高強度鋼筋混凝土結構設計與施工技術研討會
NCREE,12/09, 2016

高強度鋼筋之伸展與續接
擴頭鋼筋於外柱接頭之應用

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台灣科技大學

December 09, 2016

Outlines

- Introduction
- Properties of Reinforcement
- Development Length of Reinforcement in Tension
  - Straight bar
  - Hooked bar
  - Headed bar
- Splices

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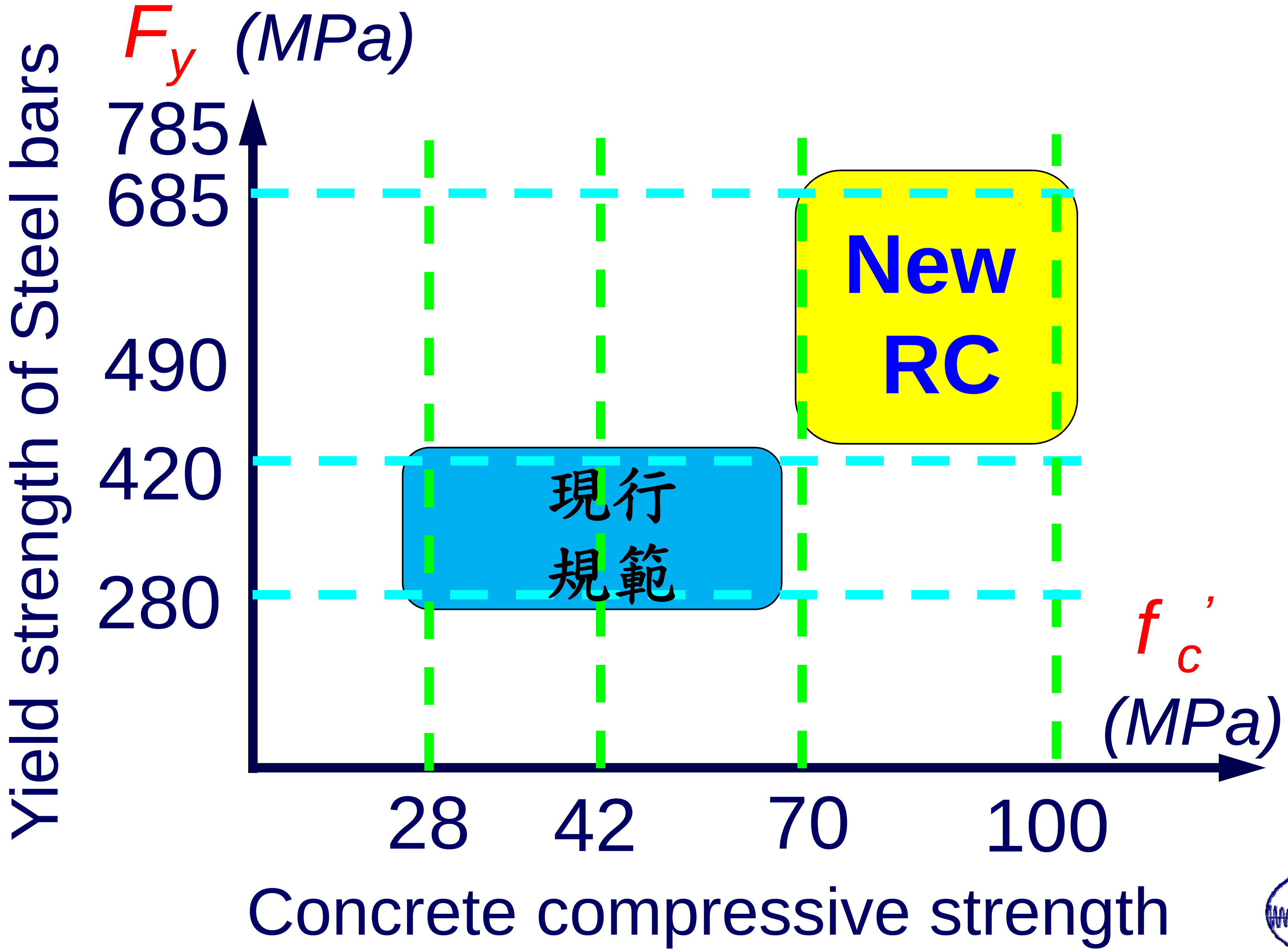
Scope of New RC Materials



Taiwan New RC Group 2008~

技術推動

產業界

潤弘、亞利
東鋼、TTK

材料規格制定與推廣

組織社團

TCI

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TW New RC
Project / Group

台灣新型高強度鋼筋
混凝土結構系統

台大土木系
台大材料系
台科大營建系
中央大學土木系
雲科大營建系
成功大學土木系

學術界

科技部整合研究

SD685、SD785
fc’ ≧ 70 MPa

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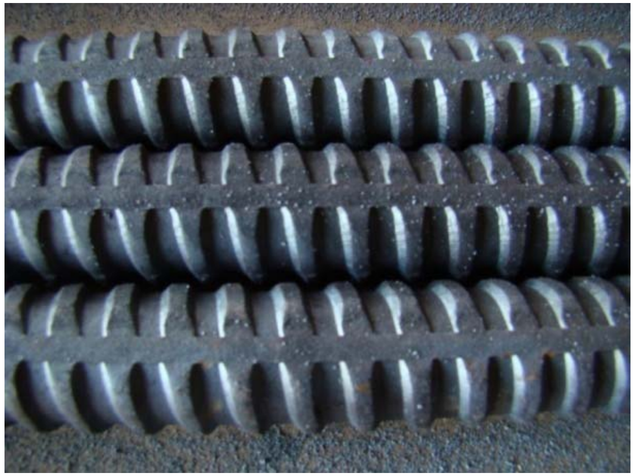
研究單位

構件行為研究
與設計指針建立

Critical Issues

- **Non-Welded, -Bent for High Strength Rebar**
- **Precast**

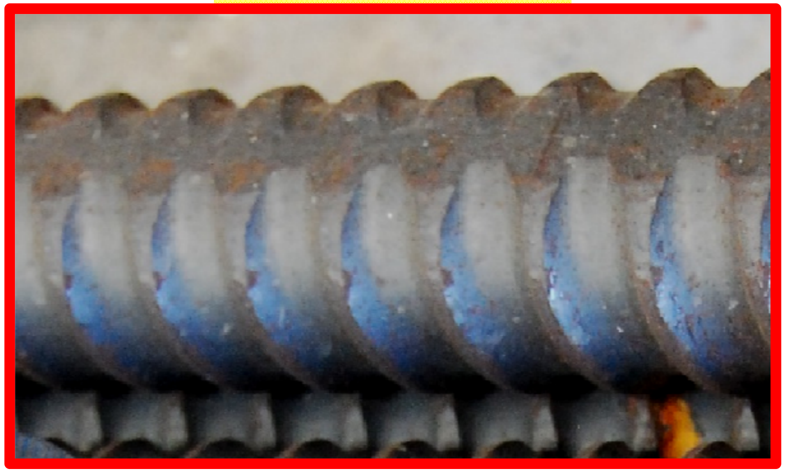
- **Threaded Rebar**



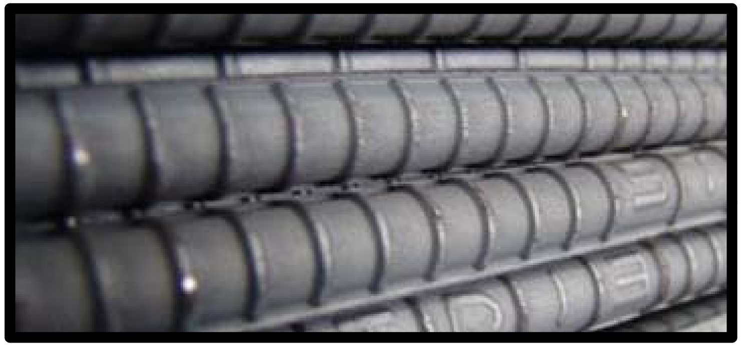
- **Mortar-filled Sleeve**
- **Mortar-filled End Anchor**

Deformation Types of Rebars

Thread Rebar



Deformed Rebar



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Mechanical Properties of Reinforcement

符號	f_y N/mm²	f_u N/mm²	$\frac{f_{ua}}{f_{ya}}$
SD490	490~625	620 以上	-
SD490W	490~625	615 以上	1.25以上
SD550W	550~675	690 以上	1.25以上
SD690	685~785	860以上	1.25以上
SD790	785以上	930以上	—

