Fermilab

PPD/MD/Engineering Analysis Group

Top Guided Case for the 31 layers Block

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This calculation is following the similar approach as Nova-doc-1147 by using a "top guided" boundary condition, as suggested by V. Guarino.

1) <u>Eigen value buckling calculation</u>

First calculation is done by using an eigen value linear buckling with E=Ecreep(3 and 20 year. The result is summarized in Table 1. The boundary condition for the 31 layers block is "top guided and bottom fixed", as shown in Fig 1

Table-1 Calculation result based on the first approach

Year	E creep _1/D (mpsi)	SF _top guided	SF _ top free
3	0.218	4.08	3.1
20	0.136	2.446	1.859

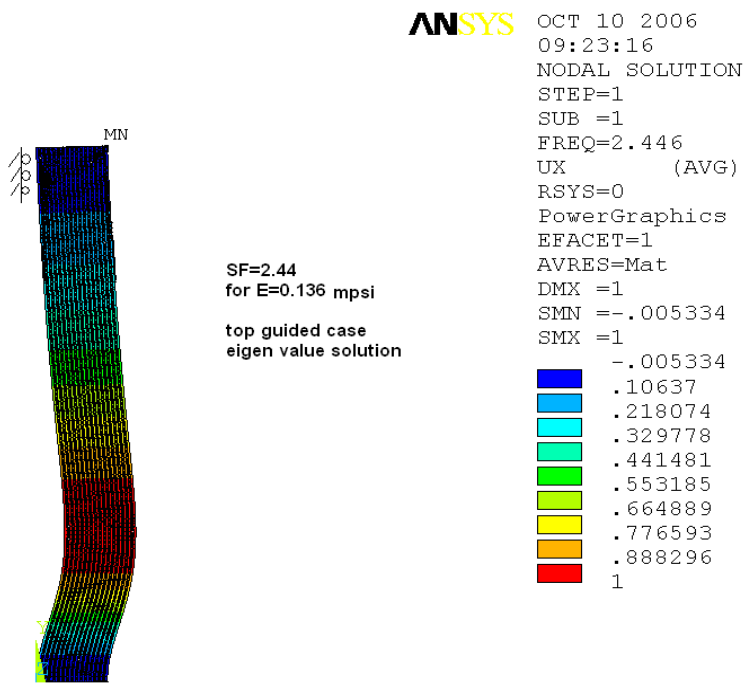

Fig 1 Eigen value calculation for E(20y)=0.136 mpsi

2) <u>A buckling calculation based on a static non-linear analysis</u>

A static nonlinear large deflection approach is used for the second analysis. E=E creep(20y)=0.136 mpsi is used for the calculation. Initially, it is assumed that the structure has 1" off-set at its middle portion of the structure to simulate the structure imperfection as shown in Fig 2. Then, the load has been increased gradually to seek a maximum value at which the structure becomes unstable. Fig 3 shows the deflection UX (beam direction) as a function of the loading. It shows that the structure deflection increases rapidly after 2.2 G load. For a load ~2.2 G , its maximum deflection is about 6" inch. SF of buckling equals ~2.2.

Table 2 Comparison for an Eigen value (Euler) and static nonlinear large deflection solution with E(20y)=0.136 mpsi

E(20y)=0.136 msi	Eigenvalue (Euler)	Static nonlinear large deflection
SF _ top guided	2.44	2.2
SF _ top free	1.85	1.75

