Study of Tim Hayler's simple model of the beam splitter

Justin Greenhalgh, 3 Dec 2006

This model was built to allow exploration of the effect on natural frequency of various beamsplitter model layouts.

1. Modal mass

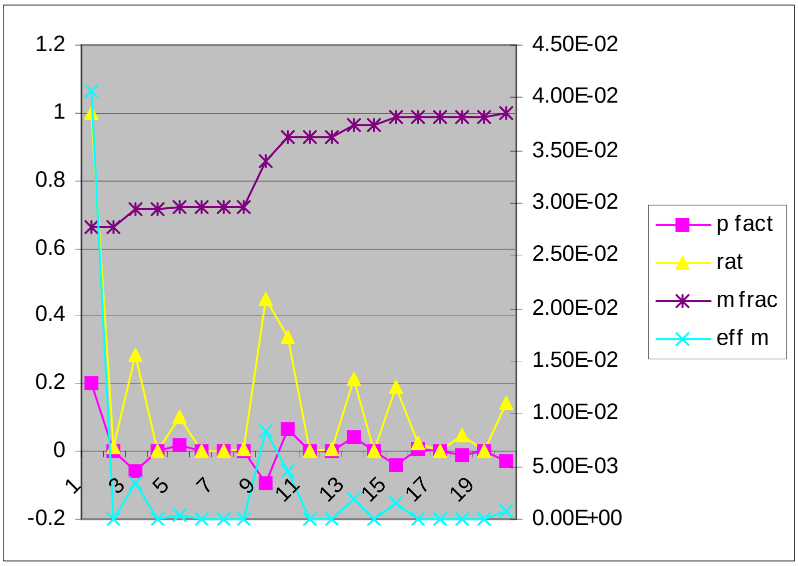
I wanted to see if the concept of modal mass could help us to be more quantitative about which modes really matter in terms of controls issues with the seismic platform. The idea is that a mode with very little associated mass does not have a big effect on the controls. This idea was behind the concept of so-called "stay modes", which were thought of as modes involving only the (lightweight) stays. When the "stay modes" were first mooted, the frequencies of the stays fro models being considered at the time were much lower than those of the whole structure, so they were easy to identify. This is not longer the case for structures and stays under consideration.

I could not find a way to get ANSYS to tell me "modal mass" per se (as referenced in, eg ANSYS theory chapter 15 eqn 15.97). However, Tim had already arranged for a printout of the modal participation factors like this in the output during solve:

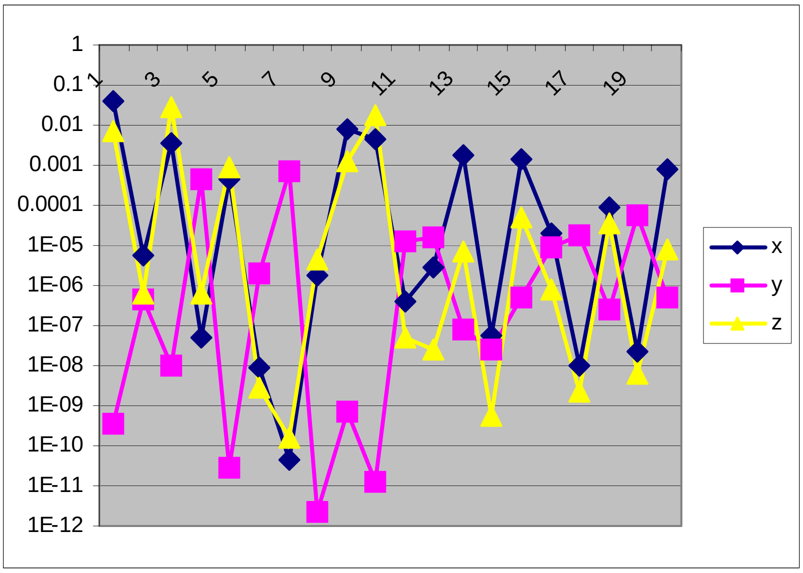
```
          ***** PARTICIPATION FACTOR CALCULATION *****  X  DIRECTION
                                                                                      CUMULATIVE
 MODE      FREQUENCY         PERIOD     PARTIC.FACTOR        RATIO      EFFECTIVE MASS      MASS
FRACTION

    1     107.339       0.93163E-02    0.20154         1.000000       0.406198E-01      0.659982
    2     109.921       0.90974E-02    0.23706E-02     0.011762       0.561957E-05      0.660073
    3     117.266       0.85276E-02   -0.57895E-01     0.287260       0.335189E-02      0.714534
    4     117.373       0.85199E-02    0.22969E-03     0.001140       0.527592E-07      0.714535
    5     120.448       0.83023E-02    0.20979E-01     0.104094       0.440136E-03      0.721686
```

(etc)

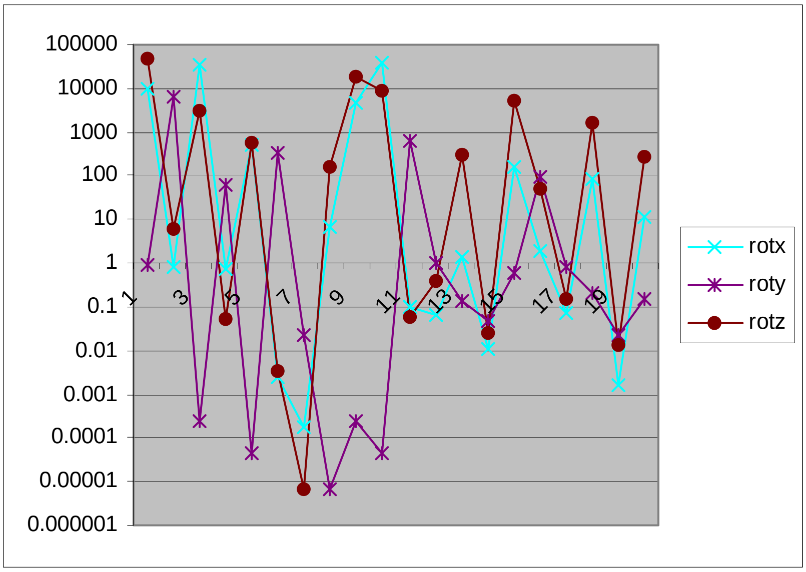
I plotted the various output columns against frequency for the x direction, thus:



And concluded that any of the values “partic. Factor”, “ratio”, or “effective mass” would show up the important modes. I went for “effective mass” and plotted that against mode number for x,y and z:

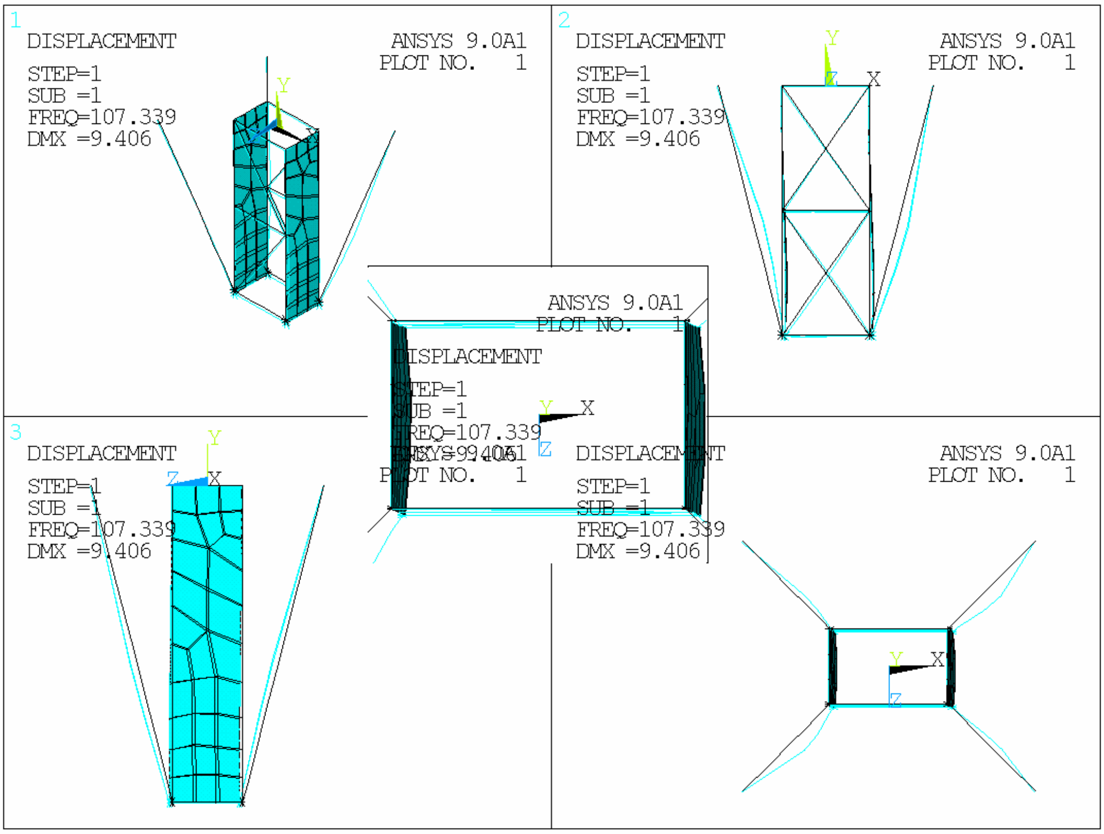


and for rotx, roty, rotz:

