

### **FEA Calculations and Hand Calculation Check on Ladder:**

FEA, finite element analysis, output from Algor Software is shown. The loads applied to the fourth step were:

Vertical = 240 pounds.

Horizontal = 70 pounds.

With these low live loads, which are discussed later, the ladder is stable from tipping over. The stresses range from 48,000 psi in the brace, which will cause failure in the brace, to an average of 16,000 psi across most of the lower leg that will not cause failure in the lower leg or rail until the brace buckles. When hand calculations are made for the lower leg by treating the leg as a simple rigidly supported cantilever beam, which it is not, the stresses are 16,845.6 psi. This compares with the 16,000 psi determined by the FEA method. In other words, the hand calculations verify that the FEA calculations are correct for any skeptics.

Hand calculations based on strength of material theory are crude in comparison to finite element analysis. These calculations based on idealized situations get ballpark results. In these comparisons between FEA and hand calculations, FEA is very accurate and the hand calculations are "ball park" values. If there is a significant factor of safety, the hand calculations are often adequate. In type II and type III ladders, there is essentially no factor of safety because of normal dynamic loading on ladders.

In addition, the authors have used Algor (Finite Element Analysis) to certify a broad range of products from seating systems in major auditoriums to products in large retail chains. Physical tests show these products fail at the high stress areas found through FEA. In fact FEA is superior to physical testing in most cases because high stress areas are often carried for awhile by low stress areas. A product may pass a single load test, but it will fail under repeated loading. FEA is the state of art way to determine whether a product is safe for public use.

