NARLabs 國家實驗研究院
國家地震工程研究中心

2016建築物耐震評估與補強技術講習會

耐震能力詳細評估之介紹(TEASPA)

主講人：周德光

May 13, 2016

NCREE

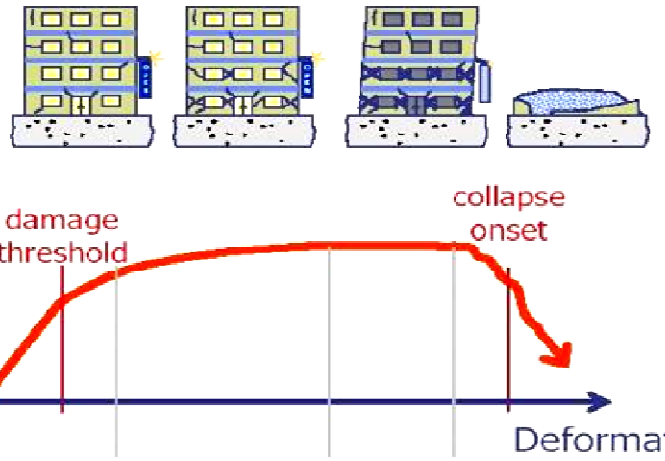
簡報大綱

- 前言
- 分析模型
- 模型建立
- 設定非線性鉸
- 輔助分析程式

前言

前言

- 建立建築物之數值模型
  - 柱、梁構件 → 彎矩與剪力非線性鉸
  - 磚牆 → 等值斜撐模擬
  - RC 牆 → 等值寬柱模擬
- 以 ETABS 軟體分析建築物之容量曲線
- 將建築物之容量曲線轉換為容量震譜求得性能目標地表加速度

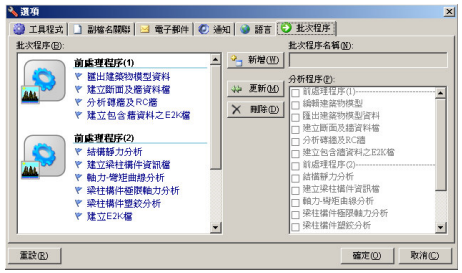


臺灣耐震評估方法

- **TEASPA**
  - **Taiwan Earthquake Assessment for Structures by Pushover Analysis**

臉書粉絲專頁：
https://www.facebook.com/groups/1420428518211927/

- **SERCB**
  - **Seismic Evaluation of Reinforced Concrete Building**

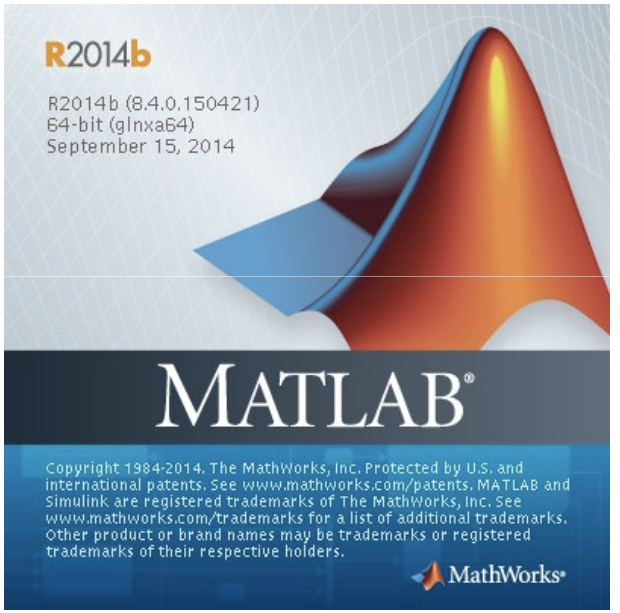


技術交流網頁：
http://sercb.dyndns.org/SERCBWeb/Default.aspx

TEASPA 分析方法所需工具

- **CSI ETABS (8.0 以上版本)**

- **MATLAB 或 MCR Installer**



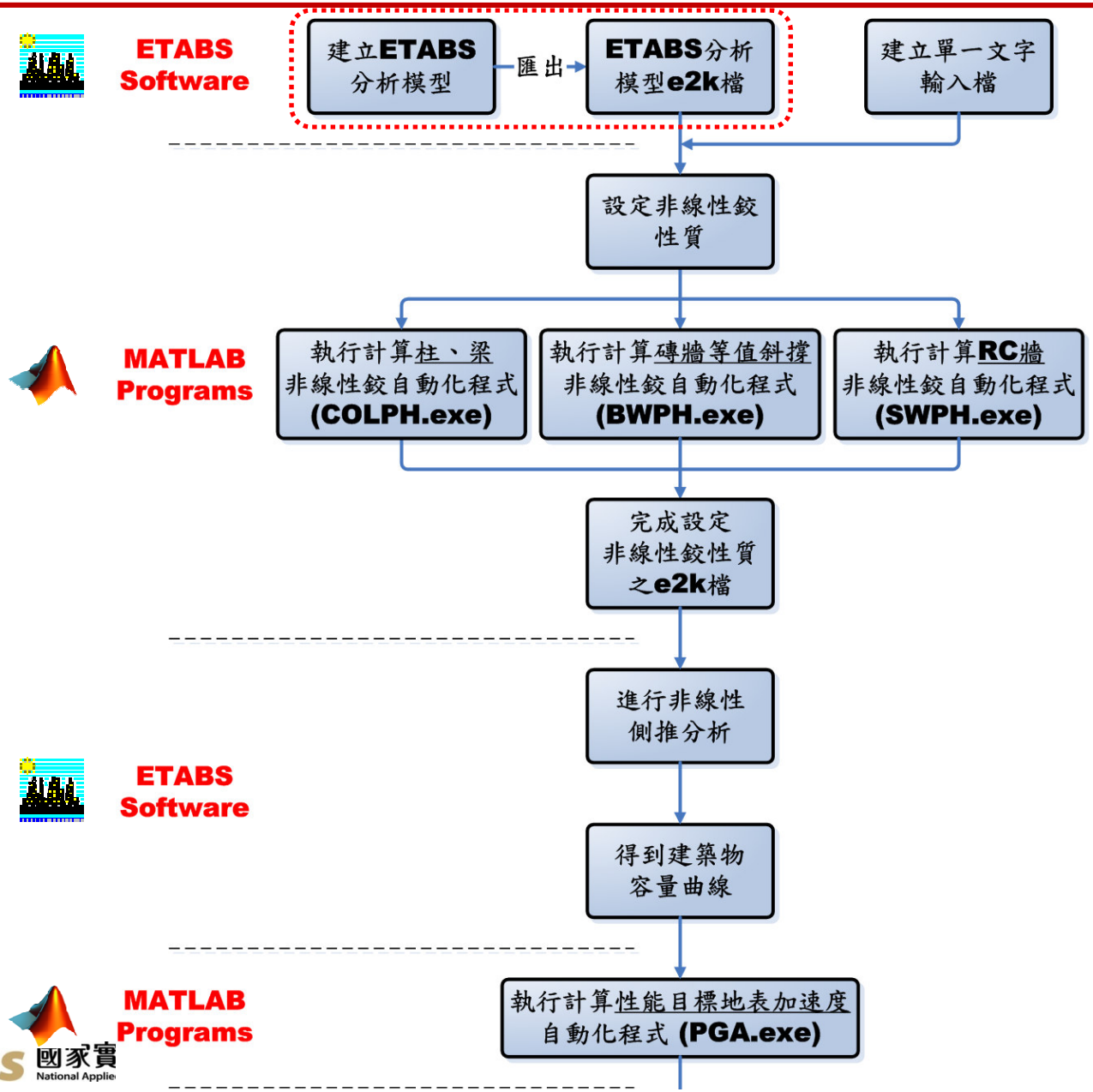
TEASPA 耐震評估方法

https://www.facebook.com/groups/1420428518211927/

- 討論區
- 最新活動
- 檔案下載
  - 技術手冊
  - 示範例模型
  - 講習會簡報
  - MCR Installer
    - 32 位元
    - 64 位元
  - 輔助分析程式
    - 32 位元
    - 64 位元

分析模型

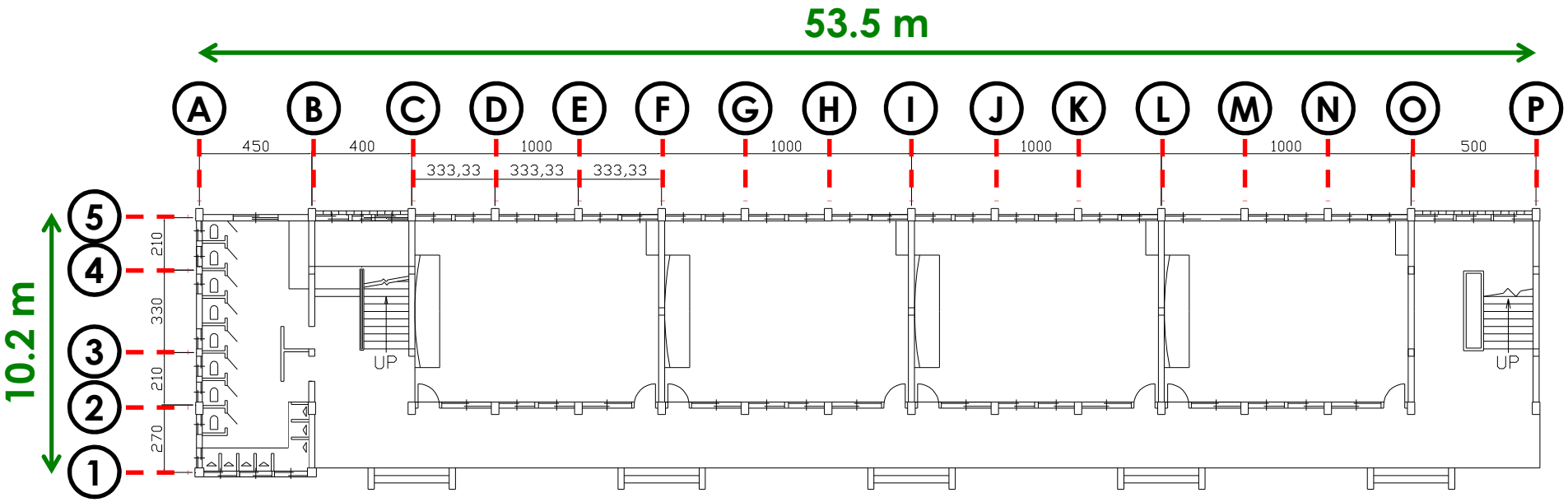
TEASPA 分析流程


ETABS Software
建立ETABS分析模型
匯出
ETABS分析模型e2k檔
建立單一文字輸入檔
設定非線性鉸性質
MATLAB Programs
執行計算柱、梁非線性鉸自動化程式 (COLPH.exe)
執行計算磚牆等值斜撐非線性鉸自動化程式 (BWPH.exe)
執行計算RC牆非線性鉸自動化程式 (SWPH.exe)
完成設定非線性鉸性質之e2k檔
進行非線性側推分析
ETABS Software
得到建築物容量曲線
MATLAB Programs
執行計算性能目標地表加速度自動化程式 (PGA.exe)

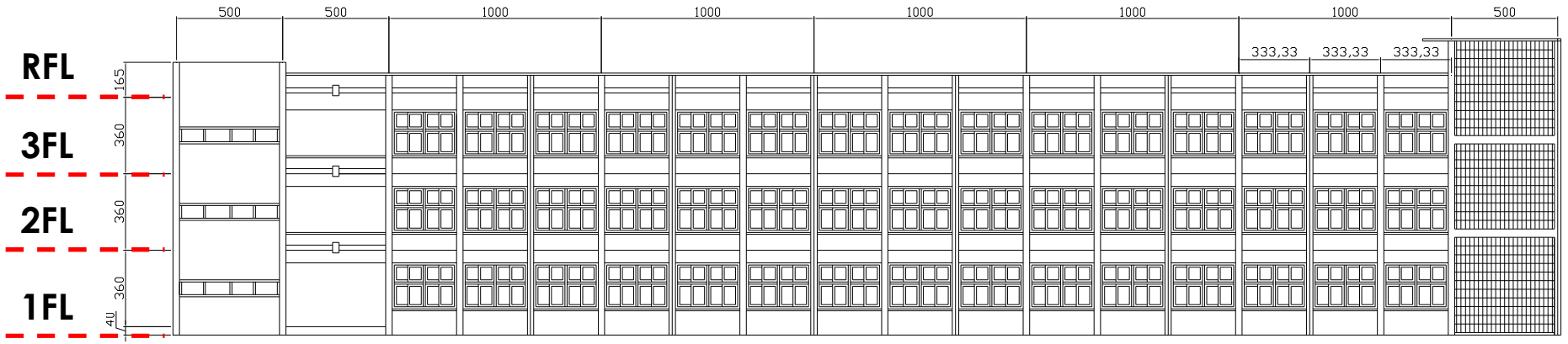
建立分析模型時所需資料

- 結構圖說：
  - 平面圖、立面圖、配筋圖、結構平面圖...
- 外觀照片：
  - 正面、背面、左右側面...
- 材料強度：
  - 鋼筋、混凝土、紅磚、水泥砂漿...
- 現場勘查：
  - 建築物現況、磚牆尺寸、窗台高度...

平、立面圖


53.5 m
A B C D E F G H I J K L M N O P
450 400 1000 1000 1000 1000 1000 500
333,33 333,33 333,33
5 4 3 2 1
10.2 m
210 330 210 270
UP
UP

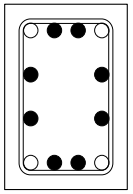
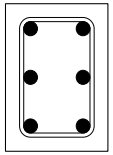
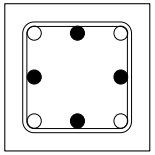
平面圖

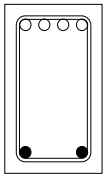
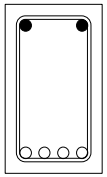
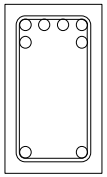
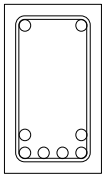
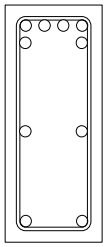
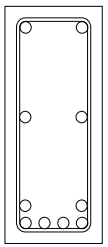

500 500 1000 1000 1000 1000 1000 1000 500
333,33 333,33 333,33
RFL
3FL
2FL
1FL
165 360 360 360
40

立面圖

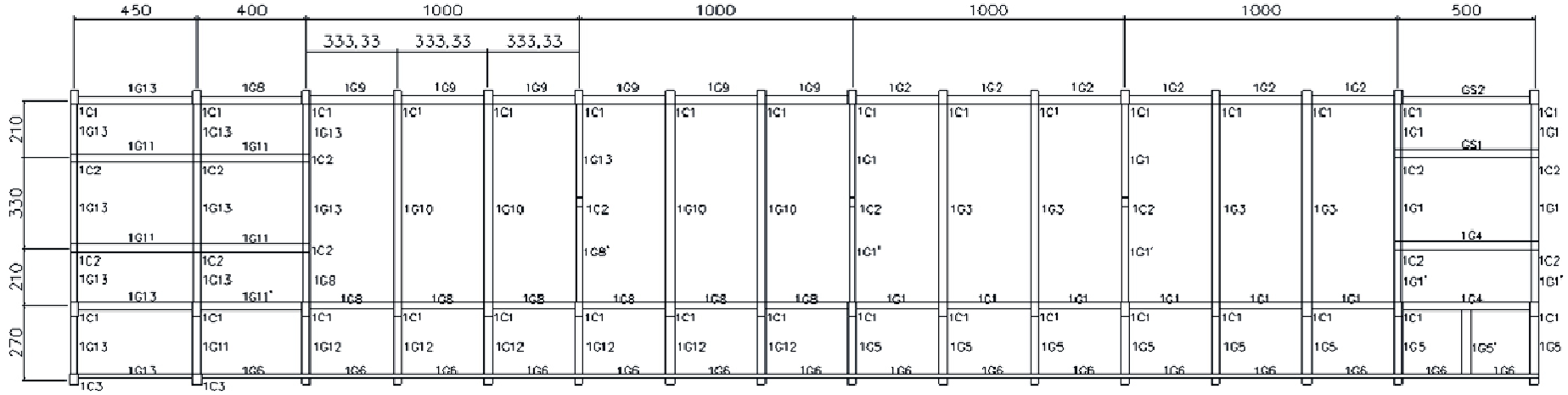
配筋圖

單位：cm

柱編號	C1	C2	C3
斷面			
主筋	∘4-D22 ●8-D19	●6-D16	∘4-D19 ●4-D16
箍筋	D10@25	D10@25	D10@25
尺寸	30x50	24x30	36x36

梁編號	G1		G2		G3	
斷面	兩端	中央	兩端	中央	兩端	中央
						
主筋	∘4-D19 ●2-D16		∘8-D22		∘10-D22	
箍筋	D10@25		D10@25		D10@25	
尺寸	24x60		30x60		30x90	

結構平面圖

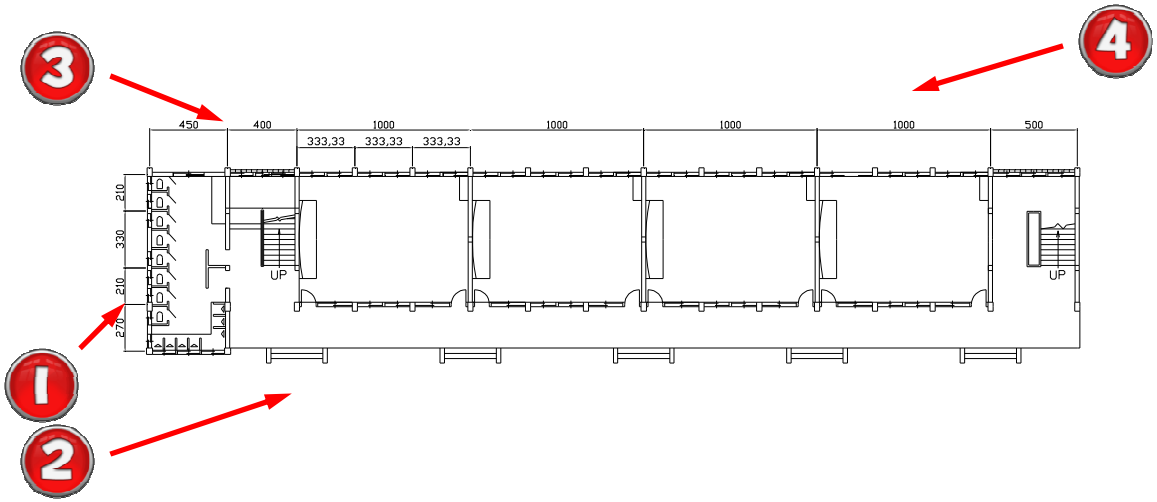


柱：1C1、1C2、1C3

梁：1G1、1G2、1G3、1G4、1G5、1G6、1G8、1G9、1G10、1G11、1G12、1G13

版：1S1、1S2

建築物外觀照片


3
4
1
2
450
400
1000
1000
1000
1000
500
333,33
333,33
333,33
210
330
210
270
UP
UP


4
安全・人人有責


1


2


3

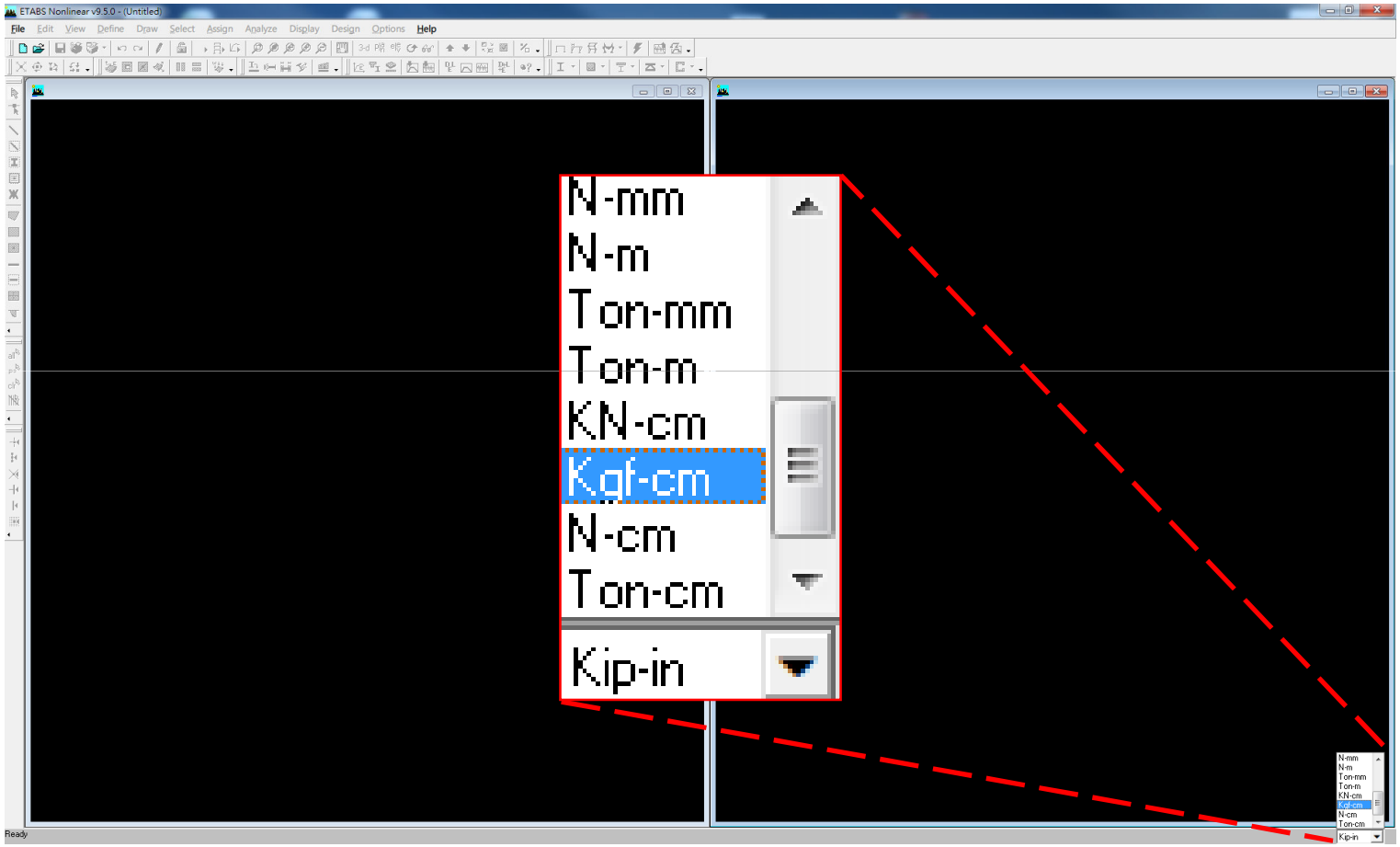
標的物基本資料

- 地上三層之鋼筋混凝土建築物，每層高度為 3.6 公尺
- 教室外單側有走廊，但走廊外無柱
- 長向長度為 53.5 公尺、短向為 10.2 公尺
- 長向有 90 公分高之窗台，教室間設置 1B 隔間磚牆
- 材料強度
  - 混凝土抗壓強度 f'_c = 160 kgf/cm^2
  - 主筋與箍筋降伏強度均為 f_y = 2800 kgf/cm^2
  - 紅磚抗壓強度 f_{bc} = 150 kgf/cm^2
  - 水泥砂漿抗壓強度 f_{mc} = 150 kgf/cm^2