- 依據規範規定，耐震用鋼筋應滿足下列兩條件：
  - 降伏強度實際值不得大於規定值18000 psi
  - 實際的拉力強度與降伏強度比值不得小於1.25
- 銲接性之要求：
  - 應符合美國銲接學會AWS D1.4 (AWS, 2011)規定，碳當量(CE)不超過0.55。

15.3.5 耐震構材之鋼筋

15.3.5.1 用以承受地震引致之彎矩與軸力之構架構材及結構牆之邊界構件，其主筋應符合 CNS 560 中 *SD 420W* 及 *SD 280W* 之要求。CNS 560 中 *SD 420* 及 *SD 280* 鋼筋亦可使用，惟應符合下列規定：

(1) 實測降伏強度不得超出規定降伏強度 f_y 達 *1,200 kgf/cm²* 以上。

(2) 實測極限抗拉強度與實測降伏強度之比值不得小於 *1.25*。

15.3.5.2 橫向鋼筋包括螺箍筋之 f_{yt} 不得超過 *4,200 kgf/cm²*。

21.1.5.2 — Deformed reinforcement resisting earthquake-induced flexure, axial force, or both, shall comply with ASTM A706, Grade 60. ASTM A615 Grades 40 and 60 reinforcement shall be permitted if:

(a) The actual yield strength based on mill tests does not exceed f_y by more than 18,000 psi; and

(b) The ratio of the actual tensile strength to the actual yield strength is not less than 1.25.

Applications of Longitudinal Reinforcement

符號	續接形式		錨定形式		
	銲接	搭接	彎鉤	銲接錨定裝置	套筒式錨定裝置
SD490	X	▲	O	X	O
SD490W	O	▲	O	O	O
SD550W	O	▲	O	O	O
SD690	X	X	X	X	O

- **SD690**：不得採用銲接或搭接續接，端部不得以彎鉤或銲接錨定裝置作為錨定之用。
- **SD790**：僅適用於橫向鋼筋，不作為梁、柱構件之縱向主筋。

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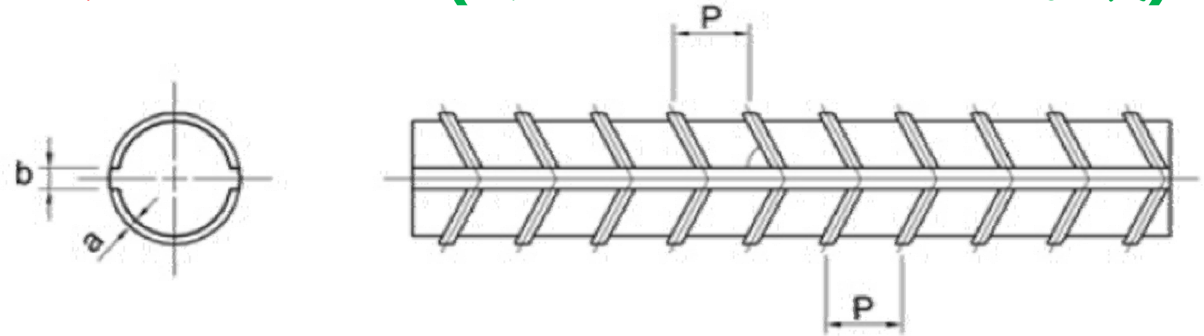
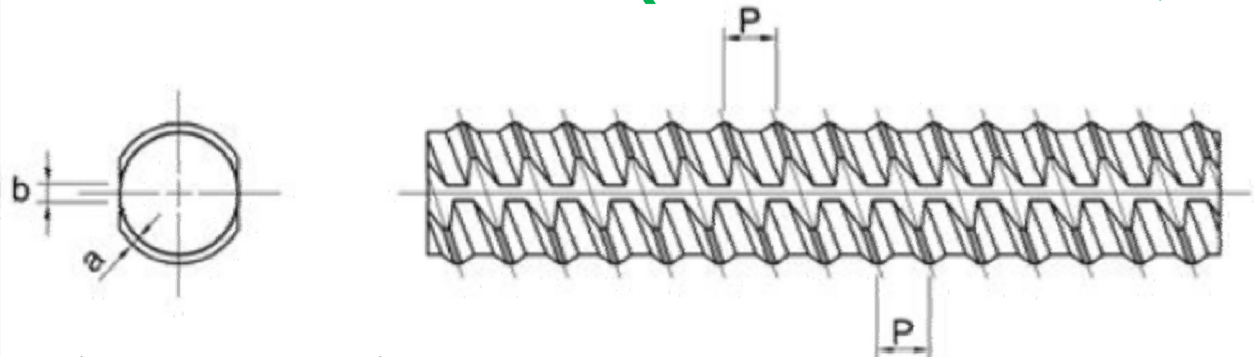
Surface Geometry of Reinforcement

- 竹節鋼筋：鋼筋表面節之平均節高與平均節距比值，分別不得小於0.1。**(採用ACI 408-03建議)**



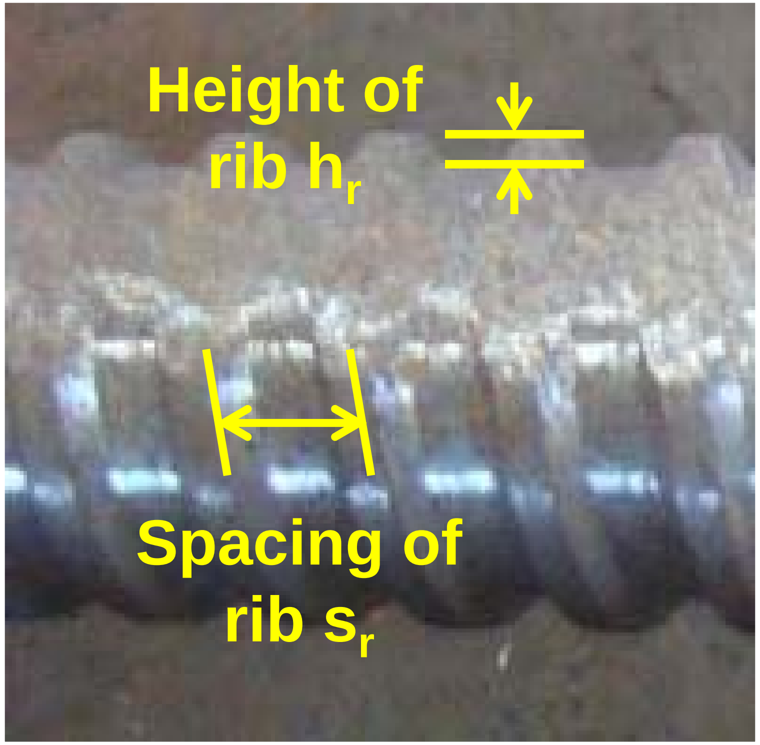
- 螺紋節鋼筋：鋼筋表面節之平均節高與平均節距比值，分別不得小於0.17。**(採用國震中心研究成果)**

