# 開孔ＲＣ牆在低矮型建築耐震補強之應用

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計畫主持人：黃世建　主任

July 16, 2018

# 大綱

- 研究動機
- 測試規劃
- 實驗觀察
- 討論
  - ACI 318-14分析方法
  - 軟化壓拉桿(SST)分析之建議方法
- 結論

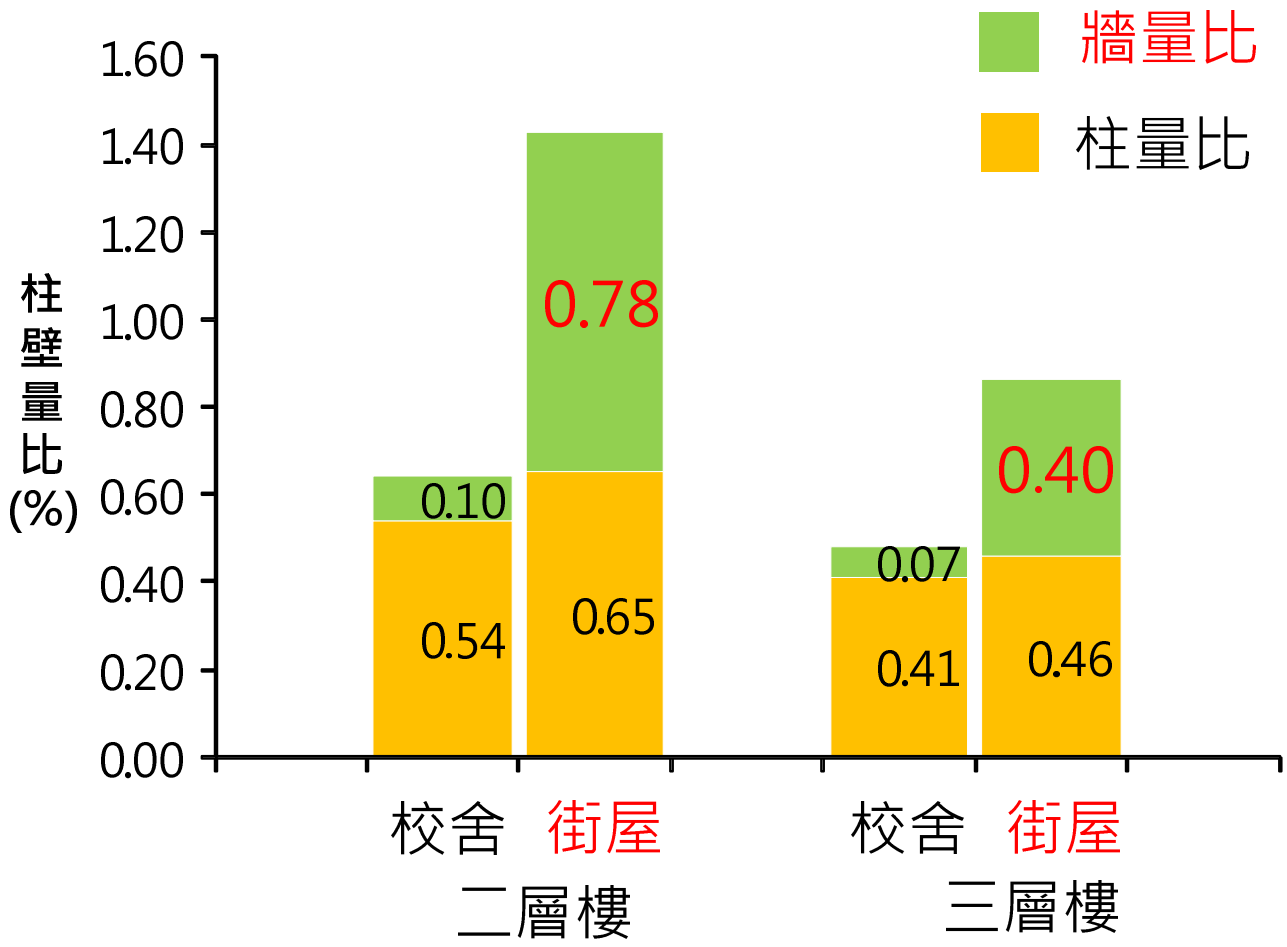
# 研究動機

**梯間牆**

**屋後牆**

Reference: 杜昱石 (2014) 「低矮鋼筋混凝土街屋具典型開口外牆之耐震行為研究」

- 皆為開孔RC牆
- 不可忽略開孔RC牆之耐震能力貢獻




Reference:邱聰智(2015) 「低矮型鋼筋混凝土住宅結構耐震快速評估法之開發與驗證」

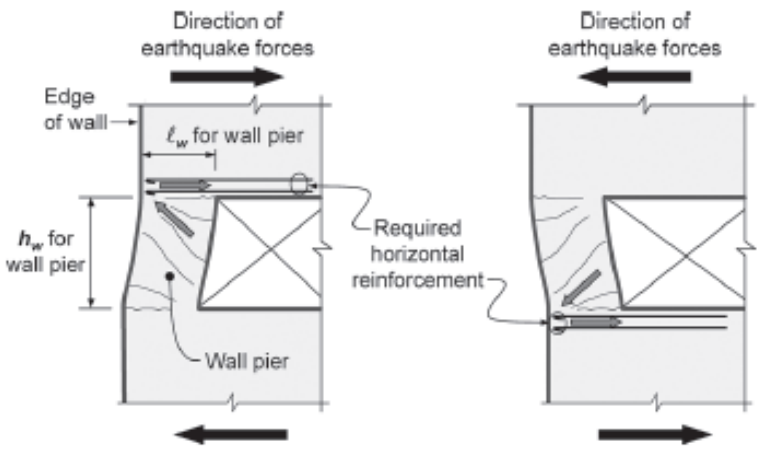
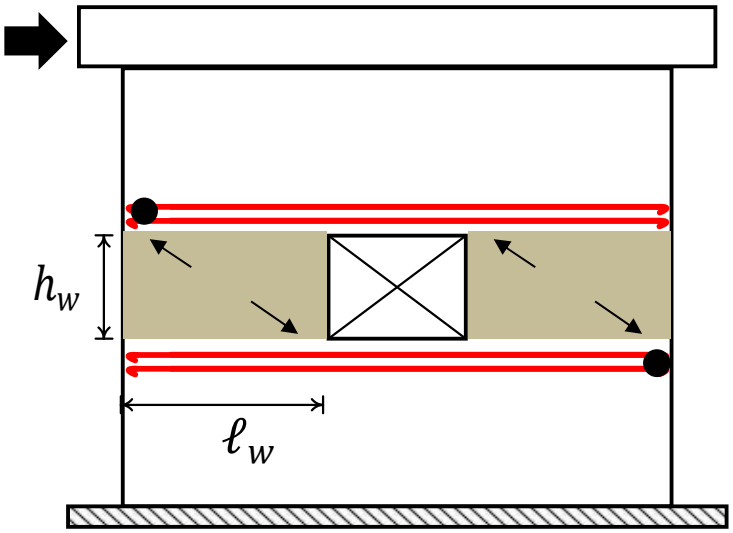
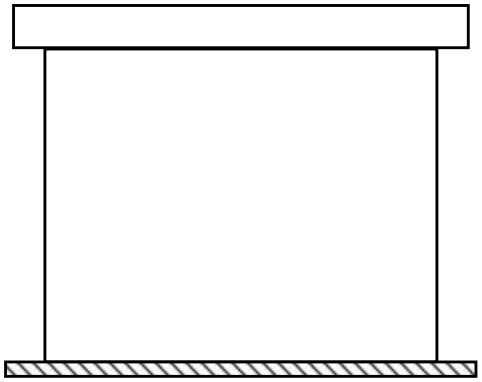



