Effect of steel base blocks on frequency measurements on BS structure.

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1. MOTIVATION

Frequency measurements differ from FEA predictions, with more massive structures and higher frequencies being the most affected. This note explores the idea that the finite elasticity of the massive steel blocks to which the structure is bolted, may at least partially explain the discrepancy.

2. CROSS SECTION PROPERTIES

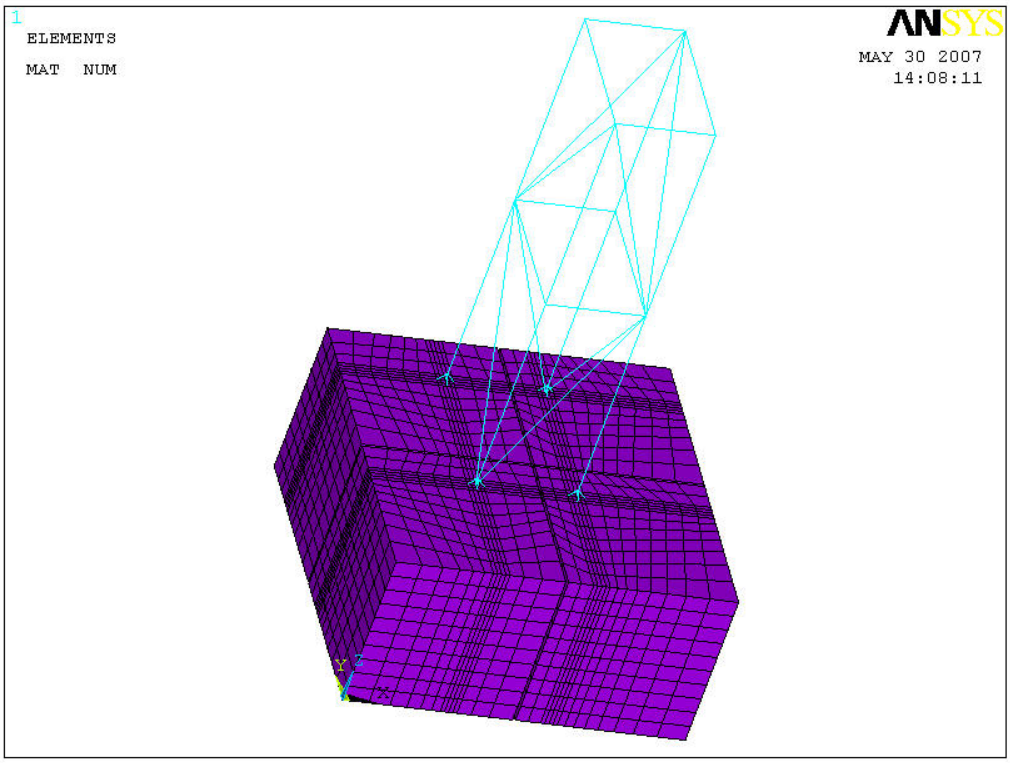
I use two cross-sections, for simplicity

(See spreadsheet)

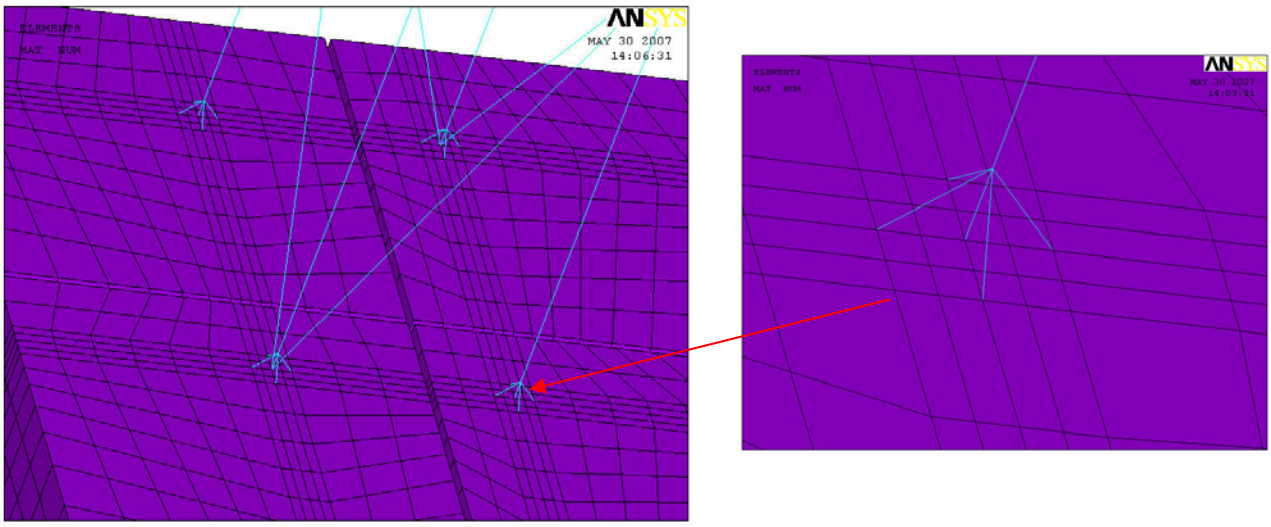
	I	A
50 by 50 by 5	3.08E-07	0.0009
50 by 50 solid	5.21E-07	0.0025