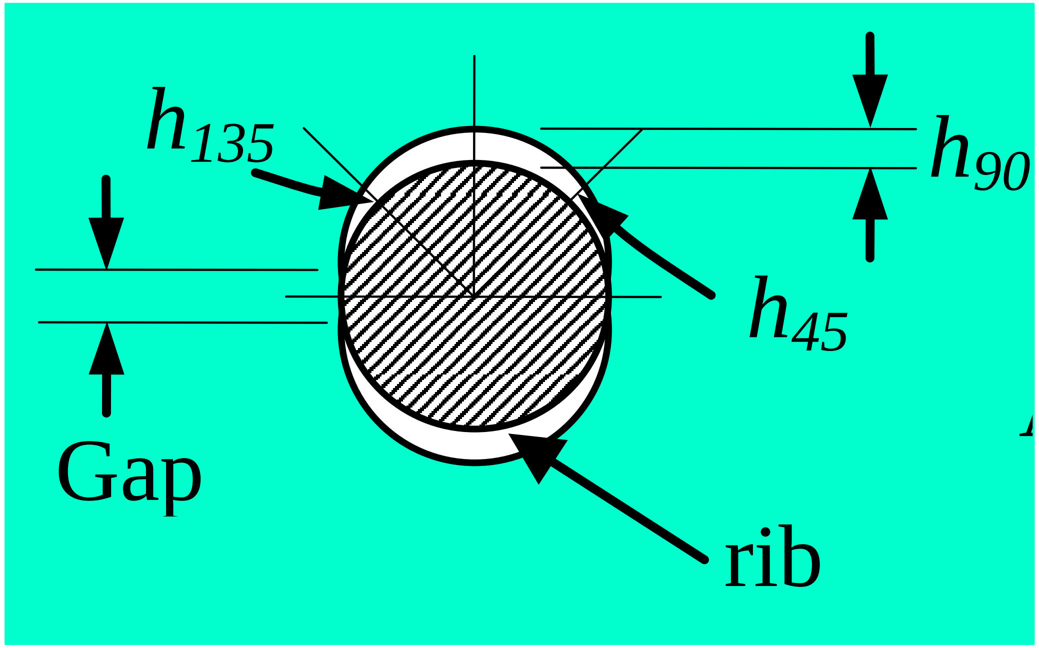


- 一般竹節與螺紋節鋼筋之表面形狀尺度分別詳設計手冊中之表C3-2與表C3-3。

Parameter of Threaded Rebar

Relative Rib Area R_r





$$R_r = \frac{\text{bearing area}}{\text{shear area}} \approx \frac{h_r}{s_r}$$

Max. $h_r = h_{90}$

Avg. $h_r = (h_{90}+h_{45}+h_{135})/3$

$$\boxed{R_{r,ave} = \frac{h_{r,ave}}{s_r} \geq 0.17}$$

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Standard Specification for Reinforcement

社團法人 台灣混凝土學會

Taiwan Concrete Institute

鋼筋混凝土用鋼筋

Steel bars for Concrete Reinforcement

—SD550W、SD685、SD785

新高強度鋼筋混凝土技術委員會報告

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蔡江洋 蔡益超

研究助理： 陳智軒 (按姓氏筆畫順序)

2014年09月審定版

4. 形狀、尺度、質量及許可差

4.5 鋼筋之節，其高度最小值及最大值依表2之規定。為確保鋼筋在混凝土之握裹強度，**竹節鋼筋稱號D22以上**，其節之高度平均值不得小於其節距平均值之**10%**；**螺紋節鋼筋稱號D22以上**，其節之高度平均值不得小於其節距平均值之**18% (17%)**。

表 4 螺紋節鋼筋之標示代號、單位質量、標稱尺度及節之尺度

鋼筋稱號	標示代號	單位質量 (W) kg/m	標稱直徑 (d) mm	標稱剖面積 (S) mm²	標稱周長 (ℓ) mm	節之尺度：節距平均值最大值 (P) mm	節之高度(a) 最小值 (h) mm	節之高度(a) 最大值 (H) mm	單一間隙寬度最大值 (b) mm
D13	4	0.994	12.7	126.7	40	6.4	0.8	1.3	5.0
D16	5	1.56	15.9	198.6	50	8.0	1.0	1.7	6.2
D19	6	2.25	19.1	286.5	60	9.6	1.2	2.0	7.5
D22	7	3.04	22.2	387.1	70	11.1	1.3	2.2	8.7
D25	8	3.98	25.4	506.7	80	12.7	1.6	2.6	10.0
D29	9	5.08	28.7	646.9	90	14.4	1.7	2.8	11.3
D32	10	6.39	32.2	814.3	101	16.1	1.9	3.2	12.6
D36	11	7.90	35.8	1007	113	17.9	2.2	3.6	14.1
D39	12	9.57	39.4	1219	124	19.7	2.4	4.0	15.5
D43	14	11.4	43.0	1452	135	21.5	2.5	4.2	16.9
D50	16	15.5	50.2	1979	158	25.1	3.0	5.0	19.7
D57	18	20.2	57.3	2579	180	28.7	3.5	5.8	22.5

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Objectives

ACI 318-11, 14 and Taiwan (2011) Codes

Straight Development length in tension (unit : SI)

$$l_d = \frac{A_b \cdot f_s}{\pi \cdot u \cdot d_b} \Rightarrow l_d = 0.9 \frac{f_y}{\sqrt{f_c'}} \frac{1}{\left(\frac{c_b + k_{tr}}{d_b}\right)} d_b$$

Limitations for Equation

- $f_y \leqq 420$ MPa
- $f_{yt} \leqq 420$ MPa
- $f_c' \leqq 70$ MPa

$$1.0 \leq \left(\frac{c_b + K_{tr}}{d_b}\right) \leq 2.5$$

$$K_{tr} = \frac{40 A_{tr}}{sn} \quad \text{(ACI 318-11)}$$

$$K_{tr} = \frac{A_{tr} f_{yt}}{10.3 sn} \quad \text{(Taiwan, 2011)}$$

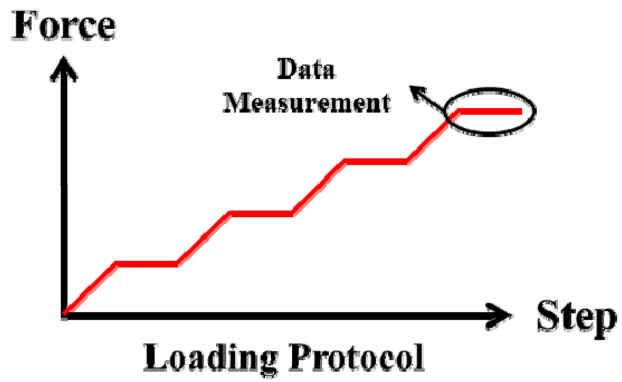
25.4.1.4 The values of $\sqrt{f_c'}$ used to calculate development length shall not exceed 100 psi.