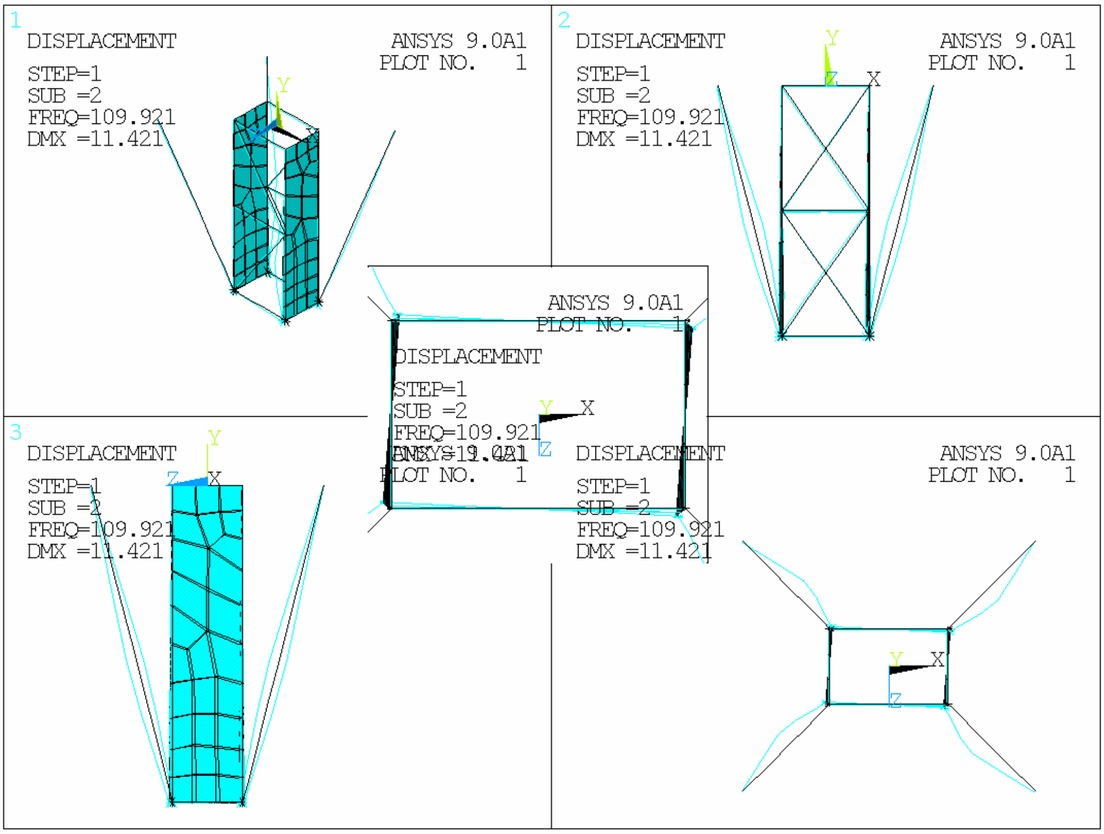


A quick look at the mode shapes for the first few modes suggested that at least the values of the effective mass tie up with the mode shapes. Compare the mode shapes (below) with the charts of effective mass (above). Taking the first three modes:

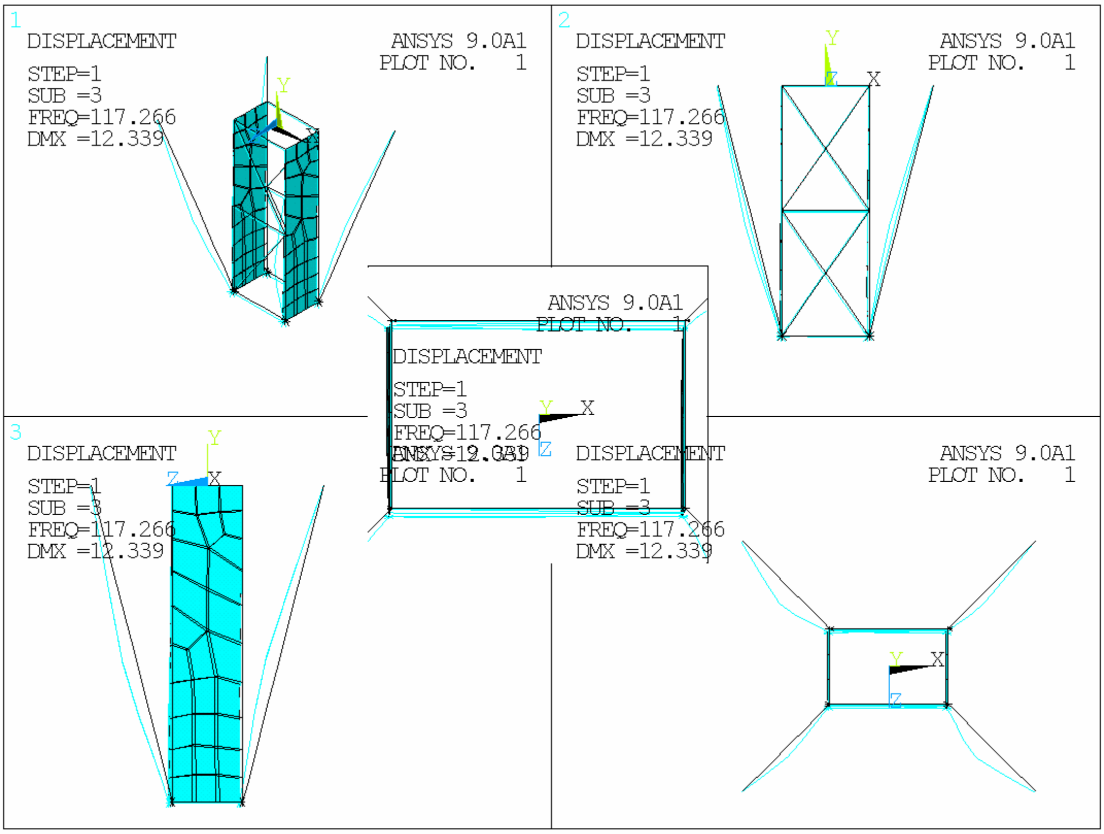
Mode 1 involves movement at the bottom of the structure mostly in X and a little in Z; this involves rotation about the Z axis (principally) and the X axis (a little):



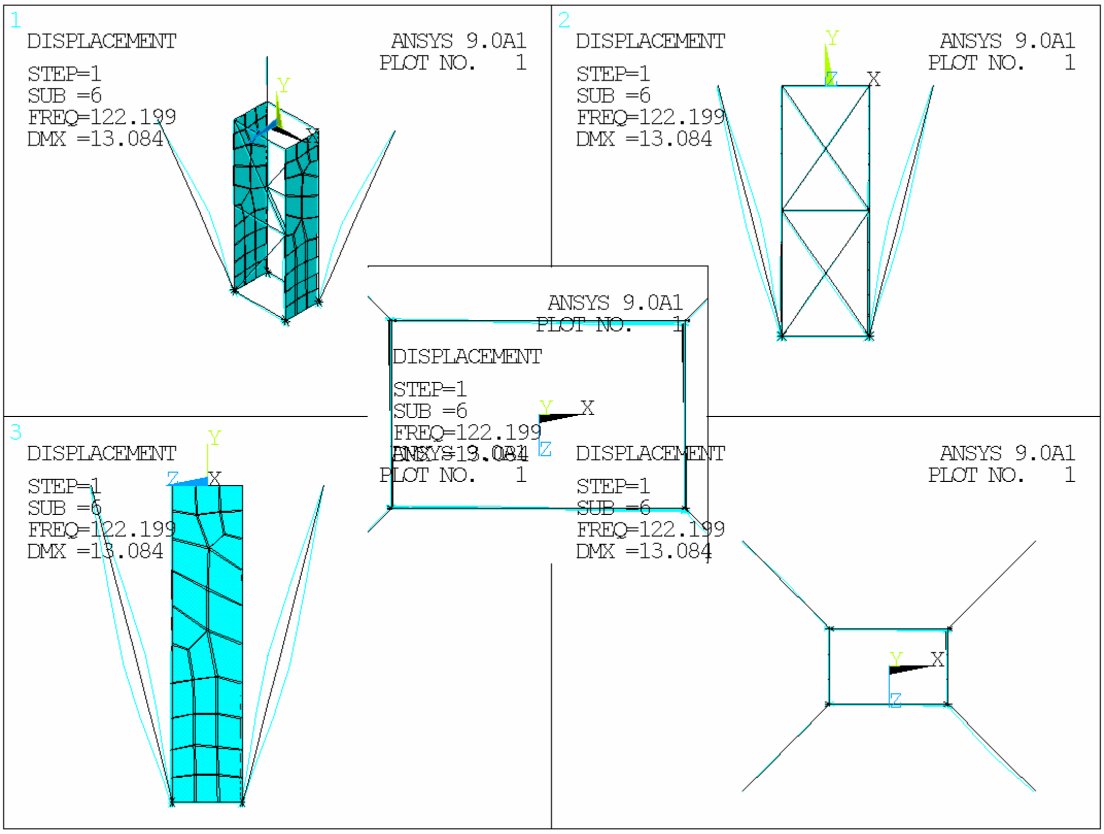
Mode 2 is a twist of the bottom of the structure (ROTY) with little other movement except in the stays:

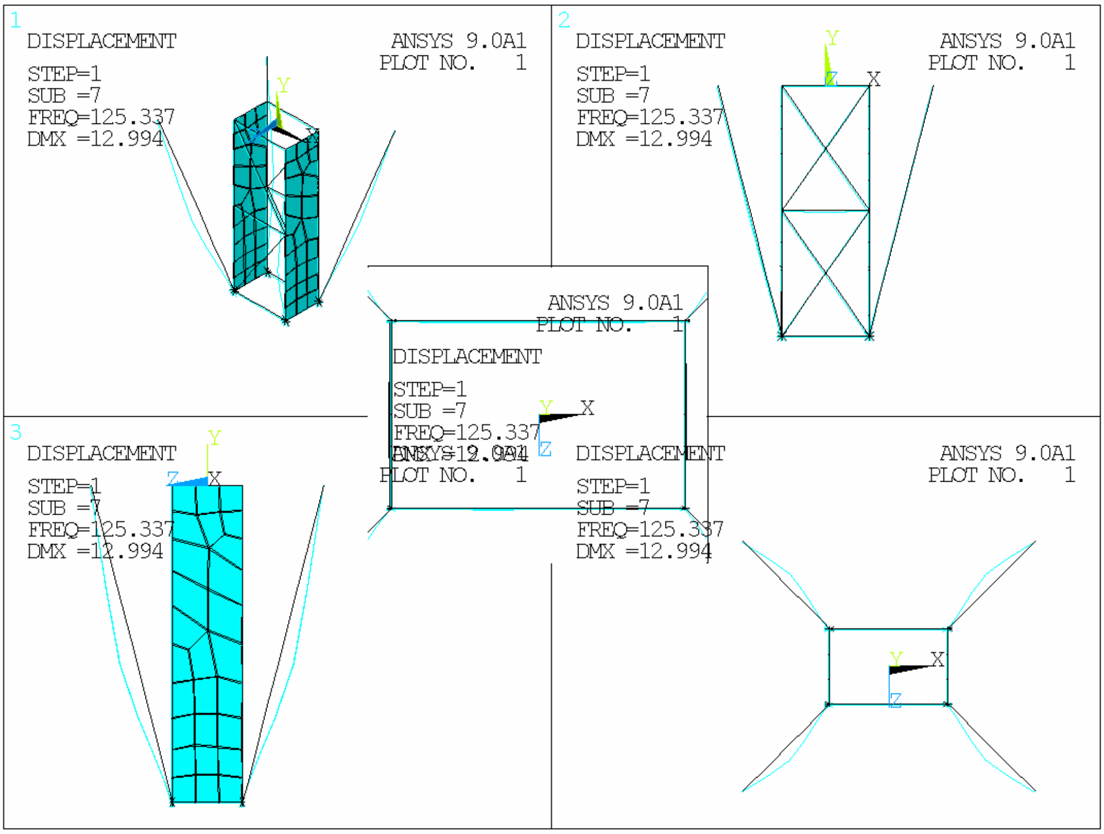


Mode 3 involves movement at the base mostly in Z and a little in X, with the corresponding rotations:



Modes 6 and 7 (from the charts above) have very little effective mass and one might expect to see movement of stays only. Here they are:



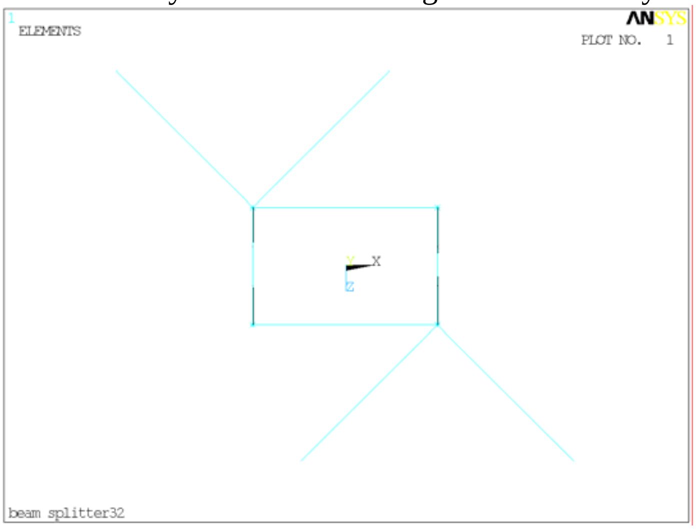


All of which suggests that a study of the effective mass can give a quantitative indication of the "importance" of particular modes – especially if note were taken of the sensitivities of the SEI control system to the various modes. In this case the very first mode has the highest effective mass and so it is unlikely we can ignore it.

2. Configuration of stays – using "folded stays" on the full model

Model 1:

This work follows up an interesting discovery of Ian Wilmut. One would have thought (at least – I would have thought) that a structure with tetrahedral features would be very stiff. So this arrangement of the stays should work well:

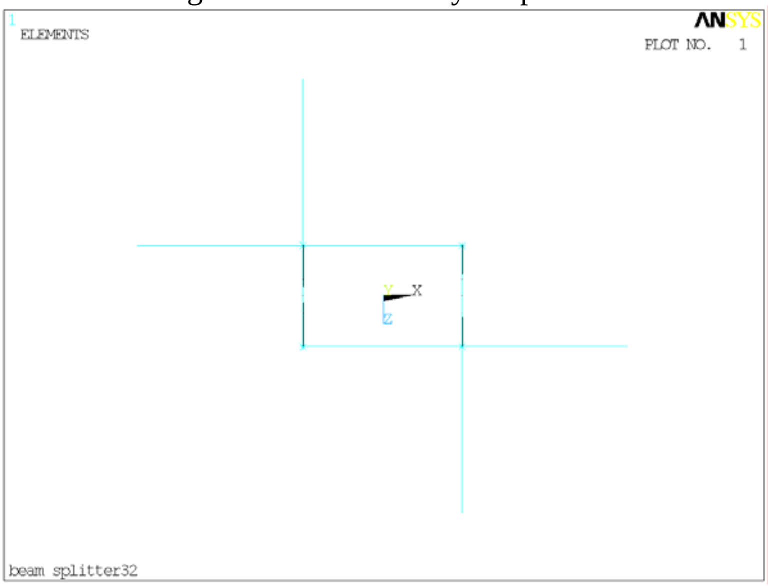


The frequencies are

SET	old	New (1)	change %
1	107.339	103.78	-3%
2	109.921	108.67	-1%
3	117.266	109.74	-6%
4	117.373	117.7	0%
5	120.448	128.88	7%
6	122.199	129.49	6%
7	125.337	130.53	4%
8	125.916	130.57	4%
9	140.374	133.76	-5%
10	153.983	140.89	-9%
11	164.51	169.06	3%
12	181.426	181.39	0%
13	181.995	181.44	0%
14	183.684	182.92	0%
15	205.189	192.71	-6%
16	207.558	201.81	-3%
17	215.054	215.09	0%
18	219.369	218.46	0%
19	246.881	246.82	0%
20	249.096	249.07	0%

So by and large the ones that don't matter have improved, and the important ones have got worse – but not by a large margin.

Model 2:
A further change is to rotate the stays in plan:

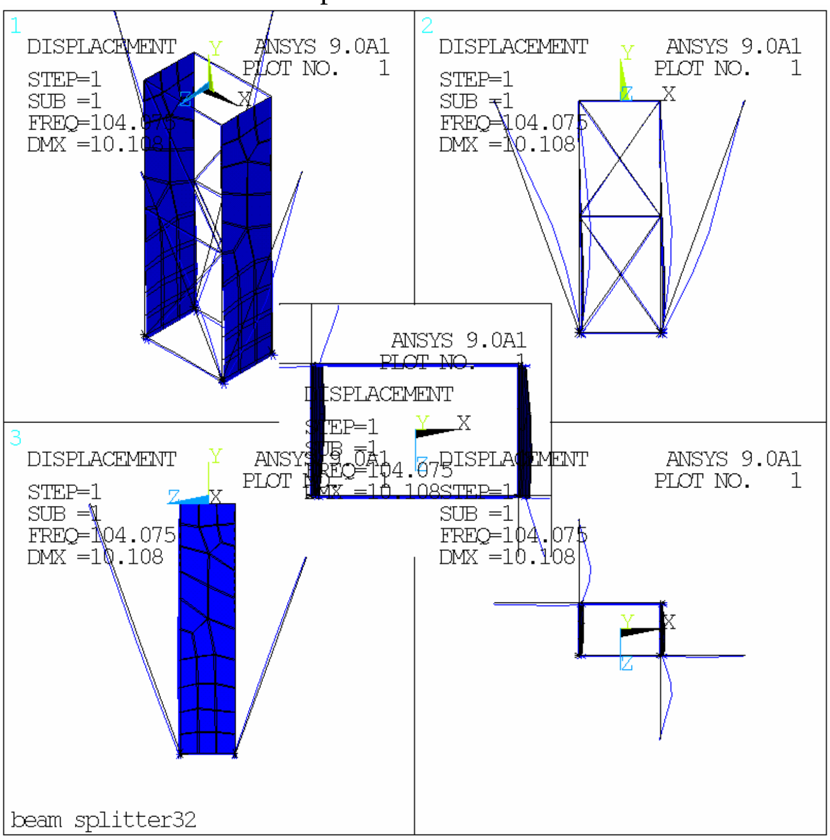


Very little change:

SET	old	New (1)	change %	new(2)
1	107.339	103.78	-3%	104.07
2	109.921	108.67	-1%	108.91
3	117.266	109.74	-6%	110.18
4	117.373	117.7	0%	116.95

