Plastic Analysis and Design

Final term project 2018

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Group 3

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Introduction

Etabs model

TEASPA

Xtract

ATC-40

FEMA273

Upper bound method

Conclusion

Introduction

Purposes

1. After the 921 earthquake, many school buildings collapsed. The lack of seismic design building code in the past was discovered. So that the seismic design of the school buildings began to be carried out with today's norms.

2. Focus on the collapsed Chiayi Minxung factory, we investigate the defects in the structure and the reasons for the collapse.

3. Using Etabs, TEASPA, and Xtract structural analysis model with ATC-40 and FEMA273 building code to investigate the damage of the structure.

Introduction

Basic information

Building name	:	Chiayi Minxung factory
Soil type	:	Type 2
Building function	:	School building
Structure system	:	RC MRF
Structure size	:	2 floor without basement
Materials	:	Concrete strength 280 kg/cm^2 , Rebar strength 2800 kg/cm^2
loadings	:	Dead load 850 kg/m^2 , live load 250 kg/m^2

Introduction

Analysis cases

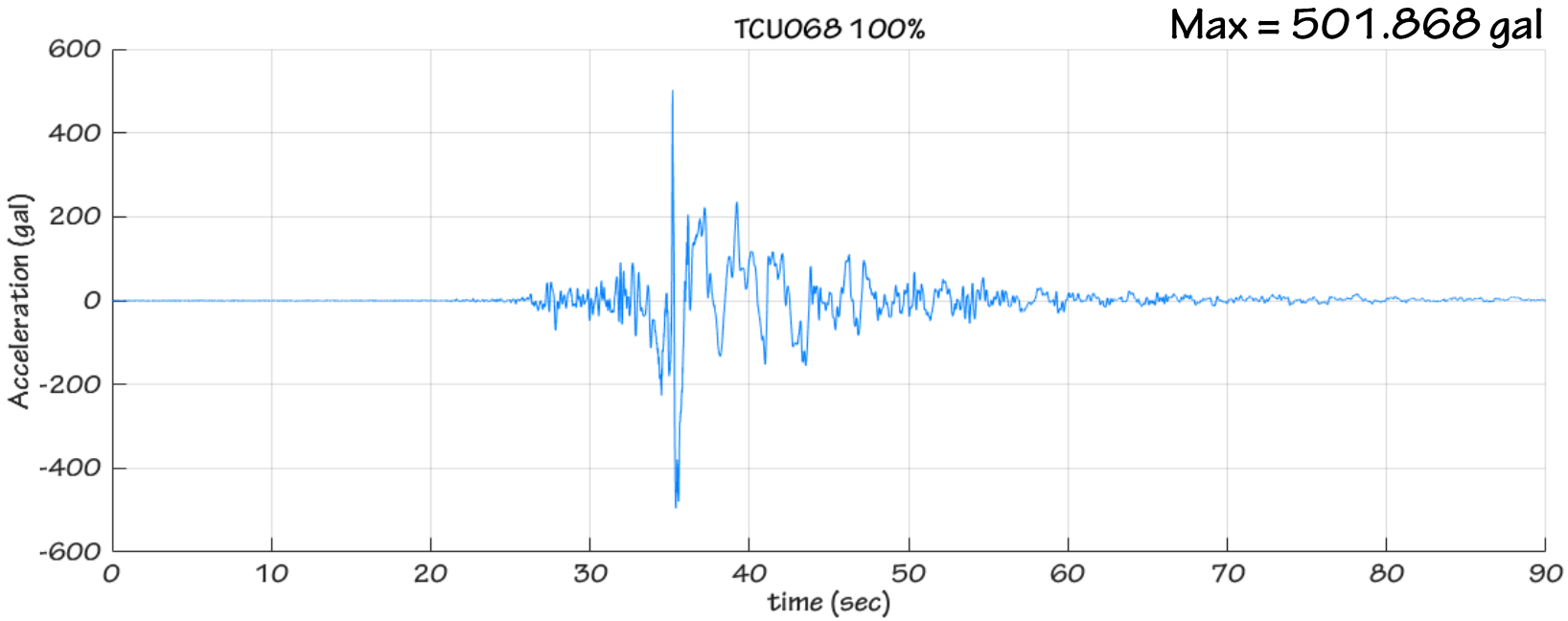
Team	Stirrups for Columns (cm)	Analysis Cases		
1	D10 @ 10	Small to moderate seismic response spectrum (30-year return period)	Design seismic response spectrum (475-year return period)	1022CHY037 30%&100%
2	D10 @ 30			1022CHY037 30%&100%
3	D10 @ 10			921TCU068 30%&100%
4	D10 @ 30			921TCU068 30%&100%
5	D10 @ 10			921TCU052 30%&100%

Note：

1. Software used： ETABS & TEASPA
2. Analysis Direction：Long Direction
3. consider walls as rigid members
4. The units of time history data are sec. and gal

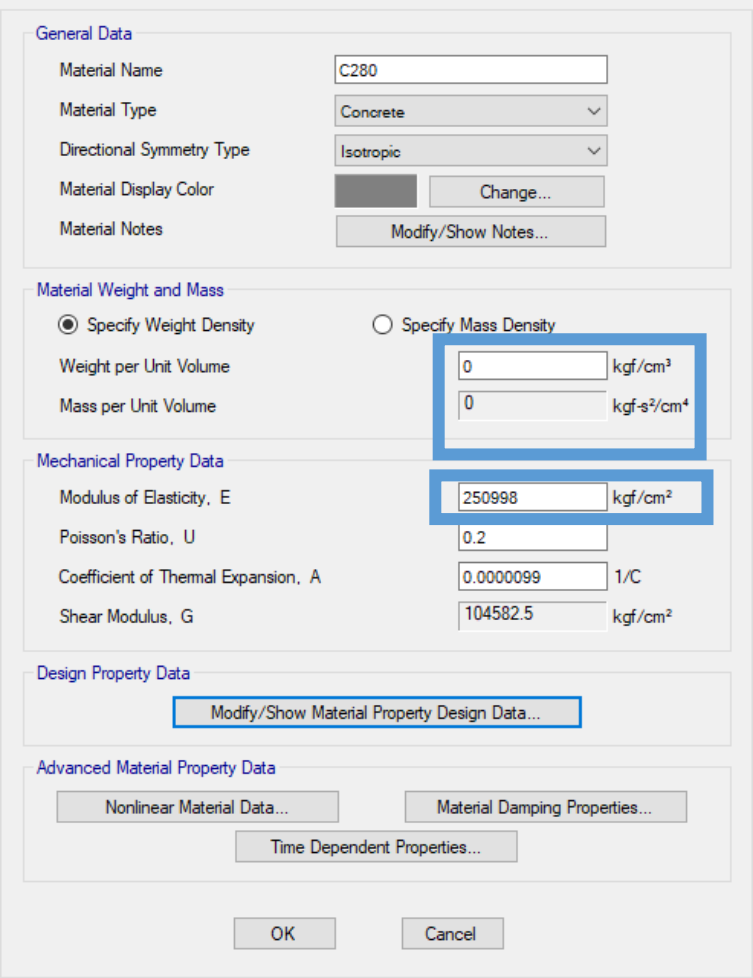
Introduction

Seismic records



Etabs model

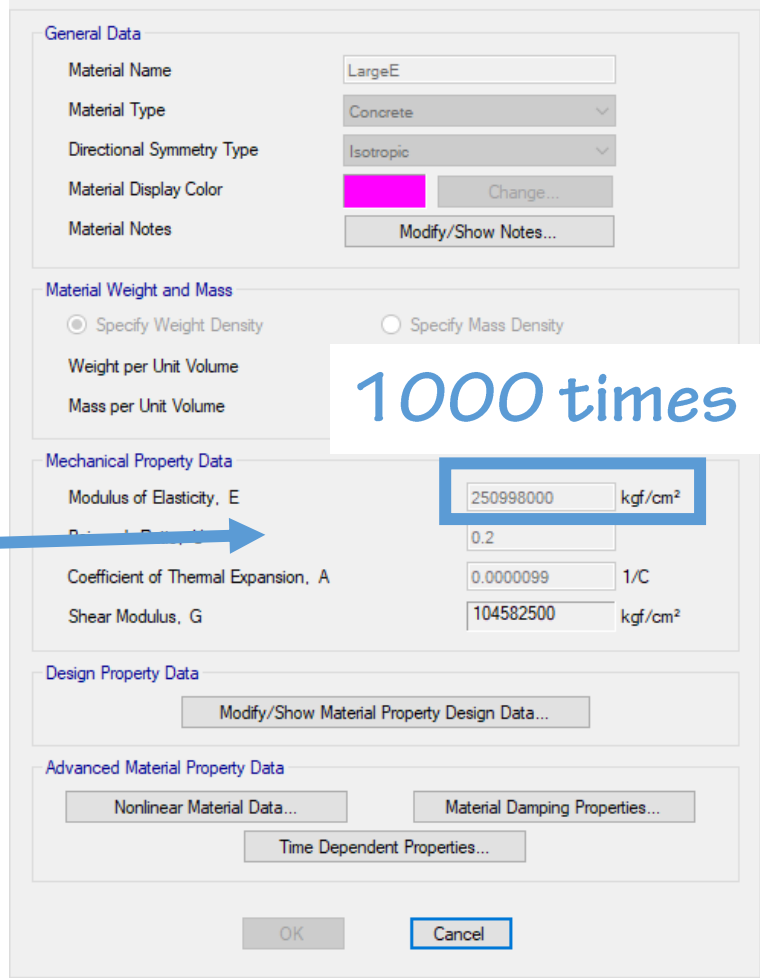
Material



Concrete

Note：

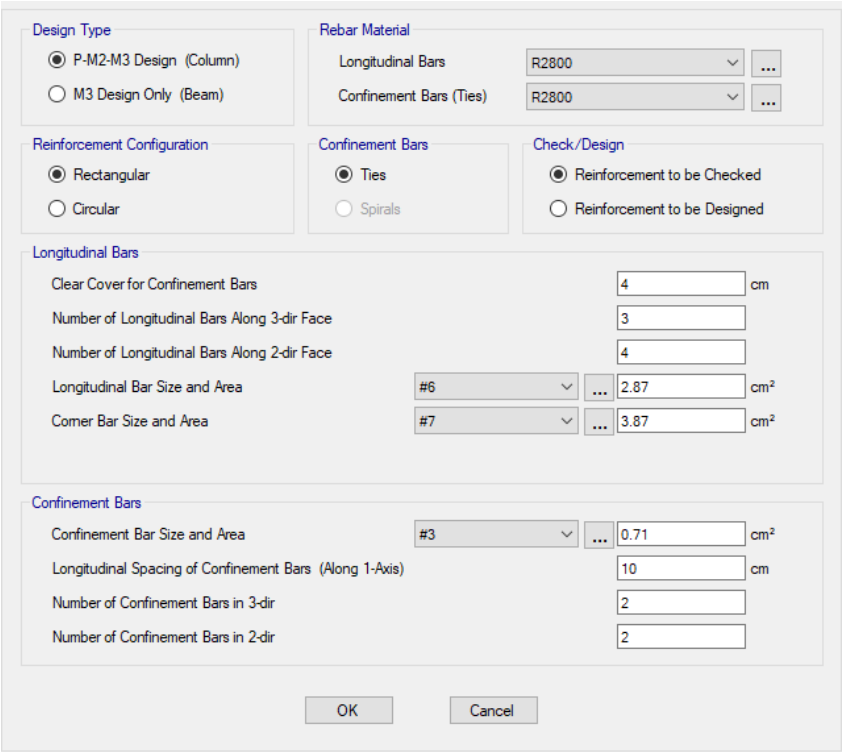
1. Software used： ETABS & TEASPA
2. Analysis Direction：Long Direction
3. consider walls as rigid members