From 1989

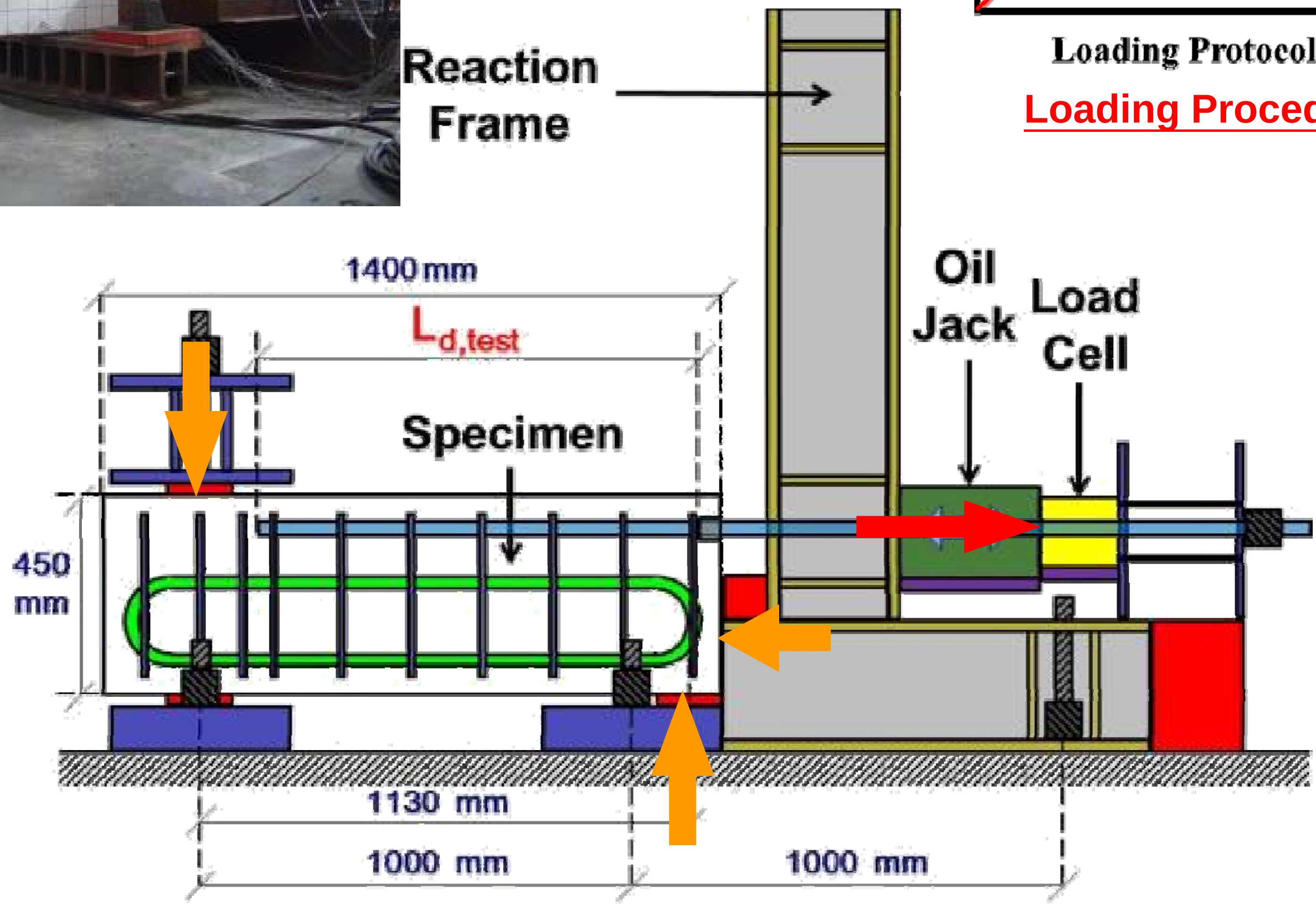
Experimental Program

Stopping Criteria

1. Concrete Failure
2. Bar Fracture
3. Bar Pullout

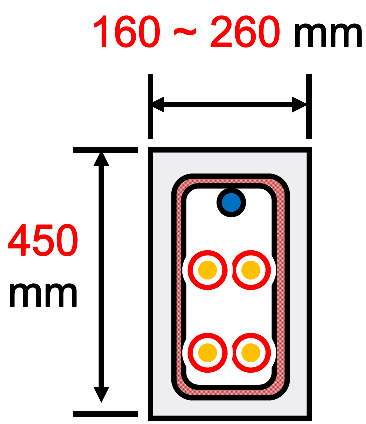


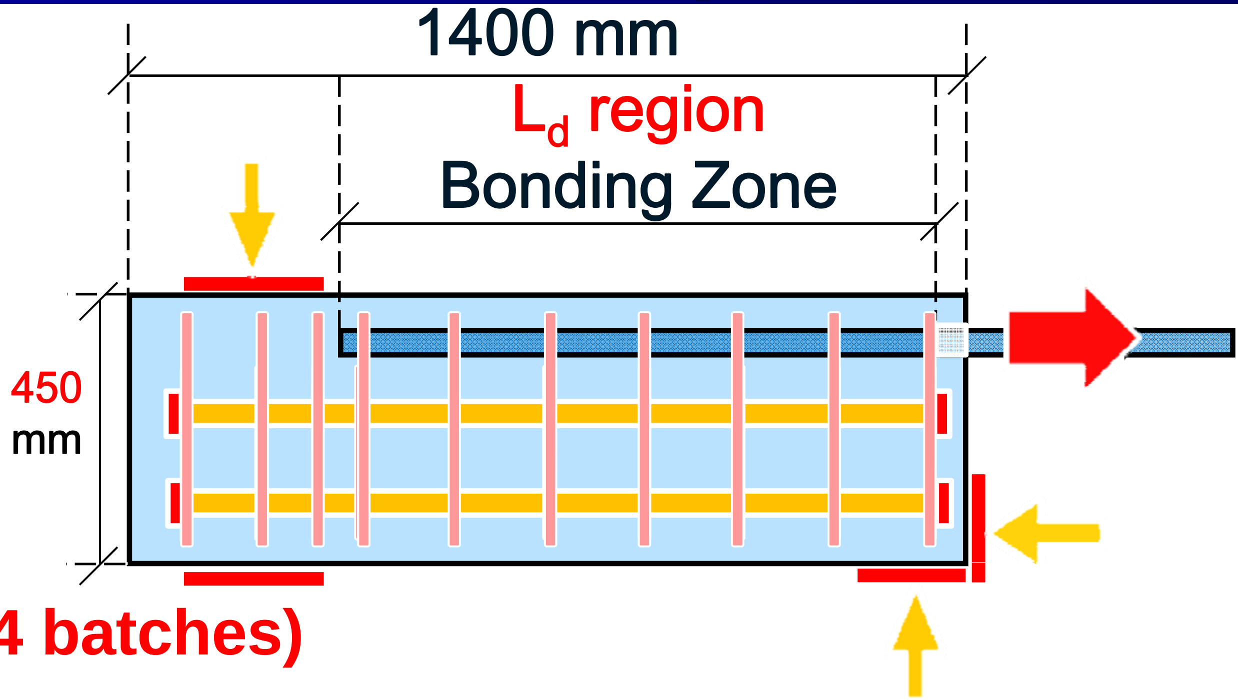
Loading Procedure



Design Variables of All Specimens

紀凱甯-2012~2016



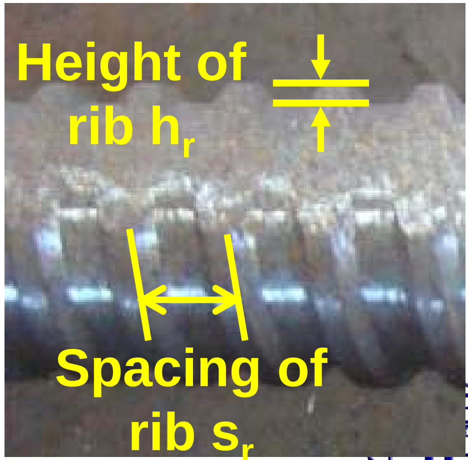


Specimens：72 (4 batches)

Design variables

1. Bar size：D25, D32, D35, D38, D41
2. Geometry：Plain, Thread (R_r = 0.12 – 0.19)
3. f_c'：56, 70, 80, 100 MPa
4. f_{yt}：280, 420, 790 MPa
5. $\frac{c_{b,t} + K_{tr}}{d_b} = 2.3 - 5.2$

$$R_{r,ave} = \frac{h_r}{s_r}$$



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Actual Concrete Strength

Specimen	f_c', Testing Day (MPa)
BE1~BE3	64.3
BE4~BE6	62.7
BE7~BE9	90.9
BE10~BE12	91.8
SP1	80.4
SP2	110.6
SP3	84.8
SP4	110.7
SP5	90.7
SP6	106.2
SP7	93.8
SP8	109.0
SP9	86.6
SP10	106.4
SP11	91.4
SP12	102.3
TD1	71.8
TD2	71.8
Test-1	42.3
Test-2	41.7

Specimen	f_c', Testing Day (MPa)
D25C4F56	61.2
D25C4F8-V	72.0
D25C5F10	92.0
D25C7F8	78.0
D32C4F56	61.2
D32C4F8-V	72.0
D32C5F10	92.0
D32C7F8	78.0
D35C4F56	61.2
D35C4F8-V	72.0
D35C5F10	92.0
D35C7F8	78.0
D38C4F56	61.2
D38C4F8-V	72.0
D38C5F10	92.0
D38C7F8	78.0
D41C4F56	61.2
D41C4F8-V	72.0
D41C5F10	92.0
D41C7F8	78.0

