建築物耐震能力評估及補強講習會

鋼筋混凝土建築物耐震能力詳細評估系統SERCB之介紹

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[2]國立台北科技大學土木工程系

Session 1 (北部)

2016.04.12

國立台北科技大學
(綜合科館第二演講廳)

Session 2 (中部)

2016.04.19

臺中市政府公務人力訓練中心
(7樓簡報室)

Session 3 (南部)

2016.04.26

台南成功大學校光復校區學生活動中心B1(第二演講室)

Session 4 (東部)

2016.05.03

宜蘭縣建築師公會
(3F會議室)

TAIPEI TECH

報告內容

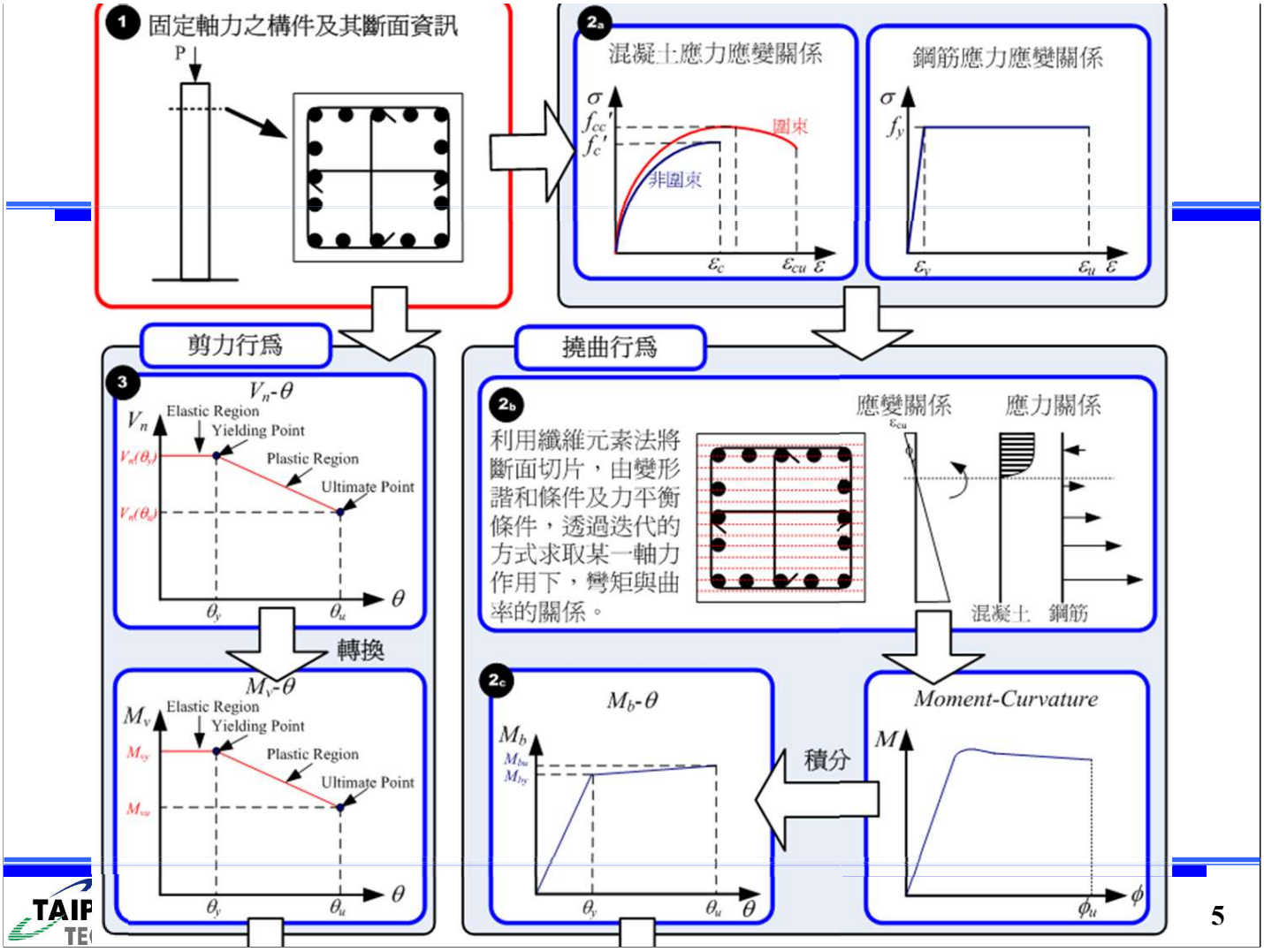
1. 前言
2. 鋼筋混凝土建築結構非線性行為
3. 鋼筋混凝土建築結構耐震能力評估
4. 鋼筋混凝土建築結構耐震補強
5. 結論

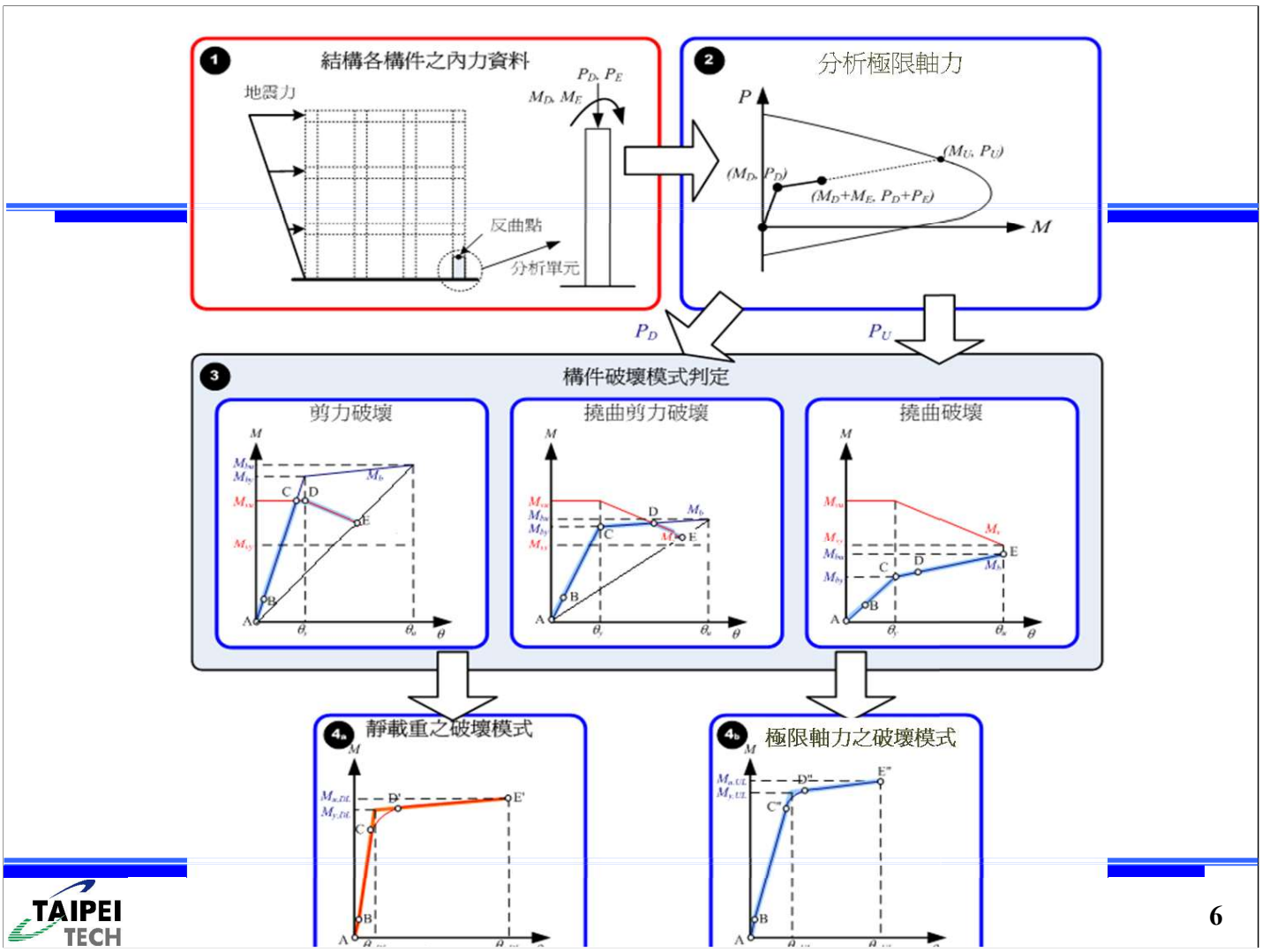
鋼筋混凝土建築結構非線性行為

靜態側推分析
（Pushover Analysis）

❶藉由施加側向力於結構物上，隨著力量緩慢增加，記錄構材開裂、降伏、塑性變形和結構失敗等發展行為，並在一連串的迭代過程中，依各不同受力階段之結構行為，修正構材有效勁度與不平衡力，採用階段線性分析的方式，直到塑性鉸發展至崩塌機制或到達極限塑性變形為止。

❷能清楚地提供結構物在各性能階段的受力與變形行為。


1 固定軸力之構件及其斷面資訊
P
2a
混凝土應力應變關係
σ
f_{cc}'
f_c'
圍束
非圍束
ε_c
ε_{cu} ε
鋼筋應力應變關係
σ
f_y
ε_y
ε_u ε
剪力行爲
撓曲行爲
3
V_n-θ
V_n
Elastic Region
Yielding Point
Plastic Region
Ultimate Point
$V_n(\theta_y)$
$V_n(\theta_u)$
θ_y
θ_u
θ
轉換
M_v-θ
M_v
Elastic Region
Yielding Point
Plastic Region
Ultimate Point
M_{vy}
M_{vu}
θ_y
θ_u
θ
2b
利用纖維元素法將斷面切片，由變形諧和條件及力平衡條件，透過迭代的方式求取某一軸力作用下，彎矩與曲率的關係。
應變關係
ε_{cu}
應力關係
混凝土
鋼筋
2c
M_b-θ
M_b
M_{bu}
M_{by}
θ_y
θ_u
θ
積分
Moment-Curvature
M
ϕ_u
ϕ


1 結構各構件之內力資料
地震力
P_D, P_E
M_D, M_E
反曲點
分析單元
2 分析極限軸力
P
(M_U, P_U)
(M_D, P_D)
(M_D+M_E, P_D+P_E)
M
P_D
P_U
3 構件破壞模式判定
剪力破壞
撓曲剪力破壞
撓曲破壞
M
M_{bu}
M_{by}
M_{vu}
M_{vy}
M_b
M_v
A
B
C
D
E
θ_y
θ_u
θ
4a 靜載重之破壞模式
$M_{v,DL}$
$M_{v,DL}$
B'
C'
E'
4b 極限軸力之破壞模式
$M_{v,UL}$
$M_{v,UL}$
B''
C''
D''
E''

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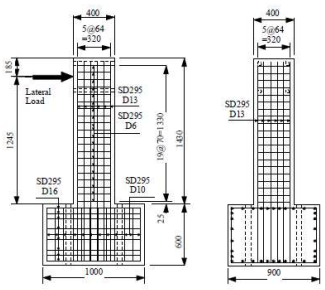
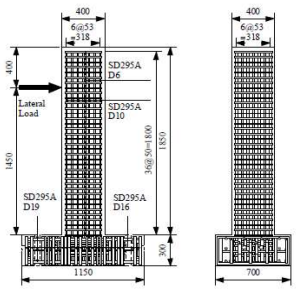


TP2



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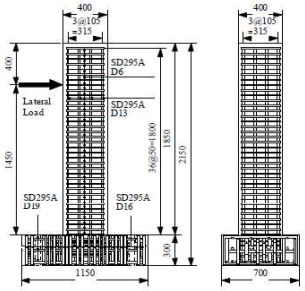

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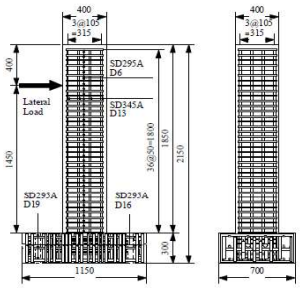

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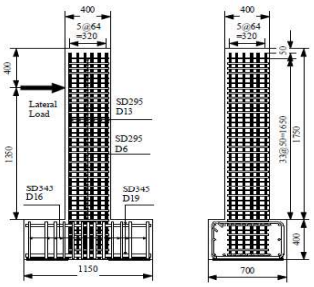

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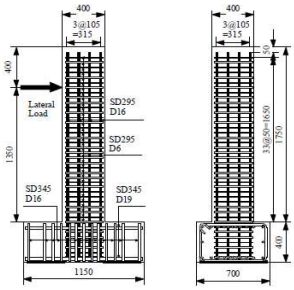

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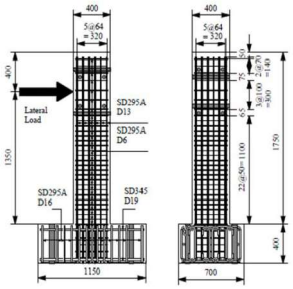

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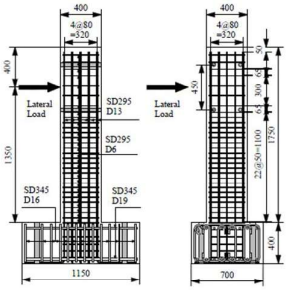

TP74

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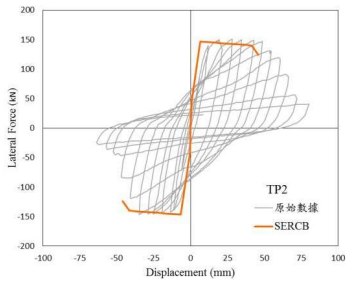
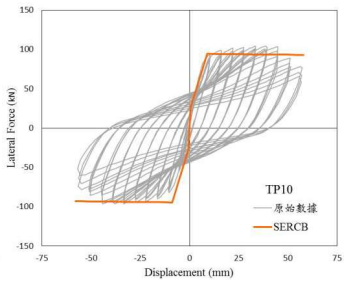
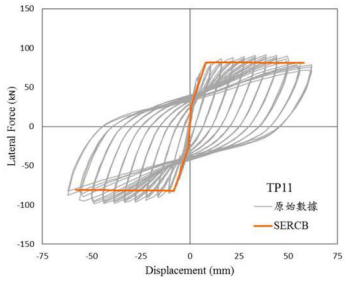
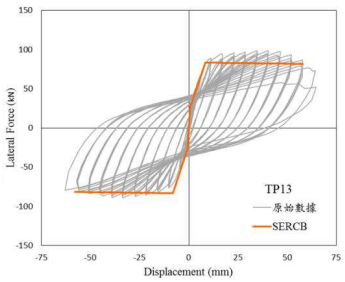
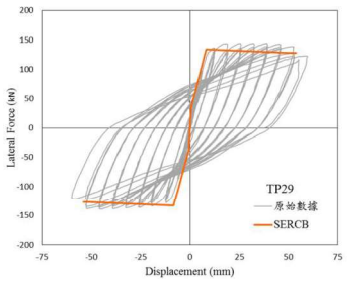
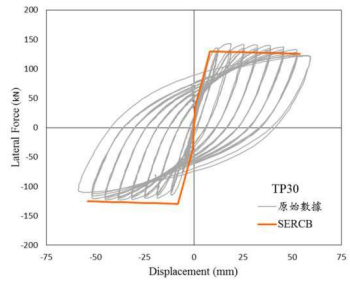


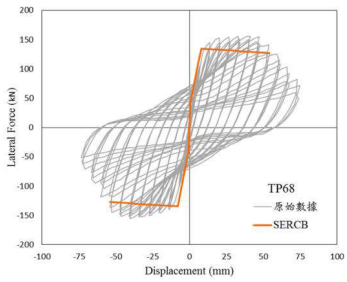


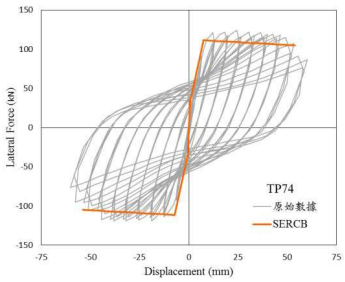




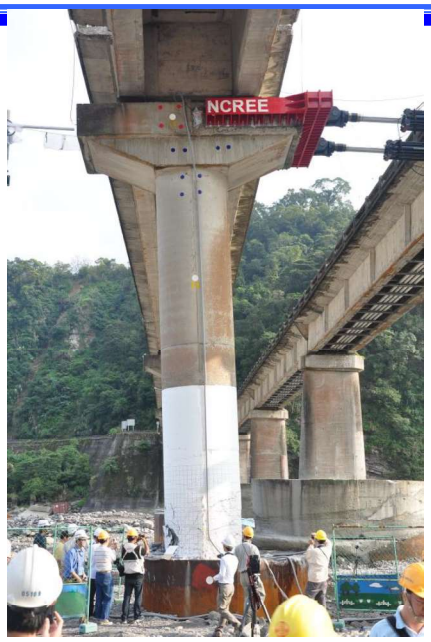


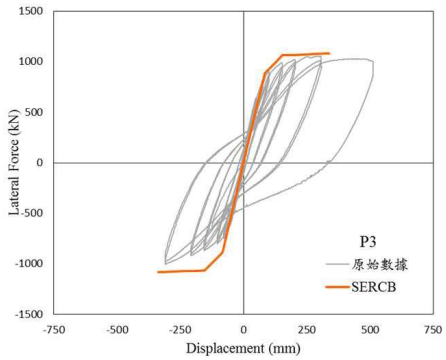


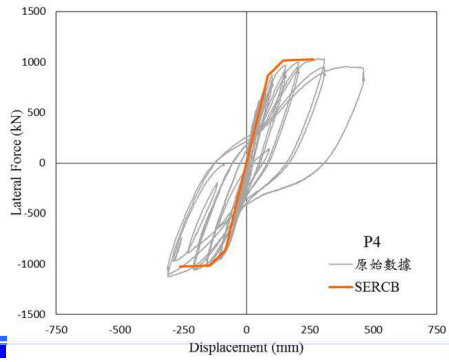




牛鬥橋單柱試體

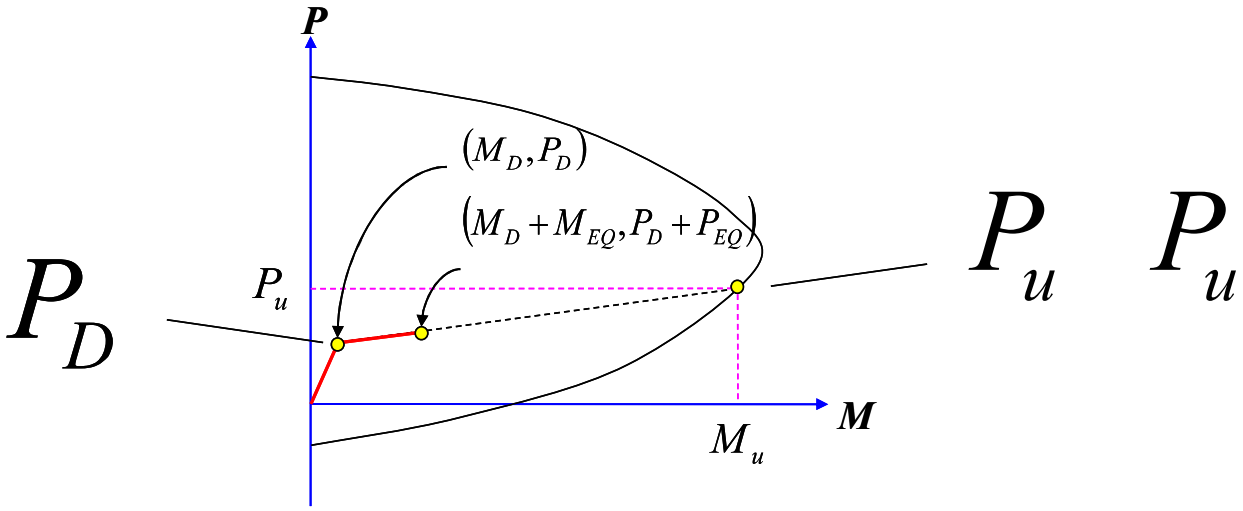






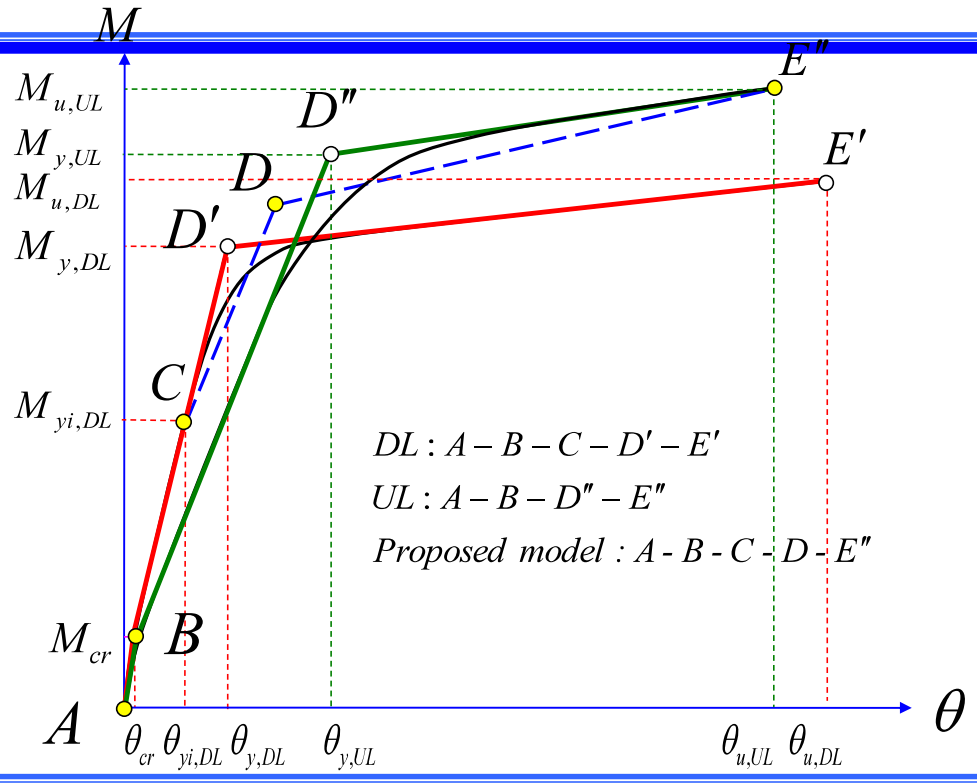
改良式構架鋼筋混凝土柱塑鉸之設定

【軸力-彎矩交互關係圖】



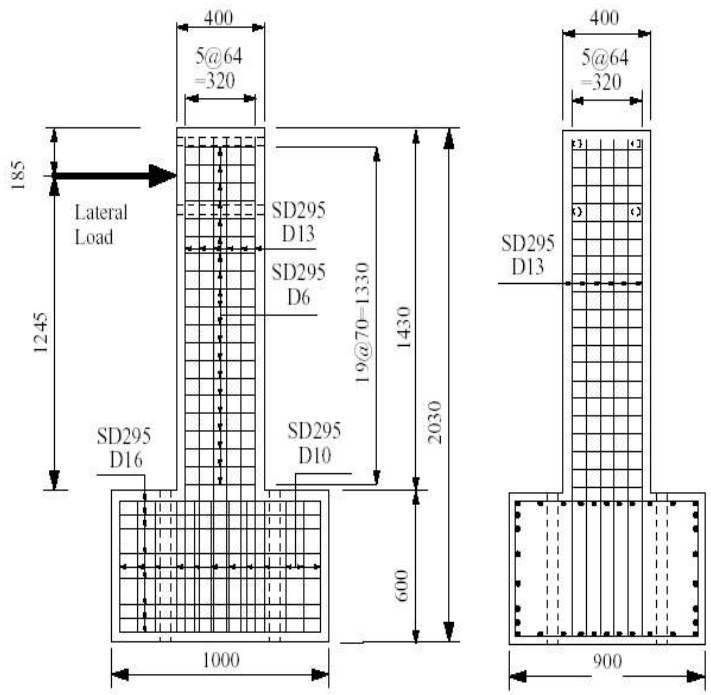
尋找柱斷面軸力

考慮軸力變化之塑鉸定義方式

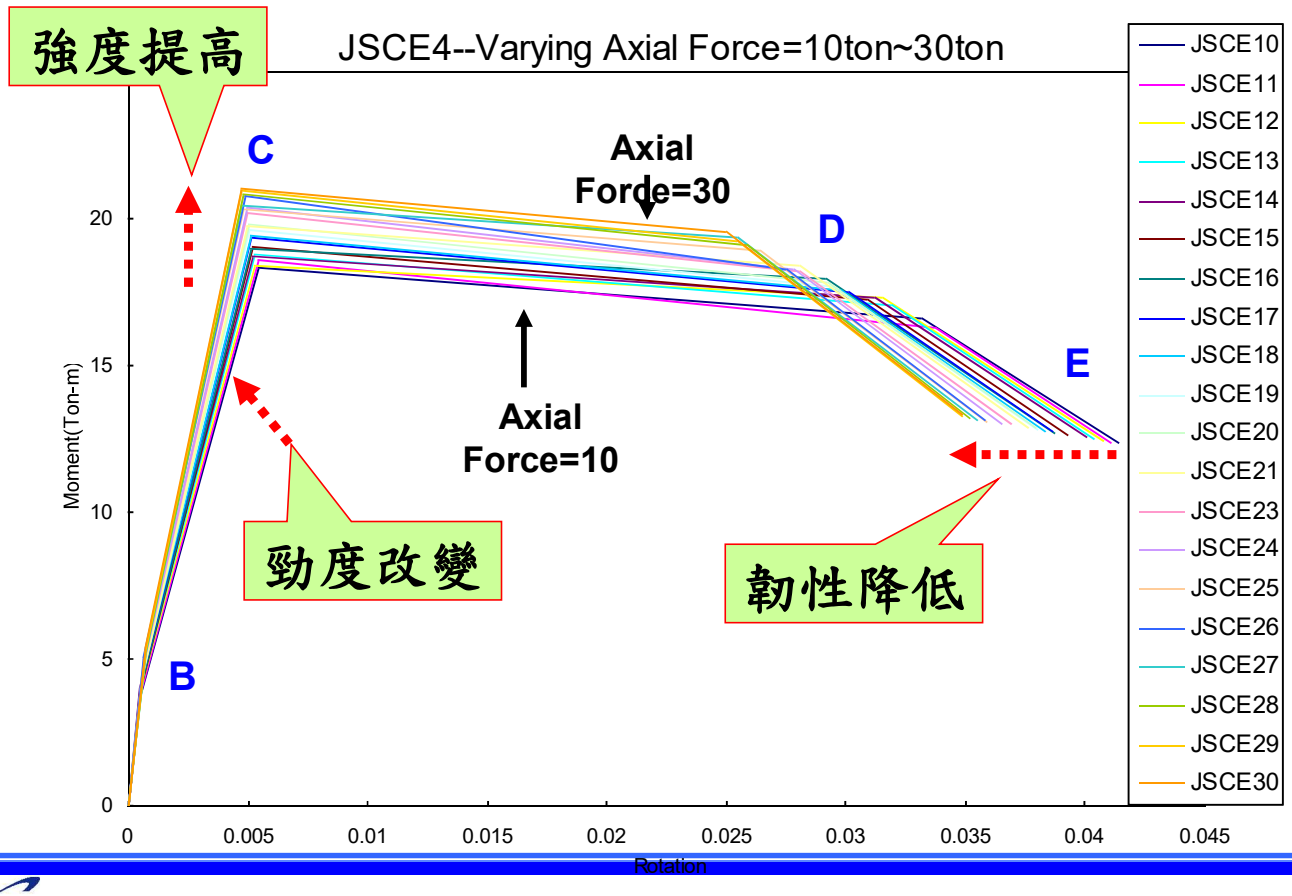


Case1.混凝土固定(fc`=350)-軸力變化(10ton~30ton)

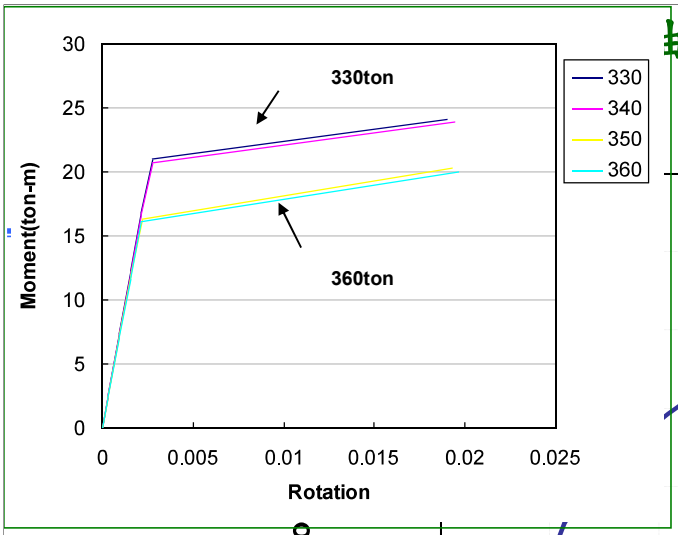
JSCE4

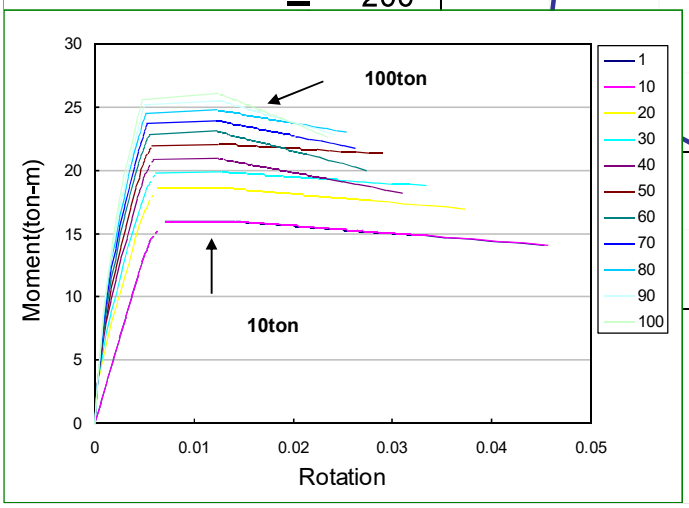


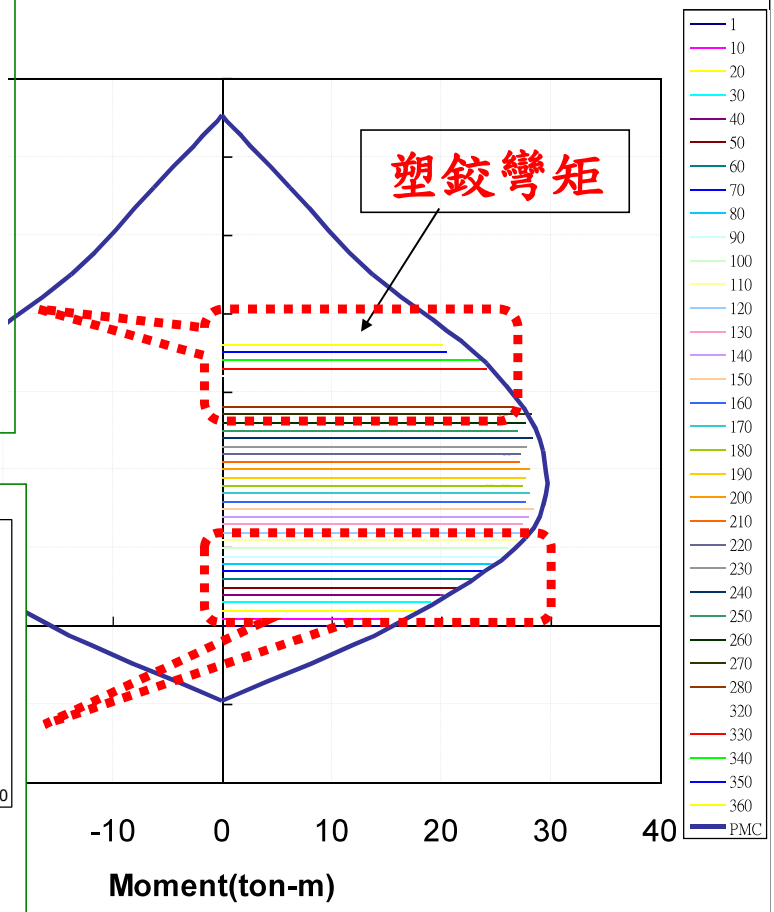
Case1.混凝土固定(fc`=350)-軸力變化(10ton~30ton)



