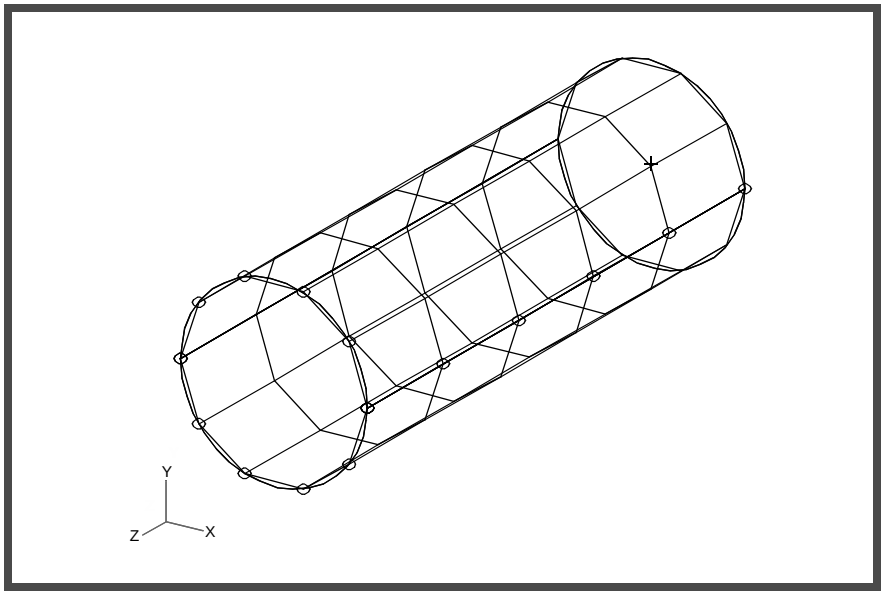
APPENDIX E

Rigid Element Analysis with RBE2 and CONM2 (SI)



Objectives:

- Idealize a rigid end using RBE2 elements.
- Define a concentrated mass, to represent the weight of the rigid enclosure (CONM2).
- Produce a Nastran input file that represents the tube.
- Submit the file for analysis in MSC.Nastran.
- Find the displacement vectors.

Model Description:

The goal of this example is to maintain a circular cross section at the rigid end of the tube, (using a RBE2 element), while applying a gravitational force of 2.7g in the z-direction.

Additionally, a concentrated mass needs to be defined to represent the weight of the rigid enclosure. It is very important to account for all the weight contribution since inertial loading is used in this problem.

Below is a Finite Element representation of the tube. One end of the tube is considered rigid, and the other end is fixed in all translational and rotational degrees of freedom. Table E.1 contains all the necessary parameters to construct the input file

Figure E.1 - Grid Coordinates and Element Connectivities.