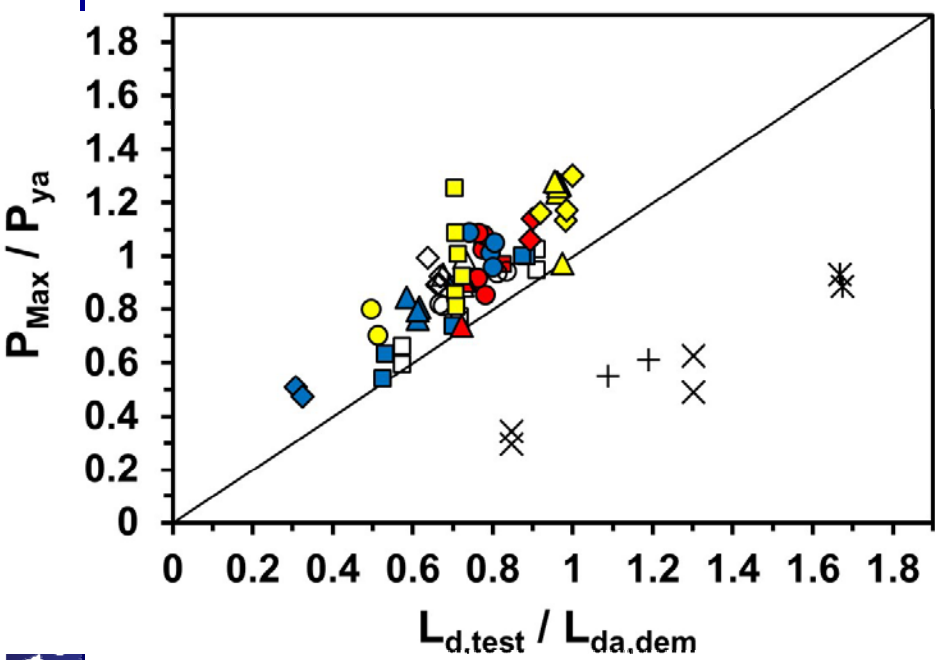
Specimen	f_c', Testing Day (MPa)
D25C5F8-U	79.5
D25C8F8-U	81.1
D25C9F8-U	81.1
D25C5F8-S20	79.5
D25C8F8-S20	81.1
D25C5F8-S10	81.1
D32C6.5F8-U	78.4
D32C8F8-U	79.5
D32C10F8-U	81.1
D32C6.5F8-S20	78.4
D32C8F8-S20	79.5
D32C6.5F8-S10	79.5
D35C7F8-U	79.5
D35C9F8-U	79.5
D35C10F8-U	78.4
D35C7F8-S20	78.4
D35C9F8-S20	78.4
D35C7F8-S10	78.4
D25C5F8-UP	81.1
D25C5F8-S20P	81.1
D32C6.5F8-UP	81.1
D32C6.5F8-S20P	81.1

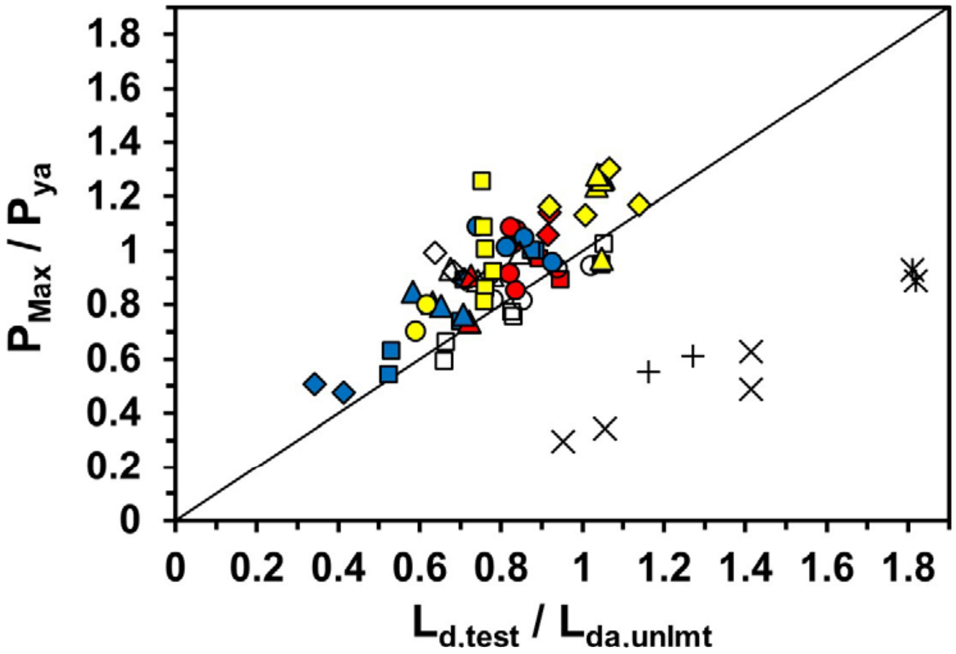
Actual Reinforcement Strength

Group	Specimens	Bar Size	Type	h_r (mm)	s_r (mm)	Relative of Area, R_r	Yield f_{ya}(MPa)	Ult. f_{ua} (MPa)
Series (I)	BE1-BE6	D25	SD685 Hot Roll	1.44	10.00	0.143	738	932
	BE7-BE12	D32		1.50	11.90	0.126	742	966
Series (II)	SP1-SP2	D32	SD685 Hot Roll	1.56	11.88	0.131	710	924
	SP3-SP4			2.21	12.06	0.183	716	933
	SP5-SP6		SD685 Milled	2.21	12.01	0.184	777	971
	SP9-SP10		SD490 Plain	X	X	X	503	698
	SP7-SP8 SP11-SP12	D39	SD490 Hot Roll	2.37	14.80	0.160	534	701
	TD1-TD2	D32	USD685 Hot Roll	2.22	12.34	0.180	693	925
	Test-1 – Test-2	D25		1.75	9.90	0.177	730	x
Series (III)	D25 Type	D25	USD685 Hot Roll	2.03	10.44	0.194	694	x
	D32 Type	D32		2.28	13.27	0.172	671	x
	D35 Type	D35		2.46	14.00	0.176	677	x
	D38 Type	D38		2.72	15.24	0.178	679	x
	D41 Type	D41		2.83	15.96	0.177	693	x
Series (IV)	D25 Type	D25	USD685 Hot Roll	1.98	10.73	0.185	710	x
	D32 Type	D32		2.25	13.41	0.168	688	x
	D35 Type	D35		2.76	15.08	0.183	686	x
	D25~D35 Plain	D25~ D32	SD420 Plain	X	X	X	412	x

Test Results - Strength

- ⋇ #8- Rr = 0
- × #10-Rr = 0
- + #11- Rr = 0
- □ #10-Rr = 0.126
- ■ #10-Rr = 0.132
- ■ #8-Rr = 0.143 (fca' < 70MPa)
- ○ #12-Rr = 0.160
- ● #10-Rr = 0.168
- ● #10-Rr = 0.172
- △ #11-Rr = 0.176
- ▲ #8-Rr = 0.177 (fca' < 70MPa)
- ▲ #14-Rr = 0.177
- ◇ #12-Rr = 0.178
- ◆ #10-Rr = 0.180
- ◆ #10-Rr = 0.183
- □ #11-Rr = 0.183
- ○ #10-Rr = 0.184
- △ #8 - Rr = 0.185
- ◇ #8-Rr = 0.194