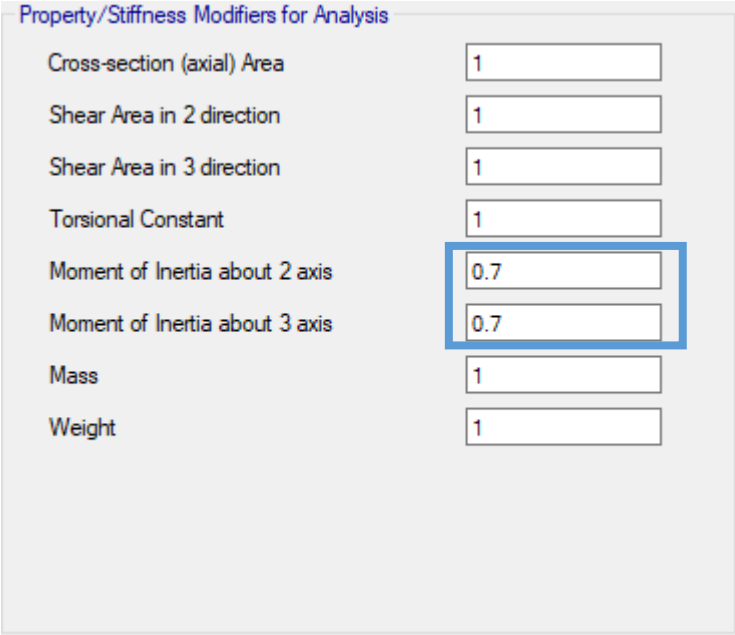


Brace

Etabs model

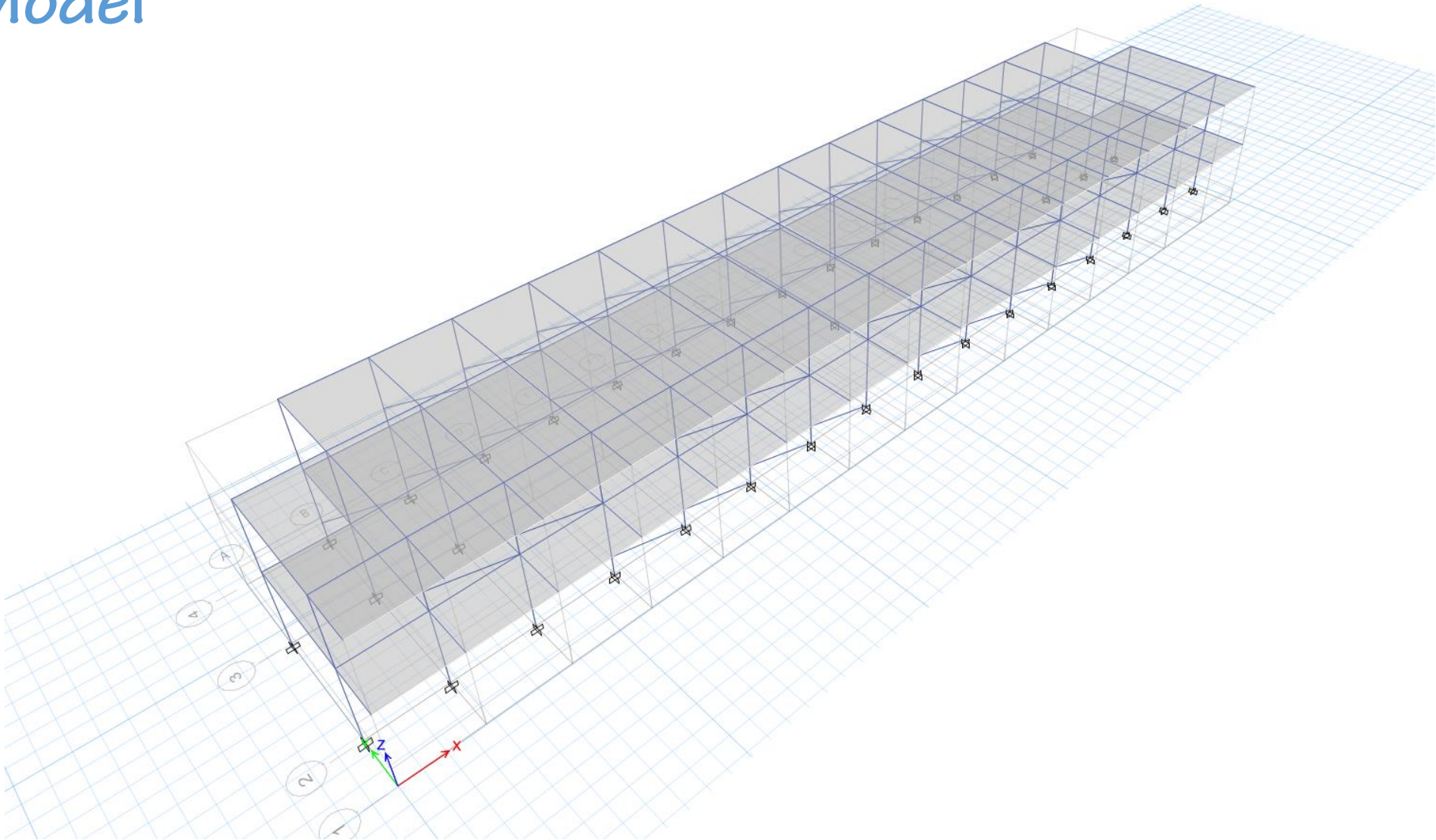
Section – Column Beam Slab





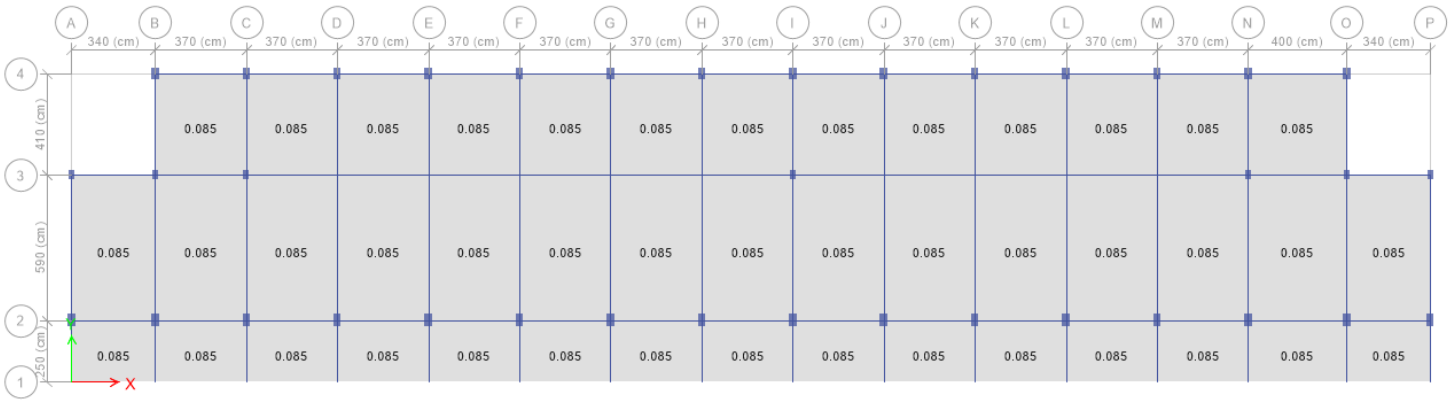
Etabs model

3D Model



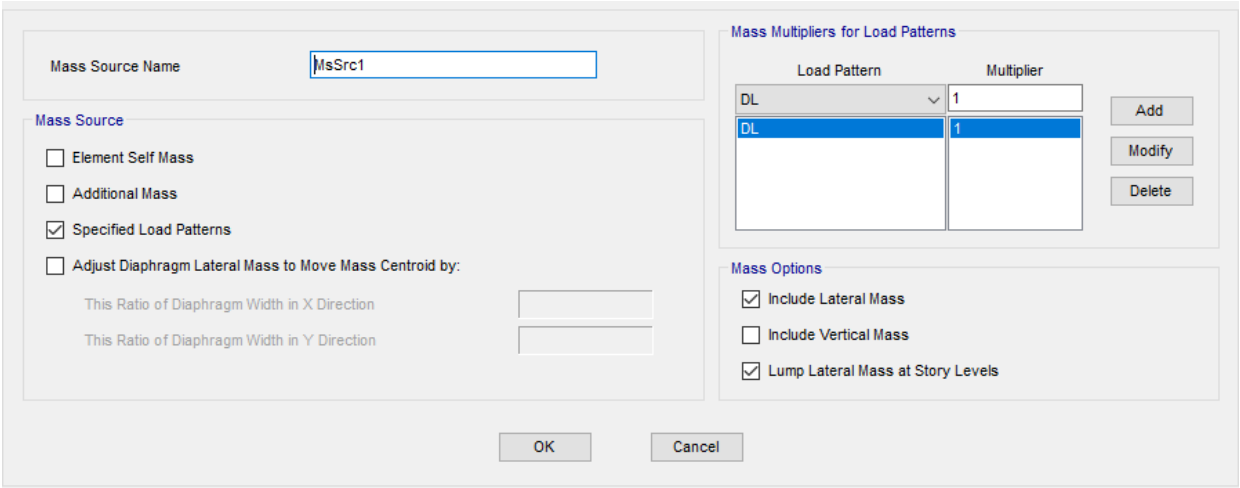
Etabs model

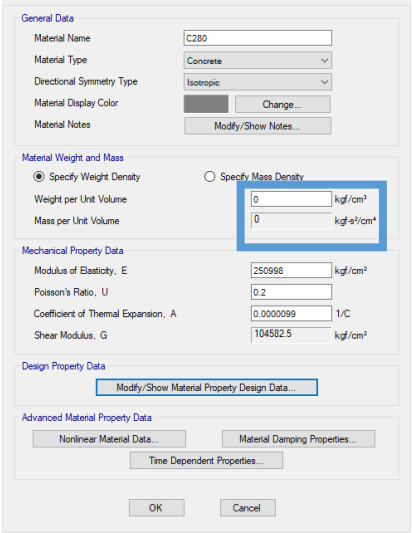
Loading



DL, LL

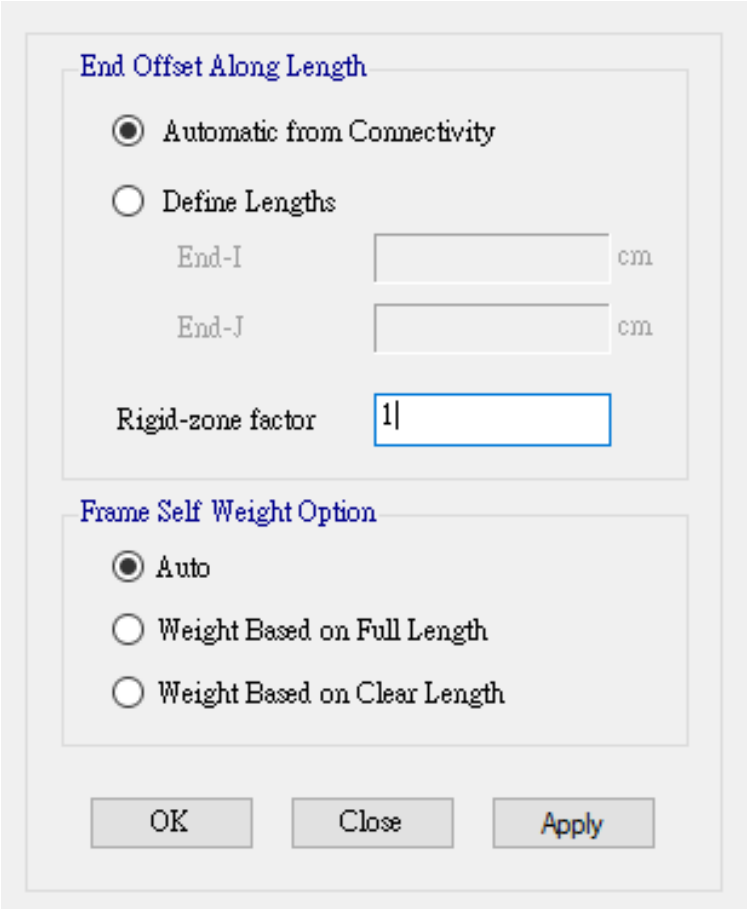
Didn't Consider Self Weight

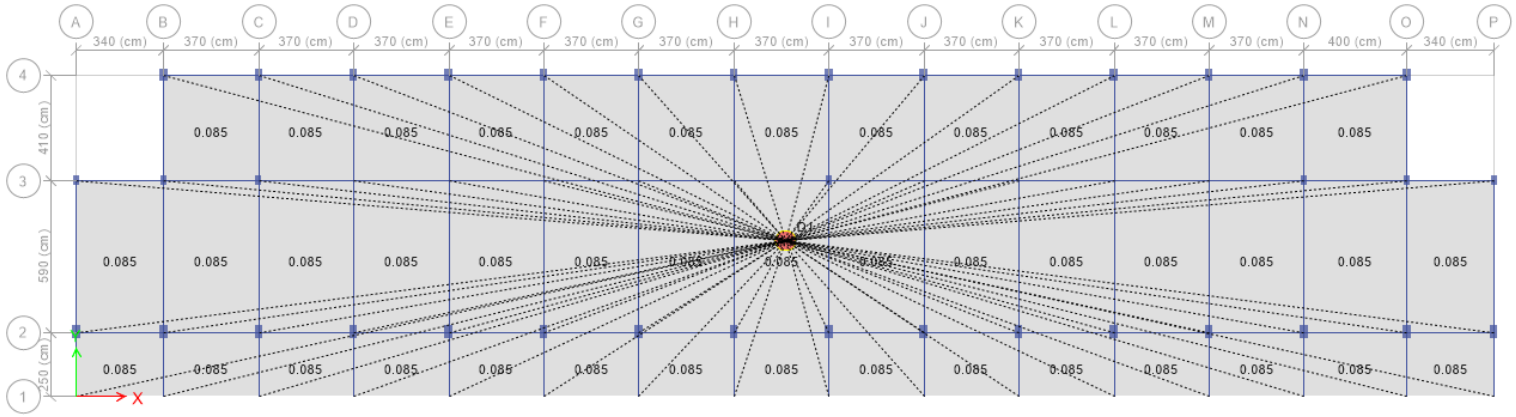




Etabs model

Rigid Zone Factor and Rigid Diaphragm





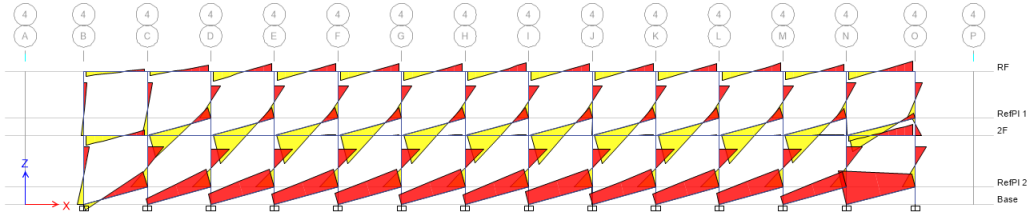
Etabs model

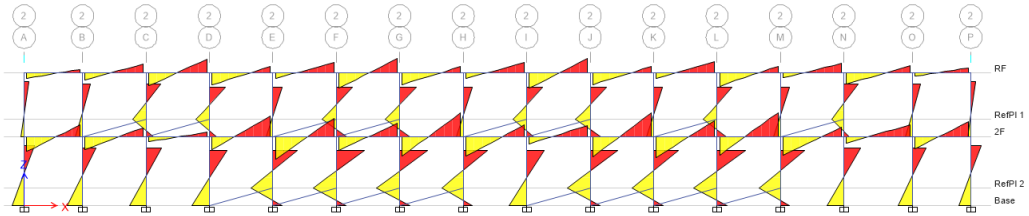
Brace Release

×

Brace Resist Moment

Column Resist Moment



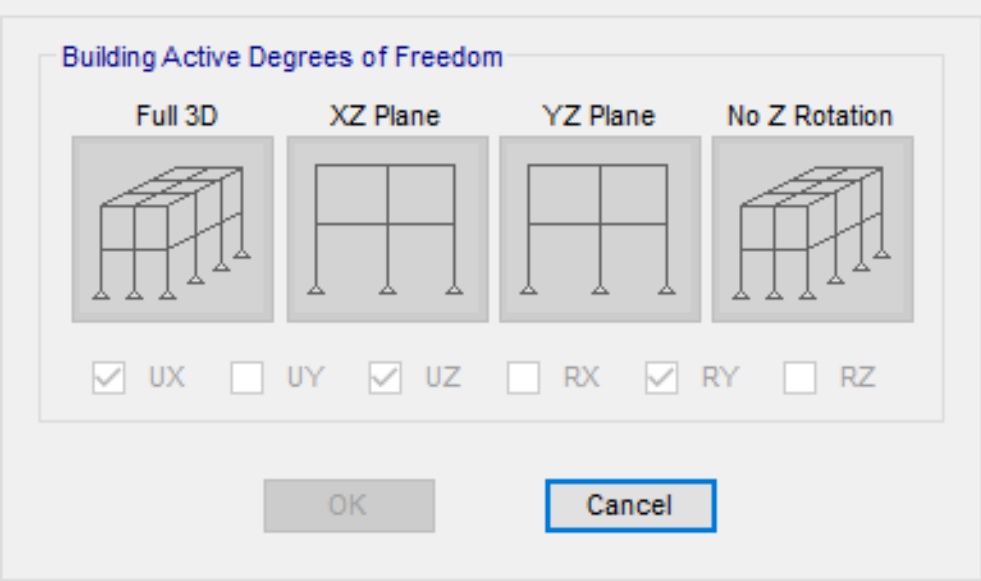


No Release

Release M3

Etabs model

Degrees of Freedom



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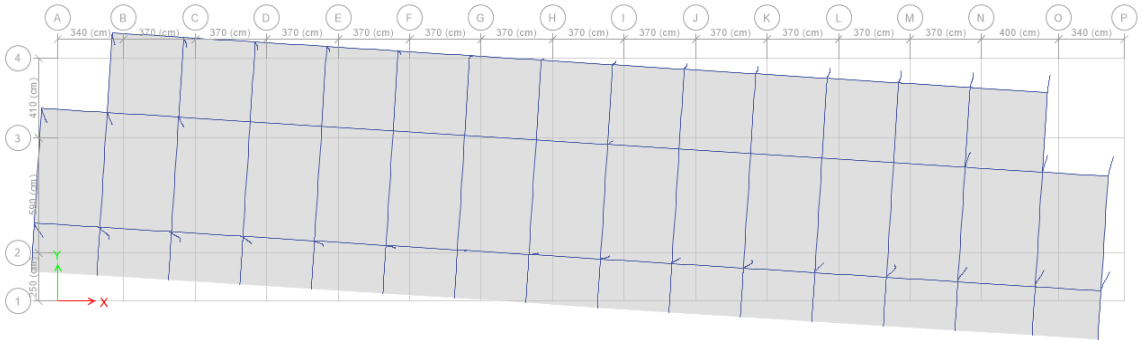
Torsion Control



Note：

1. Software used： ETABS & TEASPA
2. Analysis Direction：Long Direction
3. consider walls as rigid members

Etabs model

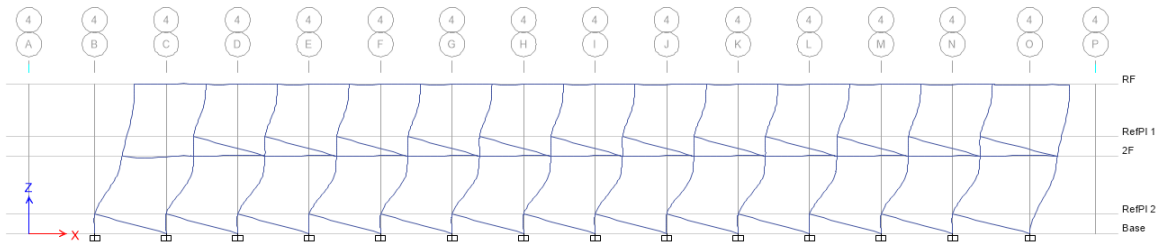
Modal Analysis

T_1 : 0.398 sec

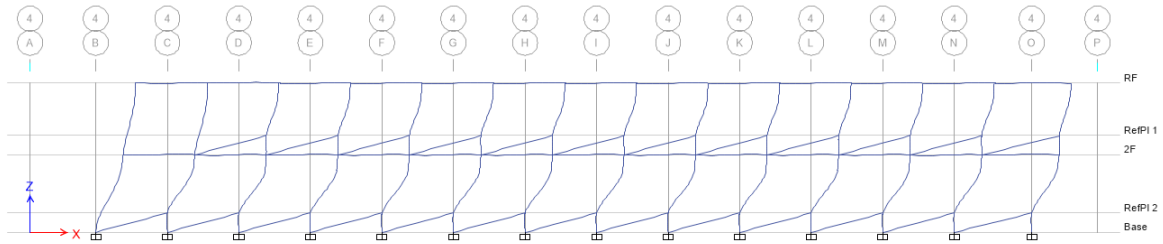
Modal Participating Mass Ratio : 96.6 %

First Mode Shape : 0.0344, 0.0236

XP

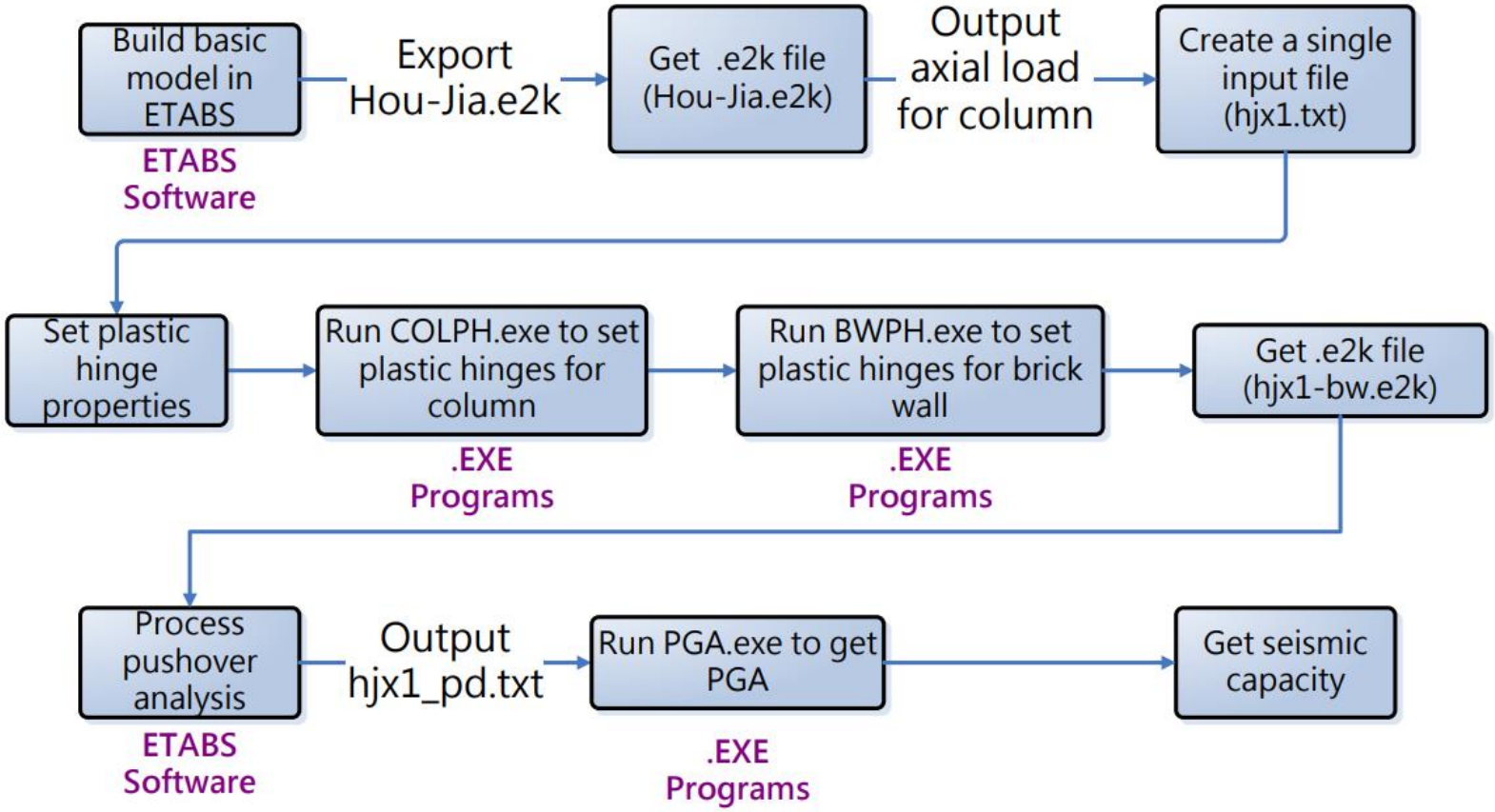


XN



TEASPA

Work Flow



TEASPA

Site Parameter

縣市	鄉鎮市區	村里	地盤類別	樓高(公尺)	用途係數, I
嘉義縣	民雄鄉	--	2	7.7	1.25

地震區域設計係數

					目前分析斷層
斷層名稱		梅山	--	--	梅山
工址與斷層水平距離	r	1.76 km	0.00 km	0.00 km	
近斷層設計地震調整因子	N_A	1.37	1.00	1.00	
	N_V	1.44	1.00	1.00	
近斷層最大地震調整因子	N_A	1.30	1.00	1.00	
	N_V	1.48	1.00	1.00	

S_S^D	0.80	F_a^D	1.00	S_{DS}	1.096
S_1^D	0.45	F_v^D	1.20	S_{D1}	0.778
S_S^M	1.00	F_a^M	1.00	S_{MS}	1.300
S_1^M	0.55	F_v^M	1.10	S_{M1}	0.895
T_0^D	0.709 秒	T_0^M	0.689 秒		

