Problem 1

11 January 2022 09:59 AM

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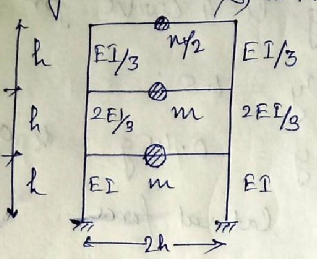
Budhaditya De 21103033 — Assignment-4 — CE 629A — 02/03/2022

Q:-7) 3-storey shear frame — ∞ Rigid beam.



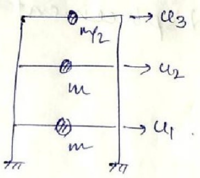
$m = 45 \text{ ton} = 45000 \text{ Kg}$.

$h = 4m$

$E = 200 GPa$; $I = 5.8 \times 10^{-4} m^4$

$\xi = 5\%$ for all modes.

As it is a shear frame with perfectly Rigid beams, the rotational degrees of freedom need not be considered.



$$\underset{\sim}{m} = \begin{bmatrix} m & 0 & 0 \\ 0 & m & 0 \\ 0 & 0 & m/2 \end{bmatrix}$$

$$\underset{\sim}{m} = 45\times10^3 \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & \frac{1}{2} \end{pmatrix}.$$

Now, column stiffness offered in lateral direction $= 12EI/l^3$.

for 1st storey,

$$k_1 = \frac{2 \times 12 \times EI}{h^3}$$

$$= \frac{24 \times 1.16\times10^8}{64}$$

$$= 0.435 \times 10^8$$

$$= \underline{43.5 \times 10^6 \text{ N/m}}$$

Similarly,

$$k_2 = \frac{2\times\left(\frac{2EI}{3}\right)\times 12}{4^3}$$

$$= \frac{2}{3}\left(\frac{2\times12\times EI}{4^3}\right)$$

$$= 29\times10^6 \text{ N/m}.$$

$$k_3 = \frac{2\times\left(\frac{EI}{3}\right)\times12}{h^3} = \frac{1}{3}\left(\frac{2\times12EI}{h^3}\right)$$

$$= 14.5 \times 10^6 \text{ N/m}.$$

∴ Stiffness matrix

$$\underset{\sim}{k} = \begin{bmatrix} (k_1+k_2) & -k_2 & 0 \\ -k_2 & (k_2+k_3) & -k_3 \\ 0 & -k_3 & k_3 \end{bmatrix}.$$

$$\Rightarrow \underset{\sim}{k} = \begin{bmatrix} 72.5\times10^6 & -29\times10^6 & 0 \\ \ldots \end{bmatrix}$$

$$\begin{bmatrix} & & \\ -29\times10^6 & 43.5\times10^6 & -14.5\times10^6 \\ 0 & -14.5\times10^6 & 14.5\times10^6 \end{bmatrix}.$$

$$\Rightarrow \underset{\sim}{k} = 10^6 \begin{bmatrix} 72.5 & -29 & 0 \\ -29 & 43.5 & \cancel{0}\,-14.5 \\ 0 & -14.5 & 14.5 \end{bmatrix} N/m.$$

for getting Natural frequencies and correspon-ding mode shapes we do the eigen-value analysis — $|\underset{\sim}{k} - \omega^2 \underset{\sim}{m}| = 0$.

Running a code in matlab using eig() command we get both eigen values and eigen vectors.

$\omega_1^2 = 202.2649 \Rightarrow \omega_1 = 14.22$ rad/s (fundamental)

$\omega_2^2 = 966.667 \Rightarrow \omega_2 = 31.09$ rad/s.

$\omega_3^2 = 2.053\times10^3. \Rightarrow \omega_3 = 45.31$ rad/s.

(Mass normalised)

$$\phi_1 = \begin{Bmatrix} 0.0014 \\ 0.0031 \\ 0.0046 \end{Bmatrix};\ \phi_2 = \begin{Bmatrix} 0.0024 \\ 0.0024 \\ -0.0047 \end{Bmatrix};\ \phi_3 = \begin{Bmatrix} -0.0038 \\ 0.0026 \\ -0.0012 \end{Bmatrix}.$$

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$\cancel{\underset{\sim}{S}} =$ $\underline{S} = \underset{\sim}{m}\,\underline{i}$. where $\underline{i}$ = influence vector

here $i = \begin{Bmatrix} 1 \\ 1 \\ 1 \end{Bmatrix}$ as all DOFs are subjected to $\ddot{u}_g(t)$.

$$\underline{S} = \underset{\sim}{m}\,\underline{i} = 45\times10^3 \begin{Bmatrix} 1 \\ 1 \\ \frac{1}{2} \end{Bmatrix}$$

Now, $\underline{S} = \sum_{n=1}^{N} S_n = \sum_{n=1}^{N} \Gamma_n \underset{\sim}{m} \phi_n$.

