NOVA Note 6/21/2005

Stress Test of a 3-Plane PVC Test Block

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Abstract

We have tested to destruction a test block of three crossed planes, each made up of 4 pieces of the 5" x 1" extrusion, made by PET .
This test was the first to subject an assembly of extrusions to large forces.
In particular, the epoxy joining the planes was stressed in shear, the way the weight of the horizontal extrusions will stress that glue layer in the NOVA far detector.
The failure mechanism is quite complex, being a combination of shear (locally concentrated) and local buckling. The maximum supported force was 15,000#.
If we assume, conservatively, that only the top extrusion effectively participated in resisting the loading, then this force is equivalent to a safety factor of 105.

Introduction

The NOVA detector is assembled from 15.7 m long, 1.3 m wide, and 0.066 m thick PVC panels , extruded with 32 cells in each panel.
The cells are filled with scintillating oil and read out with optical fibers.
Planes are assembled alternating between vertical and horizontal cells.
Planes are glued together into 32 cell blocks, followed by a 1 cm expansion gap.

Some Structural Issues

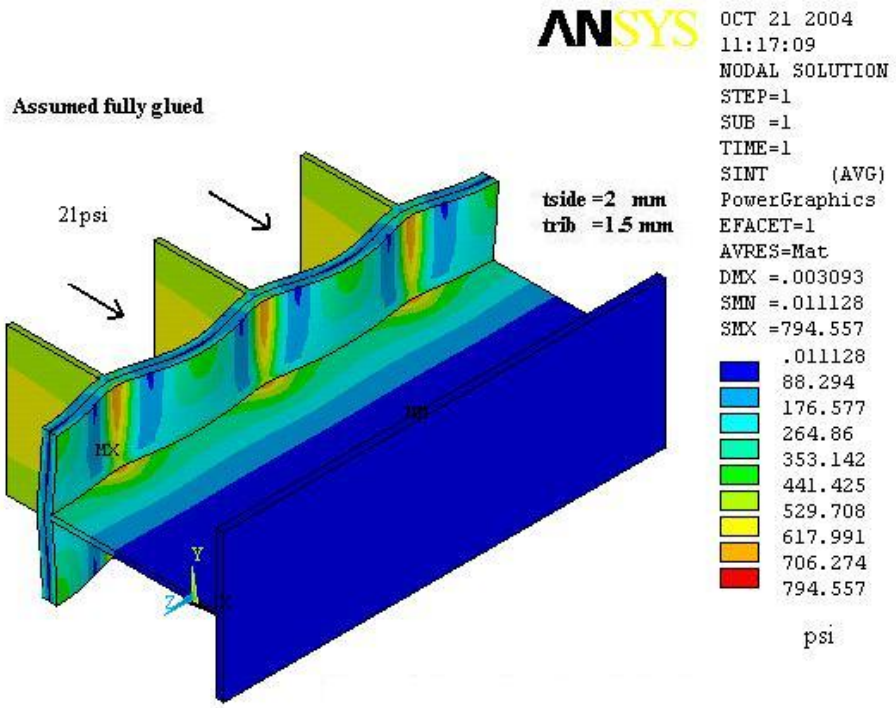
Vertical extrusions are supported by the floor, while the horizontal extrusions transfer their weight to the neighboring vertical extrusions via epoxy gluing.
The epoxy is stressed in shear, mostly.
The weight of each horizontal extrusion expresses itself along its bottom edge as a hydrostatic pressure force. This is the force that needs to get transmitted to the vertical extrusion next to the horizontal one. (Note that a block may terminate in a horizontal extrusion which is, then, only supported from one face).

The weight force is not transferred over the full contact area.
The PVC extrusion has a 3mm thick sheath wall. If this wall behaved like an immutably stiff element., then the shear stress in the epoxy would be simply the weight force divided by the contact area. Here, however, the strain in the PVC wall becomes equal to the strain in the glue bead over a very small vertical band. Beyond that band the glue does not contribute in resisting the weight force. This stresses the epoxy similar to a peeling situation, rather than a simple shear situation.

In addition the strain in the PVC can express itself as local waves and, eventually, buckling:

Figure 3

This figure shows the deformation from internal pressure in the vertical extrusion. I do not yet have an FEA analysis of the band near the lower edge of a horizontal extrusion.