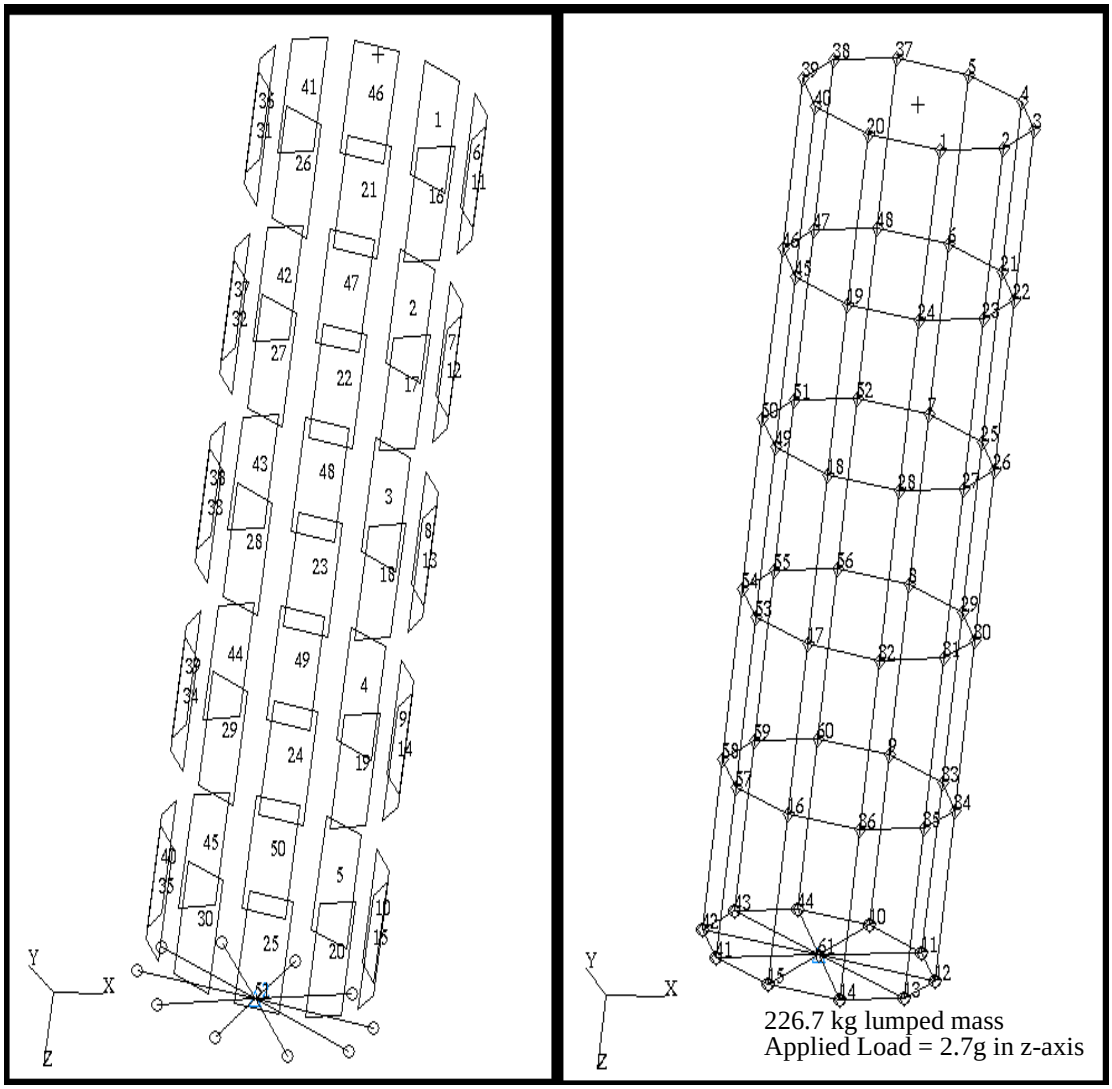


Figure E.2 - Loads and Boundary Conditions.