第三類建築物

下列公眾使用之建築物，I=1.25。

(1) 各級政府機關辦公廳舍（第一類建築物之外）。

(2) 教育文化類：幼稚園；各級學校校舍(第一類建築物之外)；集會堂、活動中心；圖書館、資料館；博物館、美術館、展覽館；寺廟、教堂；補習班；體育館。

(3) 衛生及社會福利類：醫院、診所(第一類建築物之外)；安養、療養、扶養、教養場所；殯儀館。

(4) 營業類：餐廳；百貨公司、商場、超級市場、零售市場；批發量販營業場所；展售場、觀覽場；地下街。

一棟建築物如係混合使用，上述供公眾使用場所累計樓地板面積超過 3000 平方公尺或總樓地板面積百分之二十以上者，用途係數才需用 1.25。如一棟建築物單種用途使用時，必須總樓版面積超過 1000 平方公尺，用途係數才需用 1.25。

TEASPA

Build Input File

```
$ BUILDING PROPERTIES
$ Weight Height
562802  400
562802  770
```

```
$ SITE SPECTRUM PARAMETER
$S_DS   S_D1
1.096   0.778
```

```
$ BRICK WALL PROPERTIES
$ Name  width  height  thick  f_mc   f_bc   P  Bond   Confinement
D370   370   100   24   210   150   0  3    2
D400   400   100   24   210   150   0  3    2
```

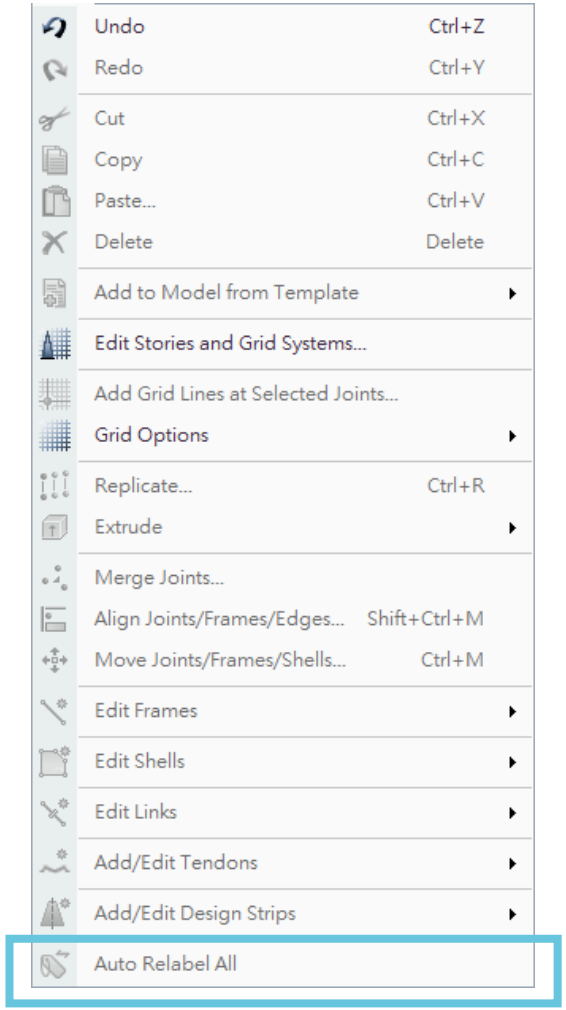
```
$ COLUMN PROPERTIES
$Name  f_cp   f_yl   f_yt   cover  hoop   spacing num_hoop   TR
1C1   280   2800   2800   4    3    10    2       0
1C2   280   2800   2800   4    3    10    2       0
```

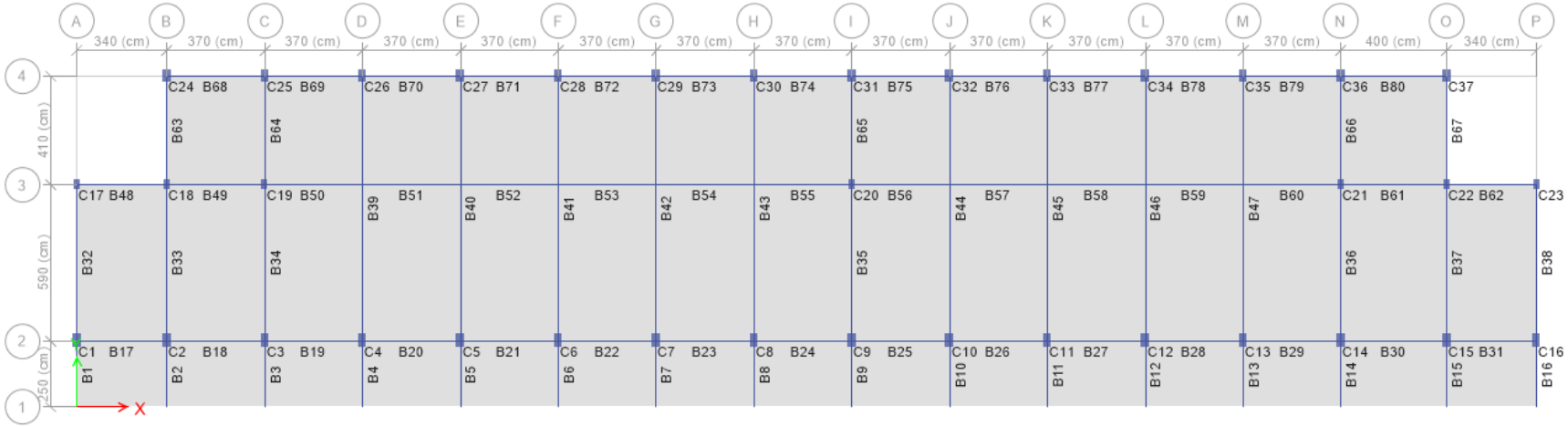
梁不同跨距與單雙翼視為不同分開建立

```
$ BEAM PROPERTIES
$Name    Lc    f_cp   f_yl   f_yt   cover  hoop   spacing num_hoop  TR
```

TEASPA

Relabel





TEASPA

Build Input File

```
$ COLUMN DATA
$Name  story  section   shape   Height L    fromBtm
```

One by One

```
$ BEAM DATA
$Name  story  section
```

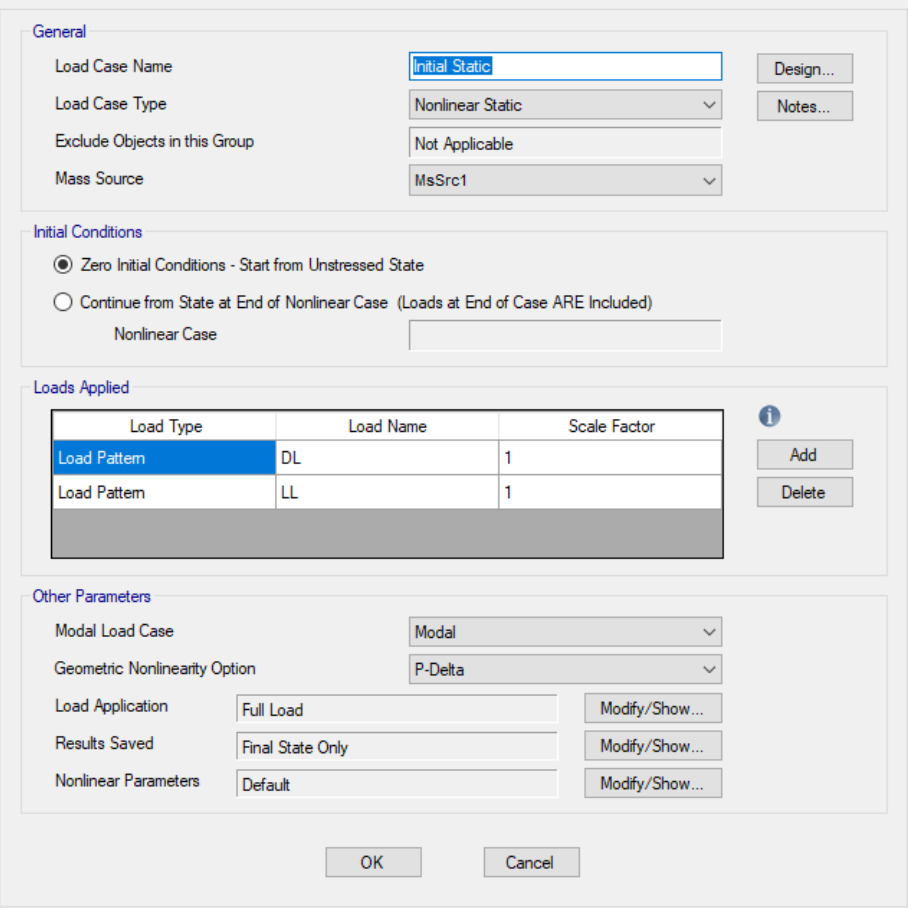
```
$ AXIAL LOAD
$ Story Column Loc   P
```

From ETABS

```
$ COLUMN SECTION PROPERTIES
2B4D_400
15    100   40    25
2.5   2800  3    3    3    3    3    3
5.95  2800       6          6
12.5  2800  3    3    3    3    3    3
34    2800       6          6
```

Beam

TEASPA
Pushover



2.2 載重係數與載重組合

結構及其構件所需提供之強度，須依係數化載重組合後之臨界狀況決定。臨界狀況可能在一種或多種載重作用時發生，其對應之標稱載重與載重組合應依據建築技術規則及相關規範之規定辦理。若建築技術規則及相關規範中並無相關規定，則須檢核下列之載重組合：

$$1.4D \quad (2.2\text{-}1)$$

$$1.2D + 1.6L \quad (2.2\text{-}2)$$

$$1.2D + 0.5L \pm 1.6W \quad (2.2\text{-}3)$$

$$1.2D + 0.5L \pm E \quad (2.2\text{-}4)$$

$$0.9D \pm E \quad (2.2\text{-}5)$$

$$0.9D \pm 1.6W \quad (2.2\text{-}6)$$

其中，

D ＝靜載重，結構物構件重量及永久附加物重量。

L ＝活載重，包括室內人員、傢俱、設備、貯存物品、活動隔間等。

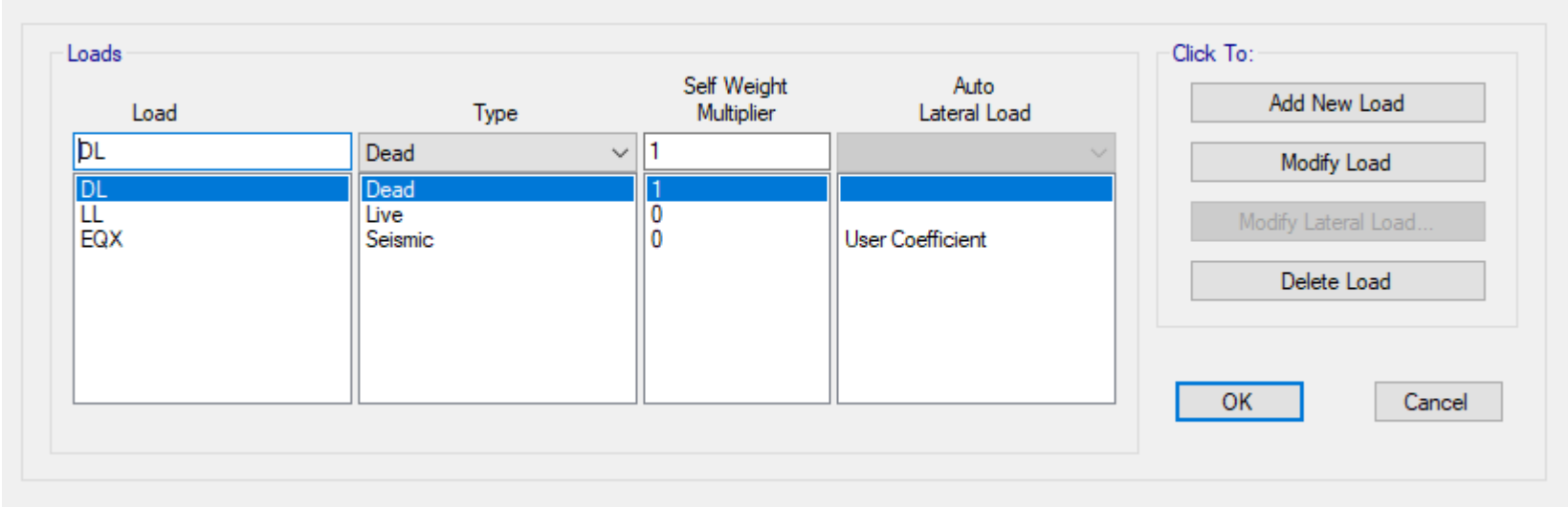
W ＝風力載重，依據「建築物耐風設計規範及解說」之規定。

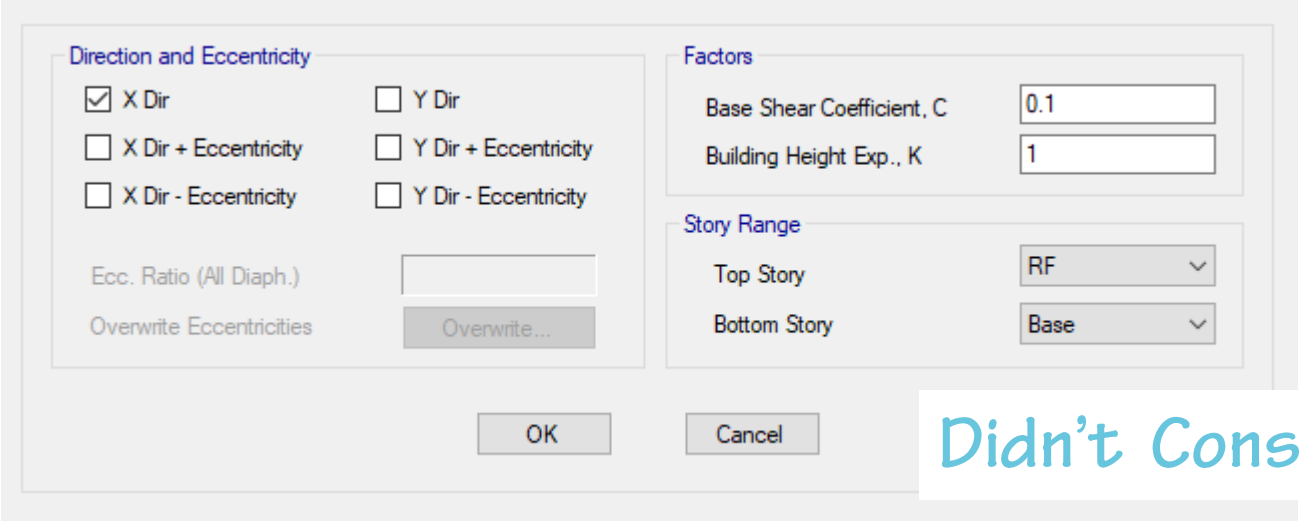
E ＝地震力載重，依據「建築物耐震設計規範及解說」之規定，惟其中起始降伏地震力放大係數 α_y 取1.0。