Now $\Gamma_n = \dfrac{\underline{\phi}_n^T \underset{\sim}{m}\,\underline{i}}{\underline{\phi}_n^T \underset{\sim}{m}\,\underline{\phi}_n} = \dfrac{L_n^h}{M_n}$.

$M_n = \underline{\phi}_n^T \underset{\sim}{m}\, \underline{\phi}_n \Rightarrow \cancel{M_1}\ M_1 = \underline{\phi}_1^T \underset{\sim}{m}\, \underline{\phi}_1 = 1.0$.

Similarly $M_2 = 1.0$ and $M_3 = 1.0$ (which is expected as the modes are mass normalised).

$\therefore \Gamma_n = L_n^h$ and $L_n^h = \underline{\phi}_n^T \underset{\sim}{m}\, \underline{i}$.

$L_1^h = \underline{\phi}_1^T \underset{\sim}{m}\, \underline{i}$.

$= \{0.0014\ \ 0.0031\ \ 0.0046\} \times \underset{\sim}{m} \times \begin{Bmatrix} 1 \\ 1 \end{Bmatrix}$

$= 307.7148$

$L_2^h = \phi_2^T \underset{\sim}{m}\, \underline{i}$

$= \{0.0024 \quad 0.0024 \quad -0.0047\} * \underset{\sim}{m} * \begin{Bmatrix} 1 \\ 1 \\ 1 \end{Bmatrix}$

$= 106.066.$

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$L_3^h = \{-0.0038 \quad 0.0026 \quad -0.0012\} * m * \begin{Bmatrix} 1 \\ 1 \\ 1 \end{Bmatrix}.$

$= -81.0037.$

$\therefore \Gamma_n = \begin{Bmatrix} 307.7148 \\ 106.066 \\ -81.0037 \end{Bmatrix}.$

$\underline{s}_1 = \Gamma_1 \underset{\sim}{m} \underline{\phi}_1 = 307.7148 \times \underset{\sim}{m} \times \begin{Bmatrix} 0.0014 \\ 0.0031 \\ 0.0046 \end{Bmatrix}.$

$= \begin{Bmatrix} 1.9813 \\ 4.3313 \\ 3.1563 \end{Bmatrix} \times 10^4.$

$\underline{s}_2 = \Gamma_2 \underset{\sim}{m} \underline{\phi}_2 = 106.066 \times \underset{\sim}{m} \times \begin{Bmatrix} 0.0024 \\ 0.0024 \\ -0.0047 \end{Bmatrix}.$

$= \begin{Bmatrix} 1.125 \\ 1.125 \\ -1.125 \end{Bmatrix} \times 10^4.$

$\underline{s}_3 = \Gamma_3 \underset{\sim}{m} \underline{\phi}_3 = -81.0037 \times \underset{\sim}{m} \times \begin{Bmatrix} -0.0038 \\ 0.0026 \\ -0.0012 \end{Bmatrix}.$

$= \begin{Bmatrix} 1.3937 \times 10^4 \\ -9.563 \times 10^3 \\ 2.1872 \times 10^3 \end{Bmatrix}.$

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Now as a check,

$\underline{s} = \underset{\sim}{m}\, \underline{i} = \sum_{n=1}^{N} s_n = \underline{s}_1 + \underline{s}_2 + \underline{s}_3$

$\Rightarrow \underline{s} = 45 \times 10^3 \begin{Bmatrix} 1 \\ 1 \\ 1/2 \end{Bmatrix} = \begin{Bmatrix} 1.9813 \times 10^4 \\ 4.3313 \times 10^4 \\ 3.1563 \times 10^4 \end{Bmatrix} + \begin{Bmatrix} 1.125 \times 10^4 \\ 1.125 \times 10^4 \\ -1.125 \times 10^4 \end{Bmatrix} + \begin{Bmatrix} 1.3937 \times 10^4 \\ -9.563 \times 10^3 \\ 2.1872 \times 10^3 \end{Bmatrix}$

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$= \begin{Bmatrix} 4.5 \times 10^4 \\ 4.5 \times 10^4 \\ 2.25 \times 10^4 \end{Bmatrix} = 45 \times 10^3 \begin{Bmatrix} 1 \\ 1 \\ 1/2 \end{Bmatrix} = \underline{s}_0.$

$\therefore$ verified

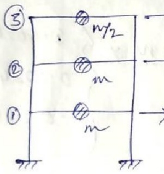
(#) Determination of Effective modal masses -.

$$M_n^* = \Gamma_n L_n^h = \frac{L_n^h \times L_n^h}{M_n}$$

$$= (L_n^h)^2 / M_n$$

$$\text{or } M_n^* = \sum_{j=1}^{N} S_{jn}$$

for Mode 1 :-



$$\left.\begin{matrix} \rightarrow 3.1563 \times 10^4 \\ \rightarrow 4.3313 \times 10^4 \\ \rightarrow 1.9813 \times 10^4 \end{matrix}\right\} \underset{\sim}{S}_1$$

$$\therefore M_{n_1}^* = \sum_{j=1}^{N} S_{j1}$$

$$= (1.9813 + 4.3313 + 3.1563) \times 10^4 = \underline{9.4689 \times 10^4} \text{ kg}.$$