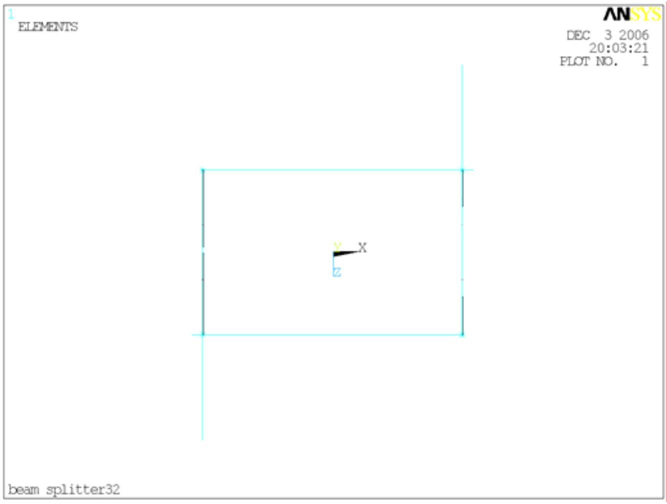
5	120.448	128.88	7%	129.03
6	122.199	129.49	6%	129.52
7	125.337	130.53	4%	130.51
8	125.916	130.57	4%	130.58
9	140.374	133.76	-5%	135.25
10	153.983	140.89	-9%	140.32
11	164.51	169.06	3%	171.18
12	181.426	181.39	0%	181.42
13	181.995	181.44	0%	181.48
14	183.684	182.92	0%	182.87
15	205.189	192.71	-6%	191.84
16	207.558	201.81	-3%	202.4
17	215.054	215.09	0%	215.11
18	219.369	218.46	0%	218.67
19	246.881	246.82	0%	246.85
20	249.096	249.07	0%	249.12

Here’s the first mode shape:



Model 3 the “folded stays”:

But - and here’s the interesting one. Why not move the stays around to use up less footprint (Ian’s cunning plan) thus:

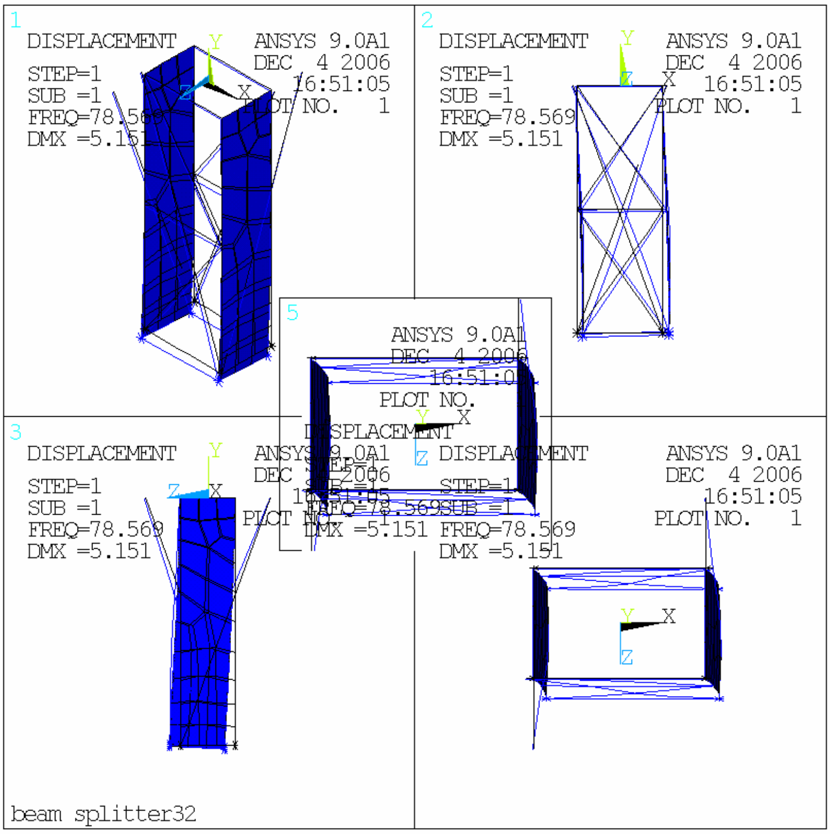


Surely the tripods will be equally effective?

Well, actually, no they aren't:

SET	old	New (1)	change %	new(2)	new(3)
1	107.339	103.78	-3%	104.07	78.569
2	109.921	108.67	-1%	108.91	106.79
3	117.266	109.74	-6%	110.18	110.86
4	117.373	117.7	0%	116.95	116.78
5	120.448	128.88	7%	129.03	126.19
6	122.199	129.49	6%	129.52	128.85
7	125.337	130.53	4%	130.51	129.56
8	125.916	130.57	4%	130.58	130.59
9	140.374	133.76	-5%	135.25	130.6
10	153.983	140.89	-9%	140.32	137.61
11	164.51	169.06	3%	171.18	157.09
12	181.426	181.39	0%	181.42	179.22
13	181.995	181.44	0%	181.48	181.05
14	183.684	182.92	0%	182.87	181.43
15	205.189	192.71	-6%	191.84	185.43
16	207.558	201.81	-3%	202.4	199.73
17	215.054	215.09	0%	215.11	215.1
18	219.369	218.46	0%	218.67	218.02
19	246.881	246.82	0%	246.85	246.86
20	249.096	249.07	0%	249.12	249

Interestingly, the only big change is in the first mode. Compare its mode shape with that for mode 1 of model 2, above.



There is now significant motion of the structure, in the direction of the short overall footprint (as Ian feared). I don't see why.

What of the effective mass?

Here are the effective masses for the two models. Model 2 has the protruding stays, model 3 has them folded:

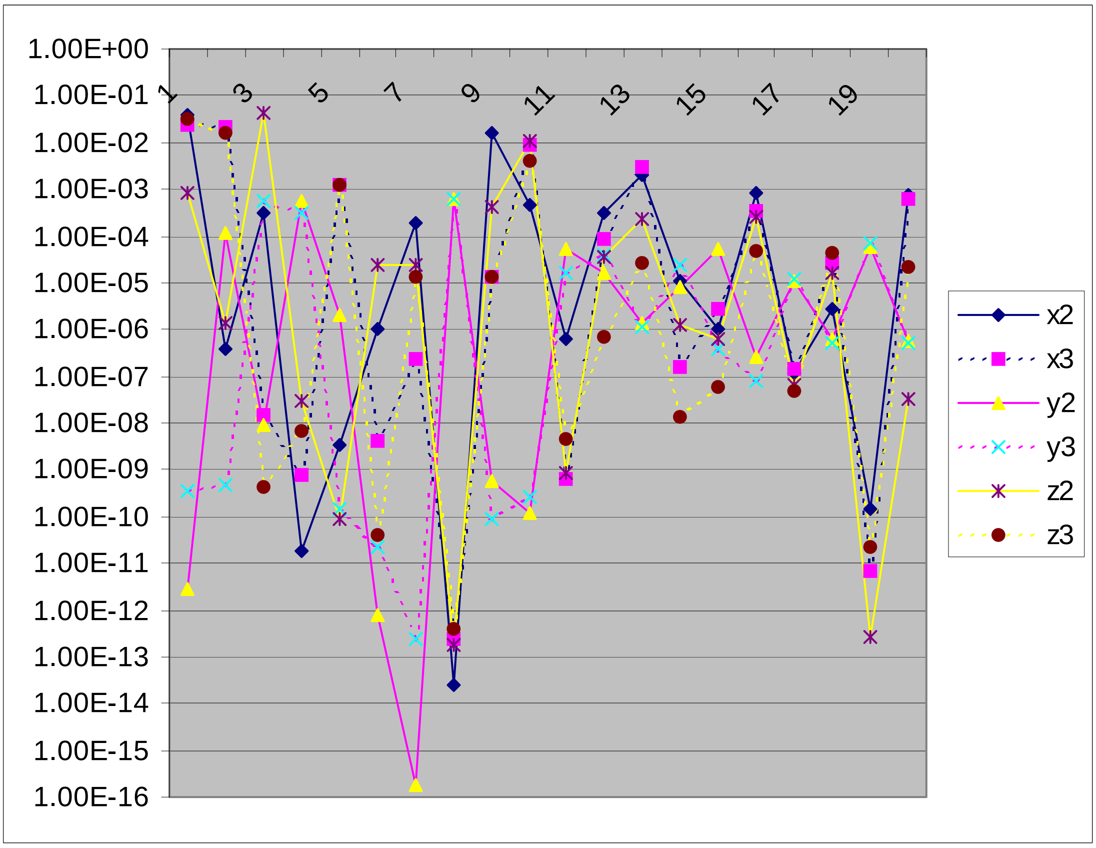
	x2	x3	y2	y3	z2	z3
1	4.05E-02	2.33E-02	2.87E-12	3.65E-10	8.55E-04	3.06E-02
2	3.70E-07	2.24E-02	1.20E-04	4.51E-10	1.42E-06	1.60E-02
3	3.19E-04	1.42E-08	8.68E-09	5.39E-04	4.22E-02	4.29E-10
4	1.77E-11	7.73E-10	5.76E-04	3.22E-04	2.92E-08	6.74E-09
5	3.50E-09	1.25E-03	2.06E-06	1.46E-10	9.22E-11	1.28E-03
6	1.03E-06	3.96E-09	8.13E-13	2.33E-11	2.44E-05	3.95E-11
7	1.86E-04	2.28E-07	1.89E-16	2.28E-13	2.38E-05	1.32E-05
8	2.58E-14	2.43E-13	6.24E-04	6.27E-04	1.80E-13	3.88E-13
9	1.52E-02	1.31E-05	5.54E-10	8.92E-11	4.03E-04	1.33E-05
10	4.78E-04	8.92E-03	1.23E-10	2.66E-10	1.05E-02	3.92E-03
11	6.42E-07	6.14E-10	5.20E-05	1.66E-05	8.16E-10	4.56E-09
12	3.11E-04	8.84E-05	1.56E-05	4.01E-05	3.40E-05	7.00E-07
13	2.04E-03	2.92E-03	1.41E-06	1.11E-06	2.24E-04	2.58E-05
14	1.12E-05	1.59E-07	7.75E-06	2.32E-05	1.31E-06	1.31E-08
15	1.06E-06	2.77E-06	5.48E-05	4.01E-07	6.00E-07	5.64E-08
16	8.60E-04	3.41E-04	2.67E-07	7.55E-08	2.48E-04	4.75E-05
17	1.17E-07	1.48E-07	1.13E-05	1.16E-05	6.47E-08	4.97E-08
18	2.75E-06	2.73E-05	6.01E-07	5.22E-07	1.57E-05	4.30E-05
19	1.52E-10	6.69E-12	5.65E-05	6.90E-05	2.70E-13	2.29E-11

