

Appendix B: Sample Mathematica Program

```

z[x_]:=17-17/(25)^2*x^2;
r=0.4;
n=200;
m=24;
t=.0025;
theta=15;
file=OpenWrite["c:\users\molloy\circle.inp"];

f[x_]:=Sqrt[1+(z[x])^2];
node=1; el=1;ymax=0;
x0=x/.Solve[z[x]==0,x][[2]];
s0=NIntegrate[f[x],{x,-x0,x0},AccuracyGoal->8,PrecisionGoal->13];

WriteString[file,"*HEADING\n",
  "TWO ARCHES WITH ",n*m," ELEMENTS EACH\n",
  theta," DEGREE ANGLE\n",
  "BASE = 25 m, HEIGHT = 12.5 m, RADIUS = 0.4 m\n",
  "**PREPRINT,MODEL=NO,HISTORY=NO,ECHO=NO\n"];

WriteString[file,"*NODE, NSET=NARCH1\n"];
Do[  si=i*s0/n;
    xi=Switch[i,0,-x0,n,x0,_,t/.FindRoot[Integrate[f[x],{x,-x0,t}]-si==0,
      {t,1},AccuracyGoal->8][[1]]];
    zi=z[xi];
    singi=Switch[i,0,Limit[-z[x]/f[x],x->xi,Direction->-1],
      n,Limit[-z[x]/f[x],x->xi,Direction->1],_,-z[xi]/f[xi]];
    cosgi=1/(f[xi]);
    Do[phij=2 j Pi/m;
      x1=Chop[xi+r*singi*N[Cos[phij]],10^-5];
      z1=Chop[zi+r*cosgi*N[Cos[phij]],10^-5];
      y1=Chop[r*N[Sin[phij]],10^-5];
      xnode=N[x1];
      If[y1==0 && z1==0,ynode=y1;
        znode=z1,
        ynode=N[Sqrt[y1^2+z1^2]*Cos[ArcTan[y1,z1]-
          theta*Degree]];
      znode=N[Sqrt[y1^2+z1^2]*Sin[ArcTan[y1,z1]-
        If[ymax<ynode,ymax=ynode];
      WriteString[file,node,"",PaddedForm[xnode,{10,6}],",",
        PaddedForm[ynode,{10,6}],",",PaddedForm[znode,{10,6}],"\n"];
      ++node,
    {j,0,m-1}],
  {i,0,n}];

```

```

WriteString[file,"*NODE, NSET=NARCH2\n"];
Do[  si=i*s0/n;
    xi=Switch[i,0,-x0,n,x0,_,t/.FindRoot[Integrate[f[x],{x,-x0,t}]-si==0,
      {t,1},AccuracyGoal->8][[1]]];
    zi=z[xi];
    singi=Switch[i,0,Limit[-z'[x]/f[x],x->xi,Direction->-1],
    n,Limit[-z'[x]/f[x],x->xi,Direction->1],_,-z'[xi]/f[xi]];
    cosgi=1/(f[xi]);
    Do[phij=2 j Pi/m;
      x1=Chop[xi+r*singi*N[Cos[phij]],10^-5];
      z1=Chop[zi+r*cosgi*N[Cos[phij]],10^-5];
      y1=Chop[r*N[Sin[phij]],10^-5];
      xnode=N[x1];
      If[y1==0 && z1==0,y2=y1;znode=z1,
      y2=N[Sqrt[y1^2+z1^2]*Cos[ArcTan[y1,z1]-theta*Degree]];
      znode=N[Sqrt[y1^2+z1^2]*Sin[ArcTan[y1,z1]-
      theta*Degree]];
      ynode=2*(ymax-y2)+y2;
      WriteString[file,node,"",PaddedForm[xnode,{10,6}],",",
      PaddedForm[ynode,{10,6}],",",PaddedForm[znode,{10,6}],"\n"];
      ++node,
    {j,0,m-1}],
{i,0,n}];

```

```

WriteString[file,"*ELEMENT, ELSET=ELARCH1, TYPE=S4R\n"];
Do[node1=i*m+j+1;
  node2=(i+1)*m+j+1;
  node3=If[j==m-1,(i+1)*m+j+2-m,(i+1)*m+j+2];
  node4=If[j==m-1,i*m+j+2-m,i*m+j+2];
  WriteString[file,el,"",node1,"",node2,"",node3,"",node4,"n"];
  ++el,{i,0,n-1},{j,0,m-1}];

```

```

WriteString[file,"*ELEMENT, ELSET=ELARCH2, TYPE=S4R\n"];
Do[node1=i*m+j+1;
  node2=If[j==m-1,i*m+j+2-m,i*m+j+2];
  node3=If[j==m-1,(i+1)*m+j+2-m,(i+1)*m+j+2];
  node4=(i+1)*m+j+1;
  WriteString[file,el,"",node1,"",node2,"",node3,"",node4,"n"];
  ++el,{i,n+1,2n},{j,0,m-1}];

```

```

WriteString[file,
"*NSET,NSET=LEFTEND1,GENERATE\n",
1,"",m,"n",
"*NSET,NSET=RGHTEND1,GENERATE\n",
n*m+1,"",(n+1)*m,"n",