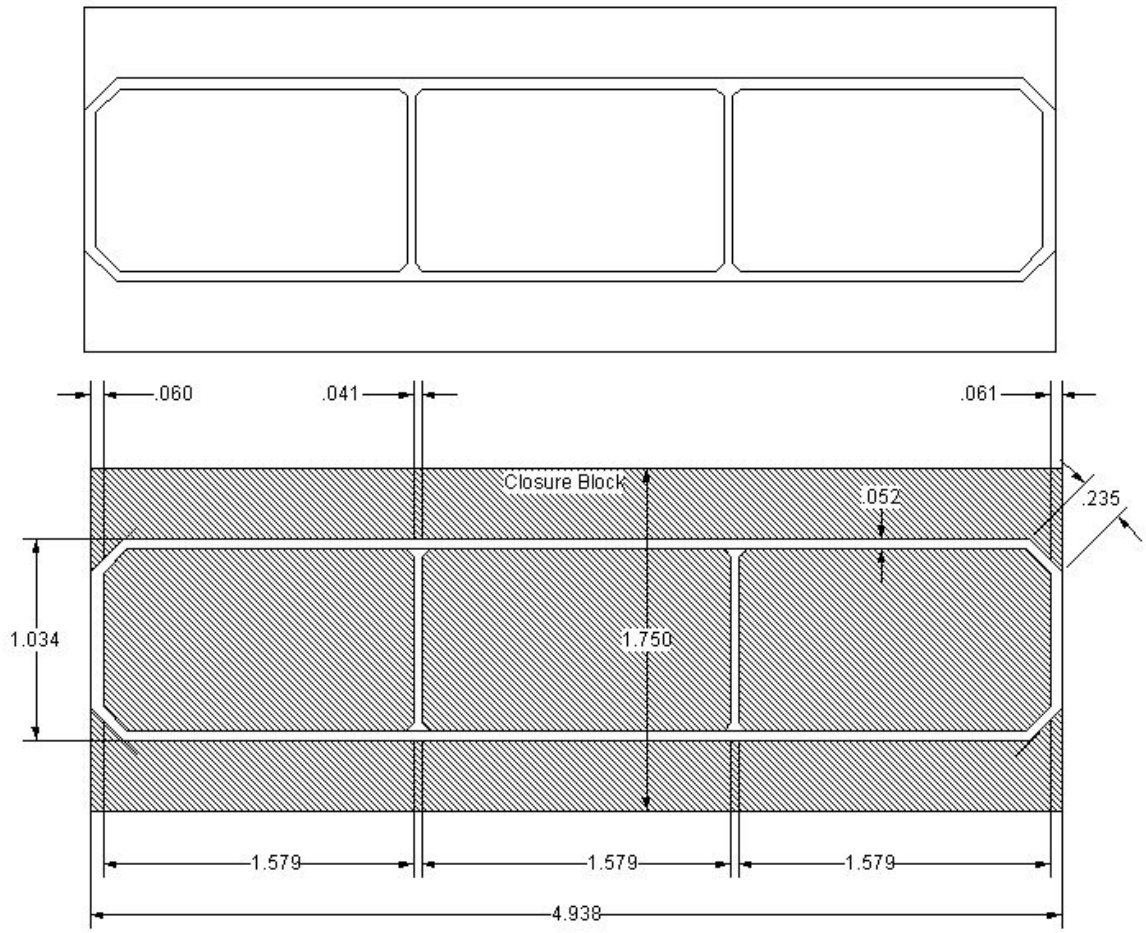
NOVA

Figure 8 **Stress for a fully glued case**

This is just to illustrate the kind of deformations and waves in the PVC structure. We have yet to run an FEA for the weight loading from horizontal extrusions.