Similarly $M_{n_2} = \sum_{j=1}^{N} S_{j2}$

$$= (1.125 + \cancel{1.125} - \cancel{1.125}) \times 10^4$$

$$= 1.125 \times 10^4 \text{ kg}.$$

and $M_{n_3} = \sum_{j=1}^{3} S_{j3} = (1.3937 - 0.9563 + 0.21872) \times 10^4$

$$= 0.65612 \times 10^4 \text{ kg}.$$

Check :-

$$\sum_{n=1}^{3} M_n^* = \sum_{j=1}^{3} m_j$$

$$\Rightarrow (9.4689 + 1.125 + 0.65612)$$

$$= 11.25 \times 10^4$$

and $\sum_{j=1}^{3} m_j = (4.5 + 4.5 + 2.25) \times 10^4$

$$= 11.25 \times 10^4$$

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$$\therefore \sum_{n=1}^{3} M_n^* = \sum_{j=1}^{3} m_j \longrightarrow \underline{\text{also verified}}.$$

$V_{bn}^{st} = M_n^*$ $\quad \therefore V_{b1}^{st} = M_{n1}^* = 9.4689 \times 10^4$ kg.

$$V_{b2}^{st} = M_2^* = 1.125 \times 10^4 \text{ kg}.$$

$$V_{b3}^{st} = M_3^* = 0.65612 \times 10^4 \text{ kg}$$

Now, $L_n^\theta = \underline{\phi}_n^T \underset{\sim}{m} \underline{h}$ where $\underline{h} = \begin{Bmatrix} 4 \\ 8 \\ 12 \end{Bmatrix}$.

$$\cancel{L_n^\theta} = L_1^\theta = \underline{\phi}_1^T \underset{\sim}{m} \underline{h}$$

$$= \{0.0014 \quad 0.0031 \quad 0.0046\} * \underset{\sim}{m} * \begin{Bmatrix} 4 \\ 8 \\ 12 \end{Bmatrix}.$$

$\Rightarrow L_1^\theta = 2.6145 \times 10^3$ kgm.

$\Rightarrow L_2^\theta = -2.8422 \times 10^{-13} \approx 0$ kgm

$\Rightarrow L_3^\theta = -67.7967$.

$$\therefore h_1^* = \frac{L_1^\theta}{L_1^h} = \frac{2.6145 \times 10^3}{307.7148} \approx 8.5 \text{ m}$$

$$h_2^* = \frac{L_2^\theta}{L_2^h} = 0.$$

$$h_3^* \quad \ldots \quad -67.7967$$

$$h_3 = \frac{L_3^{\theta}}{L_3^h} = \frac{\ldots}{-81.0037} = 0.8369\,m.$$

Representing in diagram –

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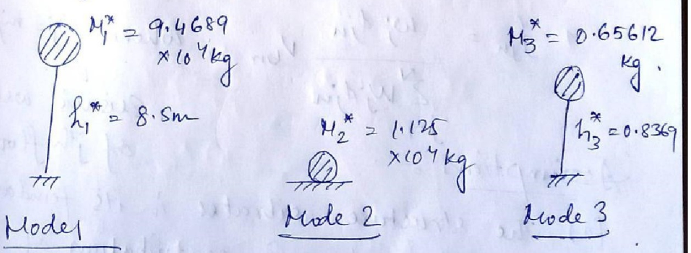

Next we perform the the n^{th} mode SDOF system analysis for the El-centro ground motion

(a) for $\omega_1 = 14.22$ rad/s.

$$T_1 = \frac{2\pi}{\omega_1} = 0.442\,s.$$

(b) for $\omega_2 = 31.09$ rad/s.

$$T_2 = \frac{2\pi}{\omega_2} = 0.202\,s.$$

(c) for $\omega_3 = 45.31$ rad/s.

$$T_3 = \frac{2\pi}{\omega_3} = 0.138\,s.$$

Performing the SDOF dynamic analysis on MATLAB, the code and plot is attached also –

Now for getting roof disp.

$$U_{jn} = U_{jn}^{st} \cdot A_n(t).$$

$$\text{Now, } U_{jn}^{st} = \frac{\Gamma_n}{\omega_n^2} \phi_{jn}.$$

Now for 3th floor disp,

Mode 1:– $U_{31}^{st} = \frac{\Gamma_1}{\omega_1^2}\phi_{31} = \frac{0.0046 \times 307.7148}{(14.22)^2}$

$= 0.007\,m = 7\ s^2$

Mode 2:– $U_{32}^{st} = \frac{\Gamma_2}{\omega_2^2}\phi_{32} = \frac{-0.0047 \times 106.66}{(31.09)^2}$

$= -0.00052\,m$

$= -0.52\ s^2$

Mode 3:– $U_{33}^{st} = \frac{\Gamma_3}{\omega_3^2}\phi_{33} = \frac{-0.0012 \times -81.0037}{(45.31)^2}$

$= \underline{0.047} \times 10^{-3}\, s^2.$

∴ Now for the 3rd storey shear :

Mode 1 :- $V_{31}^{st} = \sum_{j=3}^{3} S_{j1}$

$= 3.1563 \times 10^4$ kg.

