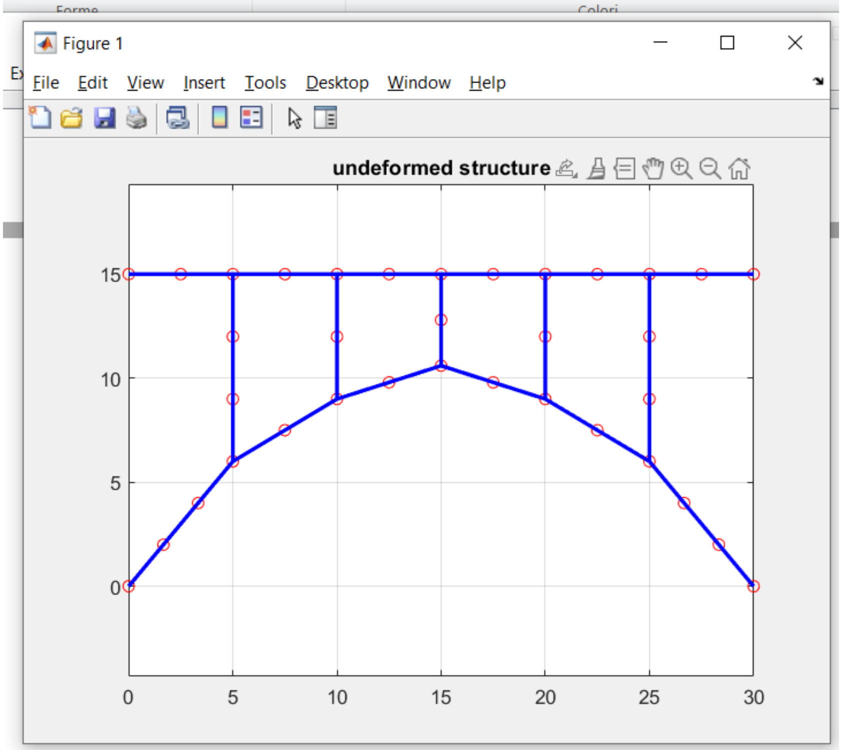
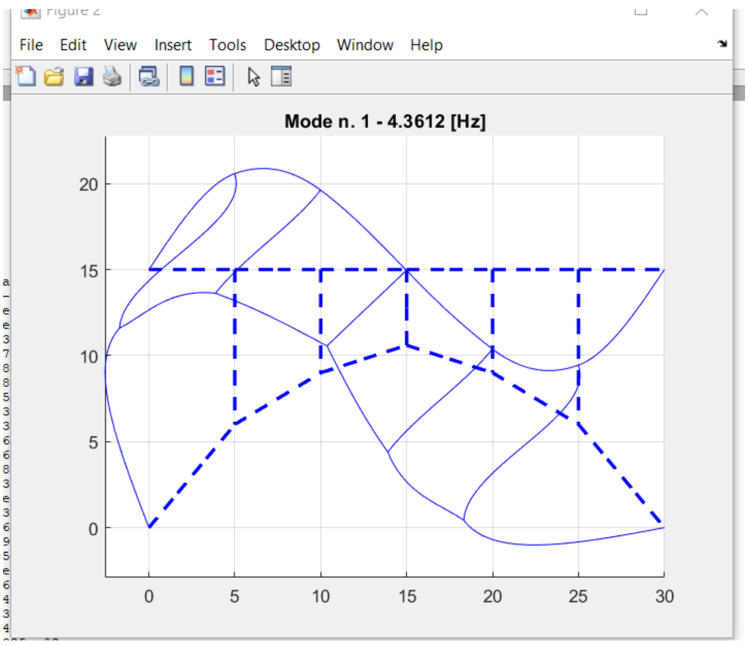
Point 1:




```
Total nodes number 35
Number of d.o.f. 97
Number of beam elements 39
Number of string elements 0
Number of tensile beam elements 0
Number of concentrated masses 0
Number of concentrated springs 0
Total mass [kg] 5170.6664
Matrices M, R, K assembled
```

Point 2:



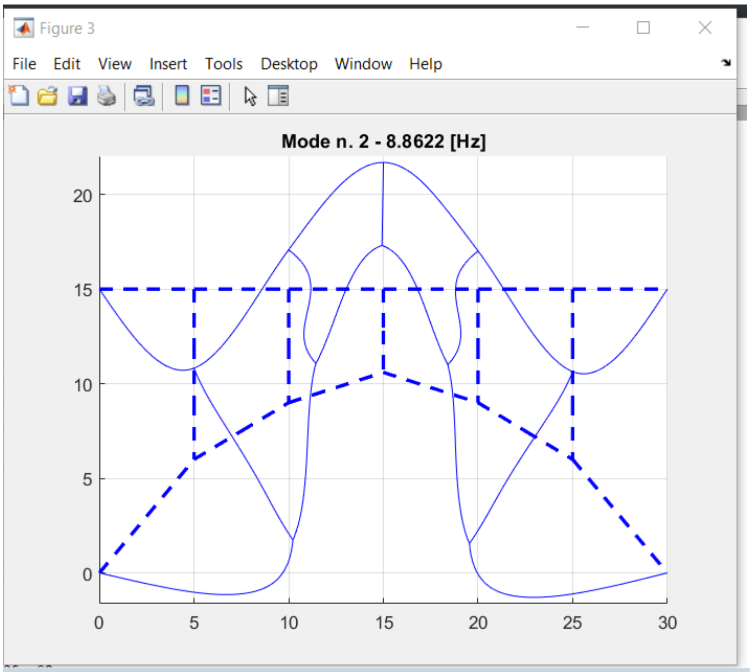


Figure 3
File Edit View Insert Tools Desktop Window Help
Mode n. 2 - 8.8622 [Hz]
20
15
10
5
0
0 5 10 15 20 25 30