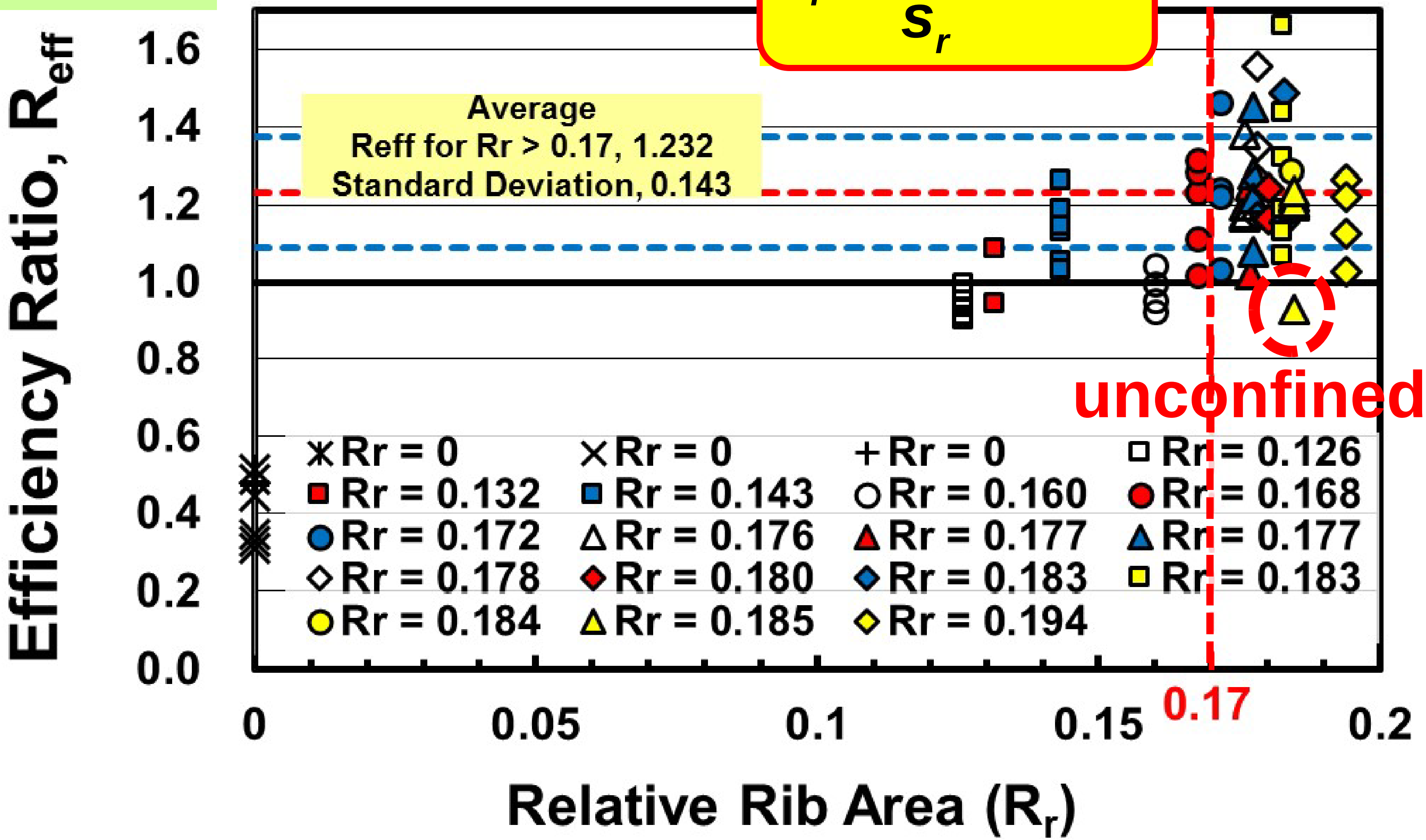
Limit for $f_c' \leqq 70$ MPa

No Limit for $f_c' \leqq 70$ MPa

Test Results - Strength

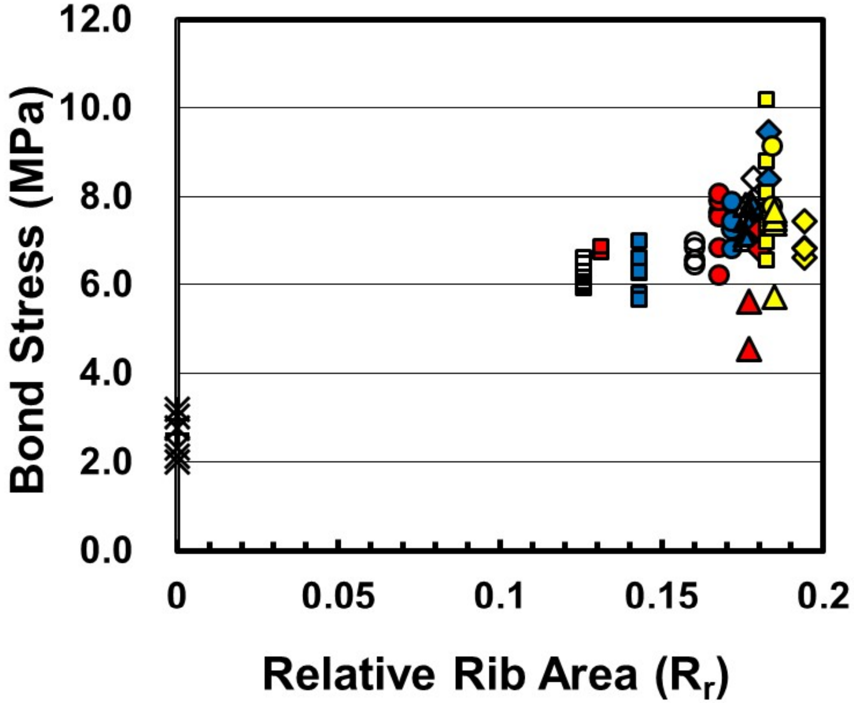
$$R_{eff} = \frac{R_P}{R_L}$$

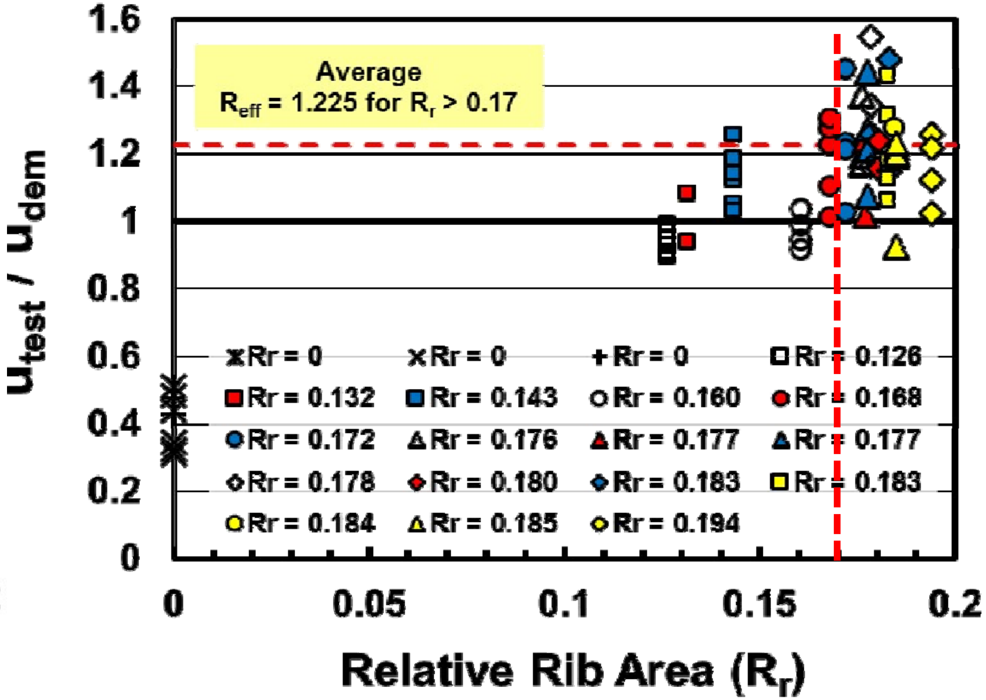
$$R_r = \frac{h_r}{s_r} \geq 0.17$$



Test Results - Bond Stress

u_{test} | u_{test}/u_{dem}





$$u_{dem} = \frac{A_b \times f_s}{\pi \times d_b \times \ell_d} = \frac{\frac{\pi d_b^{\,2}}{4} \times f_s}{\pi \times d_b \times \frac{0.9 f_s \times d_b}{\sqrt{f'_{ca}}\left(\frac{c_b + K_{tr}}{d_b}\right)}} = \frac{\sqrt{f'_{ca}}\left(\frac{c_b + K_{tr}}{d_b}\right)}{3.6} = \frac{(1 \sim 2.5)\sqrt{f'_{ca}}}{3.6}$$