模型建立

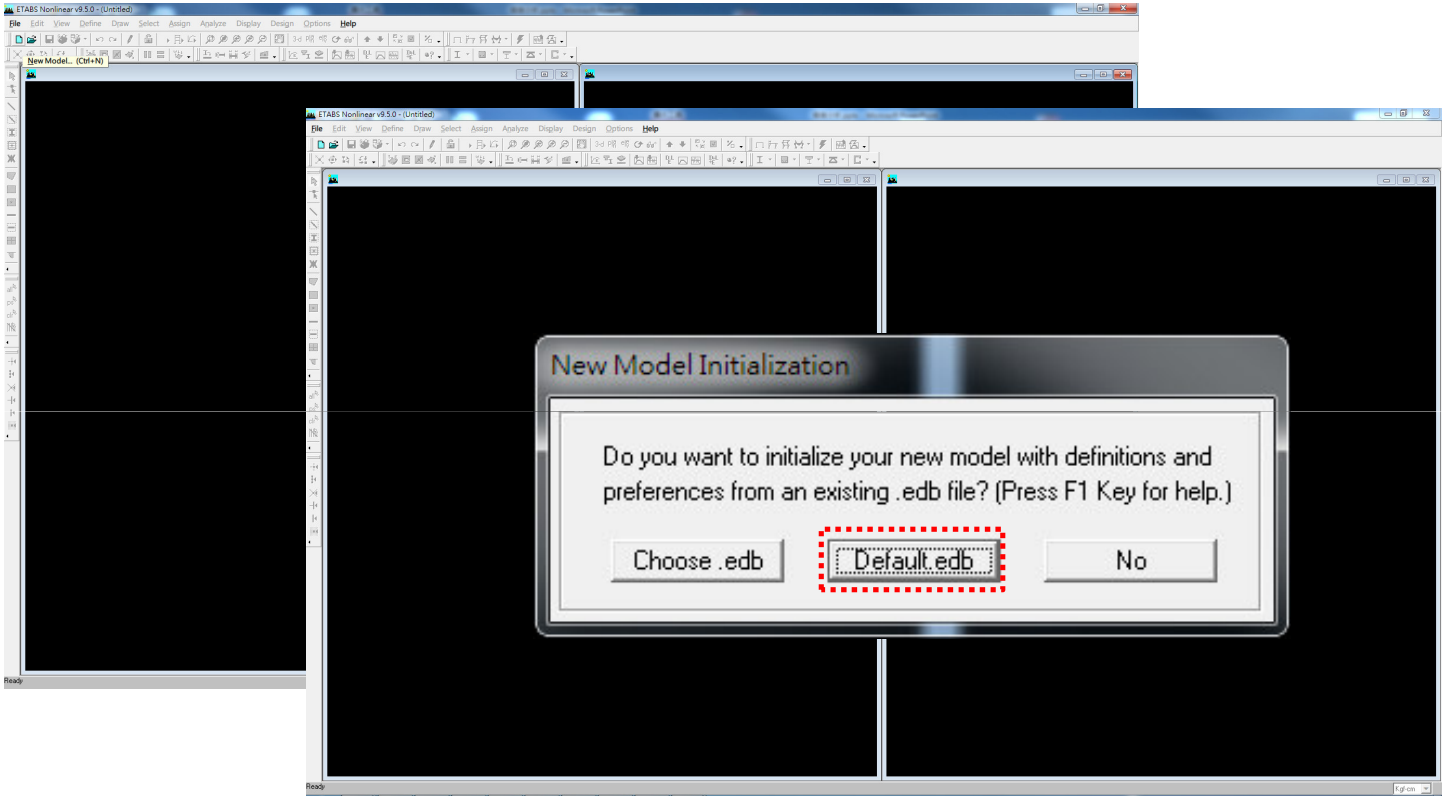
確認單位

- 調整單位為 ***kgf-cm***

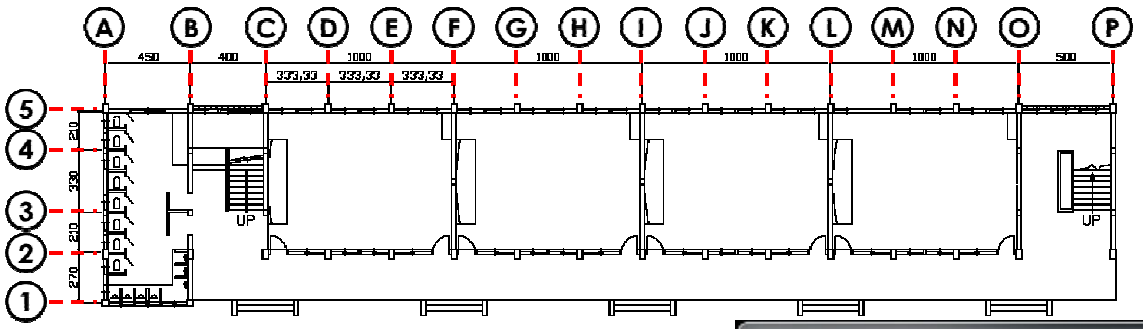


開始建立模型

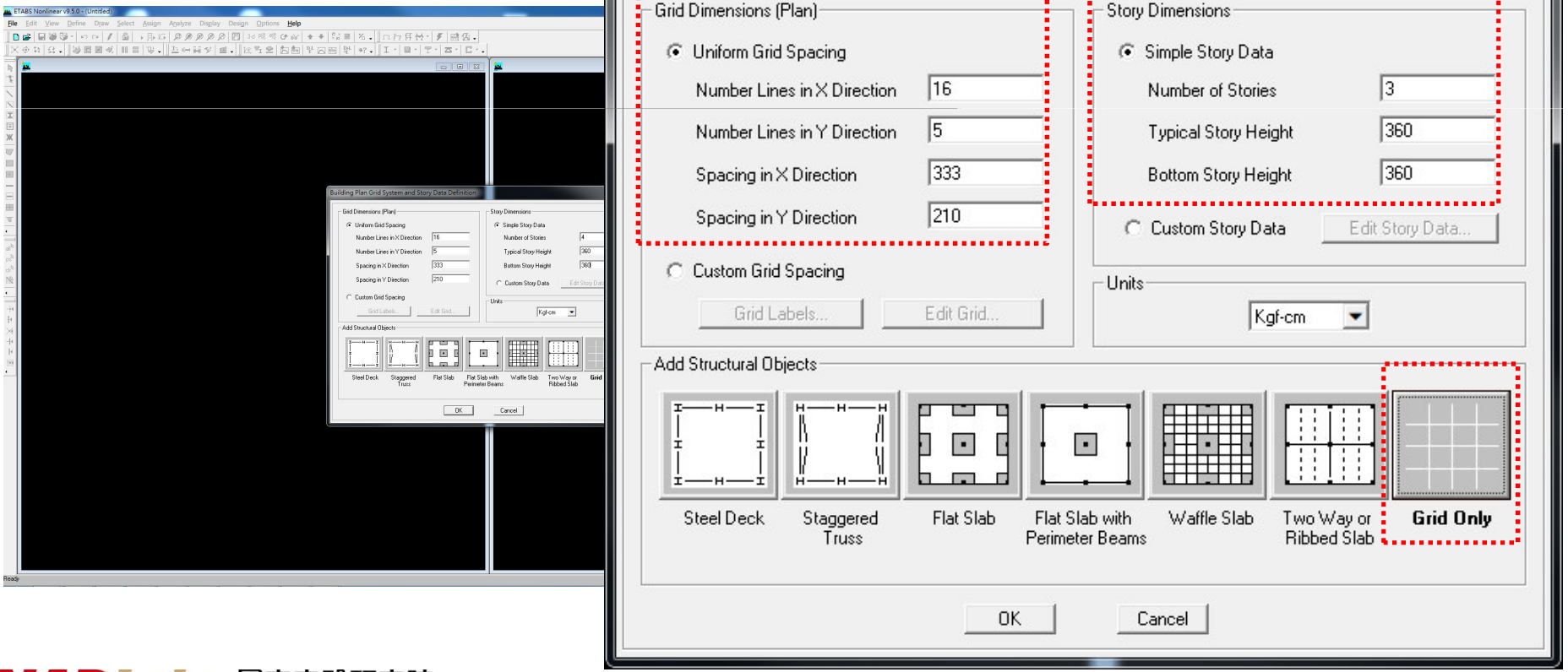
- **File → New Model**



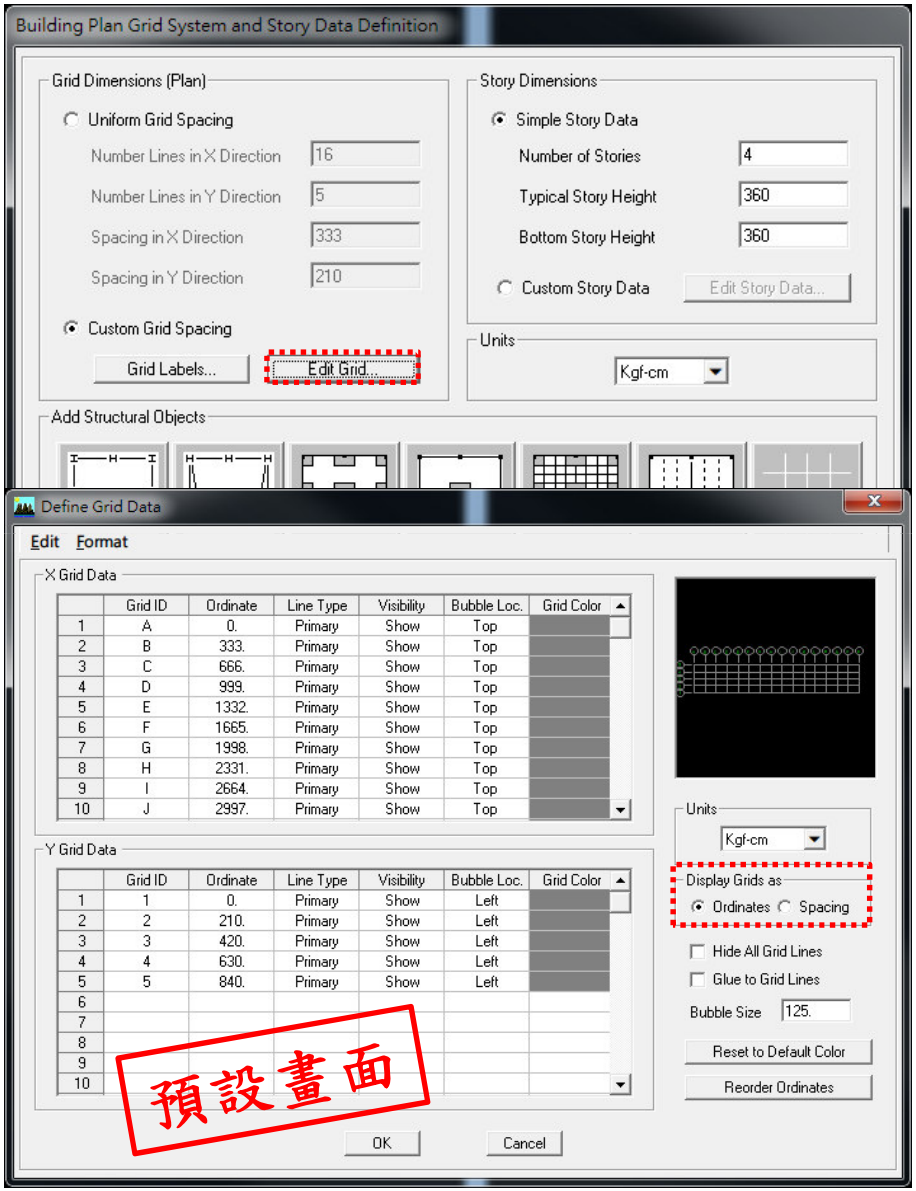
1. 繪製格線

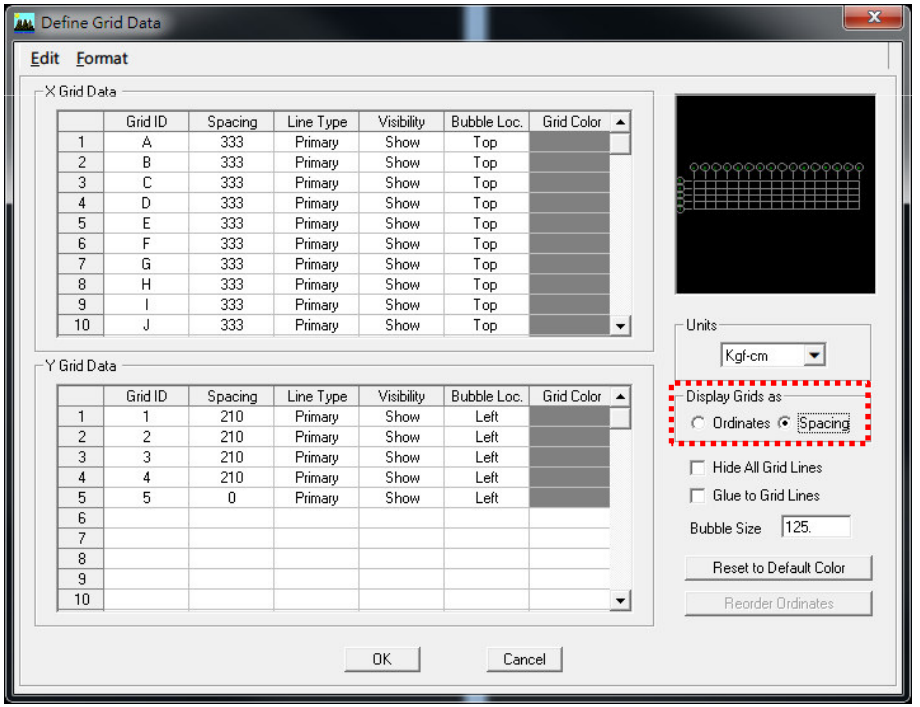

A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
1
2
3
4
5
450
400
1000
333.33
333.33
333.33
1000
1000
1000
500
210
330
210
270
UP
UP

平面圖

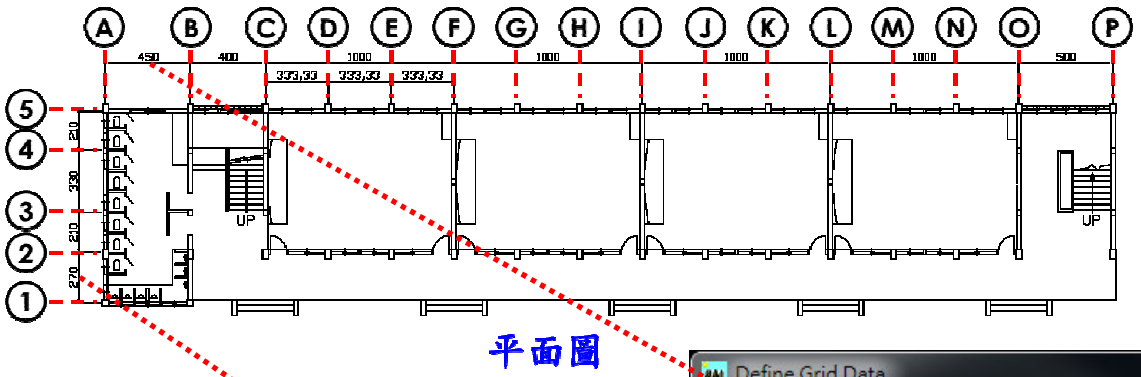

Building Plan Grid System and Story Data Definition
Grid Dimensions (Plan)
Uniform Grid Spacing
Number Lines in X Direction
16
Number Lines in Y Direction
5
Spacing in X Direction
333
Spacing in Y Direction
210
Custom Grid Spacing
Grid Labels...
Edit Grid...
Story Dimensions
Simple Story Data
Number of Stories
3
Typical Story Height
360
Bottom Story Height
360
Custom Story Data
Edit Story Data...
Units
Kgf-cm
Add Structural Objects
Steel Deck
Staggered Truss
Flat Slab
Flat Slab with Perimeter Beams
Waffle Slab
Two Way or Ribbed Slab
Grid Only
OK
Cancel

1-1 調整格線間距


Building Plan Grid System and Story Data Definition
Grid Dimensions (Plan)
Uniform Grid Spacing
Number Lines in X Direction 16
Number Lines in Y Direction 5
Spacing in X Direction 333
Spacing in Y Direction 210
Custom Grid Spacing
Grid Labels...
Edit Grid...
Story Dimensions
Simple Story Data
Number of Stories 4
Typical Story Height 360
Bottom Story Height 360
Custom Story Data
Edit Story Data...
Units
Kgf-cm
Add Structural Objects
Define Grid Data
Edit Format
X Grid Data
Grid ID Ordinate Line Type Visibility Bubble Loc. Grid Color
1 A 0. Primary Show Top
2 B 333. Primary Show Top
3 C 666. Primary Show Top
4 D 999. Primary Show Top
5 E 1332. Primary Show Top
6 F 1665. Primary Show Top
7 G 1998. Primary Show Top
8 H 2331. Primary Show Top
9 I 2664. Primary Show Top
10 J 2997. Primary Show Top
Y Grid Data
Grid ID Ordinate Line Type Visibility Bubble Loc. Grid Color
1 1 0. Primary Show Left
2 2 210. Primary Show Left
3 3 420. Primary Show Left
4 4 630. Primary Show Left
5 5 840. Primary Show Left
Units
Kgf-cm
Display Grids as
Ordinates Spacing
Hide All Grid Lines
Glue to Grid Lines
Bubble Size 125.
Reset to Default Color
Reorder Ordinates
OK
Cancel
預設畫面


Define Grid Data
Edit Format
X Grid Data
Grid ID Spacing Line Type Visibility Bubble Loc. Grid Color
1 A 333 Primary Show Top
2 B 333 Primary Show Top
3 C 333 Primary Show Top
4 D 333 Primary Show Top
5 E 333 Primary Show Top
6 F 333 Primary Show Top
7 G 333 Primary Show Top
8 H 333 Primary Show Top
9 I 333 Primary Show Top
10 J 333 Primary Show Top
Y Grid Data
Grid ID Spacing Line Type Visibility Bubble Loc. Grid Color
1 1 210 Primary Show Left
2 2 210 Primary Show Left
3 3 210 Primary Show Left
4 4 210 Primary Show Left
5 5 0 Primary Show Left
Units
Kgf-cm
Display Grids as
Ordinates Spacing
Hide All Grid Lines
Glue to Grid Lines
Bubble Size 125.
Reset to Default Color
Reorder Ordinates
OK
Cancel

1-1 調整格線間距



平面圖

Define Grid Data

Edit Format

X Grid Data

	Grid ID	Spacing	Line Type	Visibility	Bubble Loc.	Grid Color
1	A	450	Primary	Show	Top	
2	B	400	Primary	Show	Top	
3	C	333	Primary	Show	Top	
4	D	333	Primary	Show	Top	
5	E	333	Primary	Show	Top	
6	F	333	Primary	Show	Top	
7	G	333	Primary	Show	Top	
8	H	333	Primary	Show	Top	
9	I	333	Primary	Show	Top	
10	J	333	Primary	Show	Top	

Y Grid Data

	Grid ID	Spacing	Line Type	Visibility	Bubble Loc.	Grid Color
1	1	270	Primary	Show	Left	
2	2	210	Primary	Show	Left	
3	3	330	Primary	Show	Left	
4	4	210	Primary	Show	Left	
5	5	0	Primary	Show	Left	
6						
7						
8						
9						
10						

Units: Kgf-cm

Display Grids as: Ordinates / Spacing

Hide All Grid Lines

Glue to Grid Lines

Bubble Size 125.

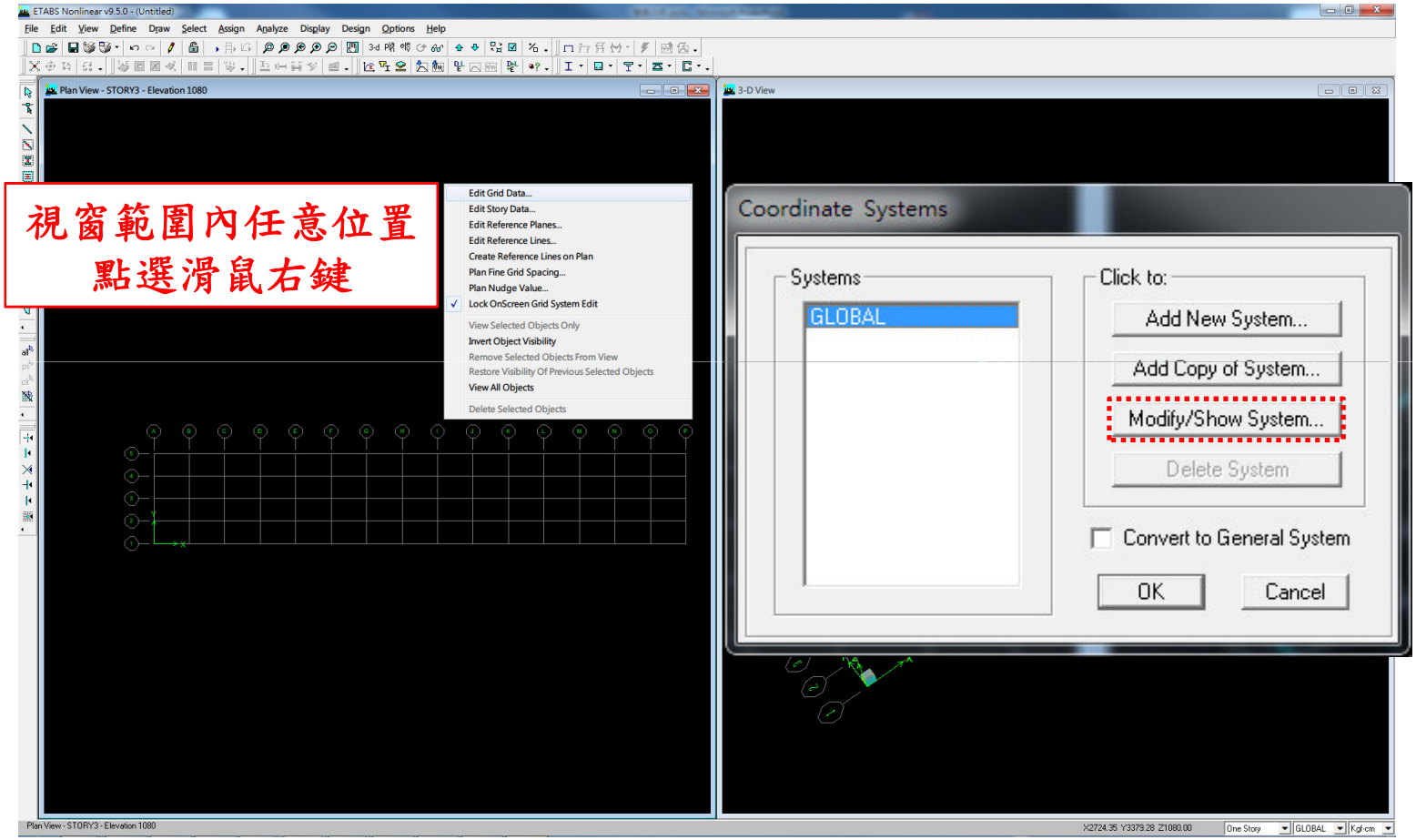
Reset to Default Color

Reorder Ordinates

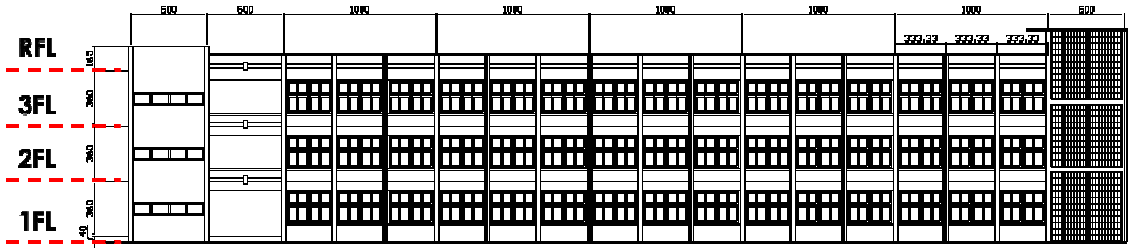
OK Cancel

1-1 調整格線間距

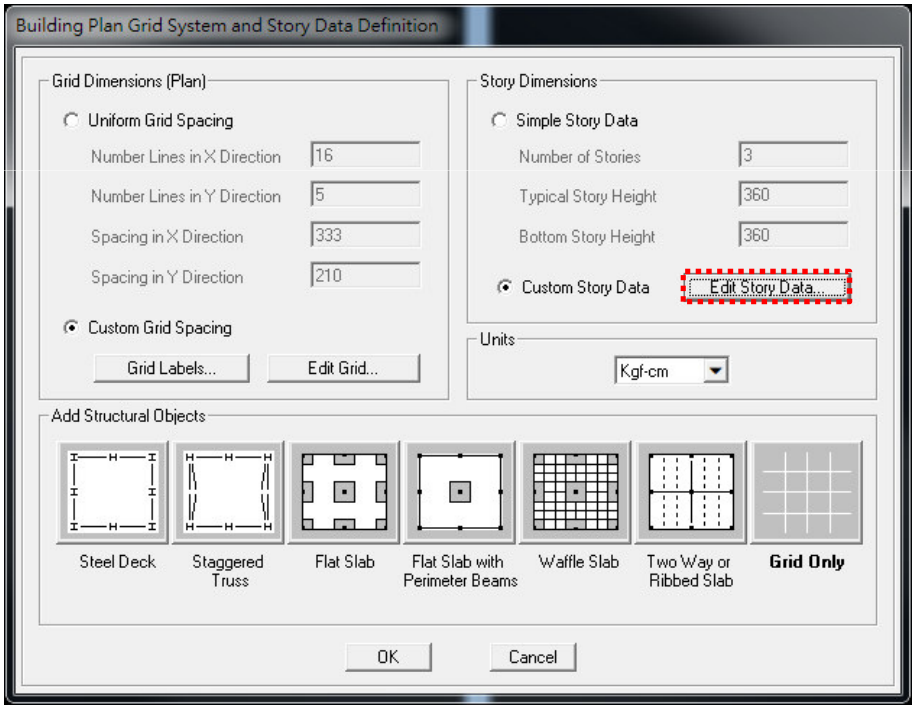
- **Edit → Edit Grid Data**



1-2 調整樓層高度

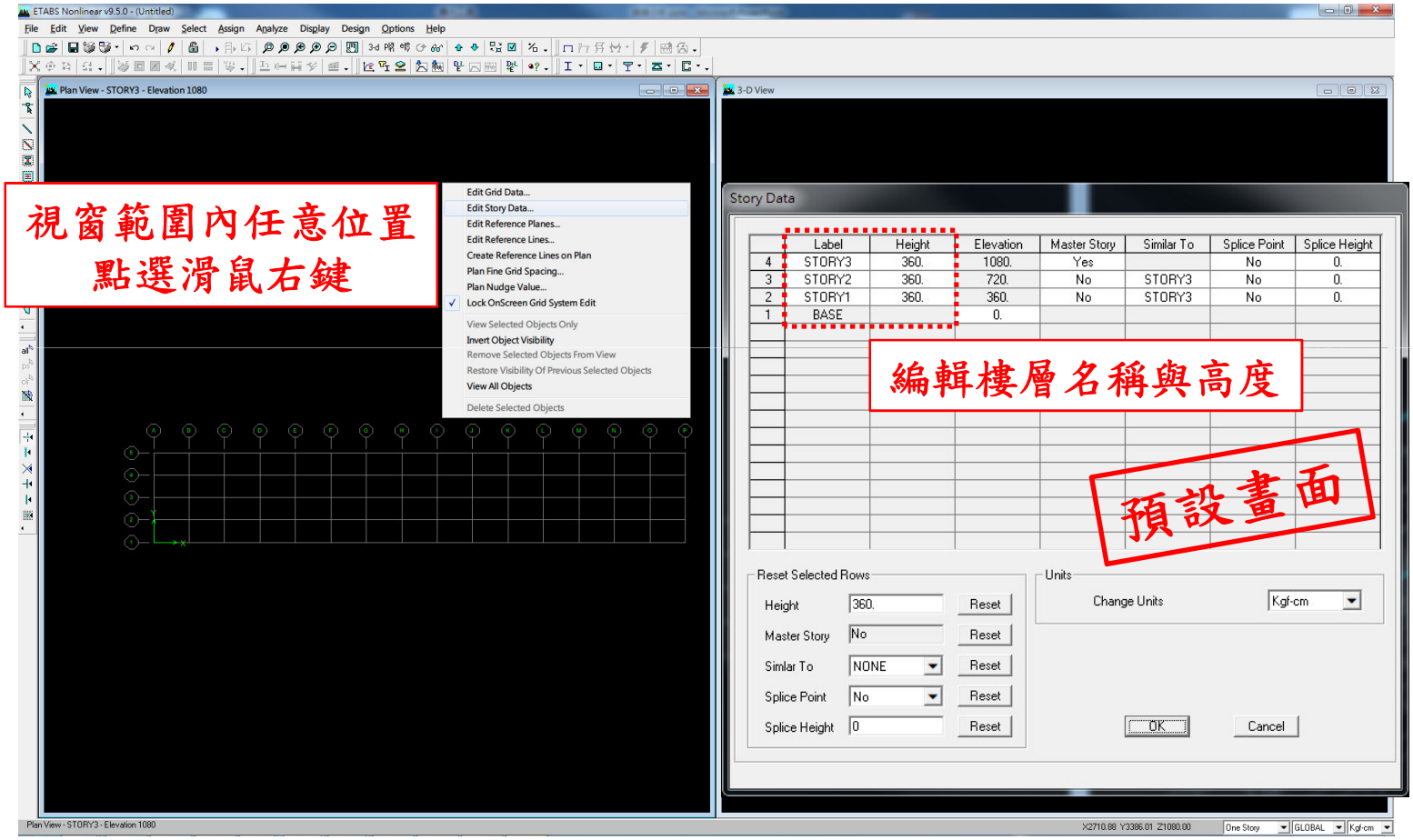


立面圖

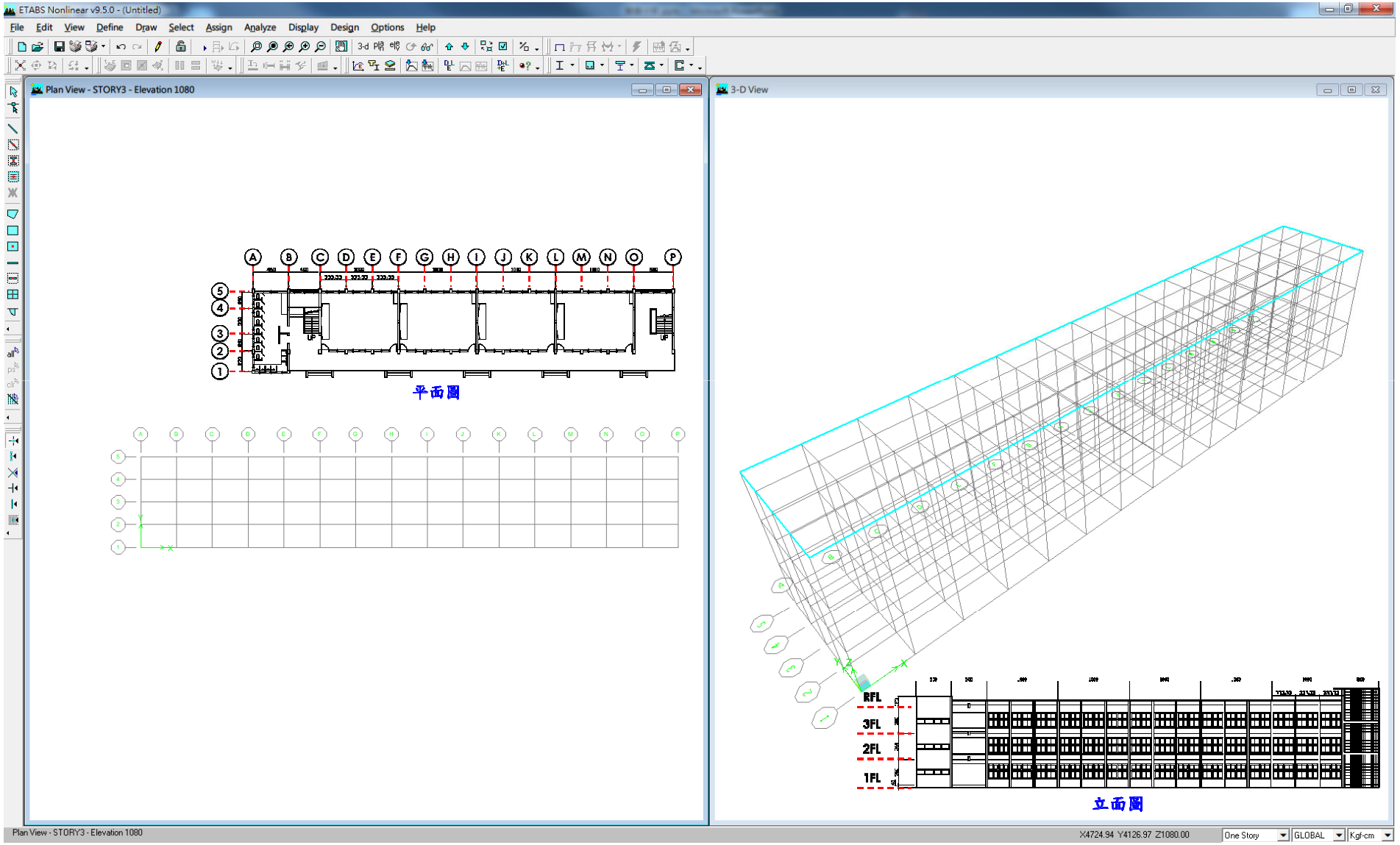


1-2 調整樓層高度

- **Edit → Edit Story Data**

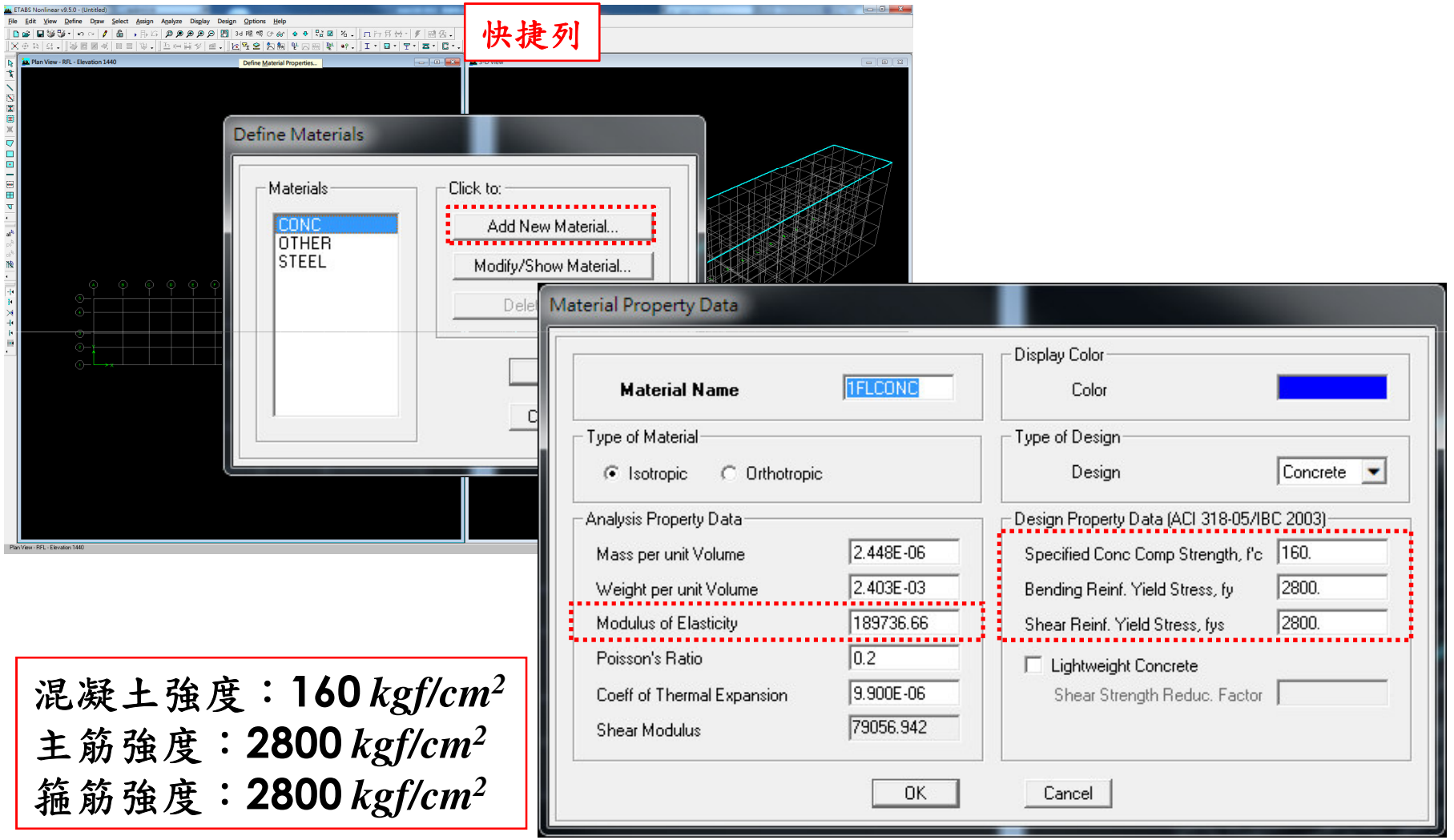


完成格線繪製


ETABS Nonlinear v9.5.0 - (Untitled)
File Edit View Define Draw Select Assign Analyze Display Design Options Help
Plan View - STORY3 - Elevation 1080
A B C D E F G H I J K L M N O P
5 4 3 2 1
平面圖
3-D View
RFL
3FL
2FL
1FL
立面圖
Plan View - STORY3 - Elevation 1080
X4724.94 Y4126.97 Z1080.00
One Story
GLOBAL
Kgf-cm