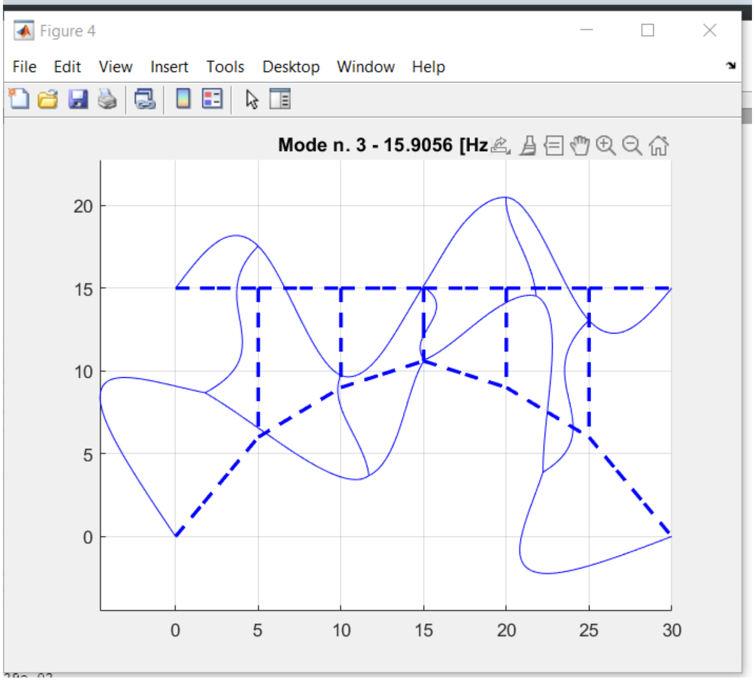
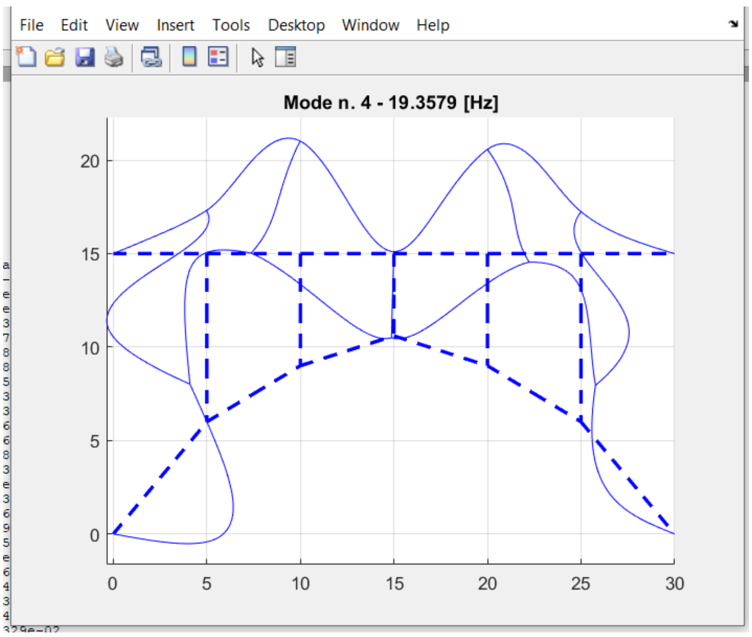
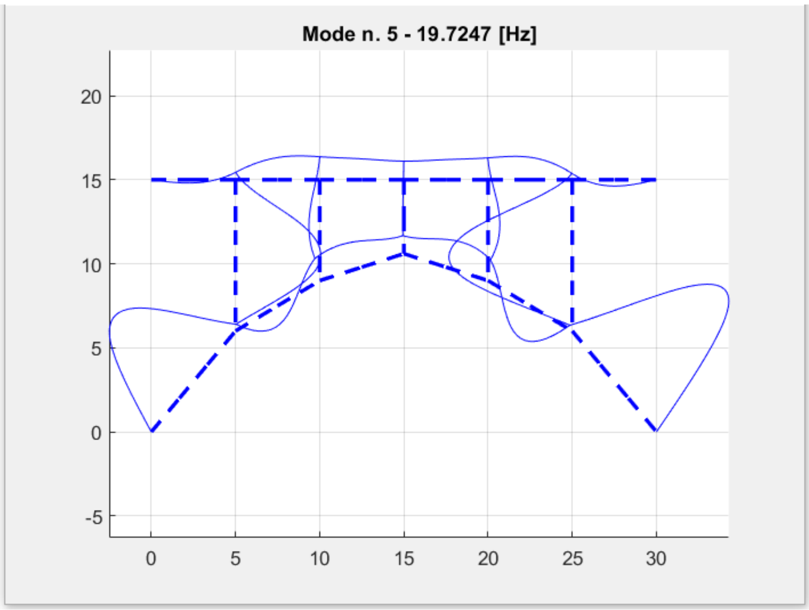


Figure 4
File Edit View Insert Tools Desktop Window Help
Mode n. 3 - 15.9056 [Hz
20
15
10
5
0
0 5 10 15 20 25 30


File Edit View Insert Tools Desktop Window Help
Mode n. 4 - 19.3579 [Hz]
20
15
10
5
0
0 5 10 15 20 25 30


Mode n. 5 - 19.7247 [Hz]
20
15
10
5
0
-5
0
5
10
15
20
25
30

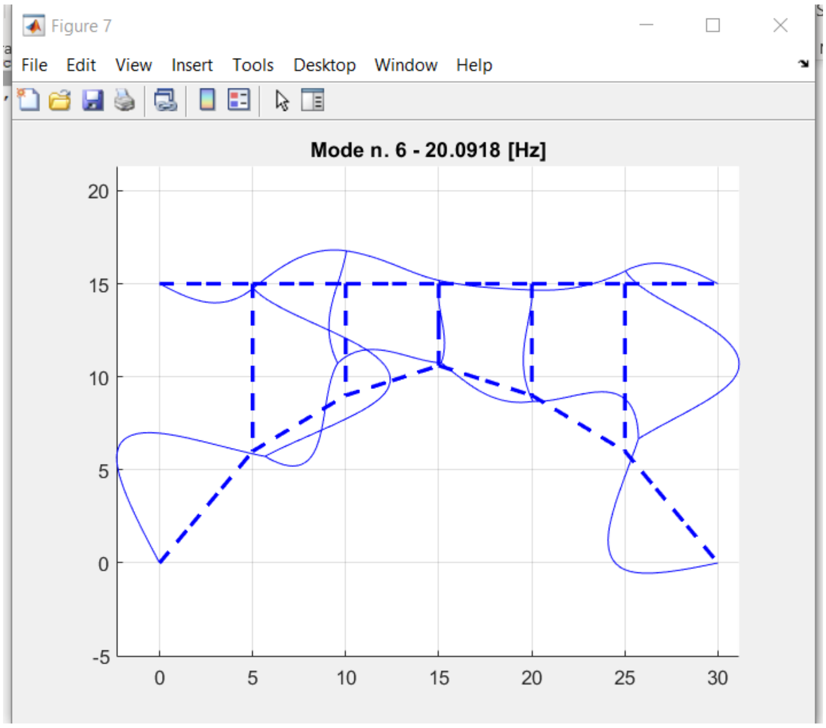


Figure 7
File Edit View Insert Tools Desktop Window Help
Mode n. 6 - 20.0918 [Hz]
20
15
10
5
0
-5
0
5
10
15
20
25
30

Point 3:

Matlab code:

```
clear all
close all
%modal
load('C:\Users\Utente\Desktop\uni\matlab\meccanica\yearwork_mkr')
MFF = M(1:ndof,1:ndof);
MFC = M(1:ndof, ndof+1:end);
KFF = K(1:ndof,1:ndof);
KFC = K(1:ndof, ndof+1:end);
CFF = R(1:ndof,1:ndof);
CFC = R(1:ndof, ndof+1:end);



[eigenvectors eigenvalues]=eig(MFF\KFF);

 freq=sqrt(diag(eigenvalues))/2/pi;
modalmatrix =  eigenvectors;



Mbar = modalmatrix'*MFF;
Mbar = Mbar*modalmatrix;   %reduced matrix
vett =[97,1];
vett = diag(Mbar);
Mdiag = diag(vett);


Kbar  = modalmatrix'*KFF;
Kbar = Kbar*modalmatrix;
vett =[97,1];
vett = diag(Kbar);
Kdiag = diag(vett);

Cbar = modalmatrix'*CFF;
Cbar = Cbar*modalmatrix;
vett =[97,1];
vett = diag(Cbar);
Cdiag = diag(vett);

%being  Kdiag*inv(Mdiag)*Cdiag= Cdiag*inv(Mdiag)*Kdiag
 %method can be applied


C_final = inv(Mdiag)*Cdiag;
K_final = inv(Mdiag)*Kdiag;
wn_matrix = sqrt(K_final);
wn_vett = diag(wn_matrix);

for i=1:1:97
    h_vett(i,1) = Cdiag(i,i)/(2*Mdiag(i,i)*wn_vett(i));
     %being each h<1 (c smaller than critical damping) --> holds wd = wn*sqrt(1-h^2)
    wd(i,1) = wn_vett(i)*sqrt(1-h_vett(i)^2);
end
fvect = wd/(2*pi);
```

adimensional damping:

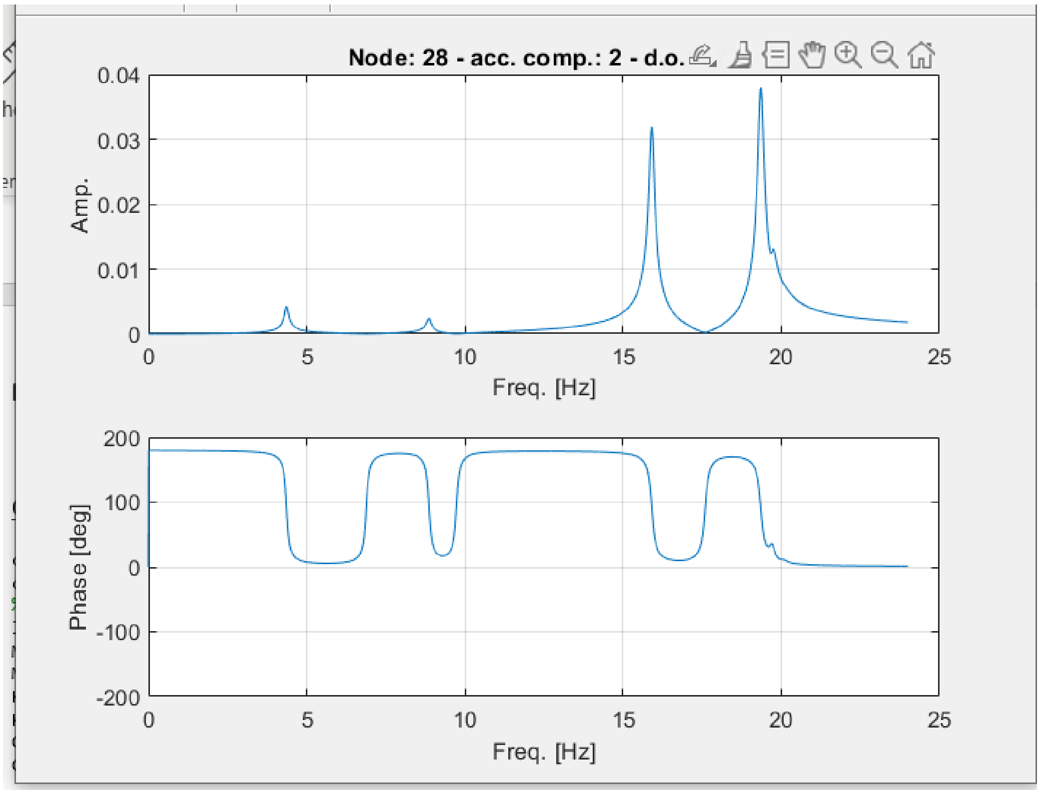
```
>> sort(h_vet

ans =

    0.0049
    0.0049
    0.0051
    0.0051
    0.0051
    0.0051
    0.0053
    0.0055
    0.0056
    0.0059
    0.0063
```

Damped freq:

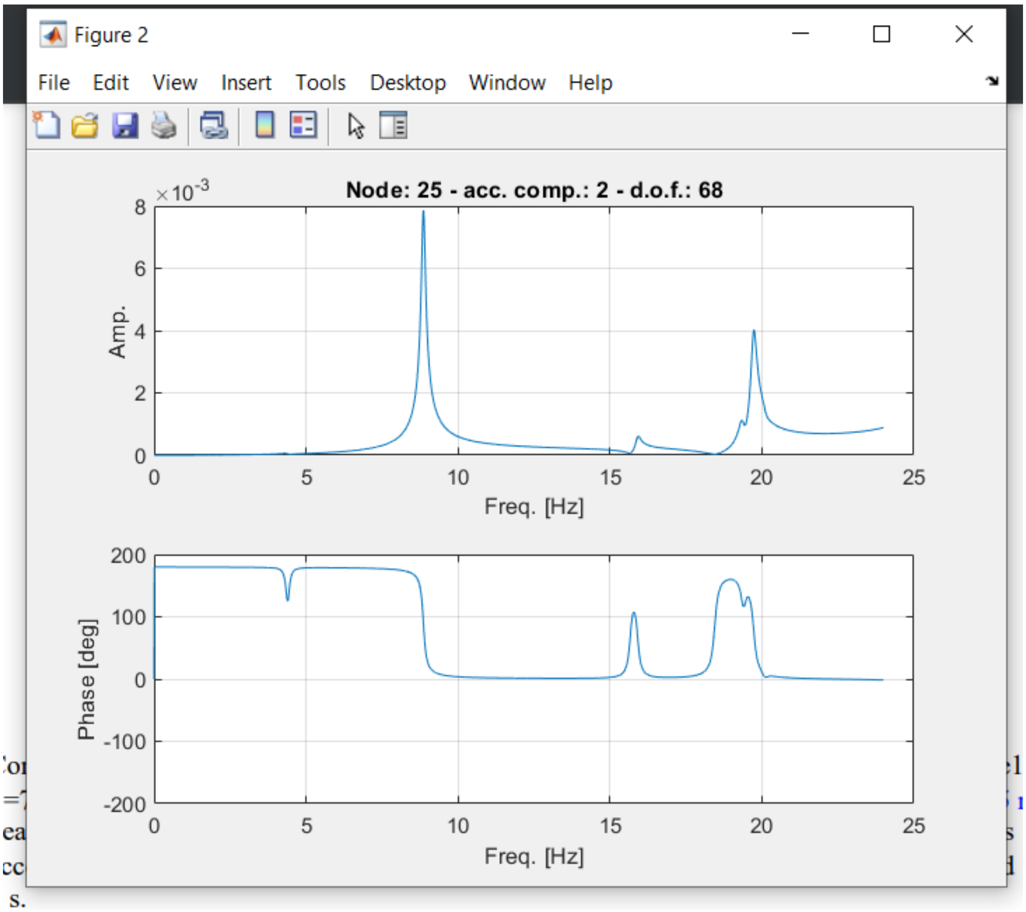
```
>> sort(fvect)

ans =

   1.0e+03 *

    0.0044
    0.0089
    0.0159
    0.0194
    0.0197
    0.0201
    0.0258
```