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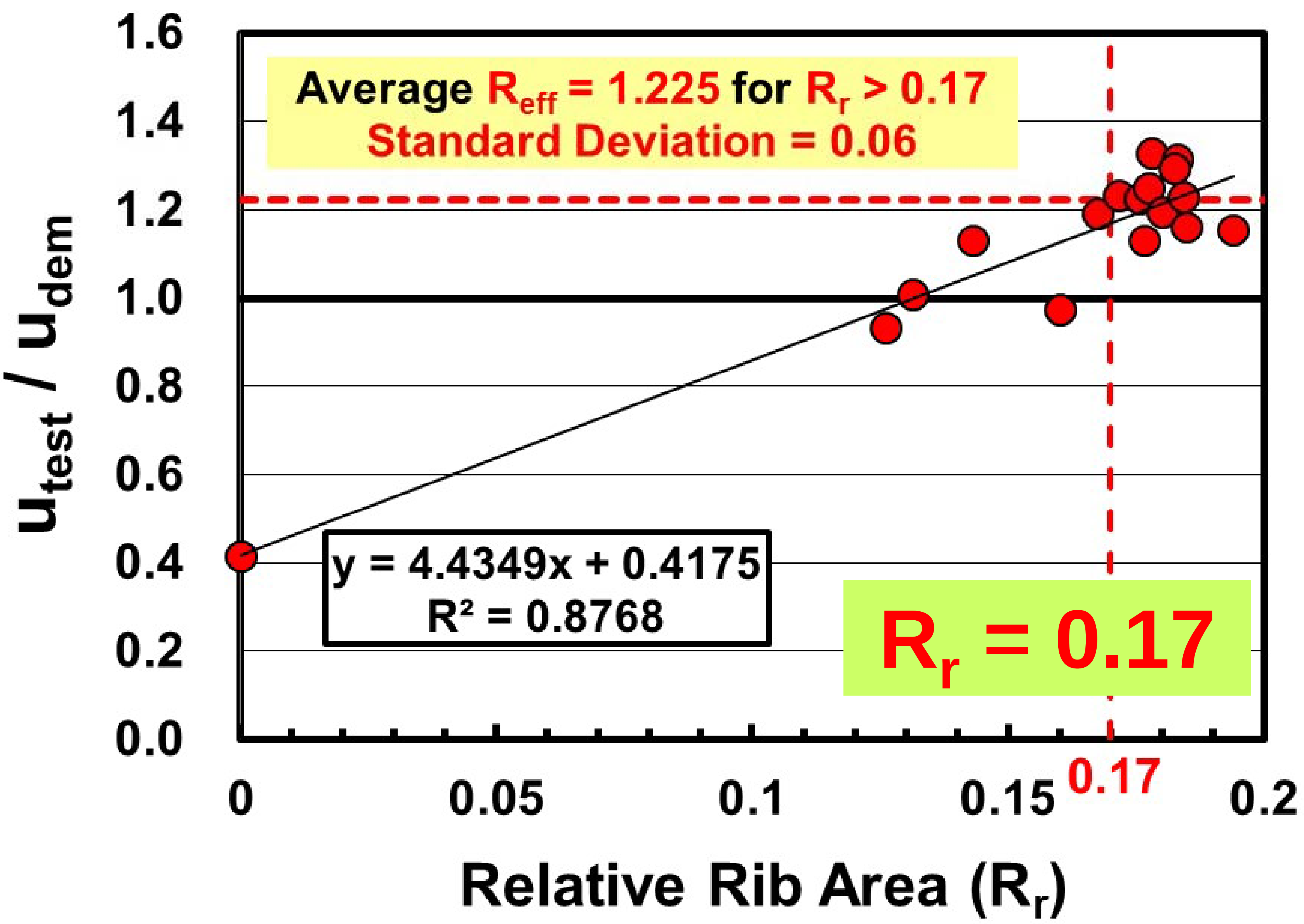
Test Results - Bond Stress



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Test Results – Splitting (I)

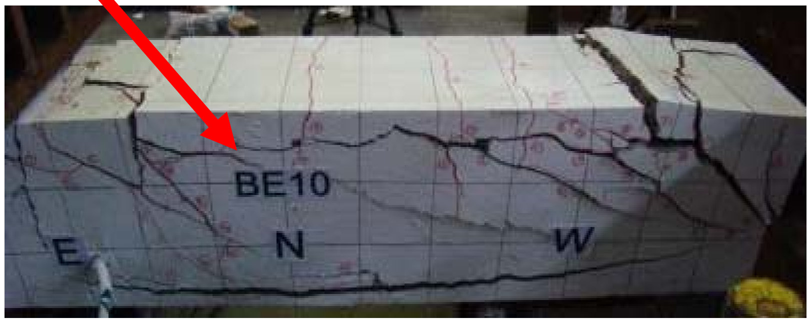
Specimen (n_b = 2)	$\frac{c_b + K_{tr}}{d_b}$			Splitting	
	Top cover	Side cover	Bar spacing	Top	Side
BE4-BE6	4.64	4.63	4.03	—	—
BE10-BE12	3.73	3.65	3.58	—	■

R_r = 0.143

R_r = 0.126

BE4

BE10



$$\left(\frac{c_b + K_{tr}}{d_b}\right) \approx 3.65$$

is a upper bound for splitting

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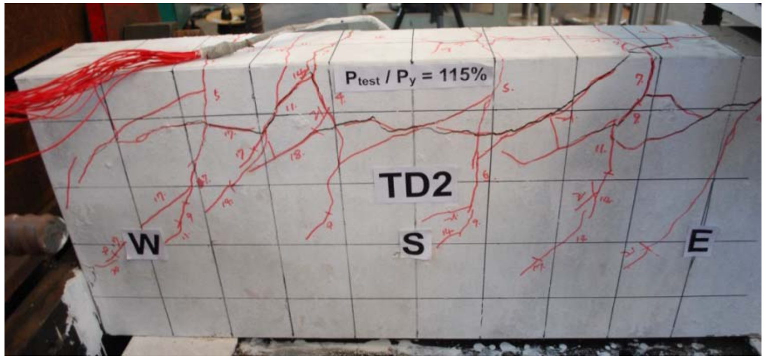
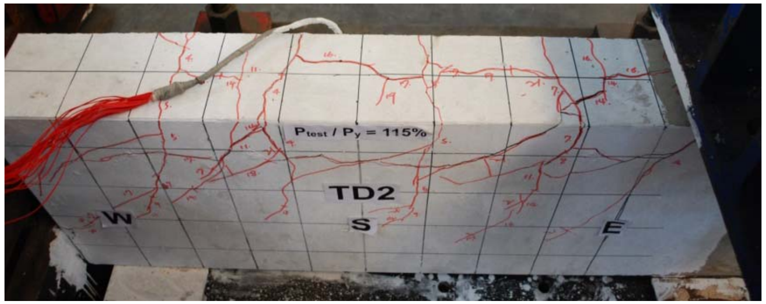
Test Results – Splitting (II)

Specimen	$\frac{c_b + K_{tr}}{d_b}$		Splitting	
	Top cover	Side cover	Top cover	Side cover
R_r = 0.18 TD1 – TD2	3.34	3.41	■	■

TD1

TD2





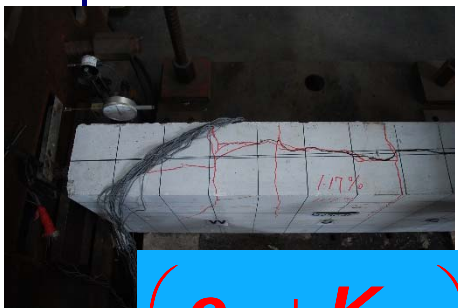
$$\left(\frac{c_b + K_{tr}}{d_b}\right) \approx 3.65$$ is a upper bound for splitting

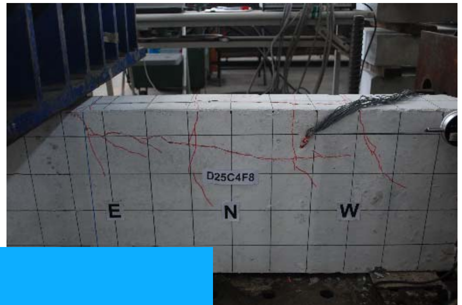
Test Results – Splitting (III)

Specimen	$\frac{c_b + K_{tr}}{d_b}$		Splitting	
	Top cover	Side cover	Top cover	Side cover
D25C4F56	3.84	4.21	■	■
D25C4F8	3.84	4.21	■	
D25C4F10	3.84	4.21	■	■
D25C7F8	5.04	4.21		■

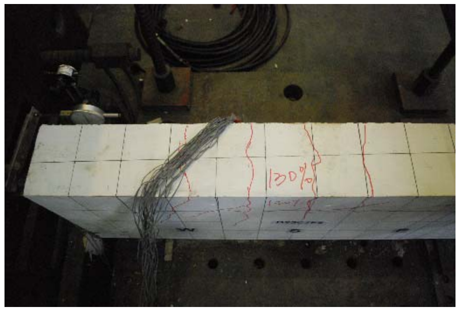
$R_r = 0.194$

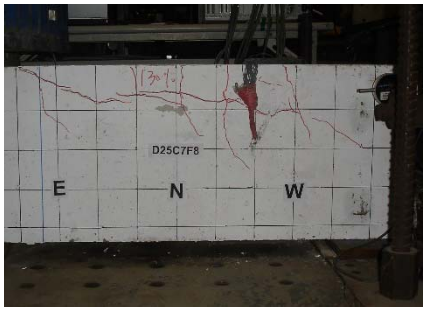
D25C4F8





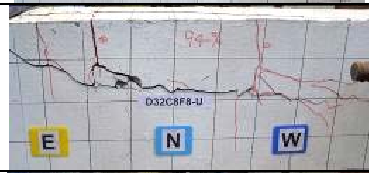
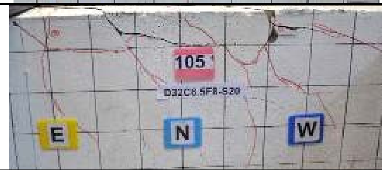
D25C7F8





$$\left(\frac{c_b + K_{tr}}{d_b}\right) \approx 4.21$$ is a upper bound to occur splitting