2. 新增材料性質

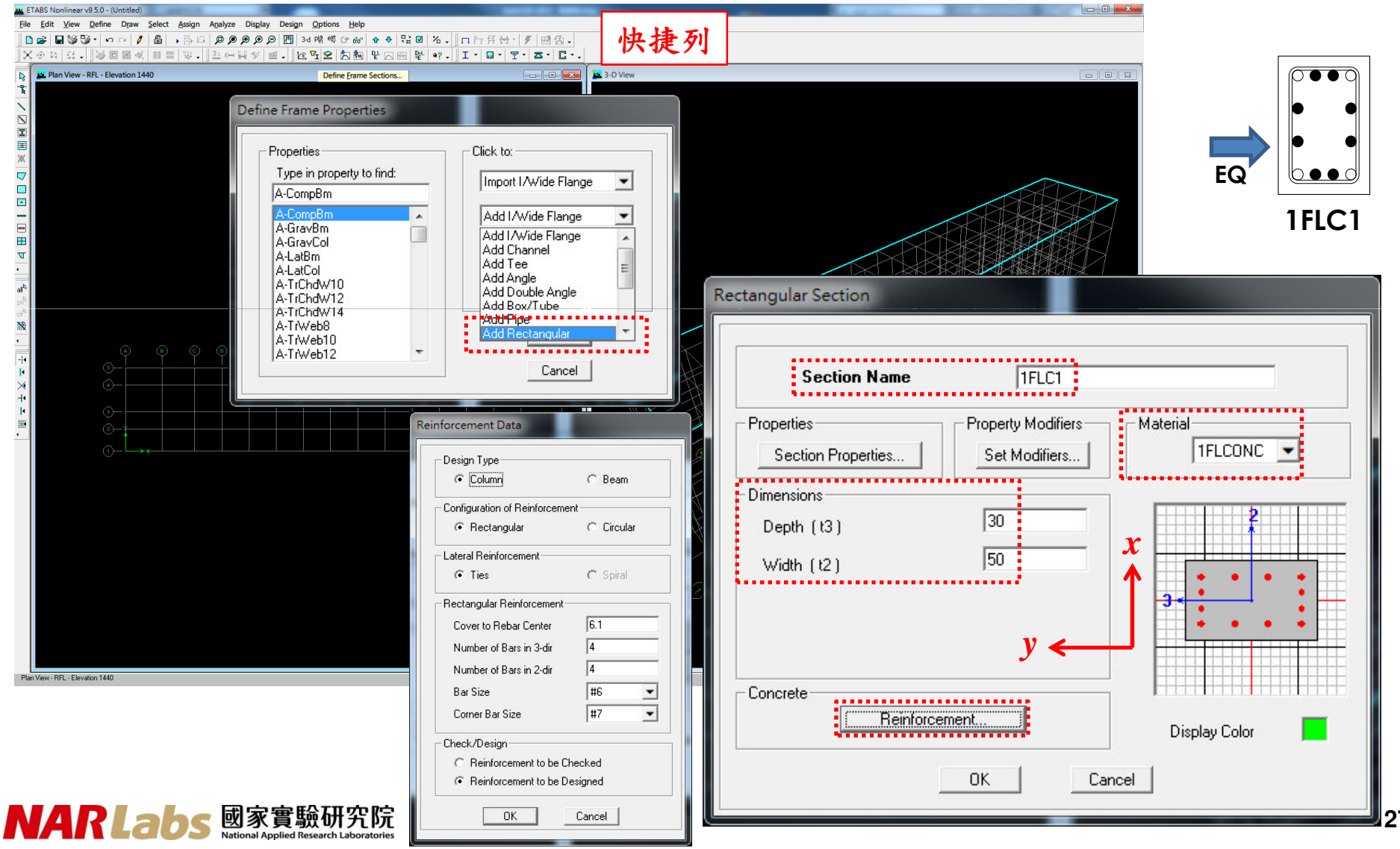
- **Define → Material Properties**



混凝土強度：160 kgf/cm^2
主筋強度：2800 kgf/cm^2
箍筋強度：2800 kgf/cm^2

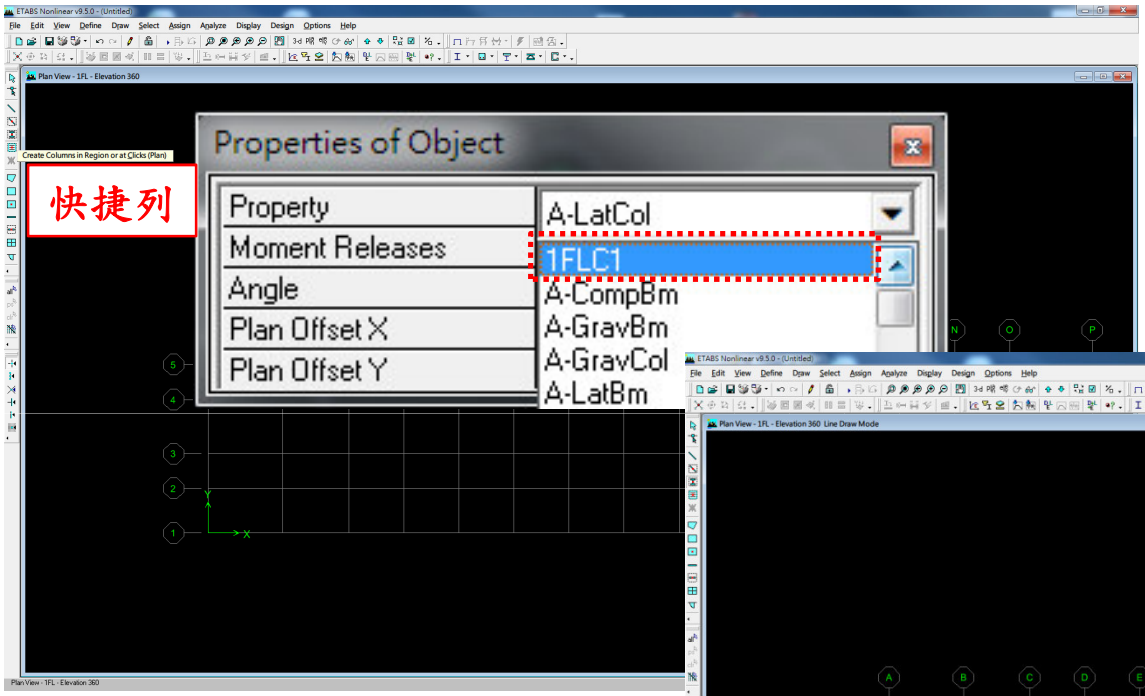
2. 新增柱、梁斷面

- **Define → Frame Sections**

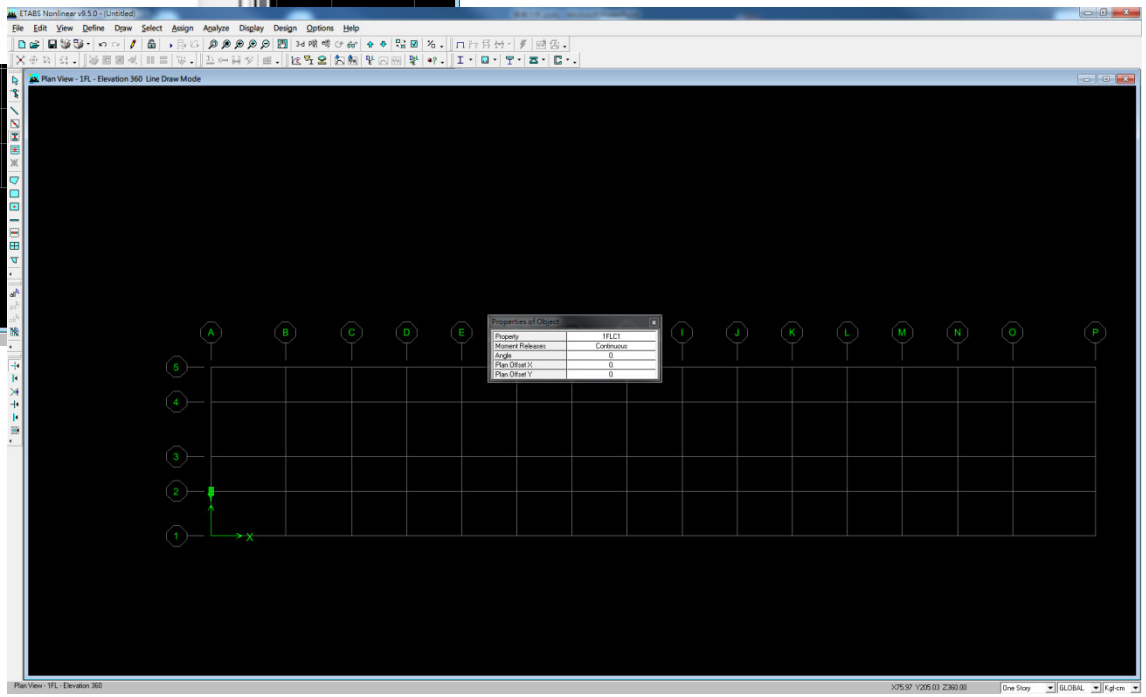


3. 繪製柱、梁

- 選擇柱斷面 (以1FLC1為例)

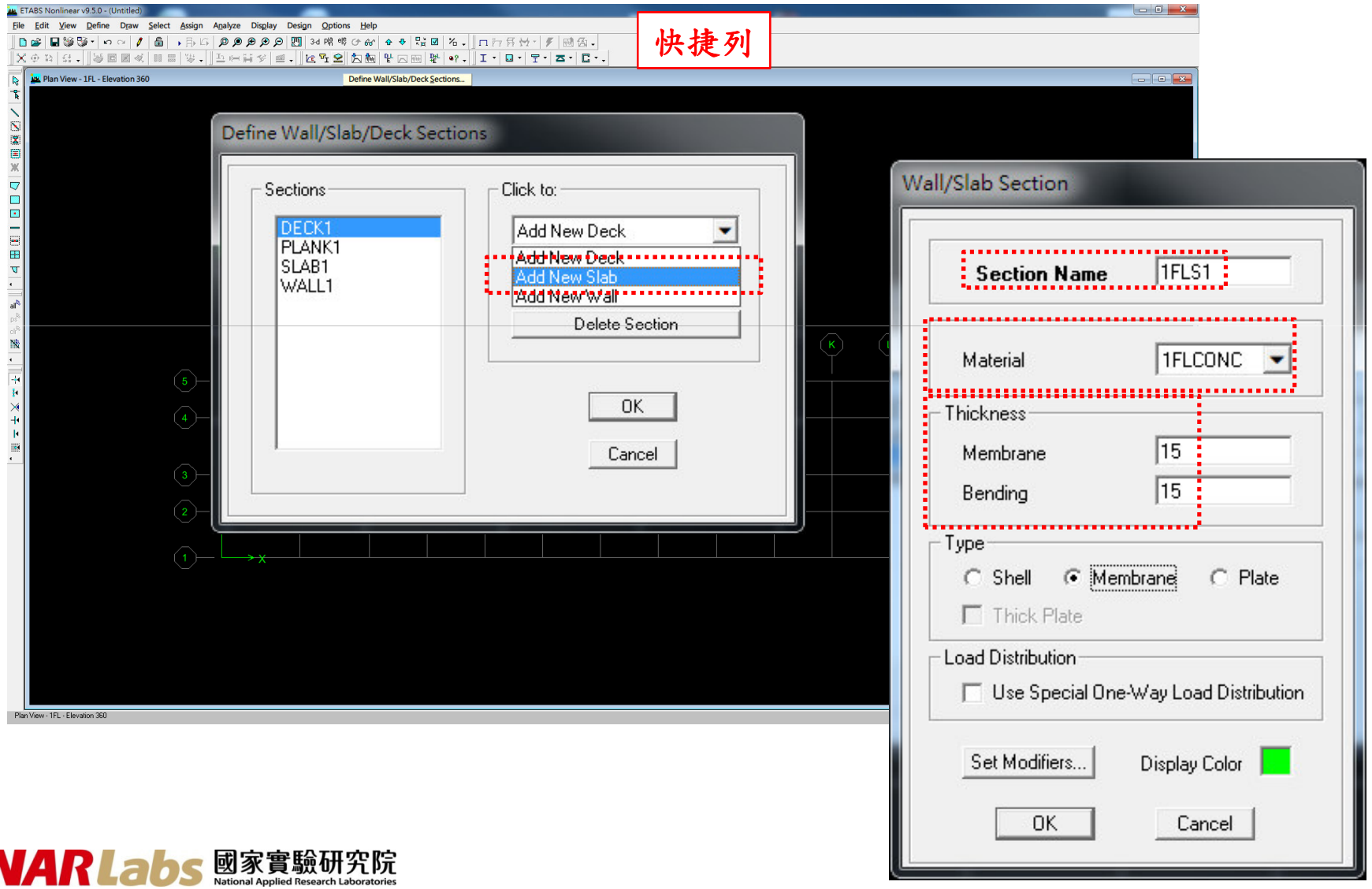


繪製前確認所在樓層 (1FL)



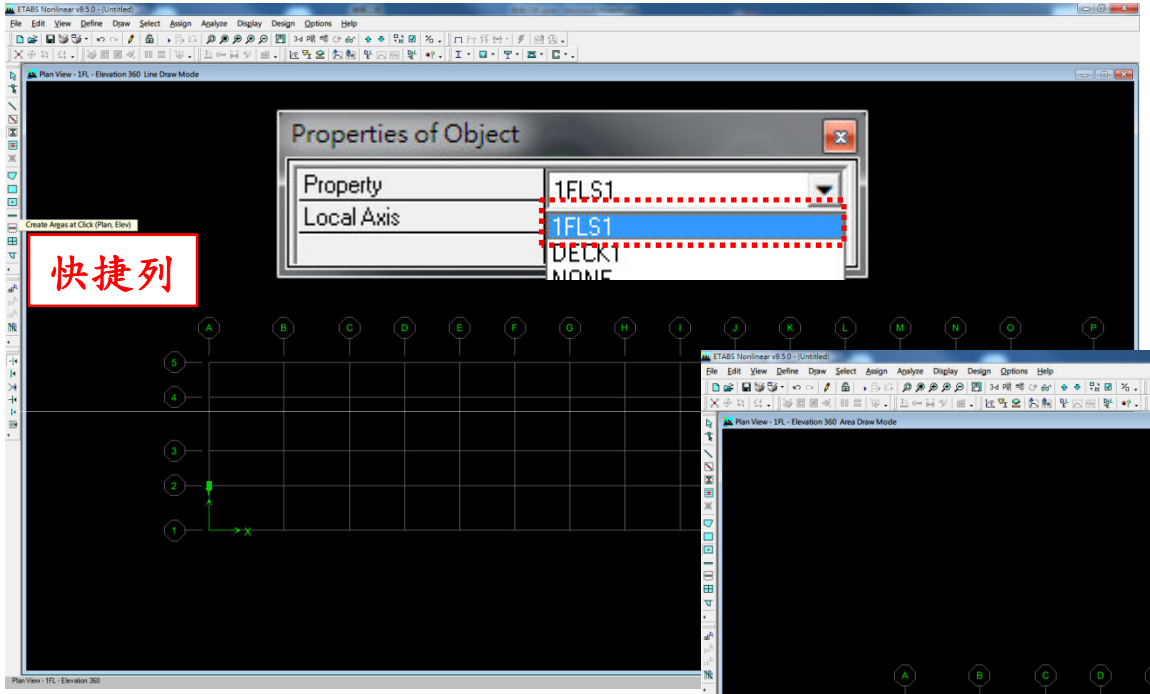
4. 新增樓版

- **Define → Wall/Slab/Deck Sections**

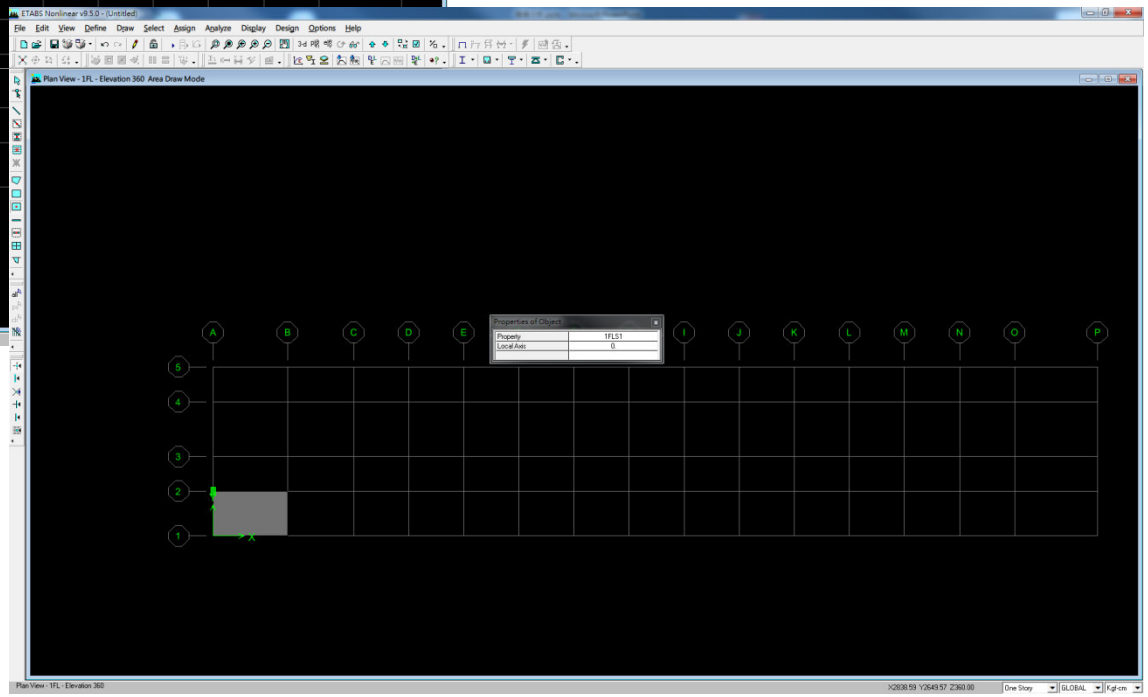


5. 繪製樓版

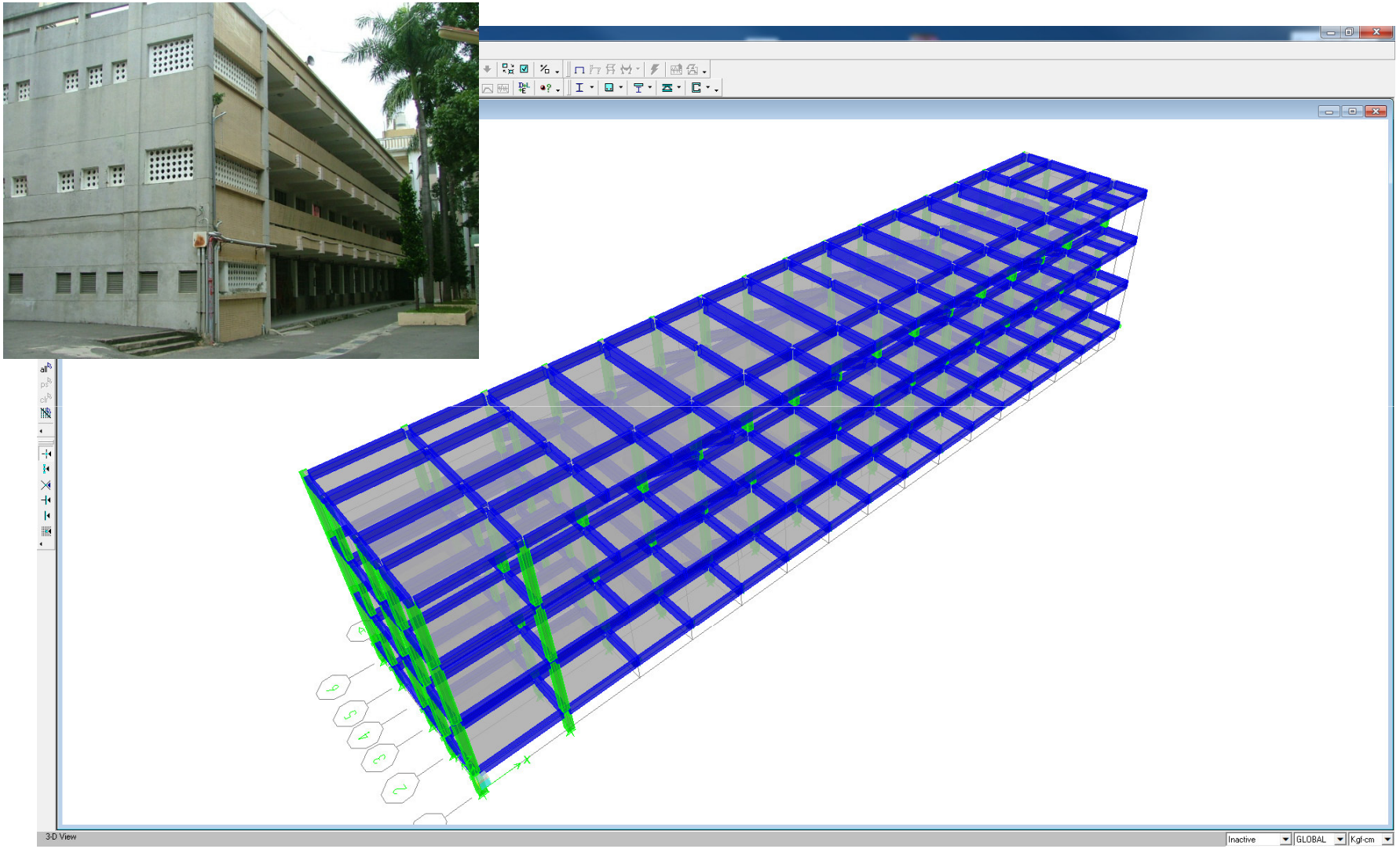
- 選擇樓版斷面 (以1FLS1為例)



繪製前確認所在樓層 (1FL)