Motivation for the Present 3-Plane Test

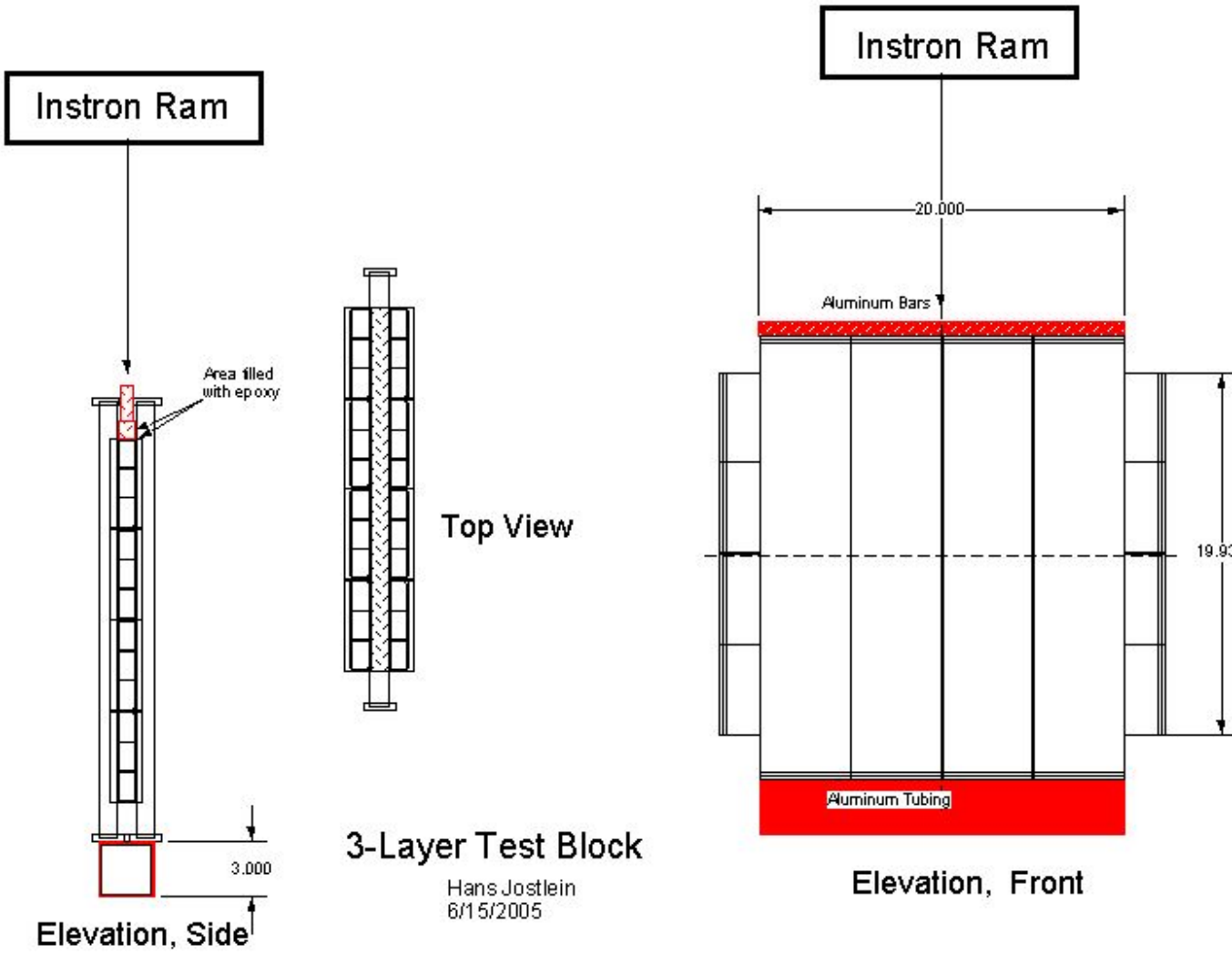
FEA calculations are extremely important and informative. Yet it is prudent to test as many situations as one reasonably can .
The 3-plane test was meant to give a first look at the actual strength one can achieve in a typical NOVA element.
Since the final NOVA extrusion has not yet been produced, we used extrusions made by PET from a much earlier NOVA 3-cell die.