Point 4:

Point B:



Point A:



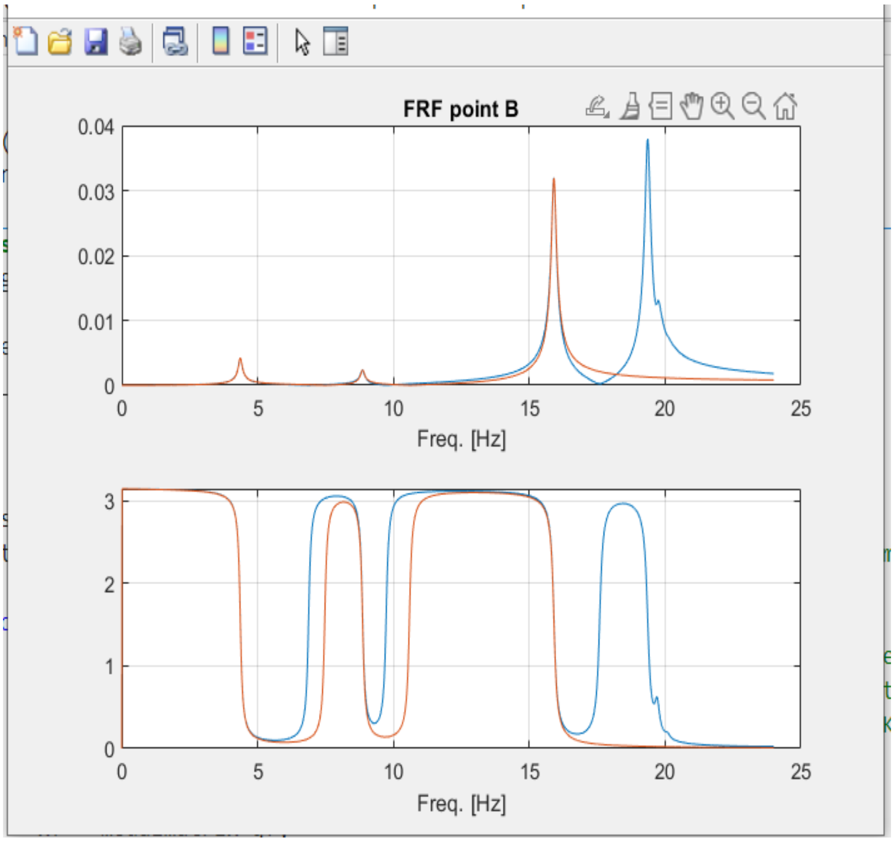
Point 5:

Code:

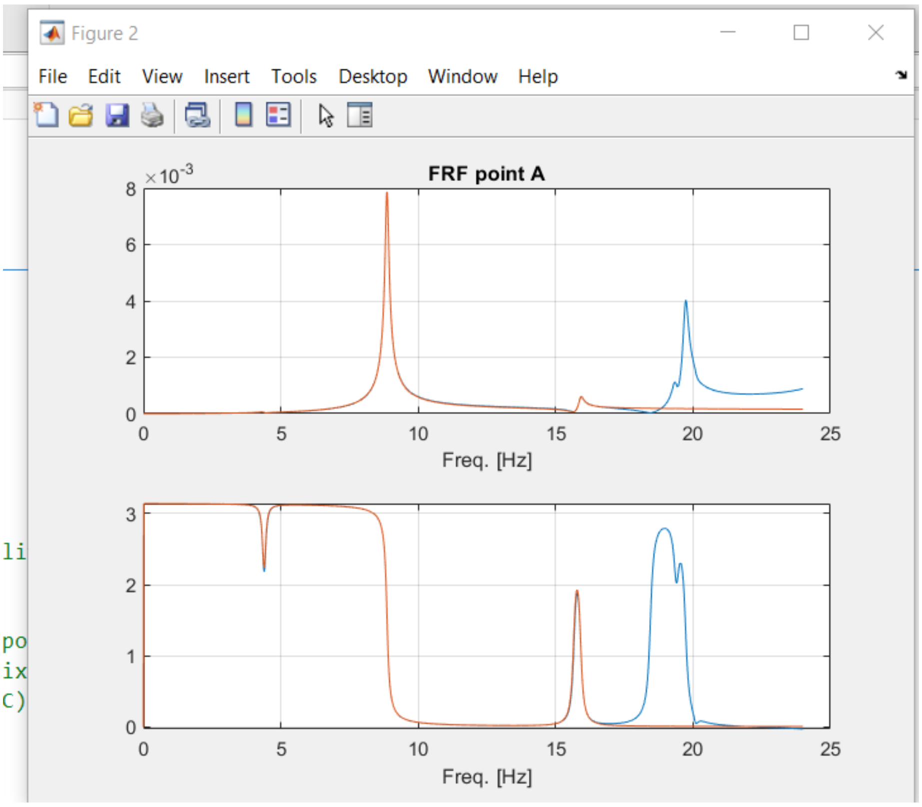
```
clear all;
close all;
load('C:\Users\Utente\Desktop\uni\matlab\meccanica\yearwork_mkr')

ndof = 97;
MFF = M(1:ndof,1:ndof);
MFC = M(1:ndof, ndof+1:end);
KFF = K(1:ndof,1:ndof);
KFC = K(1:ndof, ndof+1:end);
CFF = R(1:ndof,1:ndof);
CFC = R(1:ndof, ndof+1:end);

[eigenvectors eigenvalues]=eig(MFF\KFF);

 freq=sqrt(diag(eigenvalues))/2/pi;
red_modes =  eigenvectors;

% % frequency response
%
 i=sqrt(-1);
 vett_f=0:0.01:24
Fff = zeros(ndof,1);
Fff(77) = 1;
  for k=1:length(vett_f)
      ome=vett_f(k)*2*pi;  %from each element of freq vector compute corresponding omega
      A=-ome^2*MFF+i*ome*CFF+KFF;  %for that specific omega compute matrix
      xf=A\Fff;
      displ_pointA = xf(68);
      displ_pointB = xf(77);
      acc_pointA = -ome^2*displ_pointA;
      acc_pointB = -ome^2*displ_pointB;




%     ...
     mod1(k)=abs(acc_pointB);  %extract from first element (first indipendent variable) its
amplitude
     fas1(k)=angle(acc_pointB); %and phase
     mod2(k) = abs(acc_pointA);
     fas2(k)= angle(acc_pointA);

 end

 figure(1)
 subplot 211;plot(vett_f,mod1);grid
 title('FRF point B');
 xlabel('Freq. [Hz]');

 hold on

 subplot 212;plot(vett_f,fas1);grid
 xlabel('Freq. [Hz]');

hold on
 figure(2)
 subplot 211;plot(vett_f,mod2);grid
 title('FRF point A');
 xlabel('Freq. [Hz]');
```

```
 hold on

 subplot 212;plot(vett_f,fas2);grid
 xlabel('Freq. [Hz]');

hold on


red_modes1 = eigenvectors(:,81);
red_modes2=eigenvectors(:,82);
red_modes3=eigenvectors(:,93);
modalmatrix = [red_modes1,red_modes2,red_modes3]
Mbar = modalmatrix'*MFF;
Mbar = Mbar*modalmatrix;   %reduced matrix

Kbar  = modalmatrix'*KFF;
Kbar = Kbar*modalmatrix;

Cbar = modalmatrix'*CFF;
Cbar = Cbar*modalmatrix;

Fff = zeros(ndof,1);
Fff(77) = 1;
Fbar  = modalmatrix'*Fff;

%% solve reduced problem
[eigenvectors eigenvalues]=eig(MFF\KFF);

 freq=sqrt(diag(eigenvalues))/2/pi;
red_modes =  eigenvectors;

% % frequency response
%
 i=sqrt(-1);
 vett_f=0:0.01:24

  for k=1:length(vett_f)
      ome=vett_f(k)*2*pi;  %from each element of freq vector compute corresponding omega
      A=-ome^2*Mbar+i*ome*Cbar+Kbar;  %for that specific omega compute matrix
      qf=A\Fbar;
      xf = modalmatrix*qf;
      displ_pointA = xf(68);
      displ_pointB = xf(77);
      acc_pointB = -ome^2*displ_pointB;
      acc_pointA = -ome^2*displ_pointA;


%     ...
     mod1(k)=abs(acc_pointB);  %extract from first element (first indipendent variable) its
amplitude
     fas1(k)=angle(acc_pointB); %and phase
     mod2(k)=abs(acc_pointA);
     fas2(k)=angle(acc_pointA);


 end

 figure(1);
 subplot 211;plot(vett_f,mod1)
 subplot 212;plot(vett_f,fas1)
 figure(2);
 subplot 211;plot(vett_f,mod2)
 subplot 212;plot(vett_f,fas2)
```