式(2.2-3)與(2.2-4)中，若結構物之用途為車庫、公眾使用場所或活載重大於0.5tf/m^{2}時，L之載重係數應為1.0。

TEASPA

Load Pattern



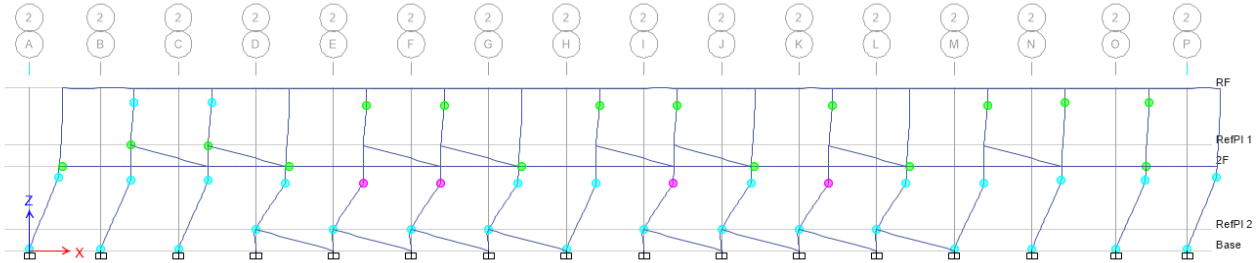


Didn't Consider Eccentricities

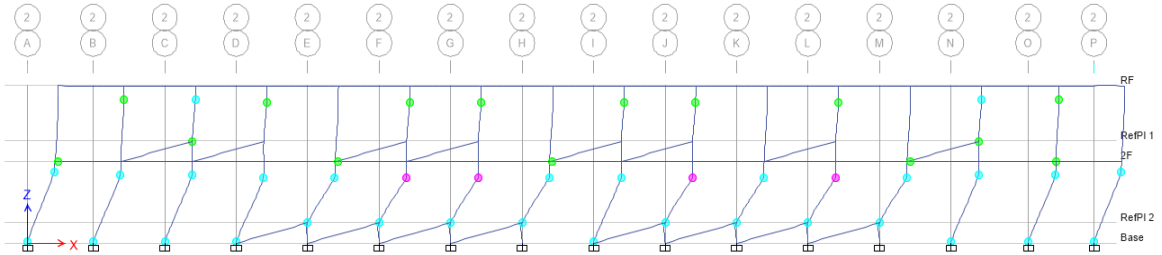
TEASPA

Nonlinear Hinge

XP



XN

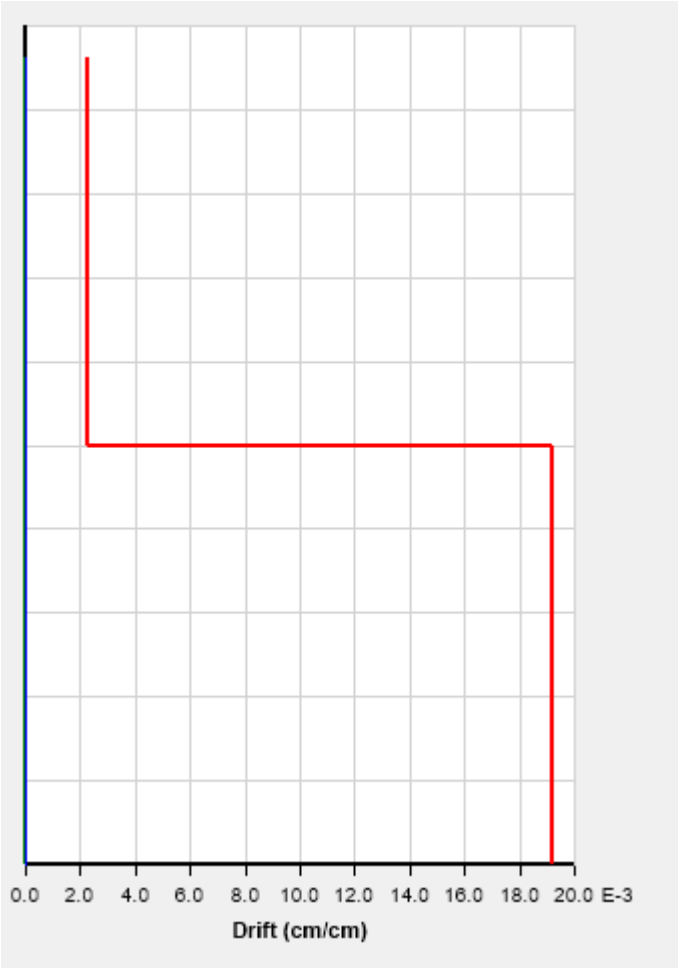


TEASPA

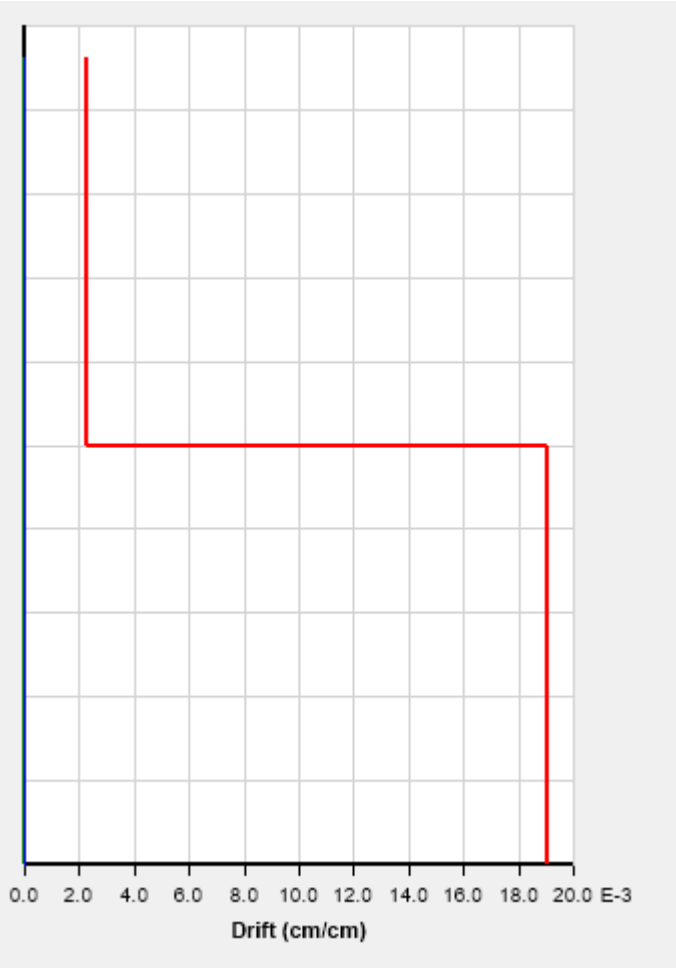
DM Performance

Smaller than 2% => OK

XP



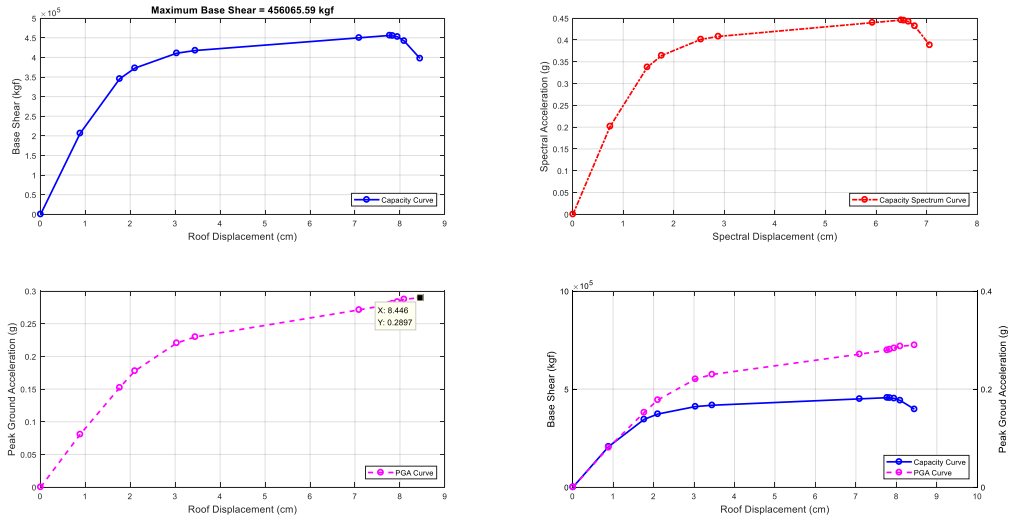
XN

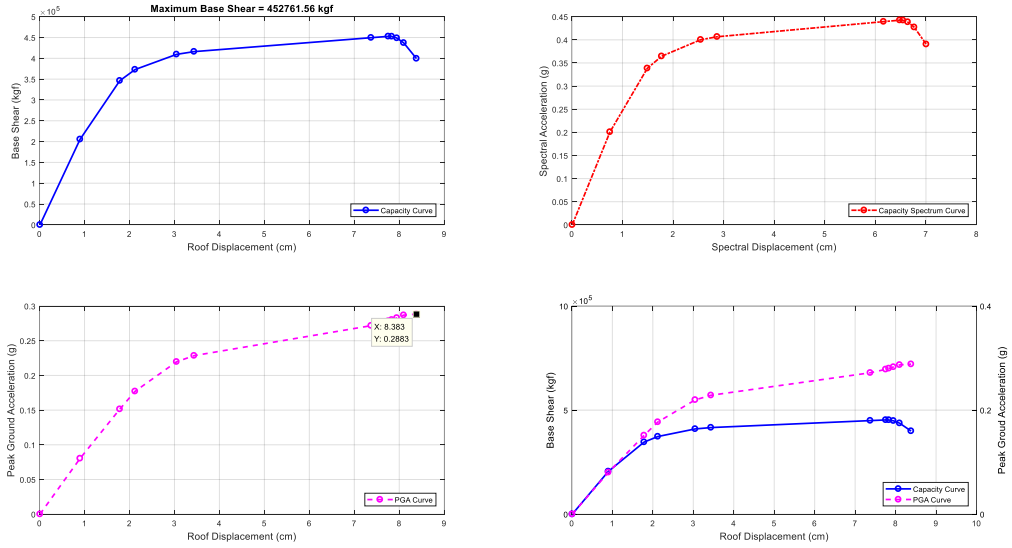


TEASPA

IM Performance

AT : 0.4 x SDS x I = 0.548





XP: Ap=0.2897 < AT => NG

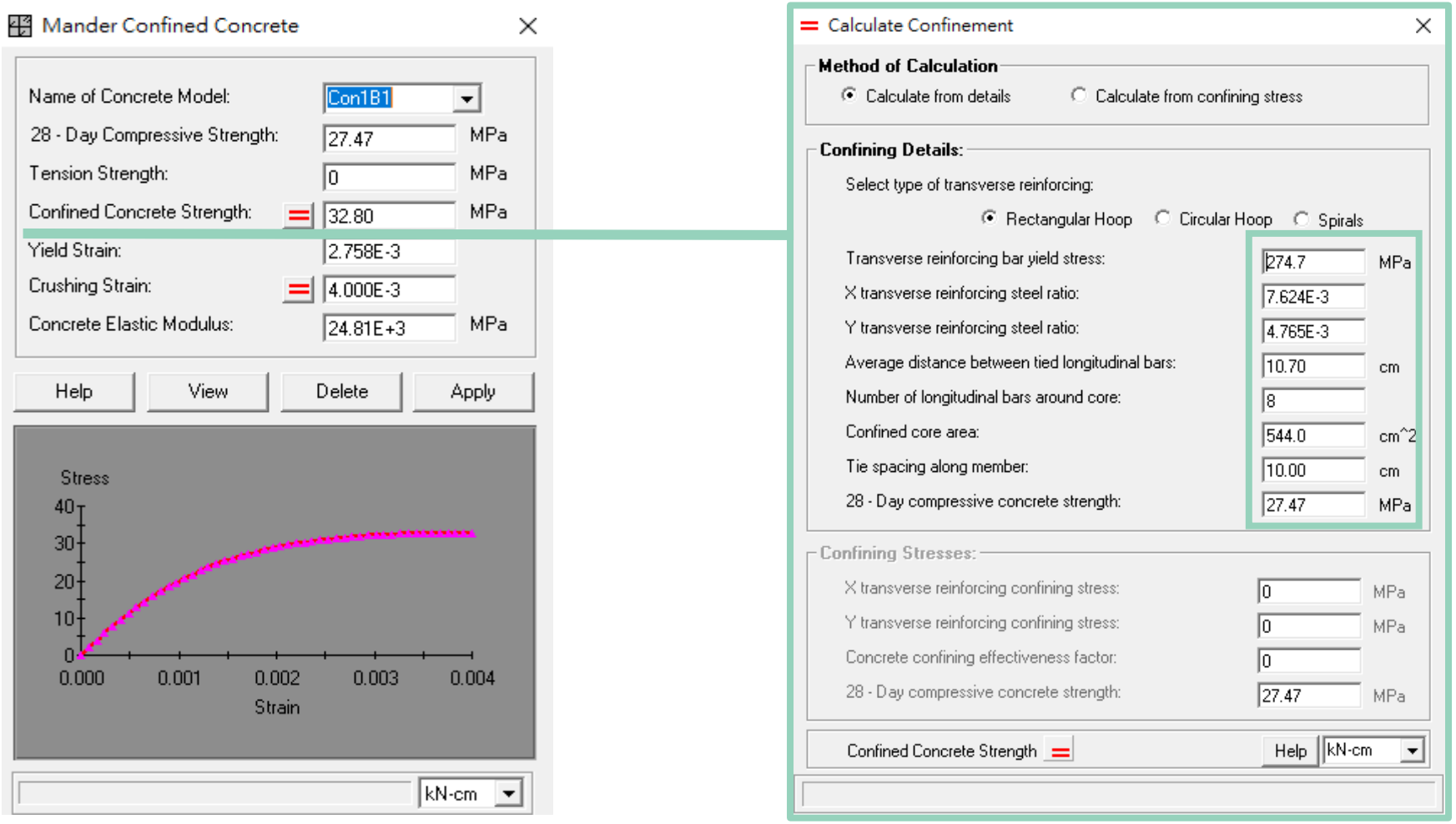
XN: Ap=0.2883 < AT => NG

Xtract

Cross section info.

kN-m	1B1	1B2,2B2	1B3,2B3	2B1	2B4	1B4	CB
Mux+	639.9	152.1	176.5	471.5	51.8	75.3	227.5
Mux-	295.6	66.1	96.9	288.3	51.8	75.3	90.7
	1C1	1C2	1C3	2C1	2C2	2C3	
Muy	118.1	101.8	41.6	108.6	75.2	43.9	

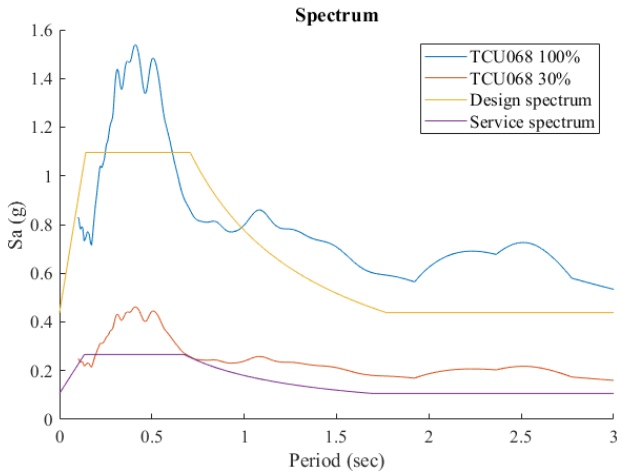
Xtract
Detail design

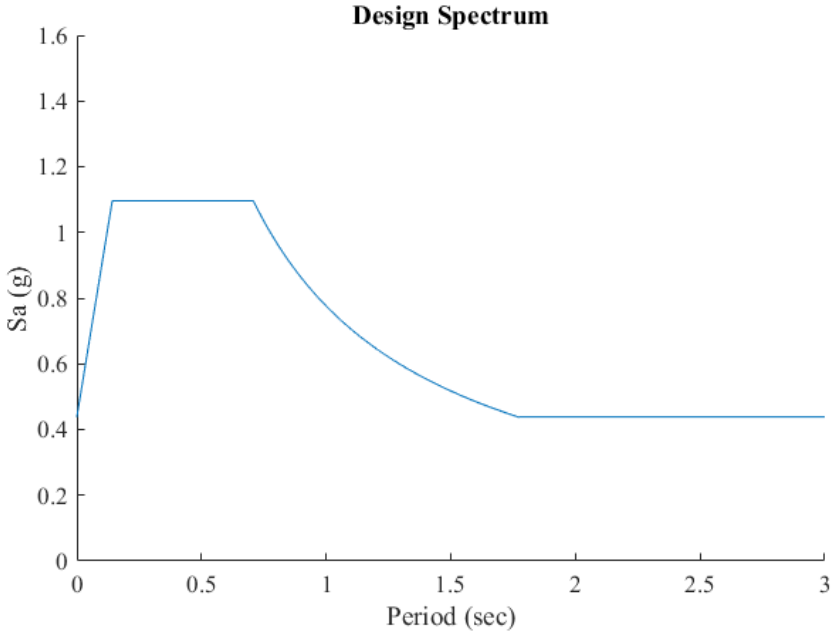


ATC-40

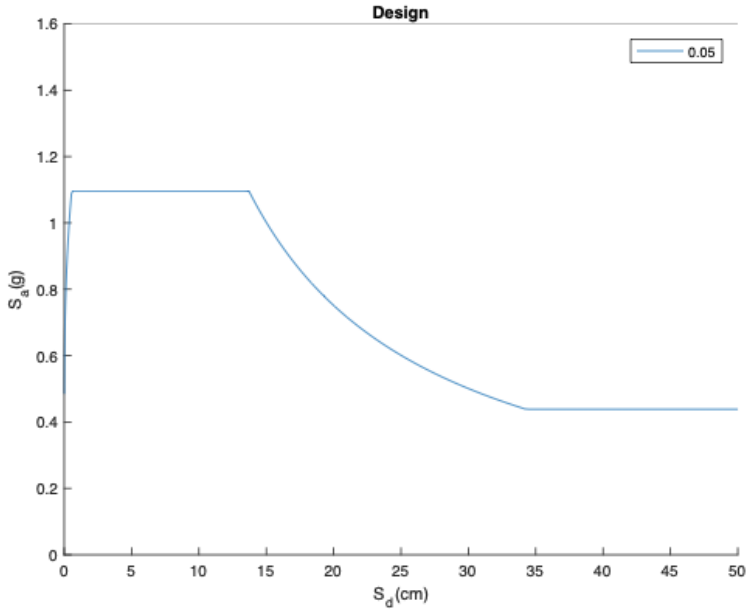
Goal nd a performance point

- Procedure A
- Procedure B
- Procedure C



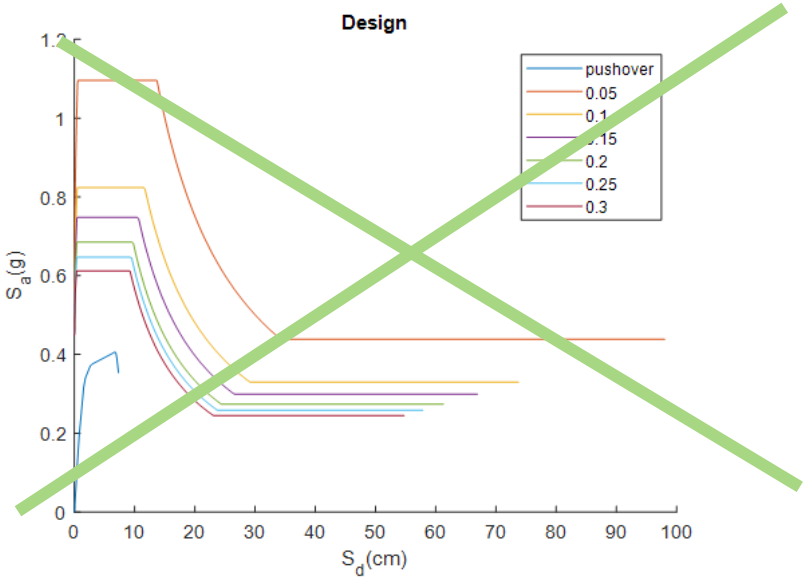


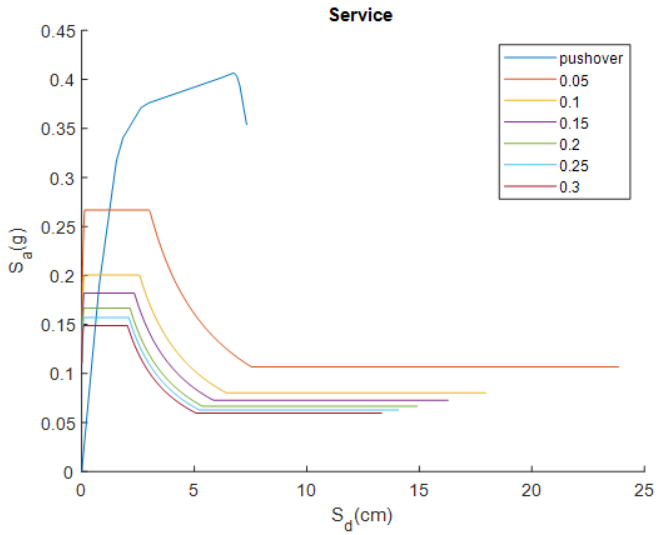
T

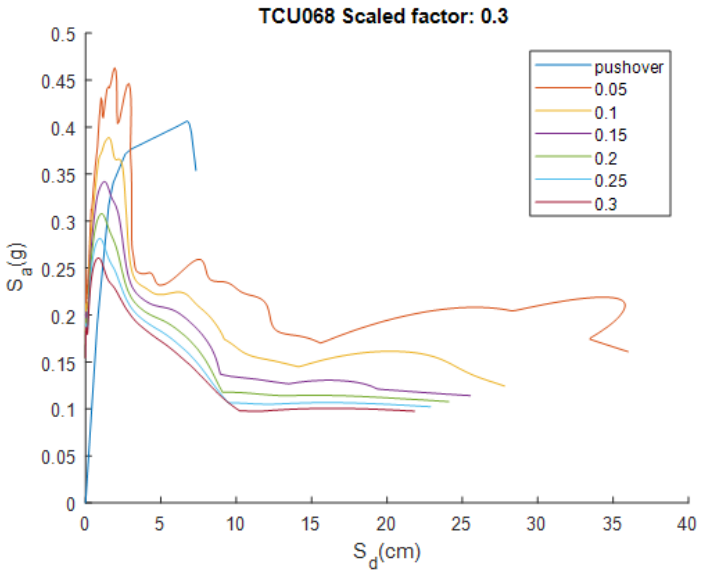


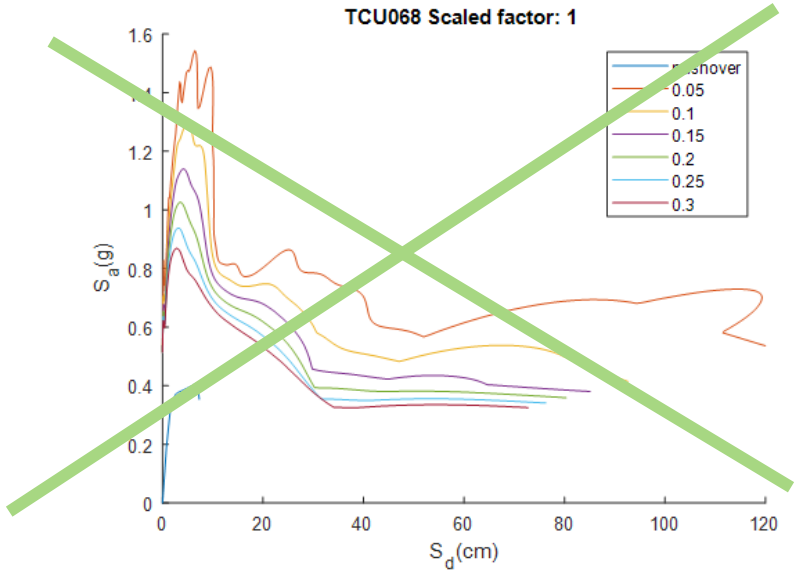
Sd

ATC-40


Design
pushover
0.05
0.1
0.15
0.2
0.25
0.3
S_a(g)
S_d(cm)


