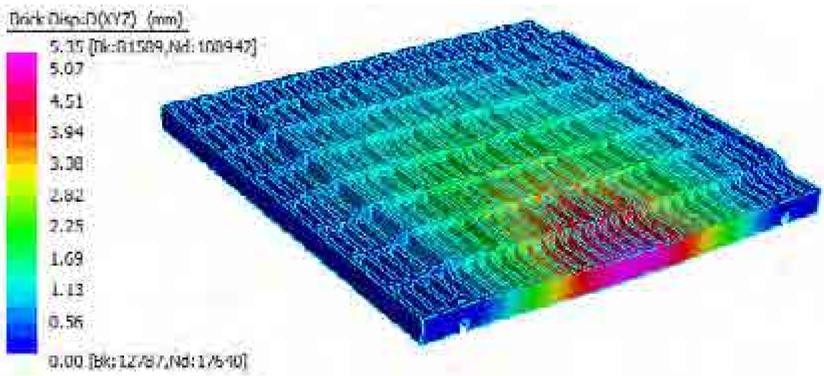


Von Mises stress at 700 N load

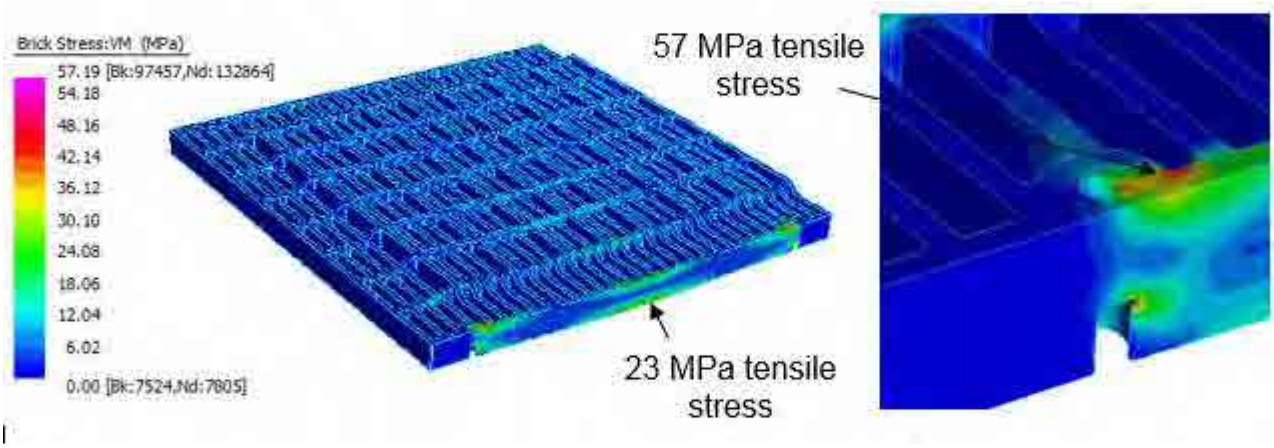
Load case 2: Pull test between screws- Point 1