Mode 2 :- $V_{32}^{st} = -1.125 \times 10^4$ kg.

Mode 3 :- $V_{33}^{st} = 2.1872 \times 10^3$ kg.

$= 0.21872 \times 10^4$ kg.

Base Shear :- $V_{bn}^{st} = M_n^*$.

$\Rightarrow V_{b1}^{st} = M_1^* = 9.4689 \times 10^4$ kg

$V_{b2}^{st} = M_2^* = 1.125 \times 10^4$ kg

$V_{b3}^{st} = M_3^* = 0.65612 \times 10^4$ kg.

Base overturning moment :-

$M_{bn}^{st} = V_{bn}^{st} \times h_n^*$.

$M_{b1}^{st} = V_{b1}^{st} h_1^* = 9.4689 \times 10^4 \times 8.5m$

$= 8.0486 \times 10^5$ kgm.

$M_{b2}^{st} = V_{b2}^{st} h_2^* = 1.125 \times 10^4 \times 0$

$= 0$ kgm.

$M_{b3}^{st} = V_{b3}^{st} h_3^* = 0.65612 \times 10^4 \times 0.8369$

$= 0.055 \times 10^5$ kgm

Verification —

$$\sum_{n=1}^{N} M_n^* h_n^* = \sum_{j=1}^{N} h_j m_j$$

$\Rightarrow (8.0486 + 0.055) \times 10^5 = 45000(4+8) + 22500 \times 12$

$\Rightarrow 8.104 \times 10^5 = 8.1 \times 10^5$ (O.K.)

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Representing in tabular format.

Mode	V_b^{st} (kg)	V_{3n}^{st} (kg)	M_{bn}^{st} (kgm)	u_{3n}^{st} (s^2)
1	9.4689×10^4	3.1563×10^4	8.0486×10^5	0.007
2	1.125×10^4	-1.125×10^4	0	-0.00052
3	0.65612×10^4	0.21872×10^4	0.055×10^5	0.047×10^{-3}

The Dynamic responses are given in the plots done on MATLAB.

EQ_HW4...

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```
%Assignment 4 P1a
clc
clearvars
m=10^3*[45  0    0
        0   45   0
        0   0  22.5];  % mass matrix
k=10^6*[72.5   -29      0
        -29    43.5  -14.5
          0   -14.5   14.5]; % stiffness matrix
h=[4;8;12]; %vector of floor heights
[V,D]=eig(k,m); % Solving eigenvalue problem to get eigenvalues and corresponding
eigenvectors
M=V'*m*V; %Modal mass matrix
i=[1;1;1]; %influence vector
Lh=V'*m*i; %Lnh vector for each mode
%nth mode contribution to the effective earthquake forces (Sn)
S1=Lh(1,1)*m*V(:,1);
S2=Lh(2,1)*m*V(:,2);
S3=Lh(3,1)*m*V(:,3);
Ltheta=V'*m*h;
```

EQ_HW4...

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```
%Assignment 4 P1b PSA response for different modes used in Modal analysis
%of 3 storey shear frame building
clc
clearvars
fid = fopen('El Centro Ground Motion data.txt') ;  % open the text file
S = textscan(fid,'%s');   % text scan the data
fclose(fid) ;      % close the file
S = S{1} ;
a_g = cellfun(@(x)str2double(x), S);  % convert the cell array to double
% Remove NaN's which were strings earlier
a_g(isnan(a_g))=[];
col = 2;
count = 0;
temp_arr =[];
temp_row = [];
for i = 1:length(a_g)
    if count == col
        temp_arr = [temp_arr;
                    temp_row];
        count = 0;
        temp_row = [];
    end
    temp_row = [temp_row,a_g(i)];
    count = count +1;
end
temp_arr = [temp_arr;
            temp_row];
a_g = temp_arr(:,2:end);
a_g=a_g.*9.81;
clear temp_arr temp_row S;
% Creating Time axis
t=zeros(length(a_g),1);
for i=2:length(a_g)
    t(i)=t(i-1)+0.02;
end
t1=0:0.005:31.18;
a_g1=interp1(t,a_g,t1);
del_t=0.005;
%Producing System response data
Tn=[0.442,0.202,0.138]; %Natural Period of the N-no. of modes
Z=0.05; %Damping ratio for each mode
u=zeros(length(a_g1),3); %Initialising displacement response vector of the SDOF system
v=zeros(length(a_g1),3); %Initialising velocity response vector of the SDOF system
a=zeros(length(a_g1),3); %Initialising Acceleration response vector for the SDOF
system
A_t=zeros(length(a_g1),3); %Matrix to store PSA for the diff. modes
for j=1:length(Tn)
```

```
Wn=(2*pi)/Tn(j); %Natural Frequency
Wd=Wn*sqrt(1-Z^2); %Damped Natural Frequency
%Defining Parameters required A,B,C,D & A1,B1,C1,D1
A=exp(-Z*Wn*del_t)*((Z/sqrt(1-Z^2))*sin(Wd*del_t)+cos(Wd*del_t));
B=exp(-Z*Wn*del_t)*(sin(Wd*del_t)/Wd);
C=(((2*Z)/(Wn*del_t))+exp(-Z*Wn*del_t)*(((1-2*Z^2)/(Wd*del_t)-(Z/sqrt(1-Z^2)))*sin
(Wd*del_t)-(1+((2*Z)/(Wn*del_t)))*cos(Wd*del_t)))/Wn^2;
D=(1-((2*Z)/(Wn*del_t))+exp(-Z*Wn*del_t)*(((2*Z^2-1)/(Wd*del_t))*sin(Wd*del_t)+((2*Z)/
```