FRF point B:



FRF point A:

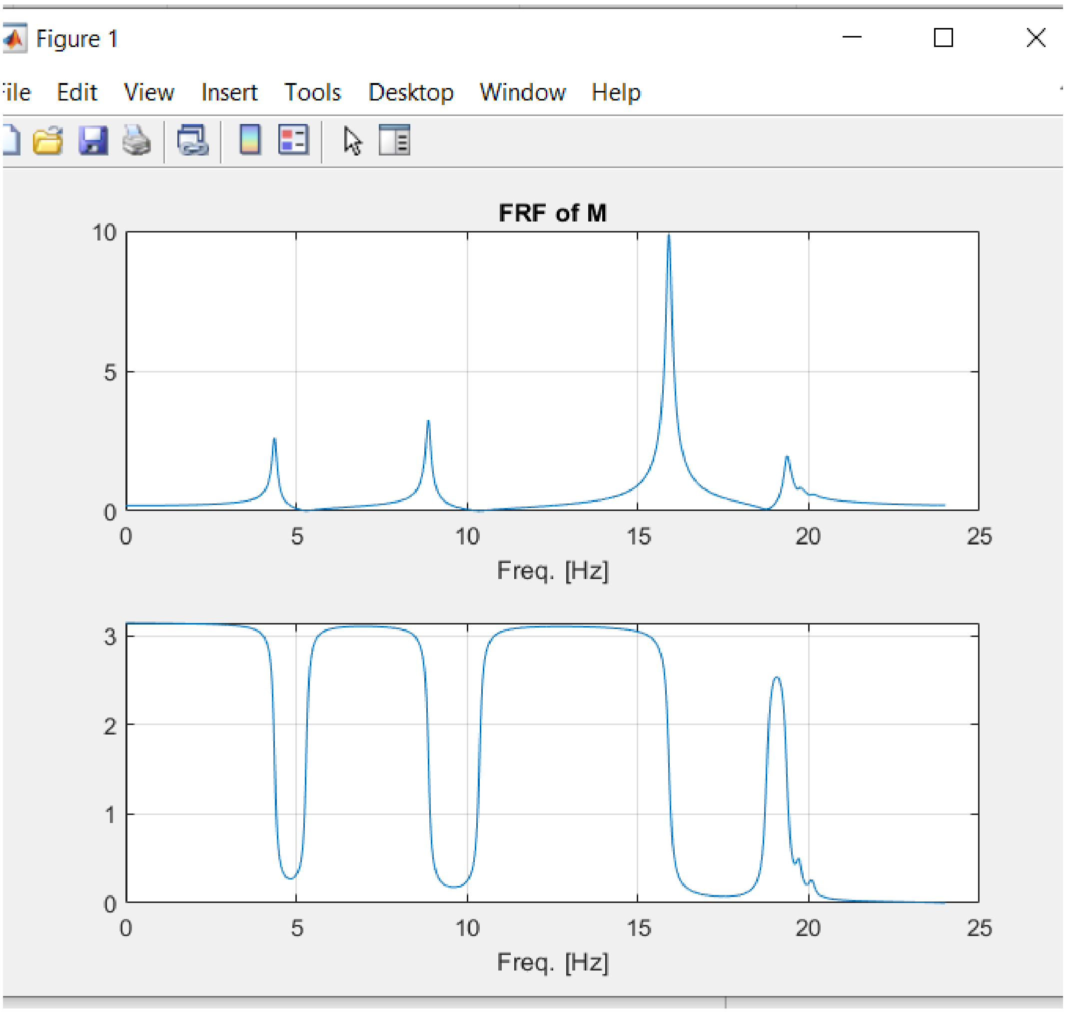


Point 6:

<u>Code:</u>

```
clear all;
close all;
syms xi real
E2 = 2.06e11 %red
I2 = 2.313e-4; %red
EI = E2*I2;
Lk = 2.5; %finite element length

% %shape function computation
% fw_xi = [0;
%           2*(xi/Lk)^3-3*(xi/Lk)^2+1;
%           Lk*( (xi/Lk)^3-2*(xi/Lk)^2+(xi/Lk) );
%           0;
%           -2*(xi/Lk)^3+3*(xi/Lk)^2;
%           Lk*((xi/Lk)^3-(xi/Lk)^2);];
%
% %derivataprima
% fw_xi_d = [0;
%             diff(fw_xi(2,1));
%             diff(fw_xi(3,1));
%             diff(fw_xi(4,1));
%             diff(fw_xi(5,1));
%             diff(fw_xi(6,1))];
% %derivataseconda
% fw_xi_dd = [0;
%              diff(fw_xi_d(2,1));
%              diff(fw_xi_d(3,1));
%              diff(fw_xi_d(4,1));
%              diff(fw_xi_d(5,1));
%              diff(fw_xi_d(6,1))];
% f(xi) = fw_xi_dd;
% xi = 0.0001;
% %derivata seconda della shaping function in 0 (coincide con point C)
% fw_xi_dd = f(xi);
% fw_xi_dd = fw_xi_dd';
final_fw_dd = [0, -74994/78125, -49997/31250, 0, 74994/78125, -24997/31250];
% w computation

load('C:\Users\Utente\Desktop\uni\matlab\meccanica\yearwork_mkr')

ndof = 97;
MFF = M(1:ndof,1:ndof);
MFC = M(1:ndof, ndof+1:end);
KFF = K(1:ndof,1:ndof);
KFC = K(1:ndof, ndof+1:end);
CFF = R(1:ndof,1:ndof);
CFC = R(1:ndof, ndof+1:end);

[eigenvectors eigenvalues]=eig(MFF\KFF);

 freq=sqrt(diag(eigenvalues))/2/pi;
red_modes =  eigenvectors;

% % frequency response
%
 i=sqrt(-1);
 vett_f=0:0.01:24;
 Fff = zeros(ndof,1);
 Fff(77) = 1;
```

```
for k=1:length(vett_f)
      ome=vett_f(k)*2*pi;  %from each element of freq vector compute corresponding omega
      A=-ome^2*MFF+i*ome*CFF+KFF;  %for that specific omega compute matrix
      xf=A\Fff;
      x = [xf(73); xf(74); xf(75); xf(76); xf(77); xf(78)];
      M = EI *final_fw_dd*x;
      mod1(k)=abs(M);
      fas1(k)=angle(M);
 end
figure(1)
subplot 211;plot(vett_f,mod1);grid
title('FRF of M');
xlabel('Freq. [Hz]');
   hold on

subplot 212;plot(vett_f,fas1);grid
xlabel('Freq. [Hz]');
```



Point 7:

Code:

```
clear all
close all
load('C:\Users\Utente\Desktop\uni\matlab\meccanica\yearwork_mkr');
load('C:\Users\Utente\Downloads\seismic_displ.txt');
ndof = 97;
MFF = M(1:ndof,1:ndof);
MFC = M(1:ndof, ndof+1:end);
KFF = K(1:ndof,1:ndof);
KFC = K(1:ndof, ndof+1:end);
CFF = R(1:ndof,1:ndof);
CFC = R(1:ndof, ndof+1:end);

fs = 100;
T = 1/fs;
Tend=60;
N = fs*Tend;
dt=T;
t=0:dt:Tend-dt;


i=1;
while seismic_displ(i,1)<Tend     %first 50s
    O11_O12(i) = seismic_displ(i,2);
    O21_O22(i) = seismic_displ(i,3);
    i = i+1;
end


figure(1);plot(t,O11_O12);grid;title("input signal 1");
figure(2);plot(t,O21_O22);grid;title("input signal 2");
figure(3);plot(t,O21_O22+O11_O12);grid;title("sum of input signals");
bin_num = 0:(N-1);
f_vett = (bin_num*fs/N)';
Fk1= fft(O11_O12,N);
Fk2 = fft(O21_O22,N);
%figure(12); plot(f_vett,abs(Fk1));grid;title("non-normalized Fk")

%normalize + clean for freq higher than fmax
Fkt1 = zeros(size(Fk1));
phik1 = zeros(size(Fk1));
Fkt2 = zeros(size(Fk2));
phik2 = zeros(size(Fk2));
for k=1:N/2+1
    Fkt1(k) = 2*abs( Fk1(k))/N;
    phik1(k) = angle(Fk1(k)/N);
    Fkt2(k) = 2*abs( Fk2(k))/N;
    phik2(k) = angle(Fk2(k)/N);
    if k ==1
        Fkt1(k) = Fk1(k)/N;
        Fkt2(k) = Fk2(k)/N;
        phik2(k)=0;
        phik1(k)=0;
    end
end


figure(4); plot(f_vett,abs(Fkt2+Fkt1));grid;title("JD normalized + cleaned sum Fk")
fmax = 24;
A_displ = idb(25,2); %node A
```

```
vertical_O11 = 2;
vertical_O12 = 6;
vertical_O21 = 4;
vertical_O22 = 8;
yA = zeros(1,N);
yAdd = zeros(1,N);

 i = sqrt(-1);
 for k=1:N/2+1
     ome=(k-1)*2*pi/Tend;
     om0 = 2*pi/Tend;
     A = -ome^2*MFF+i*ome*CFF+KFF;
     B = -ome^2*MFC+i*ome*CFC+KFC;
     G=-(A^(-1))*B;
     if k==1
         G = -(KFF^(-1))*KFC;
     end
     %Fourier coeff
     xk_yA = abs(G(A_displ,vertical_O11))*Fkt1(k);  %primo constraint displacement
     xk_yA = xk_yA + abs(G(A_displ,vertical_O12))*Fkt1(k); %secondo constraint displacement
      xk_yA = xk_yA + abs(G(A_displ,vertical_O22))*Fkt2(k);
      xk_yA = xk_yA + abs(G(A_displ,vertical_O21))*Fkt2(k);

     xk_yAdd = abs(-(ome^2)*G(A_displ,vertical_O11))*Fkt1(k);
     xk_yAdd = xk_yAdd+abs(-(ome^2)*G(A_displ,vertical_O12))*Fkt1(k);
     xk_yAdd = xk_yAdd+abs(-(ome^2)*G(A_displ,vertical_O21))*Fkt1(k);
     xk_yAdd = xk_yAdd+abs(-(ome^2)*G(A_displ,vertical_O22))*Fkt1(k);

     psik_yA = angle(G(A_displ,vertical_O11))+phik1(k);
     psik_yA = psik_yA + angle(G(A_displ,vertical_O12))+phik1(k);
     psik_yA = psik_yA + angle(G(A_displ,vertical_O22))+phik2(k);
     psik_yA = psik_yA + angle(G(A_displ,vertical_O21))+phik2(k);

     psik_yAdd = angle(-(ome^2)*G(A_displ,vertical_O11))+phik1(k);
     psik_yAdd =psik_yAdd+ angle(-(ome^2)*G(A_displ,vertical_O12))+phik1(k);
     psik_yAdd =psik_yAdd+ angle(-(ome^2)*G(A_displ,vertical_O21))+phik2(k);
     psik_yAdd =psik_yAdd+ angle(-(ome^2)*G(A_displ,vertical_O22))+phik2(k);



     if 1<k<=N/2+1
         yA = yA+xk_yA*cos((k-1)*om0*t+psik_yA);
         yAdd = yAdd+xk_yAdd*cos((k-1)*om0*t+psik_yAdd);
     end
 end
figure(10); plot(t,yA);grid;title("vertical displacement point A");
figure(11); plot(t,yAdd);grid;title("vertical acc point A");
```