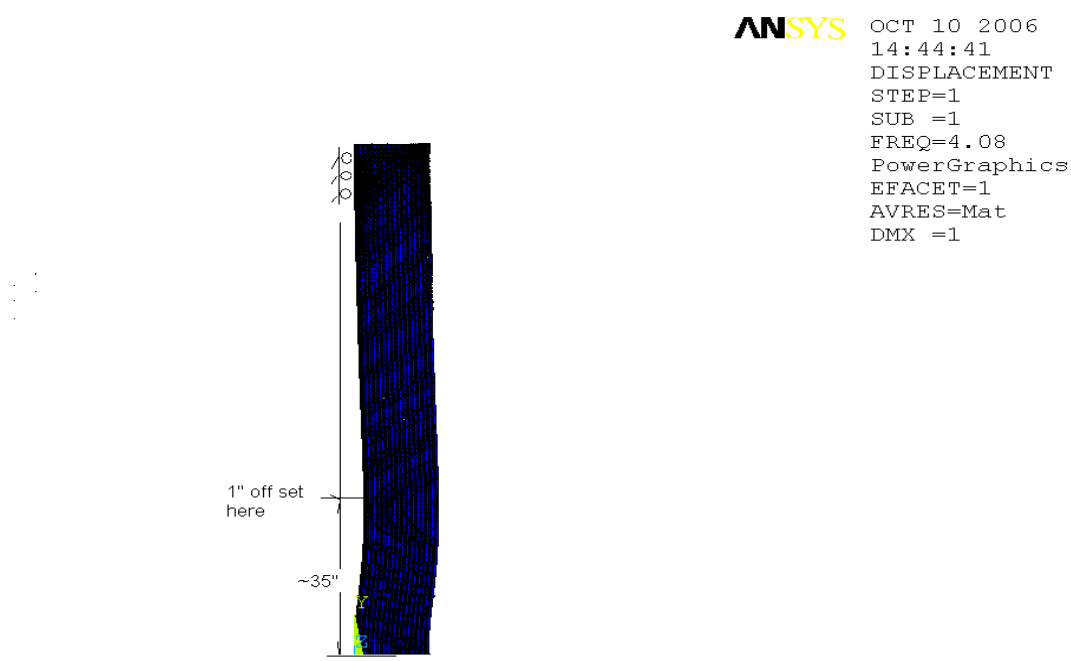

Fig2 FEA model for a top guided case

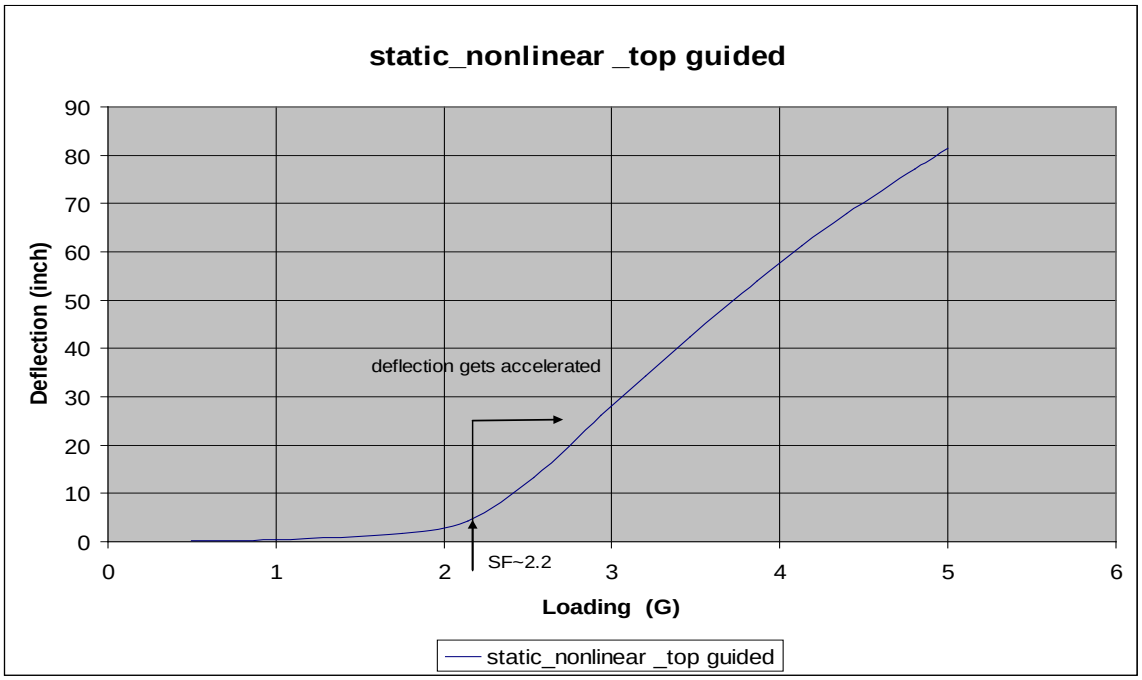

Fig 3 Deflection as a function of the G load

Above two approaches give the estimation of the how much additional force (ΔF) which structure may be able to withstand before it breaks (buckles). However, it does not address how much time is needed to develop the excessive deformation for the structure if the load is a constant.

3) Time dependent of nonlinear large deflection analysis**.**

a) Stability

A same model is used as the reference 1, except the boundary condition is modified from "top free" to "top guided" case. The result is shown on Fig 4. The structure seems very stable up 150 years or more. Since the life span for the structure is only 20 years, any interpretation beyond 50 years is probably meaningless. Fig 5 shows that the maximum deflection for both cases, "top free" and "top guided", are small for a period of first 50 years.