Service
pushover
0.05
0.1
0.15
0.2
0.25
0.3
S_a(g)
S_d(cm)


TCU068 Scaled factor: 0.3
pushover
0.05
0.1
0.15
0.2
0.25
0.3
S_a(g)
S_d(cm)


TCU068 Scaled factor: 1
0.05
0.1
0.15
0.2
0.25
0.3
S_a(g)
S_d(cm)

Procedure A

Different steps:

- Build a graphic with the Capacity Spectrum and the 5% Damped Response Spectrum
- Pick a random point on the Capacity spectrum (dpi,api)
- Build the Bilinear representation of Capacity Spectrum
- Calculate SRa and SRv

$$SRa = \frac{3{,}21 - 0{,}68\ln\left(\frac{6{,}37k(aydpi - dyapi)}{apidpi} + 5\right)}{2{,}12} \qquad SRv = \frac{2{,}31 - 0{,}41\ln\left(\frac{63{,}7k(aydpi - dyapi)}{apidpi} + 5\right)}{1{,}65}$$

where $k = 0{,}33$

- Find Sd $\quad Sd = \frac{Tod^2}{4\pi^2} \times Sds \times 981$ where $Tod = \frac{Sd1}{Sds}$
- Calculate new Ca and Cv

$$Ca = 0{,}4 \times Sds \times I \qquad Cv = 2{,}5 \times Tod \times Ca$$

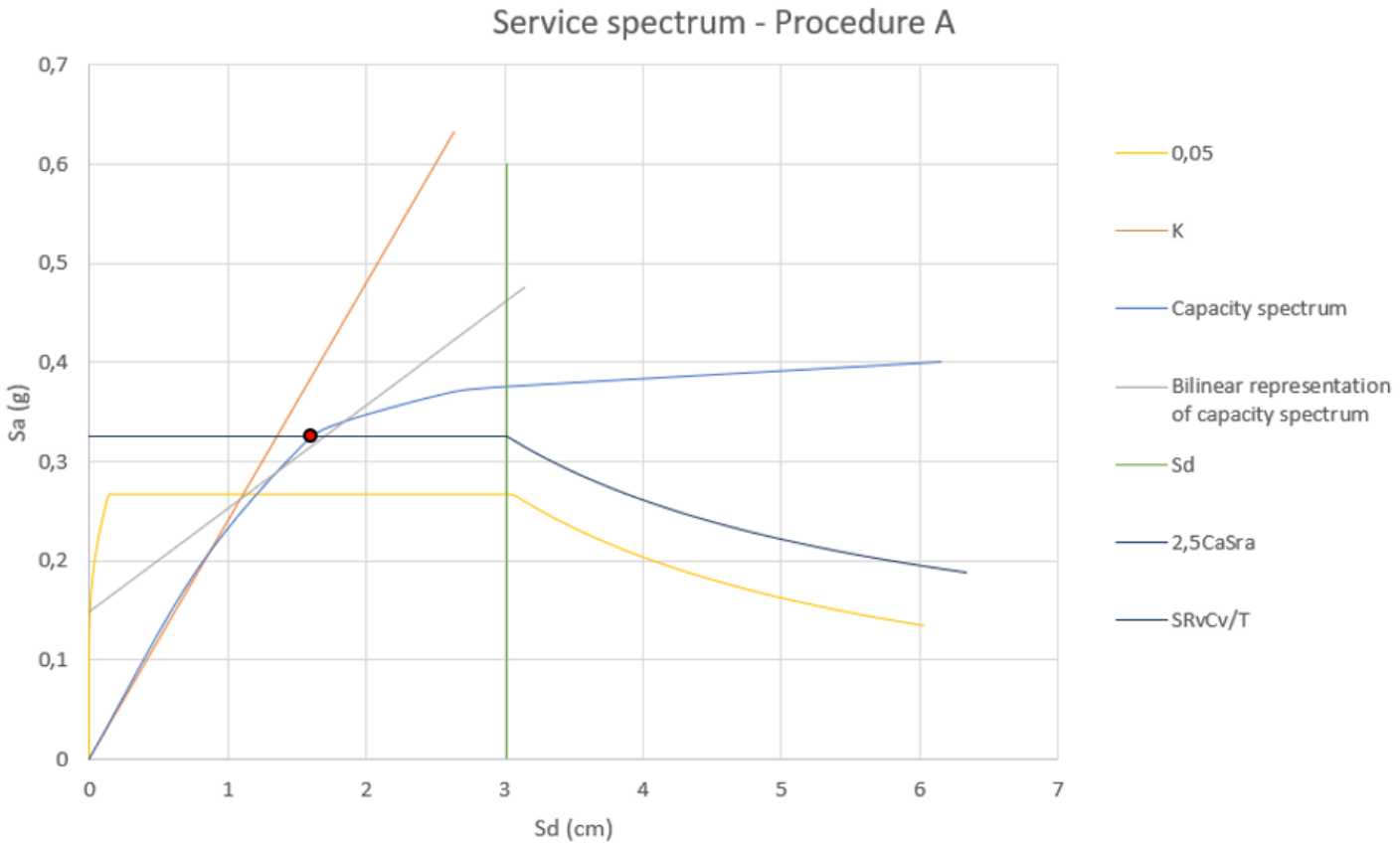
where $I = 1{,}25$

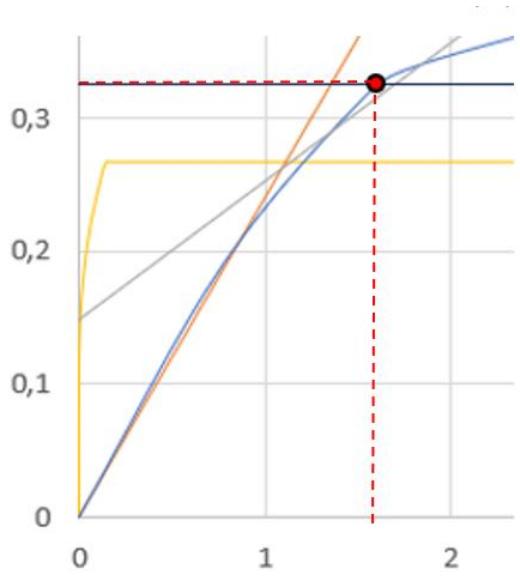
- Draw the new curve : on the left of Sd $\quad 2{,}5\mathrm{SRa}Ca$

  on the right of Sd $\quad \frac{SRvCv}{T}$
- Find the intersection between the new curve and the Capacity Spectrum

Procedure A

SERVICE SPECTRUM



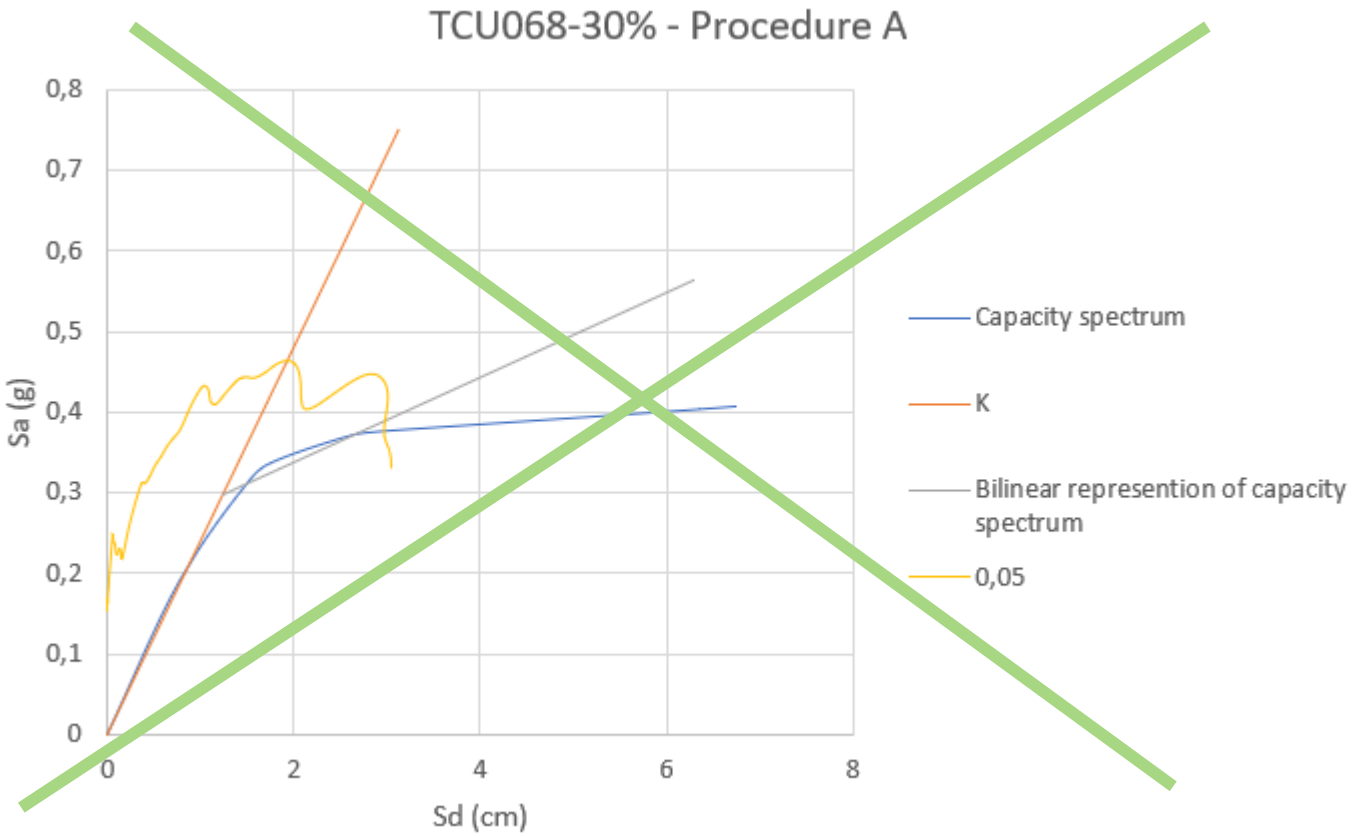


Performance point :

(1.59 , 0.33)

Procedure A

TCU068-30%



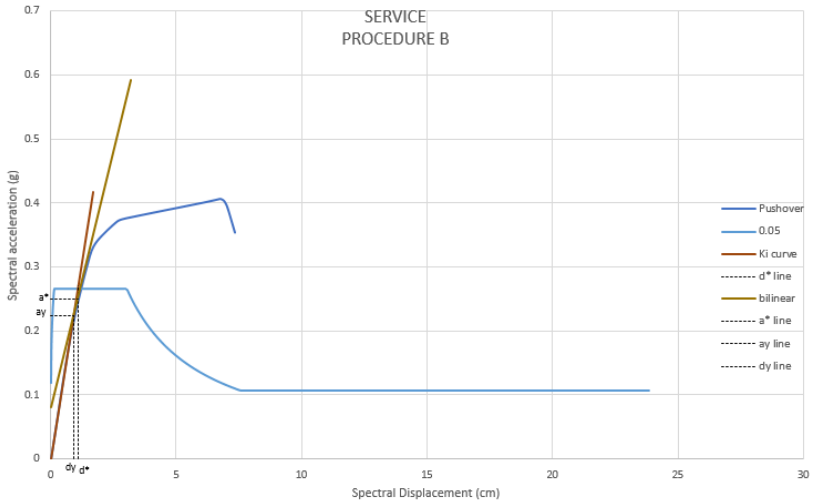
IMPOSSIBLE

No Performance point

Procedure B

Different steps:

- Build a graphic with the Capacity Spectrum and the 5% Damped Response Spectrum
- Add the 10%, 15%, 20%, 25% damped response spectrums
- Plot a bilinear representation of the capacity spectrum :
  - First line with a slope of Ki=0.33
  - Find d* and a*
  - Second line from (d*;a*), equalize A1 and A2 to get the slope
  - Find yield point on graph (intersection of 1st and 2nd line)
- Calculate a_{pi} for different d_{pi} values, using :



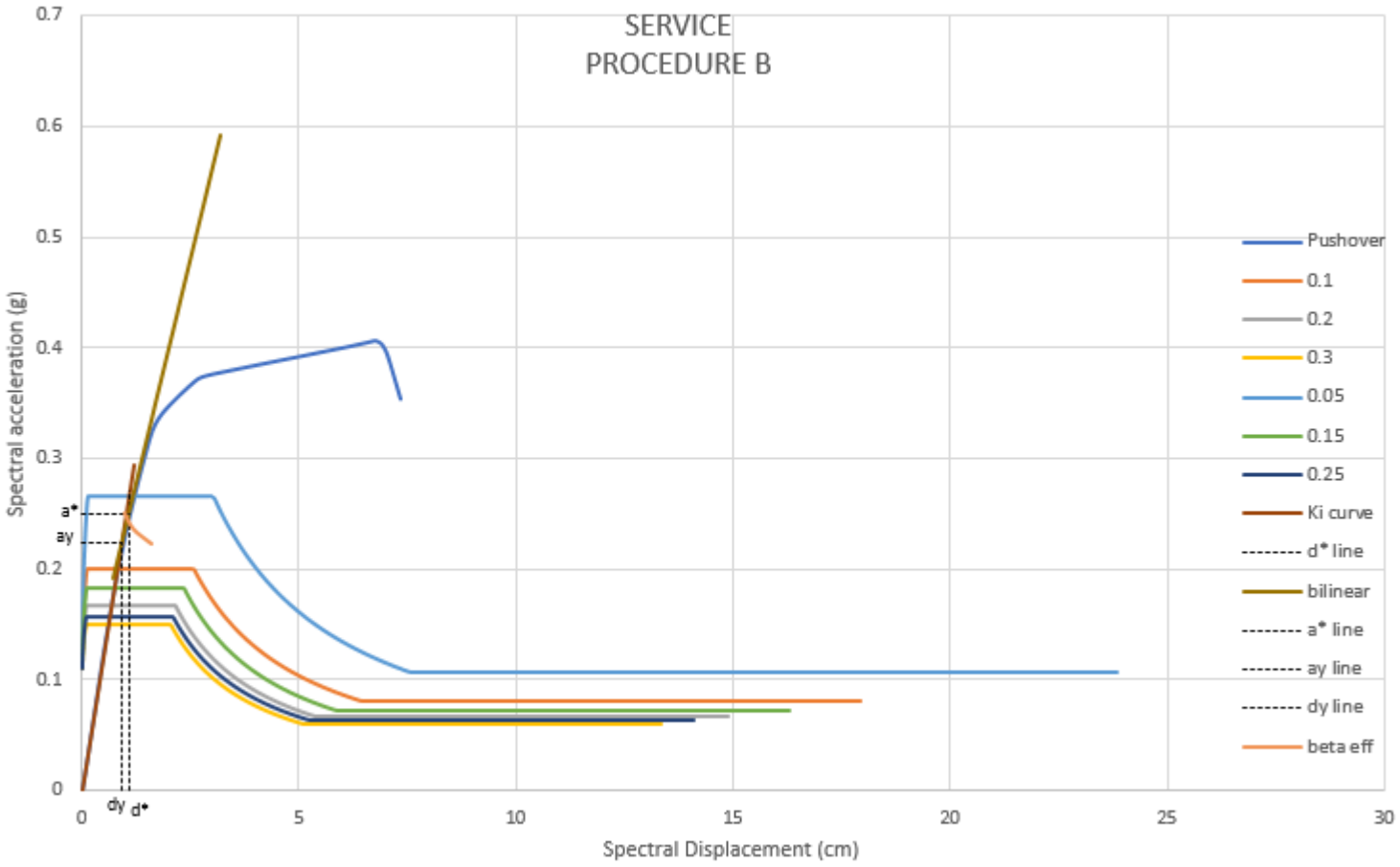
$$\frac{a^* - a_y}{d^* - d_y} = \frac{a_{pi} - a_y}{d_{pi} - d_y} \qquad a_{pi}' = \frac{(a^* - a_y)(d_{pi} - d_y)}{d^* - d_y} + a_y$$

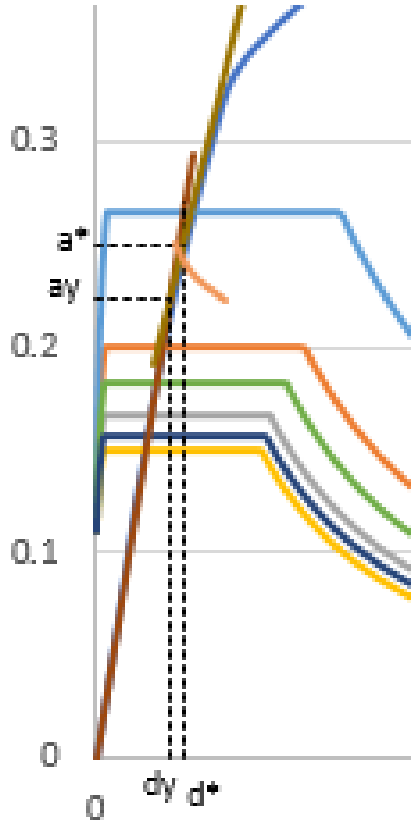
- Calculate B_{eff} for the (d_{pi};a_{pi}) points using : $\beta_{eff} = \frac{63.7\kappa(a_y d_{pi} - d_y a_{pi}')}{a_{pi}' d_{pi}} + 5$

- β_{eff} 、d_{pi} ⇨ demand curve with β_{eff} vs. Capacity curve ⇨ performance point