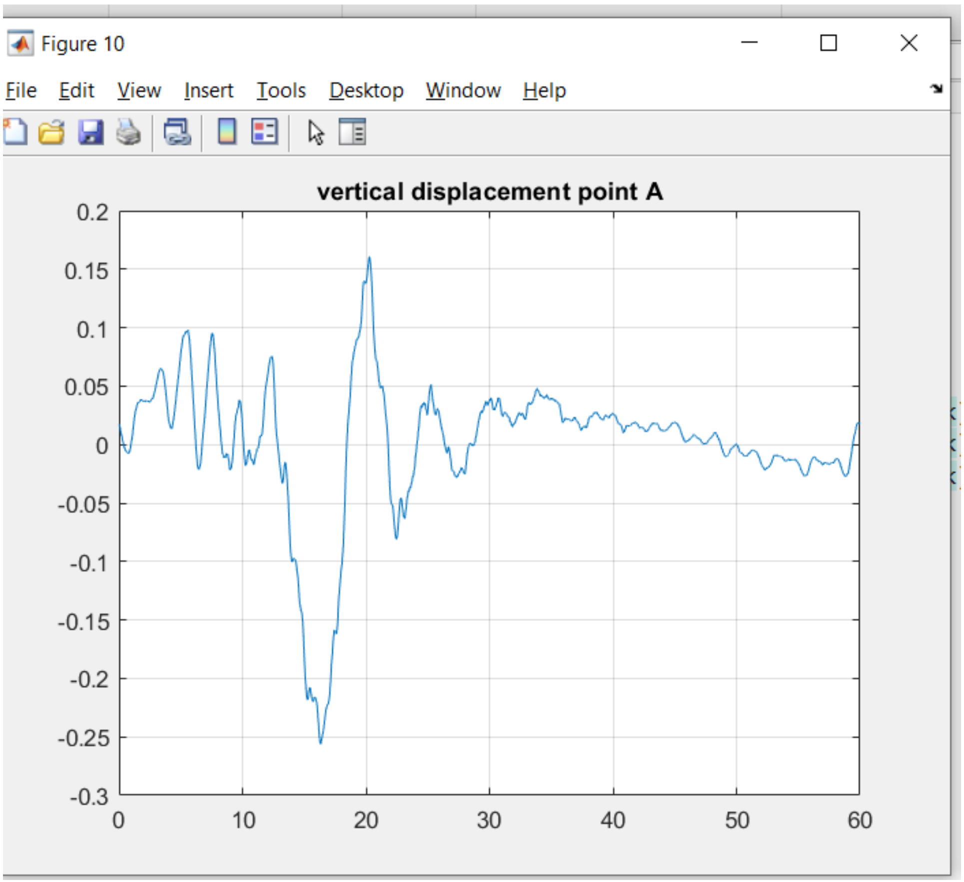


Figure 10
File Edit View Insert Tools Desktop Window Help
vertical displacement point A
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
0
10
20
30
40
50
60

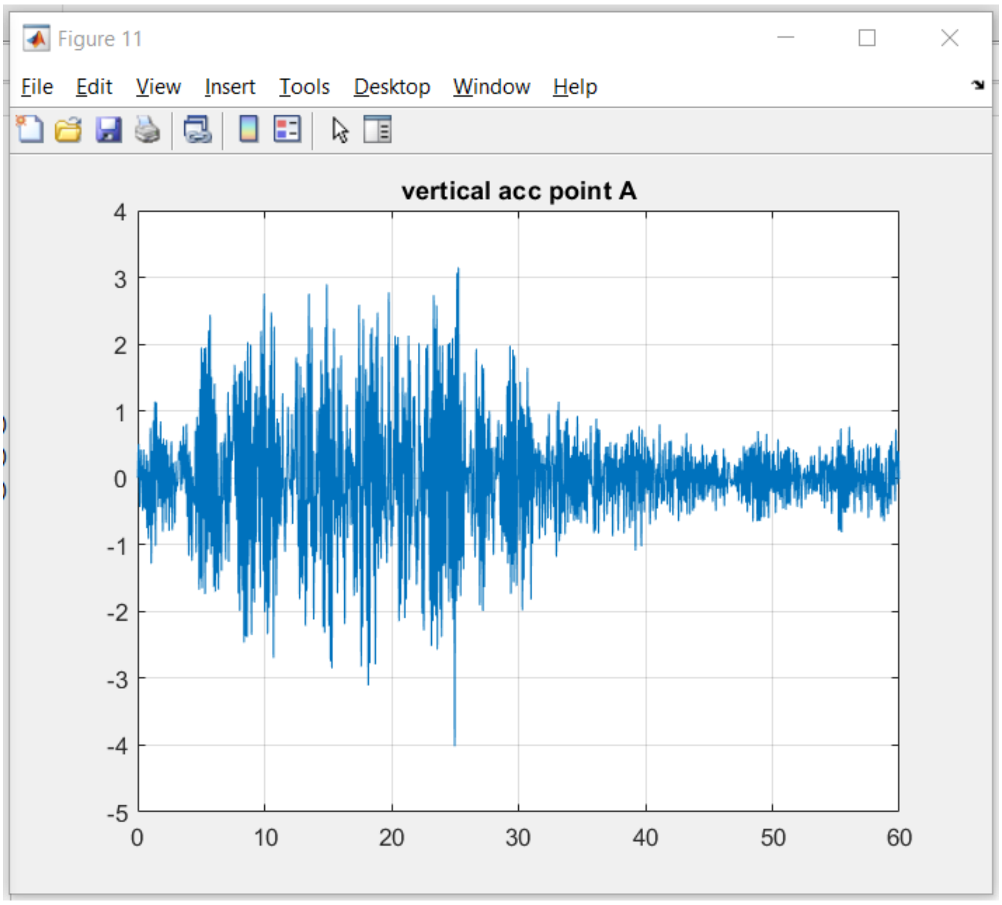
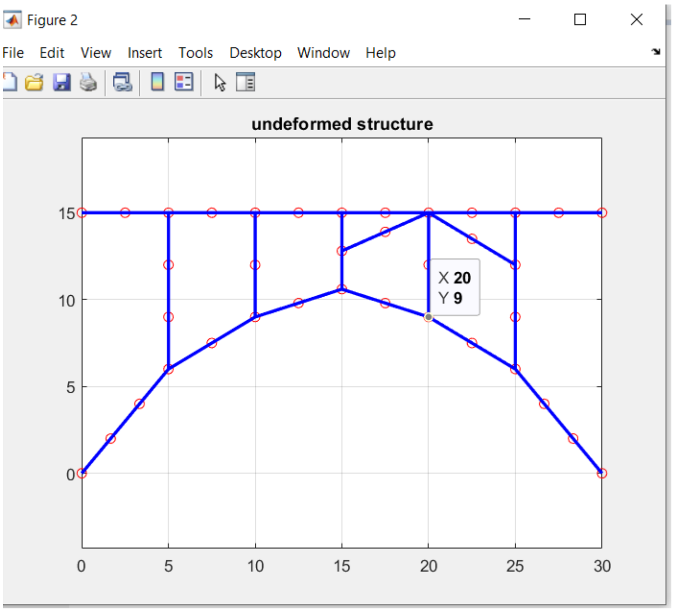