### **Finite Element Analysis of Model xxxx**

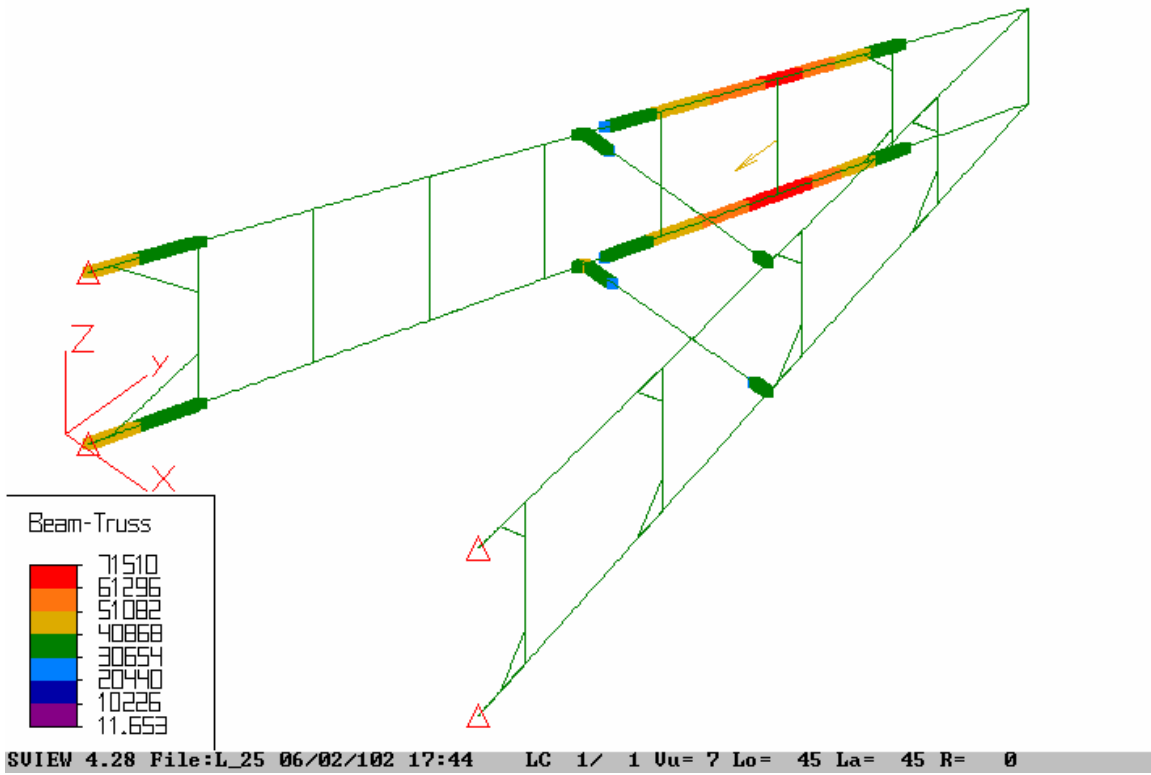
Load Case #1:           Filename: L\_25

Loading: 800 lb. Downward on 6<sup>th</sup> step with 25 pound load forward, with gravity on

Boundary Conditions: Front legs and one rear leg anchored, one leg free

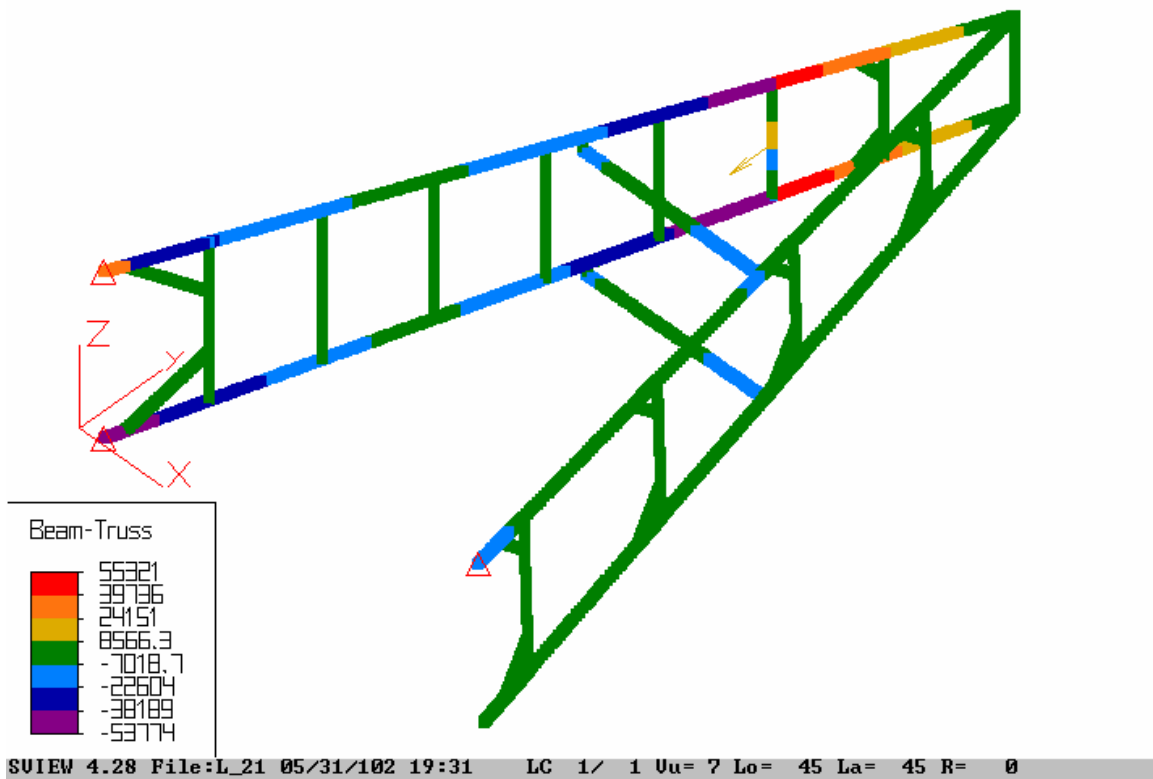
Results: Maximum stress 71,510 psi

Bitmaps:



**Figure 68 - Finite Element Analysis (FEA) of Model XX**

Shown in Figure 68 is an output from Algor finite element analysis program. The load is from a measured impact of 3 g's on the sixth step with a support under one rear leg, which is an attempt to determine the effect of racking. The actual measured impact loading was 4 g's.