3. MODEL

It consists of an aluminium alloy simple beam model, fixed to four blocks of steel (meshed with brick elements).



To get a good fix to the steel blocks, I added “extra feet” thus, at each corner. The spacing of these extra feet was set by the APDL parameter “fixoff” at 30mm from the base of the leg – simulating a fixation that spreads over about 60mm.



Model mass was

TYPE	MASS
1	51.8726
2	7081.81

(ie, aluminium parts about 50kg, steel parts 7 tonnes). This seems sensible.

An ANSYS macro is given in appendix 1.

4. RESULTS

4.1 Fix feet of structure (structure encastered), do not fix base of blocks

With the feet of the structure fixed, the steel block swung about the constraint points.

4.2 Fix feet of structure (structure encastered) and base of blocks

With the base of the steel blocks and the feet of the structure fixed, the first frequency was 63 Hz. (Block Langcos; 0-150 Hz, find 10 modes, gave this:)

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	63.708	1	1	1
2	100.89	1	2	2
3	138.63	1	3	3

The shapes were: beam bending in weak direction, beam bending in stiff direction, torsion.

4.3 Fix feet of structure to blocks and fix base of blocks

With just the base of the blocks fixed, the first frequency was almost exactly them same.

***** INDEX OF DATA SETS ON RESULTS FILE *****

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	63.375	1	1	1
2	99.515	1	2	2
3	138.09	1	3	3

Mode shapes as before.

This suggests to me that the blocks are adequately stiff. Let's try a stiffer, heavier, structure. I'll increase the modulus of the structure by a factor 4, and its density by a factor 2.

4.4 Stiffer, heavier structure

Input:
MPDATA,EX,1,,70E9*4
MPDATA,PRXY,1,,0.3
MPDATA,DENS,1,,2.7E3*2
Output:

TYPE	MASS
1	103.745
2	7081.81

The results were, feet encastered:

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	89.509	1	1	1
2	142.41	1	2	2

Feet fixed to blocks only:

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	87.659	1	1	1
2	136.50	1	2	2

4.5 Fixing less than perfect

Try removing the "extra" fixing legs.

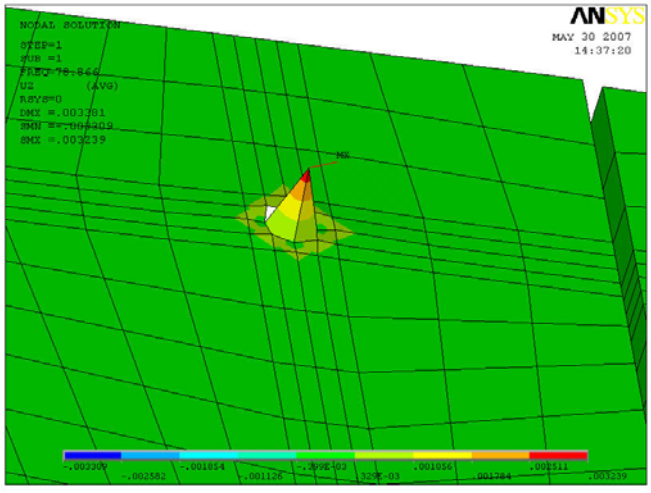
Feet encastered:

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	86.378	1	1	1
2	141.36	1	2	2

Feet fixed to steel blocks only:

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	78.866	1	1	1
2	124.30	1	2	2

This is an 8 Hz (10%) effect, but looks rather mesh-dependant. Here is a deflection picture near one of the feet:



With the "extra" legs present but "fixoff" reduced to 10mm, the results were:

Feet encastered:

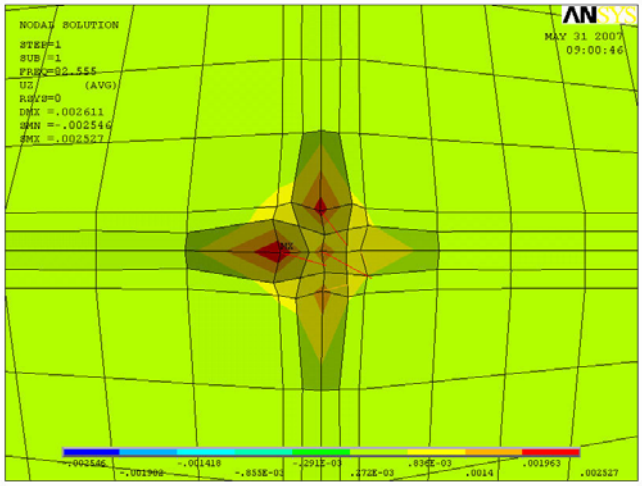
SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	87.143	1	1	1
2	141.59	1	2	2

This takes a long time to run because of the increased mesh density in the steel blocks (thanks for George Ellwood for loan of his PC).

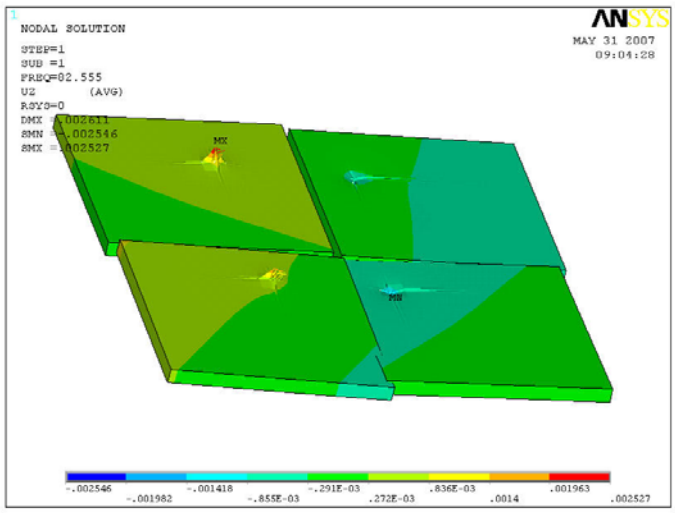
Feet fixed to steel blocks only:

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	82.555	1	1	1
2	129.65	1	2	2

Once again, the results do look to be somewhat mesh-dependant:



And, interestingly, the blocks are participating in the deformation (this effect is small: if you include the structure in the plot - even a z-wise plot - you don't see it).



5. CONCLUSION

It would seem that the distributed mass and elasticity of the steel blocks do not make a significant contribution to the natural frequency of the structure. When bolted firmly to the blocks, the structure should behave as if it were encastered. Assuming an encastered constraint at the feet should give answers close to those observed with the feet fixed to the blocks.