軸力變化(1ton~360ton)

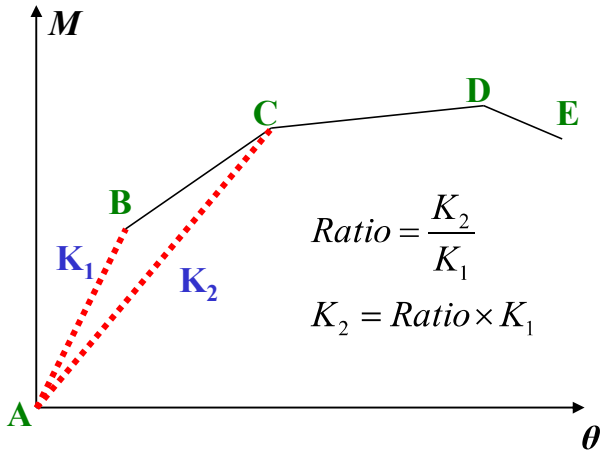


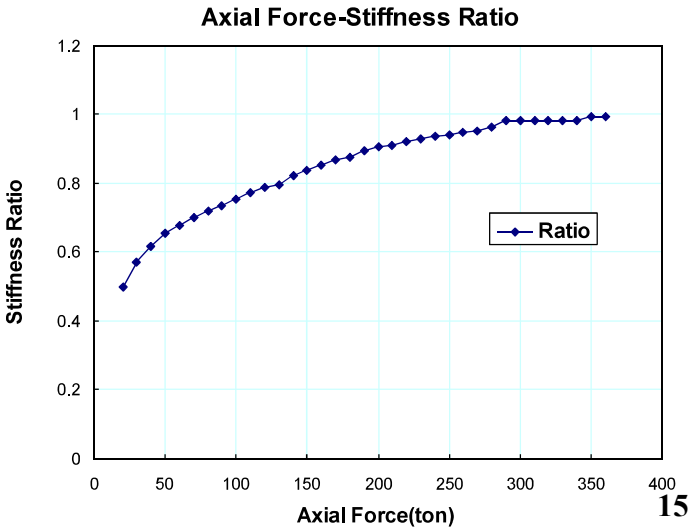




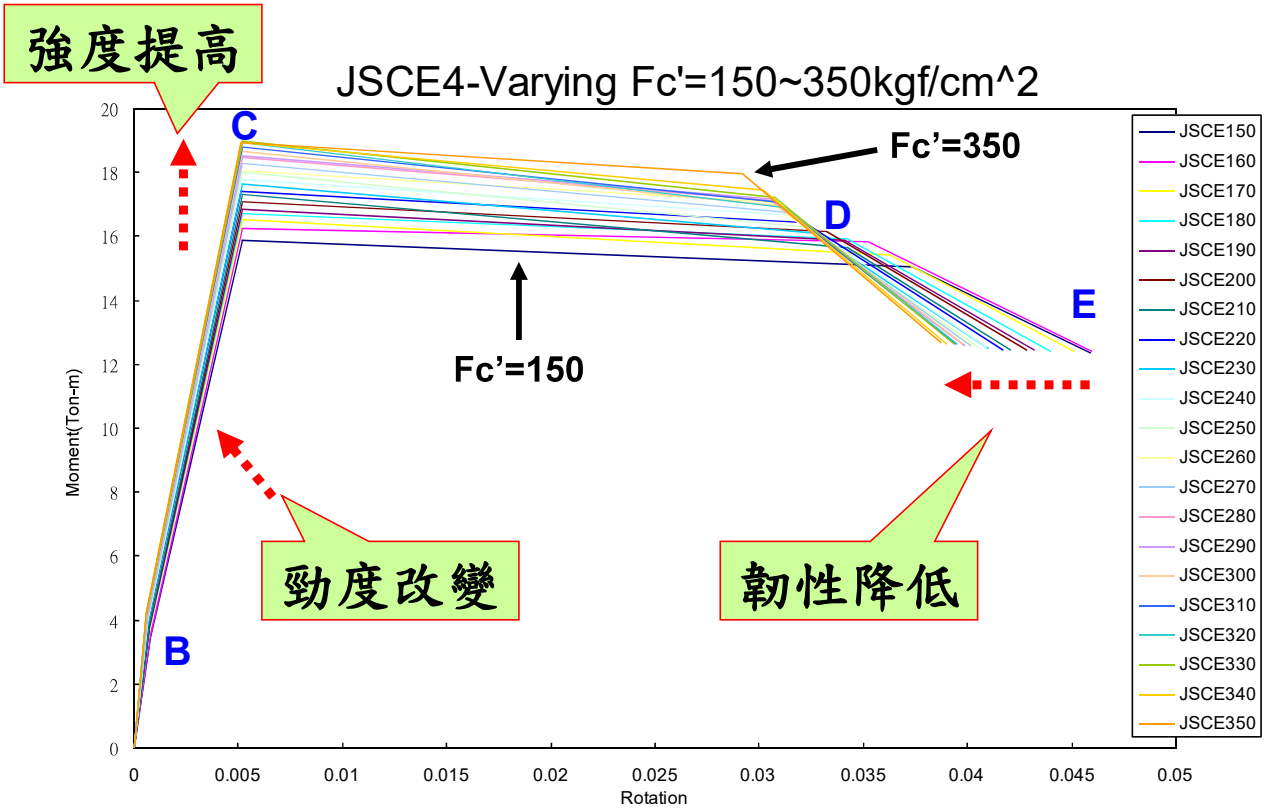
Axial Force	Ratio
20(ton)	0.500126
30	0.572653
40	0.617576
50	0.654692
60	0.677131
70	0.701033
80	0.721649
90	0.737022
100	0.752531
110	0.773794
120	0.788129
130	0.797386
140	0.821175
150	0.838802
160	0.851769
170	0.869229
180	0.875656
190	0.895279

Axial Force	Ratio
200(ton)	0.905517
210	0.910601
220	0.923186
230	0.93012
240	0.936486
250	0.940281
260	0.94852
270	0.953338
280	0.962182
290	0.983667
300	0.983783
310	0.983838
320	0.984352
330	0.984071
340	0.98372
350	0.994867
360	0.993796

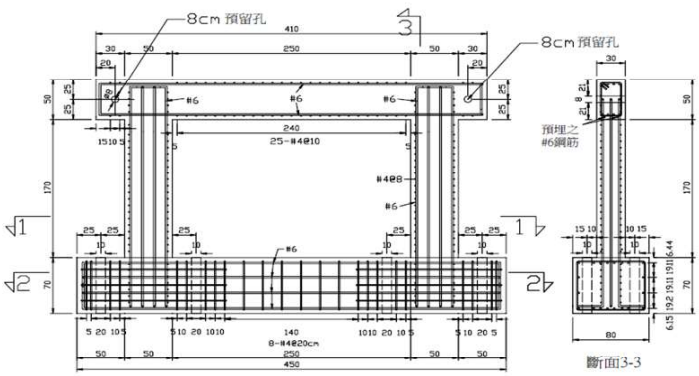


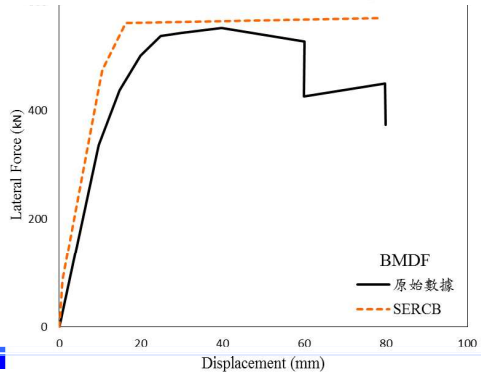


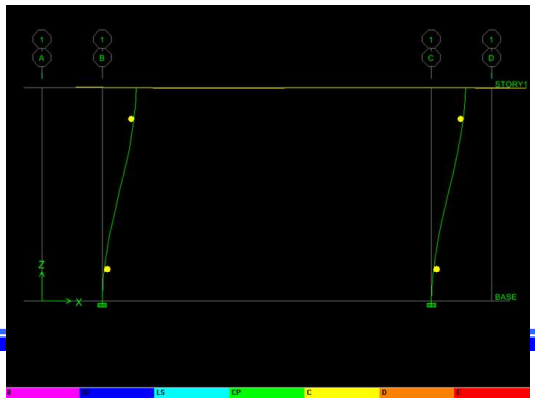
Case2.混凝土變化(fc`=150~350)-軸力固定(16ton)



構架BMDF試體

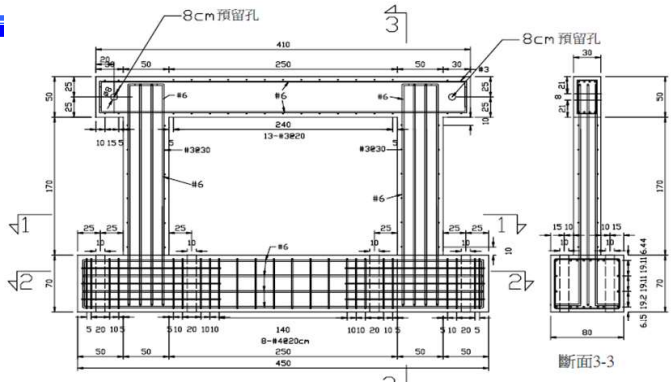


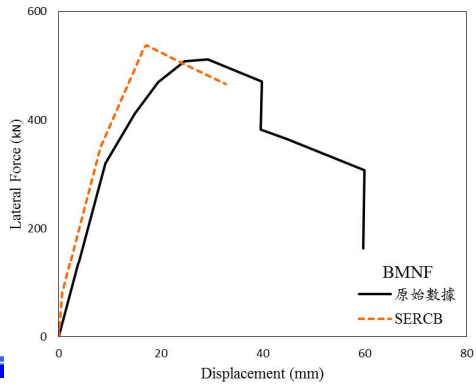


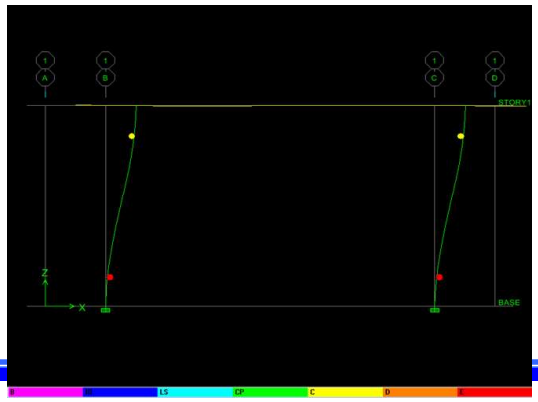


(含開口RC牆非韌性構架之耐震行為研究，黃世建、陳力平、陳俊宏，2003)

構架BMNF試體

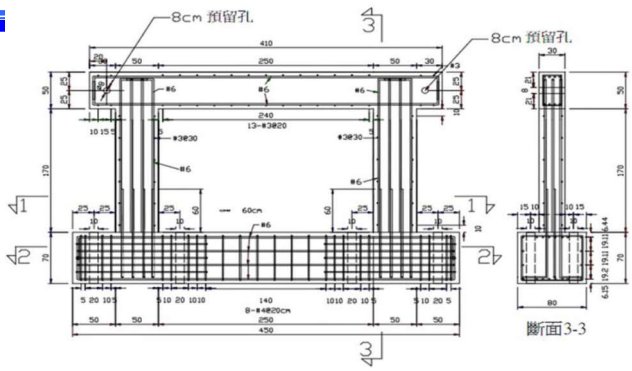


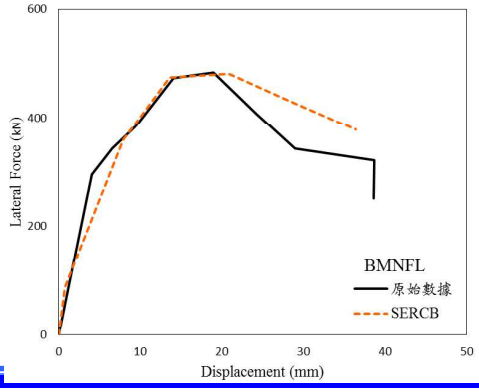


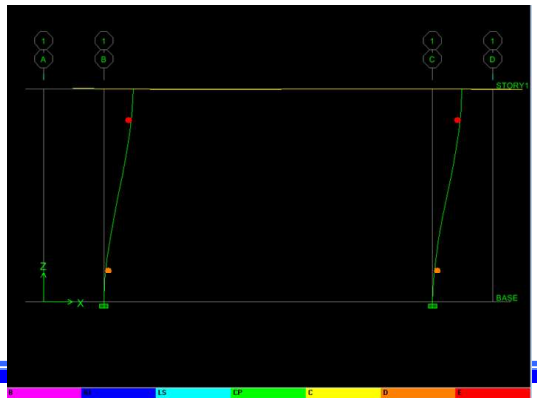


(含開口RC牆非韌性構架之耐震行為研究，黃世建、陳力平、陳俊宏，2003)

構架BMNFL試體

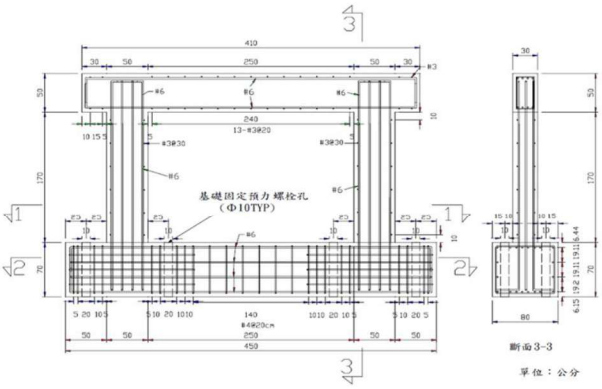


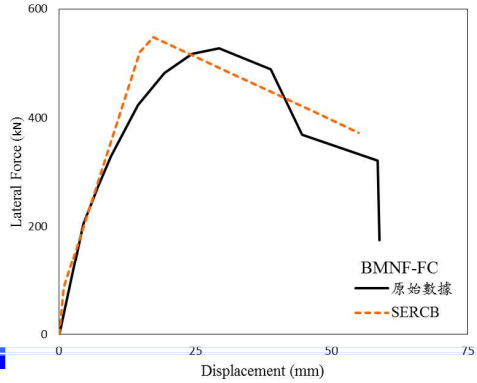


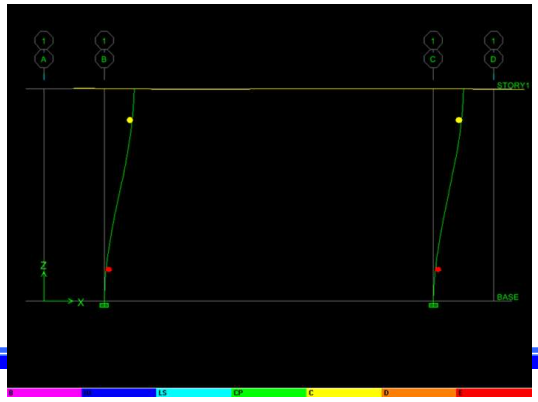


(SCFRP於含磚牆非韌性構架之耐震補強實驗與分析，陳振華、黃炯憲、張國鎮、陳俊宇，2003)

構架BMNF-FC試體

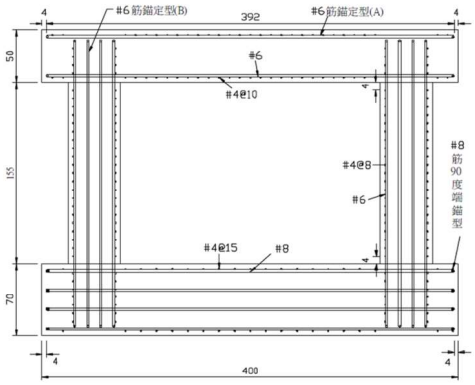


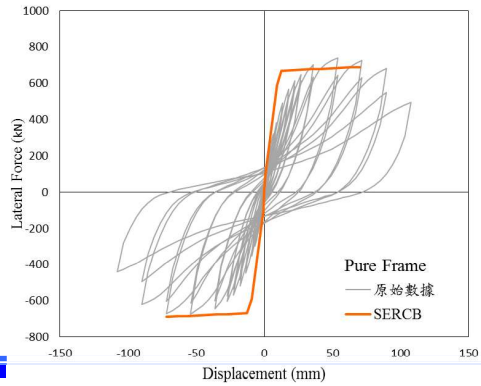


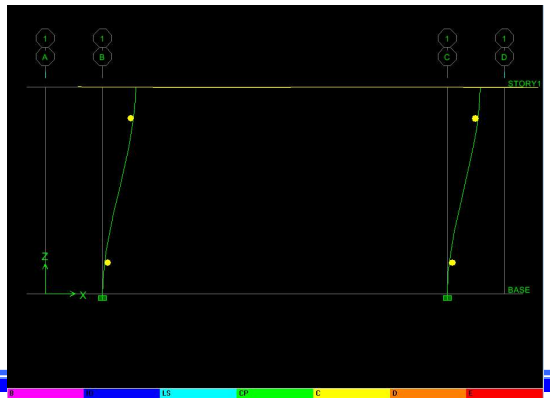


(含牆RC構架之耐震分析及設計研究，黃昭勳、蔡驥鑫，2003)

構架Pure Frame試體

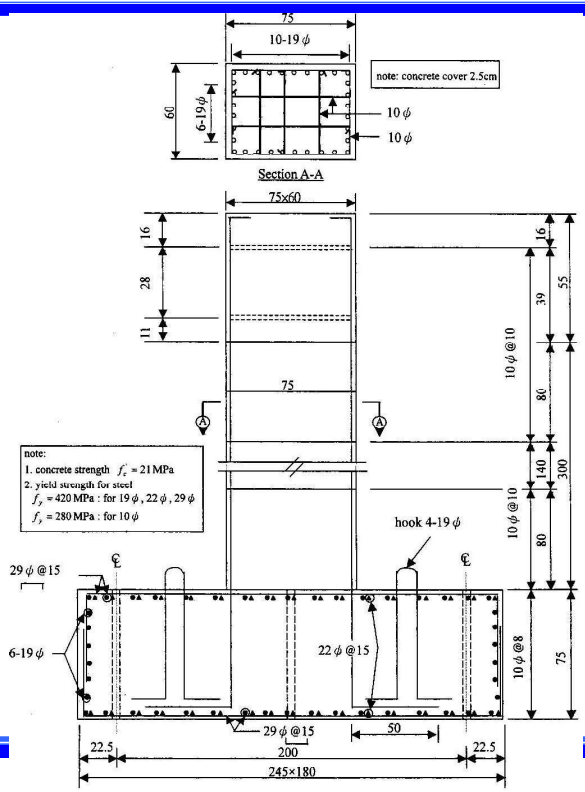






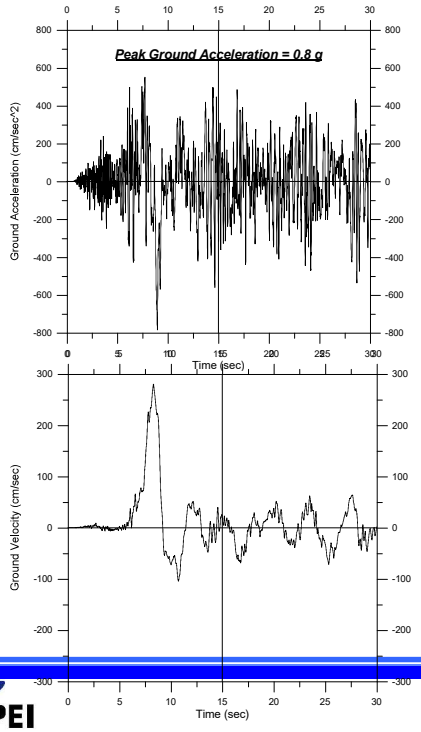
(鋼筋混凝土牆之碳纖FRP耐震補強研究，黃世建、葉永信，2001)

Pseudodynamic test of reinforced concrete columns

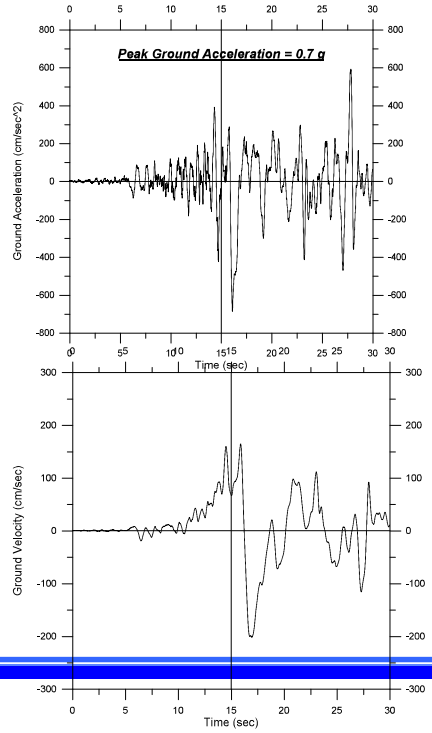


Ground acceleration and velocity for TCU075、TCU102

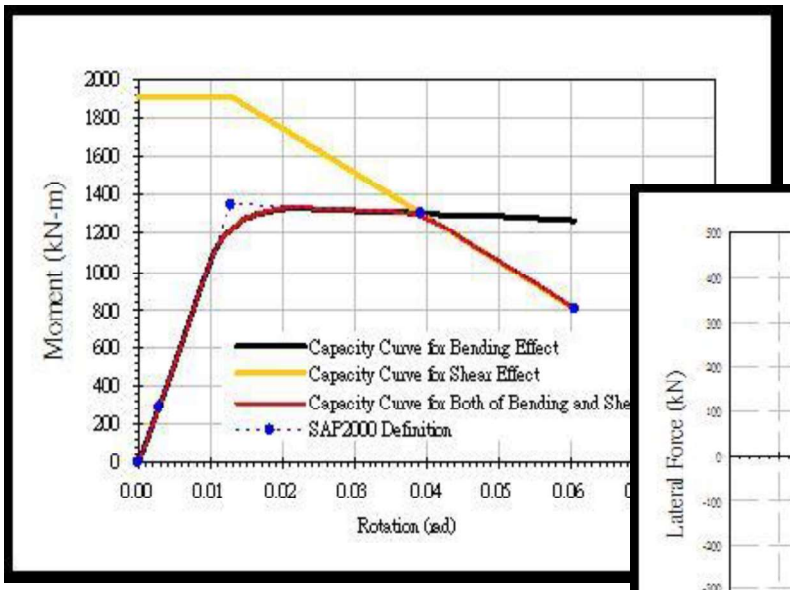
Ground acceleration and velocity for TCU075

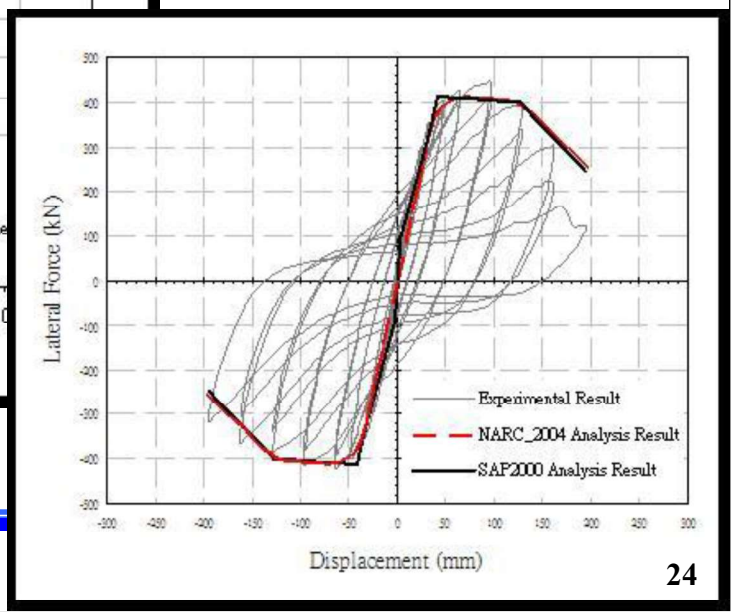


Ground acceleration and velocity for TCU102



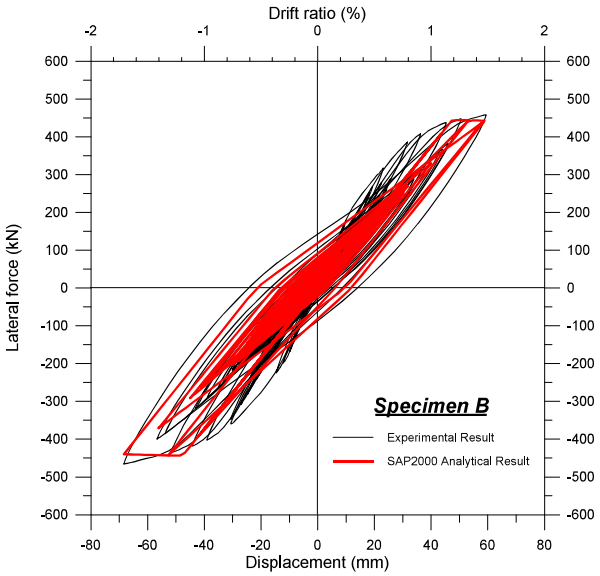
Specimen A – cyclic loading test and analysis result

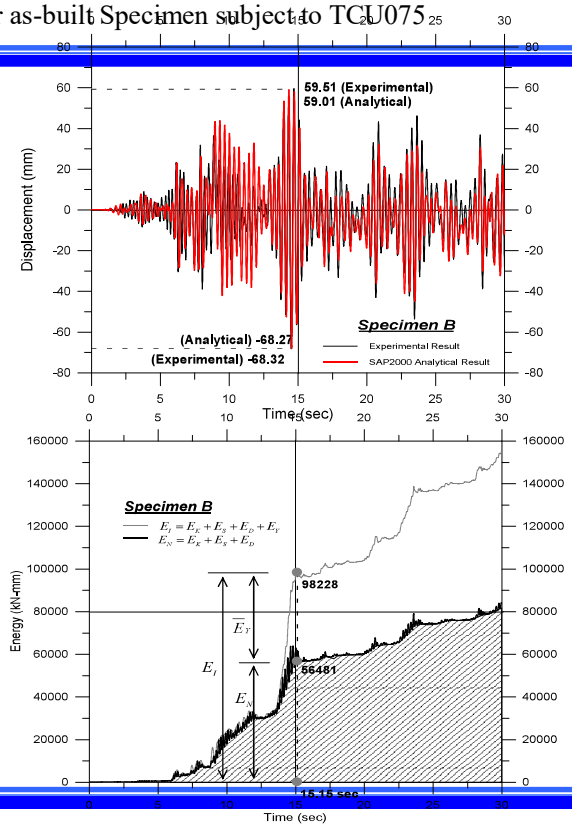




Specimen B –

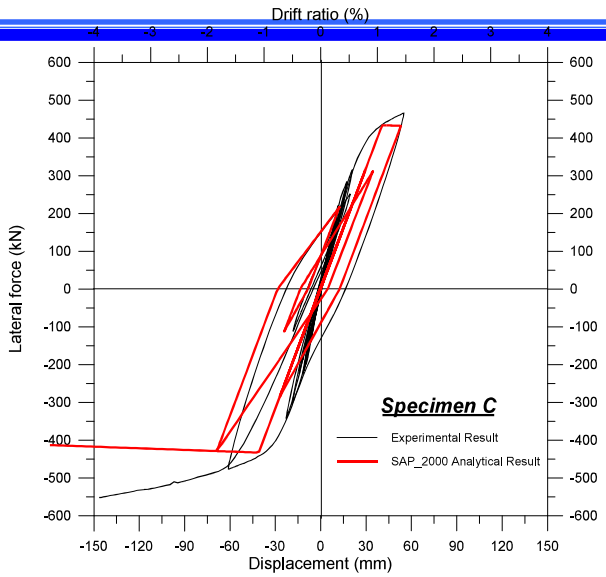
Pseudodynamic and analysis results for as-built Specimen subject to TCU075

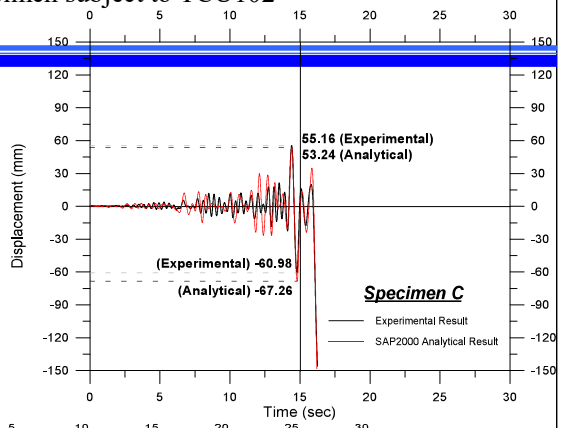


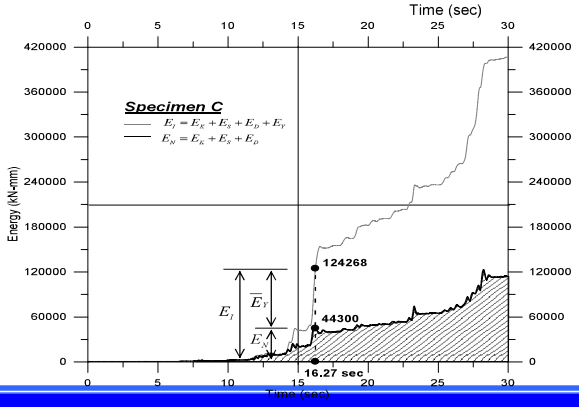


Specimen C –

Pseudodynamic and analysis results for as-built Specimen subject to TCU102



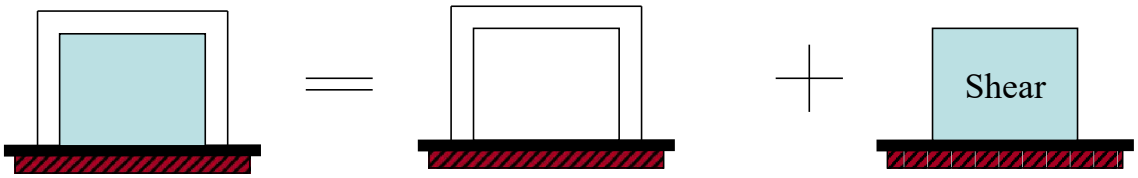




Yu-Chi Sung, Shuenn-Yih Chang and Chin-Kuo Su, "**Analytical and Experimental Responses of Reinforced Concrete Bridge Columns under Strong Near-Fault Ground Motion**" submitted to Journal of Earthquake Engineering.