20	7.41E-04	6.19E-04	5.54E-07	5.33E-07	3.32E-08	2.26E-05
	6.07E-02	5.99E-02	1.52E-03	1.65E-03	5.46E-02	5.20E-02

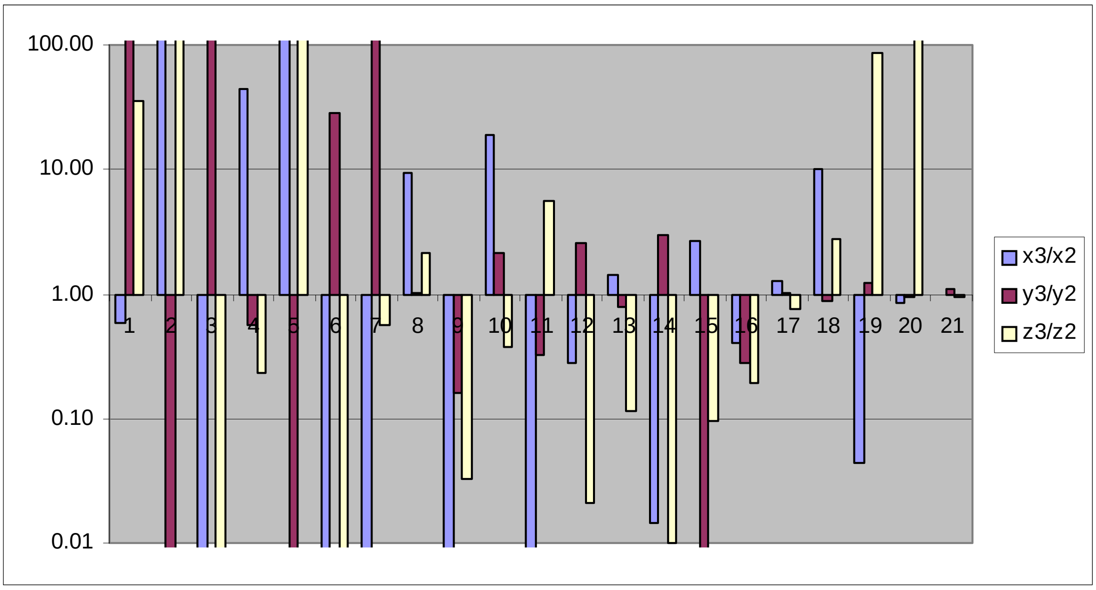
So the effective mass in x of the first mode has indeed gone down, but not very dramatically (factor of ~2) and the effective mass in z has gone up.

But – and this is interesting – although the frequencies of the modes above the first seem to match pretty well between models 2 and 3, the effective masses don't.

This plot tries to show it, but it's rather hard to follow (and factors of ~two look very small on here):

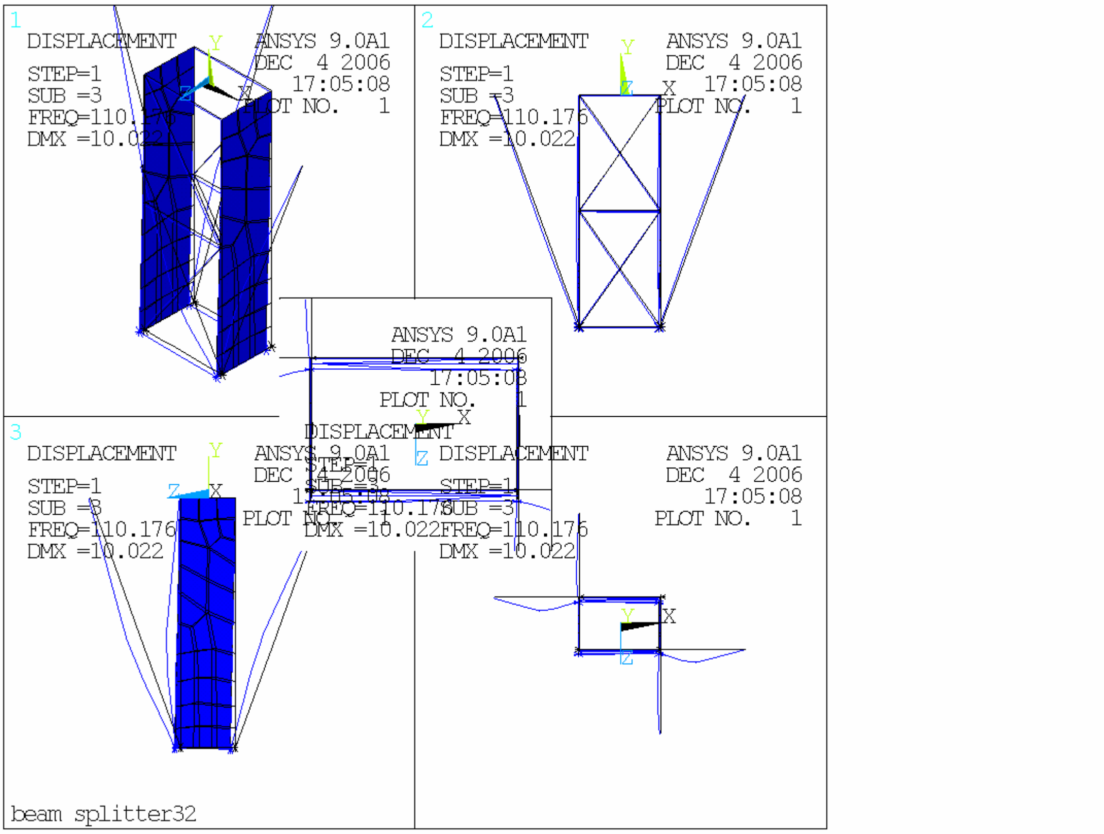


Try showing just the ratios:

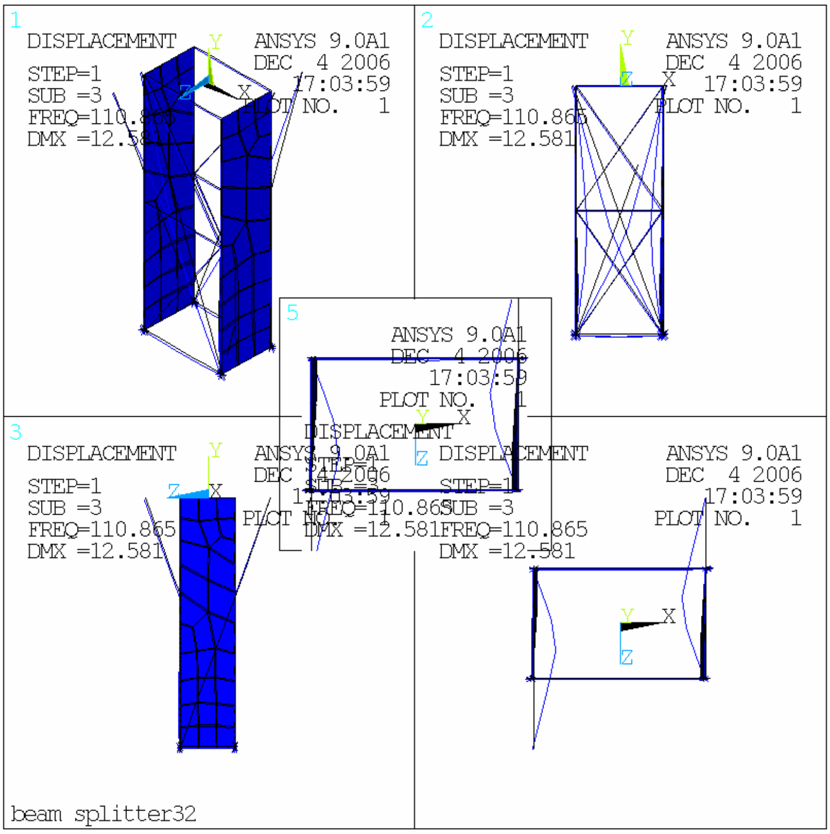


Mostly they are very large (or small) ratios. So are the mode shapes the same?
Let's take mode 3. frequencies very similar, here are the modes shapes:

Model2, mode 3:

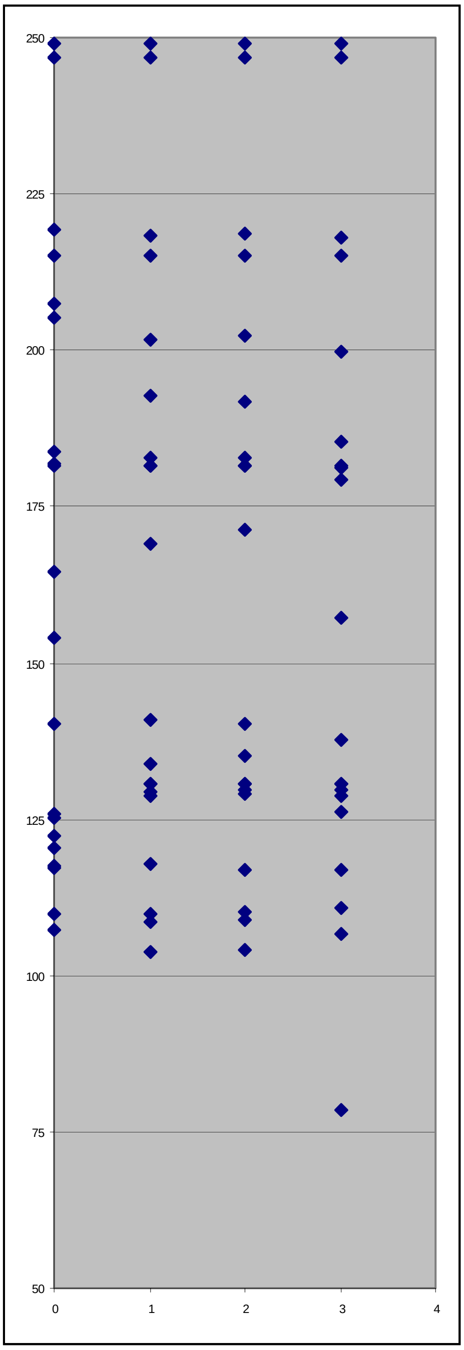


Model3, mode 3:



So, although the frequencies are the same, the mode shapes are rather different. This suggests that the similarities in frequencies is a coincidence between two sorted lists.

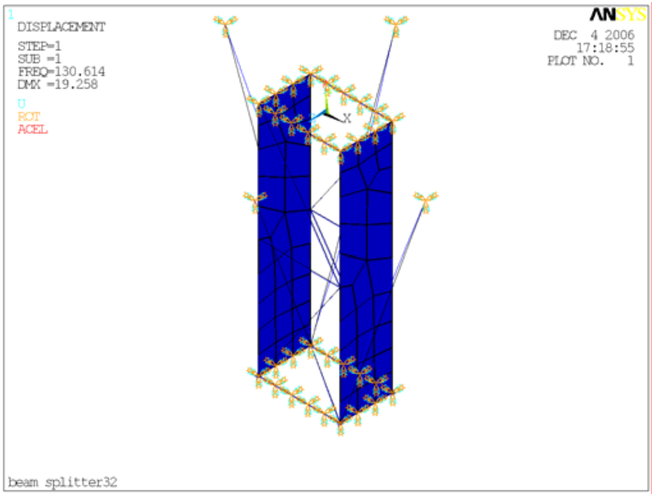
Here is a plot of all the frequencies:



You can see that the frequencies look rather better related between models 1 and 2 than between models 2 and 3. One could try matching mode shapes using the effective mass triples (x, y, z). I have not figured out an elegant way to do this (and doing by eye in the table above does not look easy). The fact remains that model 3 has this very low mode that is not present in model 2.

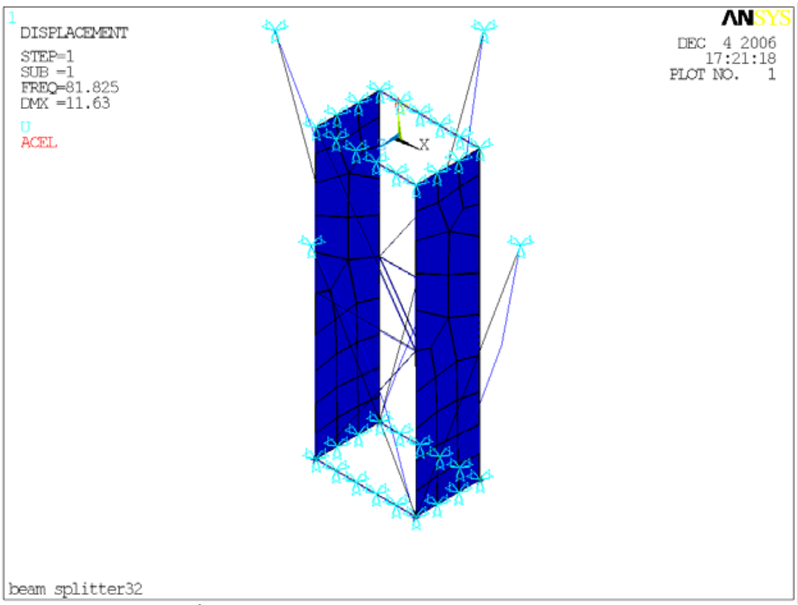
3. Modes of the stays:

It's probably worth finding out what the modes of the stays themselves are. So run model 2 (any model should do) with the bottom ring nodes fixed:



SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	130.61	1	1	1
2	130.61	1	2	1
3	130.61	1	3	1
4	130.61	1	4	1
5	130.61	1	5	1
6	130.61	1	6	1
7	130.61	1	7	1
8	130.61	1	8	1
9	178.22	1	9	1
10	181.53	1	10	1
11	188.80	1	11	1
12	189.88	1	12	1
13	216.84	1	13	1
14	216.88	1	14	1
15	248.63	1	15	1
16	248.63	1	16	1
17	285.19	1	17	1
18	285.34	1	18	1
19	291.90	1	19	1
20	300.39	1	20	1

From which we can conclude that the frequency of a fixed-fixed stay is 130 Hz.
Try pinning all constraints, which will leave the stays pinned at the top and somewhat more than pinned (by reason of their connection to the structure) at the bottom:



SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	81.825	1	1	1
2	81.838	1	2	1

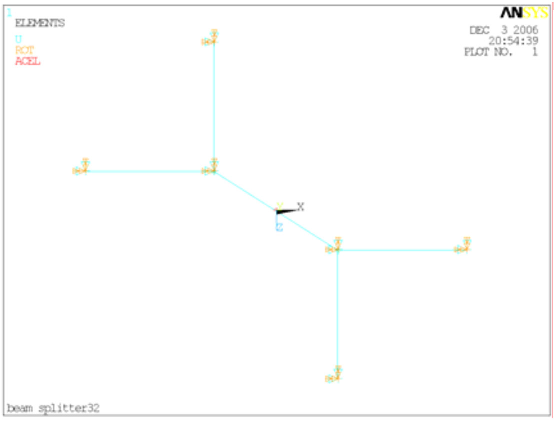
3	83.567	1	3	1
4	83.574	1	4	1
5	88.192	1	5	1
6	88.192	1	6	1
7	88.519	1	7	1
8	88.519	1	8	1
9	176.01	1	9	1
10	179.66	1	10	1
11	185.82	1	11	1
12	186.57	1	12	1
13	215.18	1	13	1
14	215.26	1	14	1
15	247.28	1	15	1
16	247.43	1	16	1
17	278.20	1	17	1
18	280.79	1	18	1
19	284.47	1	19	1
20	284.65	1	20	1

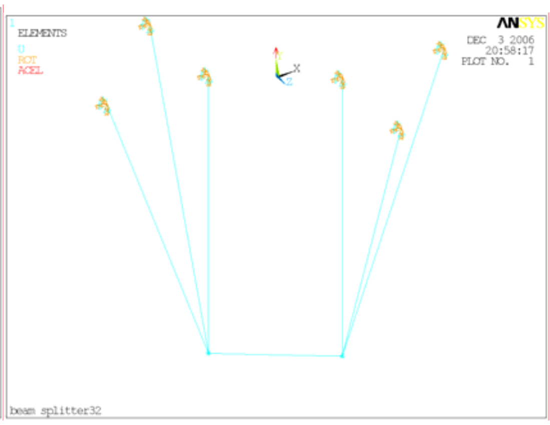
More like 82 Hz. And with the stays fixed at the top and pinned at the bottom, you get 120 to 130 Hz.

4. Configuration of stays – using "folded stays" on a cut-down model

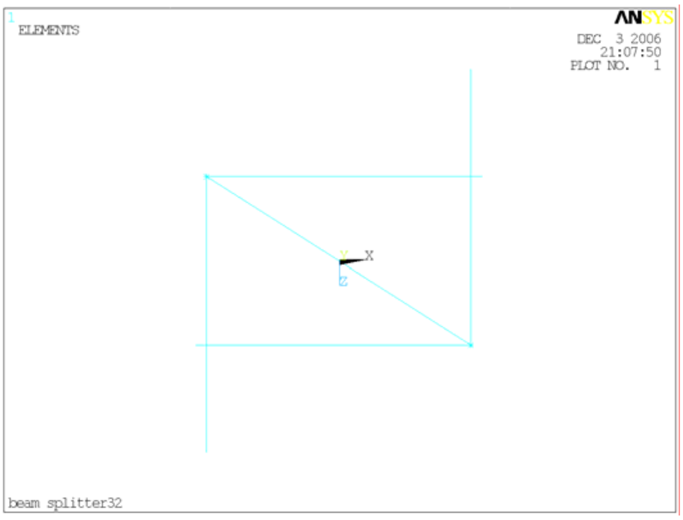
Model 4:
I am still puzzled as to why the folded stays did not work.