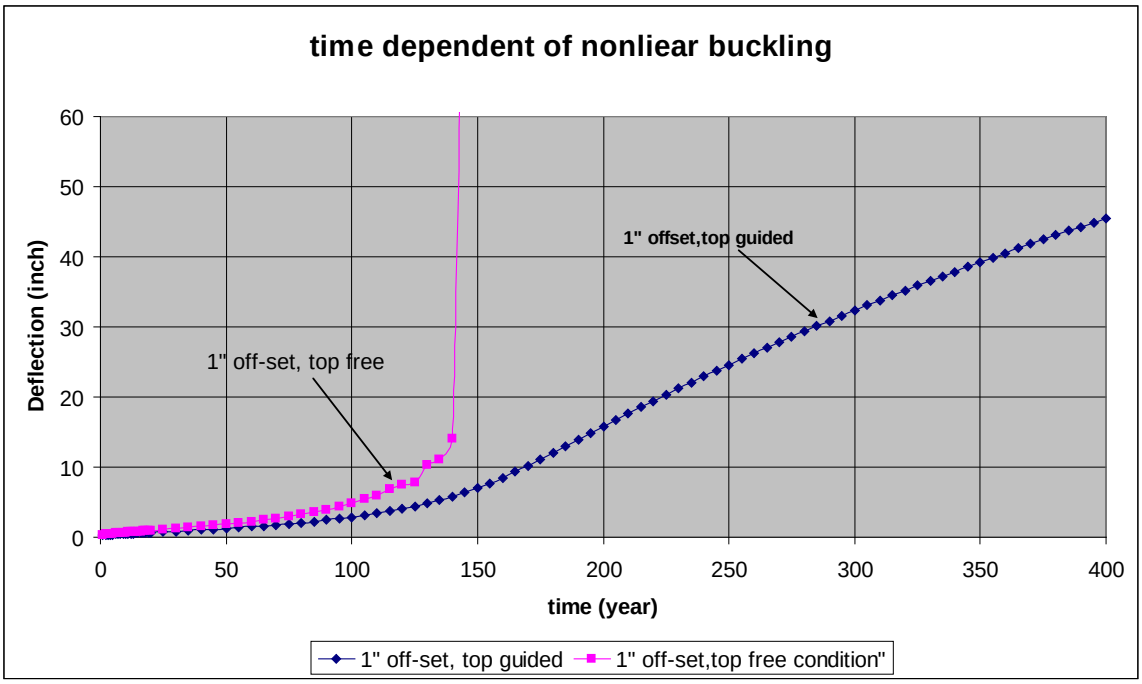

Fig 4 The deflection as function of the time approach

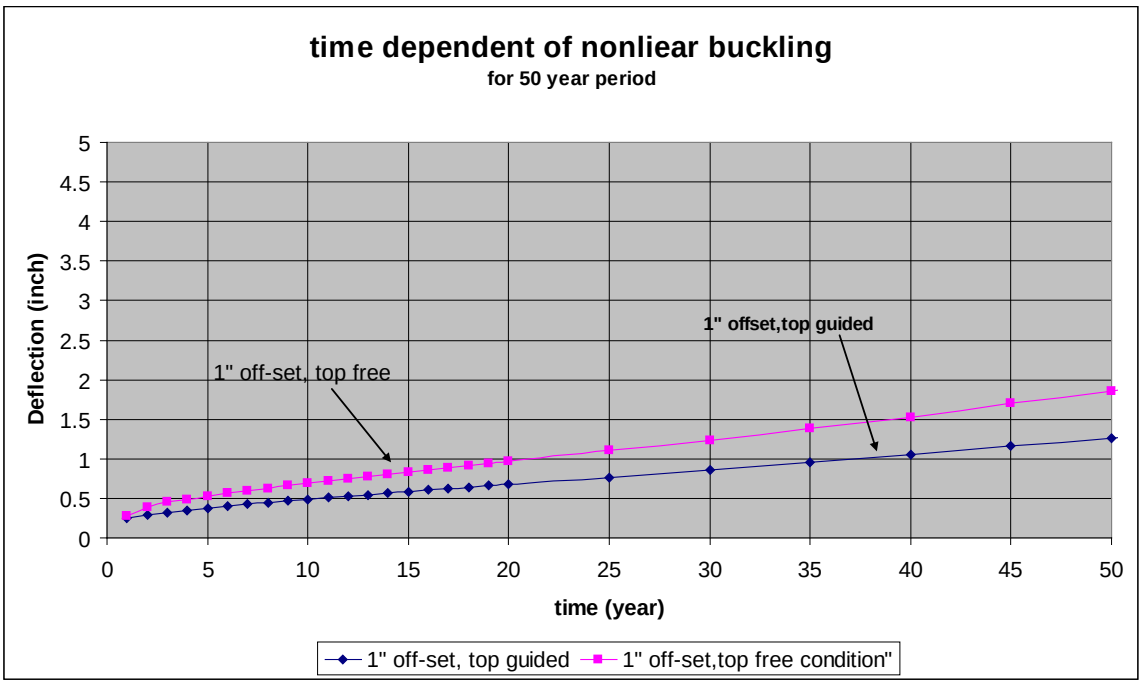

Fig 5 Deflection as function of the time for first 50 year

b) <u>Stress</u>

PVC and adhesive stress, at 20 and 40 year interval, is also extracted from same model as shown in table 2.

Table 2 The Stress and deflection based the time dependent of nonlinear large deflection for "top guided" case

Time (year)	Deflection At mid portion (inch)	*Maximum stress (psi)	*Maximum Strain (%)	*Maximum adhesive Shear (psi)	*Maximum Adhesive Peeling (psi)
20	0.88	862/568	0.61/0.41	173	36.89
40	1.37	881/585	0.79/0.51	176	41.67

* Note: Stress and strain column has a form of " corner peak value/ without considering corner peak value" as illustrated in Fig 6 and Fig 7. The adhesive stress is an average stress over the adhesive area