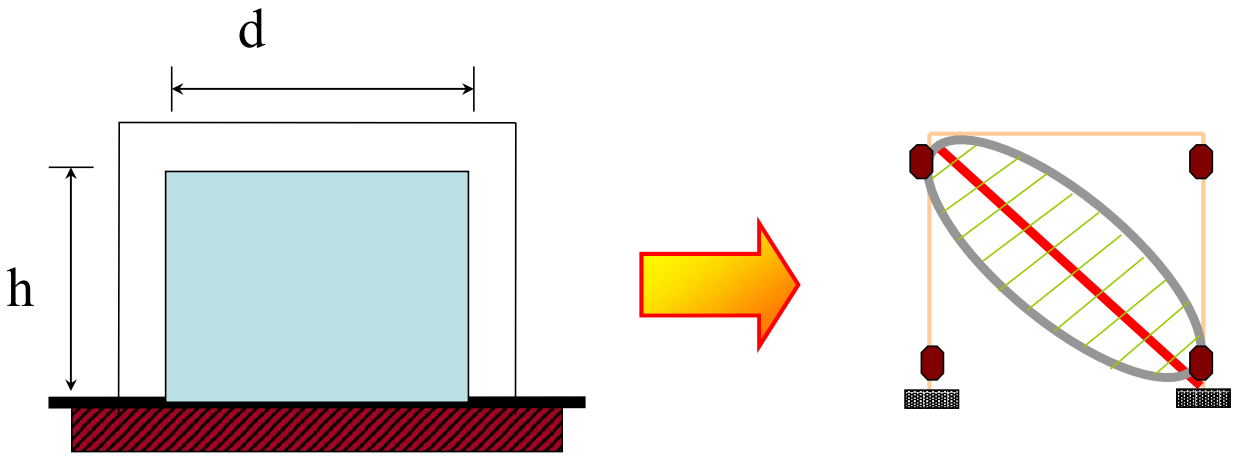
RC牆模擬分析

Frame structure infilled with RC wall	Frame structure [Bending]	RC wall [Shear]



Pushover analysis is highly sensitive to the structural nonlinearity of frame and RC wall

RC Structural Wall



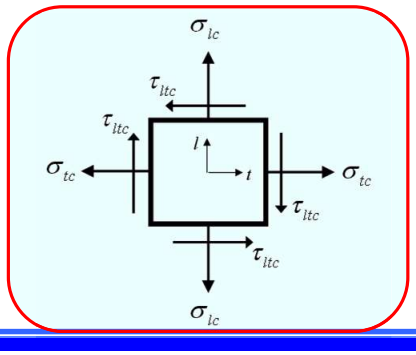
SOFTEN STRUT-TIE MODEL

Equivalent diagonal structural strut of an RC wall

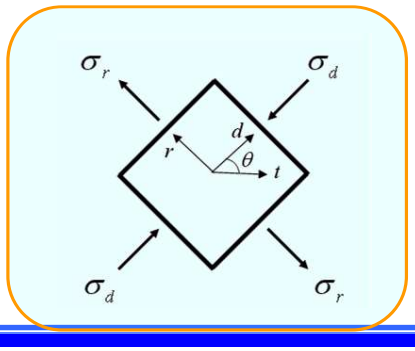
Equilibrium (1/2)

Based on the theory of fixed angle softened truss model, the angle of cracks in the postcracking concrete coincides with the angle $\theta = \tan^{-1}\left(\frac{h}{d}\right)$

$(\sigma_{lc}, \sigma_{tc}, \tau_{ltc})$

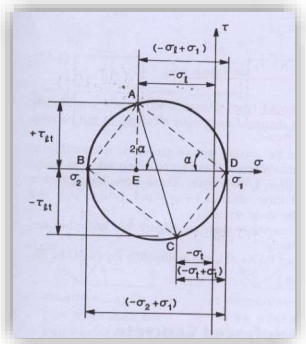


$(\sigma_d - \sigma_r)$



Equilibrium (2/2)

The equilibrium can be expressed as following Eqs., according to the Mohr circle of stress.



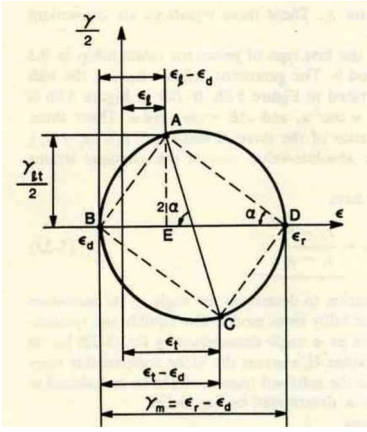
$$\sigma_{lc} = \sigma_d \cos^2\theta + \sigma_r \sin^2\theta$$
$$\sigma_{tc} = \sigma_d \sin^2\theta + \sigma_r \cos^2\theta$$
$$\tau_{ltc} = (-\sigma_d + \sigma_r)\sin\theta\cos\theta$$
$$V_c = \tau_{ltc} \times b_w \times d$$

The total shear force applied on the RC wall

$$V = V_c + V_s = \tau_{ltc} \times b_w \times d + A_{st} \times f_t \times \frac{d}{s}\tan\theta$$

Compatibility

Based on the theory of fixed angle softened truss model, the compatibility can be expressed as following Eqs., according to the Mohr circle of strain.



$$\varepsilon_l = \varepsilon_d \cos^2\theta + \varepsilon_r \sin^2\theta$$

$$\varepsilon_t = \varepsilon_d \sin^2\theta + \varepsilon_r \cos^2\theta$$

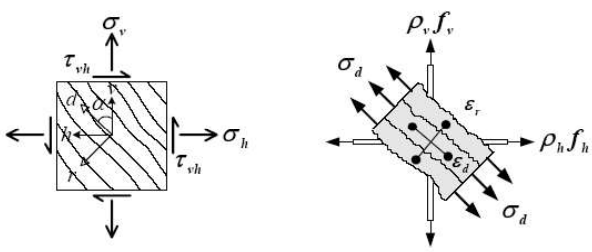
$$\gamma_{lt}/2 = (-\varepsilon_d + \varepsilon_r)\sin\theta\cos\theta$$

Constitutive Laws of Concrete(1/3)

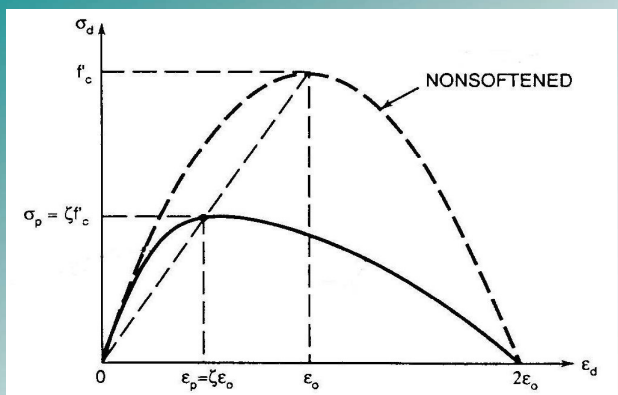
Both the strength and stiffness of cracked reinforced concrete in compression are lower than those of uniaxial compressed concrete.

Softening effect on the biaxial constitute laws of concrete

$$\zeta = \frac{0.9}{\sqrt{1+600\varepsilon_r}}$$



Constitutive Laws of Concrete(2/3)



Belarbi and Hsu

$$\varepsilon_d / \zeta\varepsilon_0 \le 1$$

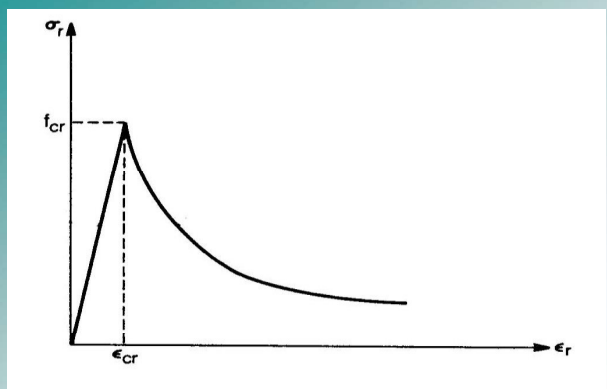
$$\sigma_d = \zeta f'_c \left[2\left(\frac{\varepsilon_d}{\zeta\varepsilon_0}\right) - \left(\frac{\varepsilon_d}{\zeta\varepsilon_0}\right)^2 \right]$$

$$\varepsilon_d / \zeta\varepsilon_0 > 1$$

$$\sigma_d = \zeta f'_c \left[1 - \left(\frac{\varepsilon_d / \zeta\varepsilon_0 - 1}{2/\zeta - 1}\right)^2 \right]$$

$$\zeta = \frac{0.9}{\sqrt{1 + 600\varepsilon_r}}$$

Constitutive Laws of Concrete(3/3)



Vecchio and Collins

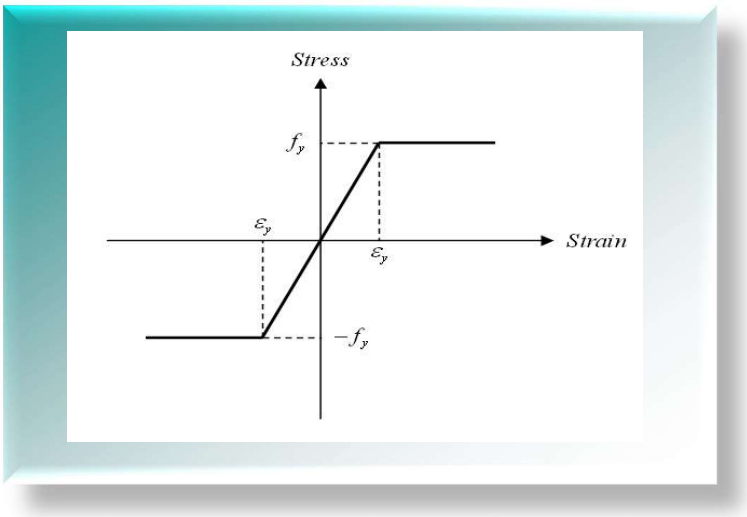
$$\varepsilon_r \le \varepsilon_{cr}$$

$$\sigma_r = E_c \varepsilon_r$$

$$\varepsilon_r > \varepsilon_{cr}$$

$$\sigma_r = f_{cr} \left(\frac{\varepsilon_{cr}}{\varepsilon_r}\right)^{0.4}$$

Constitutive Laws of Reinforcement



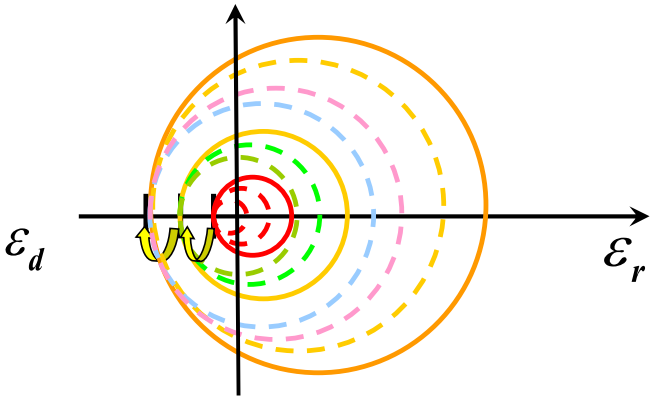
$$\varepsilon_s \le \varepsilon_y$$

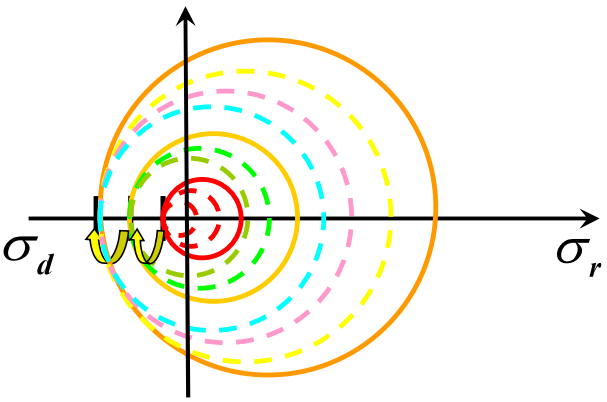
$$f_s = E_s \varepsilon_s$$

$$\varepsilon_s > \varepsilon_y$$

$$f_s = f_y$$

$$V_s = A_{st} \times f_t \times \frac{d}{s} \tan\theta$$





$$V = V_c + V_s \quad ?$$

$$V_c = \tau_{ltc} \times b_w \times d$$

$$V_s = A_{st} \times f_t \times \frac{d}{s} \tan\theta$$

RC牆剪力分析流程

$$\sigma_d = \zeta f'_c \left[2\left(\frac{\varepsilon_d}{\zeta\varepsilon_0}\right) - \left(\frac{\varepsilon_d}{\zeta\varepsilon_0}\right)^2 \right]$$

$$\sigma_d = \zeta f'_c \left[1 - \left(\frac{\varepsilon_d/\zeta\varepsilon_0 - 1}{2/\zeta - 1}\right)^2 \right]$$

$$\sigma_r = E_c\varepsilon_r \qquad \sigma_r = f_{cr}\left(\frac{\varepsilon_{cr}}{\varepsilon_r}\right)^{0.4}$$

$$\begin{cases} \text{If } \left|\dfrac{\varepsilon_d}{\varepsilon_o \times \zeta}\right| \le 1 \\ \Rightarrow \Delta V = V_u/200 \\ \text{If } \left|\dfrac{\varepsilon_d}{\varepsilon_o \times \zeta}\right| > 1 \text{ and } |\varepsilon_t| > \varepsilon_y \\ \Rightarrow \Delta V = -V_u/200 \end{cases}$$

$$|V - (V_c + V_s)| \le Tol$$

$$\varepsilon_t = \varepsilon_d \sin^2\theta + \varepsilon_r \cos^2\theta$$

$$\gamma_{lt}/2 = (-\varepsilon_d + \varepsilon_r)\sin\theta\cos\theta$$

$$\sigma_{lc} = \sigma_d \cos^2\theta + \sigma_r \sin^2\theta$$

$$\sigma_{tc} = \sigma_d \sin^2\theta + \sigma_r \cos^2\theta$$

$$\varepsilon_d, \varepsilon_r \rightarrow \varepsilon_t, \gamma_{ltc}$$

$$\sigma_d, \sigma_r \rightarrow \tau_{ltc} \rightarrow V_c$$

$$\varepsilon_{ts} = \varepsilon_t$$

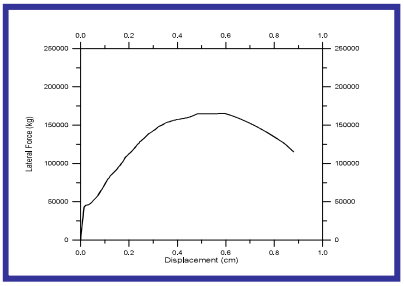
$$\varepsilon_{ts} \rightarrow f_{ts} \rightarrow V_s$$

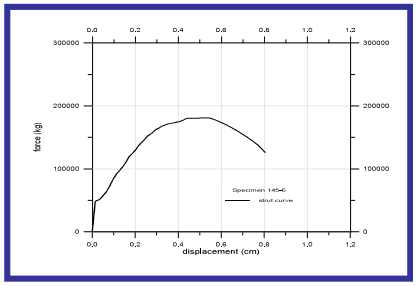
$$f_s = E_s\varepsilon_s$$

$$f_s = f_y$$

$$V_s = A_{st} \times f_t \times \frac{d}{s}\tan\theta$$

Aeff of equivalent diagonal structural strut



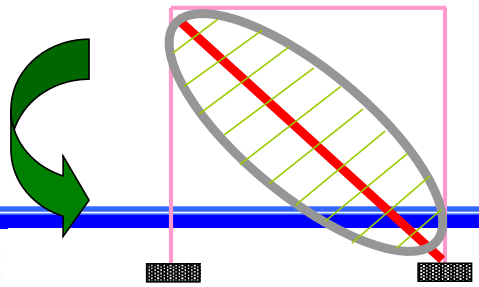


$$V = V_c + V_s$$

$$\delta = \gamma_{lt} \times h$$

$$V_{strut} = \frac{V}{\cos\theta}$$

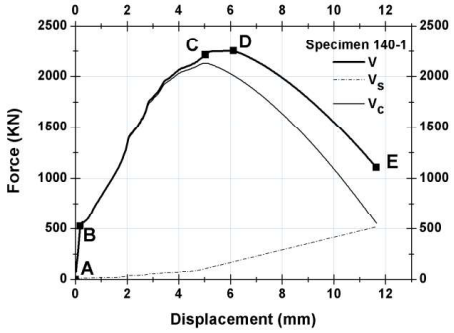
$$\delta_{strut} = \delta \times \cos\theta$$

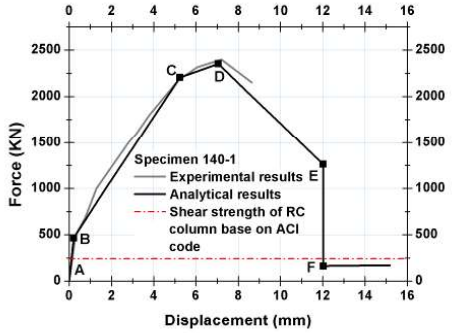


$$\Rightarrow A_{eff} = \frac{P}{\delta} \times \frac{L}{E_c}$$

Lai, M.C., **Sung, Y.C.**, "**A Study on Pushover Analysis of Frame Structure Infilled with Low-rise Reinforced Concrete Wall**", *Journal of Mechanics*, Vol. 24, 2008, p.p. 437-449

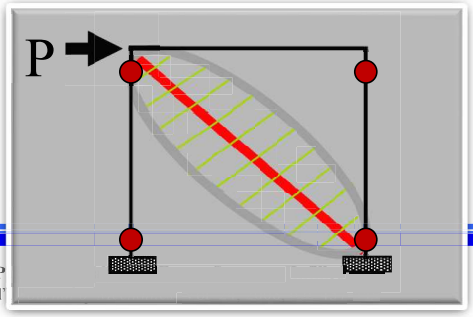
Pushover Analysis Results
(specimen 140-1)





Shear strength of RC wall

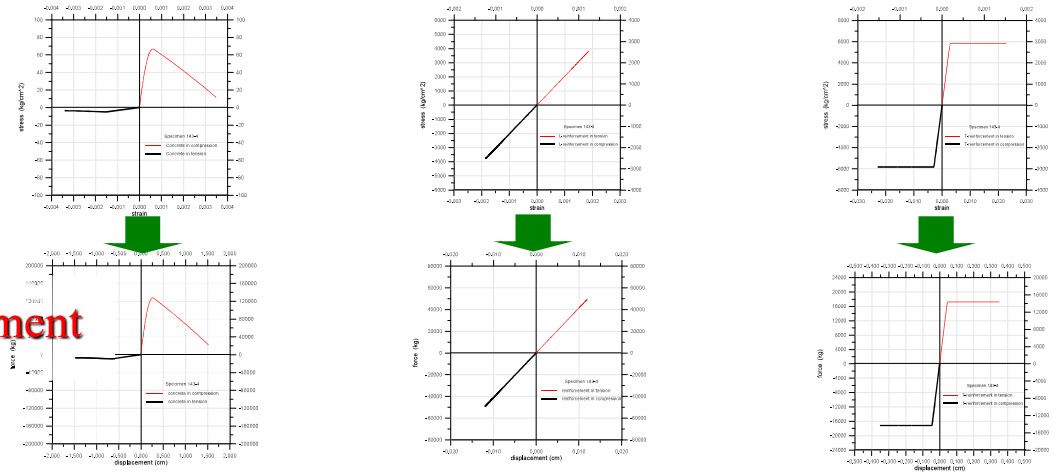
Pushover Analysis Results



分 析 方 式

Stress-Strain

Force-Displacement

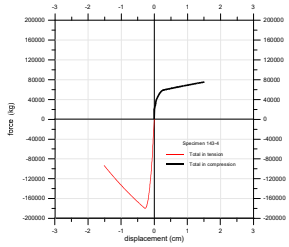


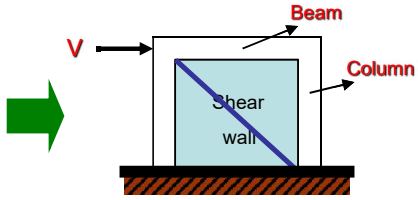
$\sum$

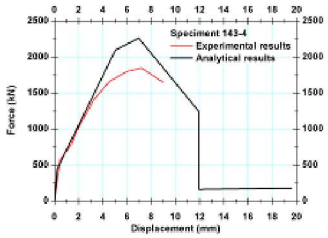
Concrete

Longitudinal reinforcements

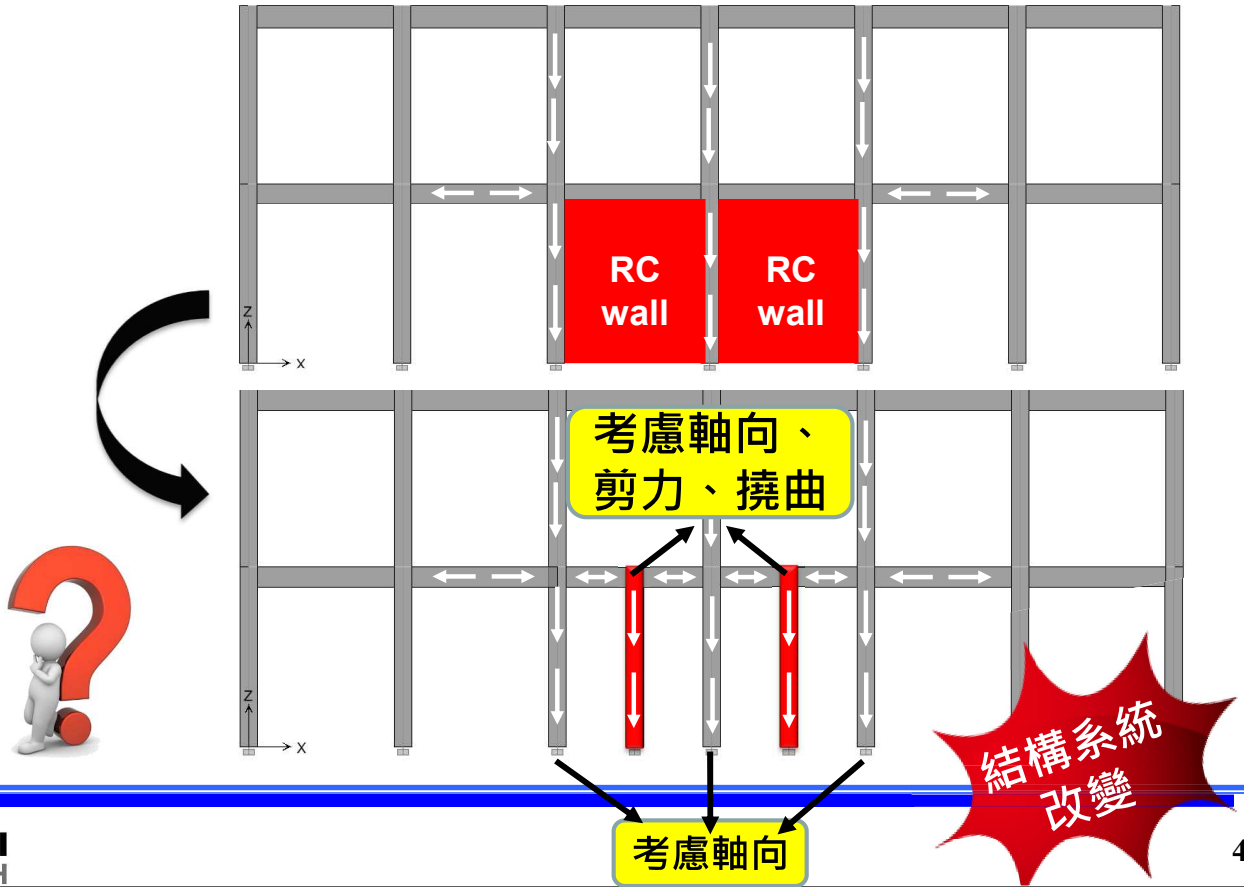
Transverse reinforcements







RC牆模擬-等值柱

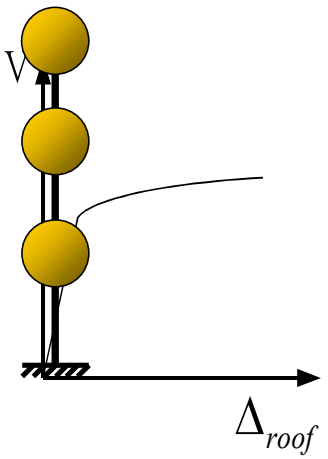


鋼筋混凝土建築結構耐震能力評估

容量震譜法

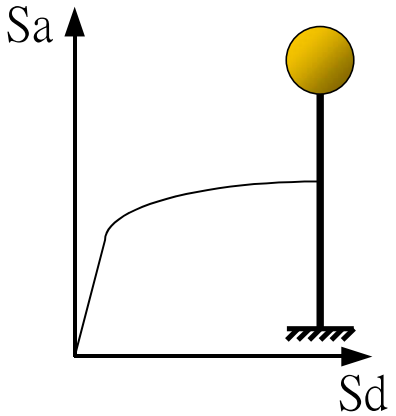
Transform Capacity Curve to Capacity Spectrum