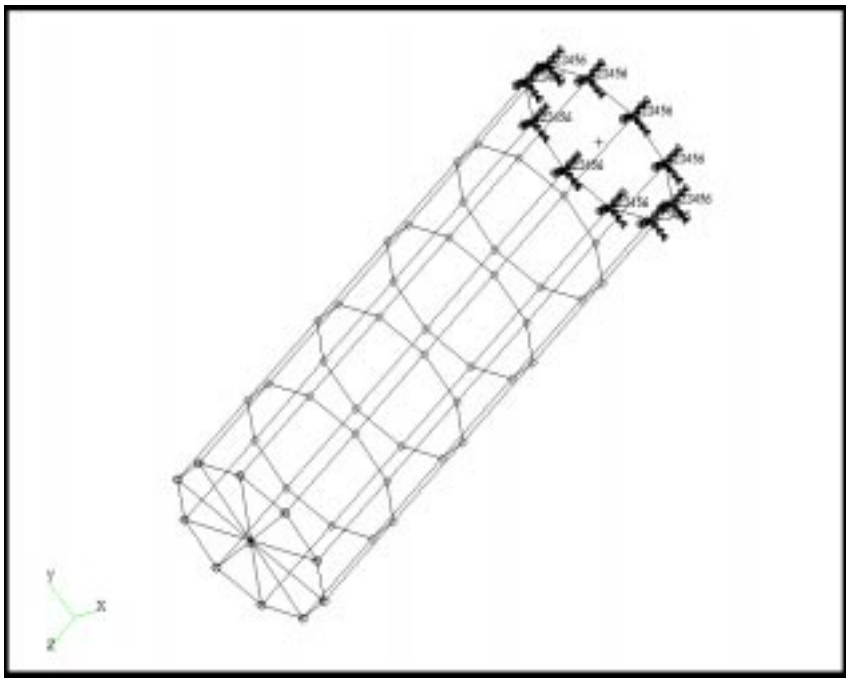


Table E.1 - Model Properties

Radius:	**381 mm**
Thickness:	**3.175 mm**
Length:	**2,286 mm**
Elastic Modulus:	**69 GPa**
Poisson Ratio:	**0.3**
Density:	**2,796 kg/m^3**

Suggested Exercise Steps:

- Build the cylinder geometry with the fixed base on the XY plane and the cylinder's axis along the Z-Axis.
- Generate a finite element representation of the cylinder structure i.e., the nodes (GRID) and element connectivity (CQUAD4).
- Define material (MAT1) and element (PSHELL) properties.
- Create grid point 61 at the center of the enclosure. This point is to serve as the load application point, as well as the connection point of for the rigid element.
- Idealize the top enclosure as a rigid element (RBE2).
- Apply the fixed boundary constraints (SPC1).
- Apply a concentrated mass of 226.7 kg at the center of the top enclosure, grid 61 (CONM2), and a gravitational force of 2.7g in the Z-direction (GRAV).
- Prepare the model for linear static analysis (SOL 101).
- Generate an Input file and submit it to the MSC.Nastran solver for linear static analysis.
- Review the results, specifically the displacements along the top edges.

Generating an Input File for MSC.Nastran Users:

MSC.Nastran users can generate an input file using the data from Table E.1. The result should be similar to the output below.