*Fig R18.10.8—Required horizontal reinforcement in wall segments above and below wall piers at the edge of a wall.*

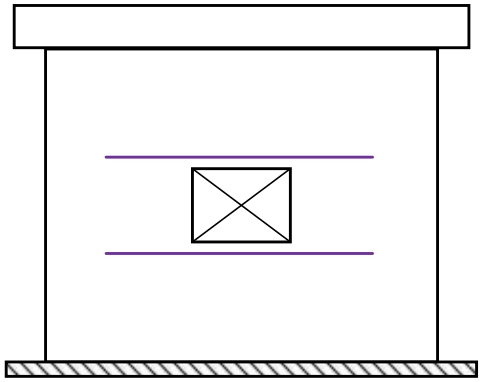



- ACI 318-14：開口附近之牆墩需配置額外水平鋼筋
  以幾何不連續選取垂直牆段高度$h_w$
- 確認水平補強鋼筋之功效
- 提出明確的評估方式

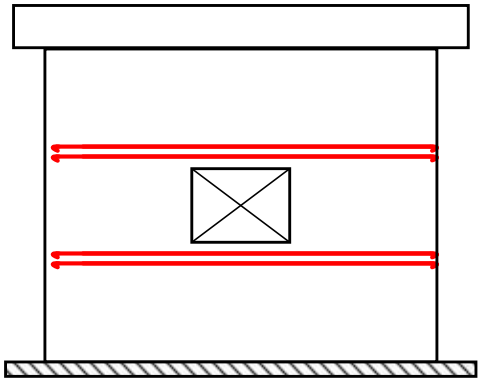
SW



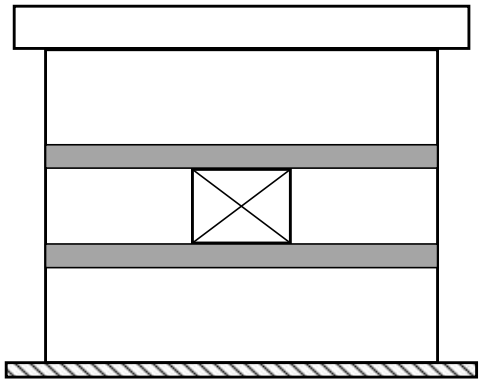
SWO



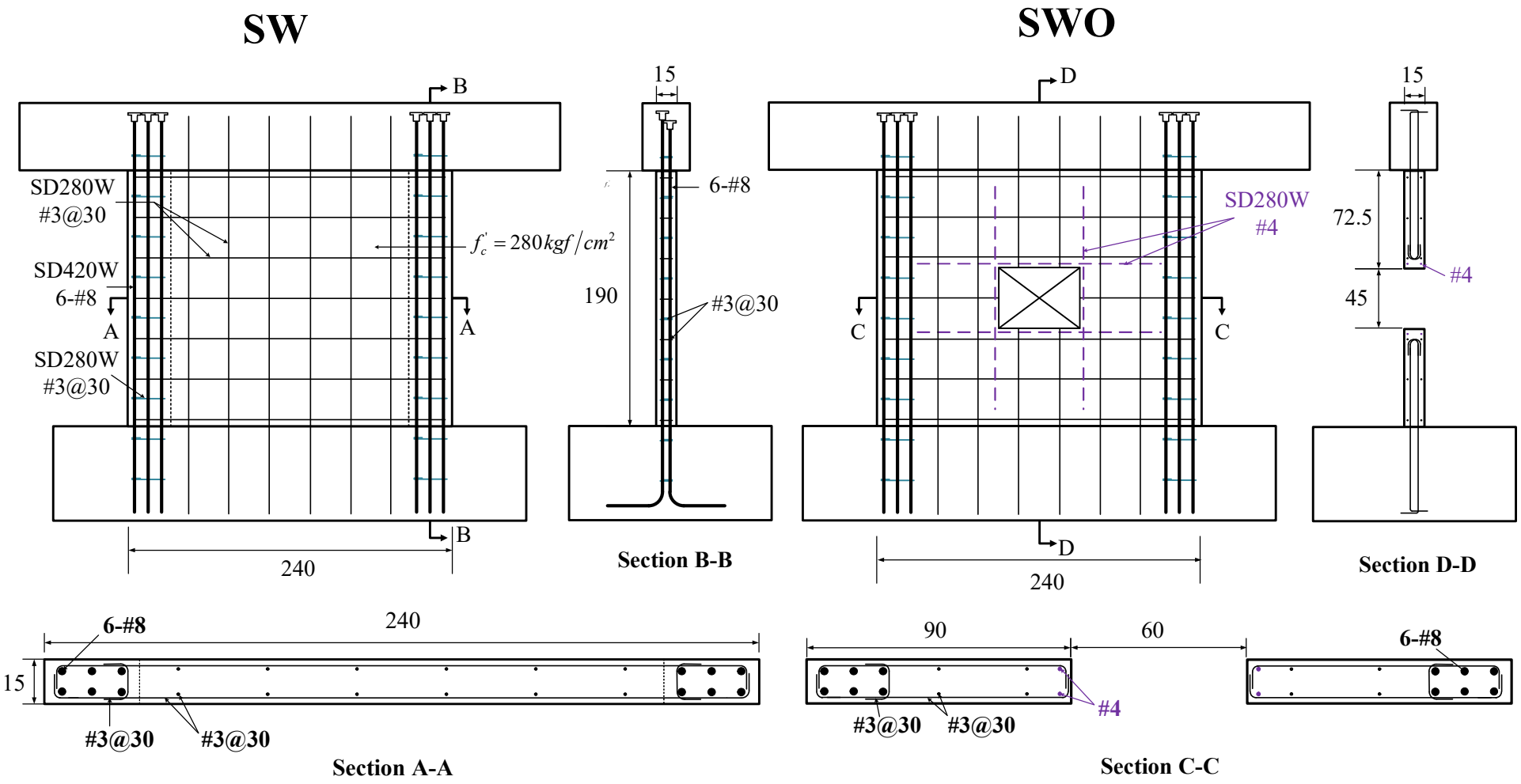
SWOS



SWOF

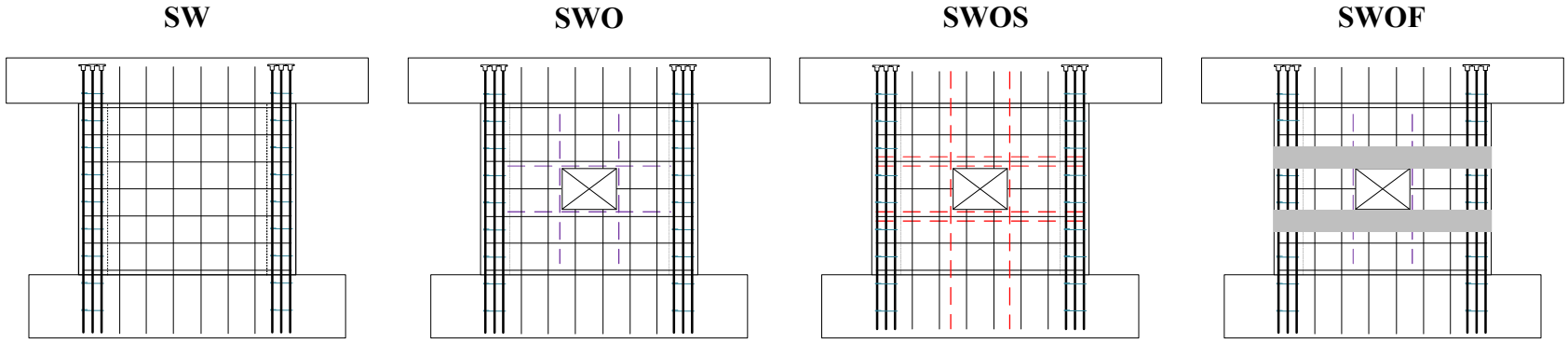


## ✱ 試體設計


SW
SWO
SD280W
#3@30
SD420W
6-#8
SD280W
#3@30
$f_c' = 280 kgf/cm^2$
A
A
B
B
240
15
6-#8
190
#3@30
Section B-B
D
D
C
C
SD280W
#4
240
15
72.5
45
#4
Section D-D
6-#8
240
15
#3@30
#3@30
Section A-A
90
60
6-#8
#4
#3@30
#3@30
Section C-C