(Capacity Curve) **(Capacity Spectrum)**

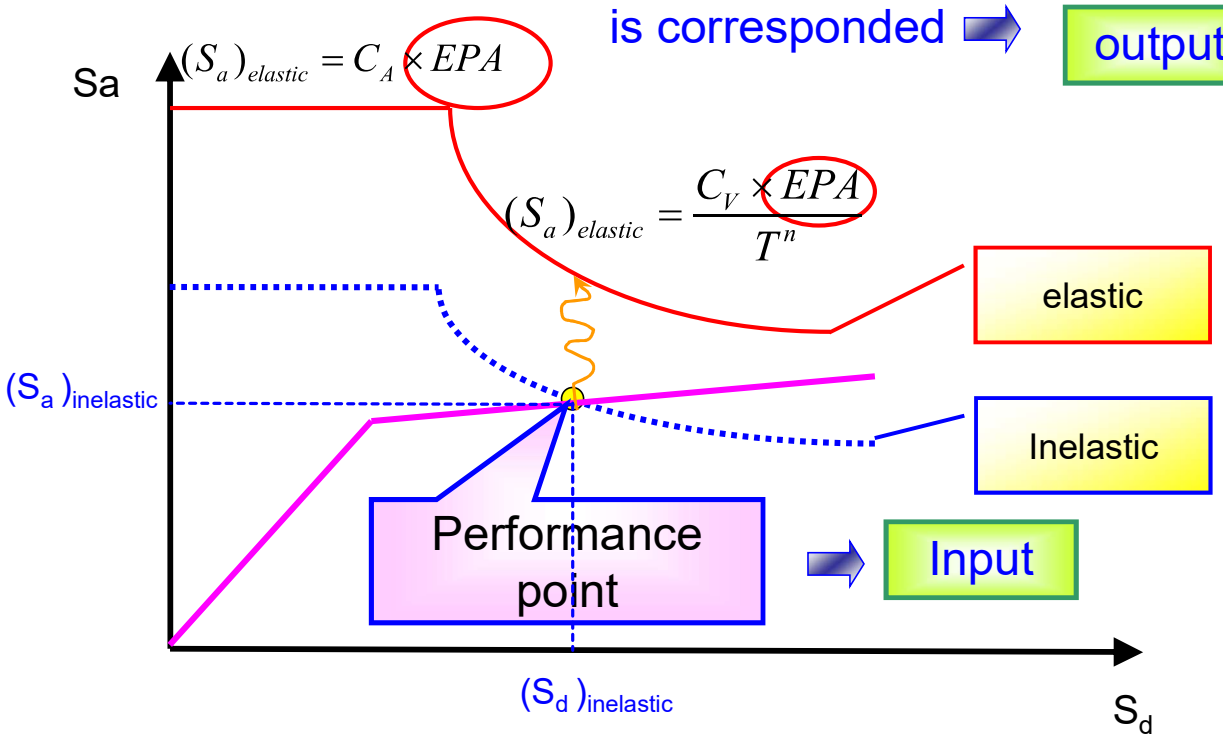


$$S_a = \frac{V}{\alpha_1 W}$$

$$S_d = \frac{\Delta_{roof}}{PF_1 \phi_{roof,1}}$$



Find EPA which every performance is corresponded ➡ output

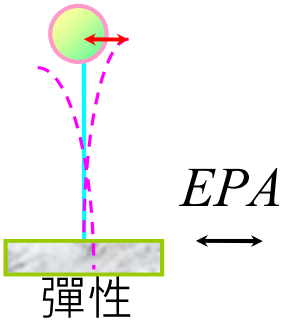


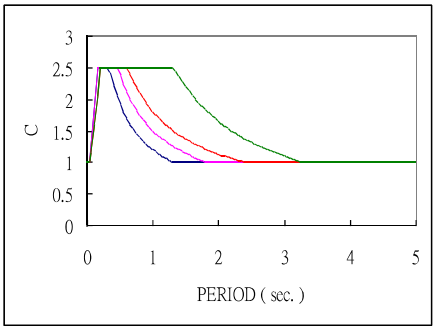
耐震設計規範中各種地震力之定義

$$S_a = EPA \times C = S_{DS}$$

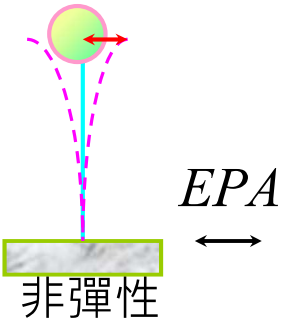
(475年回歸期地震)

$$S_{ai} = EPA \times C / F_U = S_{DS} / F_U$$





C



短週期彈性結構

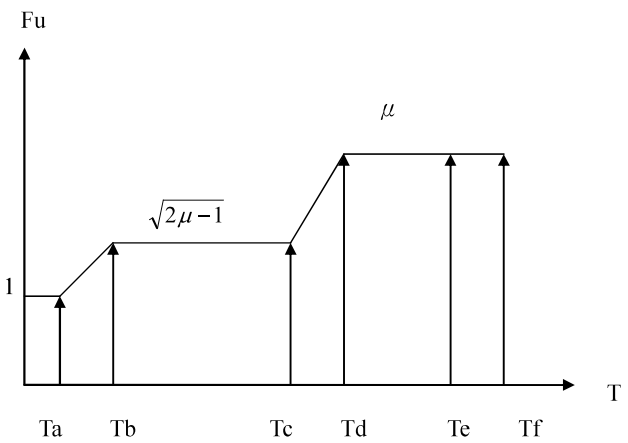
短週期非彈性結構

$$S_a = S_{DS} = EPA \times 2.5$$
$$EPA = S_{DS} / 2.5 = 0.4 S_{DS}$$

$$S_{ai} = S_{DS} / F_U = EPA \times 2.5 / F_U$$
$$EPA = S_{DS} / 2.5 = 0.4 S_{DS}$$

F_u-μ-T 結構系統地震力折減係數法

彈性週期	F_u
$T \le 0.2T_0^D$	$F_{u,1} = F_{u,2} + \left[F_{u,2} - 1\right]\dfrac{T - 0.2T_0^D}{0.2T_0^D}$
$0.2T_0^D < T \le 0.6T_0^D$	$F_{u,2} = \sqrt{\left[1+\alpha(R^* - 1)\right]\left[2R^* - 1 - \alpha(R^* - 1)\right]}$
$0.6T_0^D < T < T_0^D$	$F_{u,3} = F_{u,2} + \left[F_{u,4} - F_{u,2}\right]\dfrac{T - 0.6T_0^D}{0.4T_0^D}$
$T_0^D \le T$	$F_{u,4} = \dfrac{u_u}{u_y^*} = R^*$

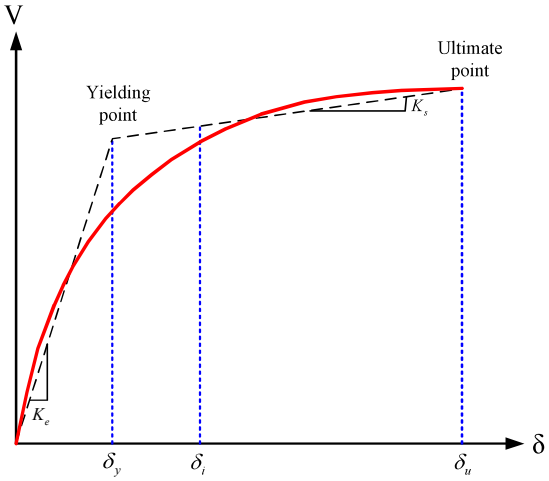


F_u-μ-T 結構系統地震力折減係數法

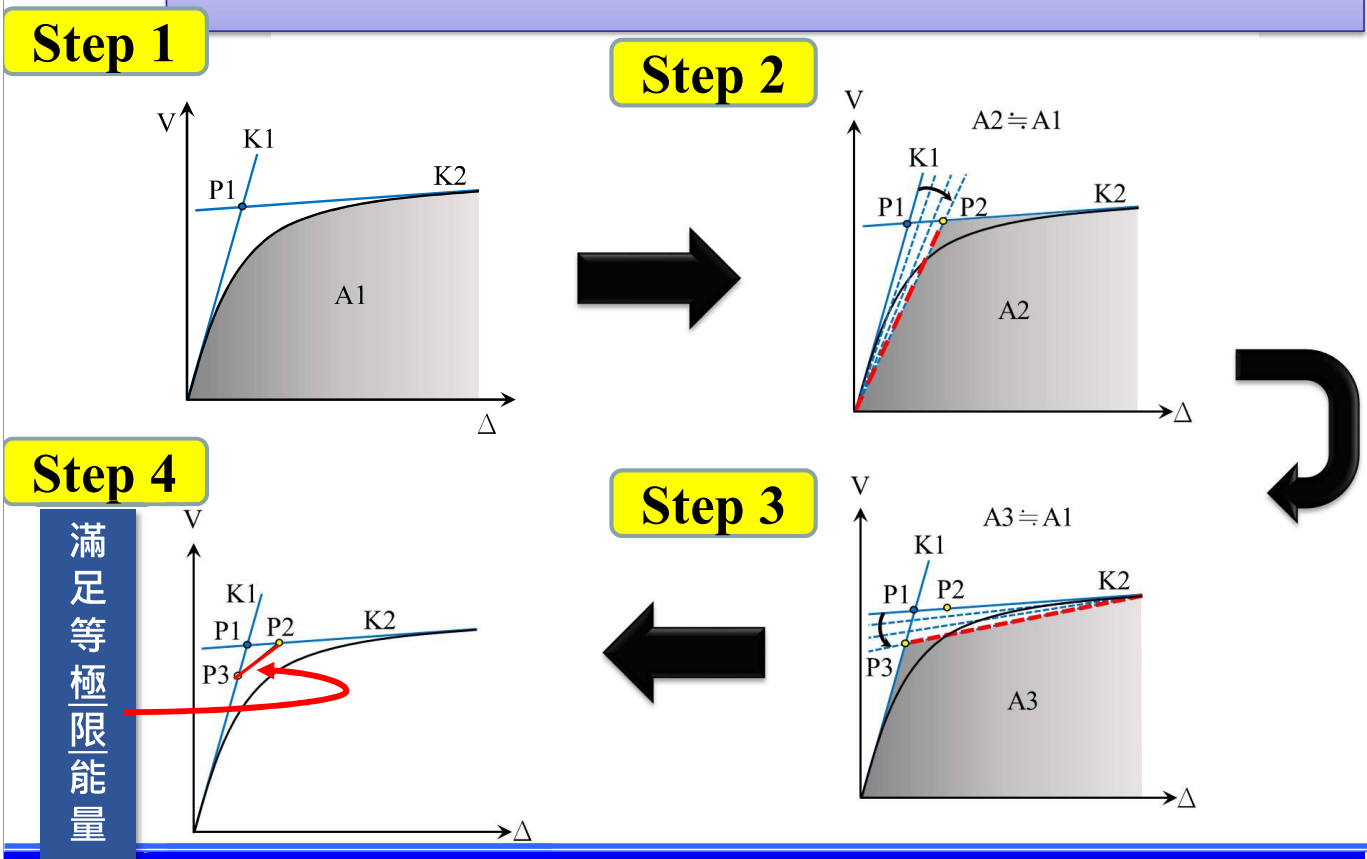
$$F_u(R)=\begin{cases} R_i & ; \quad T \ge T_0^D \\ A+(R_i\text{-}A)\times\dfrac{T\text{-}0.6T_0^D}{0.4T_0^D} & ; \quad 0.6T_0^D \le T < T_0^D \\ A & ; \quad 0.2T_0^D \le T < 0.6T_0^D \\ A+(A\text{-}1)\times\dfrac{T\text{-}0.2T_0^D}{0.2T_0^D} & ; \quad T \le 0.2T_0^D \end{cases}$$

$$A=\sqrt{[1+\alpha(R_i-1)][2R_i-1-\alpha(R_i-1)]}$$

$$R_i=\frac{\delta_i}{\delta_y}$$



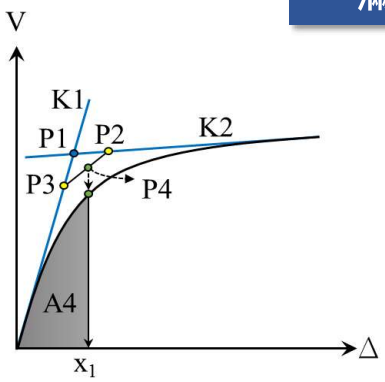
容量曲線降伏點選取辦法(1/2)



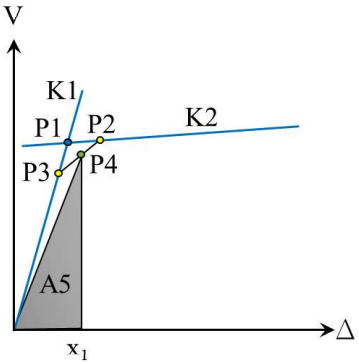
容量曲線降伏點選取辦法(2/2)

Step 5

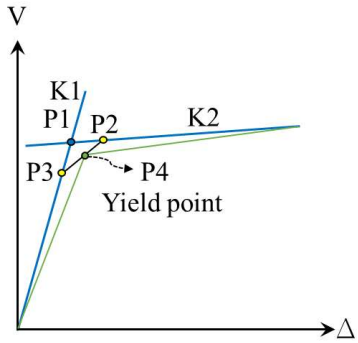
滿足等降伏能量



A5 ≒A4



Step 6



F_u-μ-T 結構系統地震力折減係數法

一般工址 有效最大加速度(EPA)

較短週期	短週期	中週期	長週期
$T \le 0.2T_0^D$	$0.2T_0^D \le T < T_0^D$	$T_0^D \le T < 2.5T_0^D$	$T \ge 2.5T_0^D$
$\dfrac{a_{pi} \times F_u(R)}{\left[\dfrac{S_{aD}(T)}{0.4S_{DS}}\right]} = \dfrac{a_{pi} \times F_u(R)}{\left[1+\dfrac{3T}{0.4T_0^D}\right]}$	$\dfrac{a_{pi} \times F_u(R)}{\left[\dfrac{S_{aD}(T)}{0.4S_{DS}}\right]} = \dfrac{a_{pi} \times F_u(R)}{2.5}$	$\dfrac{a_{pi} \times F_u(R)}{\left[\dfrac{S_{aD}(T)}{0.4S_{DS}}\right]} = \dfrac{a_{pi} \times F_u(R)}{\dfrac{S_{D1}}{0.4S_{DS}T}}$	

F_u-μ-T 結構系統地震力折減係數法

台北盆地　有效最大加速度(EPA)

較短週期	短週期	中週期	長週期
$T \le 0.2T_0^D$	$0.2T_0^D \le T < T_0^D$	$T_0^D \le T < 2.5T_0^D$	$T \ge 2.5T_0^D$
$\dfrac{a_{pi} \times F_u(R)}{\left[\dfrac{S_{aD}(T)}{0.4S_{DS}}\right]} = \dfrac{a_{pi} \times F_u(R)}{\left[1 + \dfrac{3T}{0.4T_0^D}\right]}$	$\dfrac{a_{pi} \times F_u(R)}{\left[\dfrac{S_{aD}(T)}{0.4S_{DS}}\right]} = \dfrac{a_{pi} \times F_u(R)}{2.5}$	$\dfrac{a_{pi} \times F_u(R)}{\left[\dfrac{S_{aD}(T)}{0.4S_{DS}}\right]} = \dfrac{a_{pi} \times F_u(R)}{\dfrac{T_0^D}{0.4T}}$	

等值遲滯阻尼法

有效最大加速度(EPA)

非彈性譜加速度與彈性譜加速度之比

$$B_1 \text{ or } B_s = \frac{(S_a)_{elastic}}{(S_a)_{inelastic}}$$

$$(S_a)_{inelastic} = a_{pi} \qquad (S_d)_{inelastic} = d_{pi}$$

側推分析所得容量震譜中任何一處譜加速度 a_{pi}

對應的有效最大速度(EPA)與所在工址之地震需求特性(如 S_{aD} & S_{DS} 等)，橋梁結構物等效振動週期 T、等值黏滯性阻尼 (β_{eff}) 與阻尼比異於5%加速度修正係數 B_1 或 B_s 等有關，可表示如下：

等值遲滯阻尼法

一般工址　有效最大加速度(EPA)

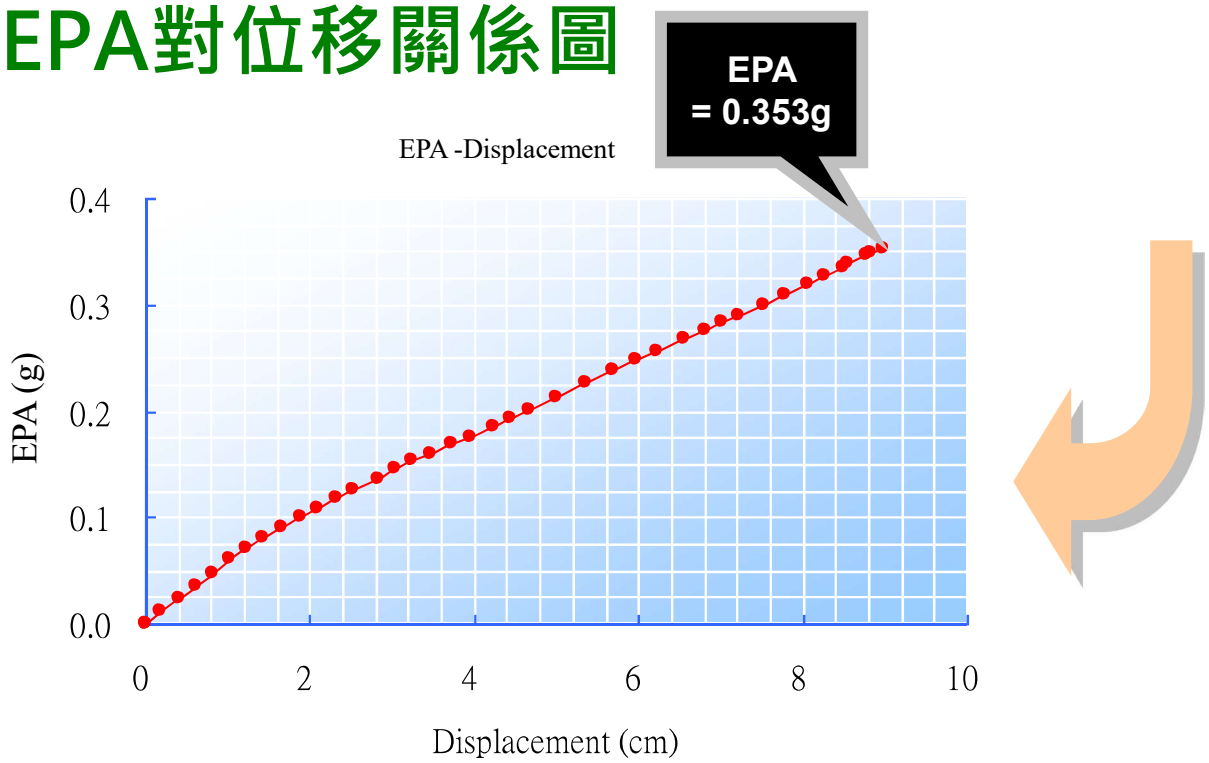
較短及短週期	中週期	長週期
$T \le T_0^D \dfrac{B_s(\beta_{eff})}{B_1(\beta_{eff})}$	$T_0^D \dfrac{B_s(\beta_{eff})}{B_1(\beta_{eff})} < T \le 2.5T_0^D \dfrac{B_s(\beta_{eff})}{B_1(\beta_{eff})}$	$2.5T_0^D \dfrac{B_s(\beta_{eff})}{B_1(\beta_{eff})} < T$
$EPA = \dfrac{a_{pi} \times B_s(\beta_{eff})}{(\frac{2.5S_{aD}(T)}{S_{DS}})} = \dfrac{a_{pi} \times B_s(\beta_{eff})}{2.5}$	$EPA = \dfrac{a_{pi} \times B_1(\beta_{eff})}{(\frac{2.5S_{aD}(T)}{S_{DS}})}$	$EPA = \dfrac{a_{pi} \times B_1(\beta_{eff})}{(\frac{2.5S_{D1}(T)}{S_{DS}T})}$

等值遲滯阻尼法

台北盆地　有效最大加速度(EPA)

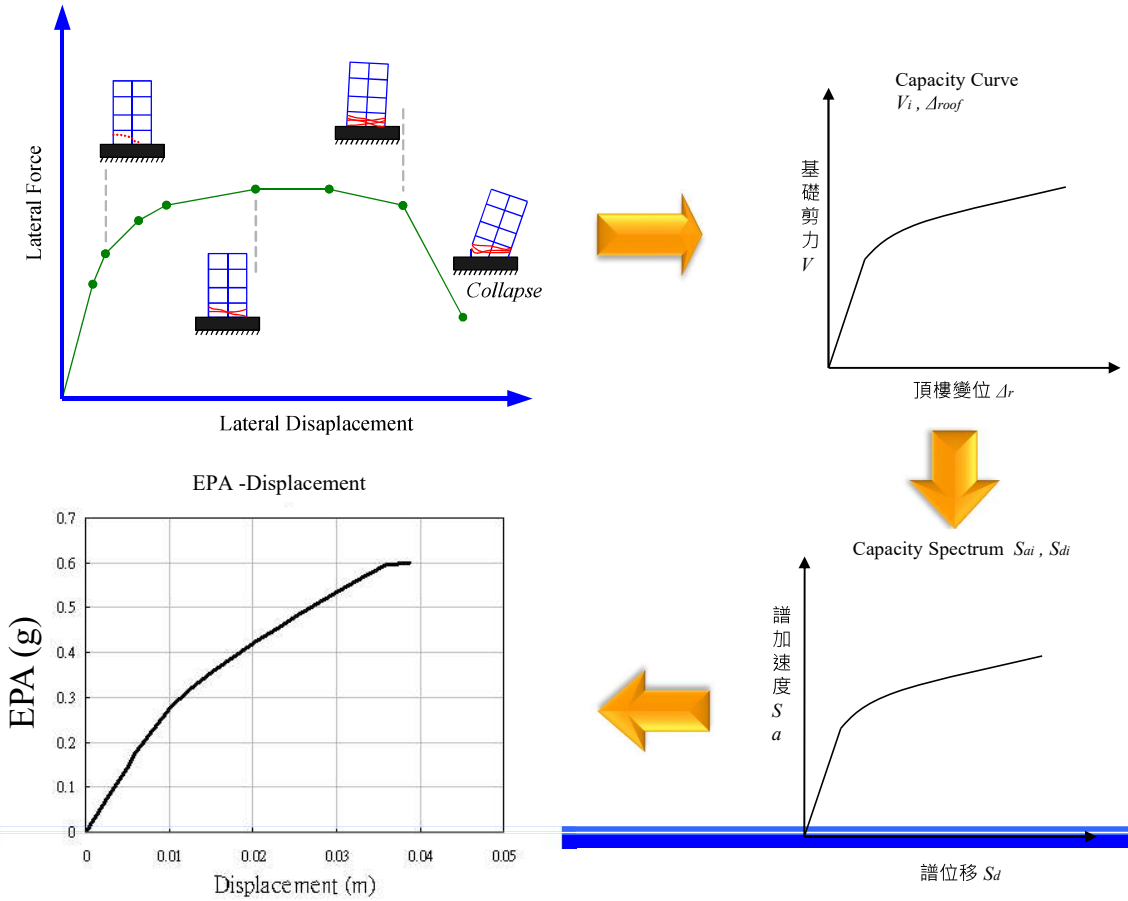
較短及短週期	中週期	長週期
$T \le T_0^D \dfrac{B_s(\beta_{eff})}{B_1(\beta_{eff})}$	$T_0^D \dfrac{B_s(\beta_{eff})}{B_1(\beta_{eff})} < T \le 2.5T_0^D \dfrac{B_s(\beta_{eff})}{B_1(\beta_{eff})}$	$2.5T_0^D \dfrac{B_s(\beta_{eff})}{B_1(\beta_{eff})} < T$
$EPA = \dfrac{a_{pi} \times B_s(\beta_{eff})}{(\frac{2.5S_{aD}(T)}{S_{DS}})} = \dfrac{a_{pi} \times B_s(\beta_{eff})}{2.5}$	$EPA = \dfrac{a_{pi} \times B_1(\beta_{eff})}{(\frac{2.5S_{aD}(T)}{S_{DS}})}$	$EPA = \dfrac{a_{pi} \times B_1(\beta_{eff})}{(\frac{2.5T_0^D}{T})}$

EPA對位移關係圖



Yu-Chi Sung, Chin-Kuo Su, Chuan-Wei Wu, and I-Chau Tsai, **"Performance-Based Damage Assessment of Low-Rise Reinforced Concrete Buildings"**, submitted to the Journal of China Institute of Engineer.【SCI、EI】

結構性能耐震評估



依中華民國一百年「建築物耐震設計規範及解說」第八章規定

8.2 耐震能力評估與耐震補強

1. 建築物進行耐震能力評估前，應對主要結構部分(如梁、柱、剪力牆與斜撐系統等)作實地調查。並應充分了解建築物之現況、震害經驗與修復補強情形等影響耐震能力之各項因素。
2. 耐震能力評估與補強的基準應為主管建築機關所認可者，耐震能力評估的方法應為公認之學理。
3. 耐震補強應依據耐震能力評估之結果，作通盤檢討後確認建築物之耐震安全性。如有必要作補強以提昇其耐震能力時，應依主管建築機關規定之程序辦理。
4. 耐震補強應依其補強的目標，採用改善結構系統、增加結構體韌性與強度等方式進行，惟應注意各項抗震構材之均衡配置，以使建築物整體結構系統耐震能力之均衡提昇。
5. 耐震補強或改修不得產生有害基礎安全之情形(如沈陷、變形等)。

內政部，建築物耐震設計規範及解說，2011

解說：

行政院已於民國 89 年 6 月 16 日核定「建築物實施耐震能力評估及補強方案」，期以公有建築物先行執行，作為民間表率，供爾後全面實施之參考，對於私有建築物擬以宣導方式推動。為確實有效進行建築物耐震評估及補強，該方案於 97 年 11 月 27 日修正部分條文，其對於耐震能力評估及補強基準如下，可供參考：

一、建築物之耐震能力評估分初步評估與詳細評估，初步評估供快速篩選優先評估順序對象之用。經初步評估判定為無疑慮者，得不必進行詳細評估；判定為有疑慮及確有疑慮者，除拆除重建外，應進行詳細評估或耐震設計補強。

二、實施耐震能力詳細評估之建築物，其不需補強或補強後之耐震能力應達下列基準：

（一）建築物之耐震能力以其能抵抗之最大地表加速度表示，其耐震能力應達本規範所規定工址回歸期475年之設計地震地表加速度乘以用途係數 I。

（二）建築物亦得以性能目標作為耐震能力之檢核標準，確保該建築物在工址回歸期475年之設計地震力下所需達到之性能水準。

（三）進行結構耐震能力評估與補強設計時，應考慮非結構牆之效應，並檢討軟弱層存在之情況。

三、用途係數 I=1.5 之建築物，應檢討其供水、供電及消防設備系統固定之耐震能力；並應考慮墜落物對建築使用機能之影響。設備系統固定處之耐震能力以其所在樓層加速度檢核之，其耐震能力應達本規範之加速度規定。

內政部，建築物耐震設計規範及解說，2011

建築物耐震設計規範及解說

8.2 耐震能力評估與耐震補強

1. 建築物進行耐震能力評估前，應對主要結構部分(如梁、柱、剪力牆與斜撐系統等)作實地調查。並應充分了解建築物之現況、震害經驗與修復補強情形等影響耐震能力之各項因素。
2. 耐震能力評估與補強的基準應為主管建築機關所認可者，耐震能力評估的方法應為公認之學理。
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5. 耐震補強或改修不得產生有害基礎安全之情形(如沈陷、變形等)。

解說：

行政院已於民國 89 年 6 月 16 日核定「建築物實施耐震能力評估及補強方案」，期以公有建築物先行執行，作為民間表率，供爾後全面實施之參考，對於私有建築物擬以宣導方式推動。為確實有效進行建築物耐震評估及補強，該方案於 97 年 11 月 27 日修正部分條文，其對於耐震能力評估及補強基準如下，可供參考：

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（二）建築物亦得以性能目標作為耐震能力之檢核標準，確保該建築物在工址回歸期475年之設計地震力下所需達到之性能水準。

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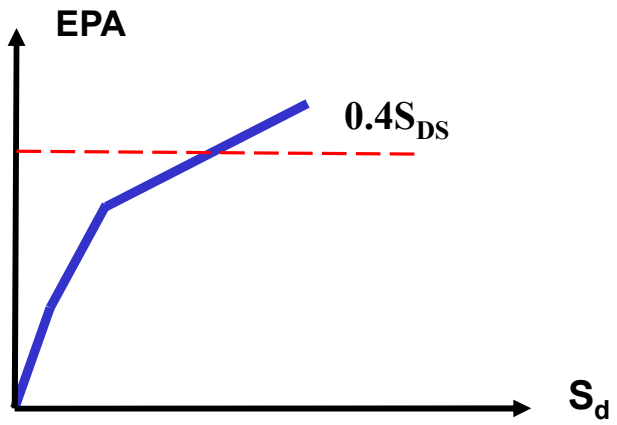
內政部，建築物耐震設計規範及解說，2011

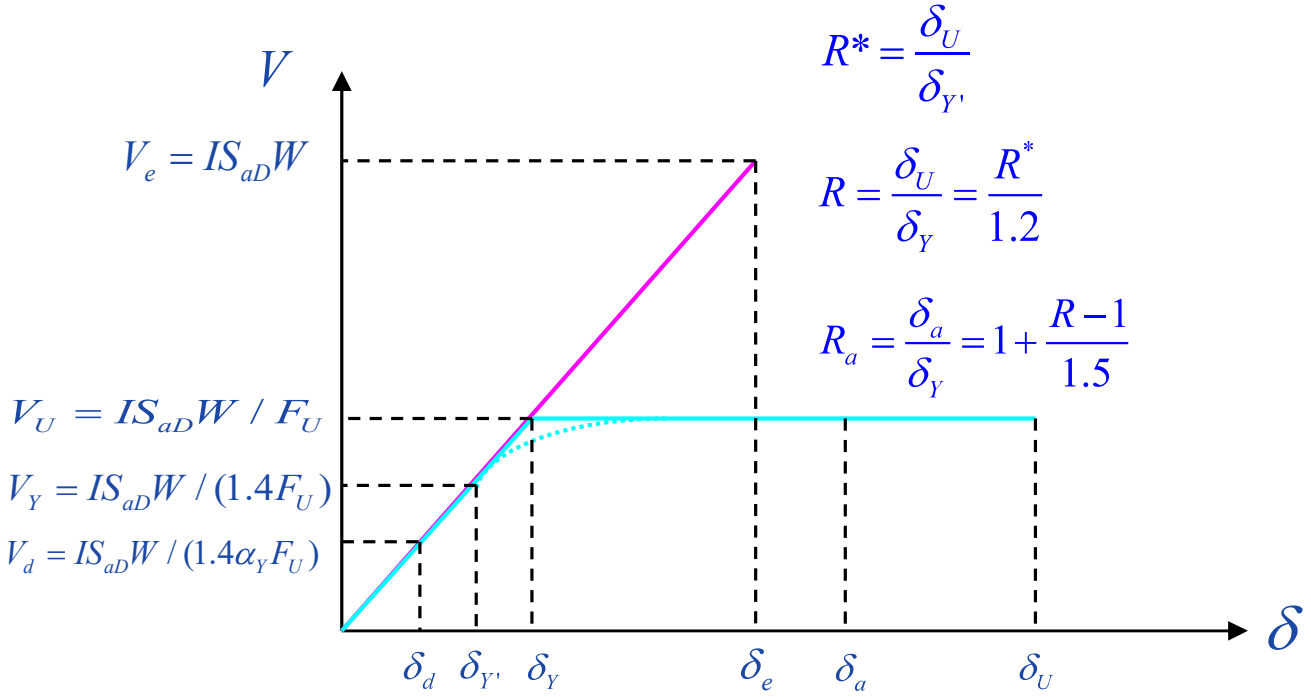
設計地震：$0.4S_{DS}$

檢核



耐震設計規範中各種地震力之定義

彈性系統與非彈性系統



$$R^* = \frac{\delta_U}{\delta_{Y'}}$$

$$R = \frac{\delta_U}{\delta_Y} = \frac{R^*}{1.2}$$

$$R_a = \frac{\delta_a}{\delta_Y} = 1 + \frac{R-1}{1.5}$$

建築物之耐震性能
(適用於一般工址或台北盆地)