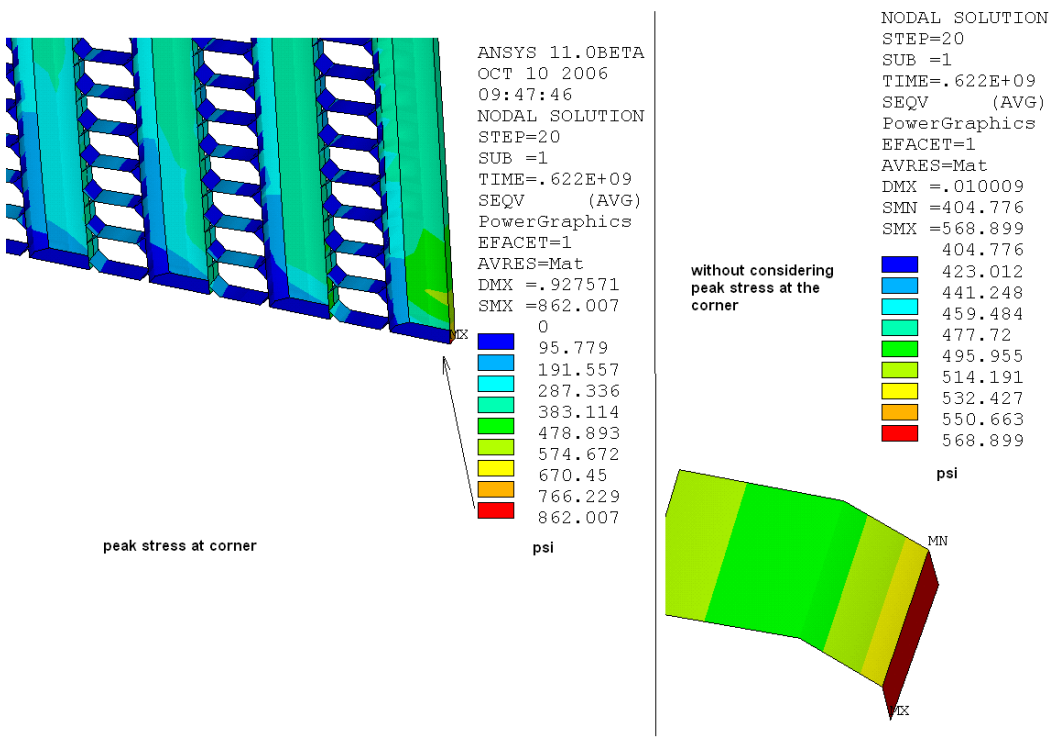

Fig 6 Von Mises **stress at t=20 years**

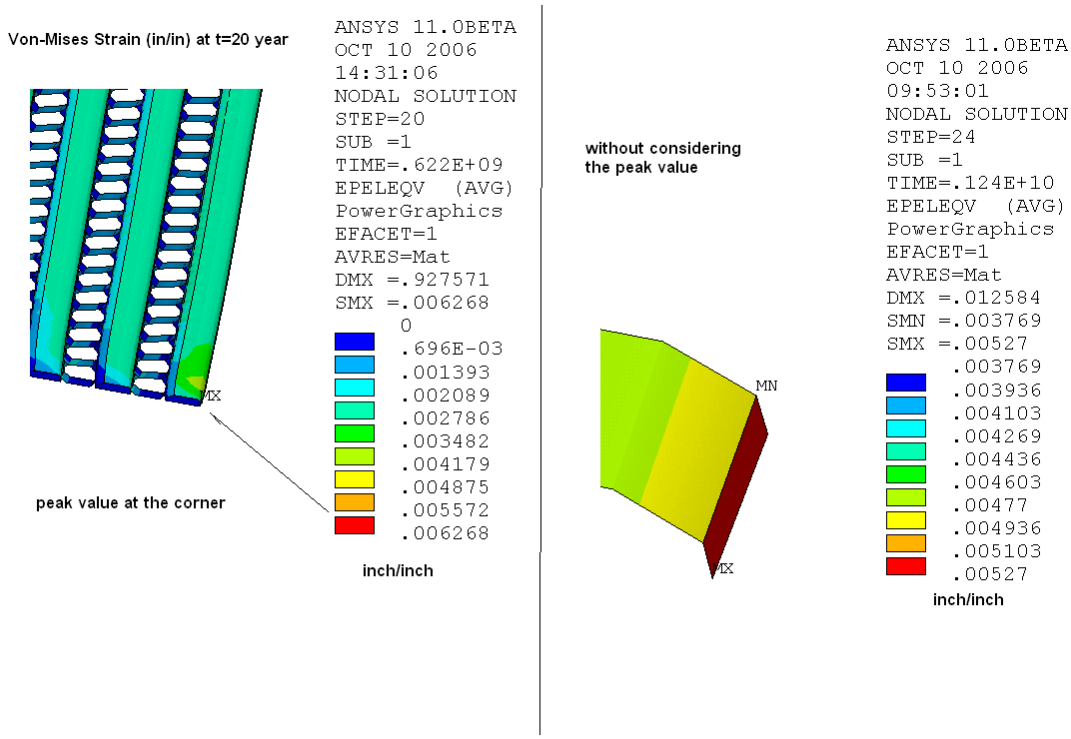

Fig 7 Von Mises strain at t=20 year

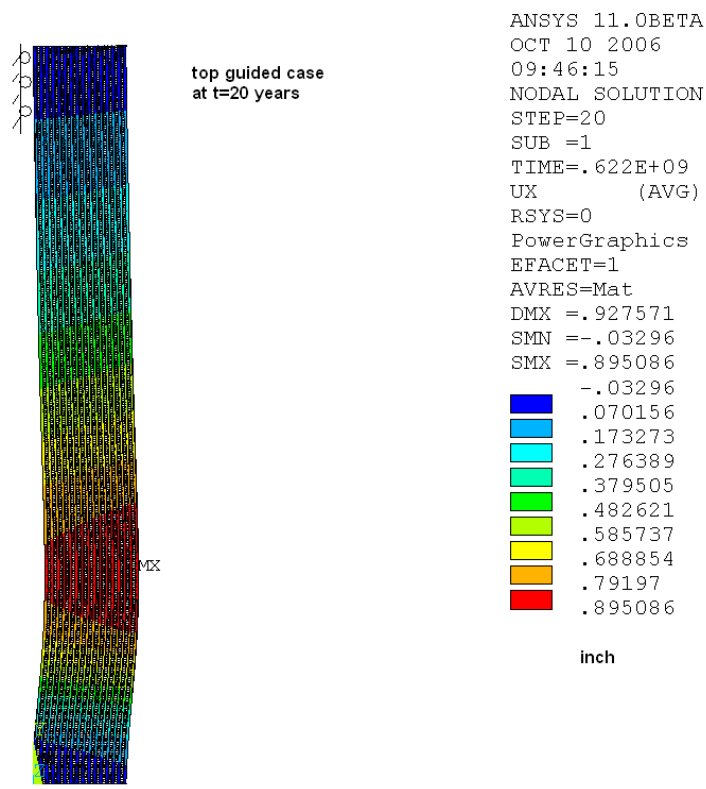

Fig 8 Deflection at t=20 years

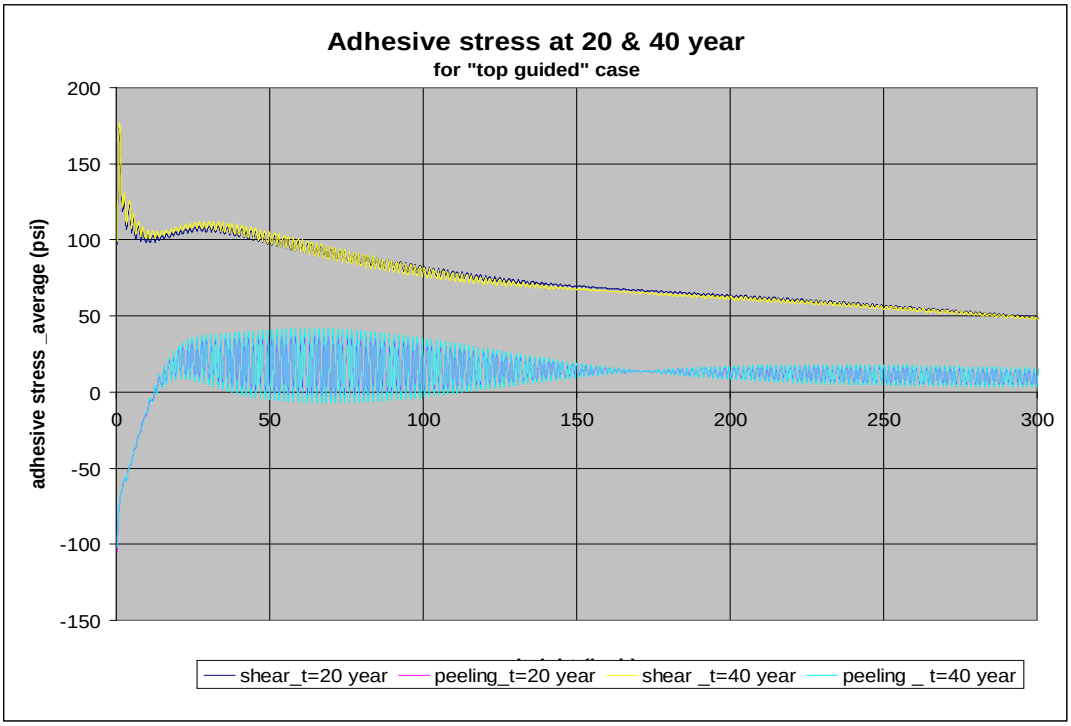

Fig 9 Adhesive stress for t=20 and 40 year

c)Edge pulling force at the top guided support

Since the top boundary condition is guided, there will be pulling force developed as shown in Fig 10. A pulling force is extracted at its lower edge for t=20 and 40 year. Result shows a F (pulling)=3909 lbf/total (or 13.09lbf/in) at t=20 years and 4961 lbf/total (or 16.61 lbf/in) at t=40 years