1. MSC.Nastran Input File: **ex03rigid.dat**

```
ID  RIGID EL,CATIAFEM
SOL     101
CEND
$..
$-------------------------------------------------------------------------------
$..
$..                   CASE CONTROL DECK
$..
TITLE = RIGID ELEMENT ANALYSIS WITH RBAR
DISPL   =       ALL
MPC     =       1
$..
SUBCASE =        1
$ CATIA RESTRAINT SET NAME :
$ FIX TO WALL
   SPC  =        1
$ CATIA LOAD SET NAME :
$ 2.7G VERTICAL LOAD
   LOAD =        1
$..
$-------------------------------------------------------------------------------
$..
$..                   BULK DATA CARDS
$..
BEGIN BULK
PARAM   POST    0
PARAM   AUTOSPC YES
$..
$-------------------------------------------------------------------------------
$..
$..                   RESTRAINTS
$..
$ NASTRAN ID =        1 / RESTRAINT SET NAME :
$ FIX TO WALL
SPC1    1       123456  1       2       3       4       5       20              1
+      137      38      39      40
$..
$-------------------------------------------------------------------------------
$..
$..                   LOADS
$..
$ NASTRAN ID =        1 / LOAD SET NAME :
$ 2.7G VERTICAL LOAD
GRAV    1               9810.   0.      0.      2.7
```

```
$..
$------------------------------------------------------------------------
$..
$..                   MATERIALS
$..
$ MATERIAL NAME : ALUM
MAT1    1       69000.01        .03     .2796-8
$..
$------------------------------------------------------------------------
$..
$..                   NODES
$..
GRID    1               -59.6016-376.309.365-14
GRID    2               172.9703-339.473-.106-13
GRID    3               339.4734-172.97 -.208-13
GRID    4               376.309459.60159-.23-13
GRID    5               269.4077269.4077-.165-13
GRID    6               269.4077269.4077457.2
GRID    7               269.4077269.4077914.4
GRID    8               269.4077269.40771371.6
GRID    9               269.4077269.40771828.8
GRID    10              269.4077269.40772286.
GRID    11              376.309459.601592286.
GRID    12              339.4734-172.97 2286.
GRID    13              172.9703-339.4732286.
GRID    14              -59.6016-376.3092286.
GRID    15              -269.408-269.4082286.
GRID    16              -269.408-269.4081828.8
GRID    17              -269.408-269.4081371.6
GRID    18              -269.408-269.408914.4
GRID    19              -269.408-269.408457.2
GRID    20              -269.408-269.408.165-13
GRID    21              376.309459.60167457.2
GRID    22              339.4735-172.97 457.2
GRID    23              172.9703-339.473457.2
GRID    24              -59.6017-376.309457.2
GRID    25              376.309459.60169914.4
GRID    26              339.4735-172.97 914.4
GRID    27              172.9703-339.473914.4
GRID    28              -59.6017-376.309914.4
GRID    29              376.309459.601691371.6
GRID    30              339.4735-172.97 1371.6
GRID    31              172.9703-339.4731371.6
GRID    32              -59.6017-376.3091371.6
GRID    33              376.309459.601671828.8
GRID    34              339.4735-172.97 1828.8
GRID    35              172.9703-339.4731828.8
GRID    36              -59.6017-376.3091828.8
GRID    37              59.60159376.3094-.365-14
GRID    38              -172.97 339.4734.1059-13
GRID    39              -339.473172.9703.2079-13
GRID    40              -376.309-59.6016.2304-13
```

```
GRID    41              -376.309-59.60162286.
GRID    42              -339.473172.97032286.
GRID    43              -172.97 339.47342286.
GRID    44              59.60159376.30942286.
GRID    45              -376.309-59.6017457.2
GRID    46              -339.473172.9703457.2
GRID    47              -172.97 339.4735457.2
GRID    48              59.60167376.3094457.2
GRID    49              -376.309-59.6017914.4
GRID    50              -339.473172.9703914.4
GRID    51              -172.97 339.4735914.4
GRID    52              59.60169376.3094914.4
GRID    53              -376.309-59.60171371.6
GRID    54              -339.473172.97031371.6
GRID    55              -172.97 339.47351371.6
GRID    56              59.60169376.30941371.6
GRID    57              -376.309-59.60171828.8
GRID    58              -339.473172.97031828.8
GRID    59              -172.97 339.47351828.8
GRID    60              59.60167376.30941828.8
GRID    61              .4121-14-.124-122286.
$..
$-------------------------------------------------------------------------------
$..
$..                   ELEMENTS
$..
CQUAD4  1       1       5       6       21      4
CQUAD4  2       1       6       7       25      21
CQUAD4  3       1       7       8       29      25
CQUAD4  4       1       8       9       33      29
CQUAD4  5       1       9       10      11      33
CQUAD4  6       1       4       21      22      3
CQUAD4  7       1       21      25      26      22
CQUAD4  8       1       25      29      30      26
CQUAD4  9       1       29      33      34      30
CQUAD4  10      1       33      11      12      34
CQUAD4  11      1       3       22      23      2
CQUAD4  12      1       22      26      27      23
CQUAD4  13      1       26      30      31      27
CQUAD4  14      1       30      34      35      31
CQUAD4  15      1       34      12      13      35
CQUAD4  16      1       2       23      24      1
CQUAD4  17      1       23      27      28      24
CQUAD4  18      1       27      31      32      28
CQUAD4  19      1       31      35      36      32
CQUAD4  20      1       35      13      14      36
CQUAD4  21      1       1       24      19      20
CQUAD4  22      1       24      28      18      19
CQUAD4  23      1       28      32      17      18
CQUAD4  24      1       32      36      16      17
CQUAD4  25      1       36      14      15      16
CQUAD4  26      1       20      19      45      40
```

```
CQUAD4  27      1       19      18      49      45
CQUAD4  28      1       18      17      53      49
CQUAD4  29      1       17      16      57      53
CQUAD4  30      1       16      15      41      57
CQUAD4  31      1       40      45      46      39
CQUAD4  32      1       45      49      50      46
CQUAD4  33      1       49      53      54      50
CQUAD4  34      1       53      57      58      54
CQUAD4  35      1       57      41      42      58
CQUAD4  36      1       39      46      47      38
CQUAD4  37      1       46      50      51      47
CQUAD4  38      1       50      54      55      51
CQUAD4  39      1       54      58      59      55
CQUAD4  40      1       58      42      43      59
CQUAD4  41      1       38      47      48      37
CQUAD4  42      1       47      51      52      48
CQUAD4  43      1       51      55      56      52
CQUAD4  44      1       55      59      60      56
CQUAD4  45      1       59      43      44      60
CQUAD4  46      1       37      48      6       5
CQUAD4  47      1       48      52      7       6
CQUAD4  48      1       52      56      8       7
CQUAD4  49      1       56      60      9       8
CQUAD4  50      1       60      44      10      9
RBE2    51      61      123456  10      11      12      13      14              2
+       215     41      42      43      44
CONM2   52      61              .2267
$..
$-------------------------------------------------------------------------------
$..
$..                   PROPERTIES
$..
PSHELL  1       1       3.175   1       1.      1       .83333
$..
ENDDATA
```