性能狀態	安全性	使用性	修復性	
			短期	長期
PL_A PL_A* PL_A**	結構保持彈性	與地震前機能相同	臨時維修	無
PL_B PL_B* PL_B**	結構產生可修復之塑性變形防止倒塌	短期搶修可恢復震前機能	緊急修復或更換受損構件	局部整修或結構補強

建築物之性能目標
(適用於一般工址或台北盆地)

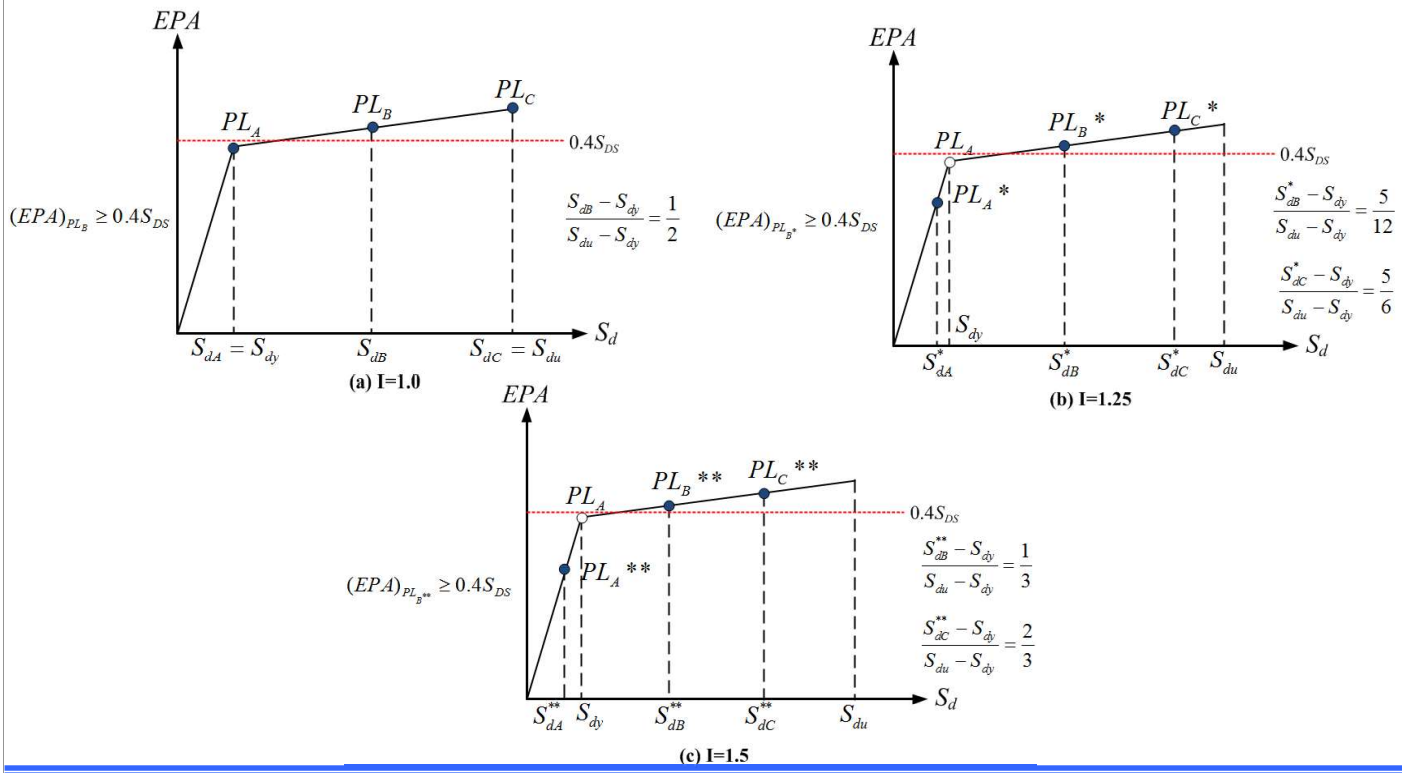
地震等級	用途係數		
	I=1.0	I=1.25	I=1.5
設計地震	PL_B	PL_B*	PL_B**

建築物非彈性位移
與非彈性位移容量之比值r

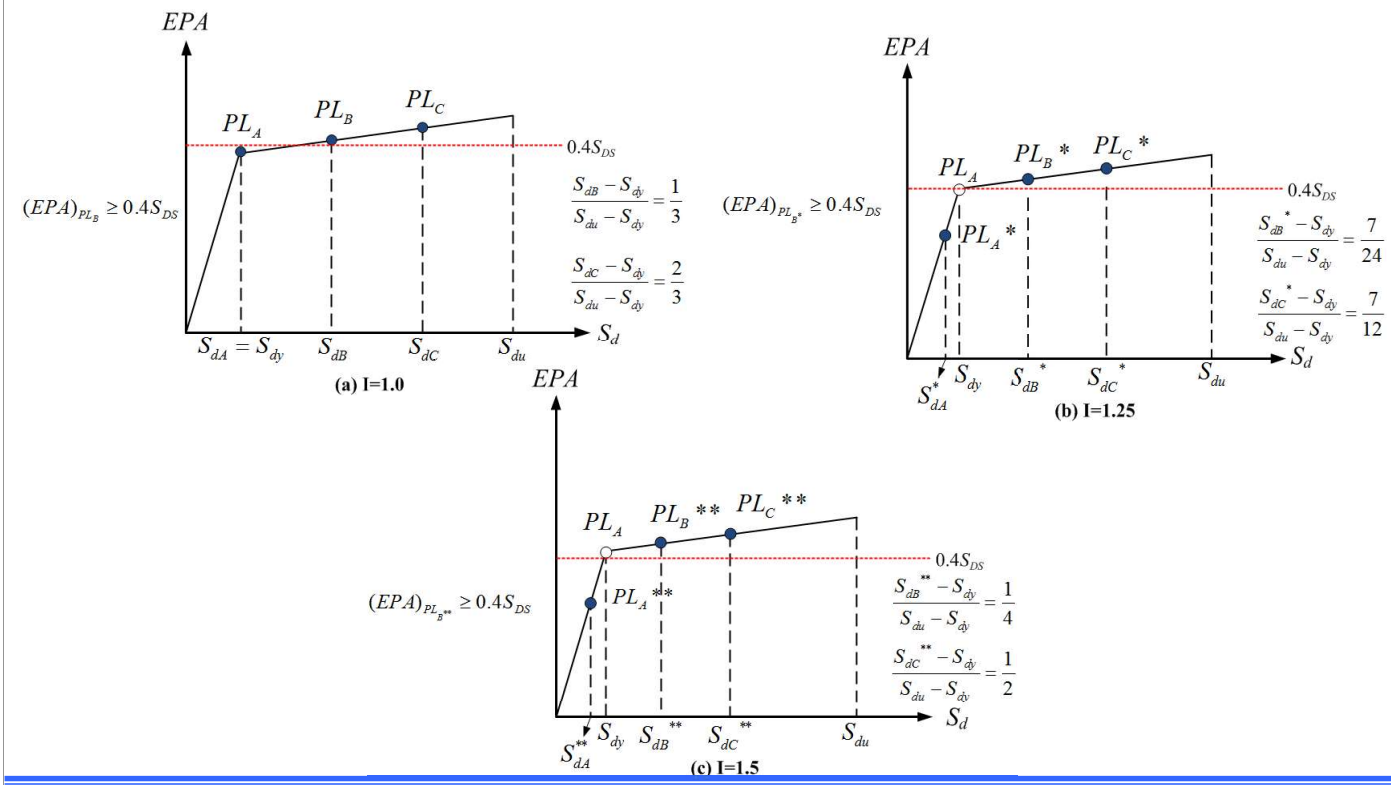
性能狀態	一般工址			台北盆地		
	I=1.0	I=1.25	I=1.5	I=1.0	I=1.25	I=1.5
PL_B	1/2	–	–	1/3	–	–
PL_B*	–	5/12	–	–	7/24	–
PL_B**	–	–	1/3	–	–	1/4

註： $r = \dfrac{S_d - S_{dy}}{S_{du} - S_{dy}}$ S_d：非彈性譜位移 S_{dy}：降伏譜位移 S_{du}：極限譜位移

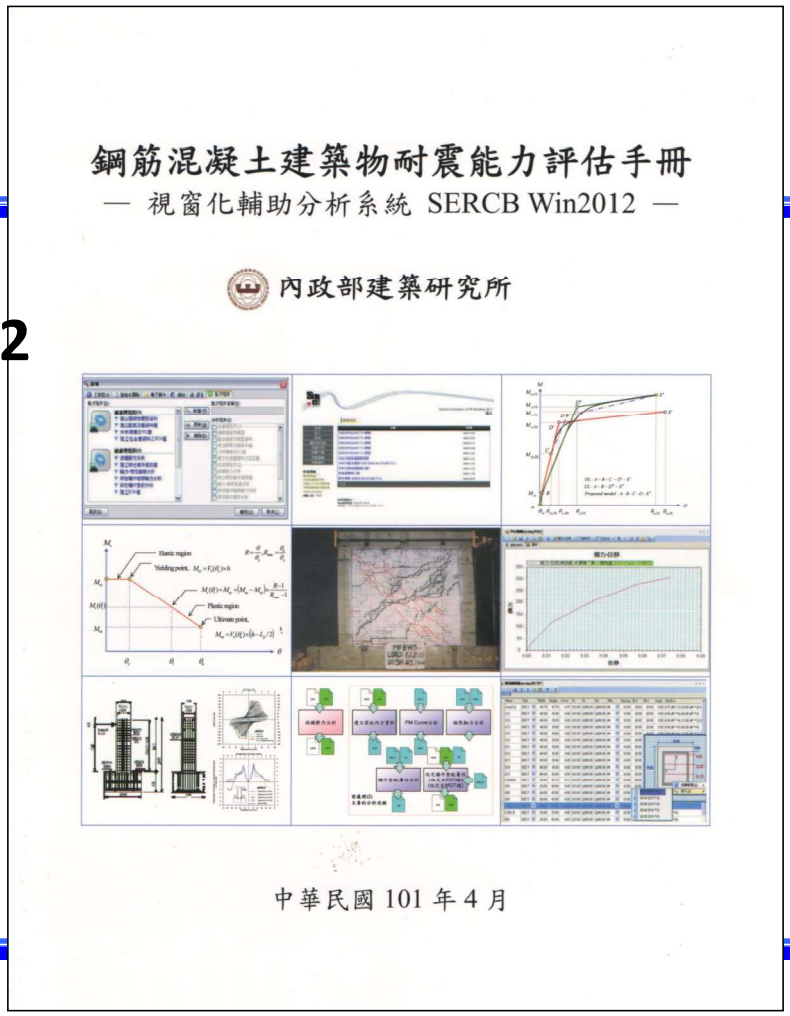
一般地址之建築物耐震性能目標



臺北盆地之建築物耐震性能目標



SERCB Win2012


鋼筋混凝土建築物耐震能力評估手冊
— 視窗化輔助分析系統 SERCB Win2012 —

內政部建築研究所

中華民國 101 年 4 月

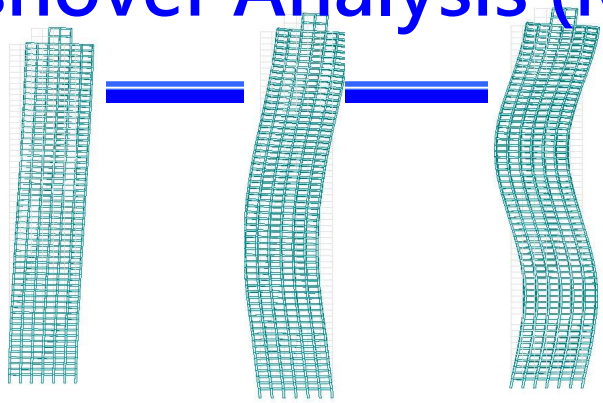
高樓層建築物耐震能力分析

Chopra 2004

Modal Pushover Analysis (MPA)

Step 1

Mode Analysis



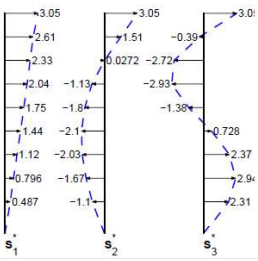
Mode 1 *Mode 2* *Mode 3* ◦ ◦ ◦ *Mode n*

Mode shape Φ_n *Frequency W_n*

Step 2

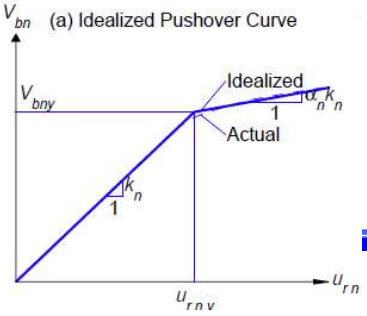
Force distributions

$$s_n^* = m\phi_n$$



Step 3

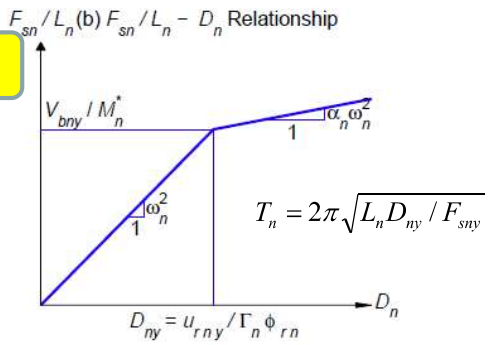
Pushover Analysis



Modal Pushover Analysis (MPA)

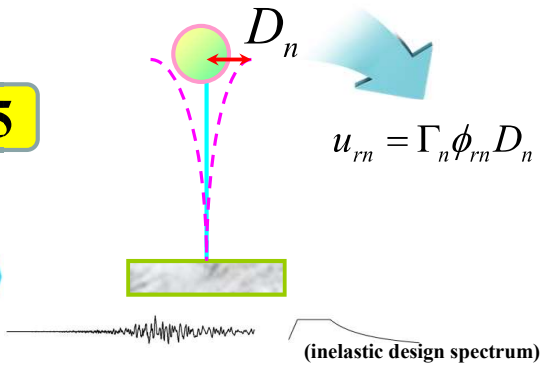
Step 4

Inelastic SDF



$$T_n = 2\pi\sqrt{L_n D_{ny}/F_{sny}}$$

Step 5



$$u_{rn} = \Gamma_n \phi_{rn} D_n$$

Nonlinear Time History Analysis

Step 6

$\leftrightarrow u_{rn}$

模態分配

Repeat Steps 3-6 for as many "modes" as required for sufficient accuracy.

Step 7

SRSS

$$u_r = \sqrt{\sum_n u_{rn}^2}$$

TAIPEI TECH

Complete Quadratic Combination Method (CQC)

$$r_a = \left(\sum_{j=1}^{N} \sum_{k=1}^{N} S_{jk} r_j r_k \right)^{1/2}$$

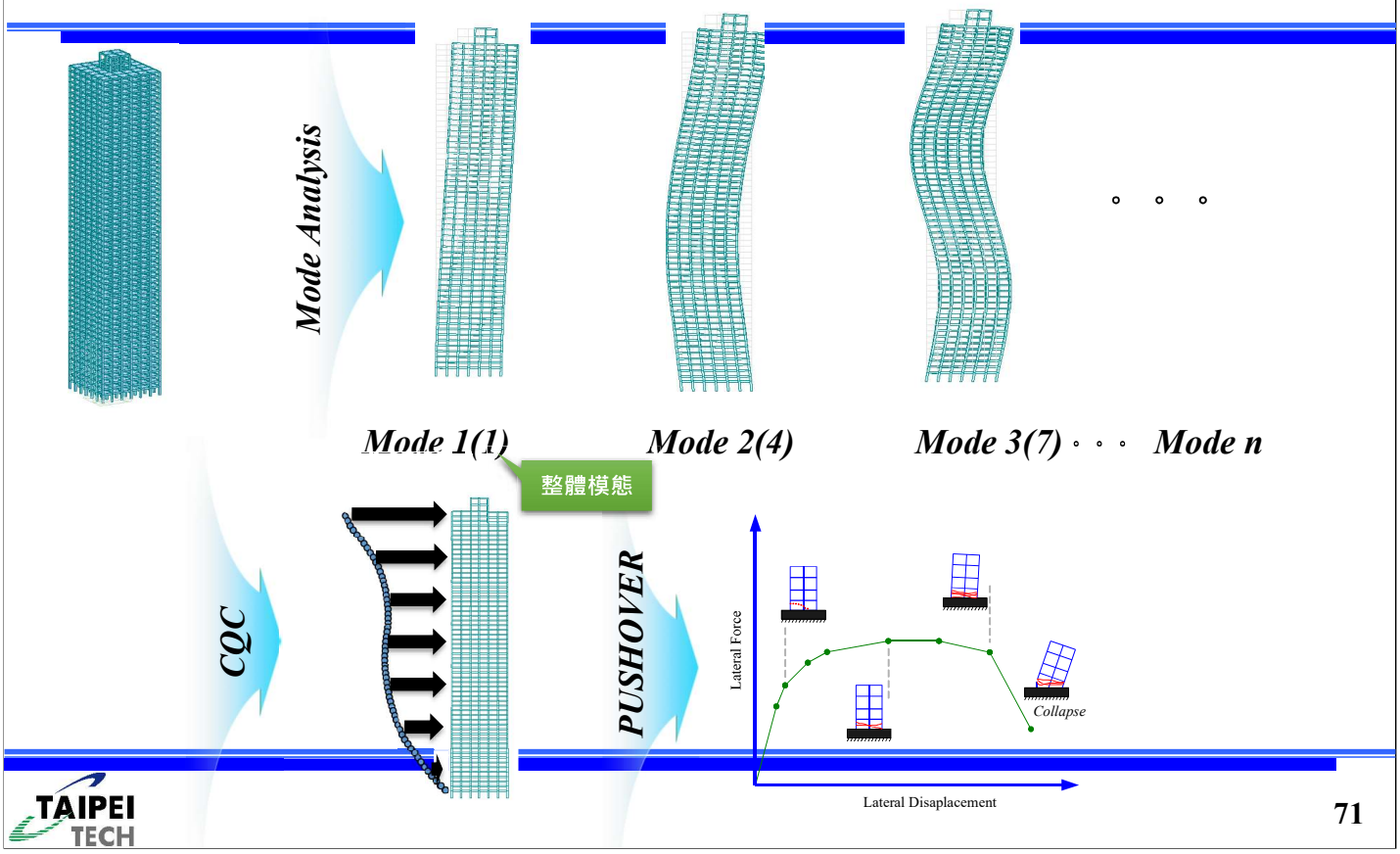
$$S_{jk} = \frac{8\sqrt{\xi_j \xi_k}\left(\xi_j + r\xi_k\right) r^{3/2}}{\left(1-r^2\right)^2 + 4\xi_j \xi_k r\left(1+r^2\right) + 4\left(\xi_j^2 + \xi_k^2\right) r^2}$$

$$r = \frac{w_k}{w_j}$$

其中，r_j ，r_k 分別為第 j 振態及第 k 振態最大反應值，S_{jk} 為第 j 振態與第 k 振態之關係係數。ξ_j 、ξ_k 分別為第 j 、k 振態的阻尼比，w_j 、w_k 分別為第 j 、k 振態的圓周頻率。

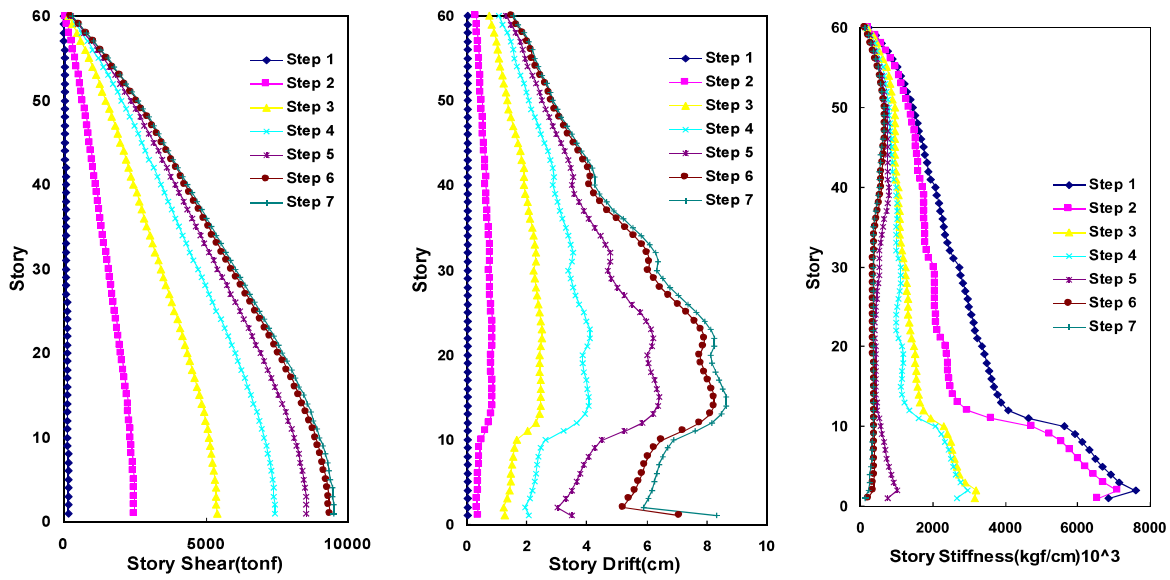
TAIPEI TECH

Complete Quadratic Combination Method (CQC)



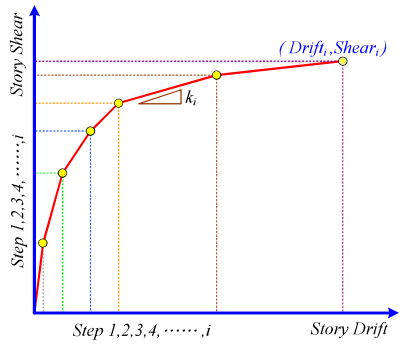
Time History Analysis

PUSHOVER可得各樓層之層間位移、層間剪力與層間勁度

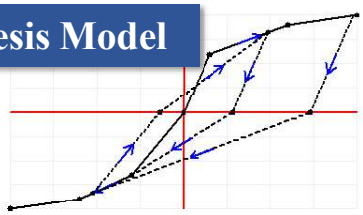


Time History Analysis

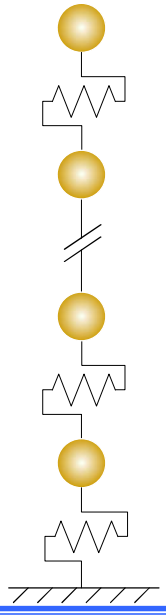
建立層間位移與層間剪力關係



Hysteresis Model

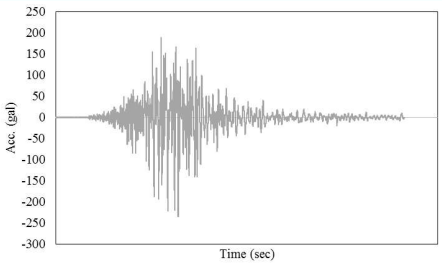


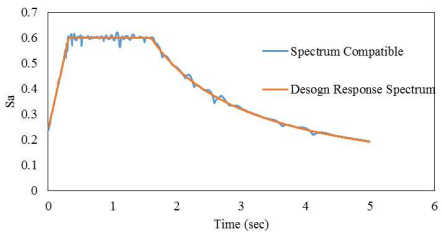
Stick Mpdel

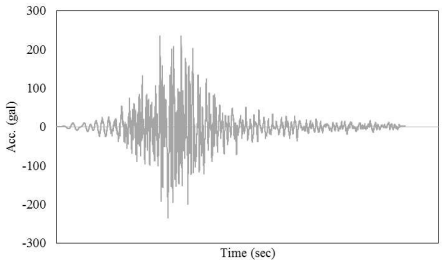


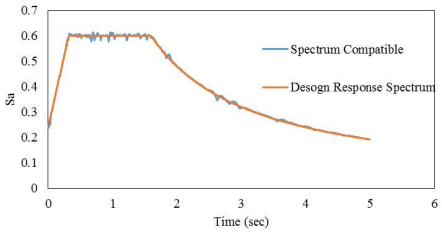
Time History Analysis

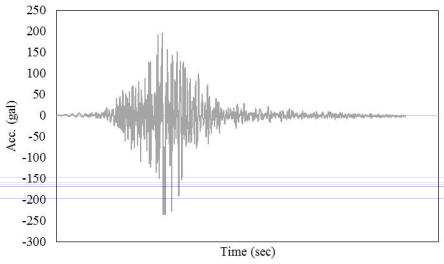
Spectrum Compatible

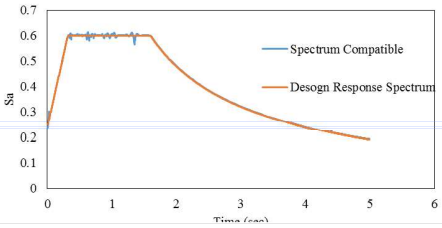






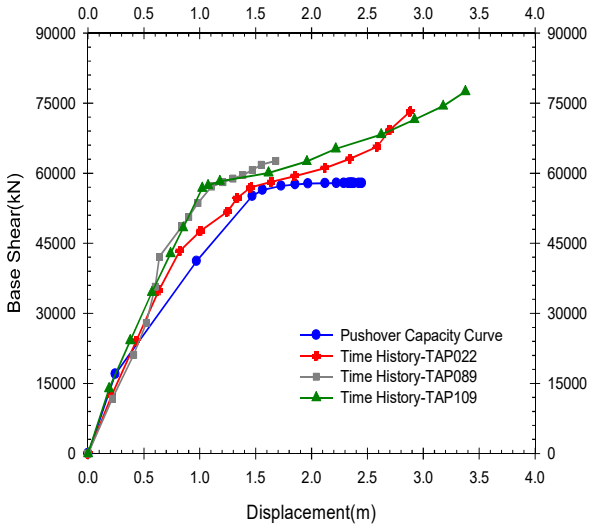




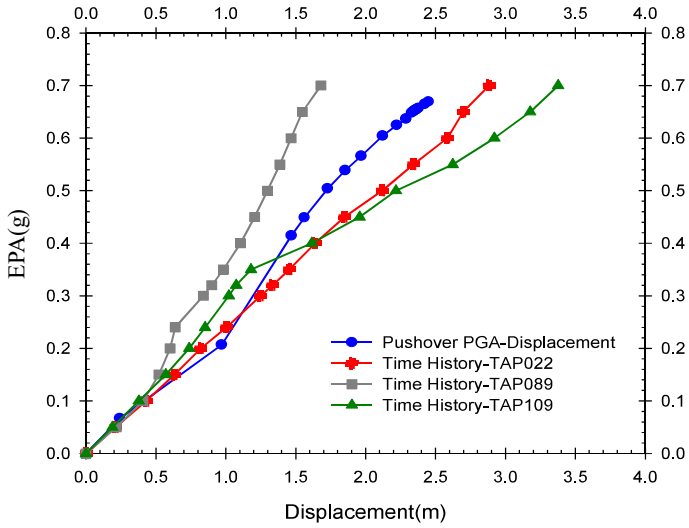


Comparison of capacity curves obtained by time history analysis and pushover analysis