Next thing would be to try just the two tripods with a link between them.





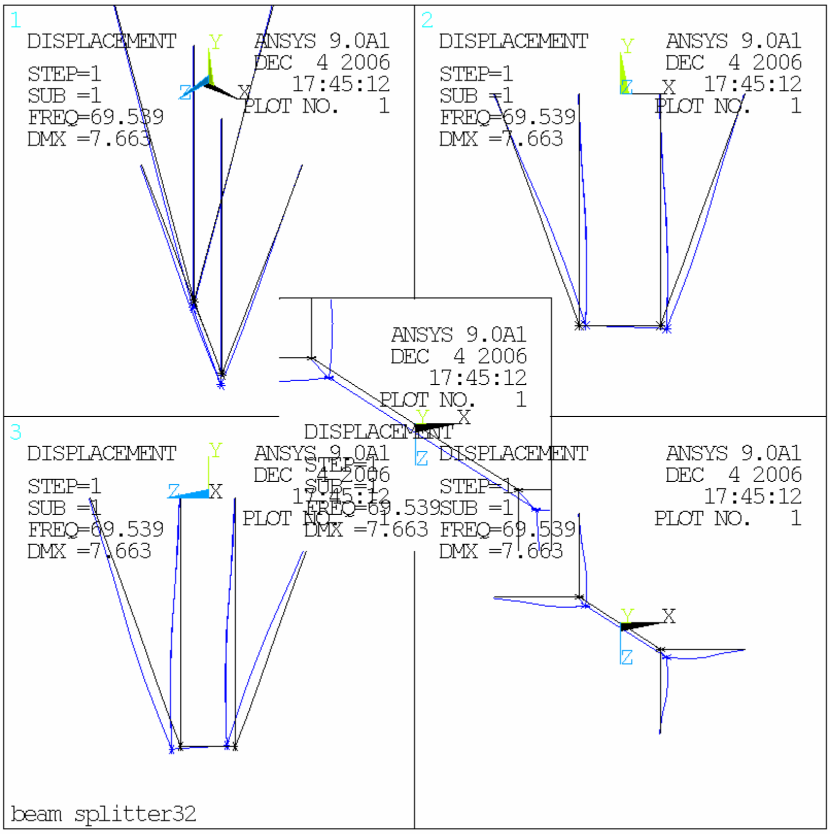
Model 5:
And then to try folding the stays as before:



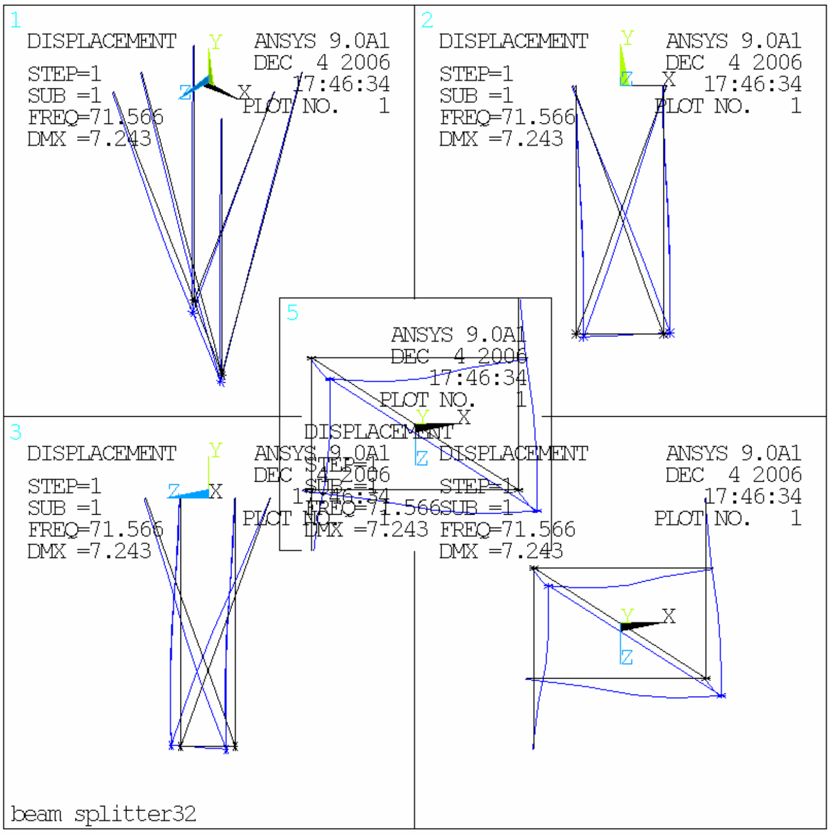
In terms of frequencies, there is very little to choose between the two. This is what I would have expected.

SET	model 4	model 5
1	69.539	71.566
2	84.843	84.871
3	87.43	89.257
4	99.199	99.177
5	125.9	125.68
6	127.98	128.33
7	131.53	131.44
8	131.57	131.57
9	136.37	132.81
10	136.8	136.79
11	137.91	137.09
12	138.38	138.39
13	144.29	140.07
14	156.84	156.86
15	171.24	168.72
16	338.1	336.78
17	348.87	349.53
18	369.73	368.72
19	380.34	383.43
20	391.36	388.01

The mode shapes of the lowest frequency look similar:
Model4, mode 1:



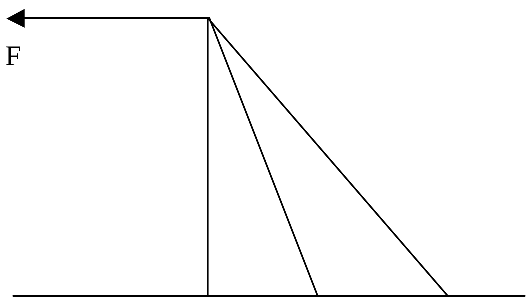
model5, mode 1:

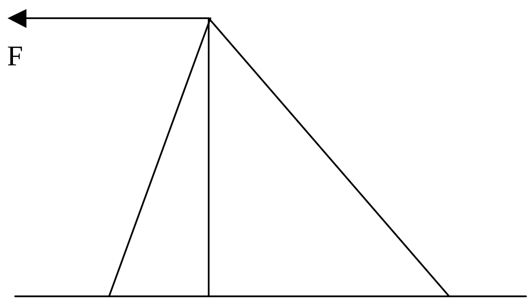


So why does this “folded stay” trick not work when you include the full model?

5. Simple test of the folded stay principle

Ian Wilmut suggested a very simple test of the principle. Is the structure on the left as stiff laterally as the structure on the right? This is amenable to solution by hand, and a start at forming the equations suggested that the two will not be equally stiff. However, I decided it would be quicker to demonstrate with a simple FEA model.





Making the vertical member 1m tall, using a cross-section for the members of 50x50x2 SHS, and properties for Al, F = 1N, I found he following results:

For the structure on the left (macro doit6 in appendix)

```
  THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

    NODE      UX          UY          UZ          USUM
       1   0.0000      0.0000      0.0000      0.0000
       2 -0.12807E-03-0.44000E-04  0.0000     0.13541E-03
       3 -0.20549E-04-0.14667E-04  0.0000     0.25246E-04
       4 -0.69556E-04-0.29333E-04  0.0000     0.75489E-04
       5   0.0000      0.0000      0.0000      0.0000
       6 -0.19948E-04 0.48386E-05  0.0000     0.20526E-04
       7 -0.50345E-04-0.34762E-05  0.0000     0.50464E-04
       8 -0.87332E-04-0.20791E-04  0.0000     0.89773E-04
       9   0.0000      0.0000      0.0000      0.0000
      10 -0.23269E-04-0.45805E-05  0.0000     0.23715E-04
      11 -0.72075E-04-0.22312E-04  0.0000     0.75449E-04

 MAXIMUM ABSOLUTE VALUES
 NODE          2           2           0           2
 VALUE  -0.12807E-03-0.44000E-04  0.0000     0.13541E-03
```

For the structure on the right

```
    NODE      UX          UY          UZ          USUM
       1   0.0000      0.0000      0.0000      0.0000
       2 -0.69562E-04 0.12511E-06  0.0000     0.69562E-04
       3 -0.11887E-04 0.41702E-07  0.0000     0.11887E-04
       4 -0.39233E-04 0.83405E-07  0.0000     0.39233E-04
       5   0.0000      0.0000      0.0000      0.0000
       6 -0.12461E-04 0.80858E-05  0.0000     0.14854E-04
       7 -0.28353E-04 0.10498E-04  0.0000     0.30234E-04
       8 -0.47560E-04 0.75981E-05  0.0000     0.48164E-04
       9   0.0000      0.0000      0.0000      0.0000
      10 -0.14068E-04-0.51681E-05  0.0000     0.14987E-04
      11 -0.39838E-04-0.38231E-05  0.0000     0.40021E-04

 MAXIMUM ABSOLUTE VALUES
 NODE          2           7           0           2
 VALUE  -0.69562E-04 0.10498E-04  0.0000     0.69562E-04
```

So the structure on the right is stiffer.