Submitting the Input File for Analysis:

2. When the run is completed, edit the **ex03rigid.f06** file and search for the word **FATAL**. If no matches exist, search for the word **WARNING**. Determine whether existing WARNING messages indicate modeling errors.

3. While still editing **ex03rigid.f06**, search for the word:

   D I S P L A C E M E N T (spaces are necessary)

   For Point ID's 10, 11, 12, 13, 14, 15, 44, 42, 43, and 44

   T3 = _____

Comparison of Results:

4. Compare the results obtained in the **.f06** file with the results on the following page.

D I S P L A C E M E N T V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	0.0	0.0	0.0	0.0
2	G	0.0	0.0	0.0	0.0	0.0	0.0
3	G	0.0	0.0	0.0	0.0	0.0	0.0
4	G	0.0	0.0	0.0	0.0	0.0	0.0
5	G	0.0	0.0	0.0	0.0	0.0	0.0
6	G	-1.399788E-04	-1.399788E-04	6.329277E-03	2.011059E-07	-2.011059E-07	-2.587686E-19
7	G	-9.960344E-05	-9.960344E-05	1.243694E-02	-1.508711E-07	1.508711E-07	6.065815E-19
8	G	-9.743001E-05	-9.743001E-05	1.831937E-02	1.232055E-07	-1.232055E-07	9.281364E-19
9	G	-1.226628E-04	-1.226628E-04	2.397823E-02	-1.906610E-07	1.906610E-07	3.629536E-19
10	G	2.592601E-08	2.592601E-08	2.941046E-02	-2.275590E-11	2.275590E-11	-3.121449E-20
11	G	2.592601E-08	2.592601E-08	2.941046E-02	-2.275590E-11	2.275590E-11	-3.121449E-20
12	G	2.592601E-08	2.592601E-08	2.941046E-02	-2.275590E-11	2.275590E-11	-3.121449E-20
13	G	2.592601E-08	2.592601E-08	2.941047E-02	-2.275590E-11	2.275590E-11	-3.121449E-20
14	G	2.592601E-08	2.592601E-08	2.941048E-02	-2.275590E-11	2.275590E-11	-3.121449E-20
15	G	2.592601E-08	2.592601E-08	2.941048E-02	-2.275590E-11	2.275590E-11	-3.121449E-20
16	G	1.226970E-04	1.226970E-04	2.397825E-02	1.906207E-07	-1.906207E-07	5.454892E-19
17	G	9.745431E-05	9.745431E-05	1.831938E-02	-1.232096E-07	1.232096E-07	1.531436E-18
18	G	9.961704E-05	9.961704E-05	1.243695E-02	1.508277E-07	-1.508277E-07	9.160661E-19
19	G	1.399814E-04	1.399814E-04	6.329282E-03	-2.011087E-07	2.011087E-07	1.115172E-19
20	G	0.0	0.0	0.0	0.0	0.0	0.0
21	G	-1.955191E-04	-3.096267E-05	6.329277E-03	4.449808E-08	-2.808728E-07	-8.485403E-11
22	G	-1.764074E-04	8.988462E-05	6.329282E-03	-1.291685E-07	-2.534824E-07	2.773145E-11
23	G	-8.986858E-05	1.763738E-04	6.329278E-03	-2.533671E-07	-1.290792E-07	6.159132E-11
24	G	3.097103E-05	1.955332E-04	6.329282E-03	-2.809439E-07	4.448850E-08	-5.920878E-11
25	G	-1.391262E-04	-2.202572E-05	1.243694E-02	-3.340813E-08	2.106890E-07	-1.491021E-10
26	G	-1.255480E-04	6.397405E-05	1.243694E-02	9.685868E-08	1.901099E-07	6.533651E-11