Unit：cm

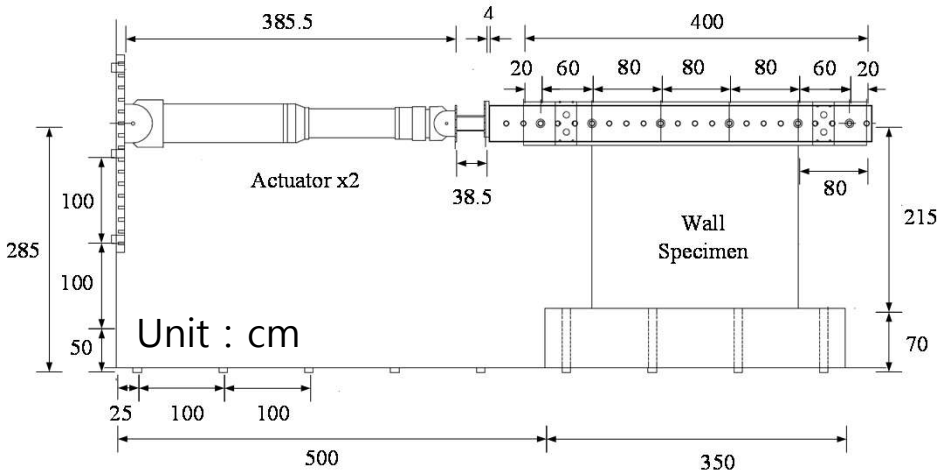
## ✱ 試體設計

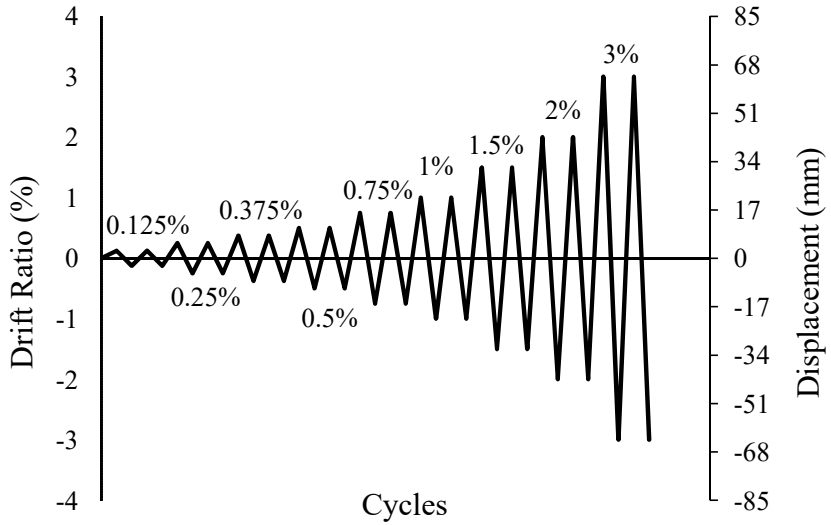



| 試體 | 混凝土 $f'_c$ | 邊界構材 | | 牆筋 | 開口補強 | |
|---|---|---|---|---|---|---|
| | | 主筋 | 箍筋 | | 補強方式 | 強度 |
| SW | 303 | 6-#8 $f_y$=4723 | #3@30 $f_y$=3551 | #3@30 ($\rho_h$=$\rho_v$=0.32%) $f_y$=3551 | None | None |
| SWO | 315 | | | | 開口四周配置2-#4，從開口延伸60cm | #4 $f_y$=3495 |
| SWOS | 325 | | | | 開口上下配置4-#5，並錨定至邊界 | #5 $f_y$=4706 |
| SWOF | 329 | | | | 開口上下全包覆25cm之CFRP貼片6層 | CFRP $f_{fe}$=11156 |