3D模型樣貌

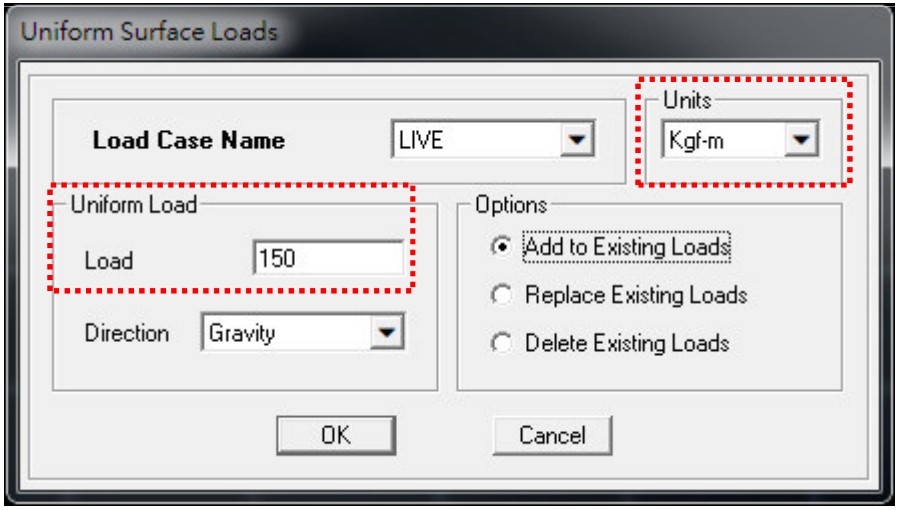


6. 設定垂直載重

- 進行側推分析時，建議考慮之垂直載重應包含設計靜載重加上 1/2 設計活載重

- 本案例校舍設定 1/2 設計活載重為 150 kgf/m^2

確認單位為 *kgf-m*



建築技術規則建築構造編第十七條：

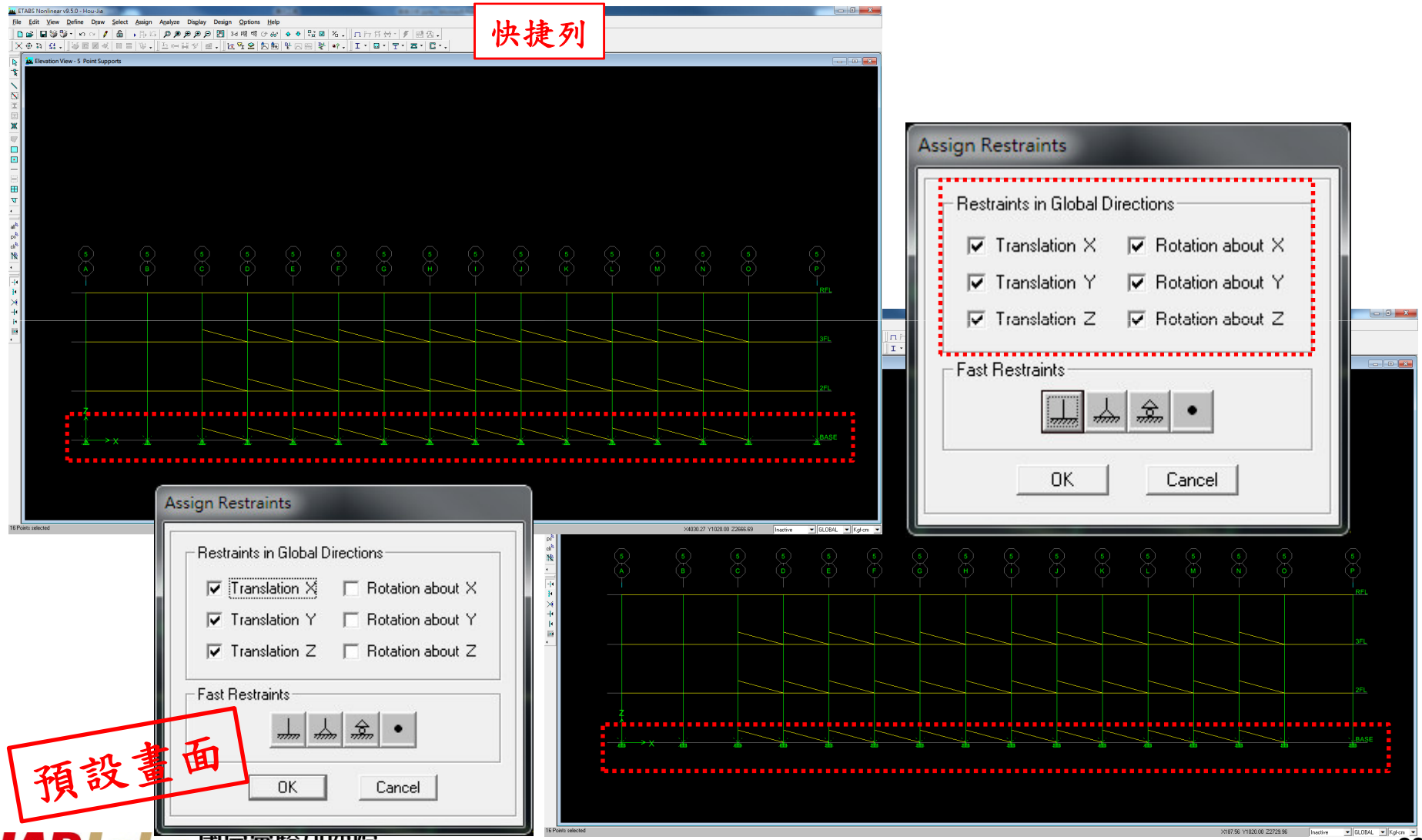
建築物構造之活載重，因樓地版之用途而不同，不得小於以下所列：

教室：250 kgf/m^2

圖書館：600 kgf/m^2

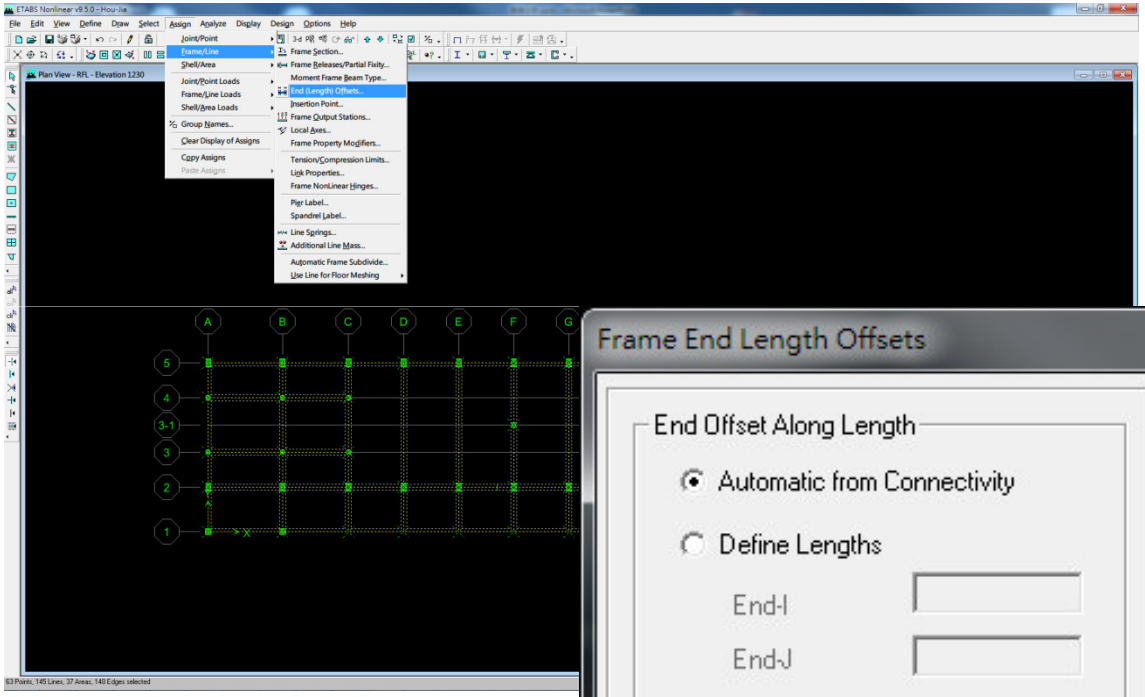
7. 設定基礎邊界條件

- **Assign → Restraints (Supports)**



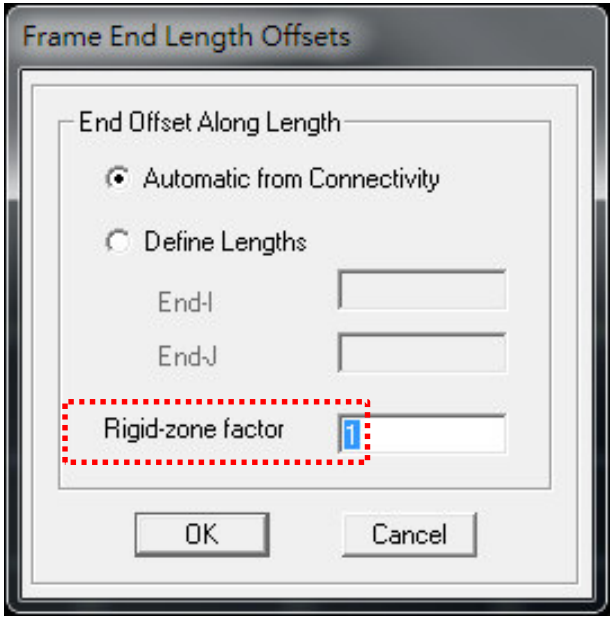
8. 設定為剛性接頭

- **Assign → Frame/Line → End (Length) Offsets**



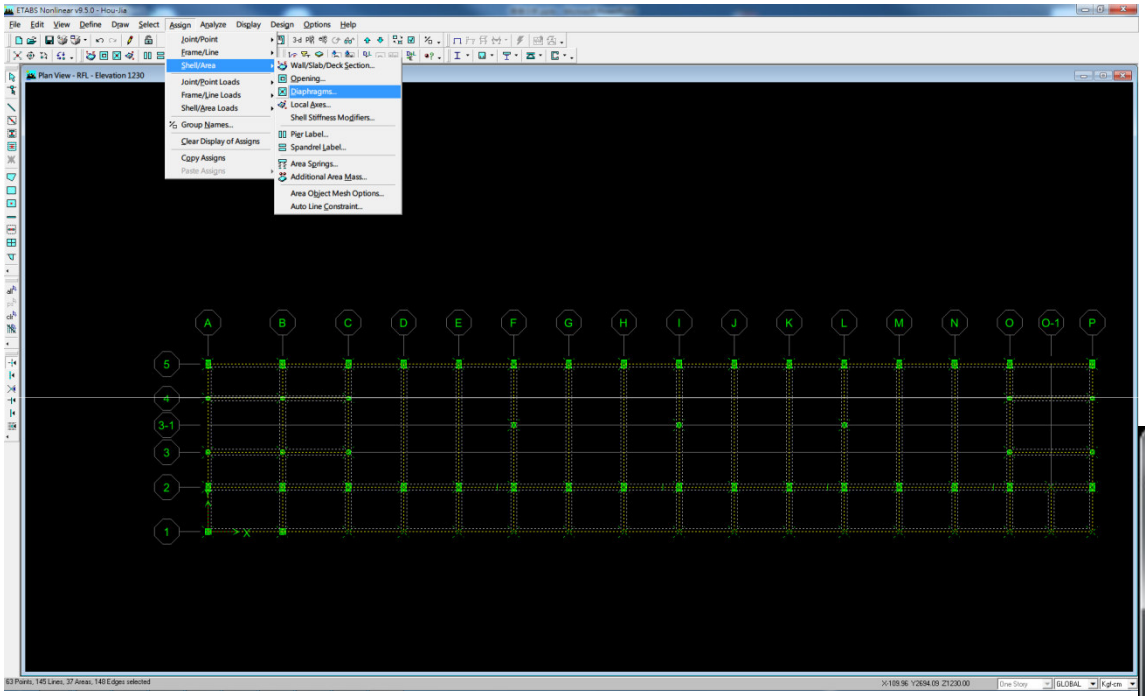
預設畫面

將梁柱接頭部分視為剛體：
Rigid zone factor=1，
預設值為 0

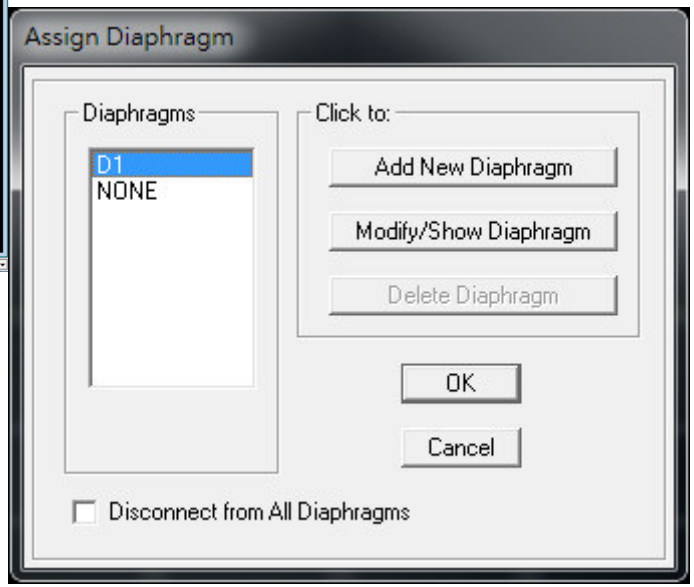


9. 設定剛性樓板

- **Assign → Shell/Area → Diaphragms**

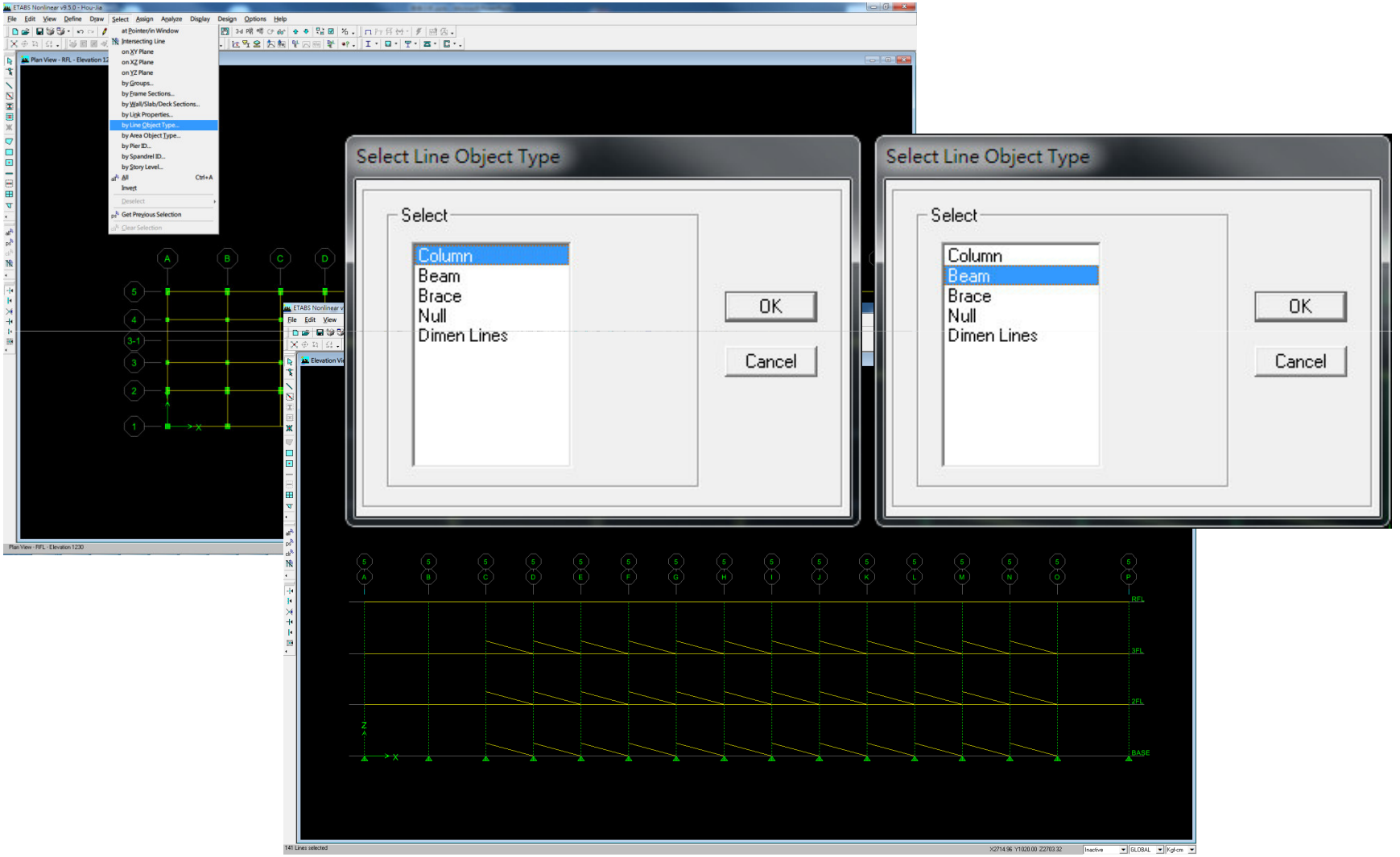


為簡化低矮型校舍結構物之側推分析，將樓版假設為剛性樓版



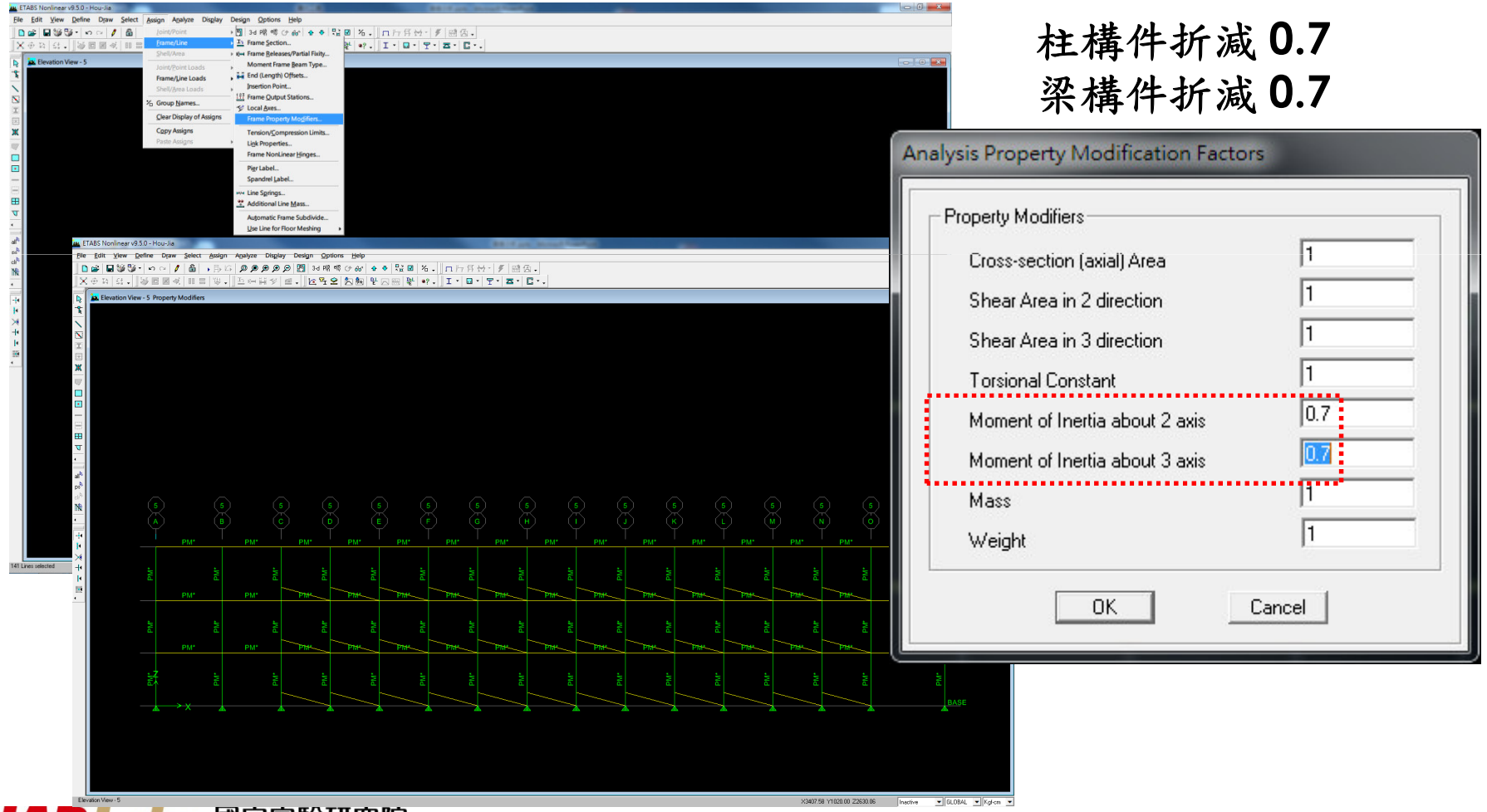
10. 撓曲勁度折減

- **Select → by Line Object Type**



10. 撓曲勁度折減

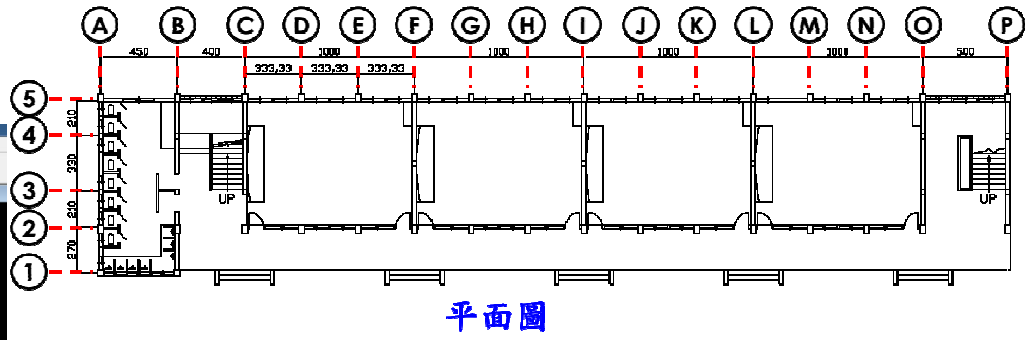
- **Assign → Frame/Line → Frame Property Modifiers**



柱構件折減 0.7
梁構件折減 0.7

快速建立模型之技巧

- **Edit → Replicate**



平面圖

設定非線性鉸

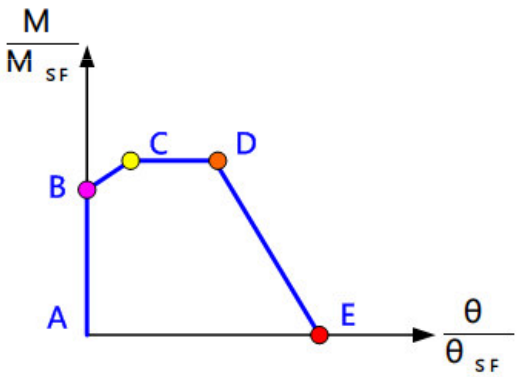
- **ETABS** 內建
- 自行定義

ETABS 內建之非線性鉸

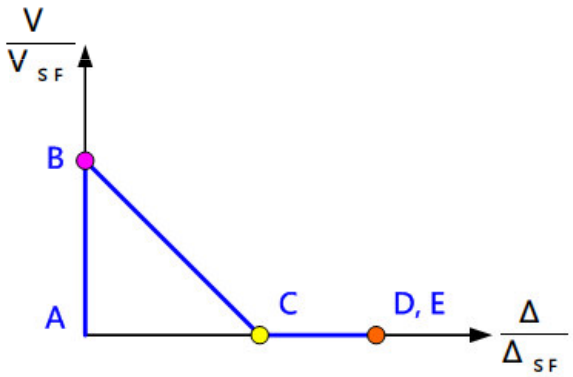
- 依據 FEMA 273 及 ATC-40 之建議，內建四種非線性鉸：
  1. 軸力非線性鉸 (axial hinge)：P
  2. 與軸力互制之彎矩非線性鉸 (P-M-M hinge)：PMM
  3. 彎矩非線性鉸 (moment hinge)：M3 (X向)、M2 (Y向)
  4. 剪力非線性鉸 (shear hinge)：V2 (X向)、V3 (Y向)

自行定義非線性鉸

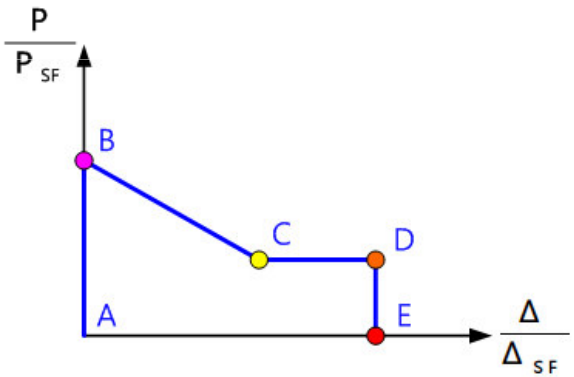
- **ETABS .e2k** 模型檔
- **TEASPA** 輔助分析程式
- 輔助程式共用輸入檔



彎矩非線性鉸參數



剪力非線性鉸參數



軸力非線性鉸參數

TEASPA 輔助分析程式

Win 32 位元

- [程式] TEASPA 32 位元 (版本 2014.4.25)
  - BWPH、COLPH、SWPH、PGA
- [程式] Windows 32 位元 MCR Installer

Win 64 位元

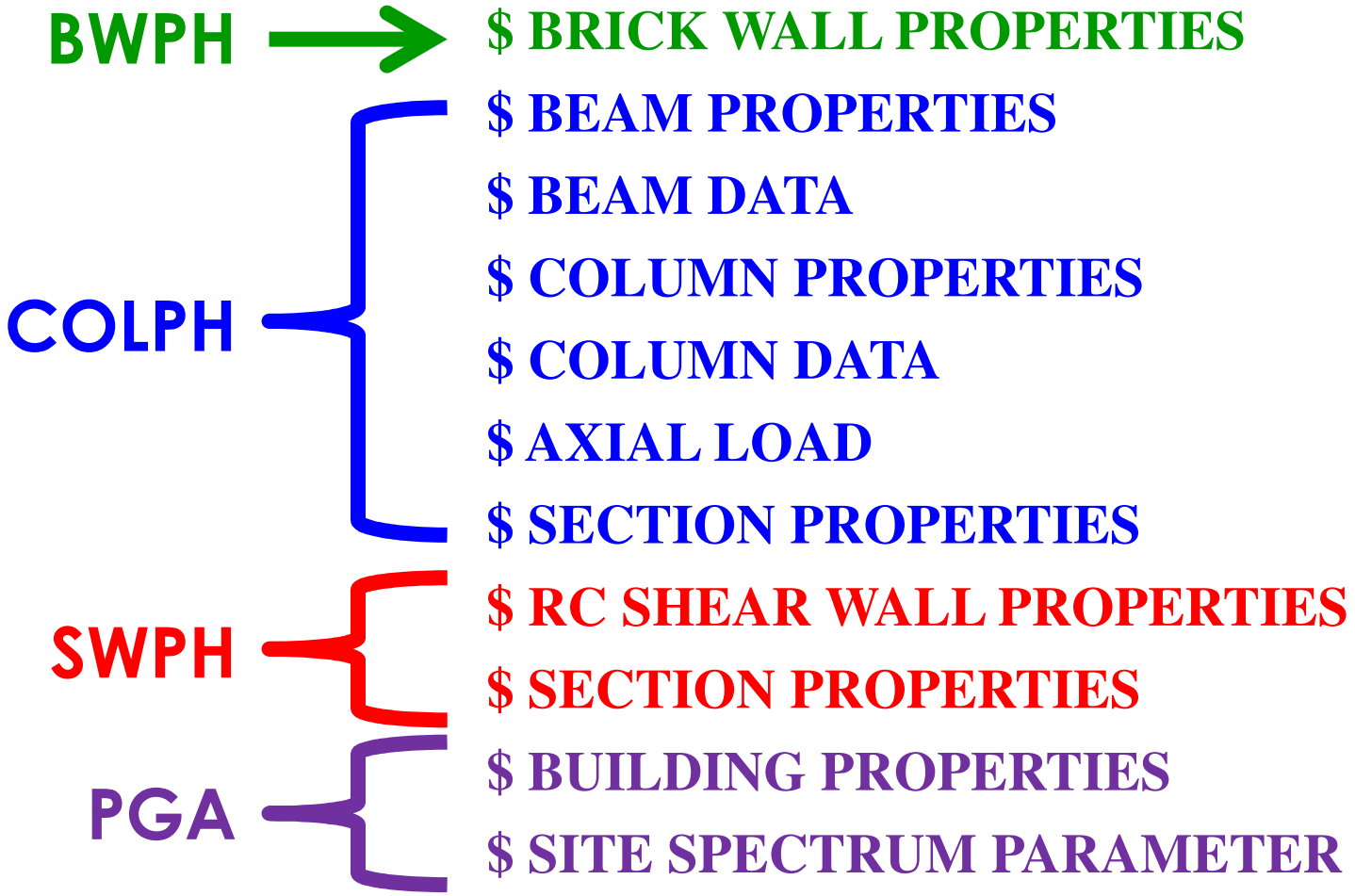
- [程式] TEASPA 64 位元 (版本 2014.4.25)
  - BWPH、COLPH、SWPH、PGA
- [程式] Windows 64 位元 MCR Installer

TEASPA 輔助分析程式

- 自動計算磚牆構件非線性鉸程式
  - BWPH.exe
- 自動計算梁柱構件非線性鉸程式
  - COLPH.exe
- 自動計算 RC 牆構件非線性鉸程式
  - SWPH.exe
- 自動計算性能目標地表加速度程式
  - PGA.exe

輔助程式共用輸入檔 (*.txt)

- 技術手冊 (NCREE 13-023) 附錄 B：
  耐震詳細評估輔助分析程式使用說明



柱、梁桿件之模擬與設定

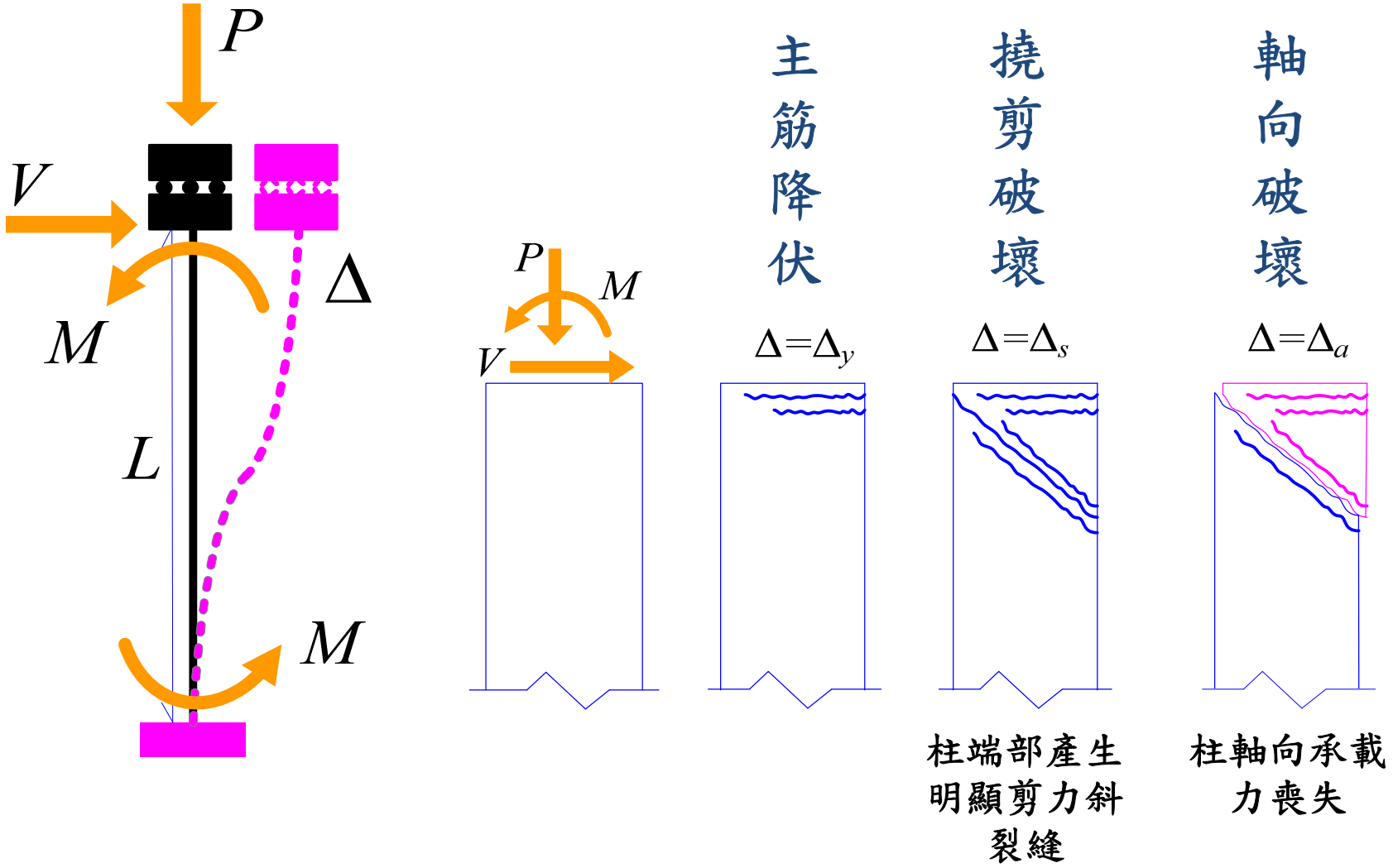
COLPH.exe

柱之破壞模式

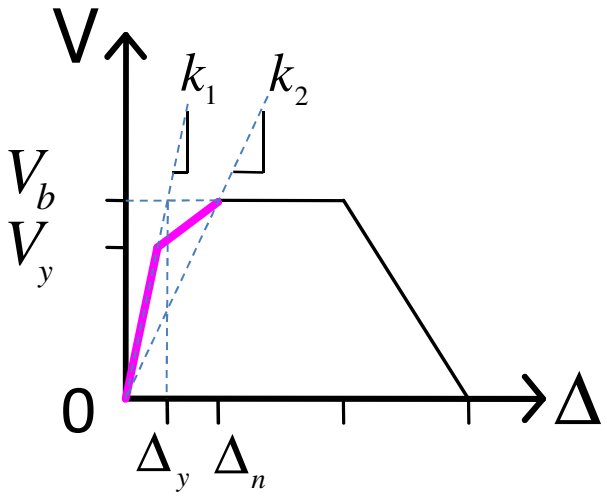
撓曲、撓剪

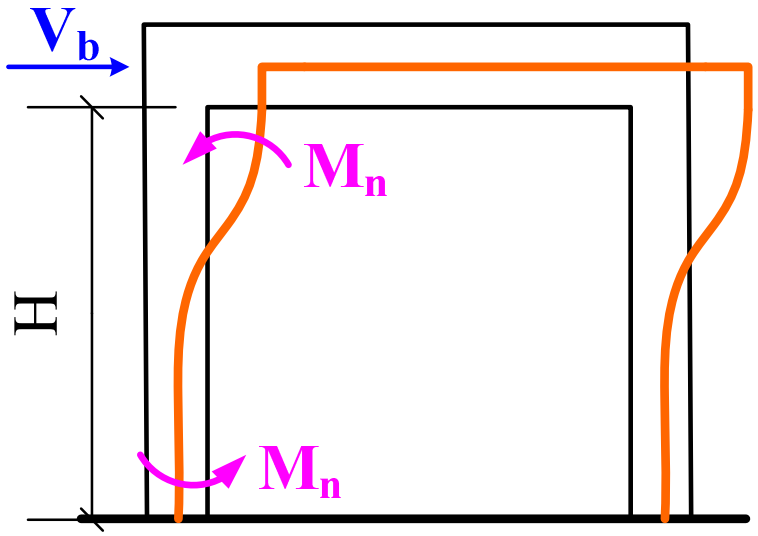
剪力

雙曲率柱側變位之發展歷程



Load Deflection Curve due to Flexure





$$V_y = \frac{2M_y}{H}$$

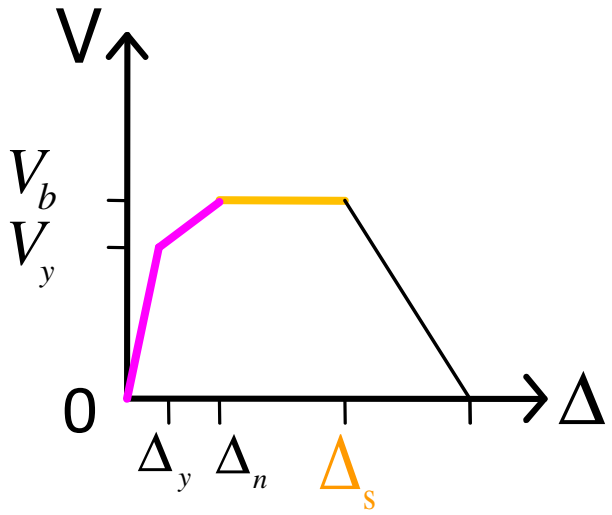
$$V_b = \frac{2M_n}{H}$$

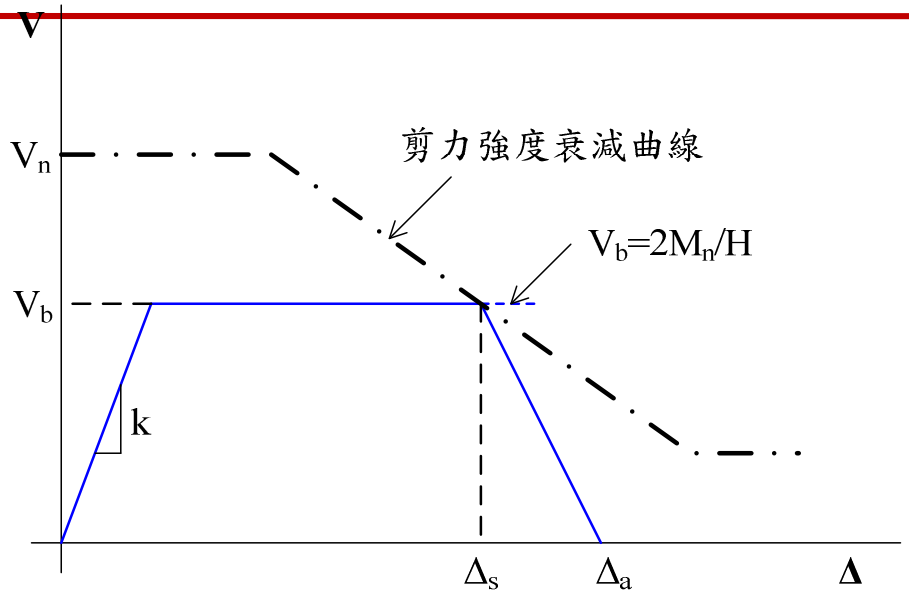
$$k_1 = \frac{12 \times 0.7 E_c I_g}{H}$$

$$k_2 = \frac{12 \times 0.35 E_c I_g}{H}$$

$$\Delta_y = \frac{V_b}{k_1} \qquad \Delta_n = \frac{V_b}{k_2}$$

Load Deflection Curve due to Flexure





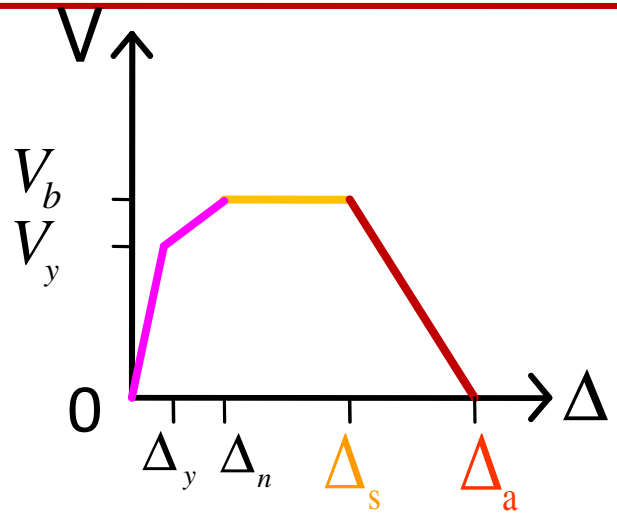
$$\Delta_s = \left(\frac{3}{100} + 4\rho'' - \frac{\nu_m}{133\sqrt{f_c'}} - \frac{P}{40 A_g f_c'} \right) H$$