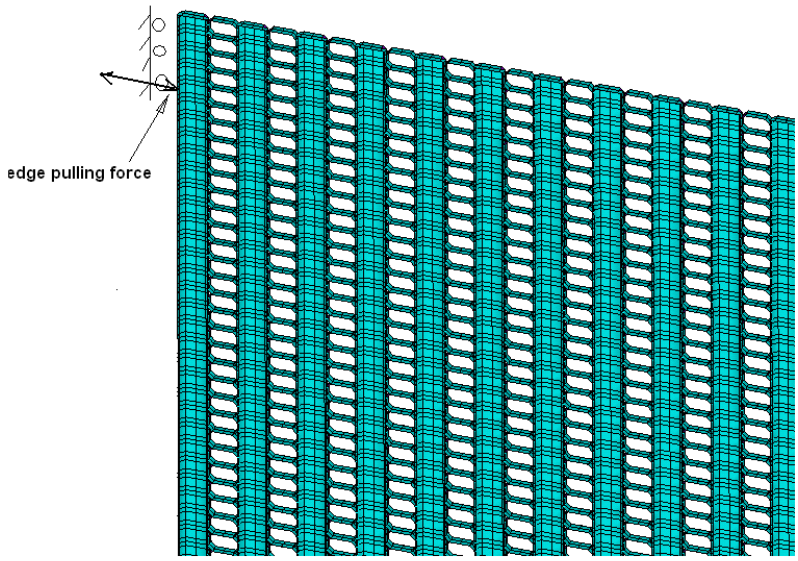

Fig 10 Edge pulling force extraction

Conclusion:

Compared with "top free" condition, the "top guided" case has a ~30% higher of SF of buckling based on both eigen value and static non-linear analysis. However, if one can be convinced that the loading will be very much kept constant during the life of structure, the critical time t_{cr}, needed to develop an excessive deformation, is quite long for a given E(t) curve.

Reference

1) A Lee, "Nonlinear Analysis for Nova Structure", Oct 5, 2006, Nova-docdb-1147

Appendix A:

Result from ANSYS

1) Solution for the first method

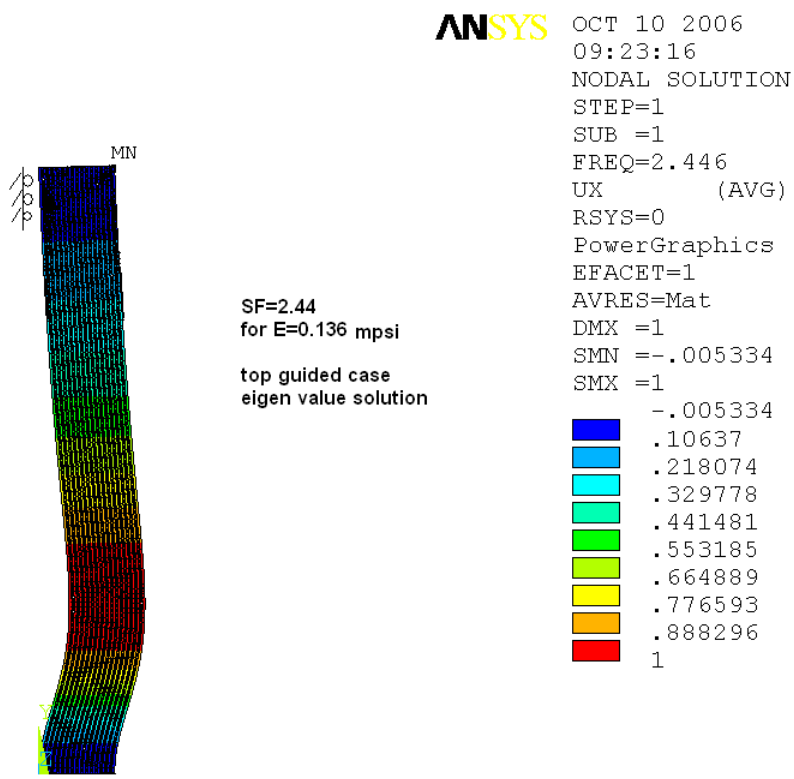

Fig A-1 Eigen value calculation for E(20y)=0.136 mpsi

2) Solution for the 2nd approach

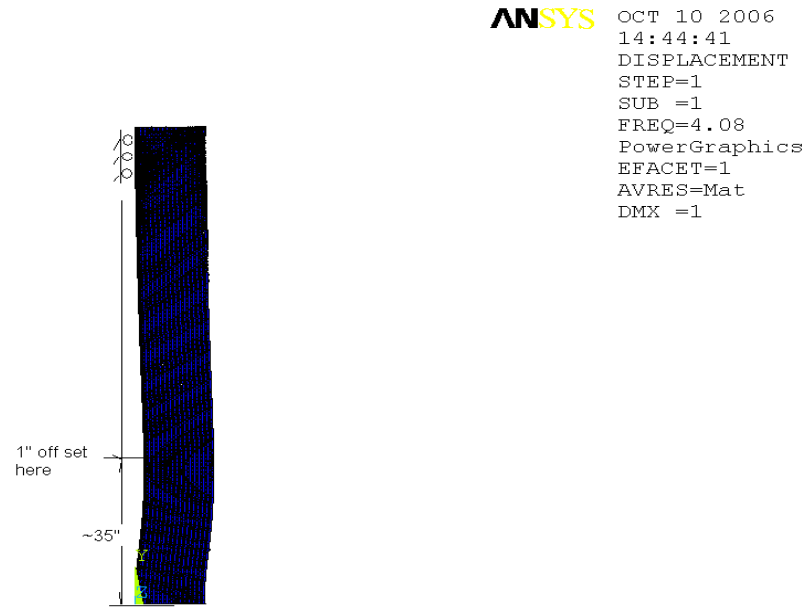

Fig A-2 Initial condition of 1" off set for a static non-linear direction

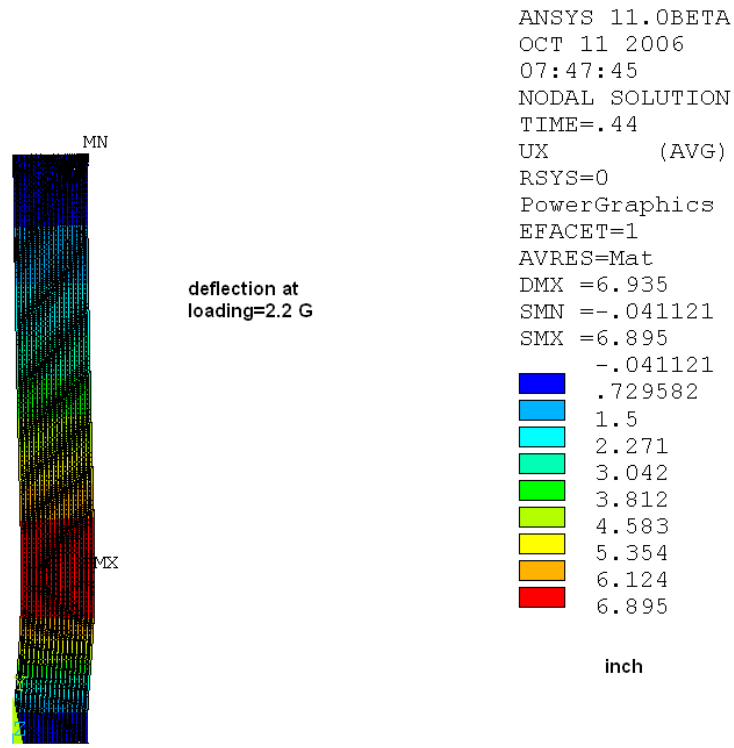