Unit：$kgf$、cm

## ✱ 試驗規劃



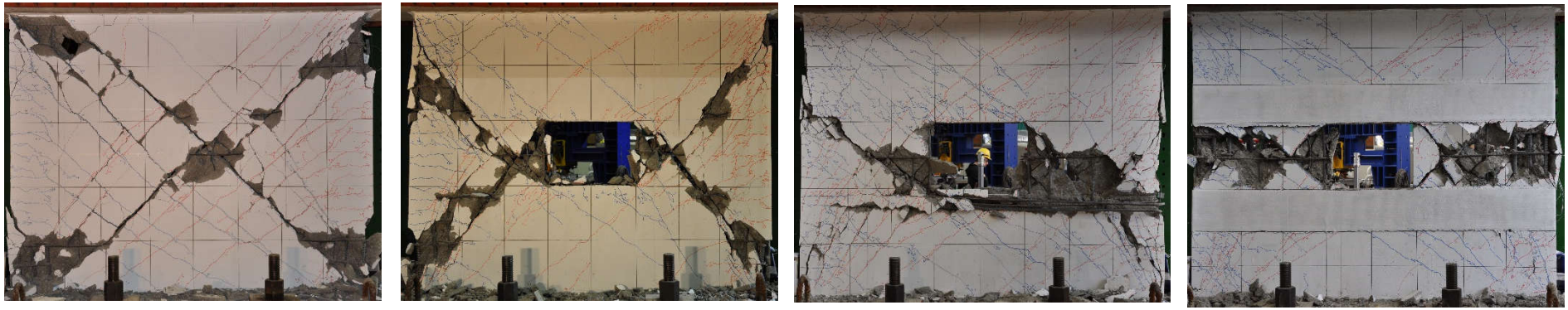

**[符合ACI 374.2R-13之建議]**

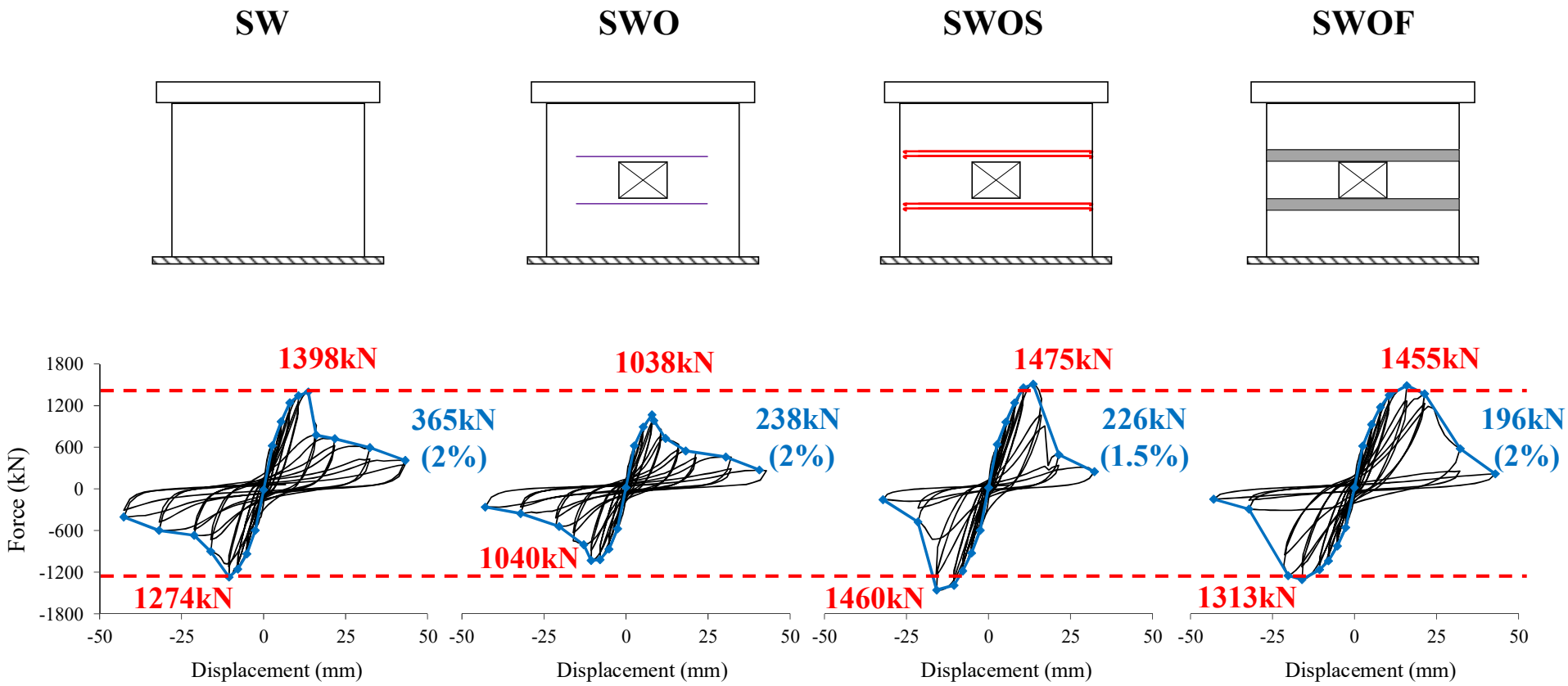
# 實驗觀察

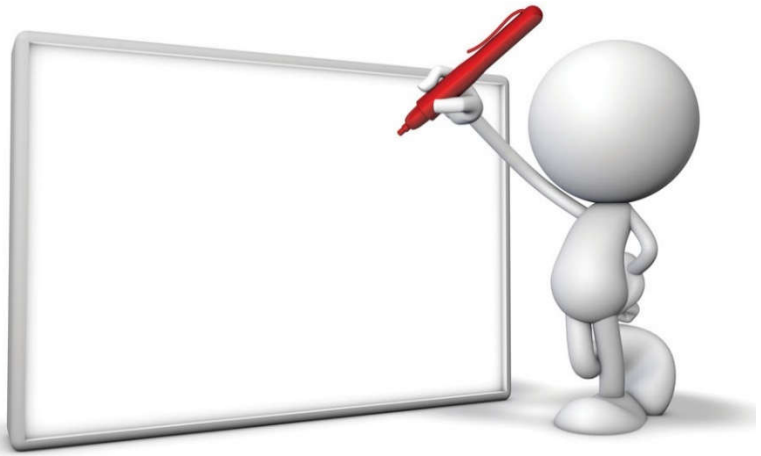
# 試驗觀察之
# 垂直牆段尺度

**SW** **SWO** **SWOS** **SWOF**

$\frac{h_w}{\ell_w}$ =0.79 $\frac{h_w}{\ell_w}$ =1.31 $\frac{h_w}{\ell_w}$ =0.58 $\frac{h_w}{\ell_w}$ =0.64




SW
SWO
SWOS
SWOF
1398kN
365kN
(2%)
1274kN
1038kN
238kN
(2%)
1040kN
1475kN
226kN
(1.5%)
1460kN
1455kN
196kN
(2%)
1313kN
Force (kN)
1800
1200
600
0
-600
-1200
-1800
-50
-25
0
25
50
Displacement (mm)