**Figure 69 - Impact load of 3 g's on sixth step with one rear leg supported**

The stresses in the area of the break on the rear legs range from 8,566 psi, pounds per square inch, tension to 7,019 psi compression with a maximum stress of 55,321 psi on the front legs at the load. Note that only one rear leg is supported as is the case with racking.

In Figure 70 the same loading is shown except the ladder is not racked. The stresses on the rear legs range from 8,728 psi tension to 5,911 psi compression. The maximum stress is 52,648 psi.

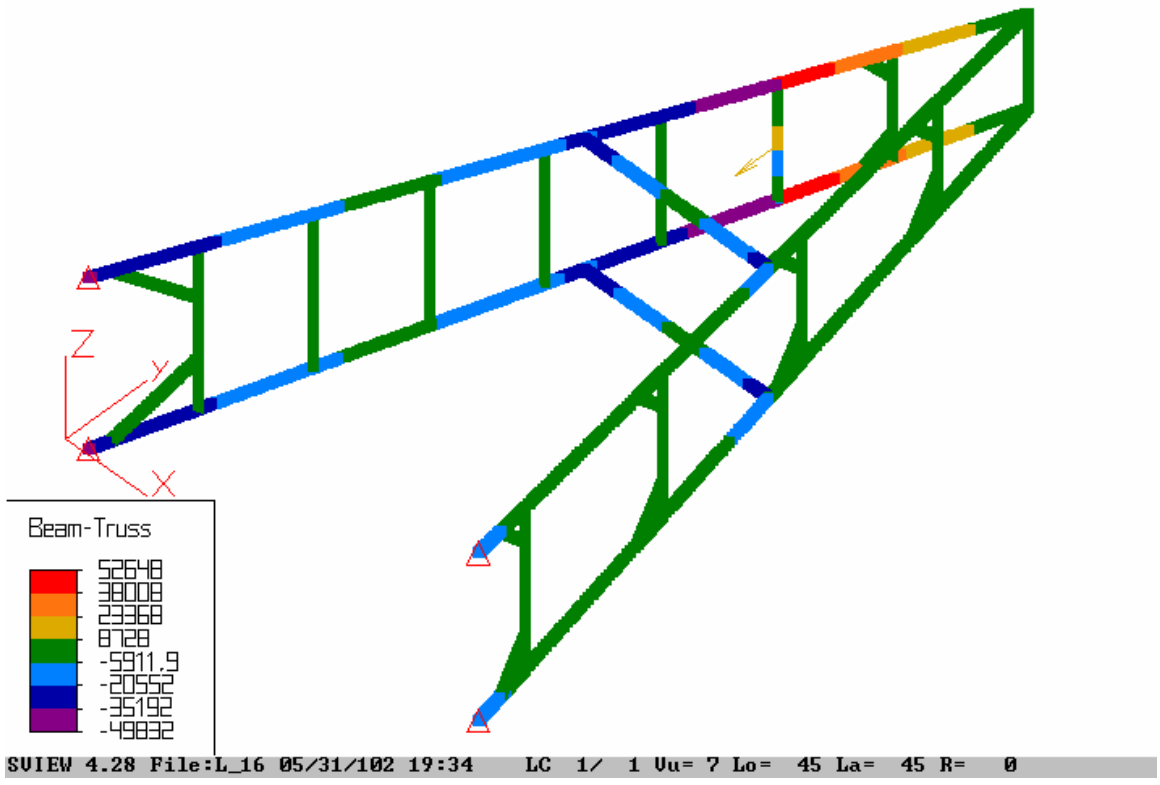


Figure 70 - Impact load of 3 g's on the 6<sup>th</sup> step and ladder not racked