Procedure B

SERVICE SPECTRUM



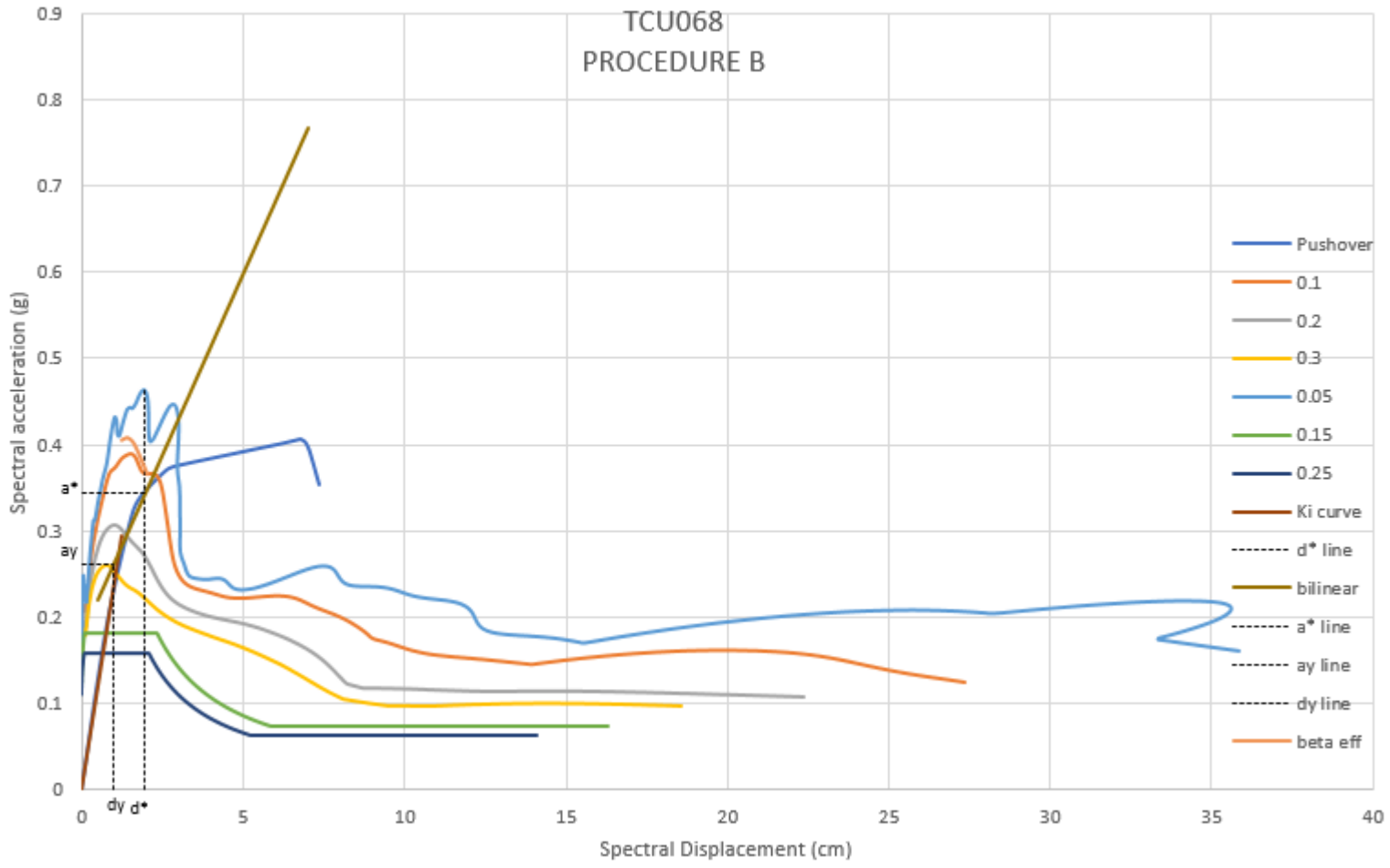


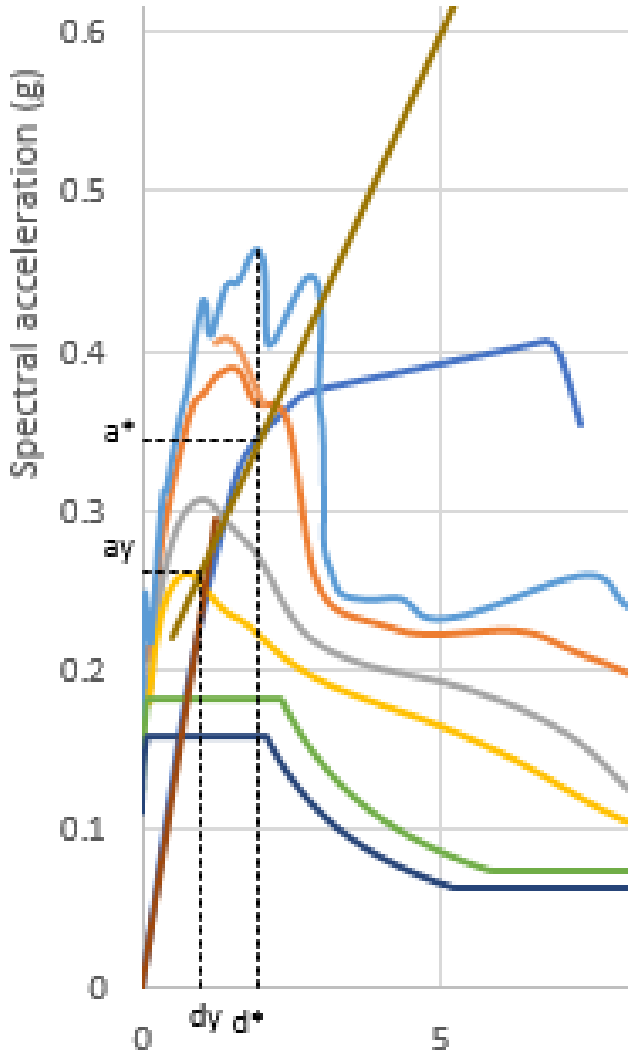
Performance point :

(1.1 , 0.258)

Procedure B

TCU068 – 30% SPECTRUM





Procedure C

Different steps:

- Build a graphic with the Capacity Spectrum and the 5% Damped Response Spectrum
- Pick a random point on the Capacity spectrum (dpi,api)
- Build the Bilinear representation of Capacity Spectrum
- Calculate α

$$\alpha = \frac{\frac{api}{ay} - 1}{\frac{dpi}{dy} - 1}$$

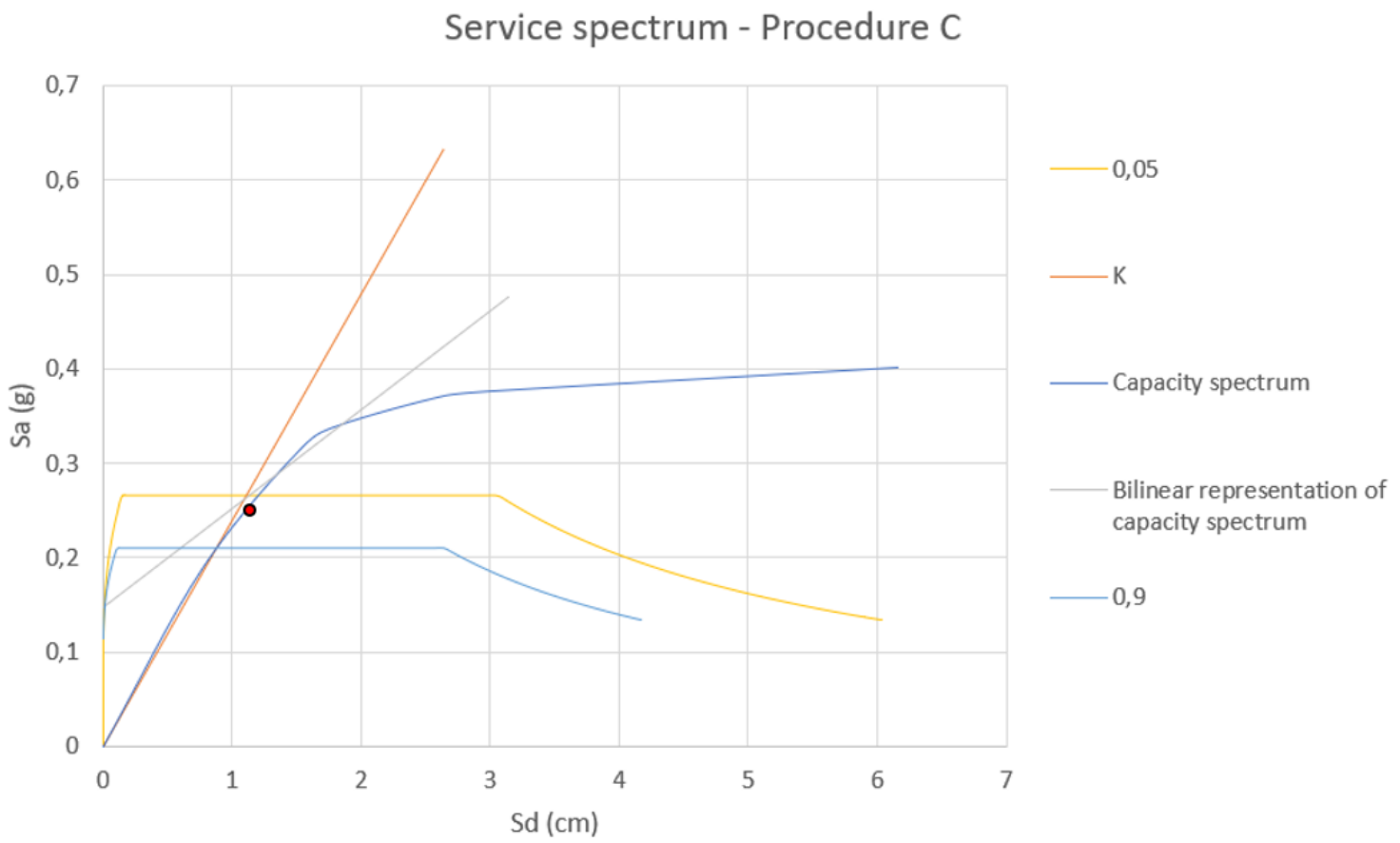
- Find the βeff in the table (for Type C)
- Draw a new curve for the new βeff
- Build 3 lines to find the performance point

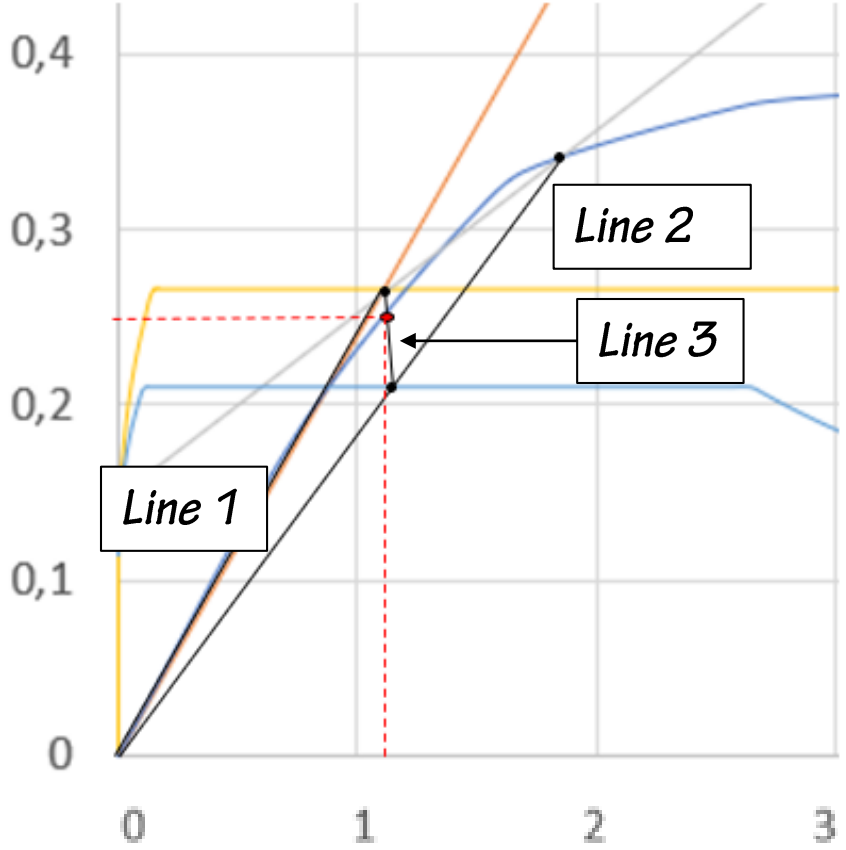
Table 8-7. Effective Damping, β_{eff}, in percent—Structural Behavior Type C

	Slope Ratio: $[(a_{pi}/a_y) - 1]/[(d_{pi}/d_y) - 1]$						
d_{pi}/d_y	0.5	0.4	0.3	0.2	0.1	0.05	0
10	7	7	9	10	14	17	20
8	7	8	9	11	15	18	20
6	7	9	10	12	16	18	20
4	8	9	11	13	16	18	20
3	9	10	11	13	16	17	19
2	9	10	11	12	14	15	16
1.5	8	9	9	10	11	11	11
1.25	7	7	8	8	9	9	9

Procedure C

SERVICE SPECTRUM



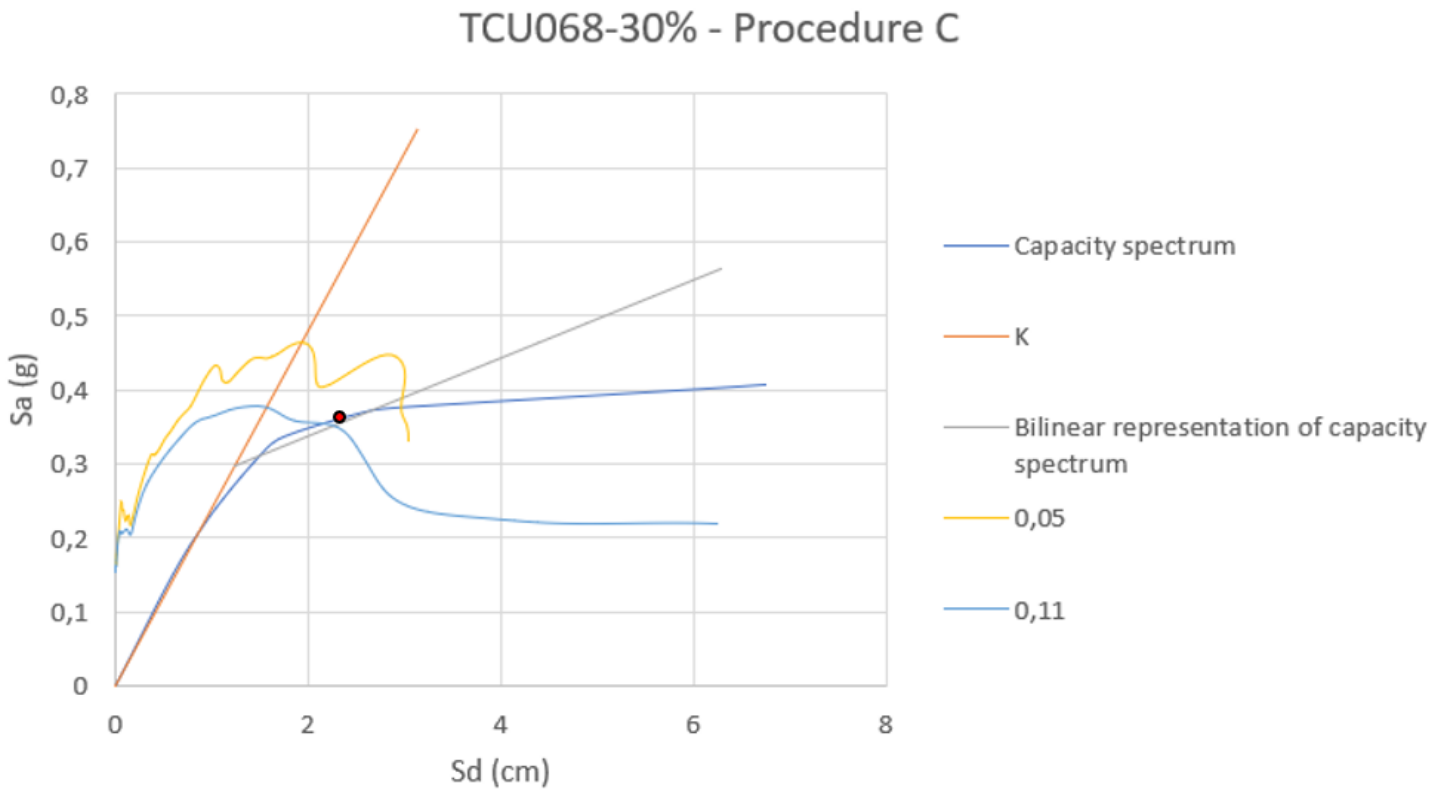


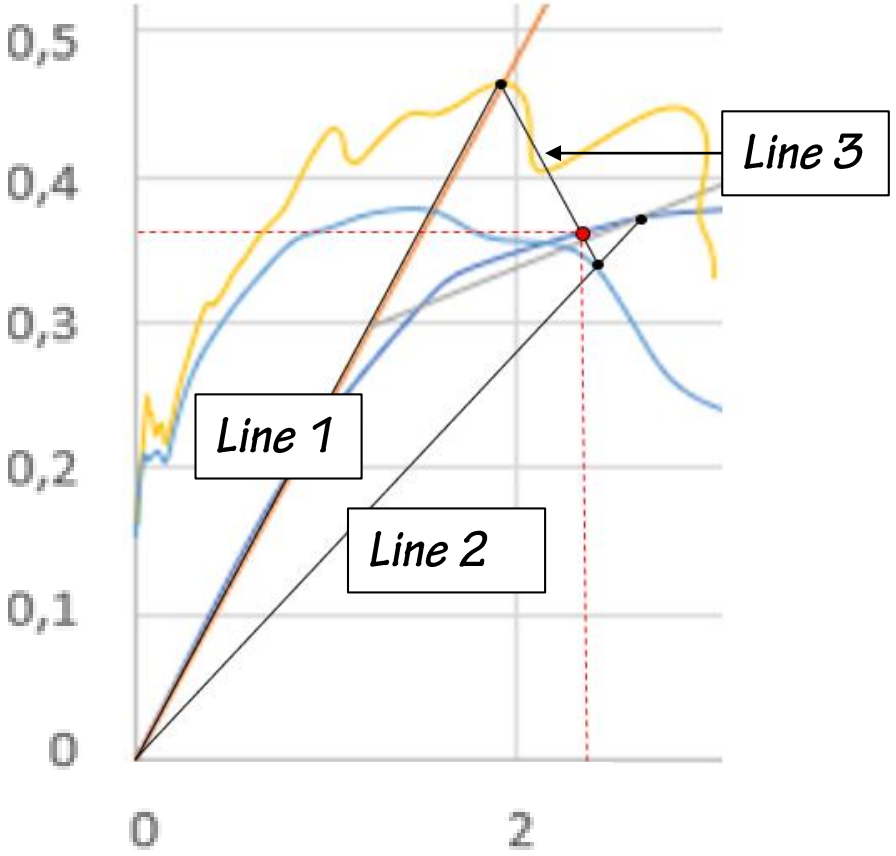
Performance point :