# 討論

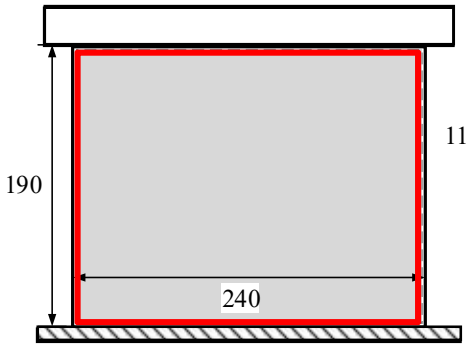
- ACI 318-14分析方法
- 軟化壓拉桿(SST)分析之建議模型

**[ACI 318-14 規範]**

- 以幾何不連續決定剪力元素之尺寸

**18.10.4.2** 18.10.4.1 中用以計算牆段 $V_n$ 所用之 $h_w/\ell_w$，應取全牆及所考慮牆段比值之較大者。

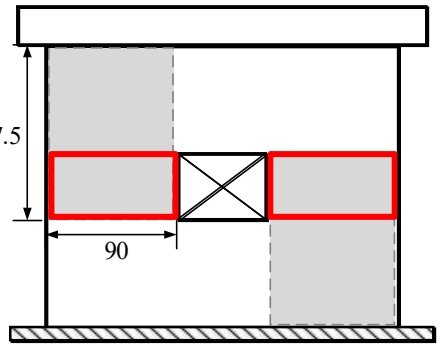
**SW**




$\frac{h_w}{\ell_w} = 0.79$

$\frac{h_w}{\ell_w} = 0.79$

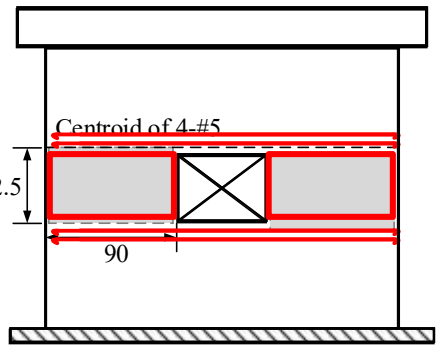
**SWO**




$\frac{h_w}{\ell_w} = 0.5 < 0.79$

$\frac{h_w}{\ell_w} = 1.31$

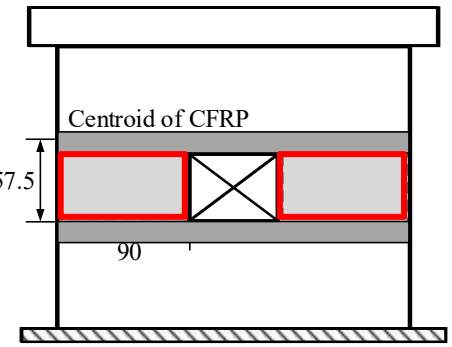
**SWOS**




$\frac{h_w}{\ell_w} = 0.5 < 0.79$

$\frac{h_w}{\ell_w} = 0.58$

**SWOF**



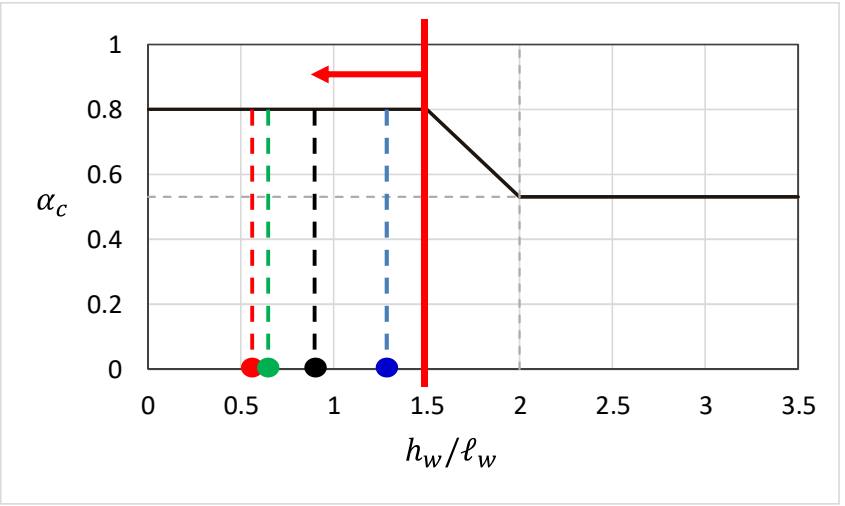

$\frac{h_w}{\ell_w} = 0.5 < 0.79$

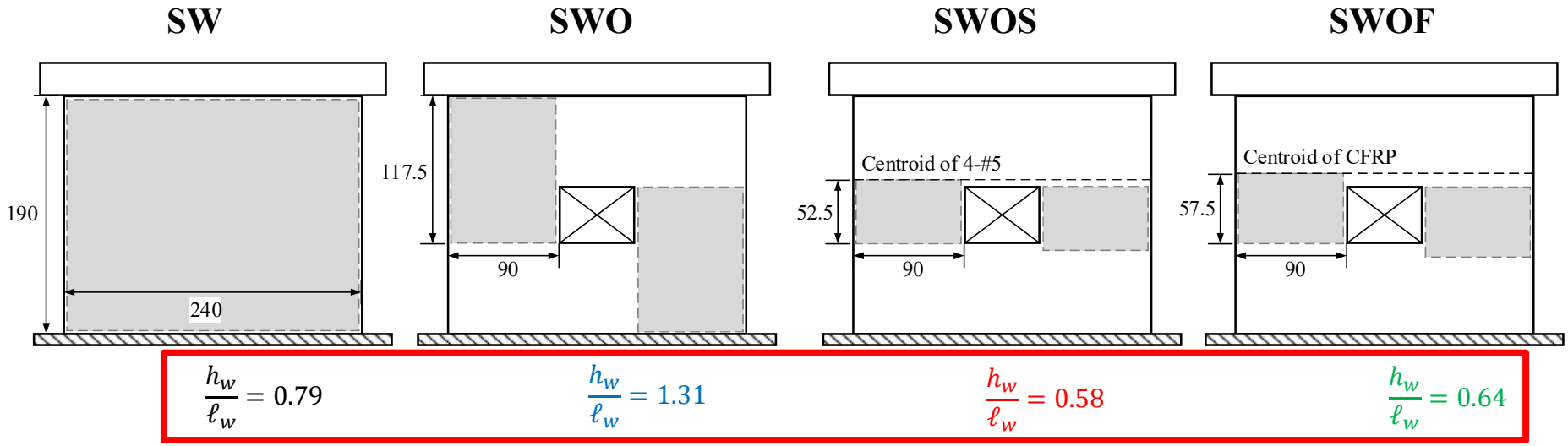
$\frac{h_w}{\ell_w} = 0.64$

Unit：cm

**[ACI 318-14 規範]**

- $V_n = A_{cv}(\alpha_c\sqrt{f_c'} + \rho_t f_y)$



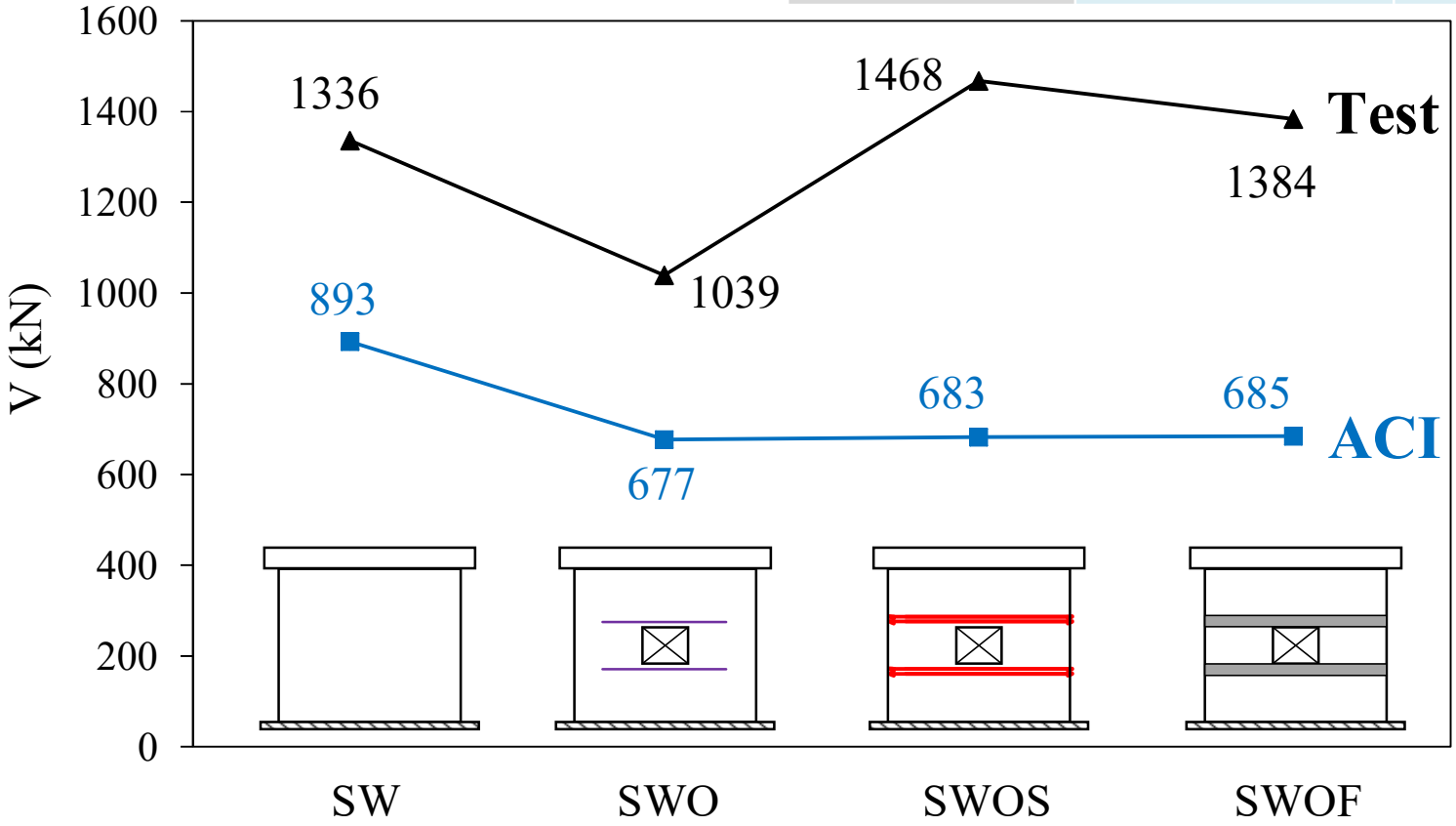




Unit：cm

**[ACI 318-14 規範]**

- $V_{n,ACI} = A_{cv}(\alpha_c\sqrt{f_c'} + \rho_t f_y)$

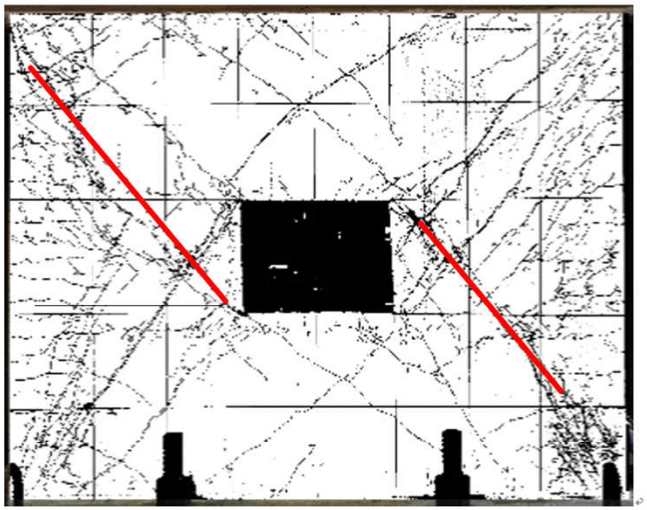