Where $\rho'' = \frac{A_{st}}{bs}$ 為剪力箍筋體積比

$$\nu_m = \frac{V_b}{bd}$$ 為剪應力

Elwood & Moehle (2005)

Load Deflection Curve due to Flexure

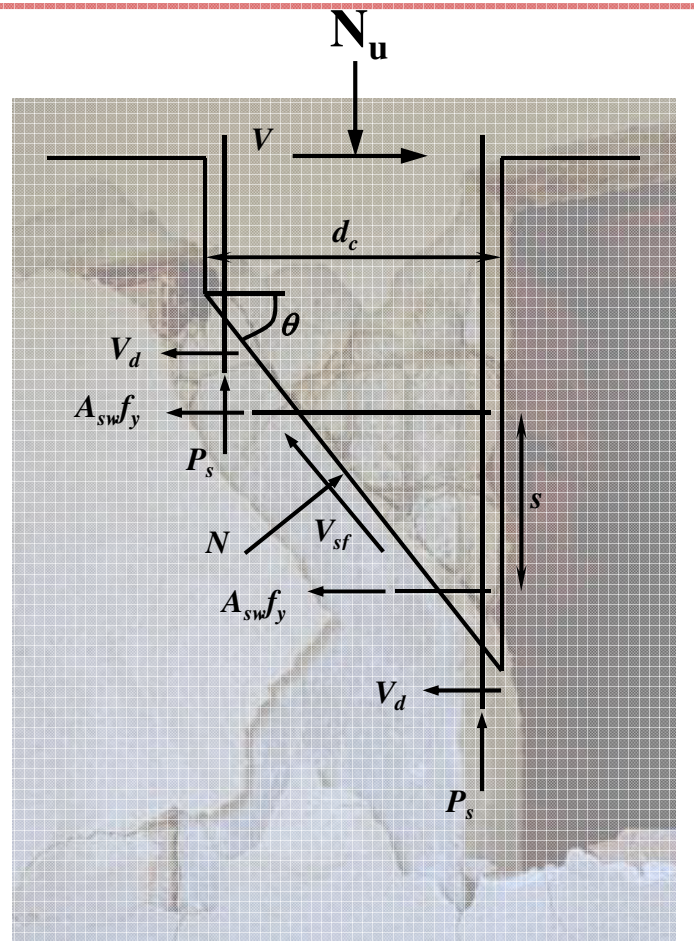


$$\Delta_a = \left(\frac{4}{100} \frac{1+\tan^2\theta}{\tan\theta + P\dfrac{s}{\kappa' A_{st} f_{yt} d_c \tan\theta}} \right) H$$

$\kappa' = 1.0,\ \text{for}\ \Delta_s/\Delta_y \le 2;$

$\kappa' = 0.7,\ \text{for}\ \Delta_s/\Delta_y \ge 6;$

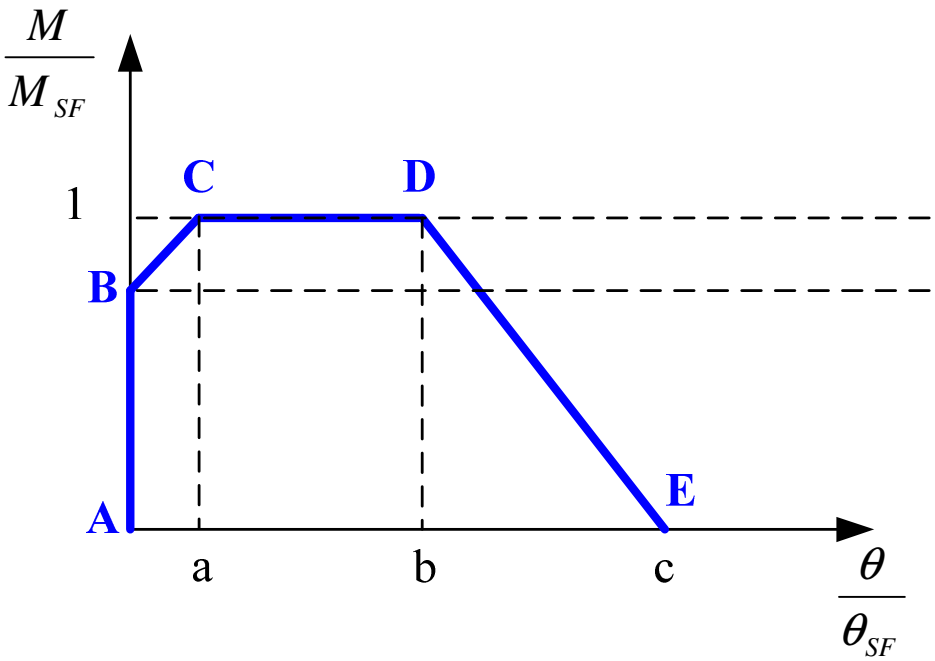
interpolaton for Δ_s/Δ_y between 2 to 6.

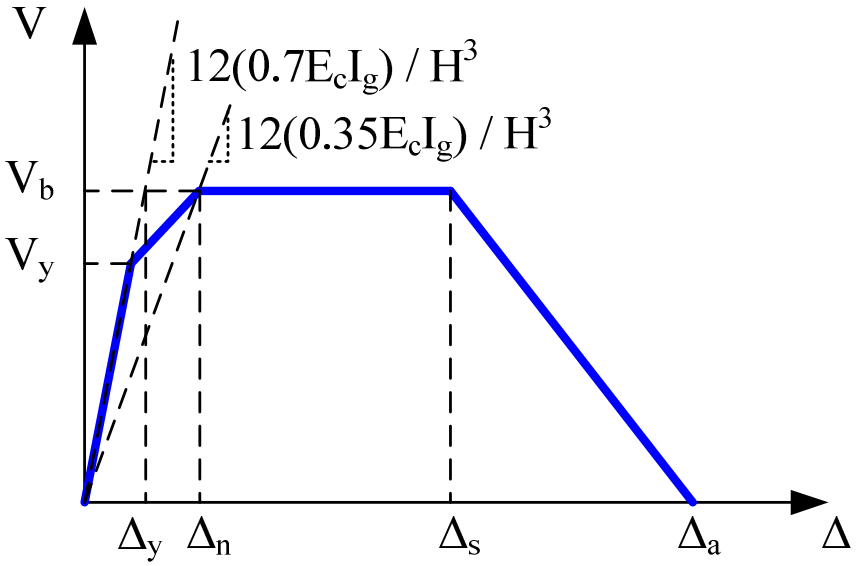


Elwood & Moehle (2005)

d_c：核心混凝土深度
(箍筋中心到中心距離)

撓剪破壞非線性鉸參數





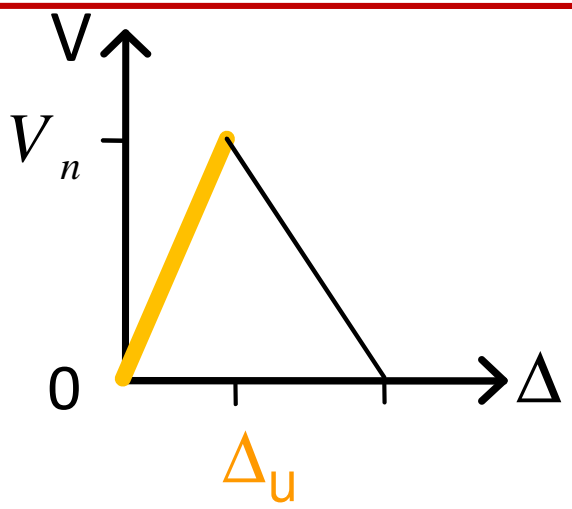
Point	Moment / SF	Rotation / SF
A	0	0
B	min(M_y/M_n, 0.95)	0
C	1	a
D	1	b
E	0	c

$$a = \frac{\Delta_n}{H} - \frac{\Delta_y}{H} \qquad b = \frac{\Delta_s}{H} - \frac{\Delta_y}{H}$$

$$c = \max\left(\frac{\Delta_a}{H}, \frac{\Delta_s}{H}\right) \qquad \Delta_y = \frac{V_b}{k} = \frac{V_b H^3}{12(0.7E_c I_g)}$$

Moment SF	M_n
Rotation SF	1

Load Deflection Curve due to Shear



- Lateral strength of double curvature column

$$V_n = V_c + V_s$$

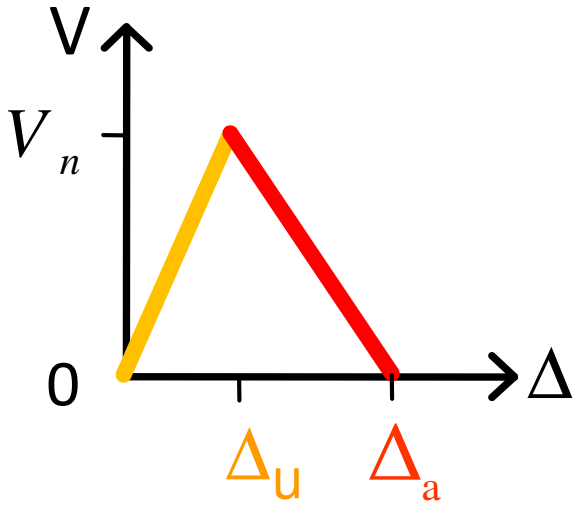
- Lateral stiffness of double curvature column

$$k_1 = \frac{12 \times 0.7 E_c I_g}{H}$$

- Lateral displacement of yielding point

$$\Delta_u = \frac{V_n}{k}$$

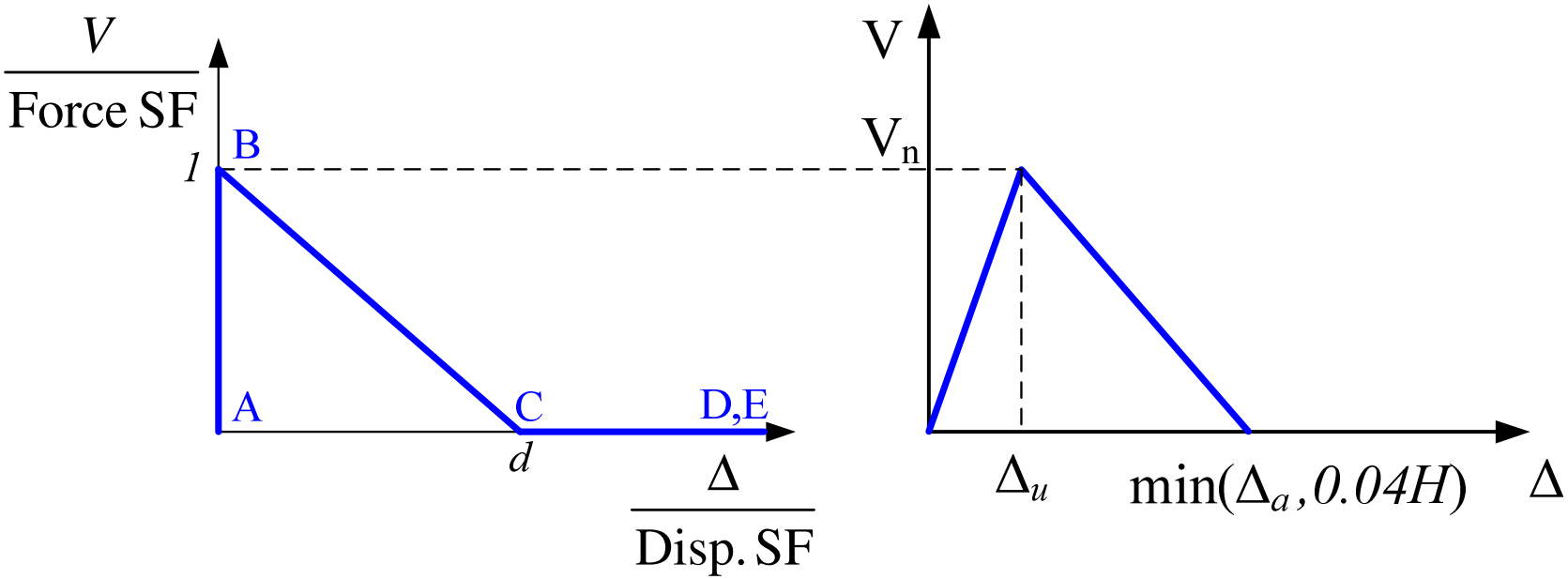
Load Deflection Curve due to Shear



$$\Delta_a = \left(\frac{4}{100} \frac{1+\tan^2\theta}{\tan\theta + P\dfrac{s}{\kappa' A_{st} f_{yt} d_c \tan\theta}} \right) H$$

$$\kappa' = 1.0, \text{ for shear failure}$$

剪力破壞非線性鉸參數

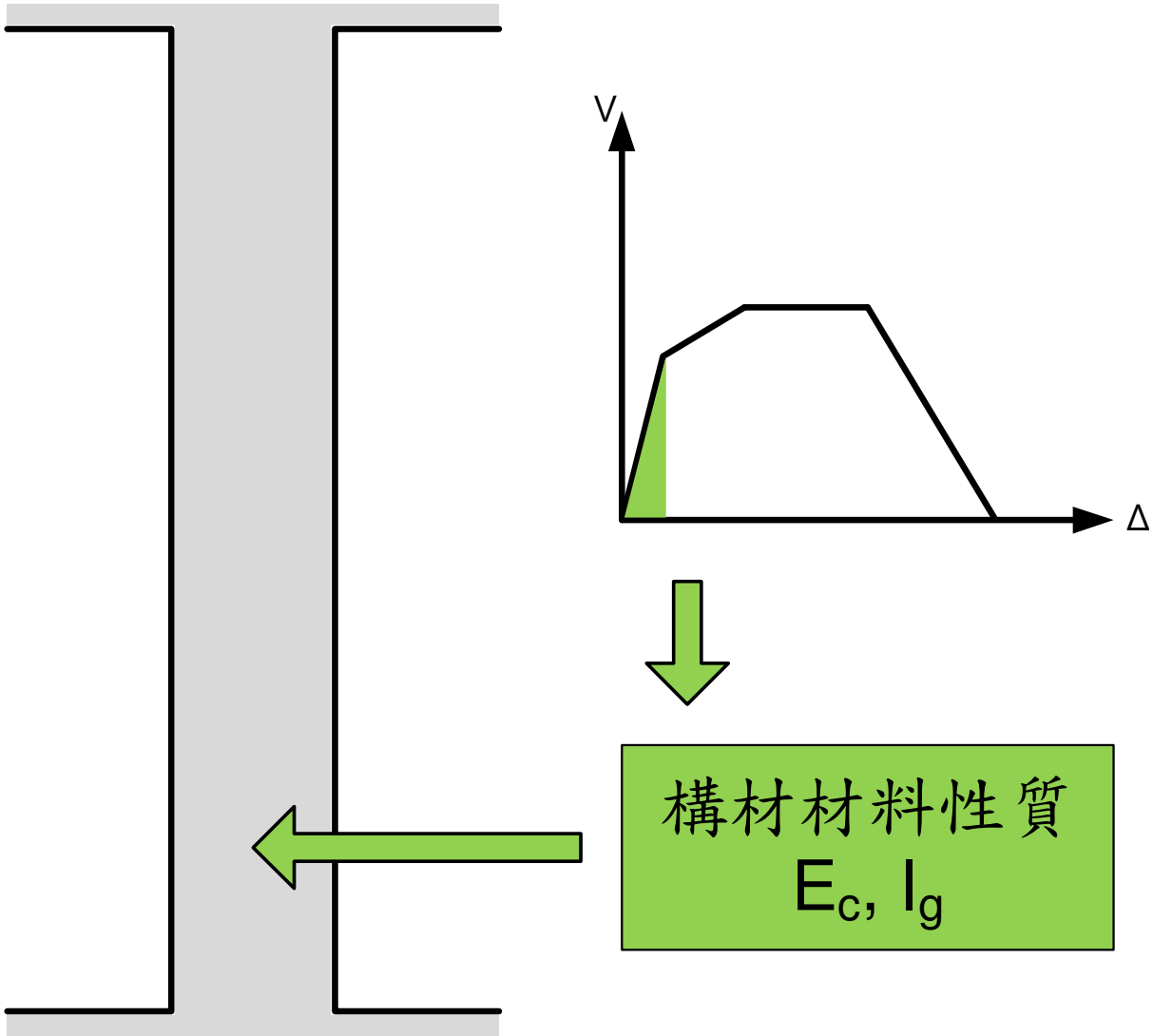


Point	Force / SF	Disp / SF
A	0	0
B	1	0
C	0	d
D	0	10d
E	0	10d

$$d = \min\left(\frac{\Delta_a}{H}, 0.04\right)$$

Force SF	V_n
Disp SF	H

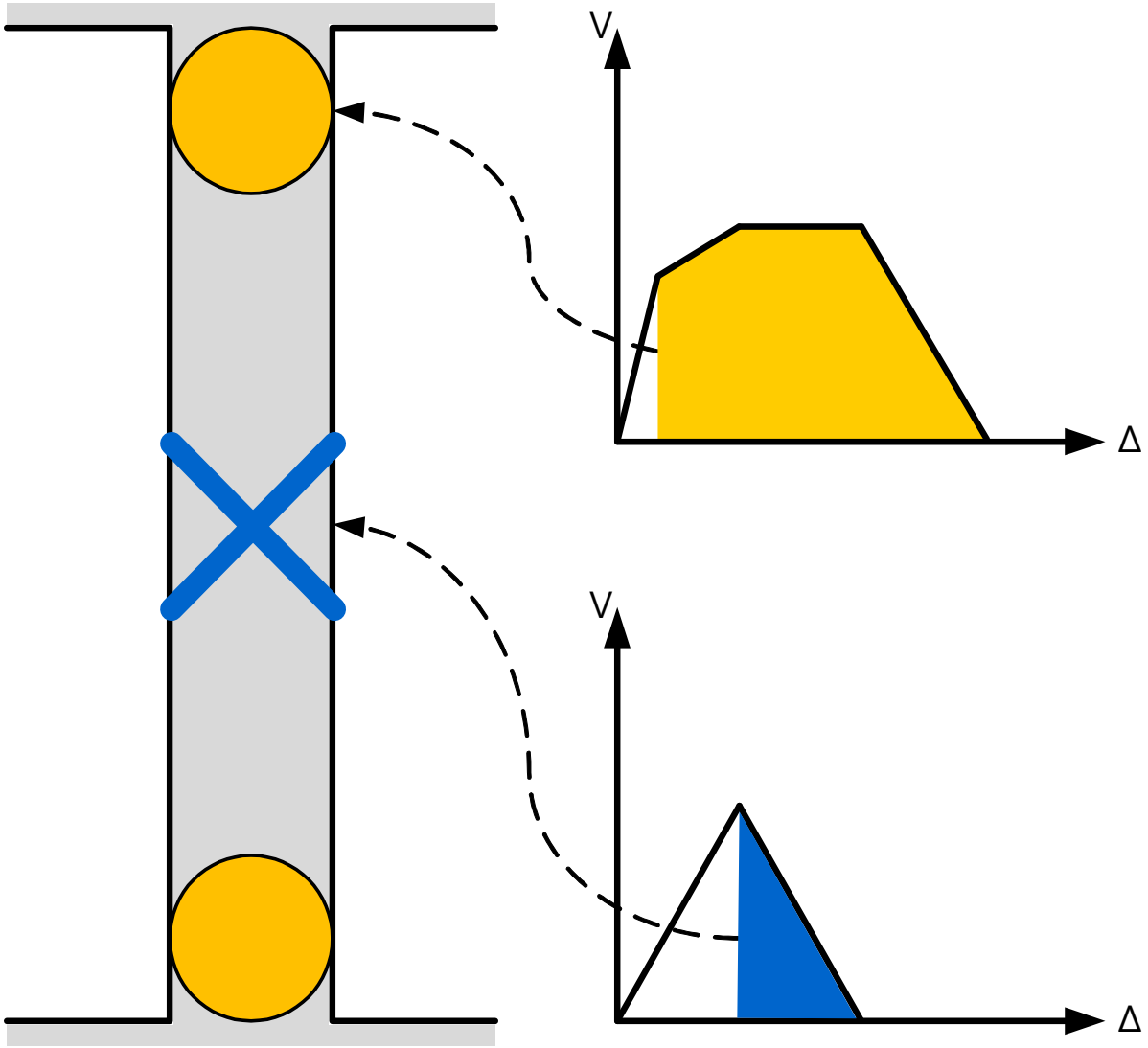
柱彈性行為模擬



彈性勁度折減

$0.7E_cI_g$

柱非線性行為模擬



撓曲與撓剪之
非線性行為

彎矩非線性鉸

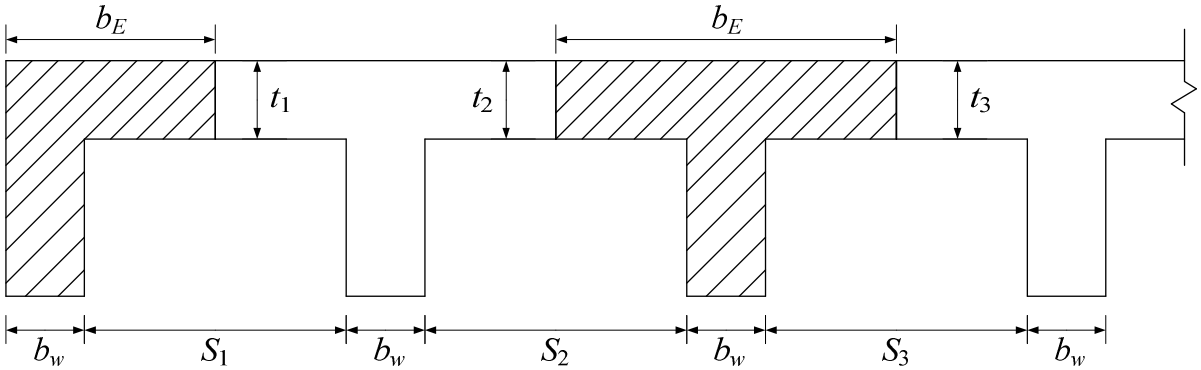
剪力破壞行為

剪力非線性鉸

梁之非線性鉸設定

- 校舍結構之梁常與樓板連接形成 T 型梁，因此梁的模擬應考慮 T 型梁之行為
- 技術手冊第三版依據 ASCE 41-06 所建議之梁非線性鉸參數進行設定
- 設定 T 型梁非線性鉸時，因斷面呈 T 型不對稱之緣故，必須注意其非線性鉸因正負彎矩的差異性，因其斷面呈 T 型不對稱之緣故

T 型梁有效翼緣寬度



1. T 型梁翼緣之有效版寬不得超過該梁跨度之1/4；梁腹每側懸出之有效翼緣寬度不得超過翼緣厚(版厚)之8倍或該梁與鄰梁間淨距之1/2。

$$b_E = \min(L/4, b_w + \min(8t_2, \frac{S_2}{2}) + \min(8t_3, \frac{S_3}{2}))$$

2. 梁僅一側有翼緣者，其有效懸出翼緣寬度不得超過該梁跨度之1/12、翼緣厚(版厚)之6倍或該梁與鄰梁間淨距之1/2。

$$b_E = \min(b_w + \frac{L}{12}, b_w + 6t_1, b_w + \frac{S_1}{2})$$

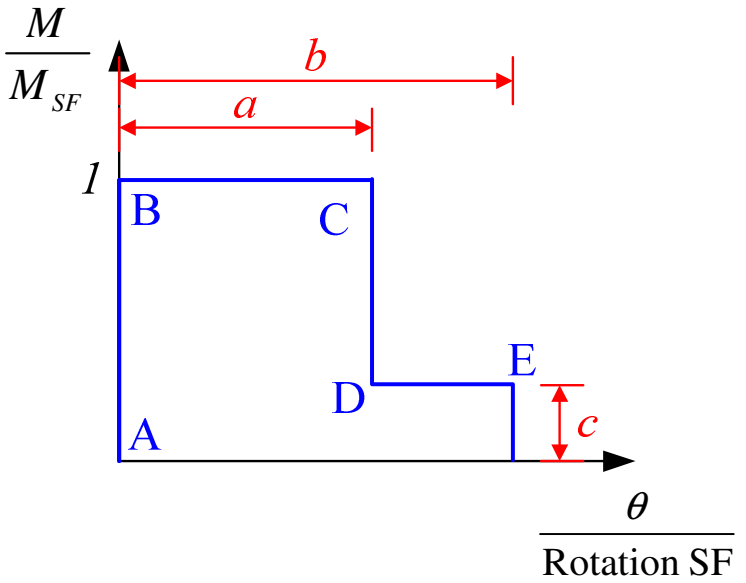
梁彎矩非線性鉸參數

$\frac{\rho-\rho'}{\rho_{bal}}$	箍筋	$\frac{V}{0.27b_w d\sqrt{f'_c}}$	a	b	c
≦0.0	有圍束	≦3	0.025	0.05	0.2
≦0.0	有圍束	≧6	0.02	0.04	0.2
≧0.5	有圍束	≦3	0.02	0.03	0.2
≧0.5	有圍束	≧6	0.015	0.02	0.2
≦0.0	無圍束	≦3	0.02	0.03	0.2
≦0.0	無圍束	≧6	0.01	0.015	0.2
≧0.5	無圍束	≦3	0.01	0.015	0.2
≧0.5	無圍束	≧6	0.005	0.01	0.2

ρ：梁斷面受拉鋼筋比

ρ’：梁斷面受壓鋼筋比

ρ_{bal}：梁斷面產生平衡應變狀態之鋼筋比

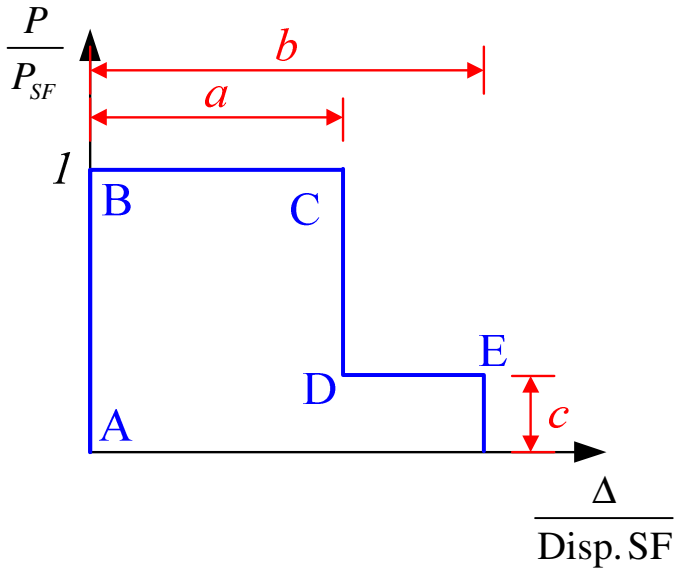


彎矩非線性鉸

Point	Moment / SF	Rotation / SF
A	0	0
B	1	0
C	1	a
D	c	a
E	c	b

梁剪力非線性鉸參數

箍筋間距	a	b	c
箍筋間距 ≤ (d/2)	0.003	0.02	0.2
箍筋間距 > (d/2)	0.003	0.01	0.2



剪力非線性鉸

Point	Force / SF	Disp / SF
A	0	0
B	1	0
C	1	a
D	c	a
E	c	b

d：有效深度
(構材最外受壓纖維至受拉鋼筋斷面重心之距離)