(1.14 , 0.253)

Procedure C

TCU068-30% Spectrum





Performance point :

(2.63 , 0.369)

Result analysis

	Design	Service	TCU068-30%	TCU068-100%
Procedure A	No performance point	(1.59 , 0.33)	No performance point	No performance point
Procedure B	No performance point	(1.1 , 0.258)	No performance point	No performance point
Procedure C	No performance point	(1.14 , 0.253)	(2.63 , 0.369)	No performance point

Damage level

SERVICE

	Sd (cm)	Δroof	Height of the building	Total drift (%)	Damage level
Procedure A	1,59	3,07347	770	0,399	Operational
Procedure B	1,1	2,1263	770	0,276	Fully Operational
Procedure C	1,14	2,20362	770	0,286	Fully Operational

$$Total\ drift = \frac{\Delta roof}{h} \times 100$$

Damage level

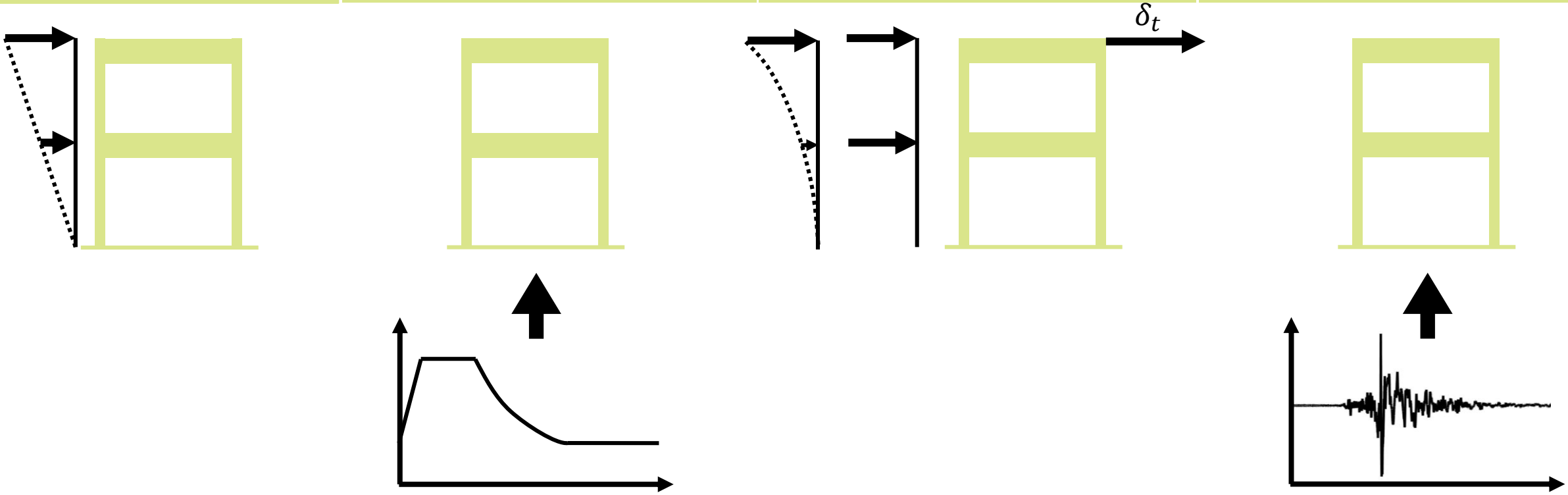
TCU068-30%

	Sd (cm)	Δroof	Height of the building	Total drift (%)	Damage level
Procedure A	No performance point		770		
Procedure B	No performance point		770		
Procedure C	2,63	5,084	770	0,7	Operational

$$Total\ drift = \frac{\Delta roof}{h} \times 100$$

FEMA273

Linear Static Procedure	Linear Dynamic Procedure	Nonlinear Static Procedure	Nonlinear Dynamic Procedure



FEMA273

Linear Static Procedure (LSP)

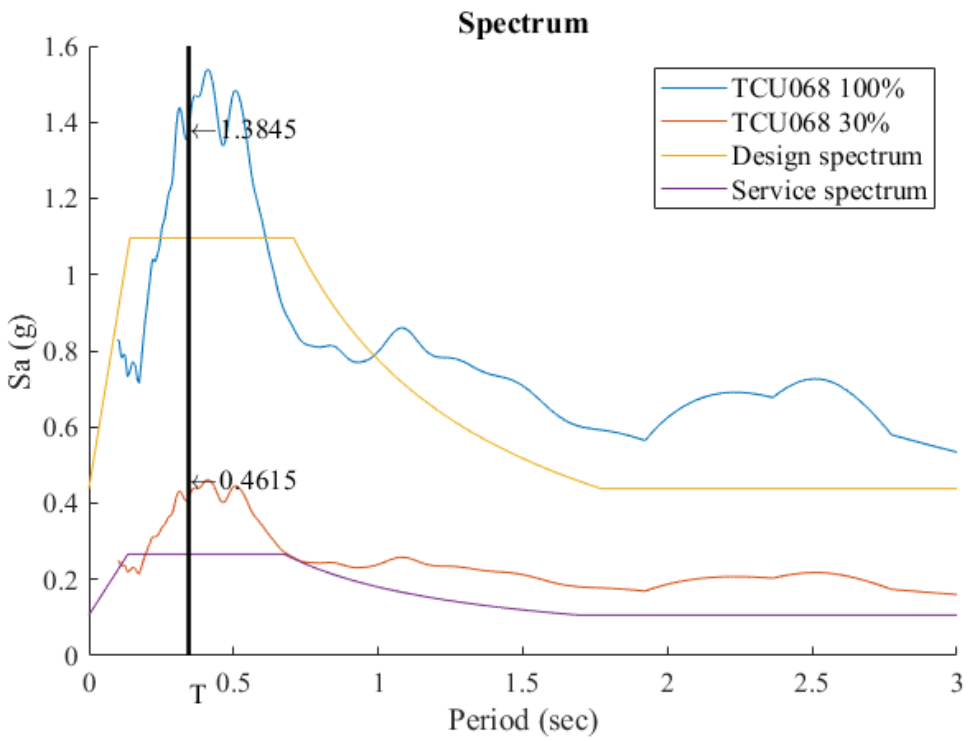
- Coefficient determination
- Lateral force distribution
- ETABS analysis
- Acceptable criteria

FEMA273

Linear Static Procedure (LSP)

- Coefficient determination $V = C_1 C_2 C_3 S_a W$

	Design EQ	Service EQ		
T_0	0.709	0.675		
T				
C1				
C2				
C3				
W				
Sa (g)	1.096	0.266	1.3845	0.4615
V (kg)	1953480.3	474111.1	2467694.8	822564.9



- Lateral force distribution
- ETABS analysis
- Acceptable criteria

FEMA273

Linear Static Procedure (LSP)

- Coefficient determination $V = C_1 C_2 C_3 S_a W$
- Lateral force distribution

$$C_{vx} = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k} \ , \ F_x = C_{vx} V$$

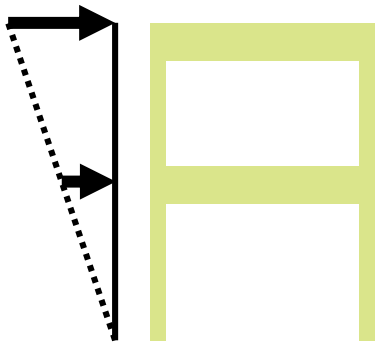
	Design EQ	Service EQ	TCU068 100%	TCU068 30%
V	1953480.3	474111.1	2467694.8	822564.9
C_{V1}		0.342		
C_{V2}		0.658		
F_1 (kg)	668090.3	162146.0	843951.6	281317.2
F_2 (kg)	1285390.0	311965.1	1623743.2	541247.7

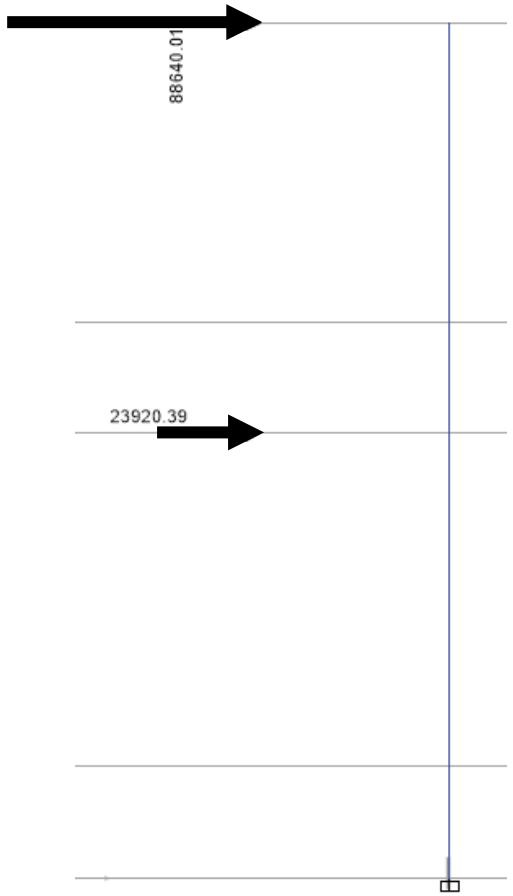
- ETABS analysis
- Acceptable criteria

FEMA273

Linear Static Procedure (LSP)

- Coefficient determination $V = C_1 C_2 C_3 S_a W$
- Lateral force distribution $F_x = C_{vx} V$
- ETABS analysis





- Acceptable criteria

FEMA273

Linear Static Procedure (LSP)

- Coefficient determination $V = C_1 C_2 C_3 S_a W$
- Lateral force distribution $F_x = C_{vx} V$
- ETABS analysis
- Acceptable criteria $mkQ_{CE} > Q_{UD}$

i. Beams controlled by flexure[1]

$\frac{\rho - \rho'}{\rho_{bal}}$	Trans. Reinf.[2]	$\frac{V}{b_w d \sqrt{f'_c}}$

i. Columns controlled by flexure[1]

$\frac{P}{A_g f'_c}$	Trans. Reinf.[2]	$\frac{V}{b_w d \sqrt{f'_c}}$

Life Safety

1.0

M_P from Xtract

M_3 from Etabs

FEMA273

Linear Static Procedure (LSP)

- Coefficient determination $V = C_1 C_2 C_3 S_a W$
- Lateral force distribution $F_x = C_{vx} V$
- ETABS analysis
- Acceptable criteria $mkQ_{CE} > Q_{UD}$

Beam *acceptance*

	DBE	SLE	TCU068 100%	TCU068 30%
1B1	100%	100%	100%	100%
1B2,2B2	100%	100%	100%	100%
1B3,2B3	100%	100%	98%	100%
2B1	100%	100%	100%	100%
2B4	100%	100%	100%	100%
1B4	100%	100%	100%	100%
CB	100%	100%	100%	100%

Column *acceptance*

	DBE	SLE	TCU068 100%	TCU068 30%
1C1	0%	100%	0%	0%
1C2	0%	100%	0%	70%
1C3	0%	0%	0%	0%
2C1	0%	100%	0%	20%
2C2	10%	100%	0%	60%
2C3	0%	100%	0%	100%

FEMA273

Linear Dynamic Procedure (LDP)

- Coefficient determination
- ETABS analysis
- Acceptable criteria

FEMA273

Linear Dynamic Procedure (LDP)

- Coefficient determination

Modification factor = $C_1 \times C_2 \times C_3$

	Design EQ	Service EQ	TCU068 100%	TCU068 30%
T_0	0.709	0.675	0.709	0.675
T		0.345		
C1		1.299		
C2		1.219		
C3		1		
Factor		1.584		

- ETABS analysis
- Acceptable criteria

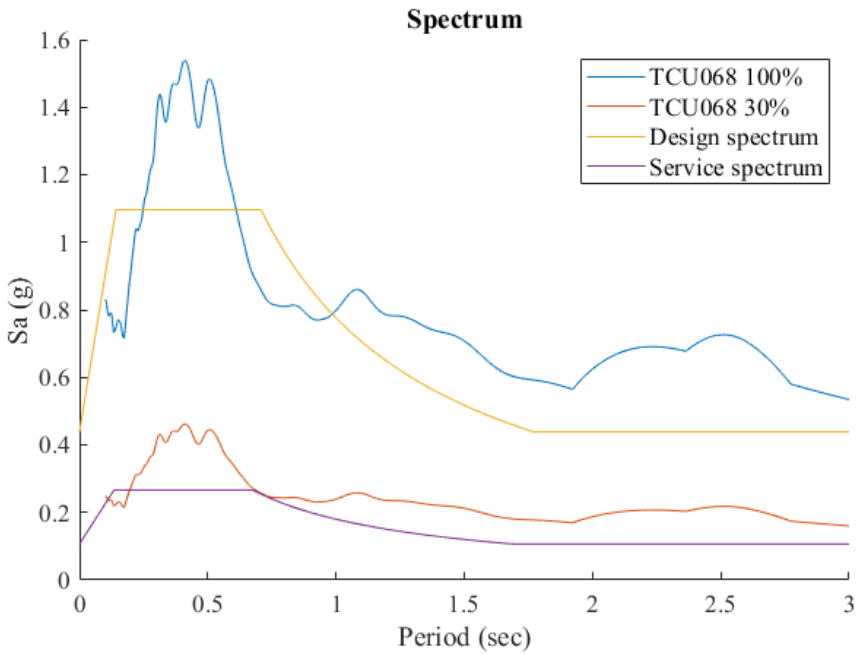
FEMA273

Linear Dynamic Procedure (LDP)

- Coefficient determination

Modification factor = $C_1 \times C_2 \times C_3 = 1.584$

- ETABS analysis



Response spectrum analysis

- Acceptable criteria

FEMA273

Linear Dynamic Procedure (LDP)

- Coefficient determination
- ETABS analysis
- Acceptable criteria

Modification factor = $C_1 \times C_2 \times C_3 = 1.584$

$mkQ_{CE} > Q_{UD}$

Beam acceptance

	DBE	SLE	TCU068 100%	TCU068 30%
1B1	100%	100%	100%	100%
1B2,2B2	100%	100%	100%	100%
1B3,2B3	100%	100%	96%	100%
2B1	100%	100%	100%	100%
2B4	100%	100%	100%	100%
1B4	100%	100%	100%	100%
CB	100%	100%	100%	100%

Column acceptance

	DBE	SLE	TCU068 100%	TCU068 30%
1C1	0%	100%	0%	10%
1C2	0%	100%	0%	70%
1C3	0%	0%	0%	0%
2C1	0%	100%	0%	20%
2C2	20%	100%	0%	60%
2C3	71%	100%	0%	100%

FEMA273

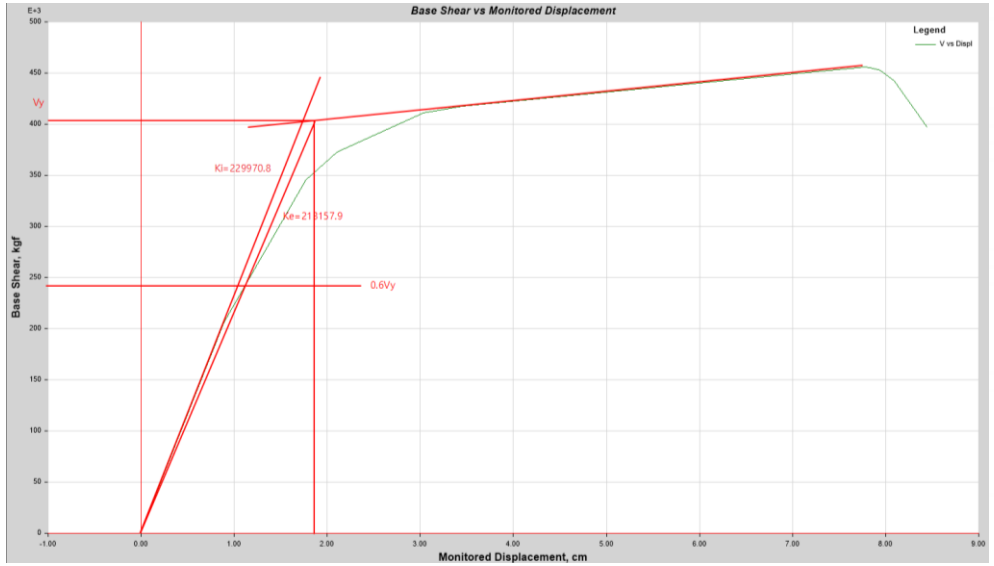
Nonlinear Static Procedure (NSP)

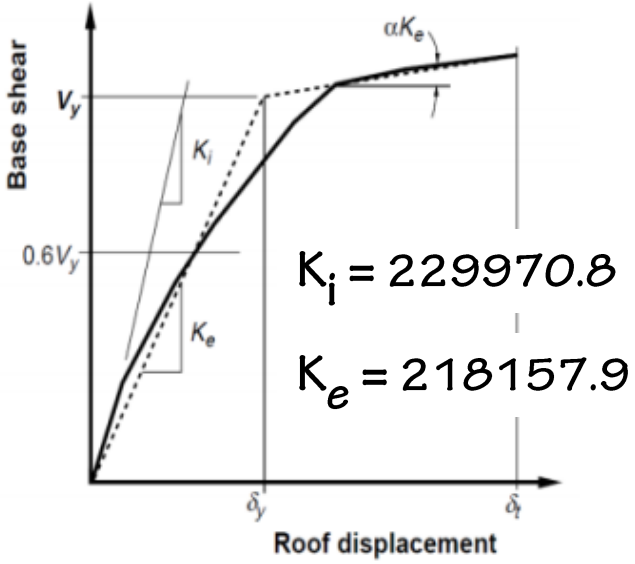
- Coefficient determination
- Target displacement determination
- ETABS analysis
- Acceptable criteria

FEMA273

Nonlinear Static Procedure (NSP)

- Coefficient determination $T_e = T_i \sqrt{\frac{K_i}{K_e}}$





	code	Etabs
T_0	0.345	0.398
T_e	0.364	0.420

- Target displacement determination
- ETABS analysis
- Acceptable criteria

FEMA273

Nonlinear Static Procedure (NSP)

- Coefficient determination $T_e = T_i\sqrt{\frac{K_i}{K_e}} = 0.364$
- Target displacement determination $\delta_t = C_0 C_1 C_2 C_3 S_a W \frac{T_e^2}{4\pi^2} g$, $R = \frac{S_a}{V_y/W} \times \frac{1}{C_0}$