Base shear vs roof displacement

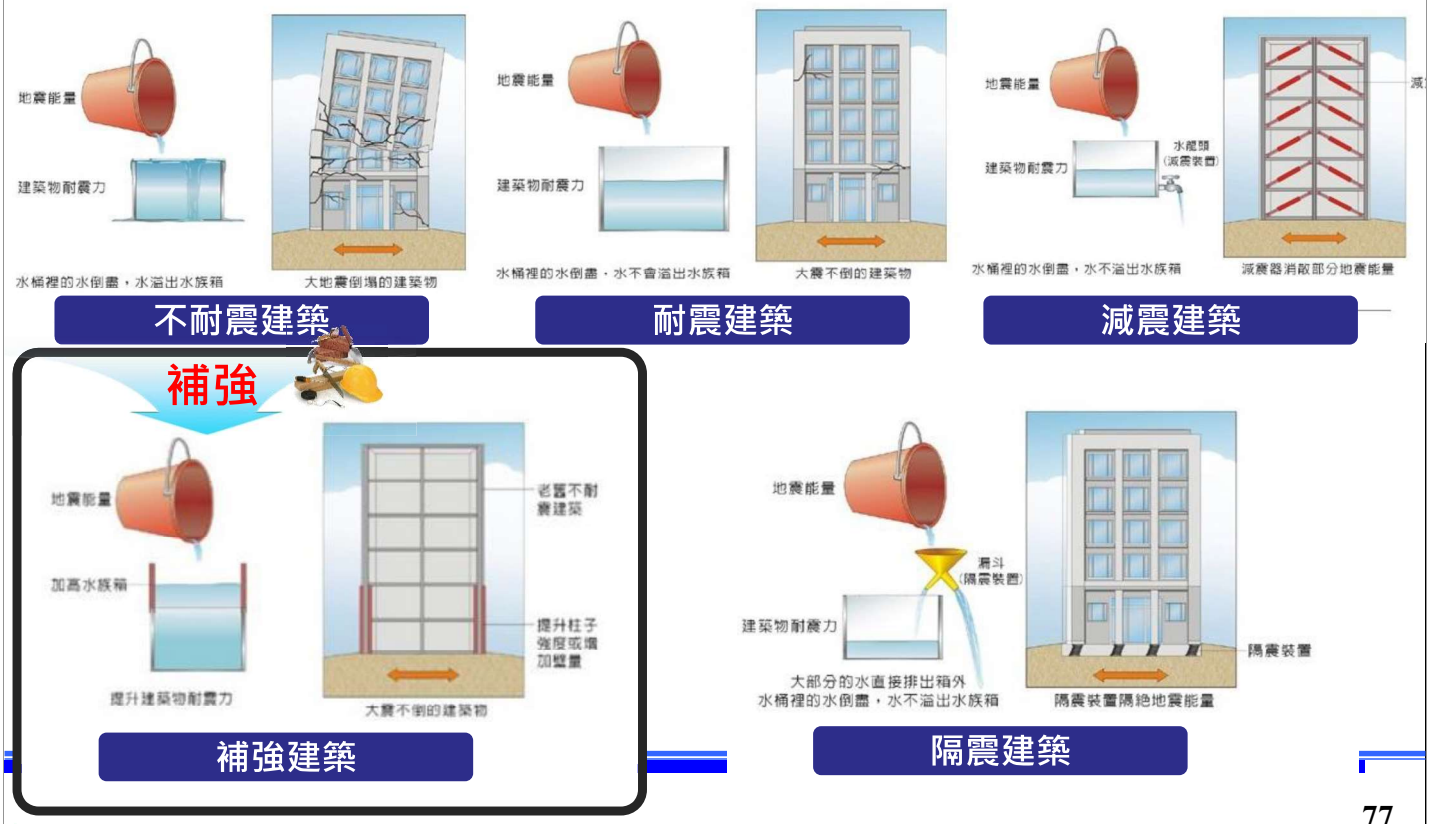


EPA vs roof displacement



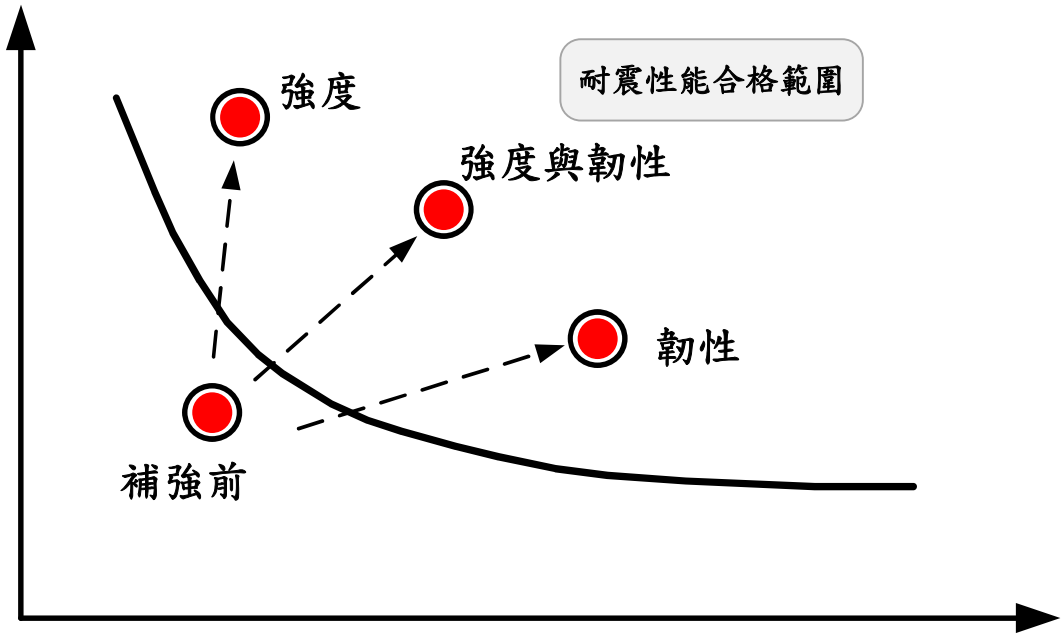
鋼筋混凝土建築結構耐震補強

建築物耐震、隔震與消能

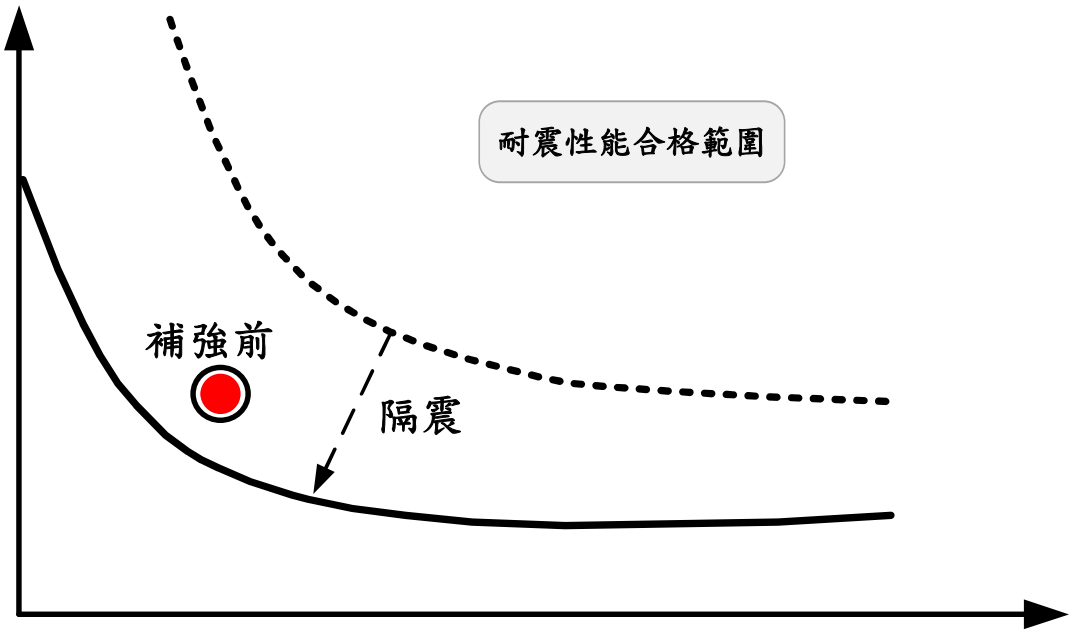


http://www.narlabs.org.tw/tw/pressroom/popsci/popsci.php?feature_id=20

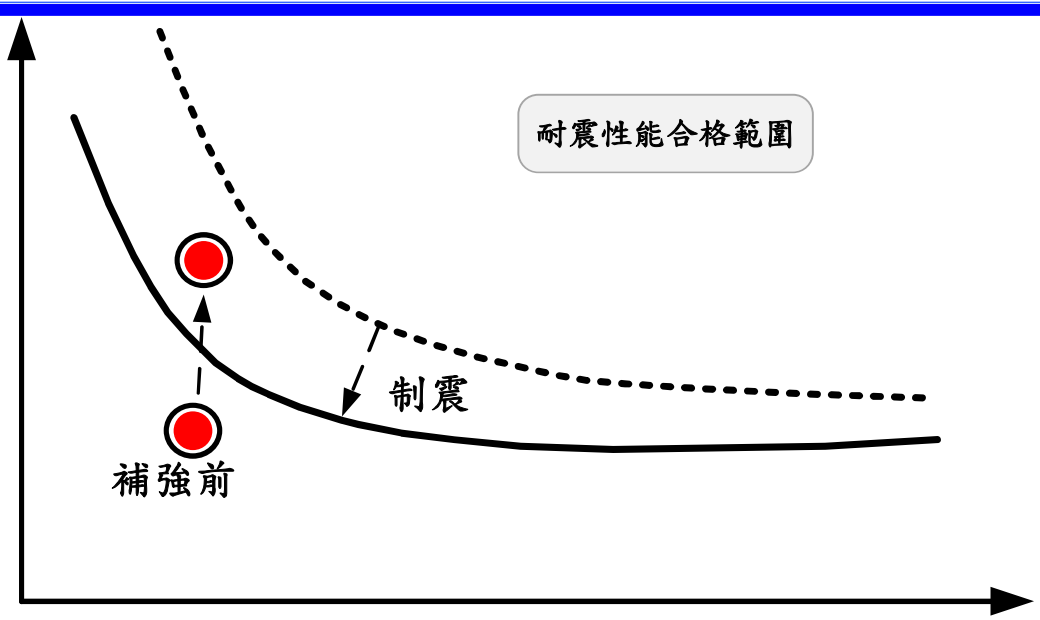
建築物耐震補強



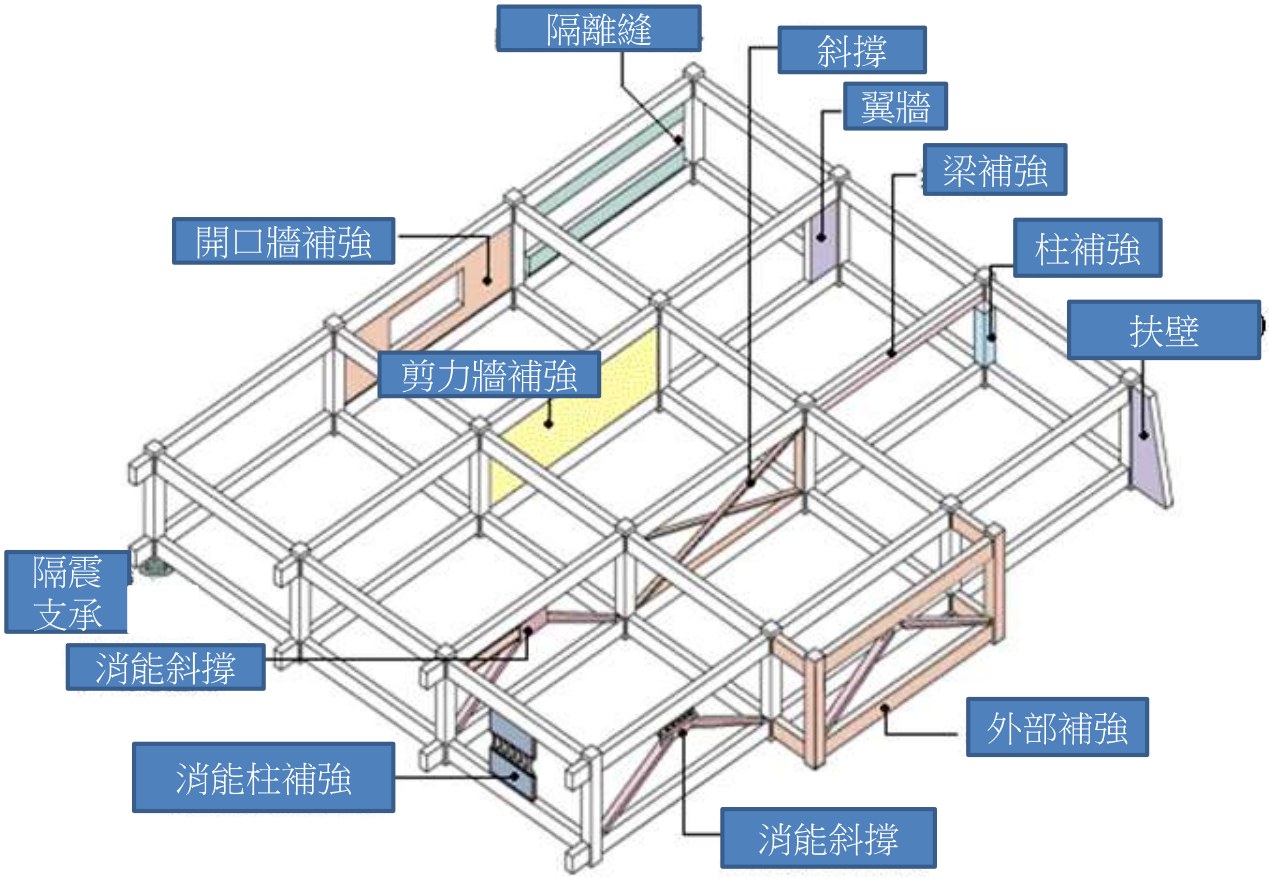
建築物隔震補強



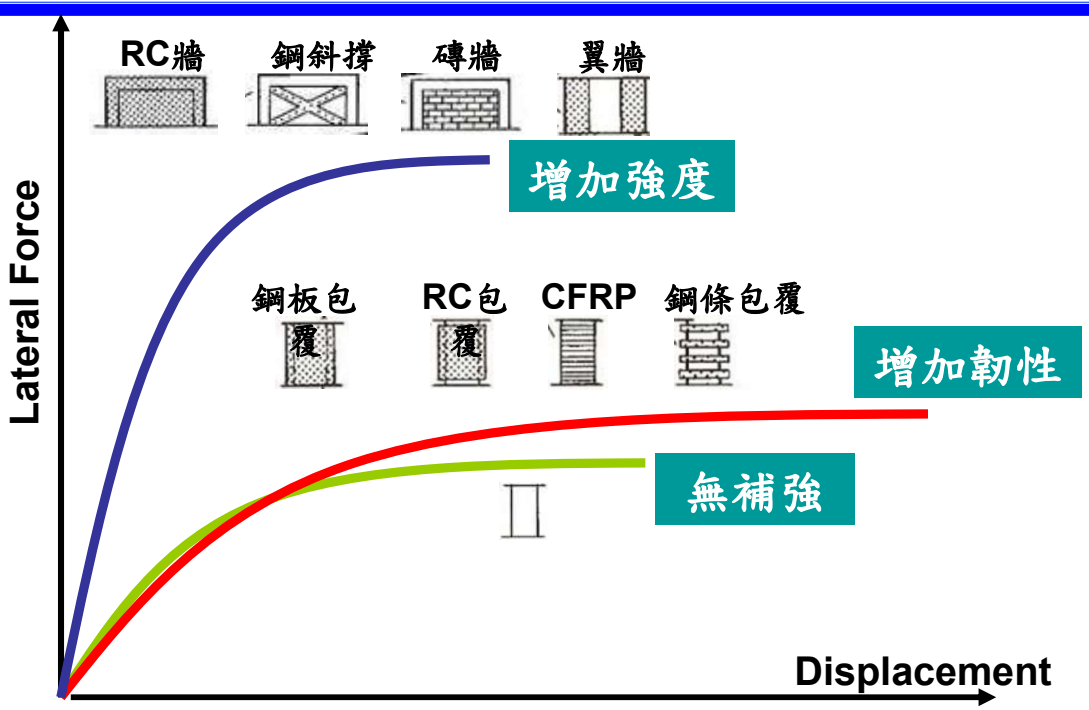
建築物消能補強



建築物補強種類



結構構材補強觀念說明

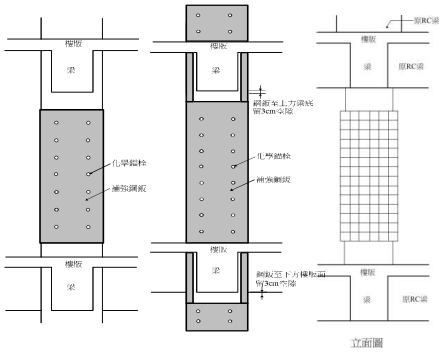


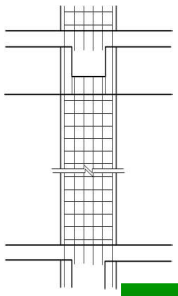
構件補強

- RC包覆強度補強
- RC包覆圍束補強
- 鋼板包覆圍束補強
- 翼牆補強

結構系統補強

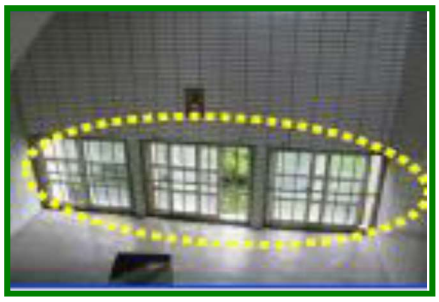
- 增設RC牆補強
- 內嵌式鋼斜撐框架補強
- 外附式鋼斜撐框架補強





國內常用補強工法

窗台填磚牆 -消除短柱



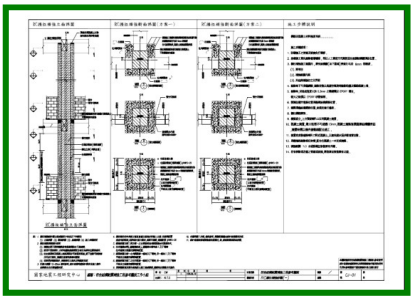
優點	缺點
□ 消除短柱效應，避免剪力破壞。 □ 可提升結構物的勁度，並提升整體耐震能力。	□ 影響原空間之採光與通風 □ 如位於樓梯間或側所之高窗，填磚後需設置通風系統及採光

資料來源:國家地震中心
東建工程顧問有限公司

國內常用補強工法

擴柱補強

校舍結構耐震補強工程參考圖說



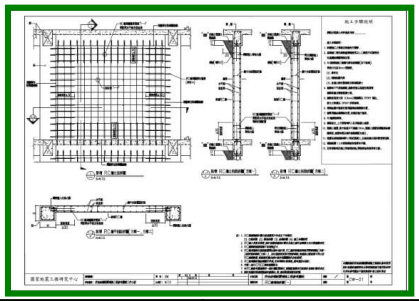
優點	缺點
□ 選用適當建材，可使外觀與原始教室較具一體性。 □ 對於教室採光影響小。	□ 設置於樓梯與出入口角落時，需要設置保護墊，避免學生撞傷。

資料來源:國家地震中心
東建工程顧問有限公司

國內常用補強工法

剪力牆補強

校舍結構耐震補強工程參考圖說



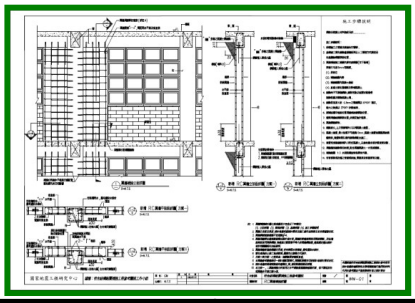
優點	缺點
□ 可以較少的補強量，達到足夠的耐震需求，減少補強工程對學校的衝擊。 □ 新增牆面可提供作為公佈欄使用增加額外。	□ 較容易影響通風與採光，應慎選配置地點。 □ 剪力牆下方基礎不易設計及施工。

資料來源:國家地震中心

國內常用補強工法

翼牆補強

校舍結構耐震補強工程參考圖說

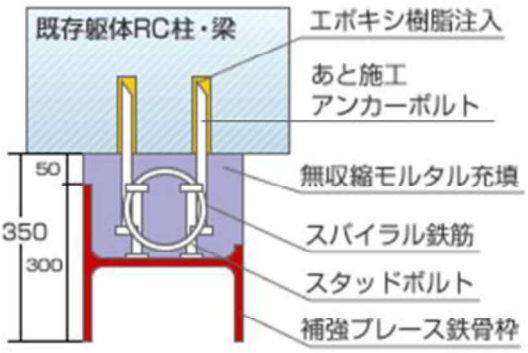


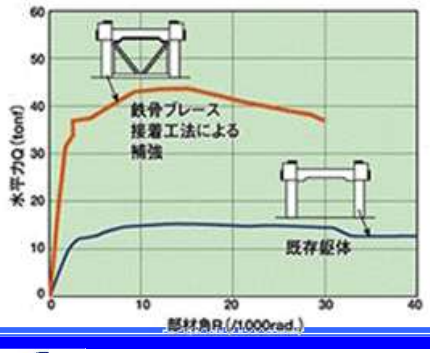
優點	缺點
□ 對於教室採光影響較剪力牆小。 □ 新增牆面可提供作為公佈欄使用。	□ 補強位置若變更門窗，將會影響到教室動線。