極短柱之模擬與設定

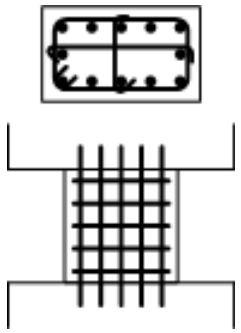
COLPH.exe

極短柱之剪力強度

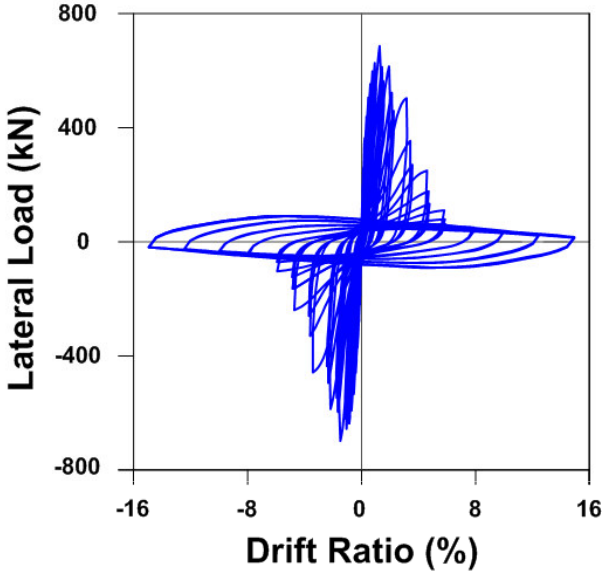
- 對於鋼筋混凝土構件之剪力強度，第二版係參酌 ACI 318 規範公式以提出建議，但若為極短柱 (高寬比≦2 者)，剪力強度之估算並不準確，恐高估鋼筋貢獻之剪力強度。
- 第三版採用軟化拉壓桿模式 (Softened Strut-and-Tie Model, SST)，做為前述剪力強度之計算，使得極短柱剪力強度之估算，更趨合理。

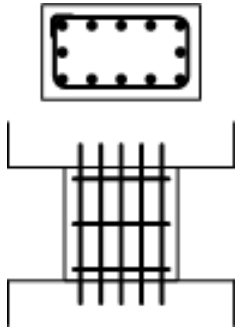
RC短柱受剪破壞之耐震評估研究

黃益堂、黃世建，「鋼筋混凝土短柱受剪破壞之耐震行為曲線研究」，國家地震工程研究中心研究報告，NCREE 08-027，2008。

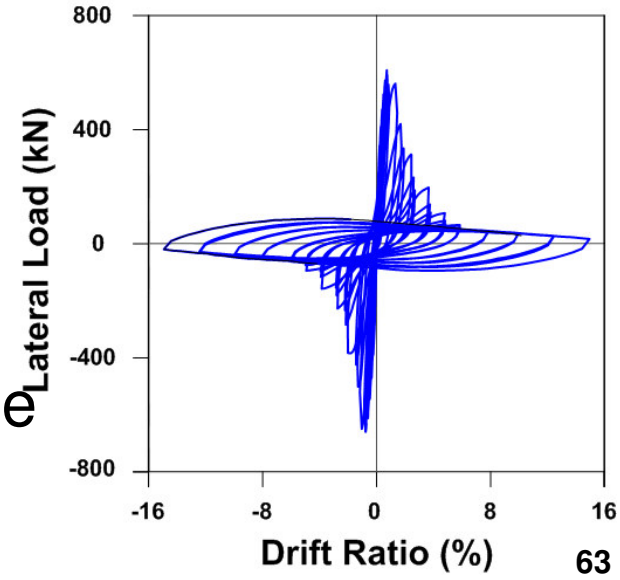


Ductile
(D)

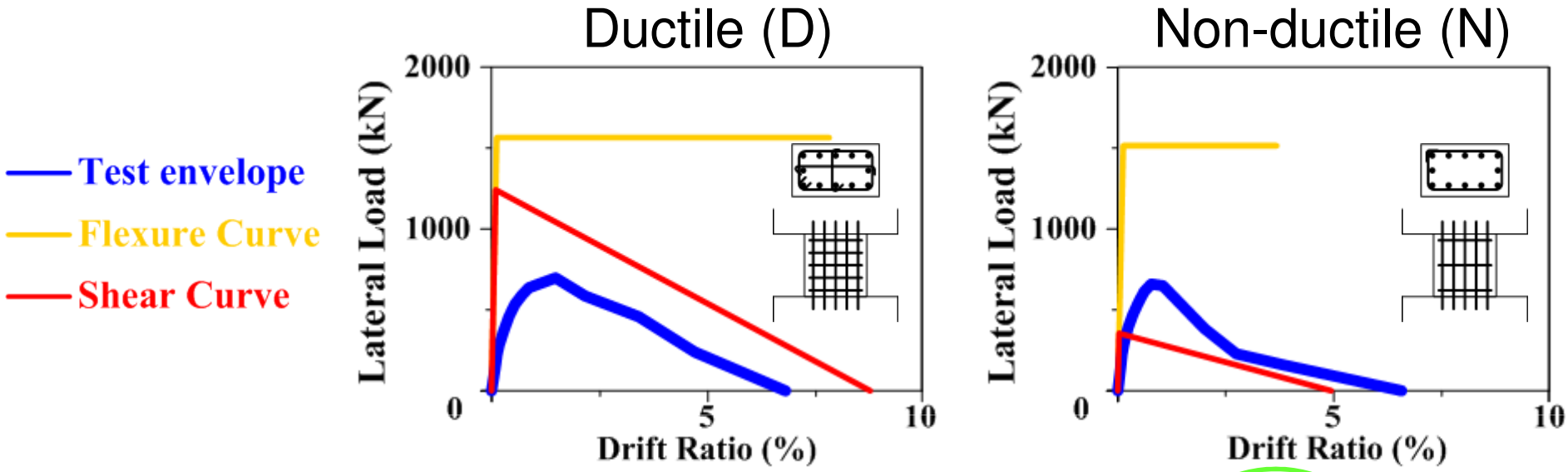




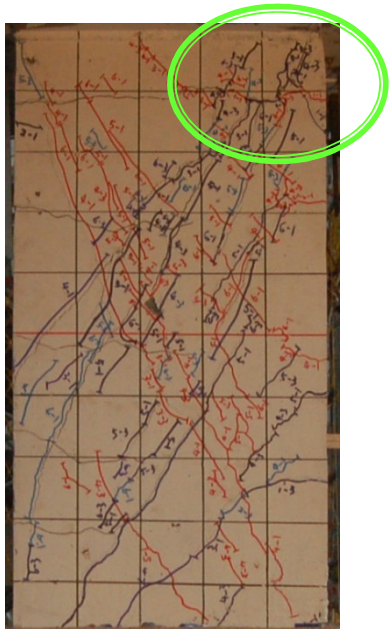
Non-ductile
(N)



技術手冊第二版評估結果

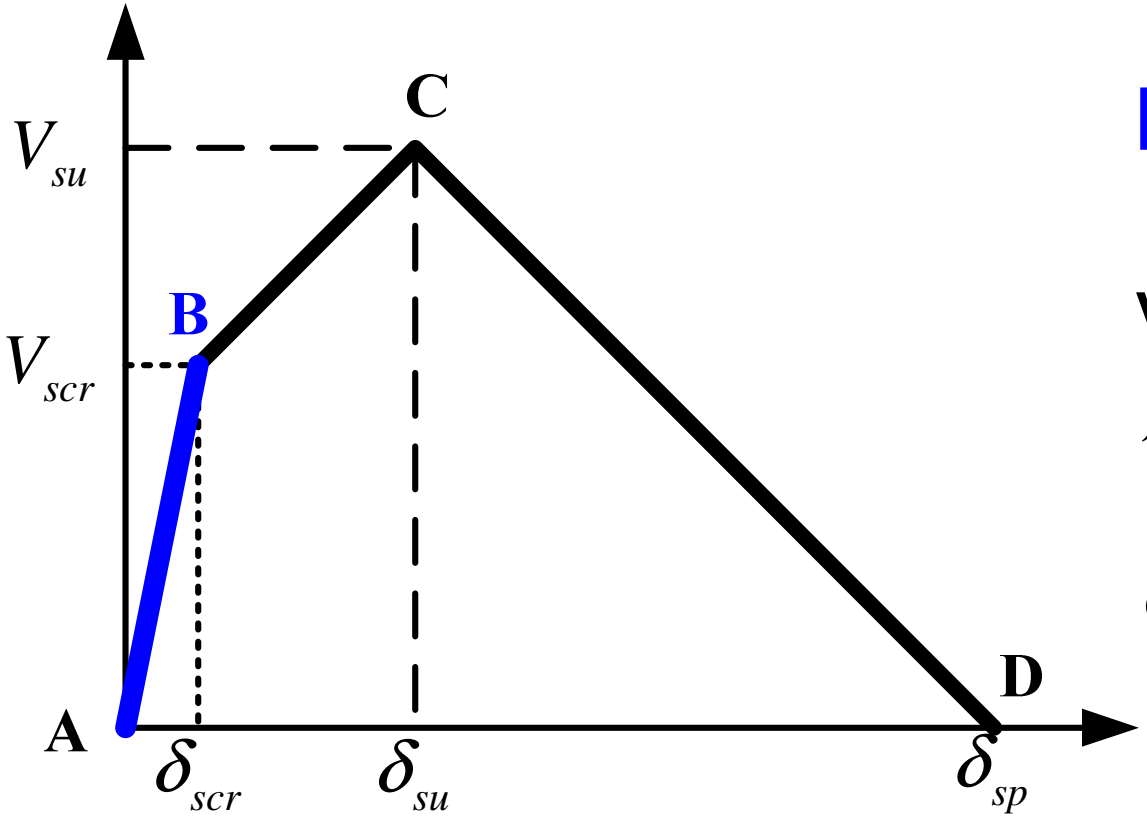


混凝土擠碎破壞



$$V_n = \frac{A_{st} f_{yt} d}{s} \cot\alpha + 0.17\left(1 + \frac{N}{14A_g}\right)\sqrt{f_c'}bd$$

極短柱之剪力非線性行為



B：剪力開裂點

V_{scr} 以 ACI 牆開裂公式計算

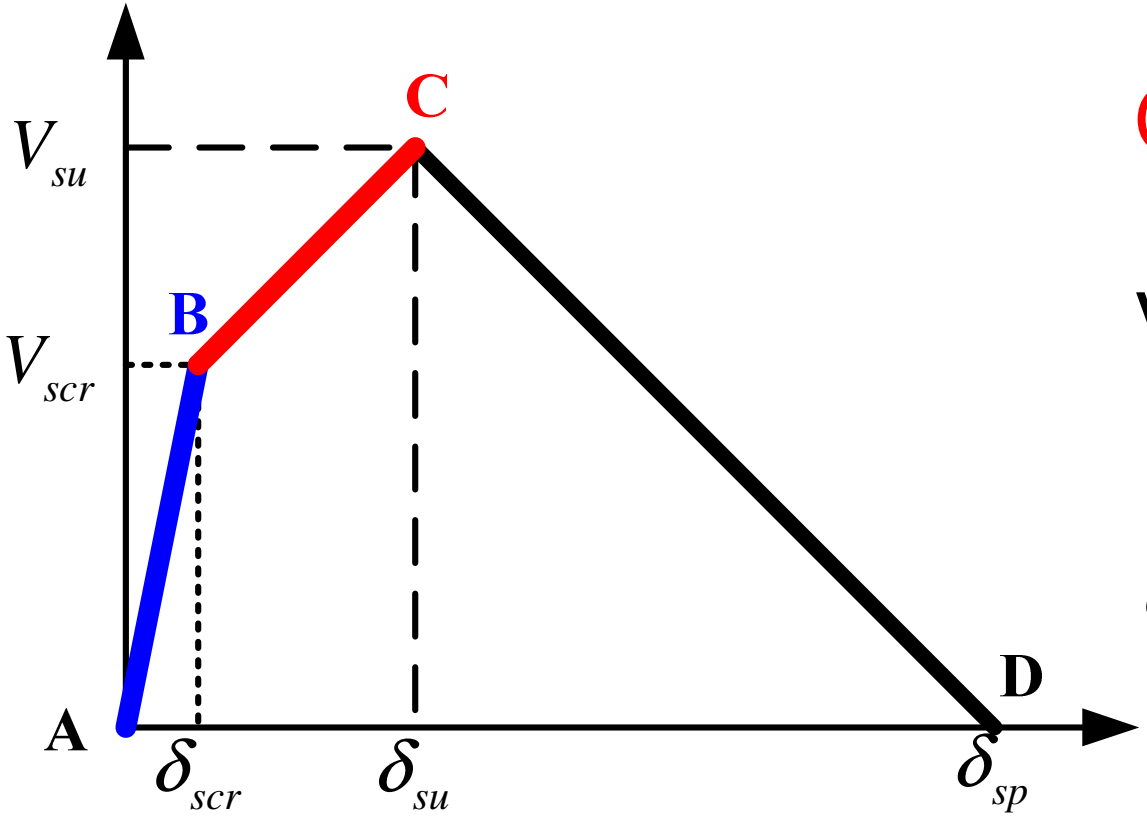
$$\delta_{scr} = \delta_{s,cr} + \delta_{f,cr}$$

$$\delta_{s,cr} = \gamma_{vh} H = \frac{2(1+\nu)}{E_c} \frac{1.2}{bh} V_{scr} H$$

$$\delta_{f,cr} = \frac{V_{scr} H^3}{12 E_c I}$$

$$I = 0.7 I_g$$

極短柱之剪力非線性行為



C：剪力極限點

V_{su} 以 SST 計算

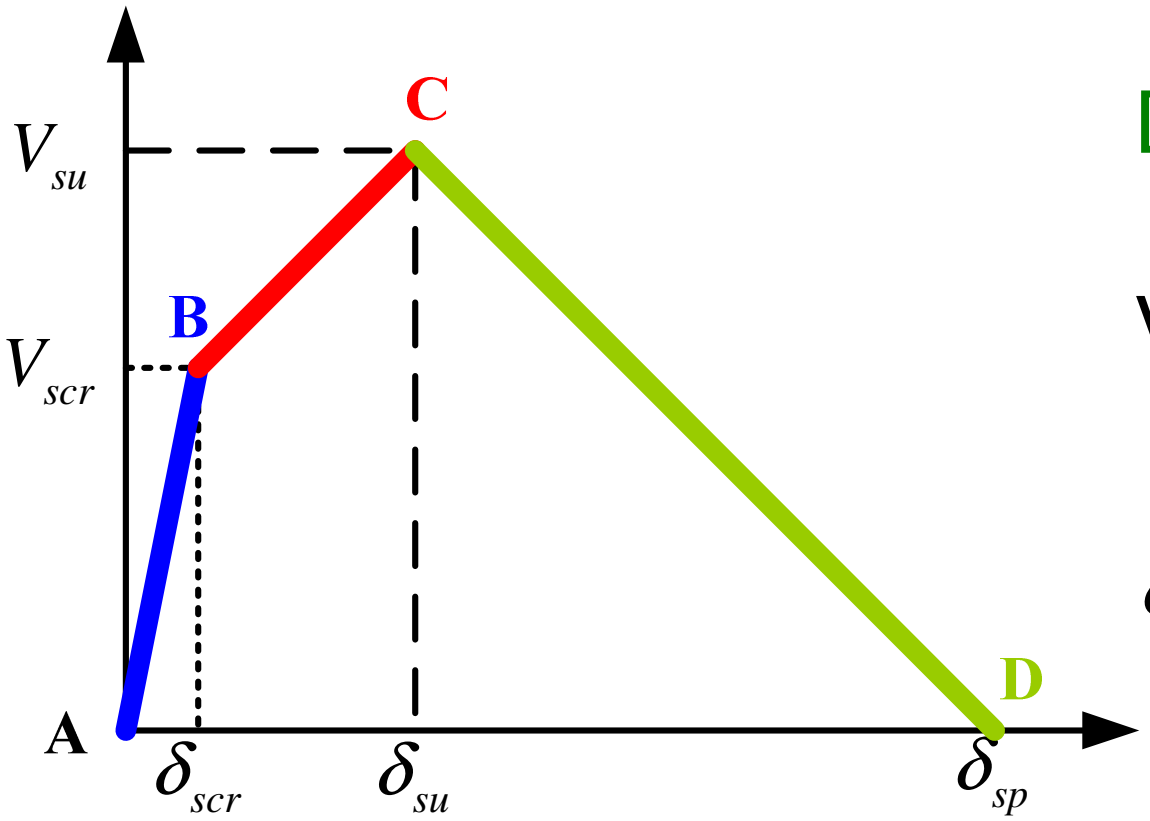
$$\delta_{su} = \delta_{s,su} + \delta_{f,su}$$

$$\delta_{s,su} = \gamma_{vh,su} H$$

$$\delta_{f,su} = \frac{V_{su} H^3}{12 E_c I}$$

$$I = 0.35 I_g$$

極短柱之剪力非線性行為



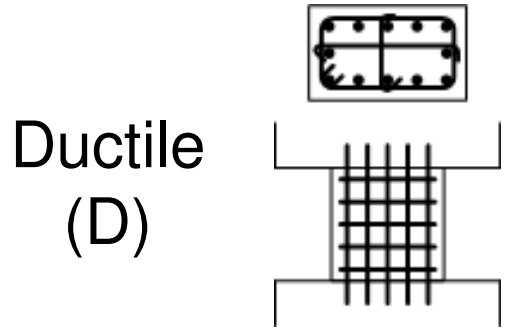
D：剪力殘餘強度點

$V_{sp} = 0$

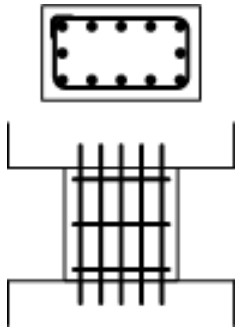
$$\delta_{sp} = \delta_{su} + rH$$

位移係數 ***r*** 可參考 **ASCE 41-06** 建議之非線性轉角係數

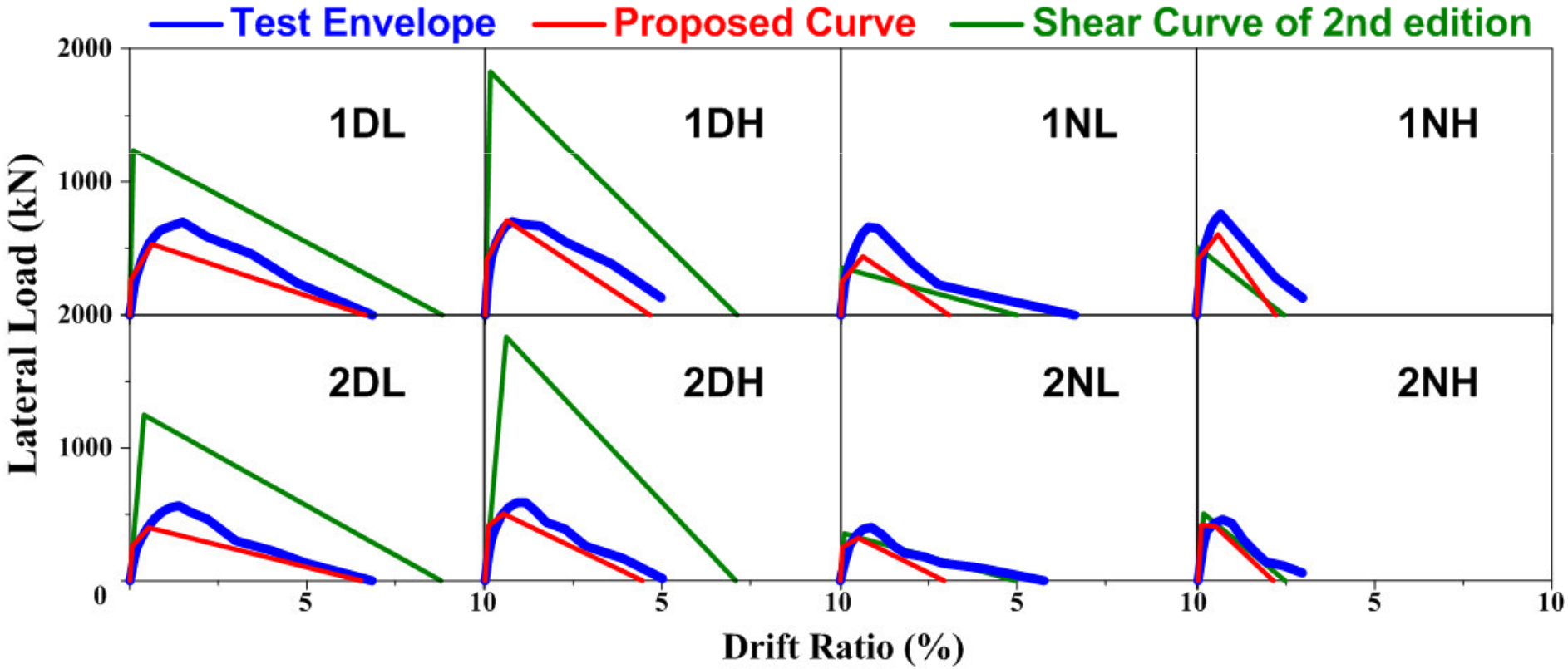
SST 模型計算 D 區剪力行為



Ductile
(D)

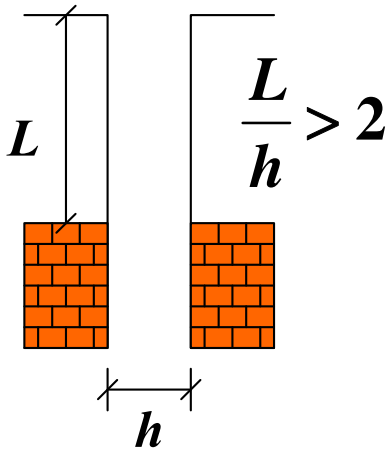


Non-ductile
(N)

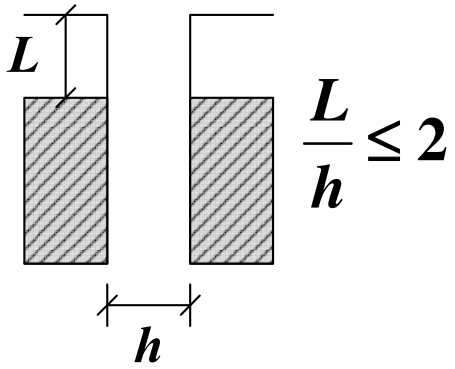


李翼安、邱聰智、蕭輔沛、黃世建，「鋼筋混凝土短柱受剪破壞之耐震評估研究」，結構工程期刊，第29卷第1期，2014年3月。

側力-位移曲線差異比較



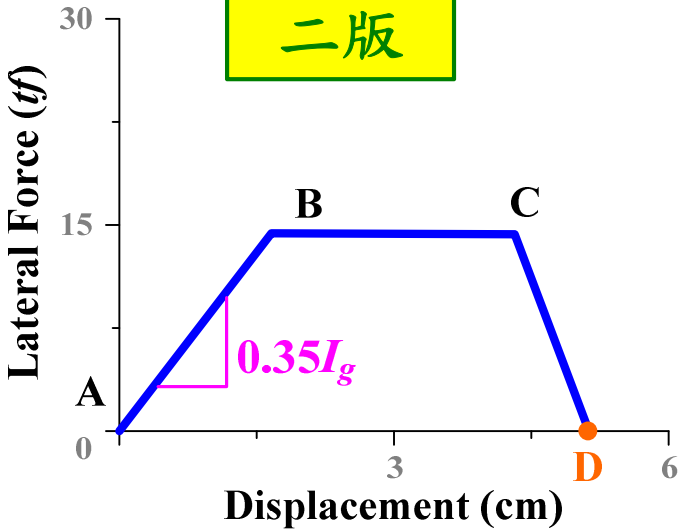
撓剪塑鉸



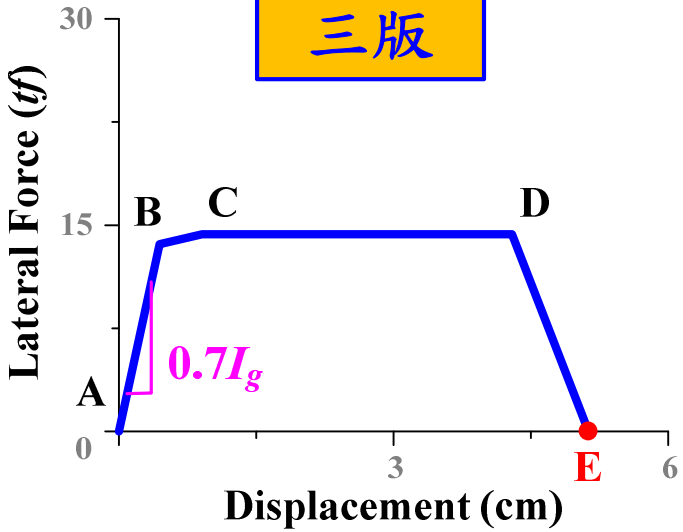
極短柱

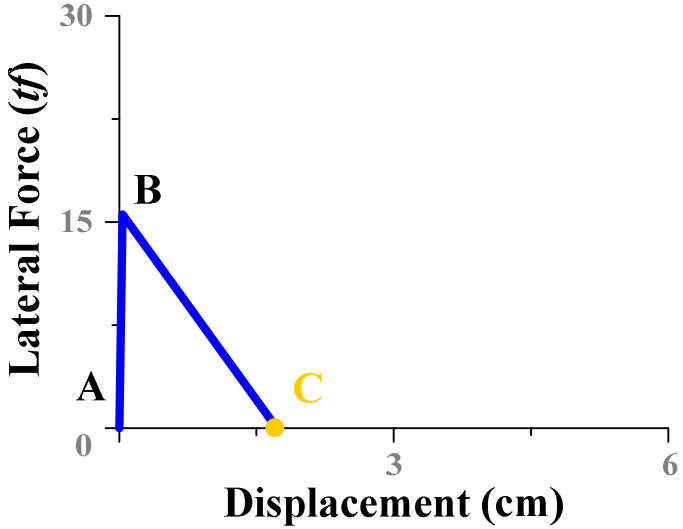
剪力塑鉸

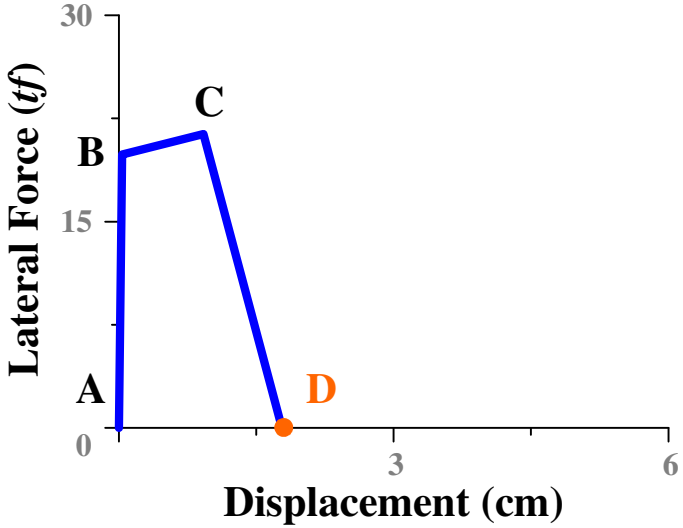
二版



三版







✓極短柱強度點延後發生

✓一般柱有機會發展強度

磚牆桿件之模擬與設定

BWPH.exe

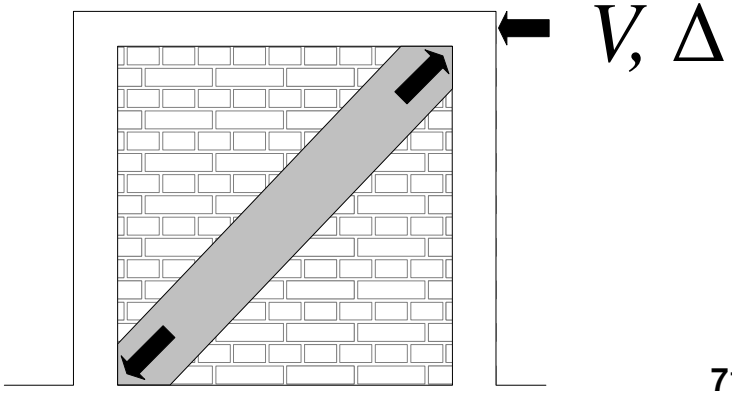
磚牆構件之非線性鉸計算

1. 磚牆行為之模擬

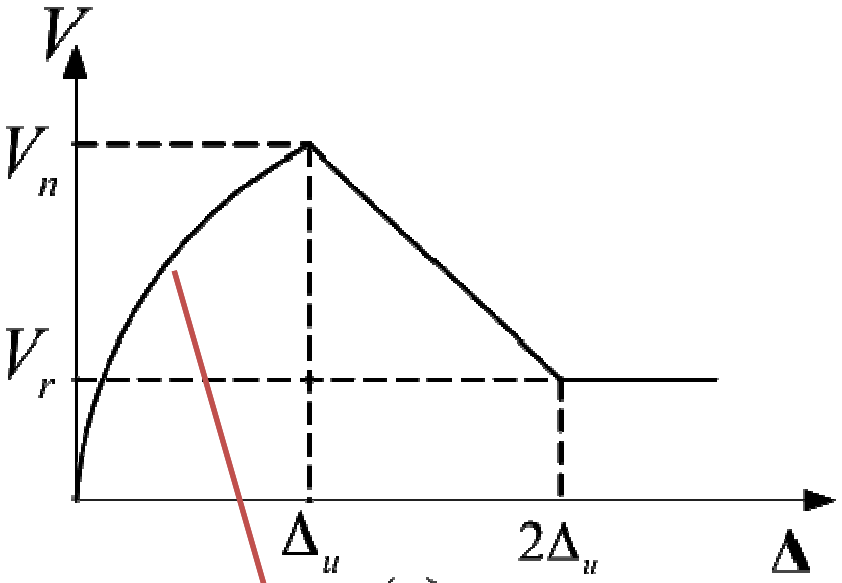
- 成大許茂雄教授進行一系列磚牆研究，建議磚牆可以一等值受壓斜撐進行模擬，該斜撐必須與磚牆具有相等之勁度與強度，其端點與構架鉸接。
- 以斜撐上之軸力非線性鉸表現磚牆之破壞行為。