	Design EQ	Service EQ	TCU068 100%	TCU068 30%
T_0	0.7095	0.675	0.7095	0.675
R	2.537	0.616	3.205	1.068
Sa (g)	1.096	0.266	1.3845	0.4615
W (kg)	1125604			
Te	0.364			
Vy (kg)	405153			
C_0	1.2			
C_1	1.575	0.467	1.653	1.055
C_2	1.219			
C_3	1			
delta t	8.314	0.598	11.022	2.344

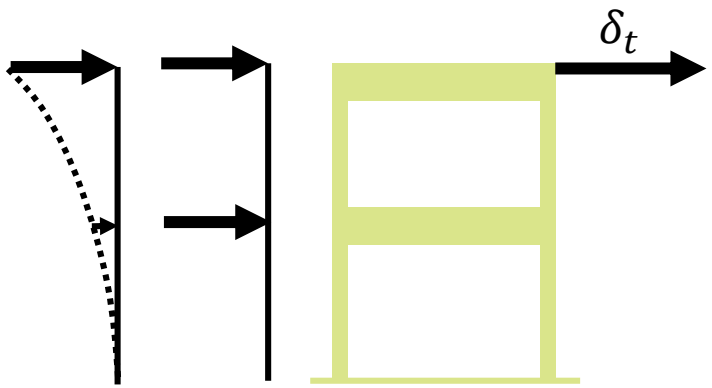
(cm)

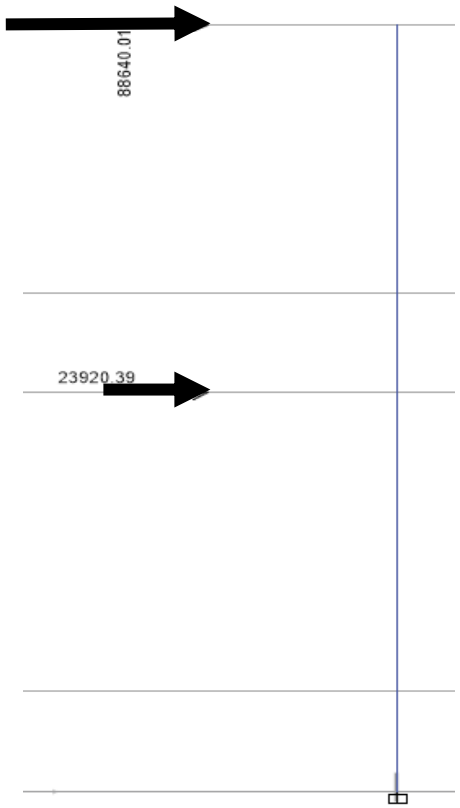
- ETABS analysis
- Acceptable criteria

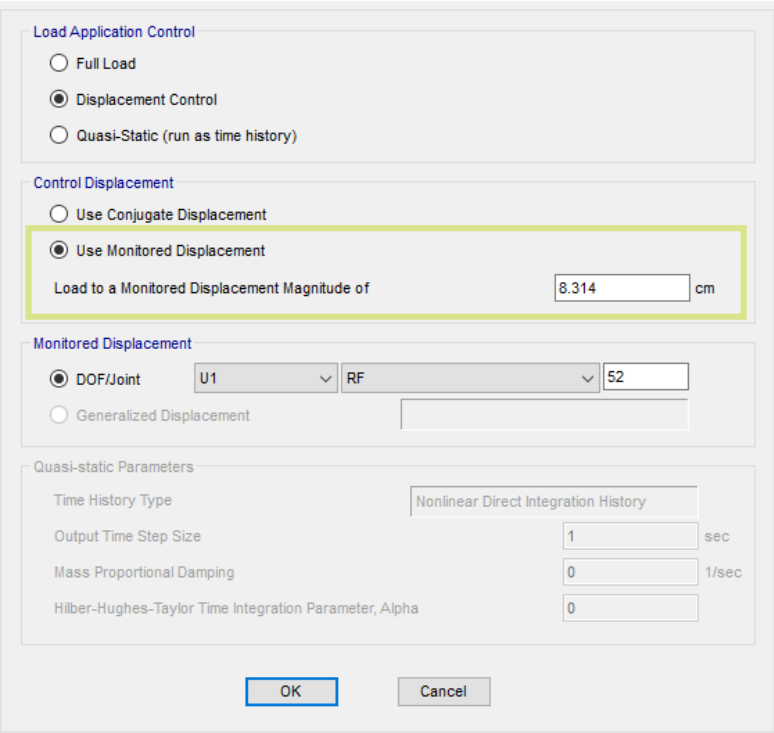
FEMA273

Nonlinear Static Procedure (NSP)

- Coefficient determination $T_e = T_i\sqrt{\frac{K_i}{K_e}} = 0.364$
- Target displacement determination $\delta_t = C_0 C_1 C_2 C_3 S_a W \frac{T_e^2}{4\pi^2} g$, $R = \frac{S_a}{V_y/W} \times \frac{1}{C_0}$
- ETABS analysis







- Acceptable criteria

FEMA273

Nonlinear Static Procedure (NSP)

- Coefficient determination $T_e = T_i \sqrt{\frac{K_i}{K_e}} = 0.364$
- Target displacement determination $\delta_t = C_0 C_1 C_2 C_3 S_a W \frac{T_e^2}{4\pi^2} g$, $R = \frac{S_a}{V_y/W} \times \frac{1}{C_0}$
- ETABS analysis
- Acceptable criteria $mkQ_{CE} > Q_{UD}$

Beam *acceptance*

	DBE	SLE	TCU068 100%	TCU068 30%
1B1	100%	100%	100%	100%
1B2,2B2	100%	100%	100%	100%
1B3,2B3	100%	100%	100%	100%
2B1	100%	100%	100%	100%
2B4	100%	100%	100%	100%
1B4	100%	100%	100%	100%
CB	100%	100%	100%	100%

Column *acceptance*

	DBE	SLE	TCU068 100%	TCU068 30%
1C1	0%	100%	0%	100%
1C2	0%	100%	0%	100%
1C3	0%	100%	0%	0%
2C1	100%	100%	100%	100%
2C2	100%	100%	100%	100%
2C3	100%	100%	100%	100%

FEMA273

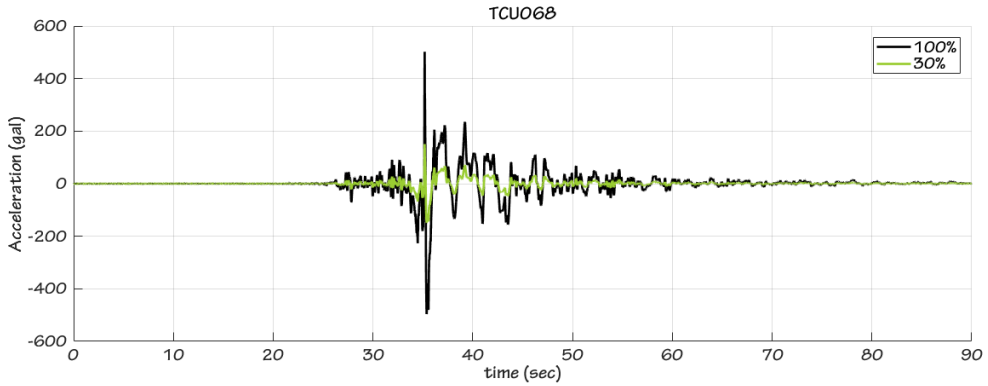
Nonlinear Dynamic Procedure (NDP)

- ETABS analysis
- Acceptable criteria

FEMA273

Nonlinear Dynamic Procedure (NDP)

- ETABS analysis



Nonlinear time history analysis

- Acceptable criteria

FEMA273

Nonlinear Dynamic Procedure (NDP)

- ETABS analysis
- Acceptable criteria

	Beam acceptance	
	TCU068 100%	TCU068 30%
1B1	100%	100%
1B2,2B2	100%	100%
1B3,2B3	100%	100%
2B1	100%	100%
2B4	100%	100%
1B4	100%	100%
CB	100%	100%

	Column acceptance	
	TCU068 100%	TCU068 30%
1C1	100%	100%
1C2	100%	100%
1C3	0%	29%
2C1	100%	100%
2C2	100%	100%
2C3	100%	100%

FEMA273

Summary

1. Focus on destruction level, the result TCU068100% > design earthquake > service earthquake which match the Sa calculated from each spectrum.

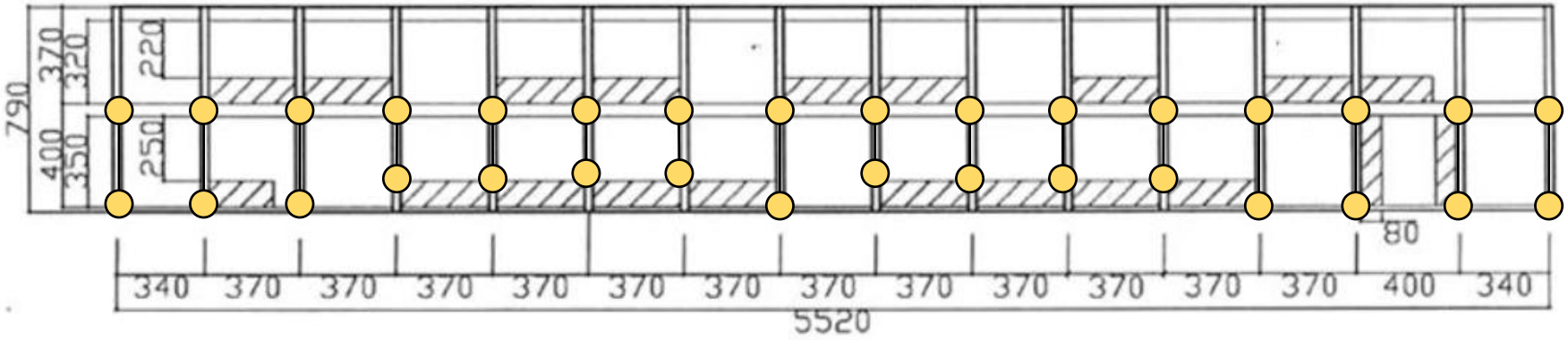
2. Comparing the above three methods, we found that most of damage occurs on the first floor columns. So we concluded the first floor is the weak floor.

3. Comparing the columns with the beams, we found that the building didn't achieve the regulation which is called 'weak beam strong column'.

Upper bound method

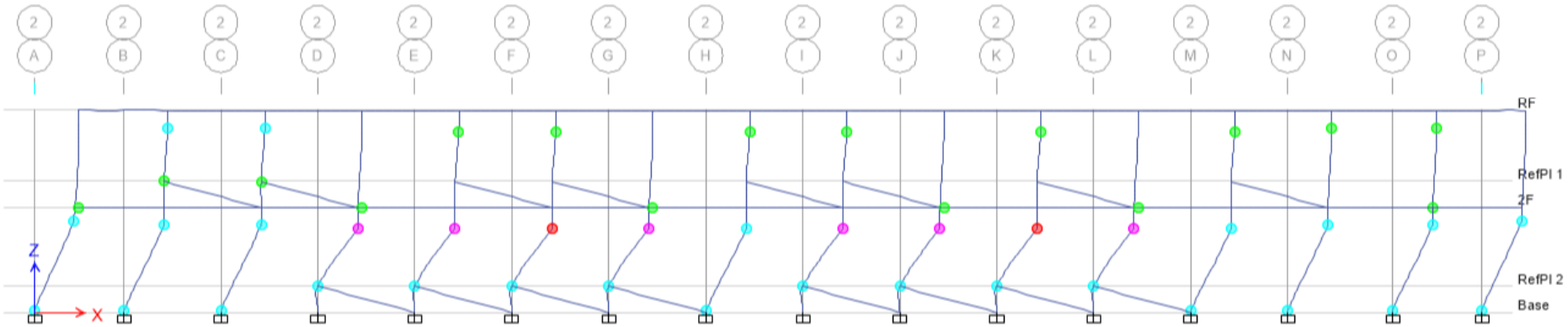
Assumption

1. The story drift on 2F is small enough to be neglected.
2. Neglect the effect on plastic hinge from 2F beam and column.
3. Only 1F panel mechanism.
4. Using Xtract to define the Mp and using TEASPA to define location of plastic hinge.
5. Compare with and without the brick wall.

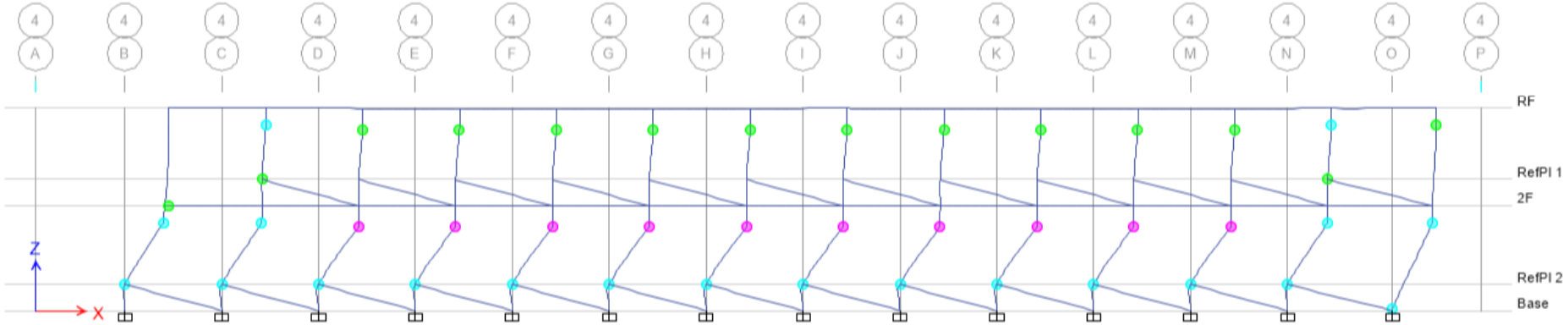


Upper bound method

Location of plastic hinge



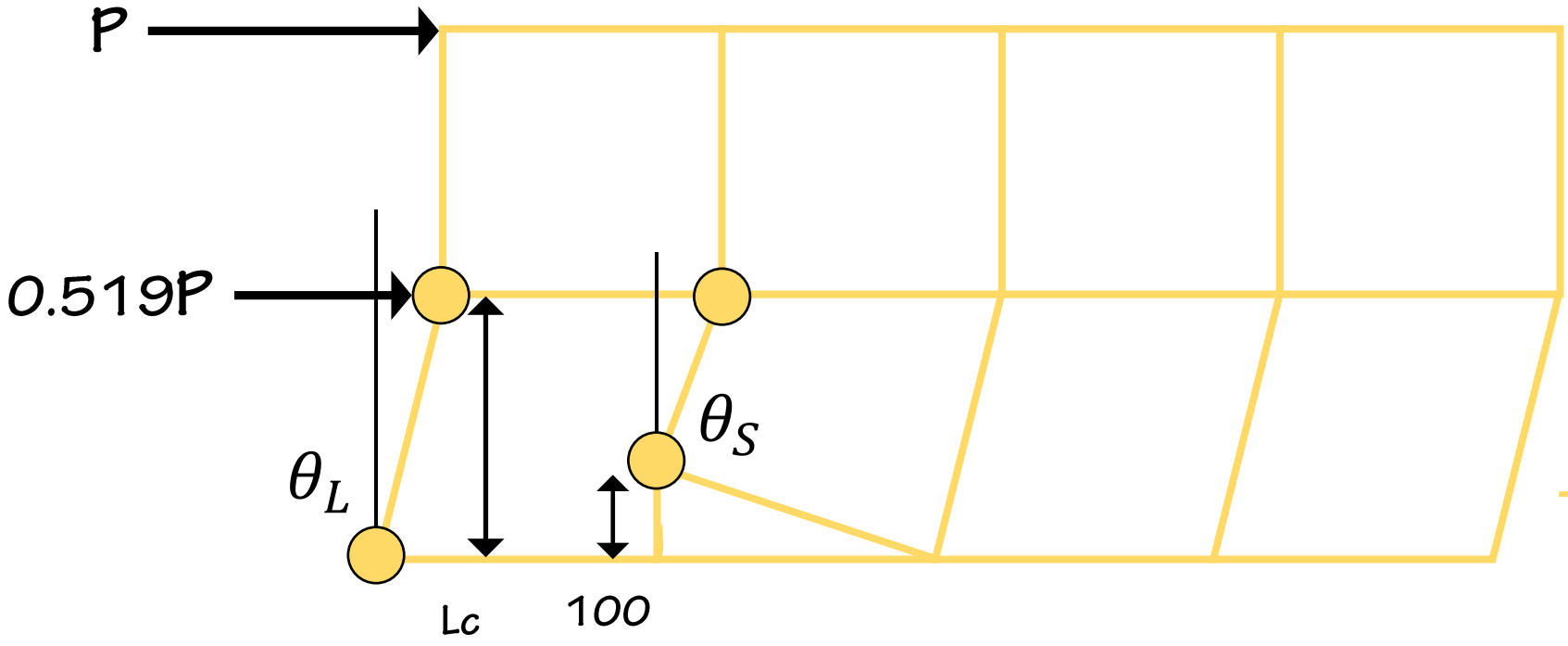
Elevation A



Elevation C

Upper bound method

Calculation



Mp	kN-m
1C1	118.1
1C2	101.8
1C3	41.6

$$\theta_S \times L_C = \theta_L \times (L_C + 100)$$

Upper bound method

Calculation with brick wall

$$\sum P_i h_i \delta\theta_i = P(400 \times \theta_L) + 0.519P(400 \times \theta_L) = 607.6P\theta_L$$

$$V_{pushover} = 456065kg$$

with brick wall

$$\sum (M_{p,i}\delta\theta_{S,i}) + \sum (M_{p,i}\delta\theta_{L,i}) = 11117364\theta_L$$

$$V_{upperbound} = (1 + 0.519)P = 1.519 \times 182971.7 = 277934.1\ kg$$

without brick wall

$$\sum (M_{p,i}\delta\theta_{S,i}) = 94274000\theta_L$$

$$V_{upperbound} = (1 + 0.519)P = 1.519 \times 155157.9 = 235685.8\ kg$$

Upper bound method

Comparison

Mp	Brick wall	$V_{upperbound}$	$V_{pushover}$	error
TEASPA	O	277934.1	456065	64%
	X	235685.8	325787	36%
XTRACT	O	204396.7	456065	123%
	X	183560.2	325787	78%

Upper bound method

Summary

1. Ultimate moment of section is underestimated by Xtract.

2. Using Mp calculated by TEASPA can get lager shear force.

3. Upper bound method is the simplified hand calculation method so the building should be a simple frame structure. therefore, the calculated results without brick wall are all better than that with brick wall.

Conclusion

1. ATC-40
2. Using dynamic procedure method in FEMA273, we found that the destruction level is similar to the actual building which all columns are collapsed.
3. Using upper bound method without considering the effect from the brick wall can get more accurate results.

Thank you for attention.