資料來源:國家地震中心
東建工程顧問有限公司

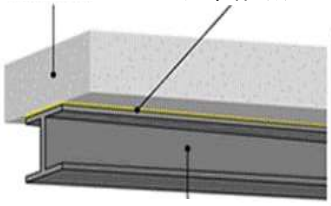
國外之補強工法

內嵌式鋼斜撐構架補強

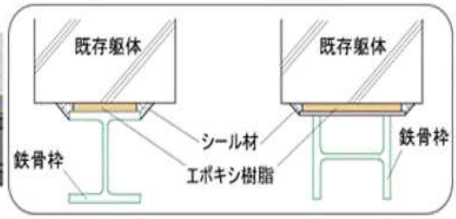




既有結構　環氧樹脂

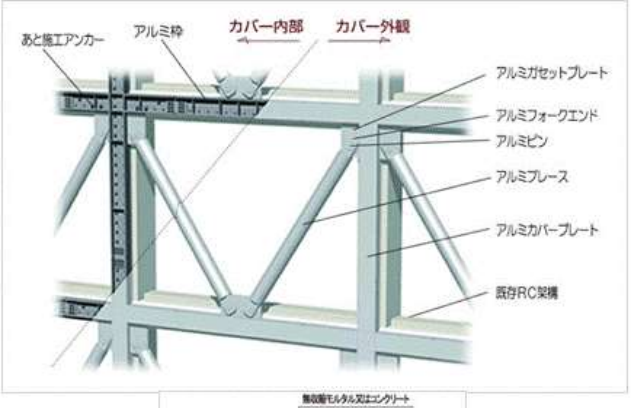


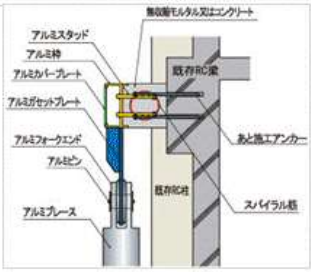
鋼骨



國外之補強工法

外附式鋼斜撐構架補強

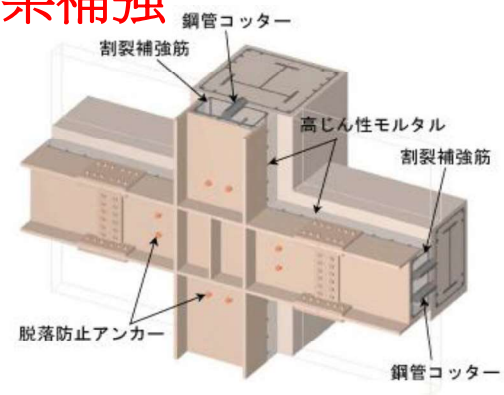


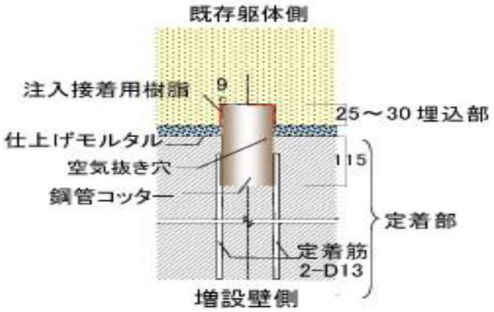


框架型示意圖

國外之補強工法

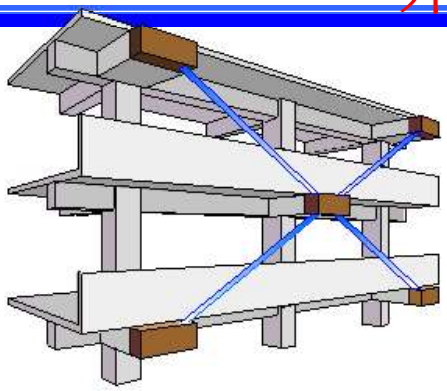
外附式鋼框架補強

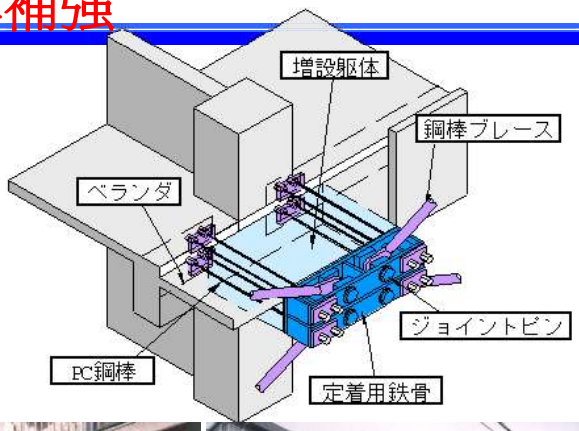




國外之補強工法

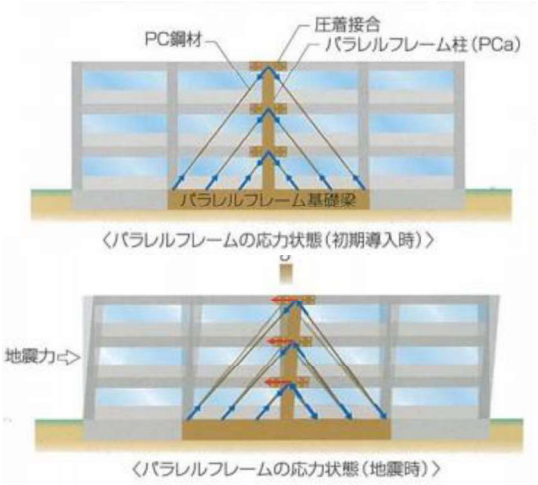
外部支撐補強

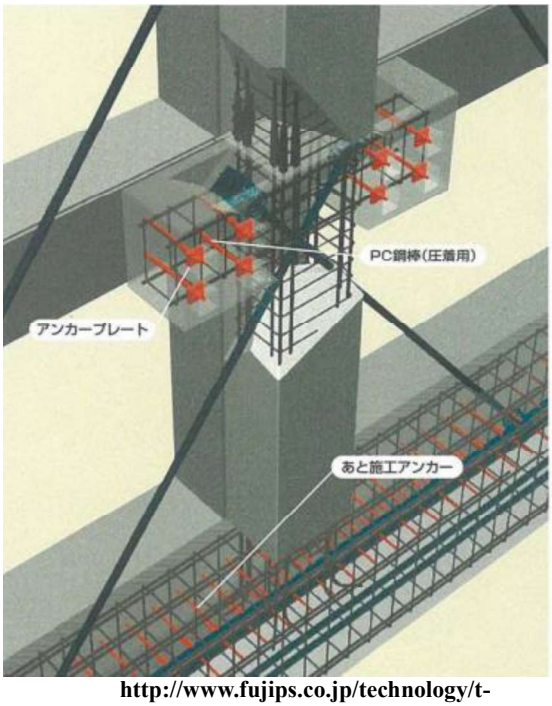




國外之補強工法

平行預力鋼索補強工法





http://www.fujips.co.jp/technology/t-reinforce/sub16010

國外補強案例探討

外加式鋼構架補強

外加式鋼斜撐構架補強

外加式鋼構架補強

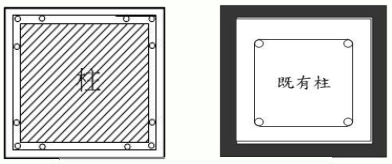
預鑄RC柱構架補強

http://www.sho-bond.co.jp/html/51-bc.html

鋼筋混凝土構件補強理論探討與分析驗證

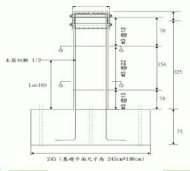
鋼筋混凝土構件補強理論探討與分析驗證

RC柱包覆補強 非線性行為探討



強度、圍束補強

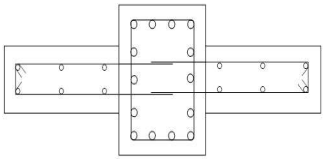
RC柱包覆補強 分析與驗證



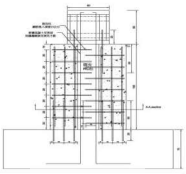
單柱

構架

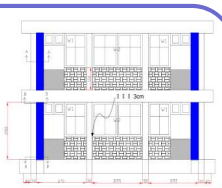
翼牆補強 分析與驗證



雙側、單側、偏心



單柱



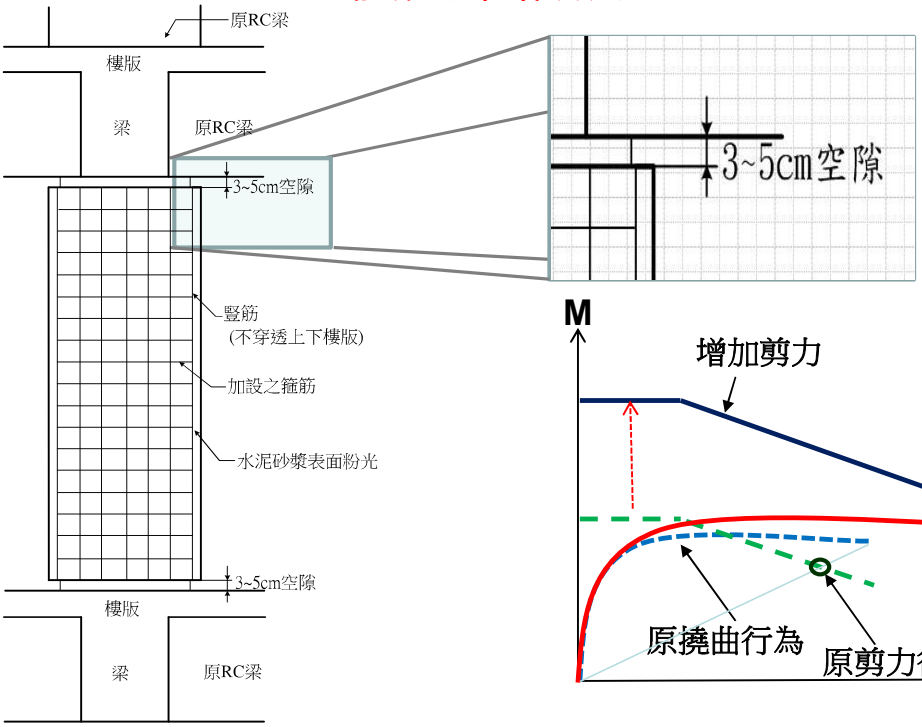
構架

分析方法

- 切片法
- 撓曲分析
- 剪力分析
- 破壞模式

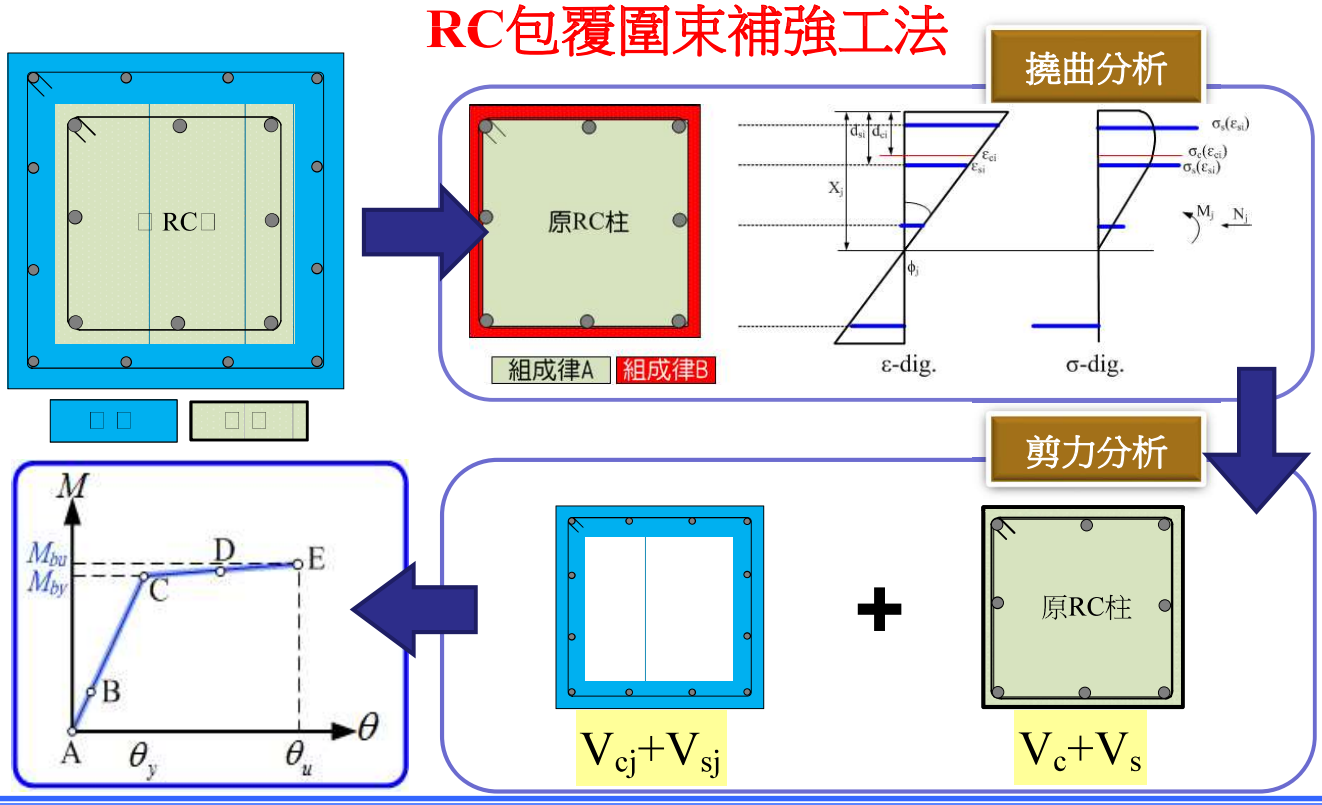
構件補強非線性行為分析方法

RC包覆圍束補強工法



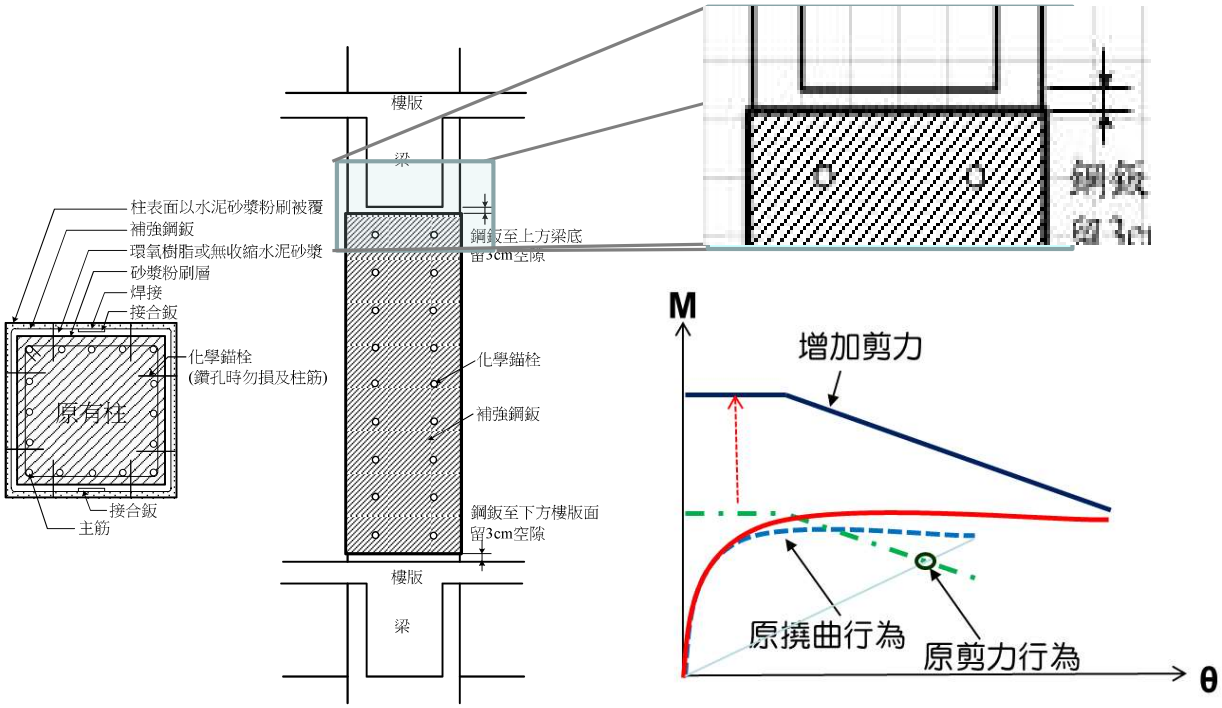
構件補強非線性行為分析方法

RC包覆圍束補強工法



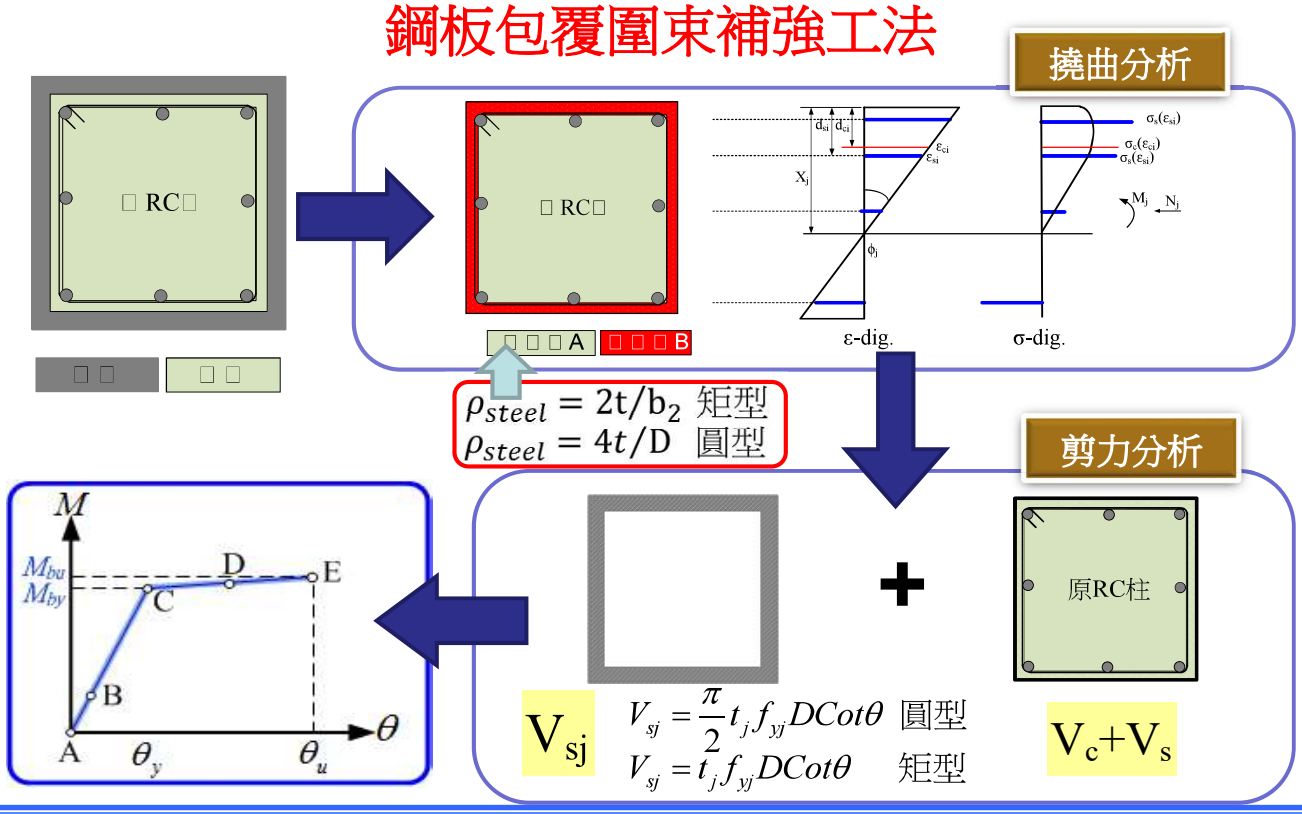
構件補強非線性行為分析方法

鋼板包覆圍束補強工法



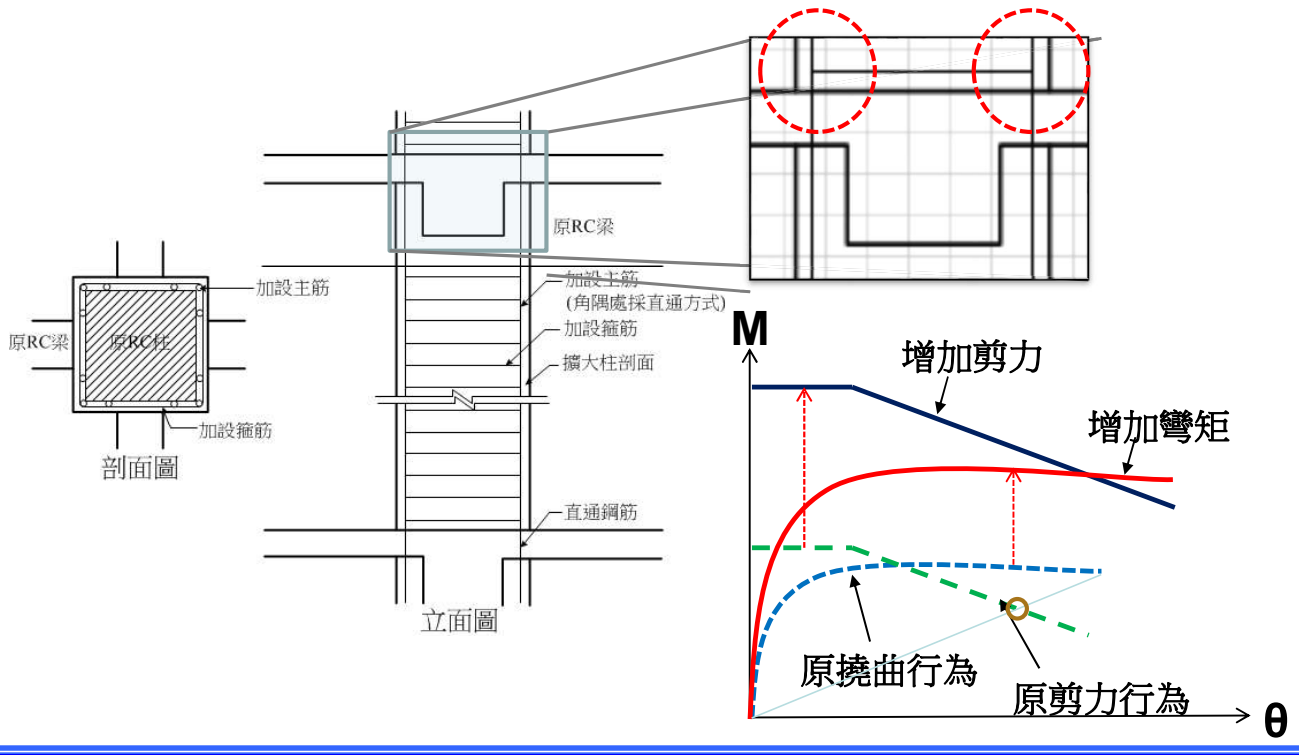
構件補強非線性行為分析方法

鋼板包覆圍束補強工法



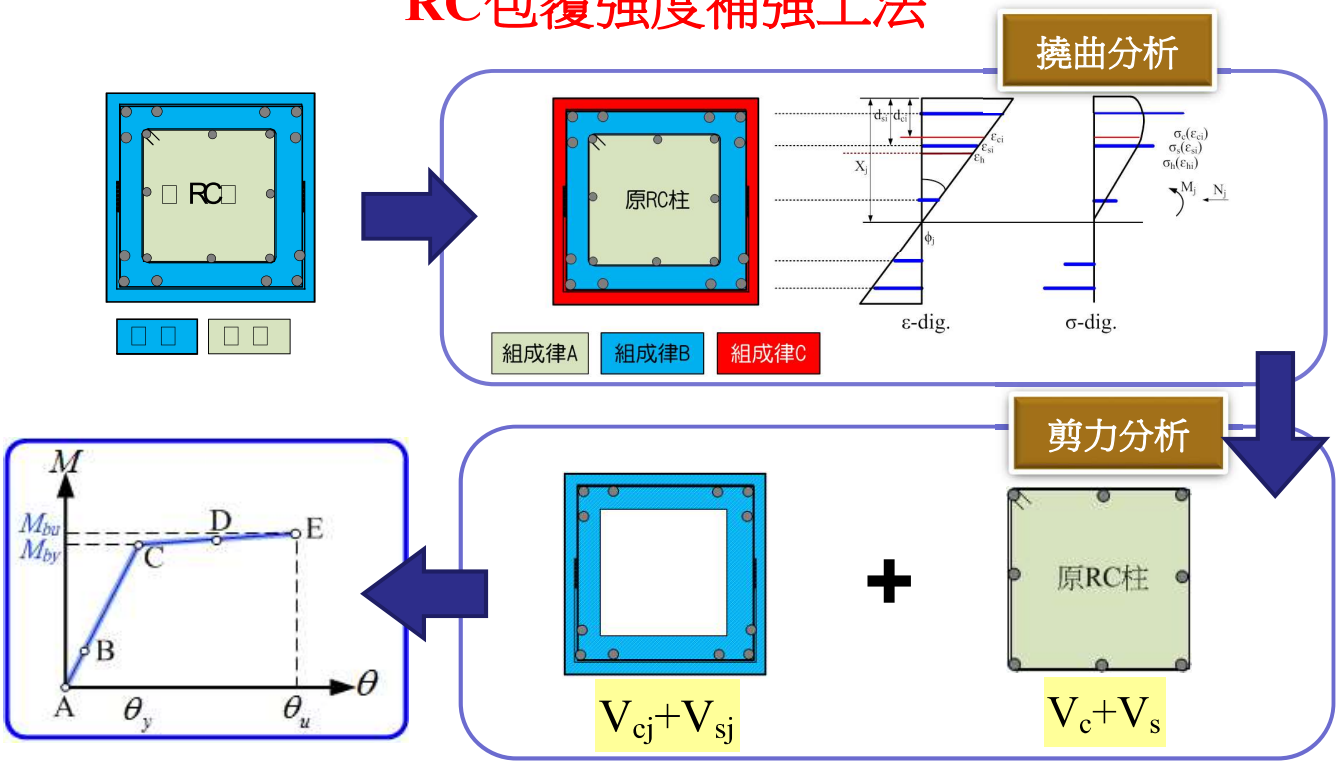
構件補強非線性行為分析方法

RC包覆強度補強工法



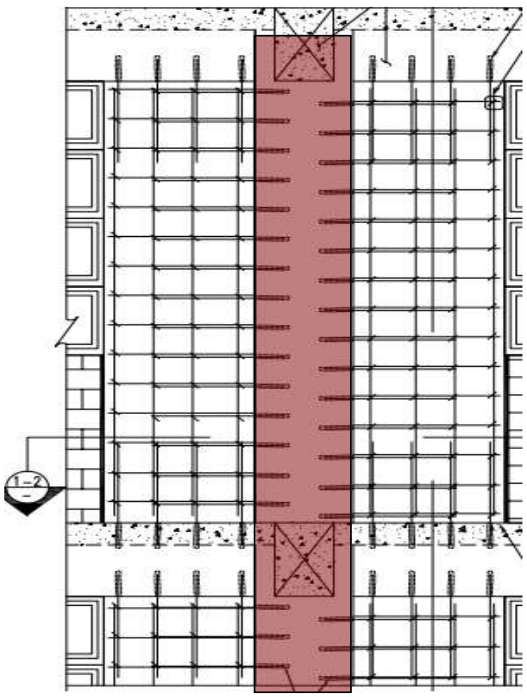
構件補強非線性行為分析方法

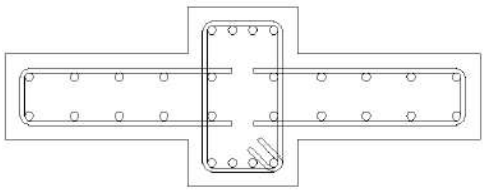
RC包覆強度補強工法

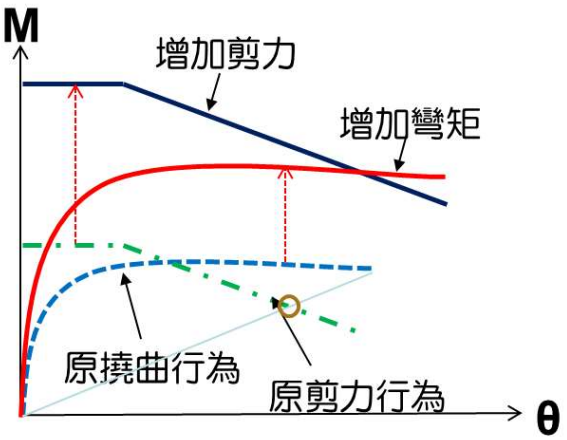


構件補強非線性行為分析方法

翼牆補強工法

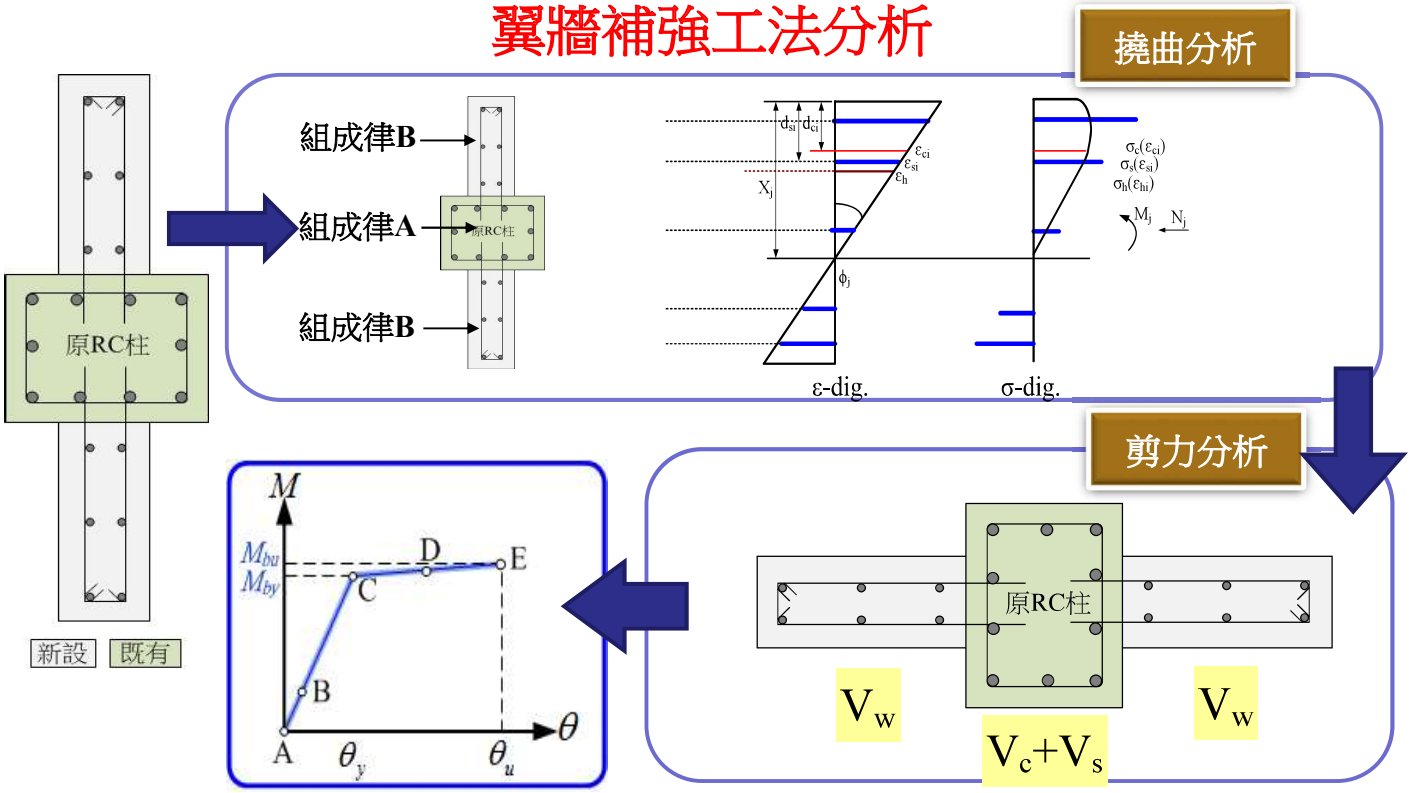






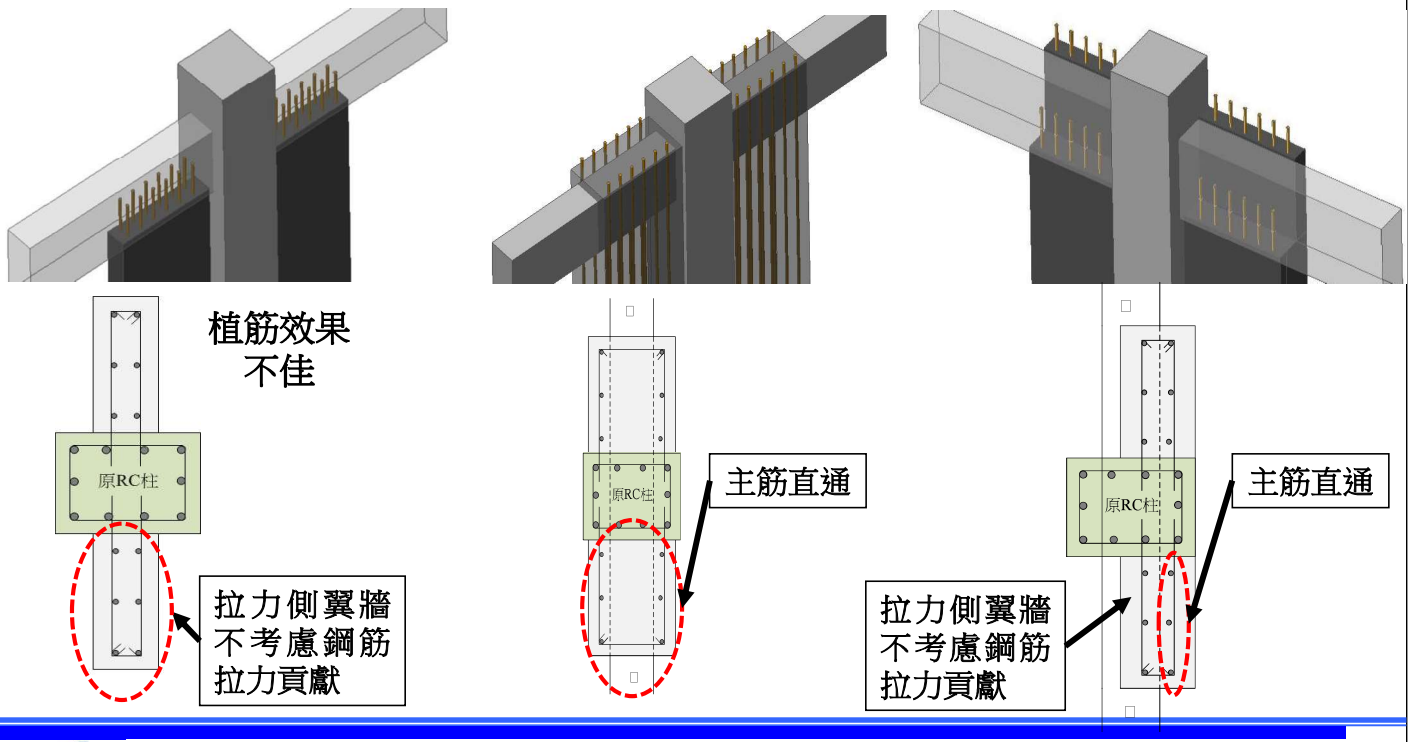
構件補強非線性行為分析方法

翼牆補強工法分析



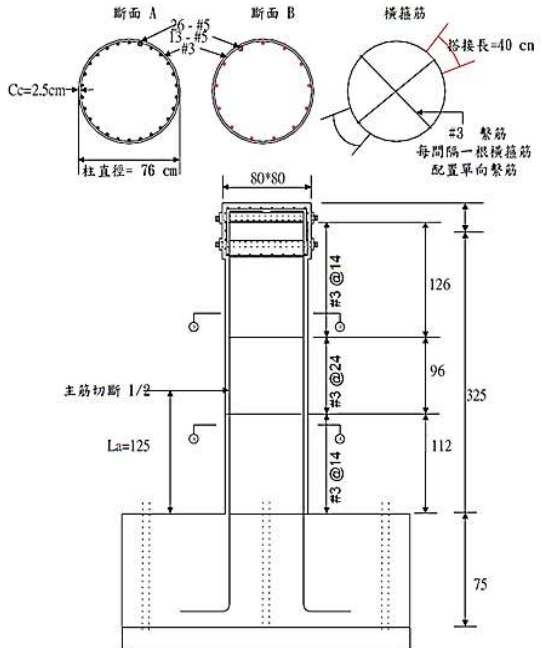
構件補強非線性行為分析方法

翼牆補強工法分析種類



構件補強非線性行為分析驗證

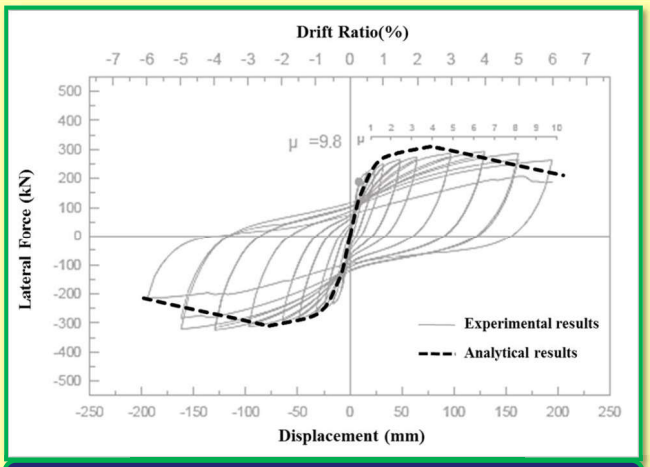
鋼板包覆圍束補強



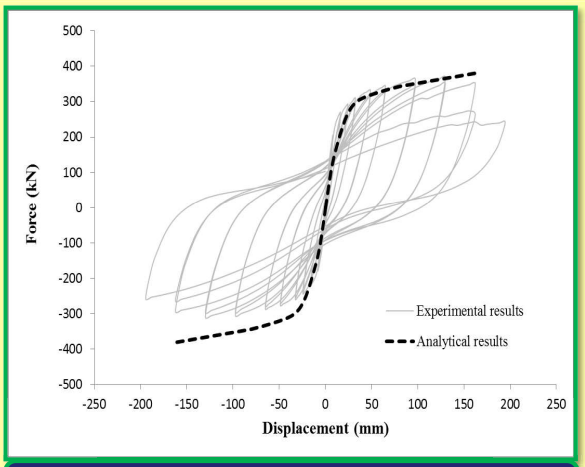
試體SC2(SC1) 配筋示意圖(黃震興，1999)

試體編號		SC2	SC3
斷面形狀		圓形	圓形
混凝土抗壓強度	kgf/cm^2	260	260
混凝土保護層	cm	2.5	2.5
斷面尺寸(深×寬)	cm	76 × 76	76 × 76
柱高	cm	325	325
主筋降伏強度	kgf/cm^2	3500	3500
主筋配置	–	26–#5	30–#5
箍筋降伏強度	kgf/cm^2	5000	5000
塑鉸區箍筋間距	cm	#3@13	#3@13
補強鋼板厚度	cm	0.3	0.3
柱軸力	tonf	143	143

構件補強非線性行為分析驗證



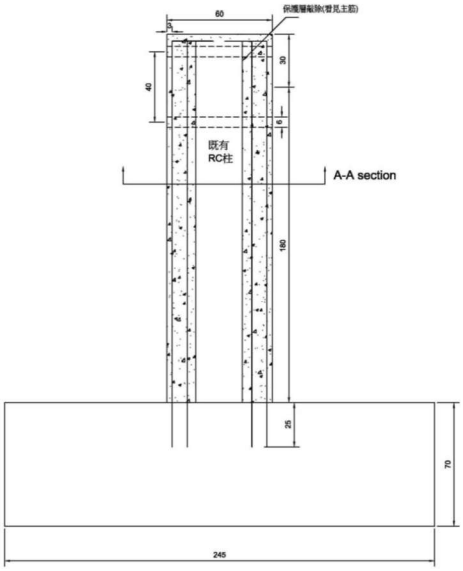
試體編號：SC2



試體編號：SC3

構件補強非線性行為分析驗證

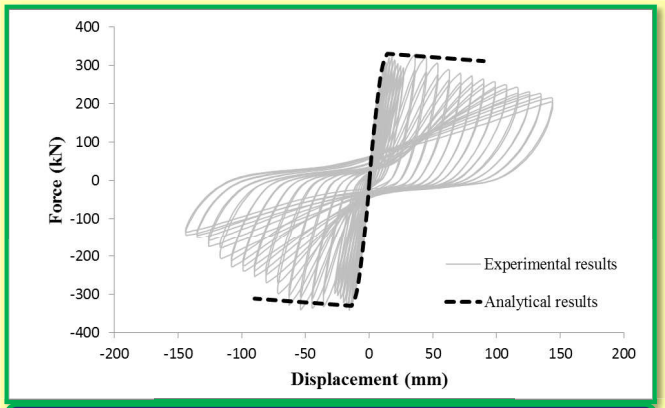
RC包覆強度補強



擴柱補強柱S2之立面圖(張順益，2010)

試體編號		S2
斷面形狀		矩形
混凝土抗壓強度	kgf/cm^2	175
混凝土保護層	cm	4
斷面尺寸(深×寬)	cm	40 × 30
柱高	cm	180
主筋降伏強度	kgf/cm^2	3547
主筋配置	–	14–#5
箍筋降伏強度	kgf/cm^2	4257
塑鉸區箍筋間距	cm	#3@25