2. 磚牆壓力非線性鉸計算依據

- 建築物磚構造設計及施工規範 (2008)

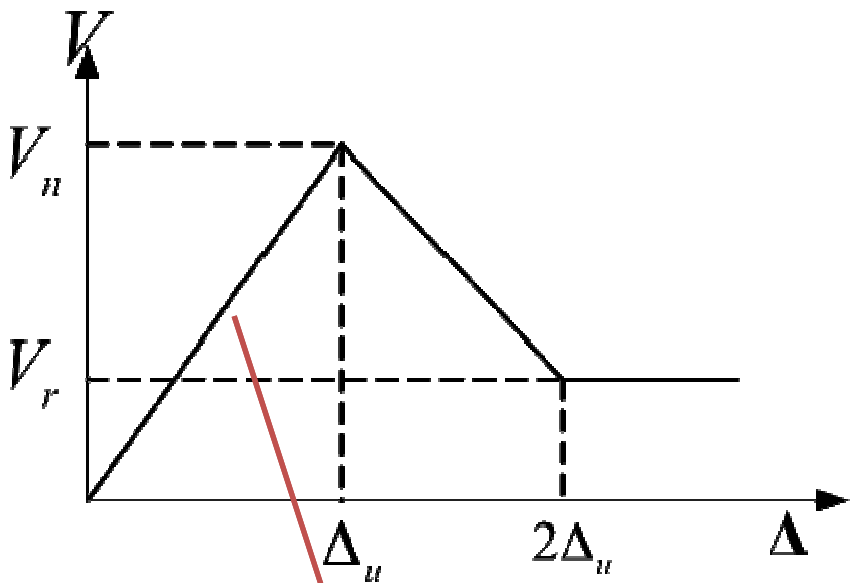


磚牆等值斜撐模型



(a)

建築物磚構造設計及施工規範
側向載重位移曲線



(b)

NCREE 建議曲線

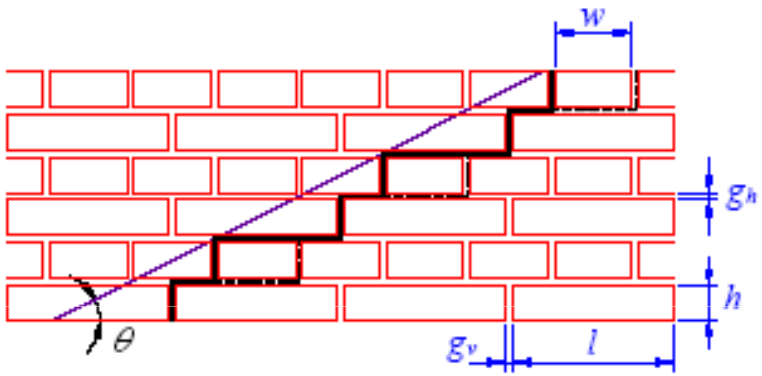
$$\frac{V}{V_u} = a_1\left(\frac{\Delta}{\Delta_u}\right) + a_2\left(\frac{\Delta}{\Delta_u}\right)^2 + a_3\left(\frac{\Delta}{\Delta_u}\right)^3$$

$$E_u = 61.29\eta_1\eta_2 f_{bc}^{0.7} f_{mc}^{0.3}$$

磚牆臨界破裂角

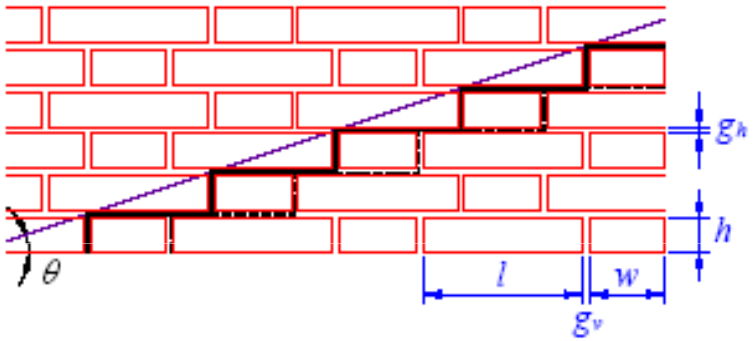
1. 英國式砌法

$$\tan\theta = \frac{h + g_h}{w + g_v}$$



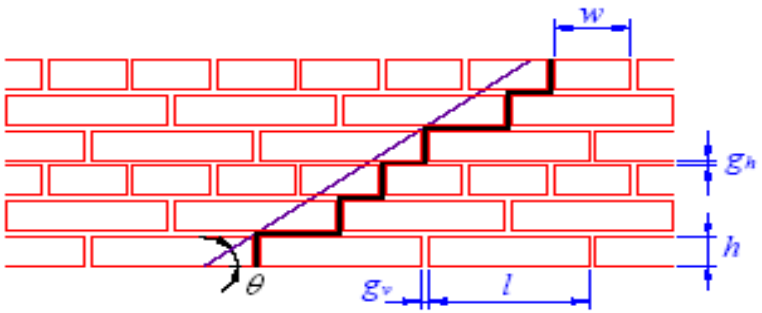
2. 法國式砌法

$$\tan\theta = \frac{2(h + g_h)}{w + l + 2g_v}$$



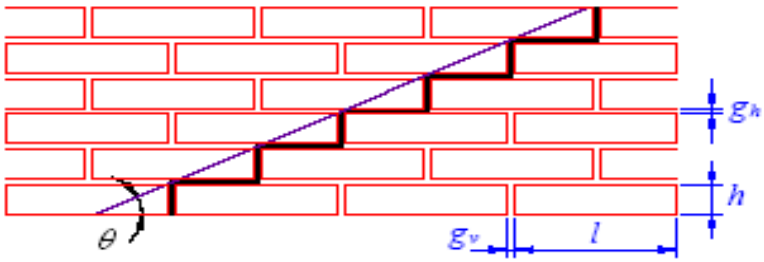
3. 二順一丁砌法

$$\tan\theta = \frac{3(h + g_h)}{2(w + g_v)}$$



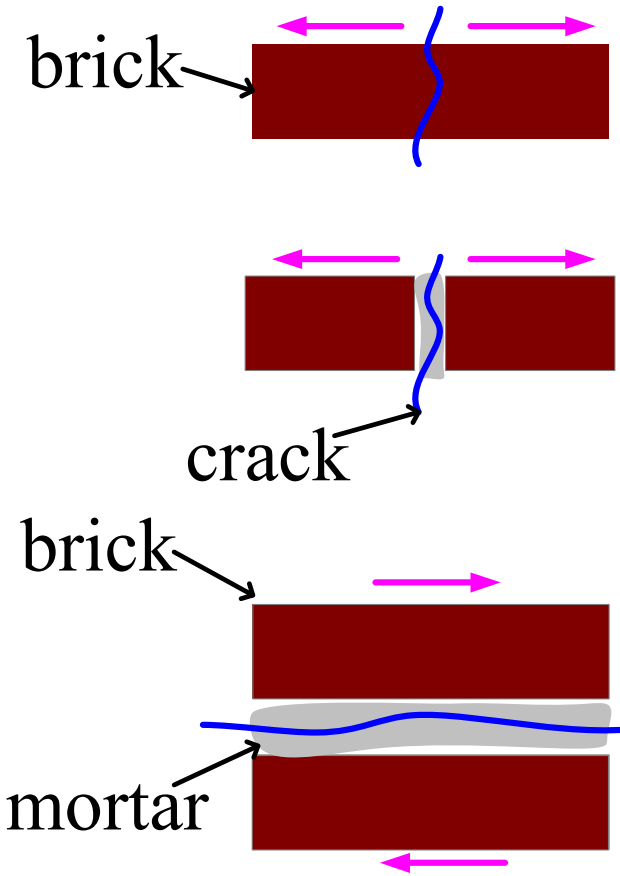
4. 順砌法

$$\tan\theta = \frac{2(h + g_h)}{l + g_v}$$



理論上裂縫將會延灰縫間發展，實際上…

Cracks of brick masonry



Splitting of brick

Splitting of mortar

Sliding of mortar

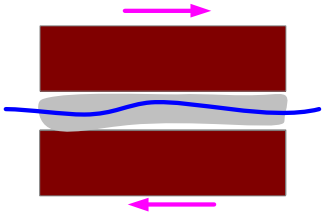
(Taiwan masonry building code, 2007)

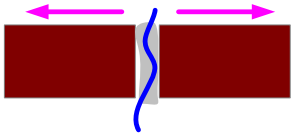
1. 豎向灰縫的劈裂裂縫
2. 豎向劈磚的劈裂裂縫
3. 水平灰縫的滑移裂縫

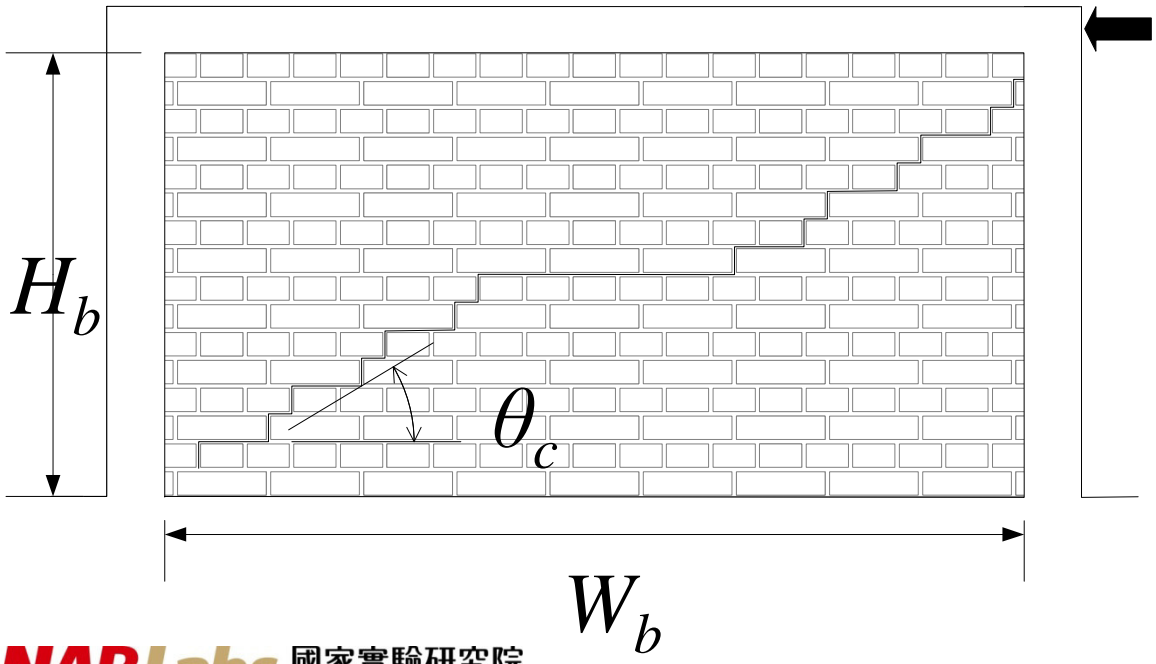
四面圍束牆：Ultimate strength

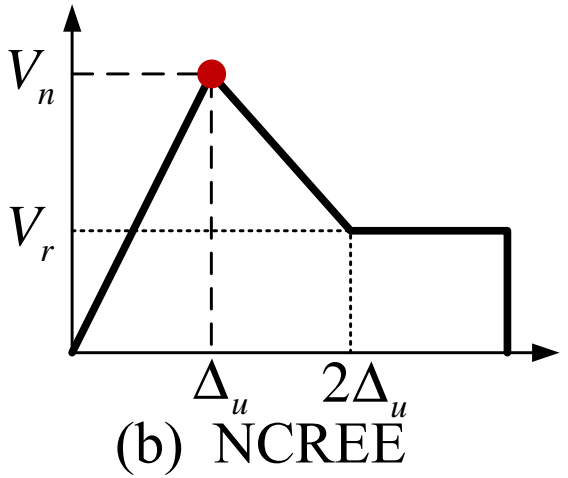
$$(H_b/W_b) \le \tan\theta_c$$

$$V_n = \tau_f (W_b \times T_b) + 0.45 f_{mbt} (H_b \times T_b)$$





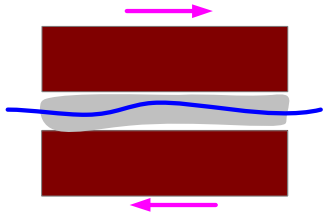


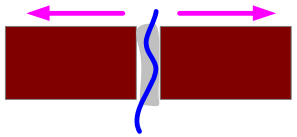


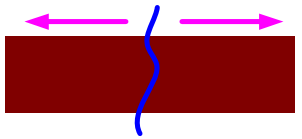
(b) NCREE

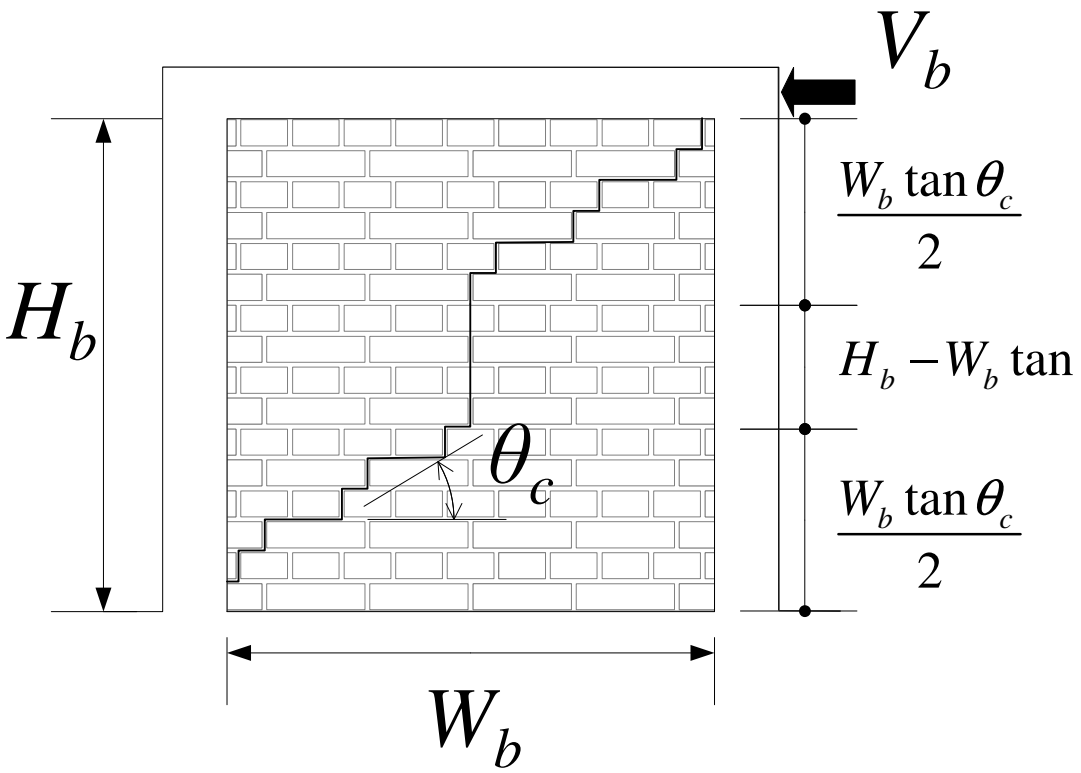
四面圍束牆：$(H_b/W_b) > \tan\theta_c$

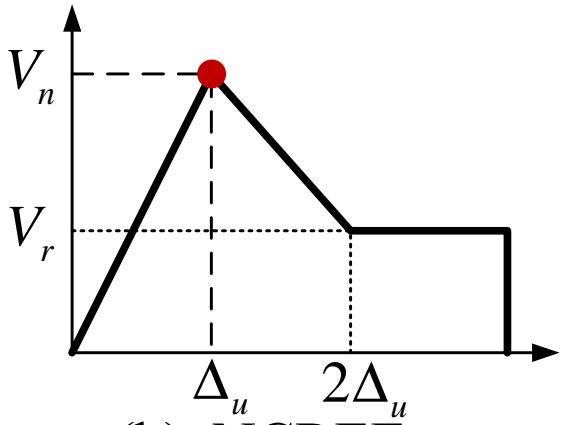
$$V_n = \tau_f (W_b \times T_b) + 0.45 f_{mbt} (W_b \tan\theta_c \times T_b) + \frac{0.45 f_{mbt} + 0.45 f_{bt}}{2} \left[(H_b - W_b \tan\theta_c) \times T_b \right]$$











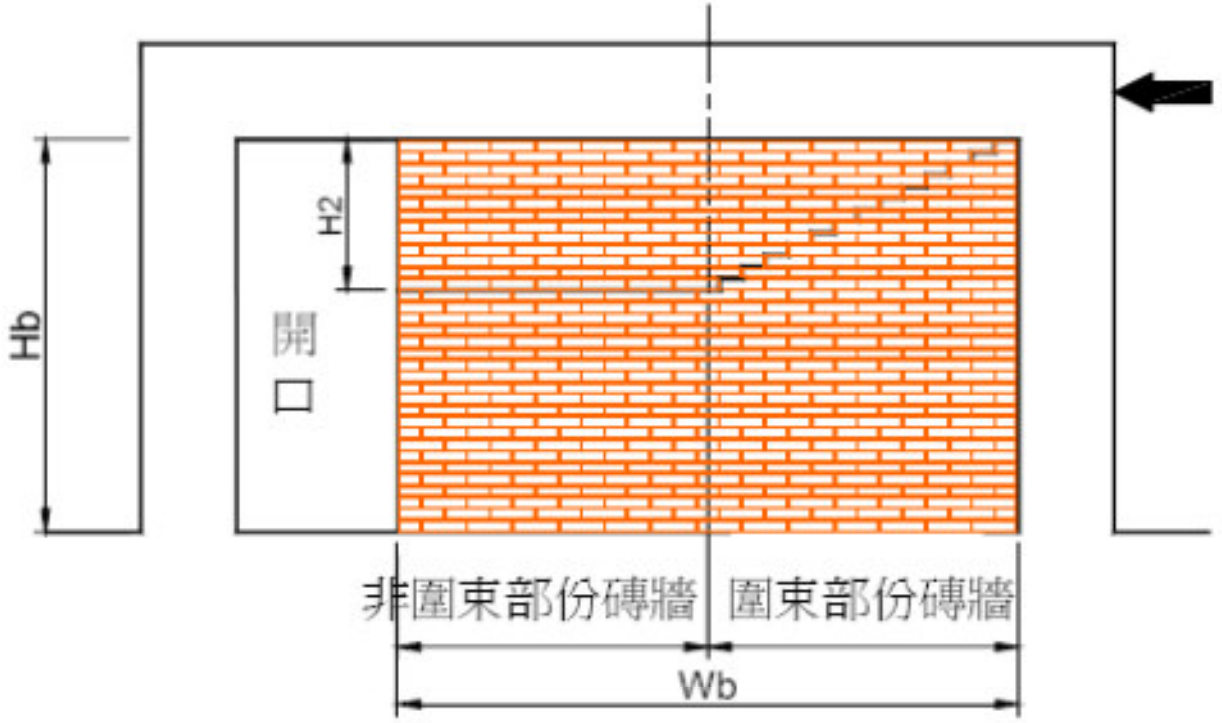
(b) NCREE

三邊圍束磚牆：

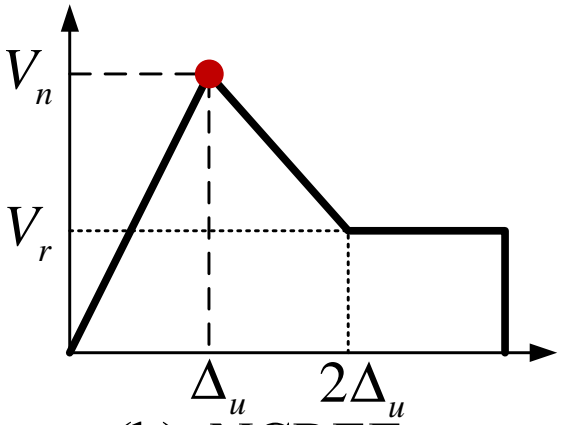
$$V_n = T_b \times (W_b \times \tau_f + H_2 \times 0.45 f_{mbt})$$