| 試體 | $V_{n,test}$ (kN) | ACI | | |
|---|---|---|---|---|
| | | $h_w/\ell_w$ | $V_{n,ACI}$(kN) | $V_{n,test}/V_{n,ACI}$ |
| SW | 1336 | 0.79 | 893 | 1.50 |
| SWO | 1039 | 0.79 | 677 | 1.53 |
| SWOS | 1468 | 0.79 | 683 | 2.15 |
| SWOF | 1384 | 0.79 | 685 | 2.02 |
| | | | AVG | 1.80 |
| | | | COV | 0.16 |

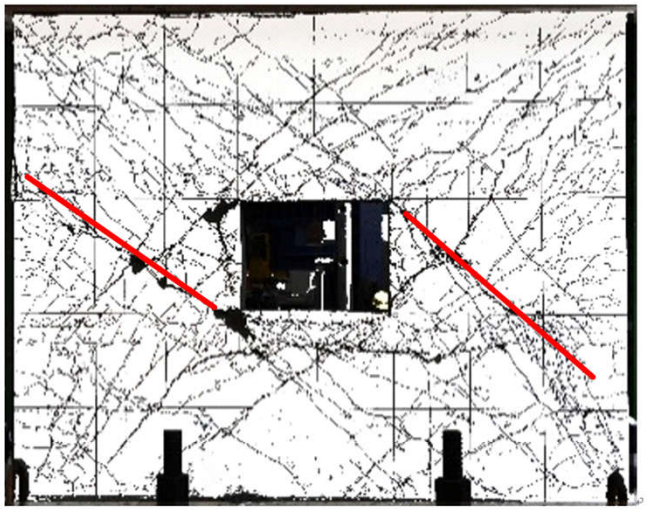


# 討論

- ACI 318-14分析方法
- 軟化壓拉桿(SST)分析之建議模型

- 實驗驗證與傳力機制之明確定義





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ACI STRUCTURAL JOURNAL TECHNICAL PAPER

MS No. S-2017-391

## Shear Strength of Reinforced Concrete Vertical Wall Segments under Seismic Loading

by Rou-Ling Yeh, Chien-Chuang Tseng, and Shyh-Jiann Hwang

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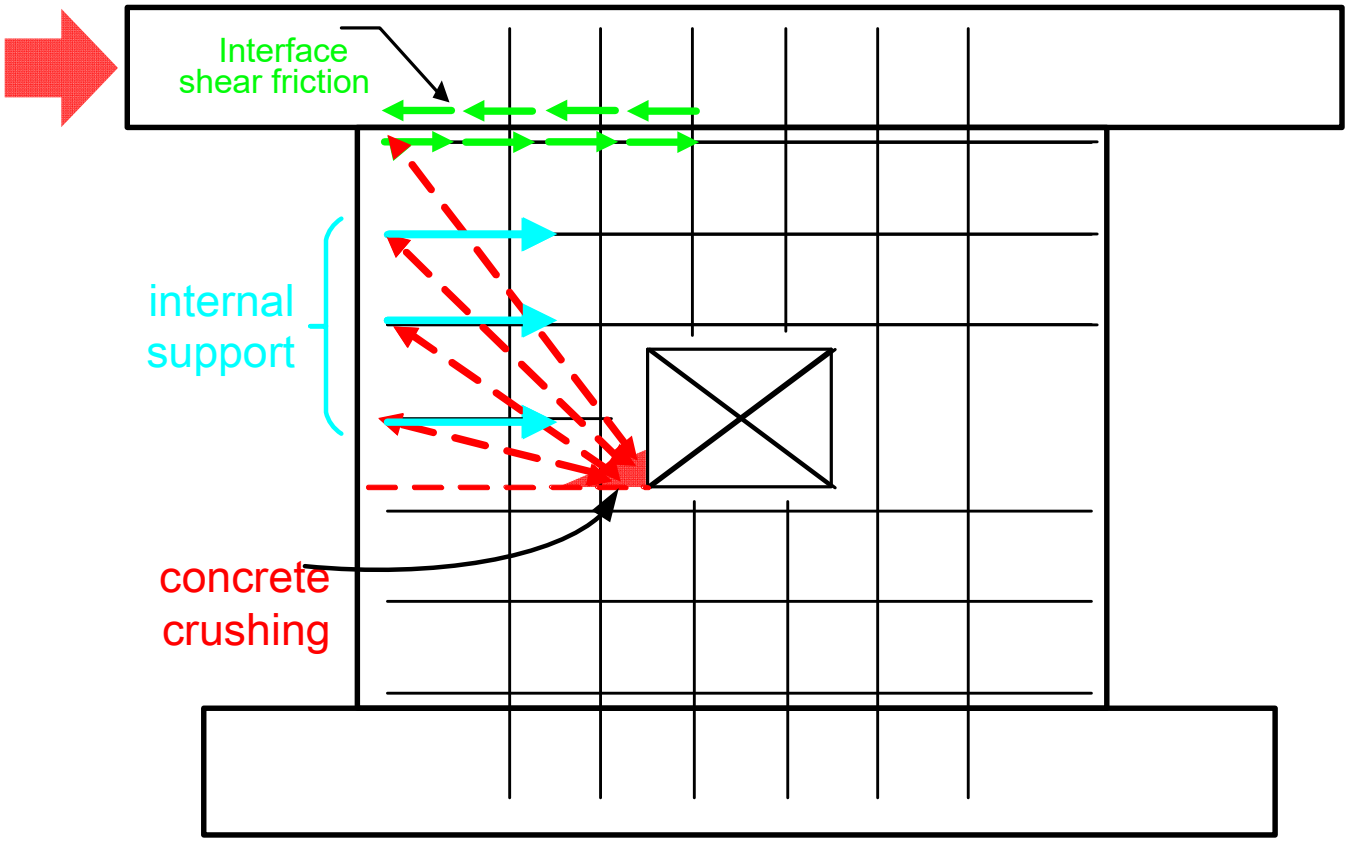
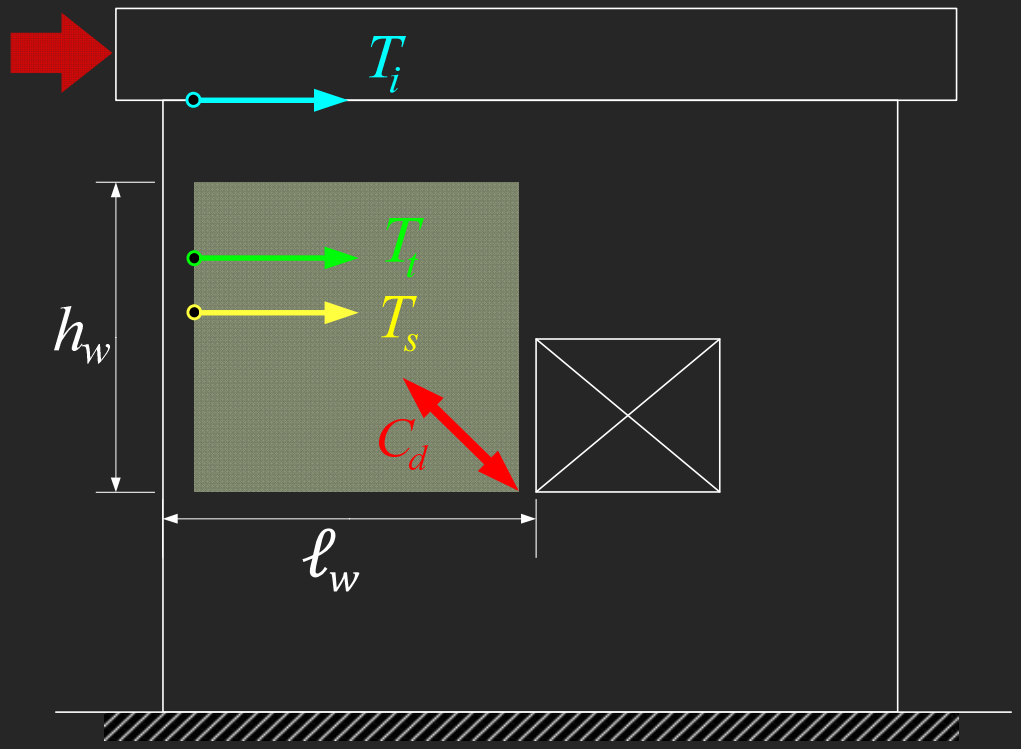
MS No. S-2017-391, doi: 10.14359/51702377, was received October 10, 2017, and reviewed under Institute publication policies. 