NOVA 3-cell test extrusion as produced

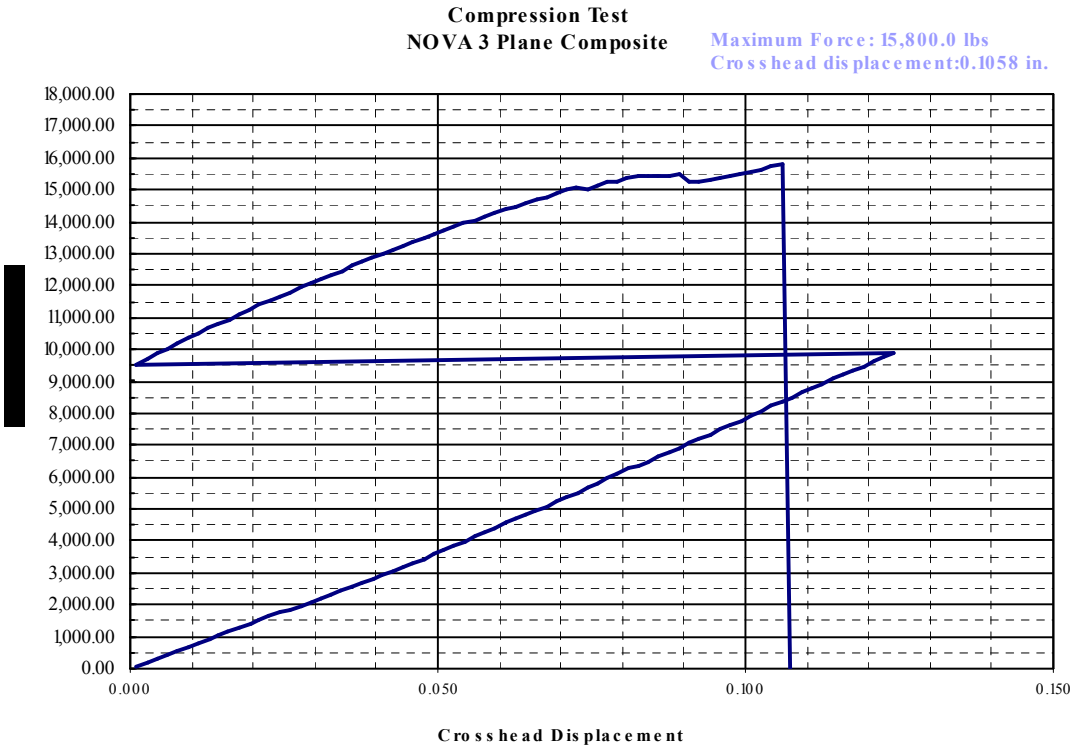
Hans Jostlein 1/11/2005

This extrusion has a 1.3 mm thick outer wall, compared to the 3mm wall expected for NOVA. The 3-plane test block was made of three crossed planes, each having 4 pieces of the 5" x 1" "PET" extrusion.
The block was oriented with the two outer planes set up with vertical extrusion orientation, while the middle plane had horizontal extrusions.
The outer planes were epoxied to a sturdy 3" x 3" aluminum tube, used to distribute the center support force of the Instron stress/ strain tester over the full 24 inch width of the block.
The top had a 1" x 1" aluminum bar epoxied to the top of the upper horizontal extrusion. The sides of the bar ended up also epoxied to the vertical extrusions next to it.
The 1" x 1" bar was reinforced with a ¾" thick by 2" high aluminum bar on its top, also connected with epoxy. This top set of bars distributed the Instron's ram force over the 24" width of the PVC block.



The Test

We brought the upper ram down with a speed of 0.100 inches per minute, while recording the position and force of the ram:



The lower curve was taken while the maximum force was set to 10,000#.
When the machine stopped at this force, we raised the maximum force to 50,000# .
Without releasing the force, we resumed testing , which brought the graph stylus back to zero strain. Significant damage to the test object started at about the 15,000# level. This is the number we take as representative in the following analysis.

Analysis and Comparison to NOVA

We are attempting to relate this measurement to the NOVA structure.
Clearly this is a small test, and it uses a very different extrusion.
Nonetheless it appears that we can deduce some useful comparisons.

To do that we make these assumptions:

a. Only a small vertical band around the bottom edge of a horizontal extrusion transfers the weight to the vertical extrusion next to it

b. The height of that band is proportional to the extrusion wall thickness

c. We look at the most stressful case where a horizontal extrusion is at the end of a block, supported only from one face.

d. In the 3-plane test, only the uppermost horizontal extrusion is loaded.

In NOVA, the weight of a 24" long by full width (1.31 m) oil filled extrusion is 32.5 kg
The force to break on the 3-plane test piece was 15,000 # or 7,500 # each side (= 3409 kg force per side). This translates into a safety factor of (3409/32.5) = 105
If one takes into account the double wall thickness, this becomes a safety factor of 210.
We may consider using a 50% glue coverage near the bottom edges of the horizontal extrusions, and only 10% coverage elsewhere. The safety factor would still be 105.

This is, of course, not a thorough failure mode analysis;
The huge safety factor does add to our confidence that a reliable and rugged structure can be assembled.