$$H_2 = 0.5 W_b \tan\theta \leq H_b$$

非圍束部份磚牆
無法形成階梯狀
對角斜撐機制



（a） 三邊圍束破壞路徑例



(b) NCREE

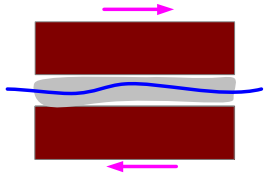
磚牆殘餘強度點之強度與位移

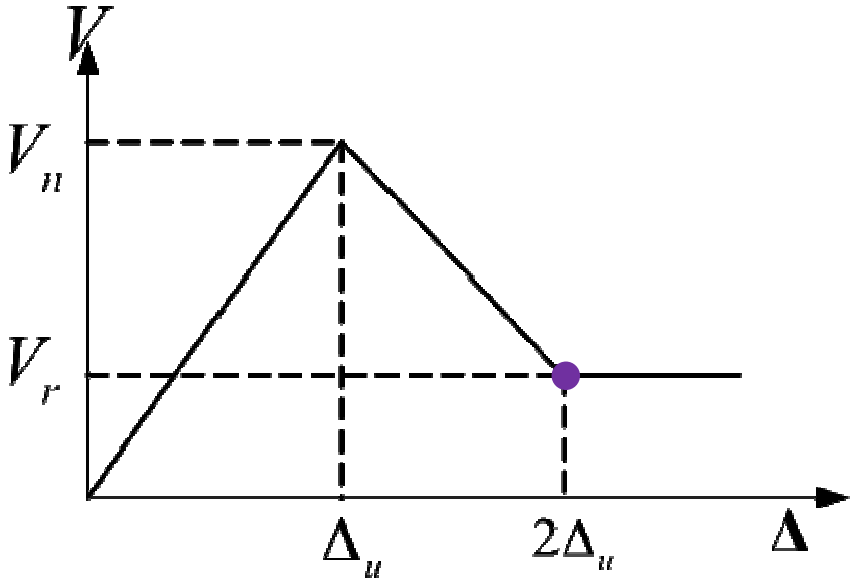
（A）非窗台磚牆之殘餘強度為：

$$V_r = \tau_f \times T_b \times W_b \leq \quad 0.6 V_n$$

（B）窗台磚牆之殘餘強度為：

$$V_r = 0.7 \times \tau_f \times T_b \times W_b \leq \quad 0.6 V_n$$

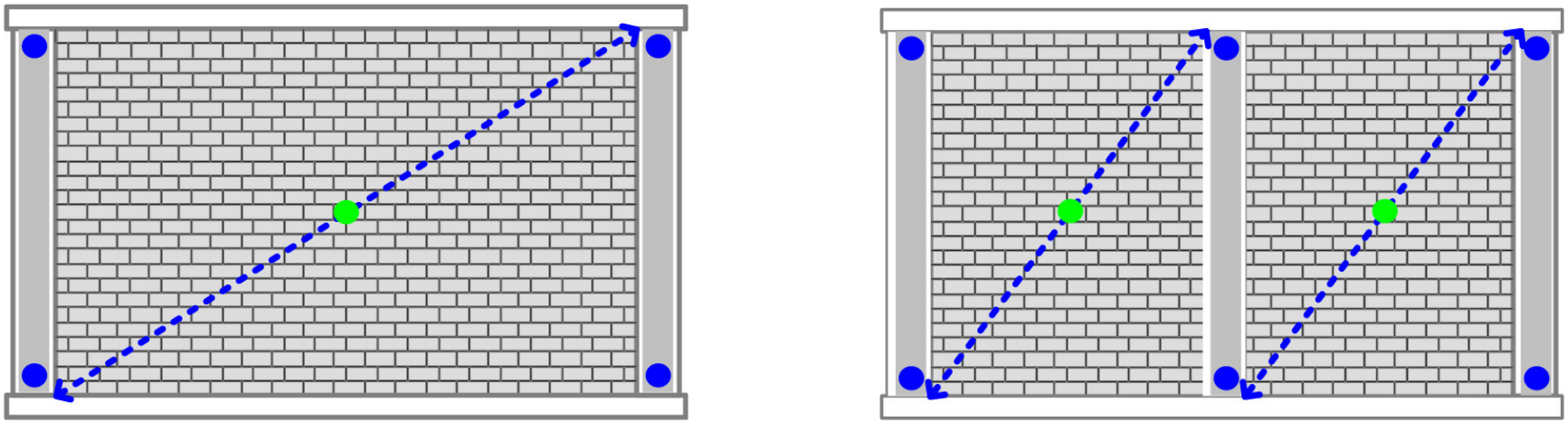




根據試驗之觀察，磚牆約在達到約兩倍水平極限位移時，磚牆強度會衰減至水平殘餘強度

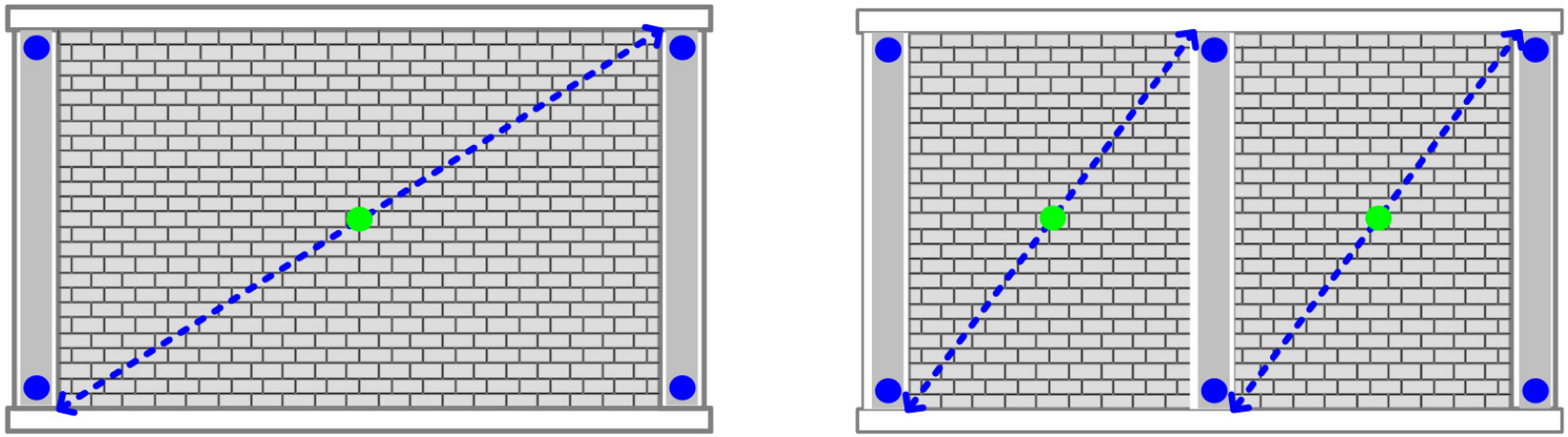
磚牆之最大水平位移可參考試驗結果並保守考慮取牆高之**2.0%**為限制

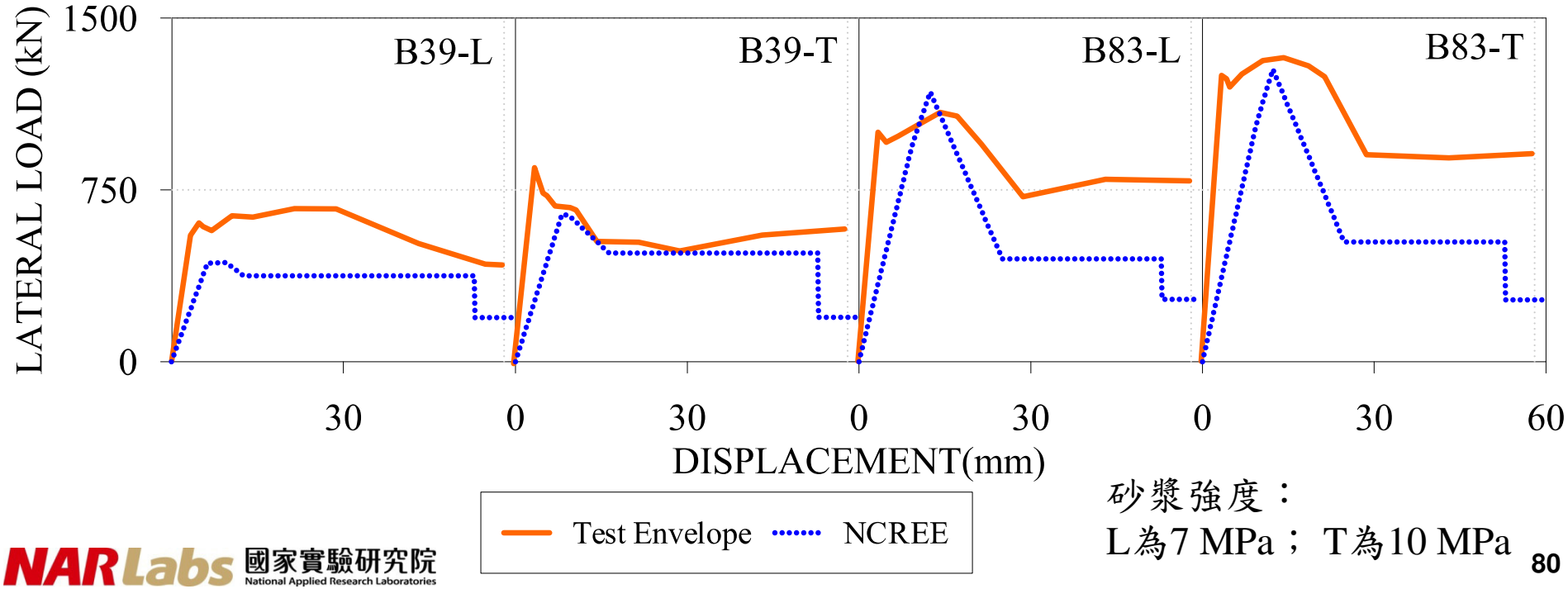
四面圍束磚牆實驗驗證



邱聰智、黃世建等，中華民國第十一屆結構工程研討會，2012年9月，Paper No. 13020

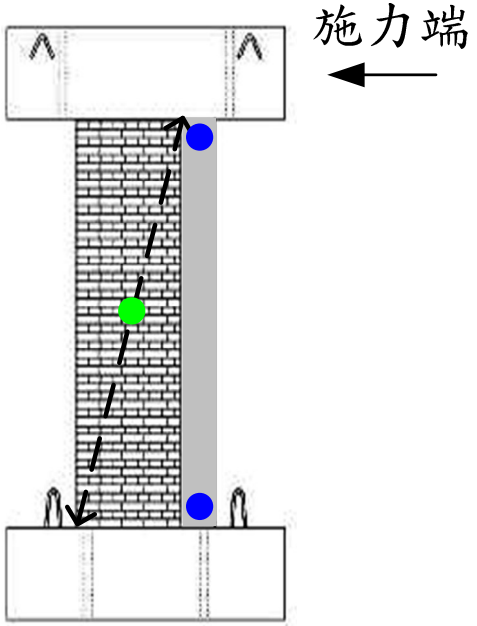
四面圍束磚牆實驗驗證



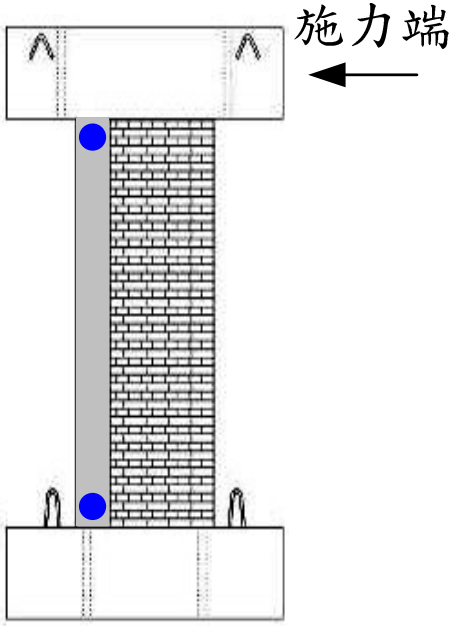


砂漿強度：
L為7 MPa； T為10 MPa

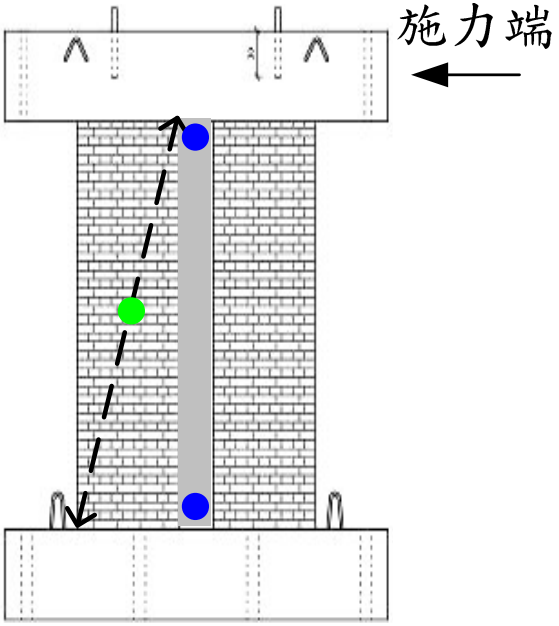
三面圍束磚牆實驗驗證



試體A、
試體AC、



試體C



試體B、
試體BC、

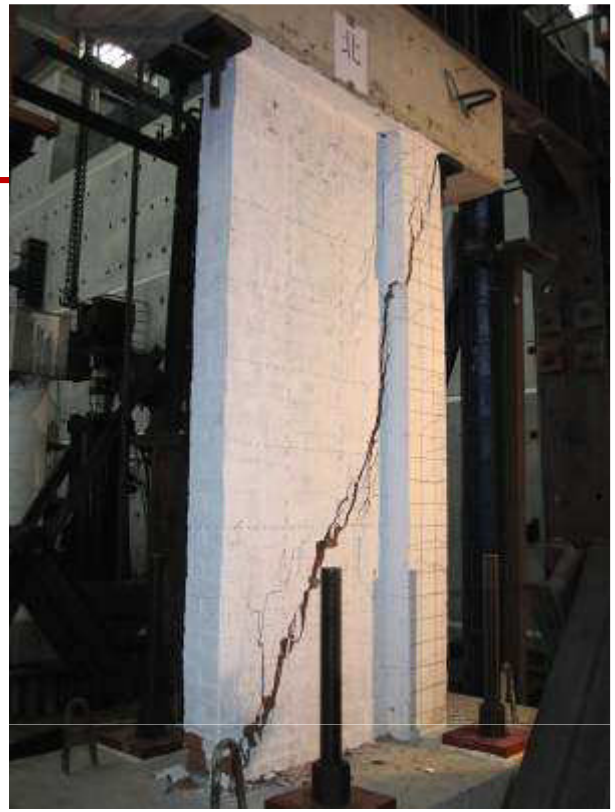
軸力非線性鉸

彎矩非線性鉸

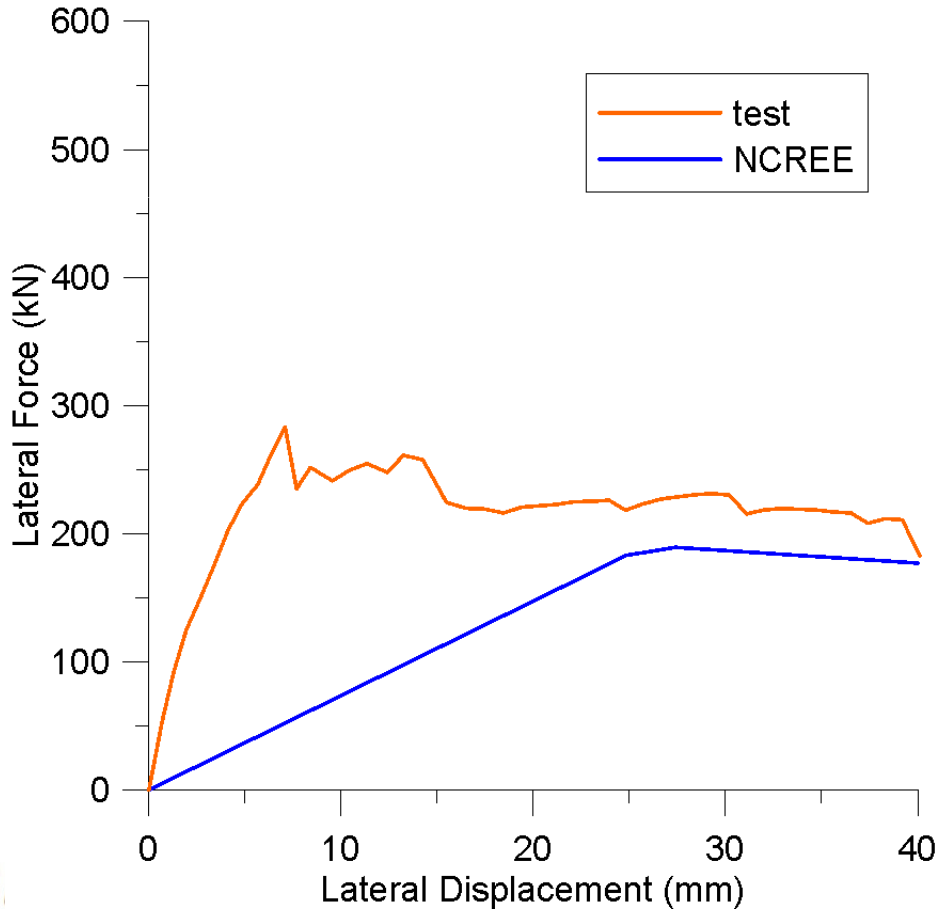
Yi-Hsuan TU (2011)

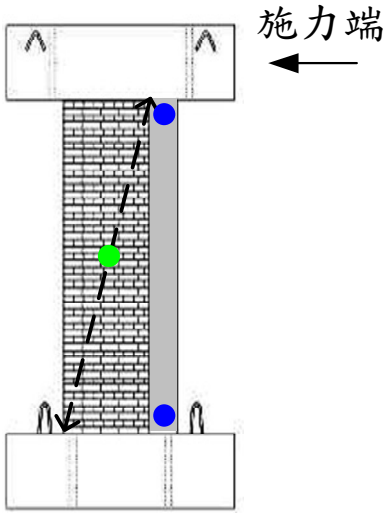
試體A：單向側推

$$\frac{V_{test}}{V_{cal.}} = 1.5$$



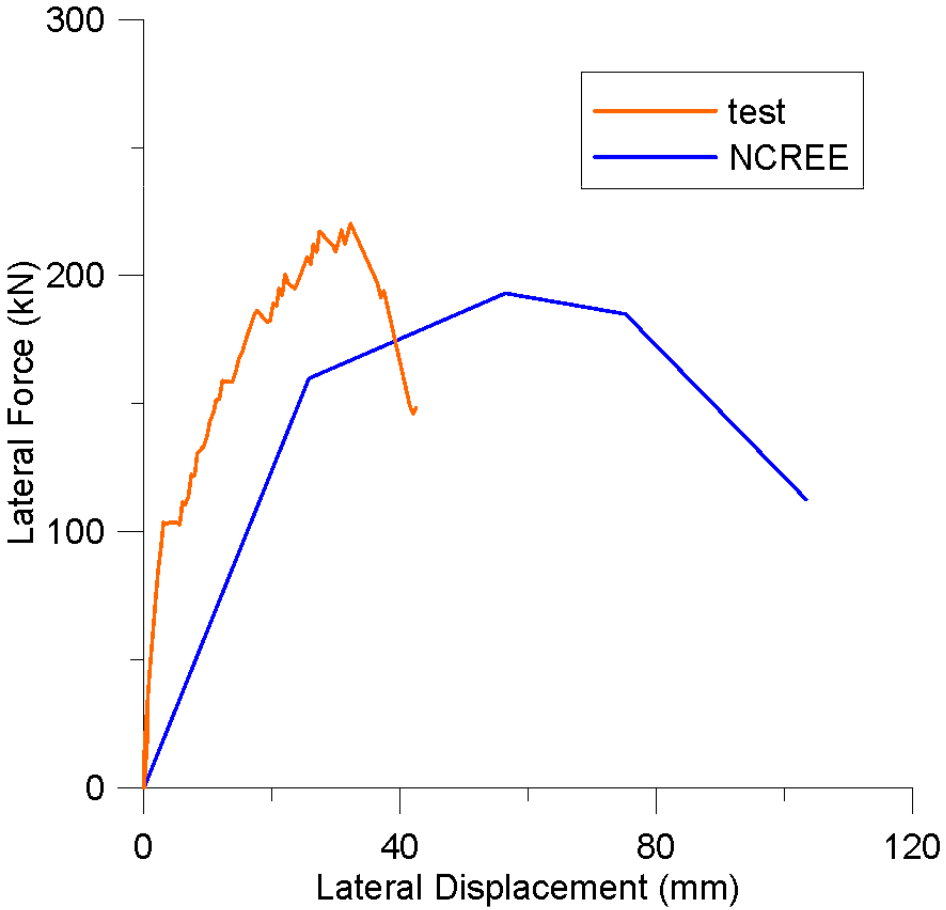
Yi-Hsuan TU (2011)



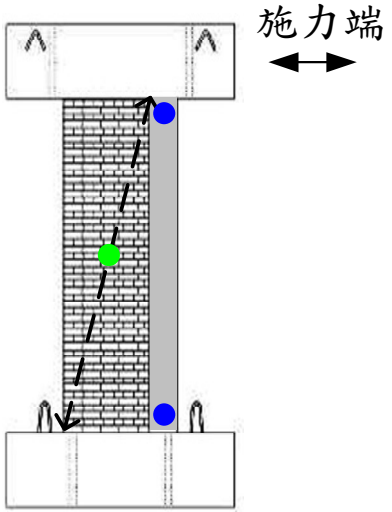


試體AC：雙向側推

$$\frac{V_{test}}{V_{cal.}} = 1.14$$



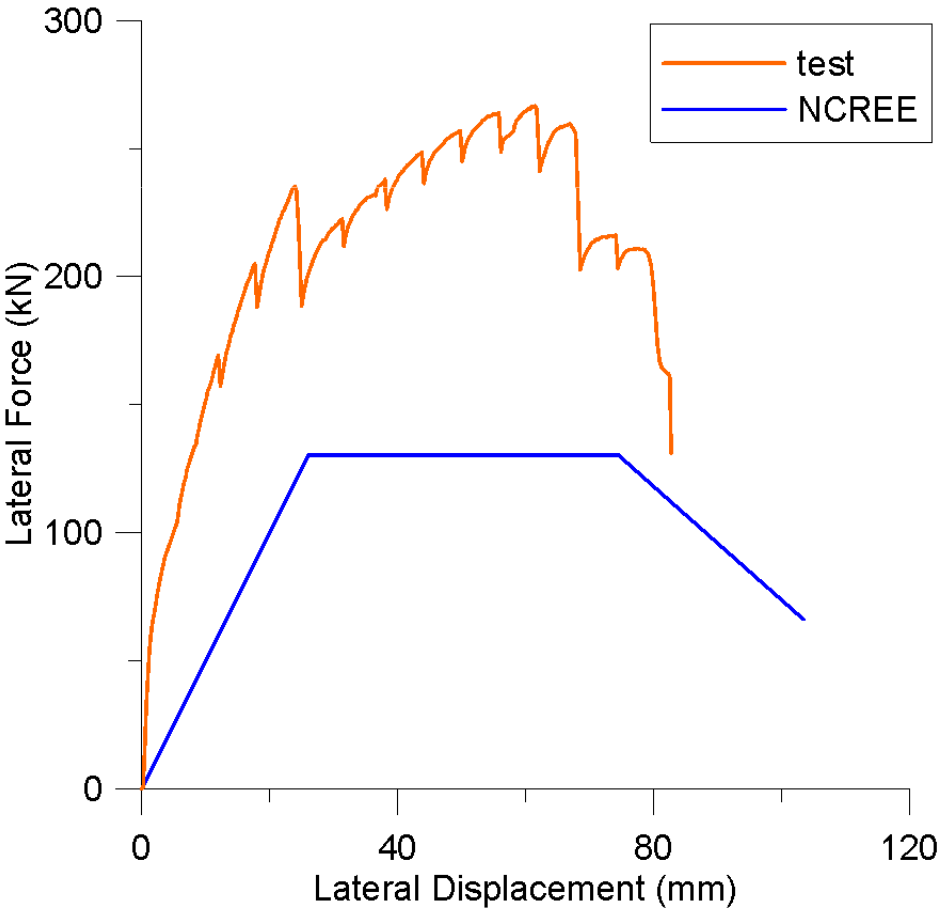
Yi-Hsuan TU (2011)



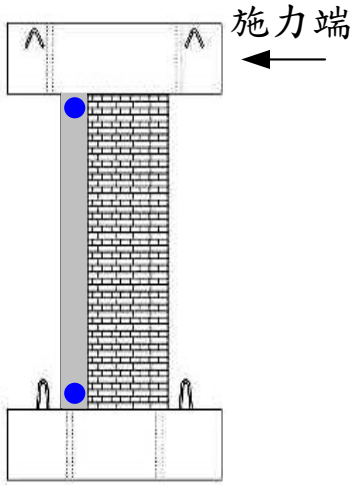
NARL

試體C：單向側推

$$\frac{V_{test}}{V_{cal.}} = 2.05$$



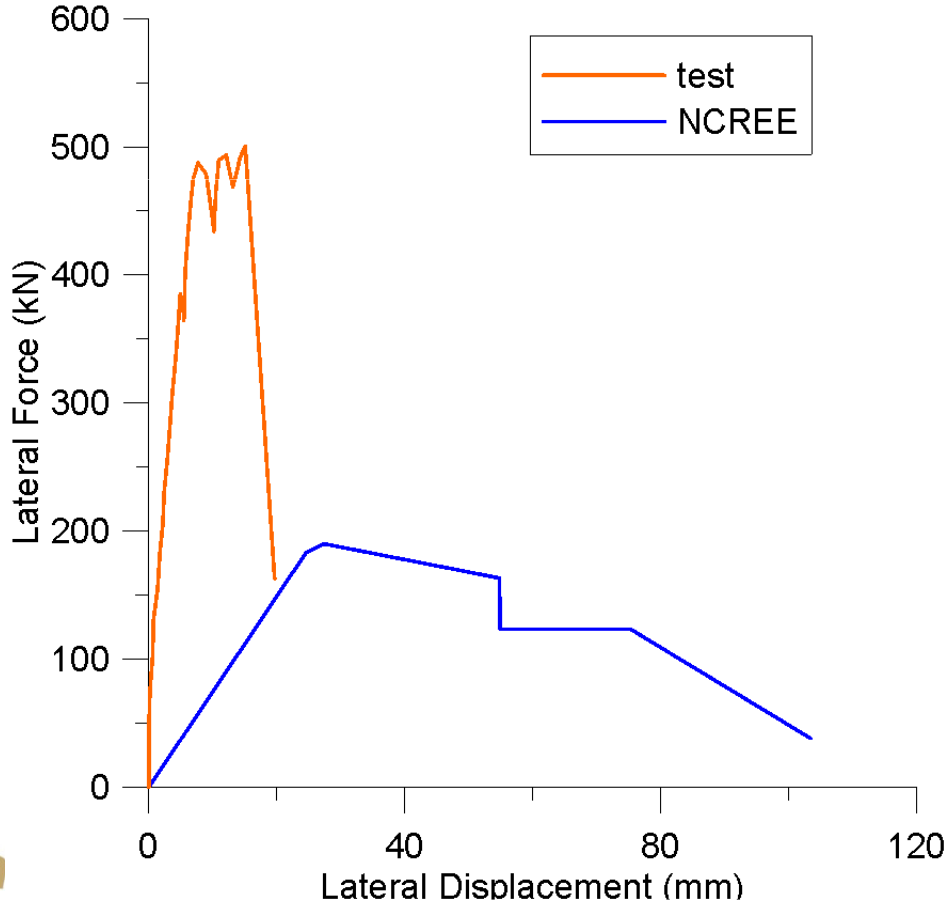
Yi-Hsuan TU (2011)

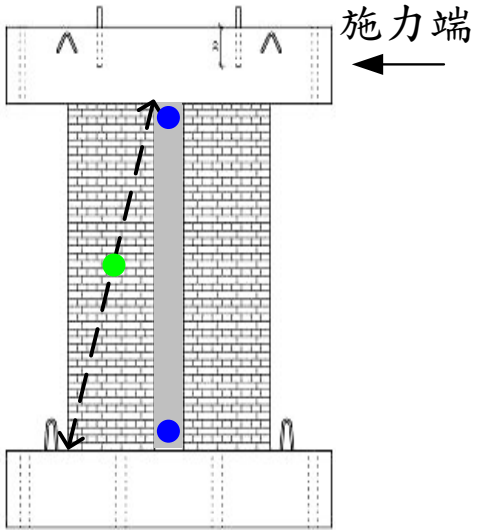


試體B：單向側推

$$\frac{V_{test}}{V_{cal.}} = 2.64$$

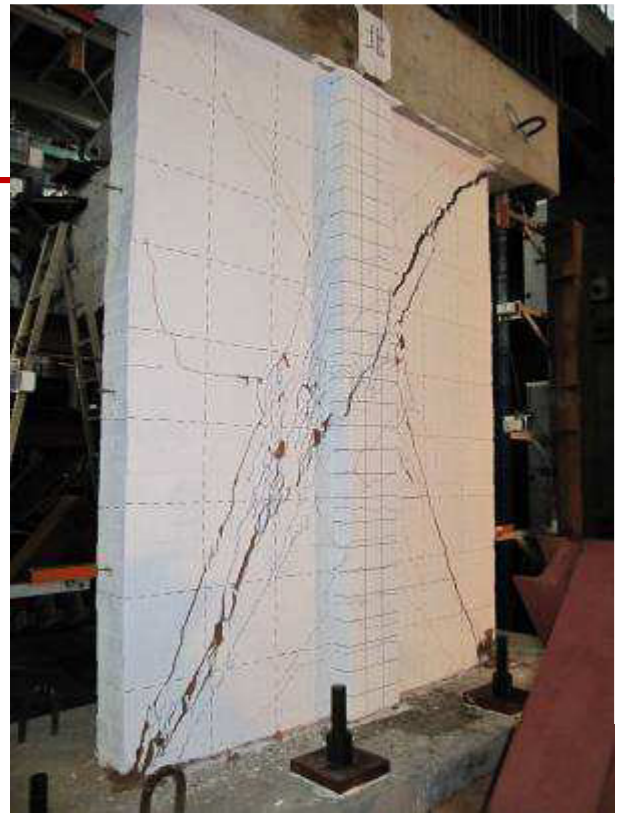
Yi-Hsuan TU (2011)



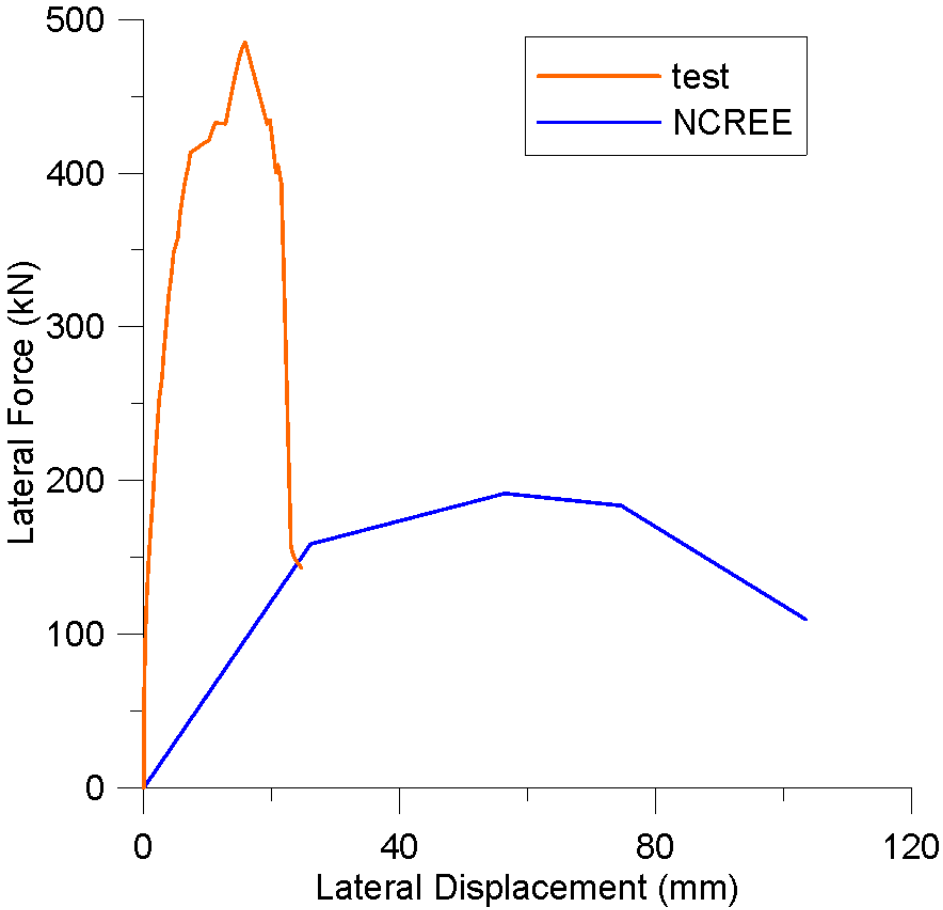


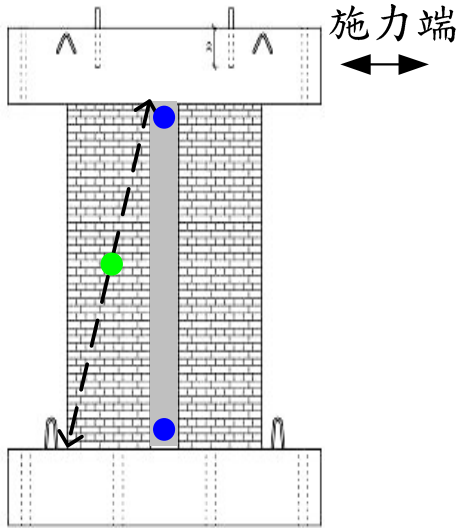
試體BC：雙向側推

$$\frac{V_{test}}{V_{cal.}} = 2.54$$



Yi-Hsuan TU (2011)





側推分析法之檢核要項

為瞭解「現況」或「補強後」之詳細評估結果與分析模型設定一致，可透過下列檢核要項加以確認：

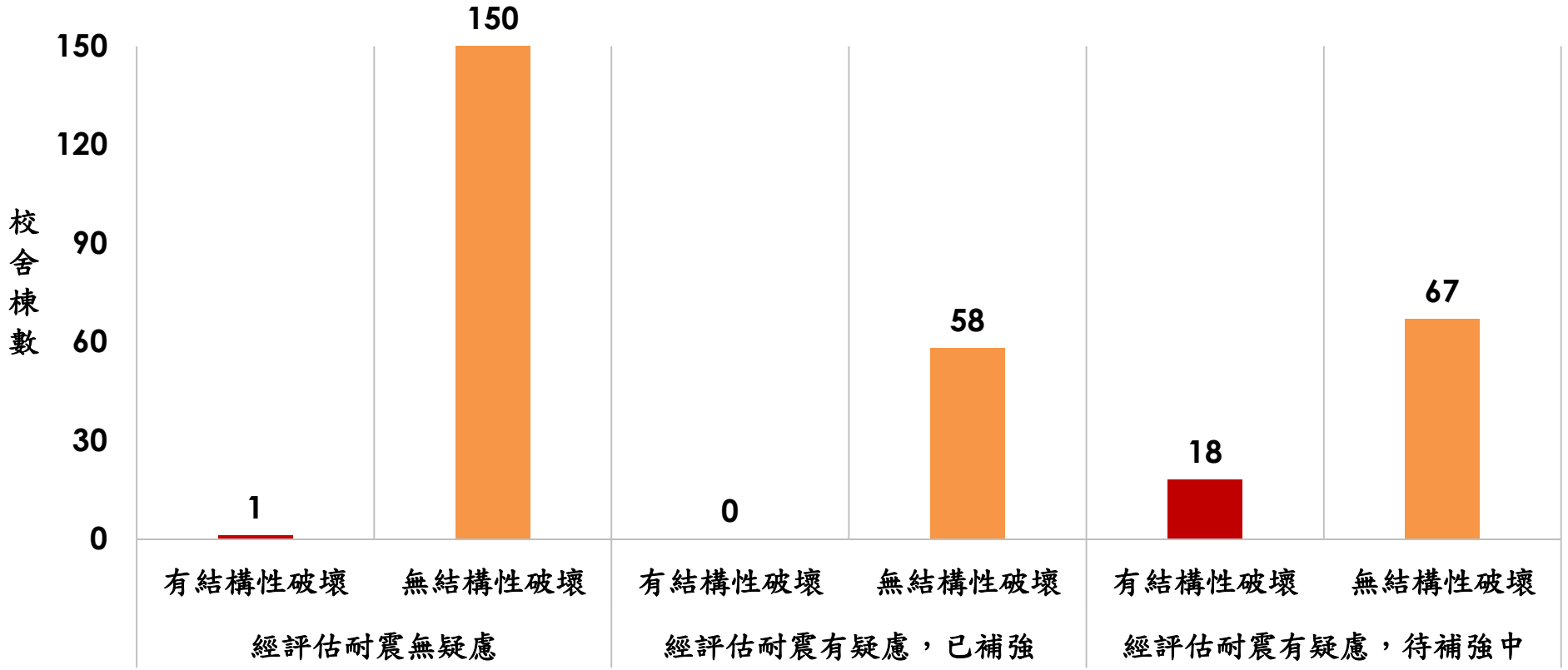
1. 結構系統模擬及設定
2. 柱軸力檢核
3. 非線性鉸參數檢核
4. 非線性鉸位置檢核
5. 最大基底剪力檢核
6. 破壞模式檢核
7. 性能目標地表加速度檢核

結論

- 非線性鉸參數可依技術手冊內容自行計算後逐一輸入，輔助分析程式係簡化非線性鉸設定之處理程序，惟使用者應瞭解文字輸入檔各欄位之定義
- 結構分析模型之設定應與現況接近，可利用檢核要項加以確認分析結果是否有異
- 非線性鉸參數影響側推分析結果甚鉅，應確實檢視非線性鉸設定是否正確無誤

臺南市0206地震震損校舍之統計

- 經評估耐震無疑慮151棟校舍中，有結構性破壞計有1棟，占0.7%
- 經評估耐震有疑慮且已補強58棟校舍中，無結構性破壞
- 經評估耐震有疑慮待補強85棟校舍中，有結構性破壞計有18棟，占21%



- 經評估耐震無疑慮：經初步評估、詳細評估或補強設計解除列管
- 經評估耐震有疑慮且已補強：完成補強或拆除程序
- 經評估耐震有疑慮待補強中：尚待執行補強或拆除作業
- 本圖僅統計歸仁區、永康區、北門區、玉井區、佳里區、山上區、善化區、麻豆區、左鎮區之校舍

簡報結束，敬請指教