構件補強非線性行為分析驗證

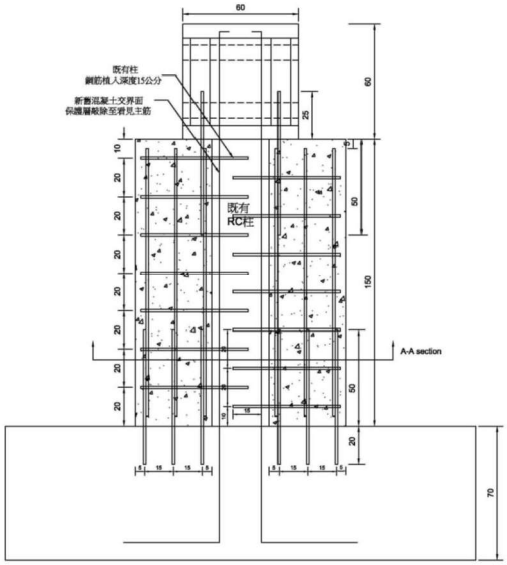


試體編號：S2

試體編號(補強資料)		S2
斷面形狀		矩形
補強混凝土厚度	cm	15
補強斷面(深×寬)	cm	70 × 60
補強區保護層	cm	3
補強混凝土強度	kgf/cm^2	245
補強主筋配置	–	12-#6
補強箍筋配置	cm	#3@10
補強主筋降伏強度	kgf/cm^2	4995
補強箍筋降伏強度	kgf/cm^2	4257
RC包覆與基礎間隙	cm	–
柱軸力	Tonf	28

構件補強非線性行為分析驗證

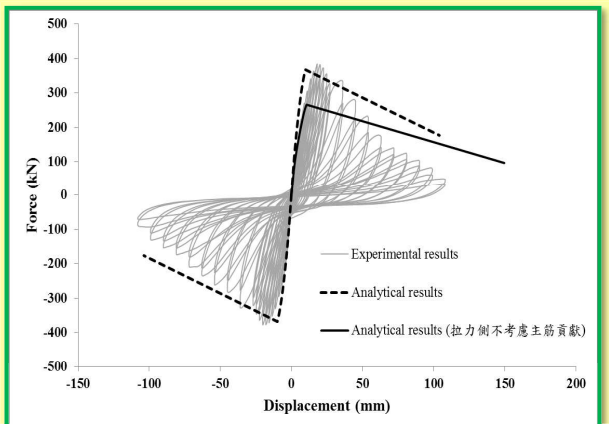
翼牆補強



翼牆補強柱S5之立面圖(張順益，2010)

試體編號		S5
斷面形狀		矩形
混凝土抗壓強度	kgf/cm^2	175
混凝土保護層	cm	4
斷面尺寸(深×寬)	cm	40 × 30
柱高	cm	150
主筋降伏強度	kgf/cm^2	3547
主筋配置	–	14–#5
箍筋降伏強度	kgf/cm^2	4257
塑鉸區箍筋間距	cm	#3@25

構件補強非線性行為分析驗證

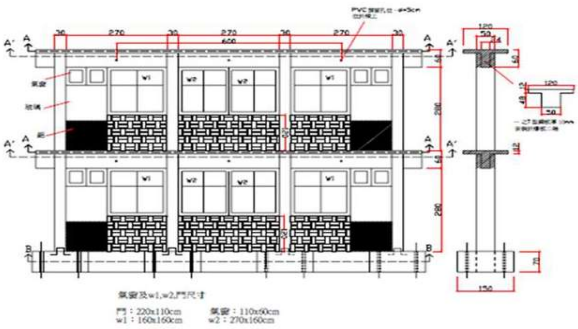


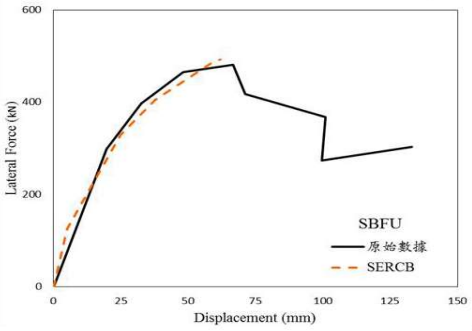
試體編號：S5

試體編號(補強資料)		S5
斷面形狀		矩形
翼牆斷面(深×寬)	cm	18× 40
補強區保護層	cm	2.7
補強混凝土強度	kgf/cm^2	245
補強主筋配置	–	6-#4
補強箍筋配置	cm	#4@20
補強主筋降伏強度	kgf/cm^2	4159
補強箍筋降伏強度	kgf/cm^2	4159
基礎間隙	cm	–
柱軸力	Tonf	28

含磚牆構架試體分析驗證

鋼筋混凝土構架-柱鋼板包覆韌性補強(SBFS)

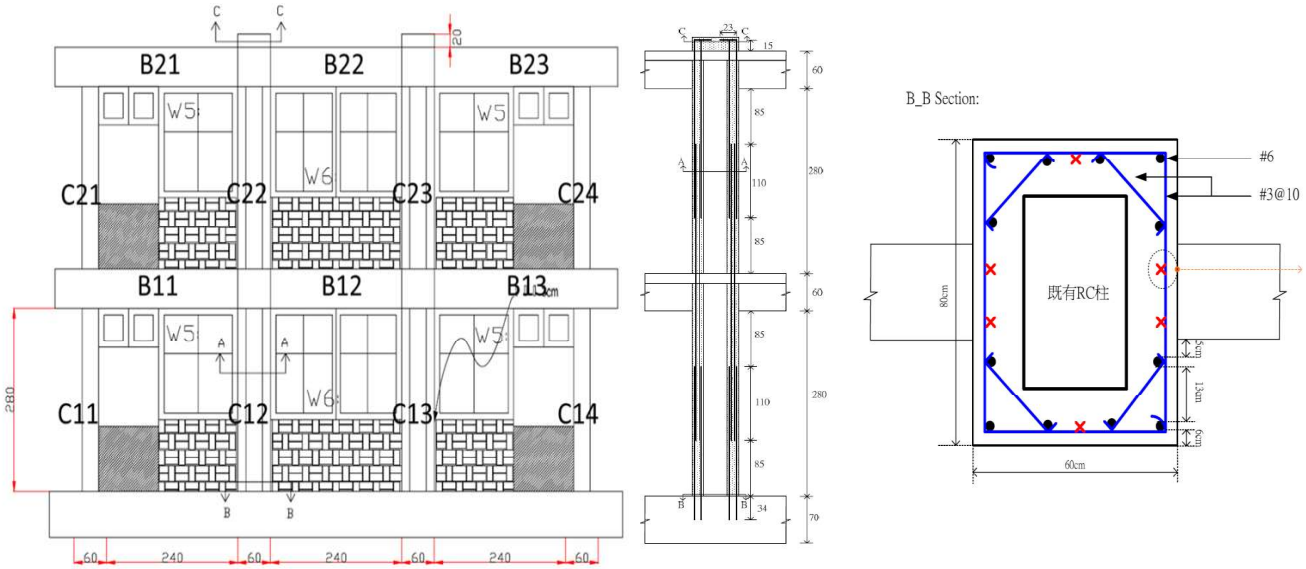




(典型校舍耐震補強設計與驗證，邱聰智、邱建國、葉勇凱、簡文郁、鐘立來、周德光，2008)

構件補強非線性行為分析驗證

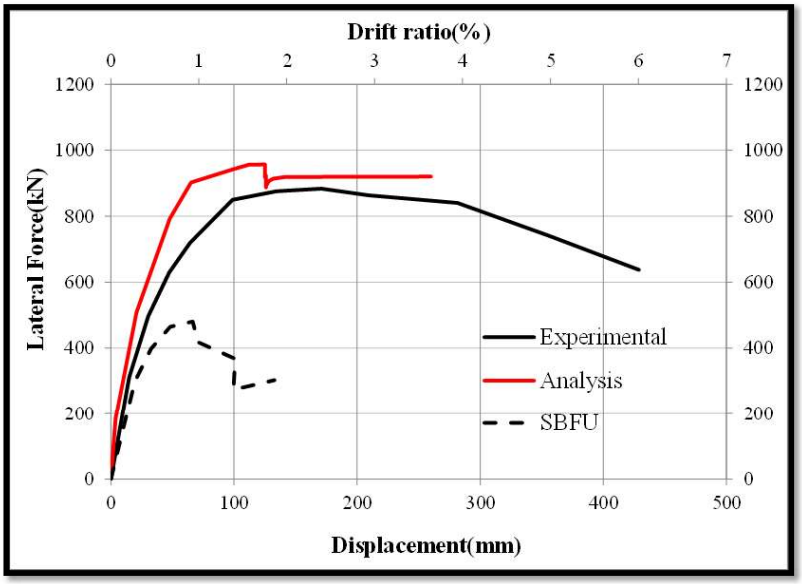
鋼筋混凝土構架- RC包覆強度補強(SBFU-C)



國家地震中心SBFU-C試體

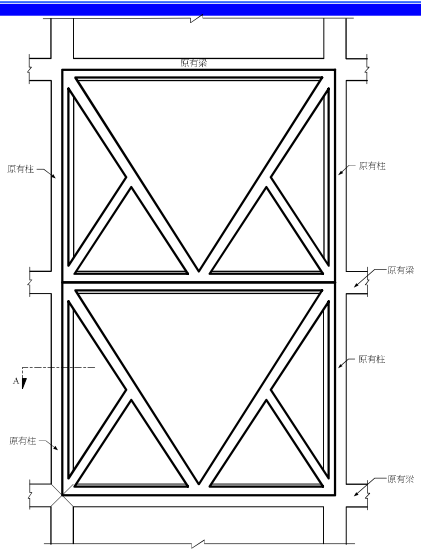
構件補強非線性行為分析驗證

鋼筋混凝土構架- RC包覆強度補強(SBFU-C)

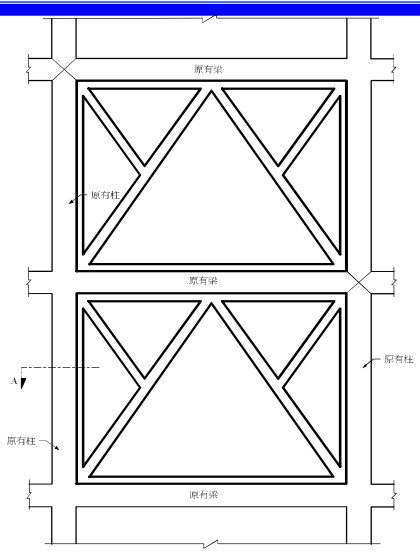


鋼斜撐框架補強理論探討與分析驗證

鋼斜撐框架補強理論探討與分析驗證



外部鋼框架補強示意圖



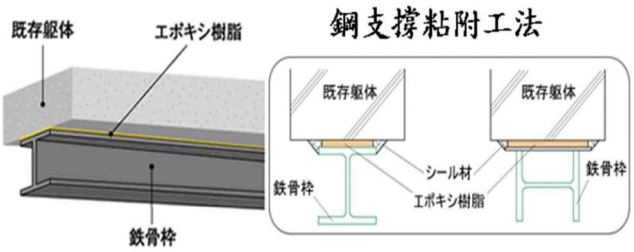
增設鋼框架補強示意圖

外附式鋼斜撐框架補強

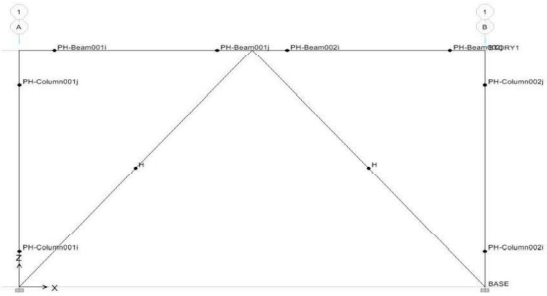
內嵌式鋼斜撐框架補強

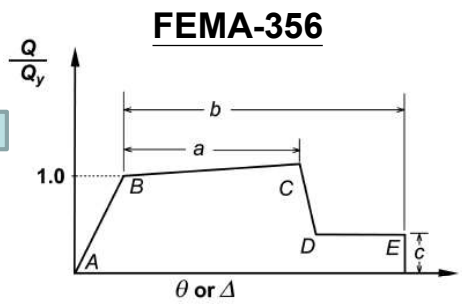
鋼斜撐框架補強理論探討與分析驗證

內嵌式-環氧樹脂接合



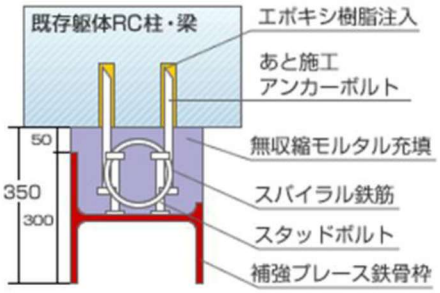
忽略鋼框架
僅考慮鋼斜撐





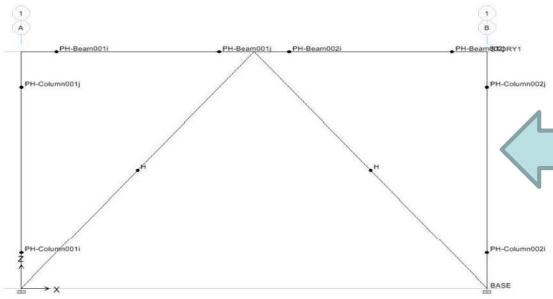
鋼斜撐框架補強理論探討與分析驗證

內嵌式-錨碇接合

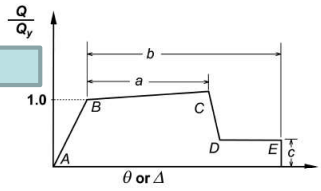


梁、柱以合成斷面進行切面法分析

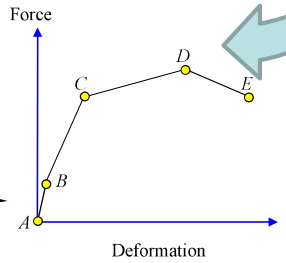
鋼斜撐-FEMA-356



FEMA-356

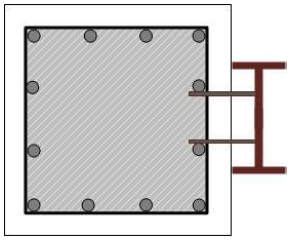


SERCB-合成斷面

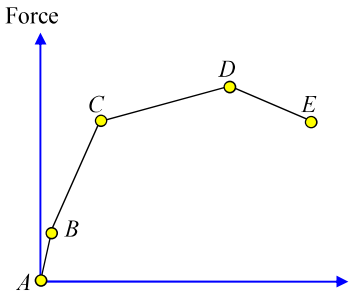


鋼斜撐框架補強理論探討與分析驗證

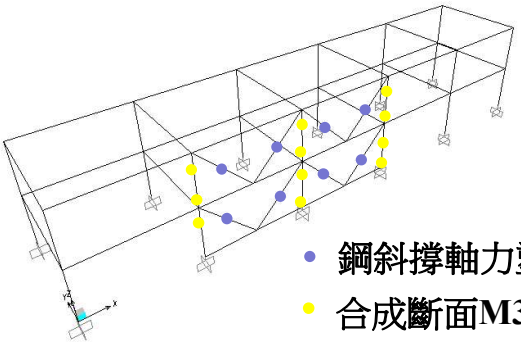
外附式鋼斜撐框架



切片法

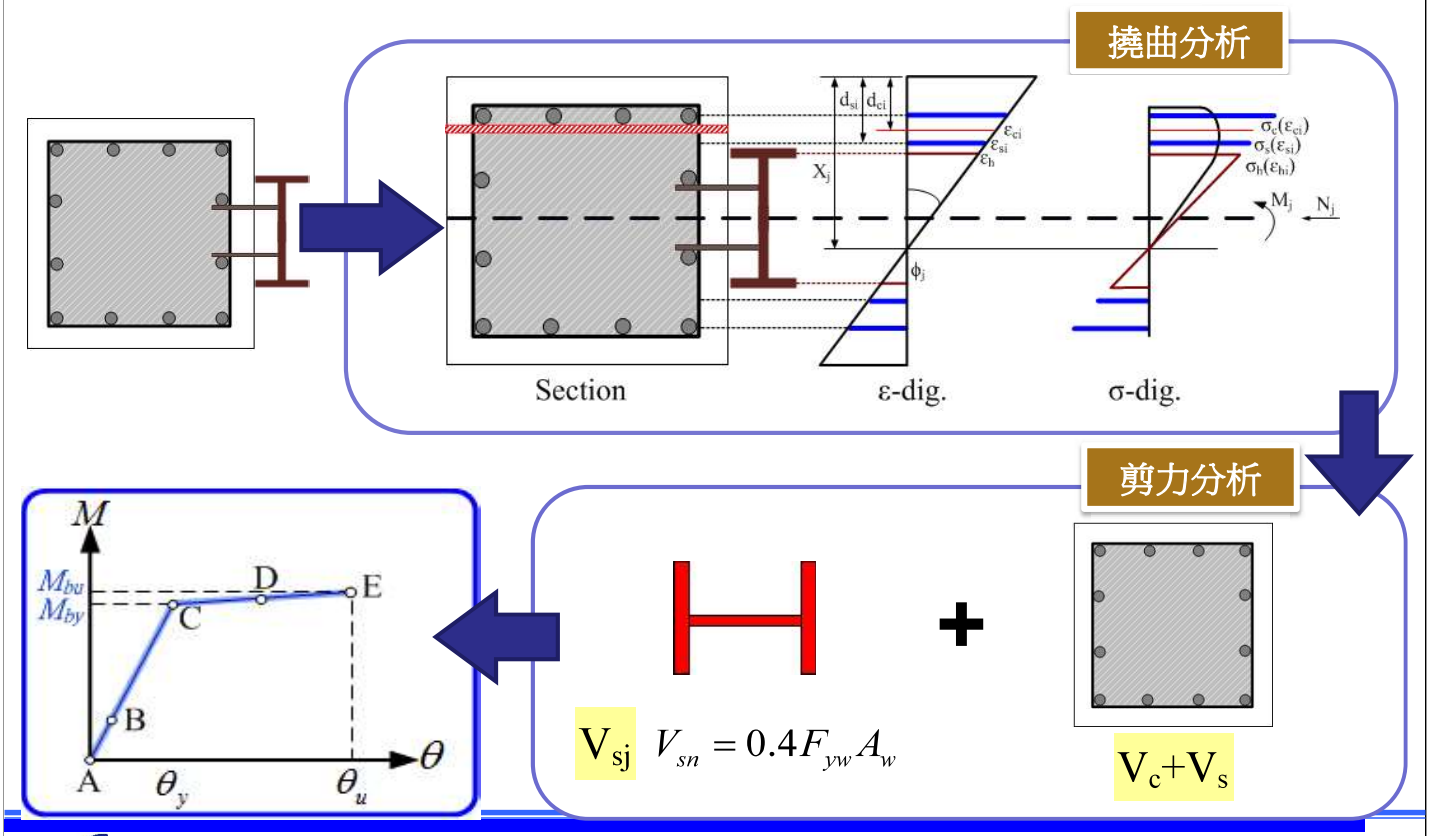


塑性鉸



- 鋼斜撐軸力塑性鉸
- 合成斷面M3塑性鉸

合成斷面非線性行為分析



鋼斜撐軸力塑性鉸求取

拉力構件

$$Q_{CE} = T_n = A_g F_y$$

A_g斜撐斷面積

壓力構件

$$Q_{CE} = P_n = A_g F_{cr}$$

$\lambda_c \le 1.5$

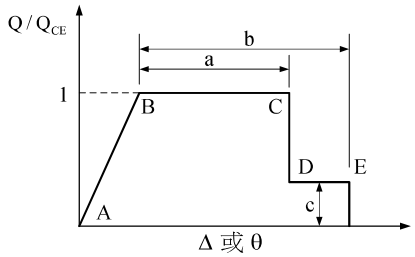
$F_{cr} = 0.658\lambda_c^2 F_y$

$\lambda_c > 1.5$

$F_{cr} = 0.877F_y / \lambda_c^2$

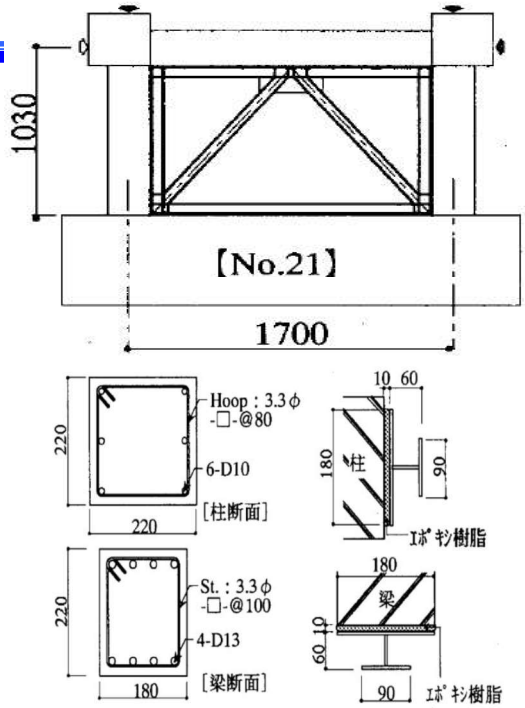
桿件	模型參數			可接受標準				
	塑性變形		殘餘強度比	塑性變形				
				IO	主要桿件		次要桿件	
	a	b	c		LS	CP	LS	CP
受壓斜撐(EBF斜撐除外)								
a. 雙角鋼面內挫屈	$0.5\Delta_c$	$9\Delta_c$	0.2	$0.25\Delta_c$	$5\Delta_c$	$7\Delta_c$	$7\Delta_c$	$8\Delta_c$
b. 雙角鋼面外挫屈	$0.5\Delta_c$	$8\Delta_c$	0.2	$0.25\Delta_c$	$4\Delta_c$	$6\Delta_c$	$6\Delta_c$	$7\Delta_c$
c. W或I型	$0.5\Delta_c$	$8\Delta_c$	0.2	$0.25\Delta_c$	$5\Delta_c$	$7\Delta_c$	$7\Delta_c$	$8\Delta_c$
d. 雙槽型鋼面內挫屈	$0.5\Delta_c$	$9\Delta_c$	0.2	$0.25\Delta_c$	$5\Delta_c$	$7\Delta_c$	$7\Delta_c$	$8\Delta_c$
e. 雙槽型鋼面外挫屈	$0.5\Delta_c$	$8\Delta_c$	0.2	$0.25\Delta_c$	$4\Delta_c$	$6\Delta_c$	$6\Delta_c$	$7\Delta_c$
f. 鋼管混凝土	$0.5\Delta_c$	$7\Delta_c$	0.2	$0.25\Delta_c$	$4\Delta_c$	$6\Delta_c$	$6\Delta_c$	$7\Delta_c$
受接斜撐(EBF斜撐除外)	$11\Delta_T$	$14\Delta_T$	0.8	$0.25\Delta_T$	$7\Delta_T$	$9\Delta_T$	$11\Delta_T$	$13\Delta_T$

Δc為挫屈軸向變形，ΔT為拉力降伏軸向變形

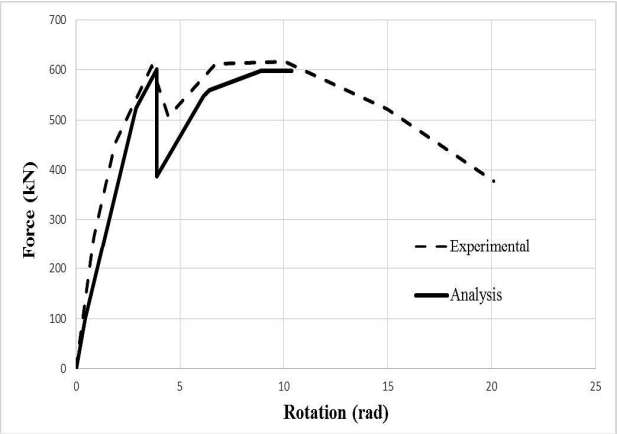


FEMA-356軸力位移關係圖

內嵌式鋼斜撐框架補強試體分析比對

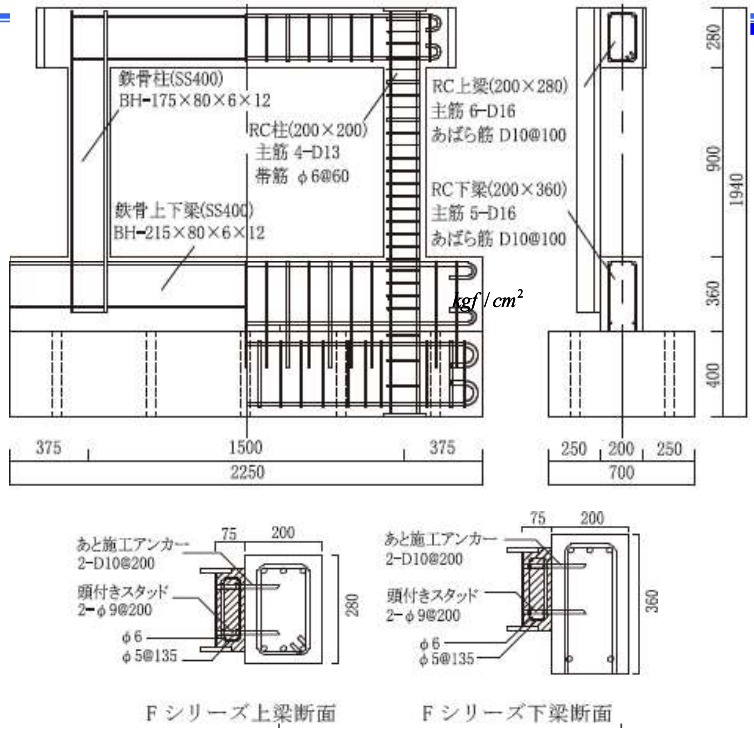


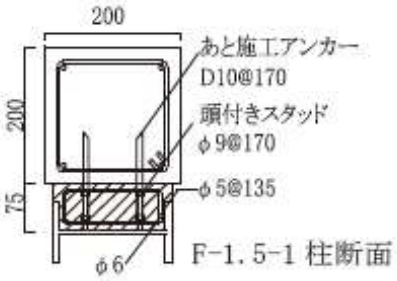
試體編號		No.21
混凝土抗壓強度	kgf/cm^2	330
型鋼降伏應力	kgf/cm^2	3180
D10 主筋降伏應力	kgf/cm^2	3720
D13 主筋降伏應力	kgf/cm^2	3710
箍筋降伏應力	kgf/cm^2	4821



大塚真祐，毛井崇博(1999)

外附式鋼框架補強試體分析比對



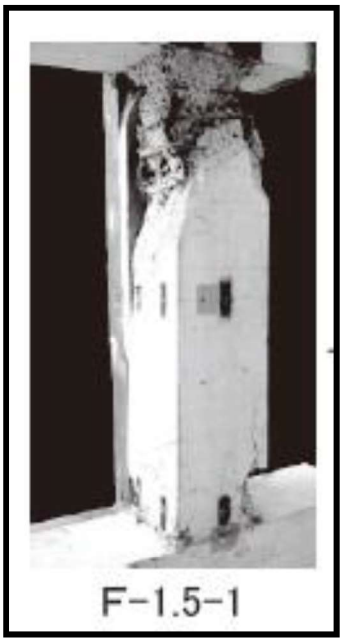


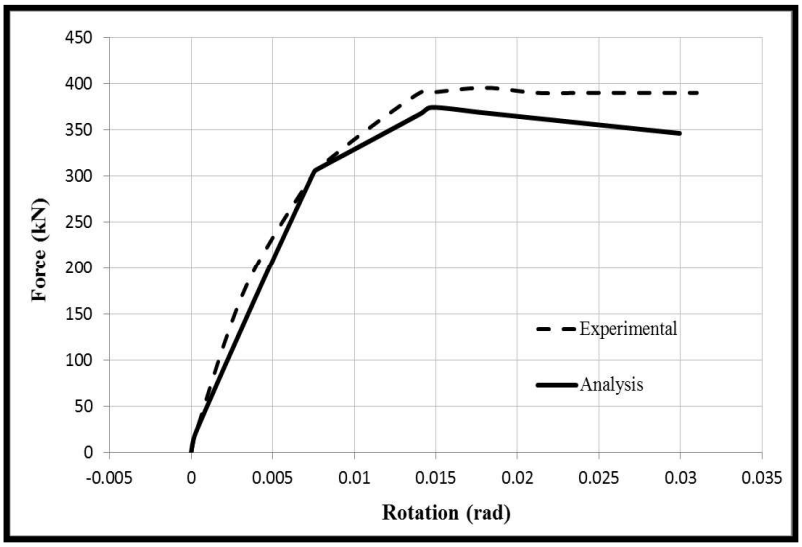
試體編號		F-1.5-1
混凝土抗壓強度	kgf/cm^2	277
型鋼降伏應力	kgf/cm^2	3506
D10 主筋降伏應力	kgf/cm^2	3792
D13 主筋降伏應力	kgf/cm^2	3578

(Rieko UEKI, Katsuhiko IMAI)

外附式鋼框架補強試體分析比對

外加鋼框架試體F-1.5-1





結論

SERCB特色

- 內政部營建署97年3月審核通過。
- 修正ATC-40所提出之容量震譜法(或稱PushOver Method)觀念，提出改良式建築物耐震能力評估方法。
- 考量材料非線性組成率，由考量彎矩-剪力互制行為建立塑鉸，理論背景完整，並已與實驗比對驗證。
- 可提供ETABS(V8.4.8與V9.0以上之版本)與MIDAS GEN(V761與V820)執行PUSHOVER分析。(持續銜接最新版)
- 考量地震力作用下，軸力變化對構件性能之影響。
- 應用上無樓層數限制。
- 操作全視窗化，易操作，易檢核分析後結果。
- 開闢專屬網頁供使用者免費下載軟體，並設立Q & A專欄作為各界意見溝通之平台。定期(每年元旦)與不定期通知使用者最新資訊。專屬網站：http://sercb.dyndns.org/SERCBWeb/Default.aspx

Thank You !

TAIPEI TECH