```

```

"*NSET,NSET=LEFTEND2,GENERATE\n",
(n+1)*m+1,"",(n+2)*m,"\n",
"*NSET,NSET=RGHTEND2,GENERATE\n",
(2*n+1)*m+1,"",2*(n+1)*m,"\n",
"*NSET,NSET=NALL\n",
"NARCH1,NARCH2\n",
"*ELSET,ELSET=ELALL\n",
"ELARCH1,ELARCH2\n",
*NSET,NSET=APEX\n",
n/2*m-m*theta/360+1+m,"\n",
(3*n/2+1)*m-m*theta/360+1+m,"\n",
"*NSET,NSET=NCROSS,GENERATE\n",
m*n/2+1,"",m*(n/2+1),"\n",
m*(3n/2+1)+1,"",m*(3n/2+2),"\n",
"*ELSET,ELSET=ELCROSS,GENERATE\n",
m*n/2+1,"",m*(n/2+1),"\n",
m*3n/2+1,"",m*(3n/2+1),"\n"];

```

node=1;

```
WriteString[file,"*NSET,NSET=TOP\n"];
```

```
Do[Do[If[0<=j<=m/8-m*theta/360 || 7m/8-m*theta/360<=j<=m,WriteString[file,node,""];
++node,{j,0,m-1}];WriteString[file,"\n",{i,0,2n+1}];
```

el=1;

```
WriteString[file,"*ELSET,ELSET=TOP\n"];
```

```
Do[Do[If[0<=j<=m/8-m*theta/360-1 || 7m/8-m*theta/360<=j<=m,WriteString[file,el,""];
++el,{j,0,m-1}];WriteString[file,"\n",{i,0,2n-1}];
```

```
pload=N[500*6*25/(2(m/2+1)*(n+1))];
```

```
WriteString[file,
```

```

"**\n",
"*SURFACE DEFINITION,NAME=SURFACE1\n",
"ELARCH1,SPOS\n",
"*SURFACE DEFINITION,NAME=SURFACE2\n",
"ELARCH2,SPOS\n",
"*CONTACT PAIR,INTERACTION=SCONT,SMALL SLIDING\n",
"SURFACE2,SURFACE1\n",
"*SURFACE INTERACTION,NAME=SCONT\n",
"**\n",
"*MATERIAL,NAME=ARCH\n",
"*DENSITY\n",
"1440.0\n",
"*ELASTIC\n",
"7.0E9, 0.3\n",
"*SHELL SECTION,ELSET=ELALL,MATERIAL=ARCH\n",
"t,\n",
"*BOUNDARY\n",

```

```
"LEFTEND1,ENCASTRE\n",
"RGHTEND1,ENCASTRE\n",
"LEFTEND2,ENCASTRE\n",
"RGHTEND2,ENCASTRE\n"];
```

```
match1=n/2*m+m/4-m*theta/360+1;
match2=(3*n/2+1)*m+m/4-m*theta/360+1;
```

```
WriteString[file,
"*EQUATION\n",
"2\n",
match1,"1,1,",match2,"1,-1\n",
"2\n",
match1,"2,1,",match2,"2,-1\n",
"2\n",
match1,"3,1,",match2,"3,-1\n",
"2\n",
match1,"4,1,",match2,"4,-1\n",
"2\n",
match1,"5,1,",match2,"5,-1\n",
"2\n",
match1,"6,1,",match2,"6,-1\n"];
```

```
WriteString[file,
"**\n",
"*RESTART,WRITE,FREQUENCY=5\n",
"**\n",
"*STEP,NLGEOM,INC=100\n",
"*STATIC\n",
"0.25,1.0,0.25,1\n",
"*DLOAD\n",
"ELALL,GRAV,9.8066,0,0,-1.0\n",
"ELALL,P,500000\n",
"*NODE PRINT,FREQUENCY=0,SUMMARY=NO\n",
"*NODE FILE,FREQUENCY=0\n",
"*EL PRINT,FREQUENCY=0,SUMMARY=NO\n",
"*END STEP\n",
"**\n",
"*STEP,NLGEOM,INC=100\n",
"*STATIC,RIKS\n",
"0.1,1.0,,0.1,1.0\n",
"*CLOAD\n",
"TOP,3,-100\n",
"*NODE PRINT,NSET=APEX,FREQUENCY=100,SUMMARY=NO\n",
"U\n",
"CF3\n",
"*NODE FILE,FREQUENCY=0\n",
```

```
"*EL PRINT,FREQUENCY=0,SUMMARY=NO\n",  
"*END STEP\n",  
"**\n",  
"*STEP,NLGEOM,INC=100\n",  
"*FREQUENCY\n",  
"10\n",  
"*NODE PRINT,FREQUENCY=0\n",  
"*EL PRINT,FREQUENCY=0\n",  
"*END STEP\n"];
```

Close[file];

Note: Many data lines were added after the mesh was generated; therefore, this sample program does not include all ABAQUS cards used during the analysis.