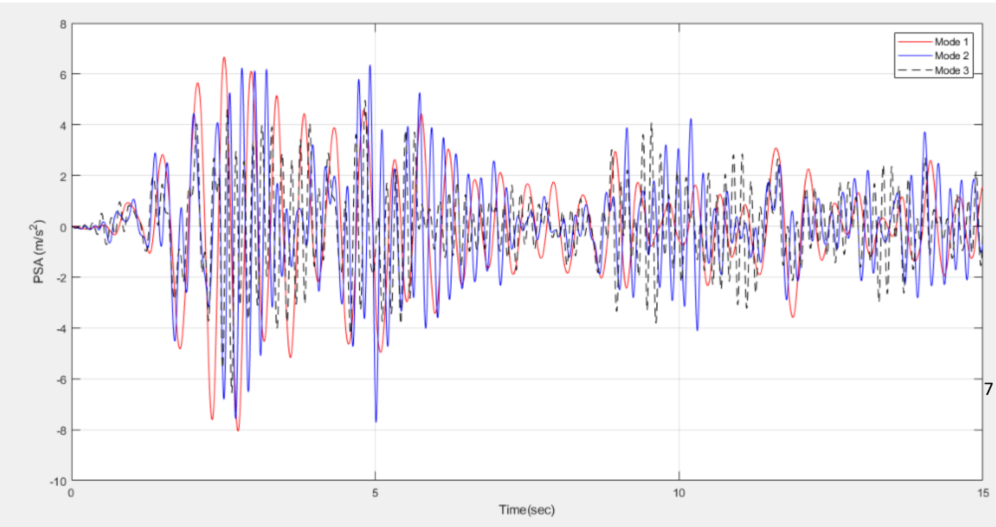


```
(Wn*del_t))*cos(Wd*del_t)))/Wn^2;
A1=-exp(-Z*Wn*del_t)*((Wn/sqrt(1-Z^2))*sin(Wd*del_t));
B1=exp(-Z*Wn*del_t)*(cos(Wd*del_t)-(Z/sqrt(1-Z^2))*sin(Wd*del_t));
C1=((-1/del_t)+exp(-Z*Wn*del_t)*(((Wn/(sqrt(1-Z^2)))+(Z/(del_t*sqrt(1-Z^2))))*sin
(Wd*del_t)+(cos(Wd*del_t)/del_t)))/Wn^2;
D1=(1-exp(-Z*Wn*del_t)*((Z/sqrt(1-Z^2))*sin(Wd*del_t)+cos(Wd*del_t)))/(Wn^2*del_t);
for i=1:length(a_g1)-1
    u(i+1,j)=A*u(i,j)+B*v(i,j)-C*a_g1(i)-D*a_g1(i+1);
    v(i+1,j)=A1*u(i,j)+B1*v(i,j)-C1*a_g1(i)-D1*a_g1(i+1);
    a(i+1,j)=-a_g1(i+1)-2*Z*Wn*v(i+1,j)-Wn^2*u(i+1,j);
    A_t(i+1,j)=Wn^2*u(i+1,j); %Pseudo Spectral Acceleration(PSA)
end
end
figure(1)
plot(t1(1:3000),A_t(1:3000,1),'r');
hold on
plot(t1(1:3000),A_t(1:3000,2),'b');
hold on
plot(t1(1:3000),A_t(1:3000,3),'k--');
xlabel('Time(sec)')
ylabel('PSA (m/s^{2})')
legend('Mode 1','Mode 2','Mode 3')
grid on
figure(2)
plot(t1(1:3000),u(1:3000,1),'r');
hold on
plot(t1(1:3000),u(1:3000,2),'b');
hold on
plot(t1(1:3000),u(1:3000,3),'k--');
xlabel('Time(sec)')
ylabel('D_{n} (m)')
legend('Mode 1','Mode 2','Mode 3')
grid on
U3n_st=[0.007,-0.00052,0.047*10^-3]; %Vector of static roof displacements for the 'n'
modes
V3n_st=10^4*[3.1563,-1.125,0.21872]; %vector of static 3rd storey shear for the 'n'
modes
Vbn_st=10^4*[9.4689,1.125,0.65612]; %vector of the static base shear for the 'n' modes
Mbn_st=10^5*[8.0486,0,0.055]; %vector of static base overturning moment for the 'n'
modes
U3n=zeros(length(A_t),3);
Vbn=zeros(length(A_t),3);
V3n=zeros(length(A_t),3);
Mbn=zeros(length(A_t),3);
%Roof Displacement Analysis
U3n(:,1)=A_t(:,1).*U3n_st(1);
U3n(:,2)=A_t(:,2).*U3n_st(2);
U3n(:,3)=A_t(:,3).*U3n_st(3);
U3=U3n(:,1)+U3n(:,2)+U3n(:,3);
U3n_max=[max(abs(U3n(:,1))),max(abs(U3n(:,2))),max(abs(U3n(:,3)))];
U3_max=max(abs(U3));
figure(3)
plot(t1(1:3000),U3n(1:3000,:).*1000,'linewidth',2);
hold on
plot(t1(1:3000),U3(1:3000).*1000,'k:','linewidth',3);
```