FEA Model -Pull test-Load case 2

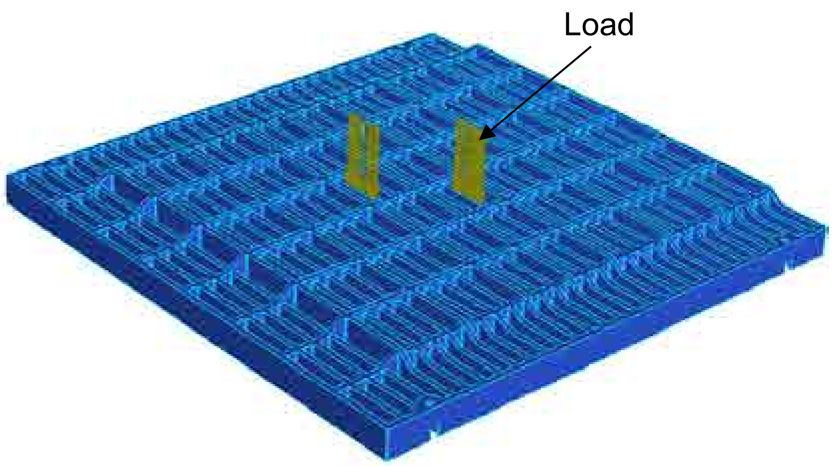


Deflection

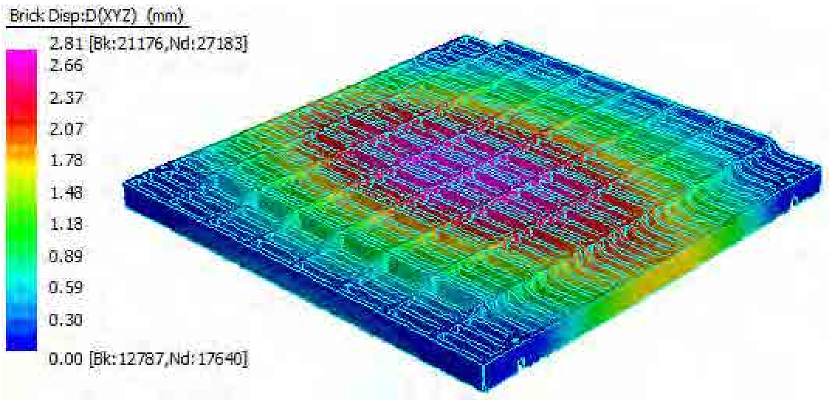


Von Mises stress at 700 N load

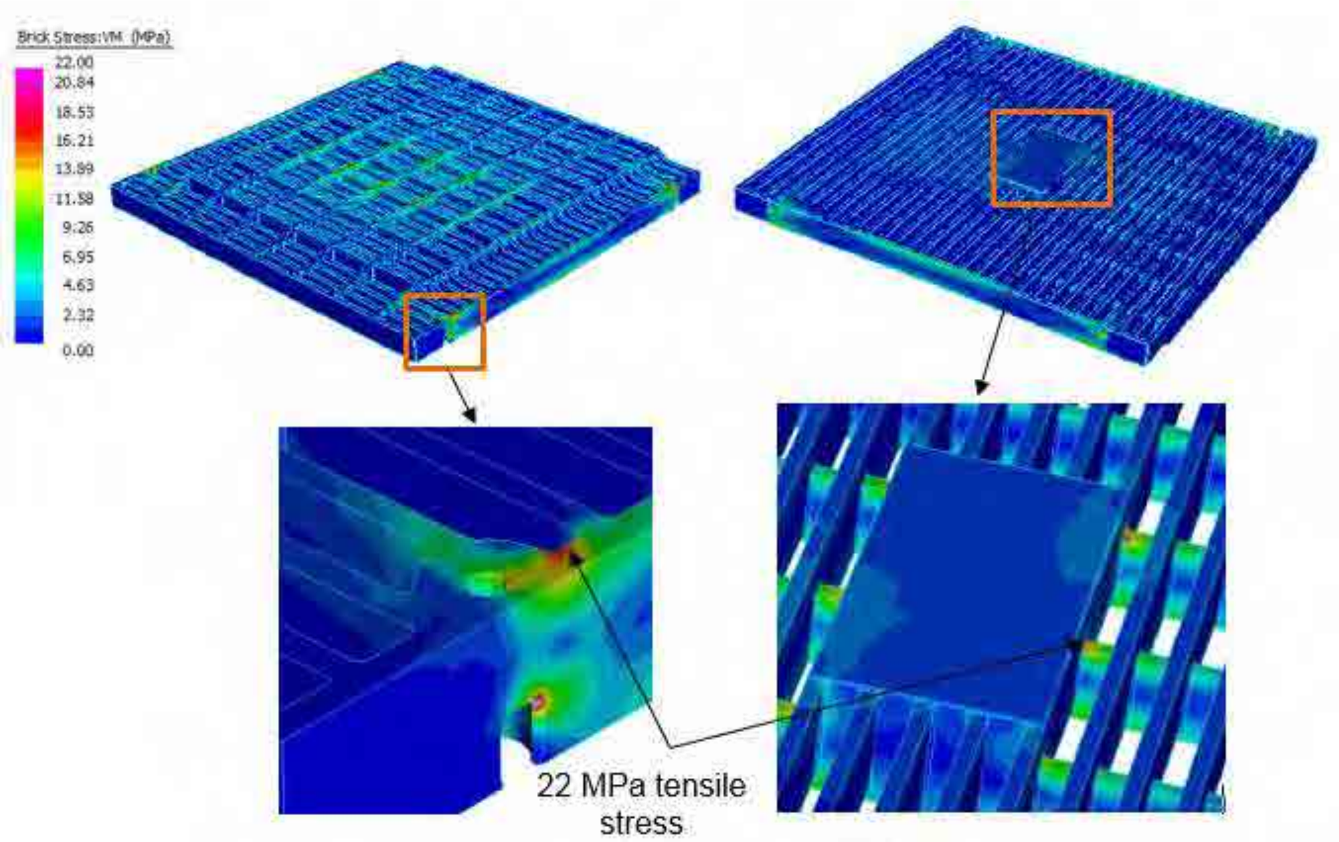
Load case 3: Pull test between screws- Point 2



FEA Model -Pull test-Load case 3



Deflection



Von Mises stress at 700 N load