Fig A-3 Deflection along the beam direction at 2.2 G load

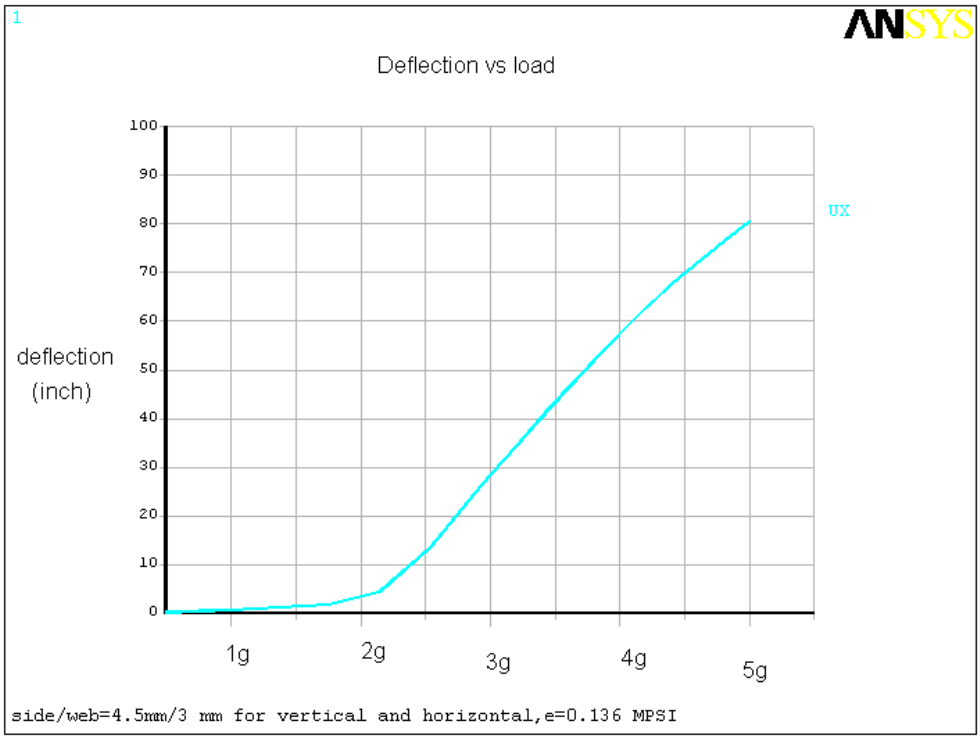

Fig A-4 Deflection vs load

3) Solution for 3rd approach

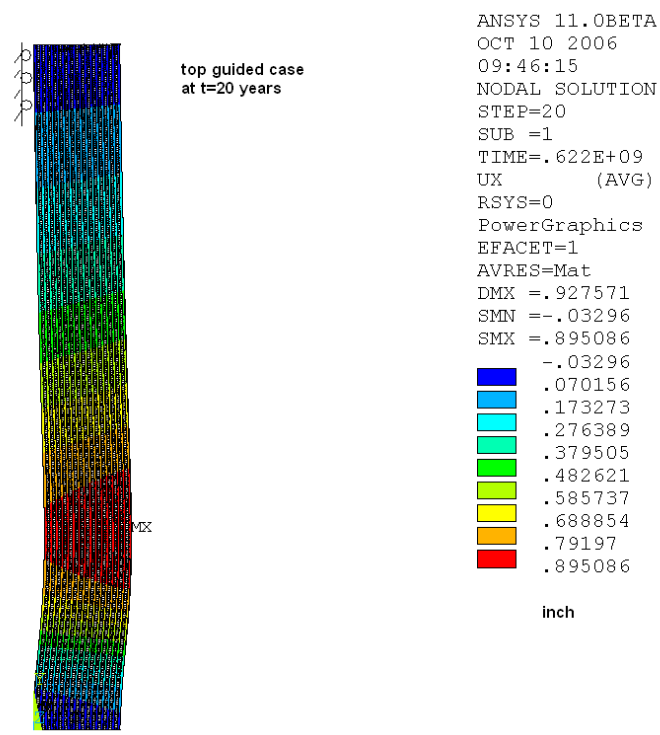

Fig A-5 Deflection after 20 year

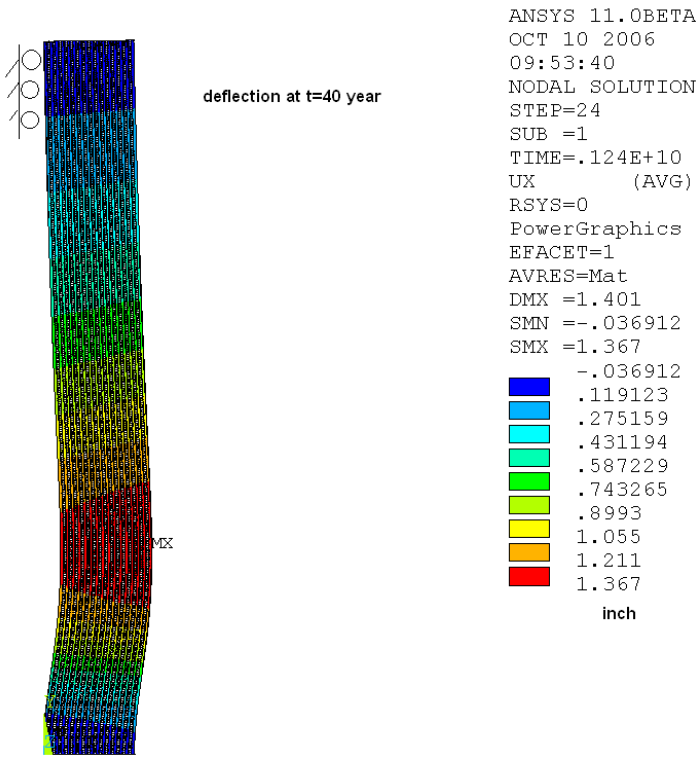

Fig A-6 Deflection after 40 year

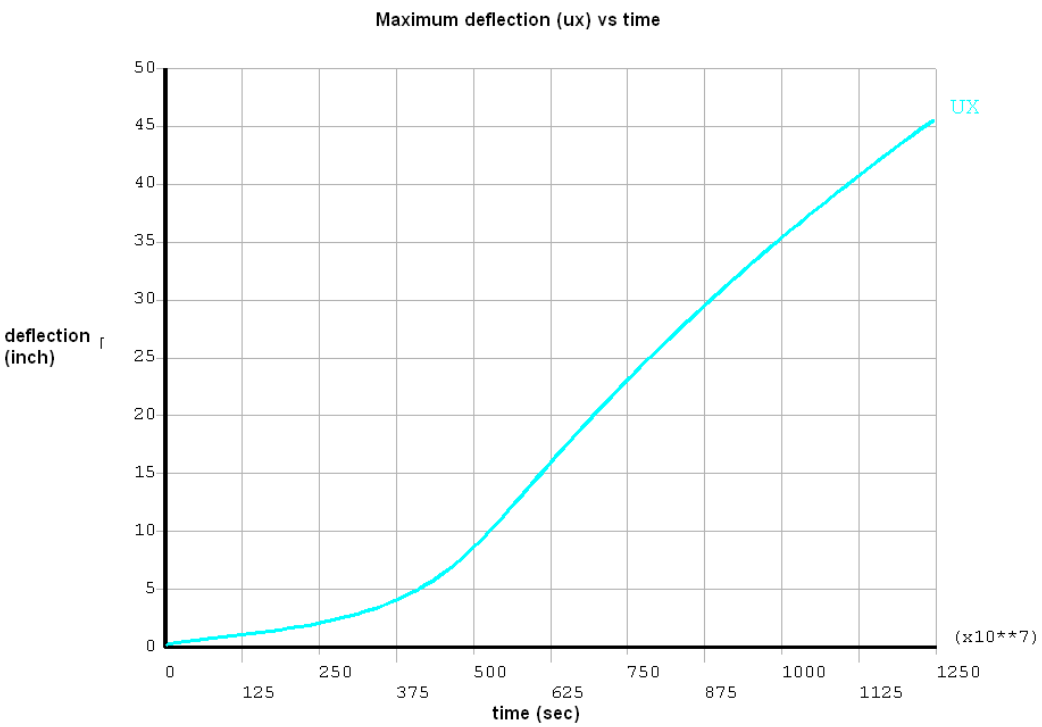

Fig A-7 Deflection curve as function of time