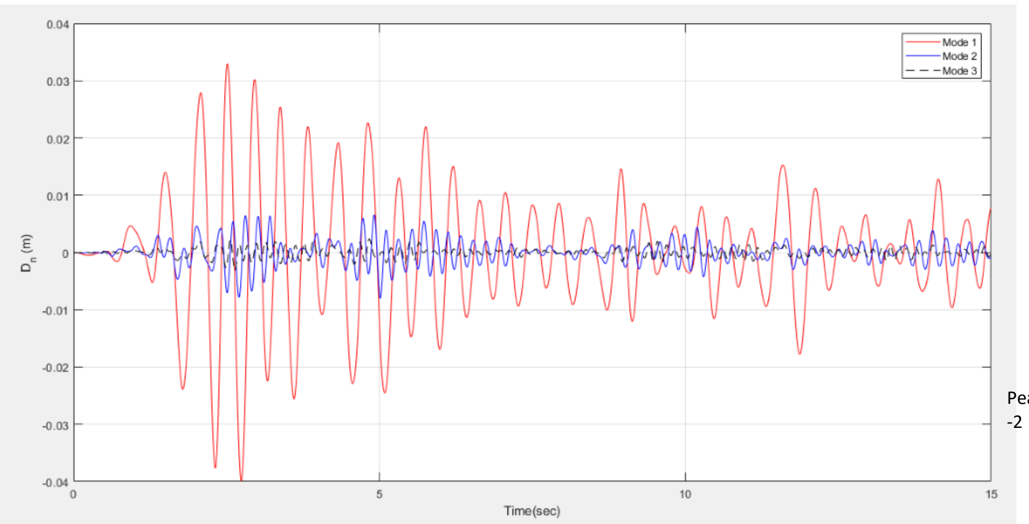
```
grid on
legend('Mode 1','Mode 2','Mode 3','Total');
xlabel('Time(sec)');
ylabel('Roof Displacement U_{3}(mm)');
%Base shear analysis
Vbn(:,1)=A_t(:,1).*Vbn_st(1);
Vbn(:,2)=A_t(:,2).*Vbn_st(2);
Vbn(:,3)=A_t(:,3).*Vbn_st(3);
Vb=Vbn(:,1)+Vbn(:,2)+Vbn(:,3);
```

```
Vbn_max=[max(abs(Vbn(:,1))),max(abs(Vbn(:,2))),max(abs(Vbn(:,3)))];
Vb_max=max(abs(Vb));
figure(4)
plot(t1(1:3000),Vbn(1:3000,:)./1000,'linewidth',2);
hold on
plot(t1(1:3000),Vb(1:3000)./1000,'k:','linewidth',3);
grid on
legend('Mode 1','Mode 2','Mode 3','Total');
xlabel('Time(sec)');
ylabel('Base shear V_{b}(KN)');
%3rd Storey shear analysis
V3n(:,1)=A_t(:,1).*V3n_st(1);
V3n(:,2)=A_t(:,2).*V3n_st(2);
V3n(:,3)=A_t(:,3).*V3n_st(3);
V3n_max=[max(abs(V3n(:,1))),max(abs(V3n(:,2))),max(abs(V3n(:,3)))];
V3=V3n(:,1)+V3n(:,2)+V3n(:,3);
V3_max=max(abs(V3));
figure(5)
plot(t1(1:3000),V3n(1:3000,:)./1000,'linewidth',2);
hold on
plot(t1(1:3000),V3(1:3000)./1000,'k:','linewidth',3);
grid on
legend('Mode 1','Mode 2','Mode 3','Total');
xlabel('Time(sec)');
ylabel('3rd storey shear V_{3}(KN)');
%Base overturning Moment
Mbn(:,1)=A_t(:,1).*Mbn_st(1);
Mbn(:,2)=A_t(:,2).*Mbn_st(2);
Mbn(:,3)=A_t(:,3).*Mbn_st(3);
Mb=Mbn(:,1)+Mbn(:,2)+Mbn(:,3);
Mbn_max=[max(abs(Mbn(:,1))),max(abs(Mbn(:,2))),max(abs(Mbn(:,3)))];
Mb_max=max(abs(Mb));
figure(6)
plot(t1(1:3000),Mbn(1:3000,:)./1000,'linewidth',2);
hold on
plot(t1(1:3000),Mb(1:3000)./1000,'k:','linewidth',3);
grid on
legend('Mode 1','Mode 2','Mode 3','Total');
xlabel('Time(sec)');
ylabel('Base overturning moment M_{b}(KNm)');
```