Figure 11
File Edit View Insert Tools Desktop Window Help
vertical acc point A
4
3
2
1
0
-1
-2
-3
-4
-5
0
10
20
30
40
50
60

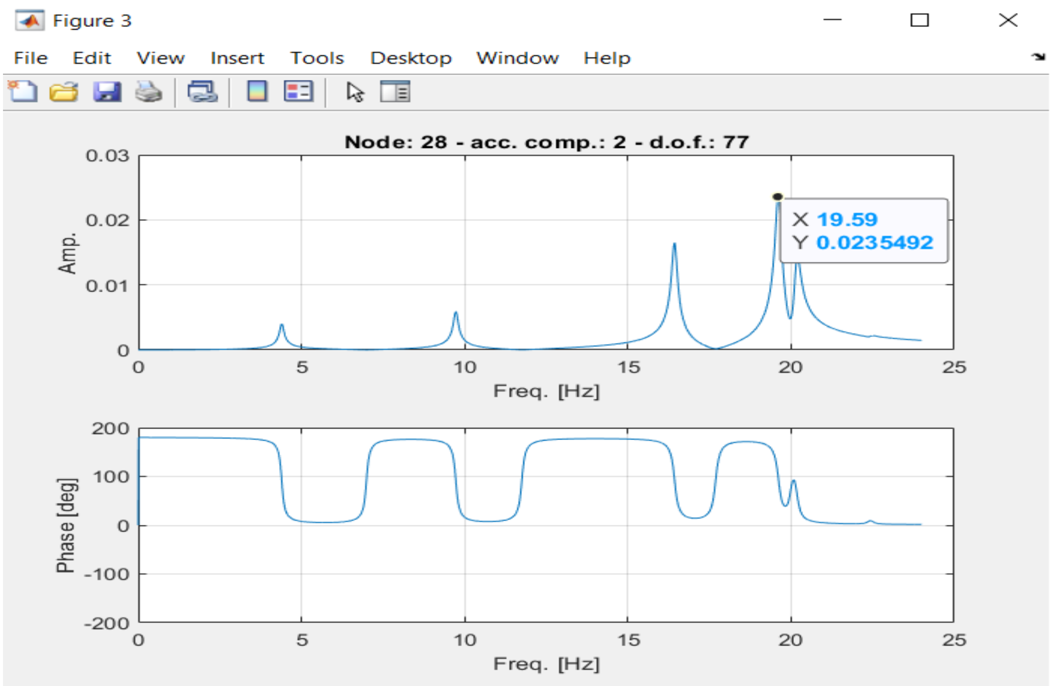
Point 8:

Modified Structure:




```
File   Graphic   Static analysis   Frequency domain analysis   Export   Utilities   ?

Total nodes number 37
Number of d.o.f. 103
Number of beam elements 43
Number of string elements 0
Number of tensile beam elements 0
Number of concentrated masses 0
Number of concentrated springs 0
Total mass [kg] 5382.9852
Matrices M, R, K assembled
```

(Limit mass is 5.4292e+03)



Reduced FRF amplitude (limit was 0.02639)

IPE 180

Geometria

Altezza	h	180.0	mm
Larghezza	b	91.0	mm
Spessore dell'anima	t_w	5.3	mm
Spessore dell'ala	t_f	8.0	mm
Altezza interna tra le ali	h_i	164.0	mm
Raggio arrotondamento interno	r_1	9.0	mm
Altezza della porzione dritta dell'anima	d	146.0	mm
Distanza	k	17.0	mm

Area della sezione

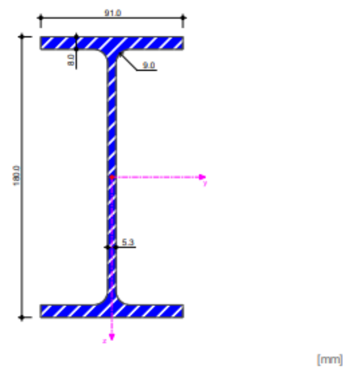
Area della sezione	A	23.95	cm^2

Flessione

Area moment of inertia about y-axis	I_y	1317.00	cm^4
Area moment of inertia about z-axis	I_z	100.90	cm^4
Polar area moment of inertia	I_p	1417.90	cm^4
Raggio di inerzia intorno all'asse y	i_y	74.2	mm
Raggio di inerzia intorno all'asse z	i_z	20.5	mm
Raggio di inerzia polare	i_p	77.0	mm
Momento statico intorno all'asse y	max S_y	83.20	cm^3
Momento statico intorno all'asse z	max S_z	8.31	cm^3
Modulo di resistenza elastico intorno all'asse y	W_y	146.30	cm^3
Modulo di resistenza elastico intorno all'asse z	W_z	22.16	cm^3

IPE 180

- Euronorm 19-57; DIN 1025-5; ASTM A 6/A 6M
- SZS



Altri

Peso	G	18.8	kg/m
Area superficie per unità di lunghezza	A_m	0.698	m^2/m
Volume	V	2395.00	cm^3/m
Coefficiente della sezione	A_m/V	291.441	1/m
Area dell'anima	A_w	8.69	cm^2
Interasse dei fori dell'ala	w	50.0	mm

<u>Modification in .inp file:</u>

```
39    14    15    41.9718    1.1085e+09    17213360
40    28    36    18.8       4933370000    2713020
41    36    34    18.8       4933370000    2713020
42    28    37    18.8       4933370000    2713020
43    37    26    18.8       4933370000    2713020
*ENDBEAMS
```