Strut-and-tie mechanism

## ● 內部支承之拉力來源




1. 垂直牆段的斜拉破壞強度

$$T_t = \left(0.17\sqrt{f_c'\,(\mathrm{MP})} + \rho_t f_{yt}\right) b_w d$$

其中 $d = 0.8\,\square_w$

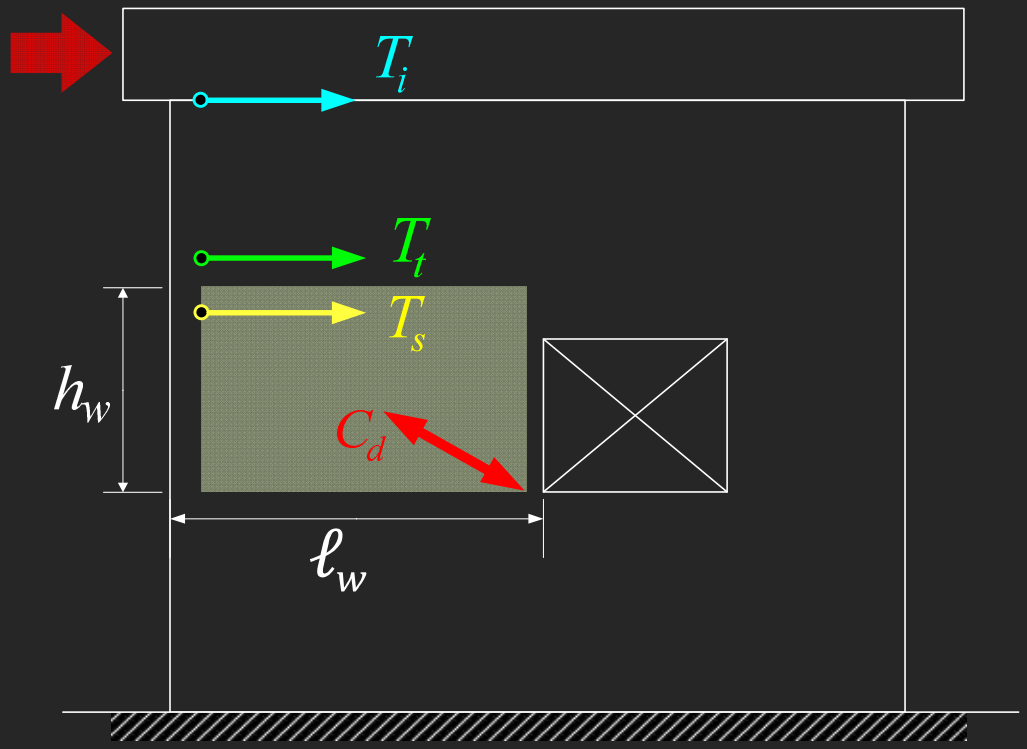
2. 開口補強筋的降伏強度

$$T_s = A_{she} f_{yhe}$$

3. 層間梁、樓板與牆體間之介面摩擦剪力

$$T_i = C_d \cos\theta - T_t - T_s$$

## ● 垂直牆段之高度計算




1. 垂直牆段的斜拉破壞強度

$$T_t = \left(0.17\sqrt{f'_c\,(\mathrm{MP})} + \rho_t f_{yt}\right) b_w d$$

其中 $d = 0.8\ell_w$

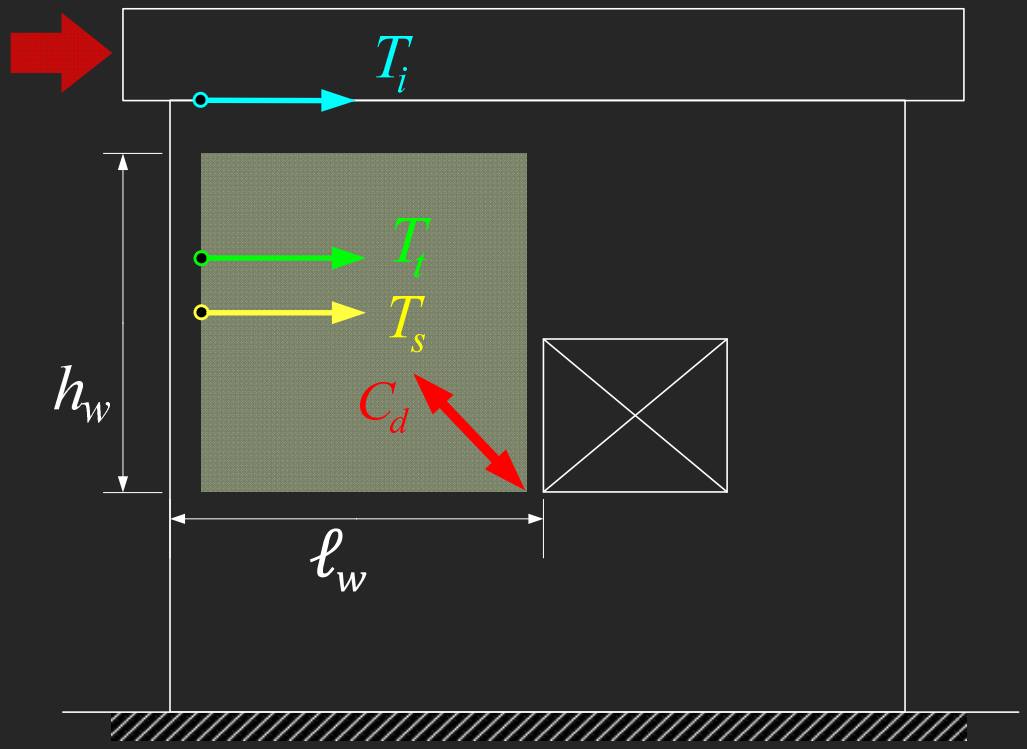
2. 開口補強筋的降伏強度

$$T_s = A_{she} f_{yhe}$$

3. 層間梁、樓板與牆體間之介面摩擦剪力

$$T_i = C_d \cos\theta - T_t - T_s$$

## ● 垂直牆段之高度計算




1. 垂直牆段的斜拉破壞強度

$$T_t = \left(0.17\sqrt{f'_c\,(\mathrm{MP})} + \rho_t f_{yt}\right) b_w d$$

其中 $d = 0.8\,\square_w$

2. 開口補強筋的降伏強度

$$T_s = A_{she} f_{yhe}$$

3. 層間梁、樓板與牆體間之介面摩擦剪力

$$T_i = C_d \cos\theta - T_t - T_s$$

## ✱ 軟化壓拉桿(SST)建議模型

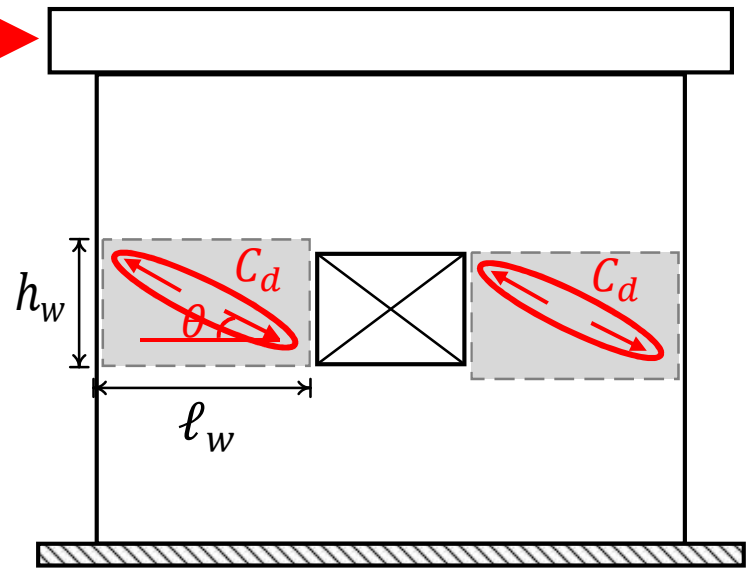
- $C_d = K\zeta f_c' A_{str}$
- $K = tan^A\theta + cot^A\theta - 1 + 1.4B \leq 1.64$