7

Fig1. Plot of Pseudo Acceleration response for all the 3 modes with time



Peak response not marked on the fig
-2

Fig2. Plot of the Displacement response of all three modes vs time

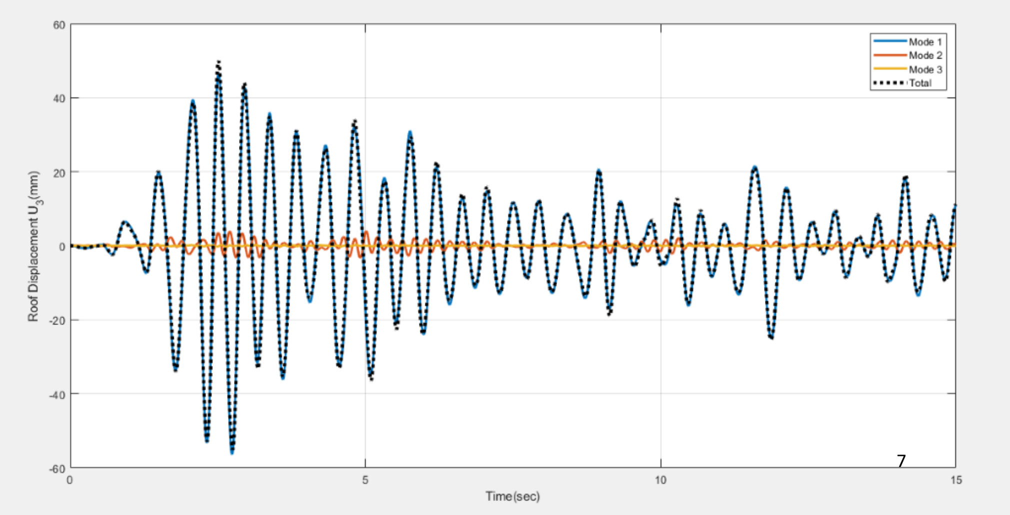


Fig3. Plot of Roof Displacement for all 3 modes as well as the Total Roof displacement vs time

From the above plots, the maximum values of the roof displacements for the 3 modes :
U3n_max = [0.0564 , 0.0040, 3.0795*10^-4] m (maximum roof displacements for each mode from left to right)
U3_max= 0.0551 m (maximum roof displacement considering all the three modes)

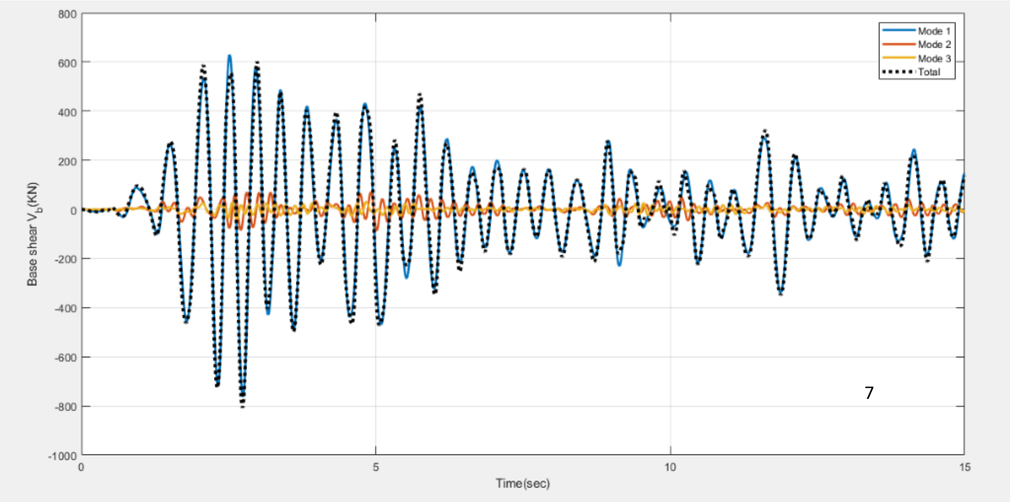


Fig 4. Plot of Base shear for all three modes and the Total Base shear vs time

From above Plot the maximum values obtained for the 3 modes:
Vbn_max=[7.633*10^5, 8.6747*10^4, 4.299*10^4] N