appendix – ANSYS macro

```
FINISH  ! Make sure we are at BEGIN level
/CLEAR
*abbr,doit,doit
*abbr,jreplo,/replot
/PREP7

! to build a simple beam model on steel blocks
!
!Element types
!*
ET,1,BEAM4
!*
ET,2,SOLID186
!*

!For the beams 1 = hollow; 2 = solid
!
R,1,0.0009,3.08E-07,3.08E-07,0.025,0.025
R,2,0.0025,5.21E-07,5.21E-07,0.025,0.025


!materials 1 = aluminium; 2 = steel
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,EX,1,,70E9
MPDATA,PRXY,1,,0.3
MPDATA,DENS,1,,2.7E3

MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,EX,2,,210E9
MPDATA,PRXY,2,,0.3
MPDATA,DENS,2,,7.8E3

! geometry

xoff = 0.23
yoff = 0.14
xstruct = 0.36
ystruct = 0.55
bsize = 0.610
gap = 0.010
zstruct1 = 0.8
zstruct2 = 1.6
fixoff = 0.03

X0 = 0
X1 = bsize - xoff
x2 = bsize
x3 = x2 + gap
x4 = x1 + xstruct
x5 = x3 + bsize
x6 = x1 - fixoff
x7 = x1 + fixoff
x8 = x4 - fixoff
x9 = x4 + fixoff

y0 = 0
y1 = bsize - yoff
y2 = bsize
y3 = y2 + gap
y4 = y1 + ystruct
y5 = y3 + bsize
y6 = y1 - fixoff
y7 = y1 + fixoff
y8 = y4 - fixoff
y9 = y4 + fixoff

z0 = 0
z1 = bsize
z2 = z1 + zstruct1
z3 = z1 + zstruct2

!

keypoints

k, 1, x0,y0,z0
k, 2, x6,y0,z0
k, 3, x1,y0,z0
k, 4, x7,y0,z0
k, 5, x2,y0,z0
k, 6, x3,y0,z0
k, 7, x8,y0,z0
k, 8, x4,y0,z0
k, 9, x9,y0,z0
k,10, x5,y0,z0

!lines 1 to 4

l,1,2
,2,3
,3,4
,4,5
!lines 5 to 8
l,6,7
,7,8
,8,9
,9,10

k,11,x0,y6,z0
k,12,x0,y1,z0
k,13,x0,y7,z0
k,14,x0,y2,z0
k,15,x0,y3,z0
k,16,x0,y8,z0
k,17,x0,y4,z0
k,18,x0,y9,z0
k,19,x0,y5,z0

!lines 9 to 12
l,1,11
,11,12
,12,13
,13,14

!lines 13 to 16
l,15,16
,16,17
,17,18
,18,19

!z dimension
k,20,x0,y0,z1
k,21,x1,y1,z1+fixoff
k,22,x1,y1,z2
k,23,x1,y1,z3

!line 17
l,1,20

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

FLST,3,8,4,ORDE,8
FITEM,3,45
FITEM,3,48
FITEM,3,50
FITEM,3,52
FITEM,3,81
FITEM,3,84
FITEM,3,86
FITEM,3,88
LGEN,2,P51X, , , ,gap, , ,0

adrag,90,91,92,93,,,13,14,15,16
adrag,94,95,96,97,,,13,14,15,16

vdrag,all,,,,,,17
```

```
/VIEW,  1, -0.236620128544    , -0.782474382372    ,

0.575972877572
/ANG,   1,   10.5782042749
/REPLO

!restart line numbering from 500
NUMSTR,LINE,500,

!line 500 - 502
l,126,21
,21,22
,22,23

!vertical legs
ldrag,151,201,176,,,,500,501,502

!middle ring
l,22,219
,219,218
,218,217
,217,22

! diagonals
l,126,219
,219,201
,201,217
,217,126

l,23,219
,219,221
,221,217
,217,23

!top ring lines 524-527
l,23,222
,222,221
,221,220
,220,23

!fixings
l,21,124
,21,131
,21,119
,21,127

,214,156
,214,152
,214,144
,214,149

,215,202
,215,206
,215,194
,215,199

,216,177
,216,169
,216,181
,216,174

!meshing
!set element size
lsel,s,line,,500,600
lesize,all,0.01

! structure except top ring
lsel,u,line,,524,527

mat, 1
real,1
type,1
lmesh,all

!top ring
lsel,s,line,,524,527
real,2
lmesh,all


!volumes
allsel
mat,2
type,2

vmesh,all

!constraints
!fix points on the ground
kpsel,s,loc,z,-0.01,0.01
dk,all,ux,0
,all,uy,0
,all,uz,0


! fix leg ends
!ksel,s,kp,,126
!,a,kp,,176
!,a,kp,,201
!,a,kp,,151

!dk,all,ux,0
!,all,uy,0
!,all,uz,0

allsel

sbctra

:end
```