  其中$K$為壓拉桿指標，簡化公式：Hwang等人 (2017)

  $$A = 12\frac{\rho f_y}{f_c'} \leq 1 \quad , \quad B = 30\frac{\rho f_y}{f_c'} \leq 1$$

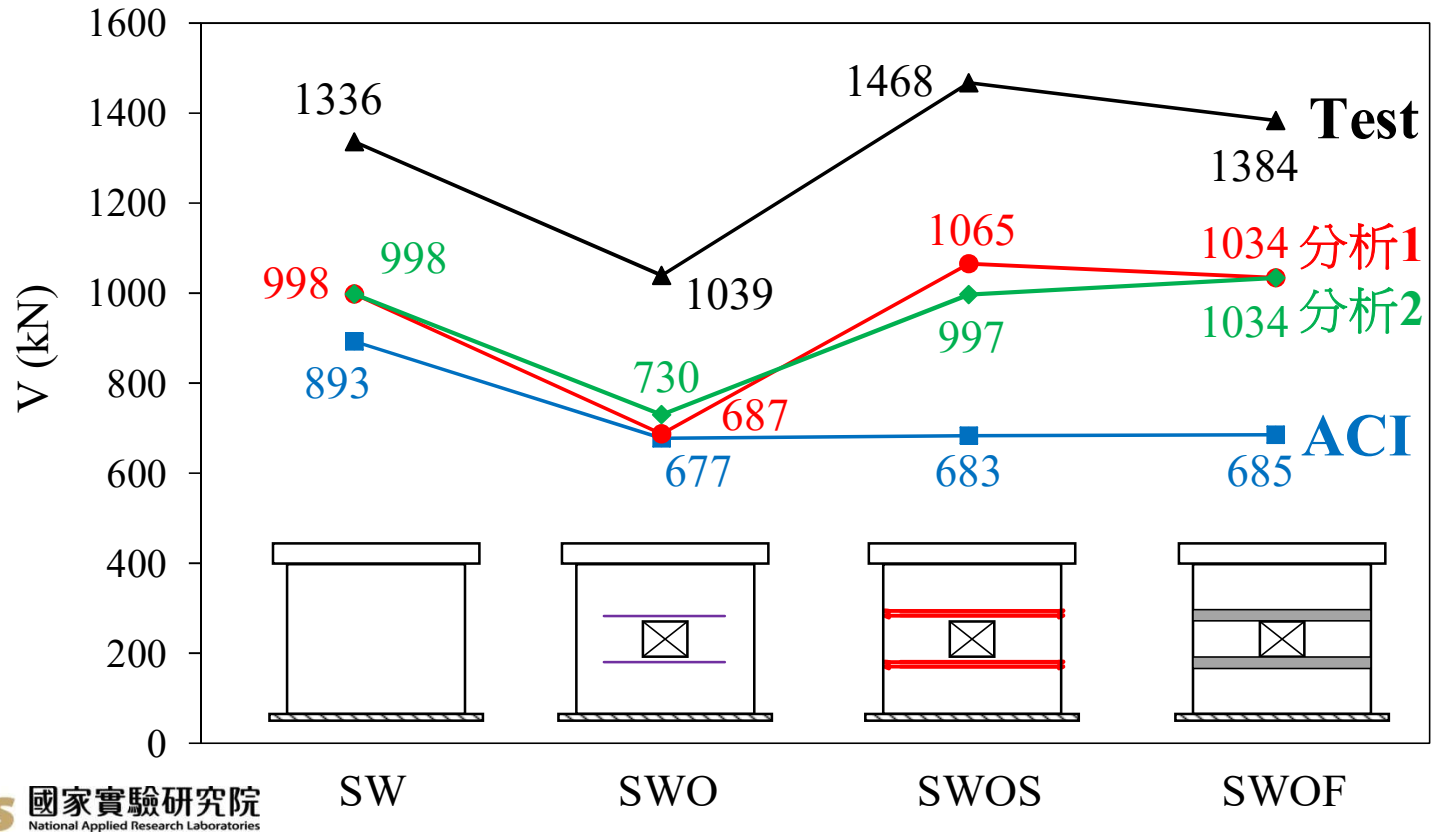
- $\zeta = \frac{3.35}{\sqrt{f_c'(MPa)}} \leq 0.52$

- $V_{n,SST} = C_d cos\theta$



★ **ACI 318-14 vs 分析1&2**

| 試體 | $V_{n,test}$ (kN) | ACI | | 分析1 | | 分析2 | |
|---|---|---|---|---|---|---|---|
| | | $h_w/\ell_w$ | $V_{n,test}/V_{n,ACI}$ | $h_w/\ell_w$ | $V_{n,test}/V_{n,1}$ | $h_w/\ell_w$ | $V_{n,test}/V_{n,2}$ |
| SW | 1336 | 0.79 | 1.50 | 0.79 | 1.40 | 0.79 | 1.40 |
| SWO | 1039 | 0.79 | 1.53 | 1.31 | 1.65 | 1.17 | 1.46 |
| SWOS | 1468 | 0.79 | 2.15 | 0.58 | 1.48 | 0.68 | 1.48 |
| SWOF | 1384 | 0.79 | 2.02 | 0.64 | 1.51 | 0.64 | 1.51 |
| | | AVG | 1.80 | | 1.51 | | 1.46 |
| | | COV | 0.16 | | 0.06 | | 0.03 |



# 結論

① 於開口上下方配置額外之水平鋼筋或CFRP貼片，皆可有效提升開口牆之剪力強度

② 不可直接以開口所造成之幾何不連續決定剪力元素尺寸，應考量開口上下鋼筋之配置

③ 本研究建議之分析法，可有效改善ACI 318-14無法考量開孔上下方鋼筋配置之缺點

④ 以節點力平衡來調整垂直牆段之高度，並計算其剪力強度，可作為開孔RC牆剪力評估之參考

# Thank you for your attention