Vb_max= 8.0763*10^5 N (Maximum base shear considering all modes)

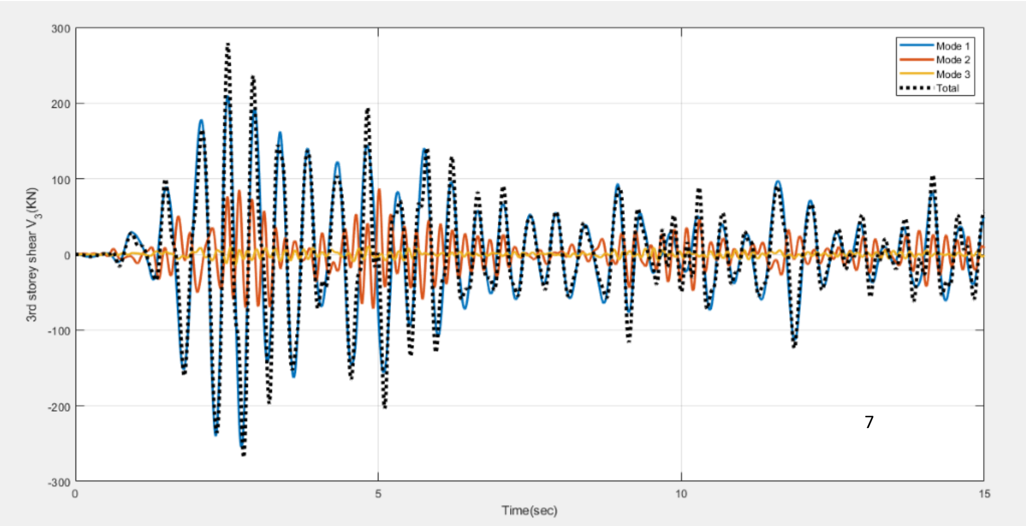


Fig 5. Plot of 3rd Storey shear for all 3 modes and the Total 3rd storey shear vs Time

The maximum values of the 3rd storey shear obtained for the 3 modes:
V3n_max=[2.544*10^5, 8.6747*10^4, 1.433*10^4] N

V3_max= 2.7945*10^5 N (maximum 3rd storey shear considering all modes)

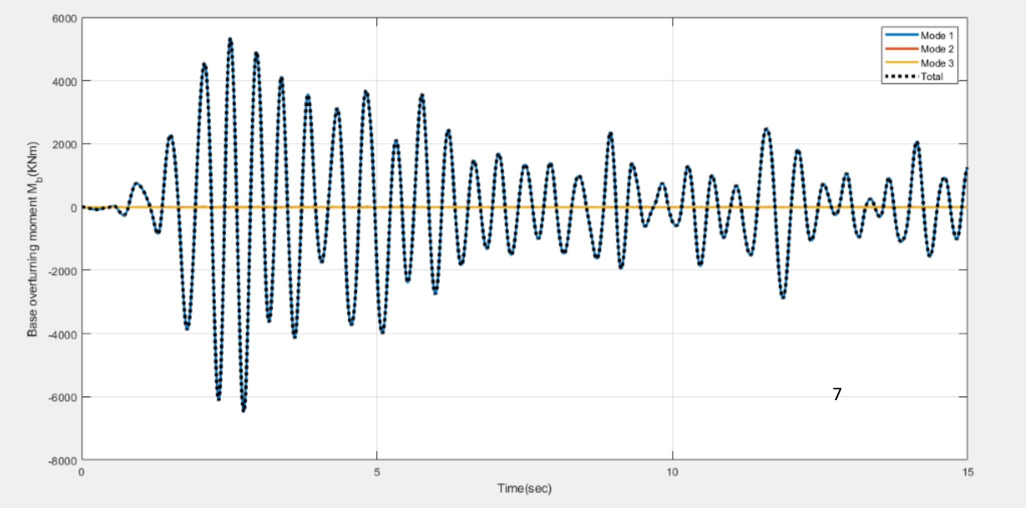


Fig 6. Plot of base overturning moment for all 3 modes and total Base overturning moment vs Time

Maximum values of Base overturning moment obtained for all 3 modes:
Mbn_max=[6.488*10^6, 0, 3.6037*10^4] Nm

Mb_max= 6.4871*10^6 Nm (maximum base overturning moment considering all modes)