27	G	-6.394355E-05	1.254984E-04	1.243694E-02	1.900656E-07	9.683231E-08	9.651231E-11
28	G	2.204478E-05	1.391506E-04	1.243695E-02	2.107152E-07	-3.335266E-08	-1.137005E-10
29	G	-1.360933E-04	-2.154116E-05	1.831937E-02	2.727034E-08	-1.720594E-07	-1.450850E-10
30	G	-1.228096E-04	6.258667E-05	1.831937E-02	-7.913094E-08	-1.552507E-07	6.398906E-11
31	G	-6.254672E-05	1.227726E-04	1.831938E-02	-1.552616E-07	-7.906487E-08	9.282436E-11
32	G	2.157017E-05	1.361269E-04	1.831938E-02	-1.721248E-07	2.726036E-08	-1.095090E-10
33	G	-1.713393E-04	-2.712014E-05	2.397823E-02	-4.220500E-08	2.662792E-07	-7.782580E-11
34	G	-1.545903E-04	7.879177E-05	2.397823E-02	1.224230E-07	2.403119E-07	2.589117E-11
35	G	-7.874594E-05	1.545909E-04	2.397824E-02	2.401599E-07	1.223845E-07	5.581398E-11
36	G	2.715905E-05	1.713829E-04	2.397824E-02	2.662992E-07	-4.215102E-08	-5.411900E-11
37	G	0.0	0.0	0.0	0.0	0.0	0.0
38	G	0.0	0.0	0.0	0.0	0.0	0.0
39	G	0.0	0.0	0.0	0.0	0.0	0.0
40	G	0.0	0.0	0.0	0.0	0.0	0.0
41	G	2.592601E-08	2.592601E-08	2.941048E-02	-2.275590E-11	2.275590E-11	-3.121449E-20
42	G	2.592601E-08	2.592601E-08	2.941047E-02	-2.275590E-11	2.275590E-11	-3.121449E-20
43	G	2.592601E-08	2.592601E-08	2.941046E-02	-2.275590E-11	2.275590E-11	-3.121449E-20
44	G	2.592601E-08	2.592601E-08	2.941046E-02	-2.275590E-11	2.275590E-11	-3.121449E-20
45	G	1.955332E-04	3.097103E-05	6.329282E-03	-4.448850E-08	2.809439E-07	5.920878E-11
46	G	1.763738E-04	-8.986858E-05	6.329278E-03	1.290792E-07	2.533671E-07	-6.159132E-11
47	G	8.988462E-05	-1.764074E-04	6.329282E-03	2.534824E-07	1.291685E-07	-2.773145E-11
48	G	-3.096267E-05	-1.955191E-04	6.329277E-03	2.808728E-07	-4.449808E-08	8.485403E-11
49	G	1.391506E-04	2.204478E-05	1.243695E-02	3.335266E-08	-2.107152E-07	1.137005E-10
50	G	1.254984E-04	-6.394355E-05	1.243694E-02	-9.683231E-08	-1.900656E-07	-9.651231E-11