Appendix: Pictures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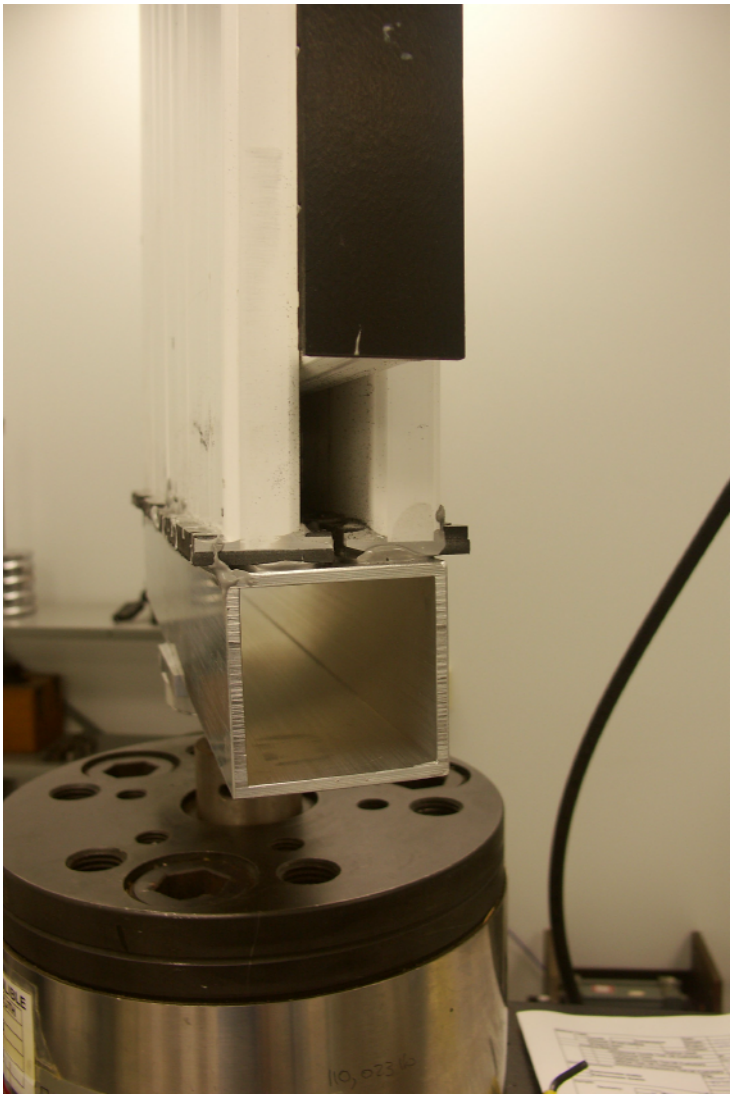
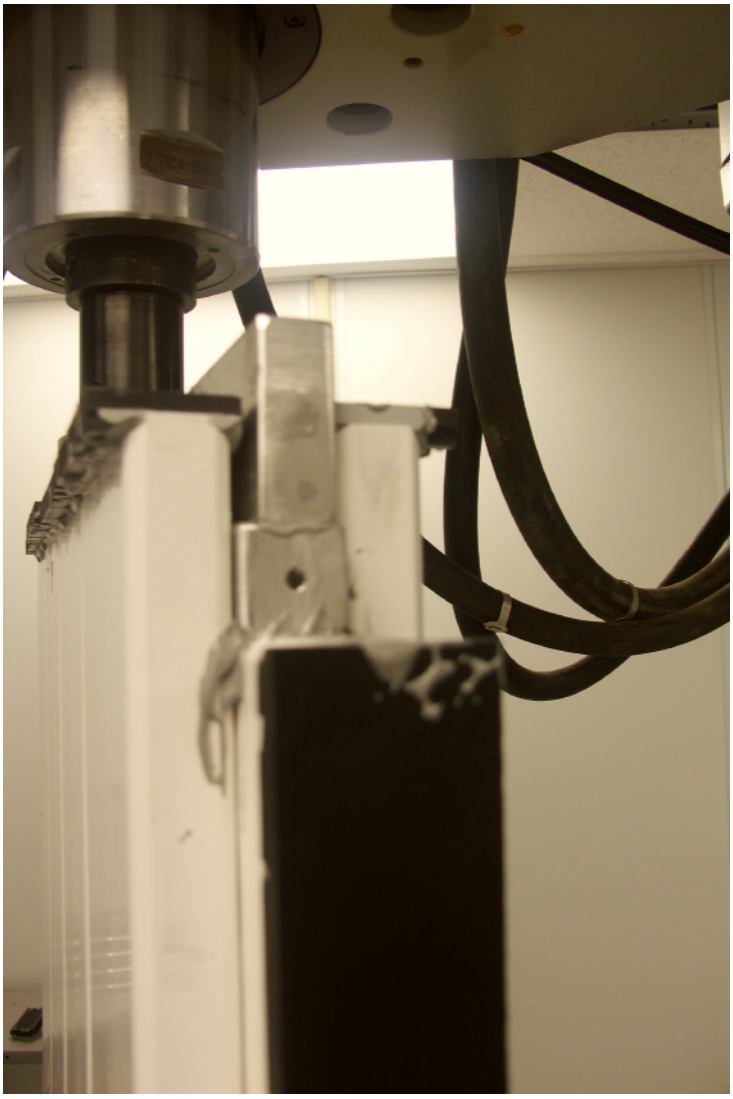
50,000 KG



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