6. Macros

6.1 Original macro from Tim Hayler

```
FINISH

/CLE
/PREP7

/title,beam splitter32

c*** structural members in either
beam188 or beam4

c*** length mm
c*** Density tonne/mm^3
c*** Mass metric tonne (1 tonne =
1000kg)


mp,ex,1,70e3
mp,prxy,1,0.3
mp,dens,1,2.7e-9

length=550
width=350
depth=-1575


*AFUN,DEG

c*** included angle theta

THETA=20
stay=sqrt(((((tan(theta))*depth)**2)/2)
)

c*** main structure
************************

k,1,-(length/2),0,-(width/2)
k,2,(length/2),0,-(width/2)
k,3,-(length/2),0,(width/2)
k,4,(length/2),0,(width/2)

k,5,-(length/2),depth/2,-(width/2)
k,6,(length/2),depth/2,-(width/2)
k,7,-(length/2),depth/2,(width/2)
k,8,(length/2),depth/2,(width/2)

k,9,-(length/2),depth,-(width/2)
k,10,(length/2),depth,-(width/2)
k,11,-(length/2),depth,(width/2)
k,12,(length/2),depth,(width/2)

l,1,2
l,2,4
l,4,3
l,3,1

l,5,6
l,8,7

l,9,10
l,10,12
l,12,11
l,11,9

l,1,5
l,2,6
l,4,8
l,3,7

l,5,9
l,6,10
l,8,12
l,7,11

l,2,5
l,5,10

l,3,8
l,8,11

c*** stays ******************

kwpave,1
csys,4
K,20,-stay,0,-stay

kwpave,2
csys,4
K,21,stay,0,-stay

kwpave,3
```

```
csys,4
K,22,-stay,0,stay

kwpave,4
csys,4
K,23,stay,0,stay

l,9,20
l,10,21
l,12,23
l,11,22

c*** side plates
***********************

a,4,2,6,10,12,8
a,3,1,5,9,11,7

c*** Element types
***************************

ET,1,BEAM188


C*** section type hollow rectangular
******
sectype,1,beam,hrec,
secdata,50,50,5,5,5,5

c*** section type circular tube
*********
sectype,2,beam,ctube,
secdata,56,60

ET,2,BEAM4

ET,3,SHELL63

ET,4,MASS21


c*** Real constants for Beam4
*****************

C***R,N,AREA,IZZ,IYY,TKZ,TKY

c*** R4 = 20 x 20 x 5mm wall
thickness
c*** R5 = 20 x 20 x 2mm wall
thickness
C*** R6 = 30 x 30 x 2mm wall
thickness
C*** R7 = 40 x 40 x 2mm wall
thickness
C*** R8 = 50 x 50 x 2mm wall
thickness
c*** R9 = 60 x 60 x 2mm wall
thickness
C*** R10 = 50 x 50 x 4mm wall
thickness
C*** R11 = 50 x 50 x 5mm wall
thickness
C*** R12 = 50 x 50 x 6mm wall
thickness
c*** R13 = 60 Dia, 5 mm wal Thk,
circular hollow section


R,4,300,12500,12500,20,20
R,5,144,7872,7872,20,20
R,6,224,29419,29419,30,30
R,7,304,73365,73365,40,40
R,8,384,147712,147712,50,50
R,9,464,260459,260459,60,60
R,10,736,261525,261525,50,50
R,11,900,307500,307500,50,50
R,12,1056,347072,347072,50,50
R,13,864,329376,329376,60,60

c*****************************
*******************


c************** Meshing
**********************

c*** stays mesh with beam188
********


MAT,1
TYPE,1
lsel,s,,,23,26
secnum,1
lmesh,all
lsel,all
```

```
c*** main structure mesh with
beam188 ******


lsel,u,,,23,26
TYPE,1
secnum,1
lmesh,all
lsel,all

c*** alternative mesh with beam4
complete structure ***

c*** Mat,1
c*** type,2
c*** real,11
c*** lmesh,all


c*** side plates mesh
**************

R,20,5
real,20
type,3
amesh,all


c*** Additional mass
********************
R,30,0.003,0.003,0.003
TYPE,4
real,30
ksel,s,,,9,12
kmesh,all
ksel,all

c**** constraints **************

NSEL,S,LOC,Y,0
D,ALL,ALL
NSEL,ALL
ACEL,,9810

FINISH
/SOLU
ANTYPE,STATIC
SOLVE

/POST1
/VIEW,1,1,1,1
PLDISP,1

FINISH
/SOLU
ANTYPE,MODAL
MODOPT,SUBSP,20
SOLVE
FINISH
```

6.2 Macro “doit4” which builds model 4

```
FINISH
/CLE
/PREP7

/title,beam splitter32

c*** structural members in either
beam188 or beam4

c*** length mm
c*** Density tonne/mm^3
c*** Mass metric tonne (1 tonne =
1000kg)


mp,ex,1,70e3
mp,prxy,1,0.3
mp,dens,1,2.7e-9

length=550
width=350
depth=-1575


*AFUN,DEG

c*** included angle theta

THETA=20
stay=sqrt(((((tan(theta))*depth)**2)/2)
)
```

```
c*** main structure
************************

k,1,-(length/2),0,-(width/2)
!k,2,(length/2),0,-(width/2)
!k,3,-(length/2),0,(width/2)
k,4,(length/2),0,(width/2)

k,5,-(length/2),depth/2,-(width/2)
!k,6,(length/2),depth/2,-(width/2)
!k,7,-(length/2),depth/2,(width/2)
k,8,(length/2),depth/2,(width/2)

k,9,-(length/2),depth,-(width/2)
!k,10,(length/2),depth,-(width/2)
!k,11,-(length/2),depth,(width/2)
k,12,(length/2),depth,(width/2)

!two tripods

l,9,12

l,1,5

l,4,8


l,5,9

l,8,12


c*** stays ******************
jstay = stay*sqrt(2)

kwpave,1
csys,4
!K,20,-stay,0,-stay
K,20,-jstay,0,0

kwpave,1
csys,4
!K,21,stay,0,-stay
k,21,0,0,-jstay

kwpave,4
csys,4
!K,22,-stay,0,stay
k,22,0,0,jstay

kwpave,4
csys,4
!K,23,stay,0,stay
k,23,jstay,0,0

l,9,20
l,9,21
l,12,23
l,12,22

c*** side plates
************************


c*** Element types
****************************

ET,1,BEAM188


C*** section type hollow rectangular
******
sectype,1,beam,hrec,
secdata,50,50,5,5,5,5

c*** section type circular tube
*********
sectype,2,beam,ctube,
secdata,56,60

ET,2,BEAM4

ET,3,SHELL63

ET,4,MASS21


c*** Real constants for Beam4
******************

C***R,N,AREA,IZZ,IYY,TKZ,TKY

c*** R4 = 20 x 20 x 5mm wall
thickness
c*** R5 = 20 x 20 x 2mm wall
thickness
C*** R6 = 30 x 30 x 2mm wall
thickness
C*** R7 = 40 x 40 x 2mm wall
thickness
```

```
C*** R8 = 50 x 50 x 2mm wall
thickness
c*** R9 = 60 x 60 x 2mm wall
thickness
C*** R10 = 50 x 50 x 4mm wall
thickness
C*** R11 = 50 x 50 x 5mm wall
thickness
C*** R12 = 50 x 50 x 6mm wall
thickness
c*** R13 = 60 Dia, 5 mm wal Thk,
circular hollow section


R,4,300,12500,12500,20,20
R,5,144,7872,7872,20,20
R,6,224,29419,29419,30,30
R,7,304,73365,73365,40,40
R,8,384,147712,147712,50,50
R,9,464,260459,260459,60,60
R,10,736,261525,261525,50,50
R,11,900,307500,307500,50,50
R,12,1056,347072,347072,50,50
R,13,864,329376,329376,60,60

c*****************************
*******************



c************** Meshing
**********************

c*** stays mesh with beam188
********


MAT,1
TYPE,1
lsel,s,,,23,26
secnum,1
lmesh,all
lsel,all


c*** main structure mesh with
beam188 ******

lsel,u,,,23,26
TYPE,1
secnum,1
lmesh,all
lsel,all

c*** alternative mesh with beam4
complete structure ***

c*** Mat,1
c*** type,2
c*** real,11
c*** lmesh,all


c*** Additional mass
********************


R,30,0.003,0.003,0.003
TYPE,4
real,30
ksel,s,,,9,12
kmesh,all
ksel,all

c**** constraints **************

NSEL,S,LOC,Y,0
D,ALL,ALL
NSEL,ALL
ACEL,,9810


FINISH
/SOLU
ANTYPE,STATIC
SOLVE

/POST1
/VIEW,1,1,1,1
PLDISP,1

FINISH
/SOLU
ANTYPE,MODAL
MODOPT,SUBSP,20
SOLVE
FINISH
```

6.3 Macro “doit6” to make a very simple model

```
FINISH
/CLE
/PREP7

/title,simple model

c*** structural members in either
beam188 or beam4

! units mm and N (static only)


mp,ex,1,70e3
mp,prxy,1,0.3
mp,dens,1,2.7e-9

length=1000
width=1000
w2 = 500

c*** main structure
************************

k,1,0,0,0
k,2,0,length,0
k,3,width,0,0
k,4,w2,0,0

!two triangles

l,1,2

l,3,2

l,4,2

c*** Element types
***************************

ET,1,BEAM3

C***R,N,AREA,IZZ

C*** R8 = 50 x 50 x 2mm wall
thickness

R,8,384,147712

c*******************************
********************

dk,1,all
dk,3,all
dk,4,all

fk,2,fx,-1

c************** Meshing
***********************

MAT,1
TYPE,1
real,8
lmesh,all

FINISH
/SOLU
ANTYPE,STATIC
SOLVE

/POST1
/VIEW,1,1,1,1
PLDISP,1
```