Test Results – Splitting (IV)

Specimen $R_r = 0.168$	Confinement Index $(c_b+K_{tr})/d_b$		Splitting Occurrence		Top Cover Splitting	Side Cover Splitting
	Top Cover	Side Cover	Top Cover	Side Cover		
D32C6.5F8-U	2.50	3.63	●	●		
D32C8F8-U	2.81	3.63	●	●		
D32C10F8-U	3.28	3.63		●		
D32C6.5F8-S20	3.45	4.42	●	●		
D32C8F8-S20	3.60	4.42	●	●		
D32C6.5F8-S10	4.55	5.21	●	●		

$$\left(\frac{c_b+K_{tr}}{d_b}\right) \approx 5.21$$ is a upper bound to occur splitting

Summary (I)

Development length in tension following ACI 318 code (unit : SI)

$$l_d = 0.9\frac{f_y}{\sqrt{f_c'}}\frac{1}{\left(\frac{c_b + k_{tr}}{d_b}\right)}d_b$$

- $f_y \leqq 690$ MPa
- $f_{yt} \leqq 420$ MPa
- $f_c' \leqq 100$ MPa

$$R_{r,ave} = \frac{h_r}{s_r} \geq 0.17$$

Limitations for Bond Equation

$$1.0 \leq \left(\frac{c_b + K_{tr}}{d_b}\right) \leq 2.5$$

$$l_d = 0.9?\,\frac{f_y}{\sqrt{f_c'}}\frac{1}{\left(\frac{c_b + k_{tr}}{d_b}\right)}d_b$$

Summary (II)

- 本試驗採用之相對節面積R_r值介於0.126~0.160之螺紋節鋼筋，應用建議公式時，混凝土強度仍須受70 MPa之上限限制，方能符合預期之握裹性能。
- 採用表現相對節面積R_r值為0.17以上之螺紋節鋼筋，應用建議公式時，可不受混凝土強度70 MPa上限之限制。

$$l_d = 0.9\frac{f_y}{\sqrt{f_c'}}\frac{1}{\left(\frac{c_b + k_{tr}}{d_b}\right)}d_b \qquad 1.0 \le \left(\frac{c_b + K_{tr}}{d_b}\right) \le 2.5$$

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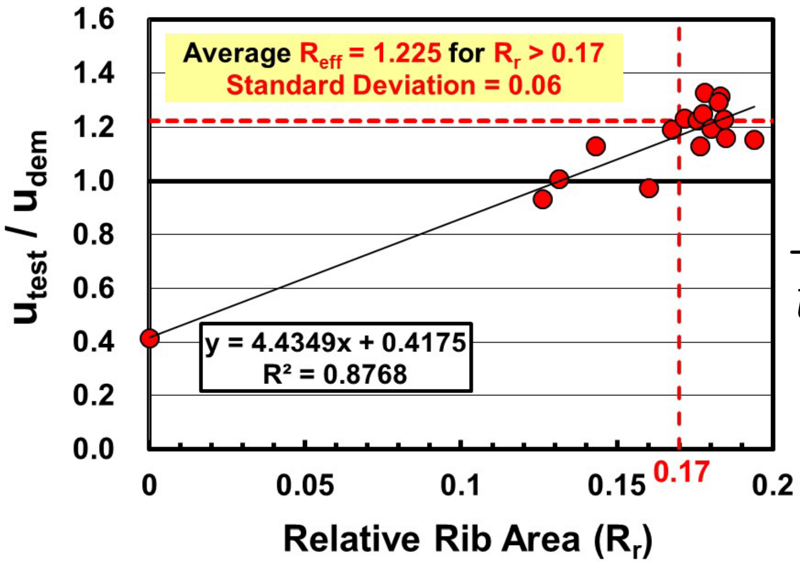
Summary (III)

- 螺紋節鋼筋之相對節面積R_r值與握裹應力成正比關係。



$$\frac{u_{test}}{u_{dem}} = \frac{\dfrac{A_b \times f_s}{\pi \times d_b \times \ell_d}}{\dfrac{\sqrt{f'_{ca}}\left(\dfrac{c_b + K_{tr}}{d_b}\right)}{3.6}} = \frac{\dfrac{A_b \times f_s}{\pi \times d_b \times \ell_d}}{\dfrac{(1 \sim 2.5)\sqrt{f'_{ca}}}{3.6}}$$

- 由握裹效益u_{test} / u_{dem}值發現，螺紋節鋼筋之相對節面積R_r值為0.17以上者，其握裹性能均符合下列公式之握裹需求，在應用此握裹模型時可不受混凝土強度70 MPa之上限限制。

Summary (IV)

- 螺紋節鋼筋其劈裂指數$(c_b+K_{tr})/d_b$大於ACI 318-11規定之2.5上限限制，甚至達5.2時，仍會發生沿主筋方向之劈裂。

R25.4.2.3

reinforcement. A limit of 2.5 is placed on the term $(c_b + K_{tr})/d_b$. When $(c_b + K_{tr})/d_b$ is less than 2.5, splitting failures are likely to occur. For values above 2.5, a pullout failure is expected, and an increase in cover or transverse reinforcement is unlikely to increase the anchorage capacity.

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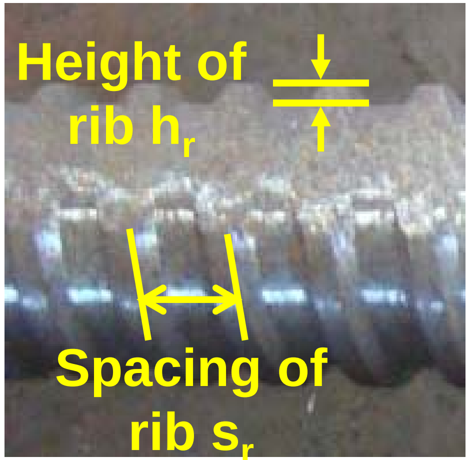
Development Length of Bars

Section 8.1.2

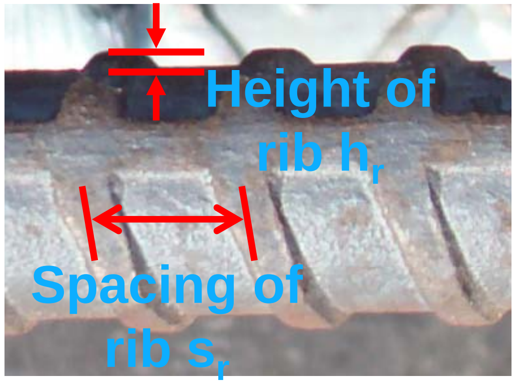
(本設計手冊建議)

Development length in tension following ACI 318 code (unit : SI)

$$l_d = 0.9\frac{f_y}{\sqrt{f_c'}}\frac{\psi_t\psi_e\psi_s\lambda}{\left(\dfrac{c_b + k_{tr}}{d_b}\right)}d_b$$



$$R_{r,ave} = \frac{h_r}{s_r} \geq 0.17$$



$$R_{r,ave} = \frac{h_r}{s_r} \geq 0.10$$

Limitations for Bond Equation

- $f_y \leqq 690$ MPa
- $f_{yt} \leqq 420$ MPa
- $f_c' \leqq 100$ MPa

$$1.0 \leq \left(\frac{c_b + K_{tr}}{d_b}\right) \leq 2.5$$

$$K_{tr} = \frac{A_{tr} f_{yt}}{10.3sn}$$

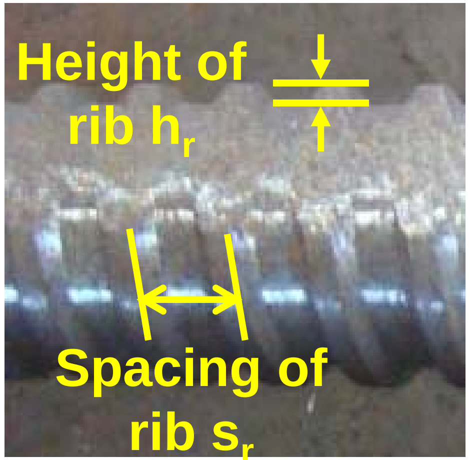
Development Length of Bars

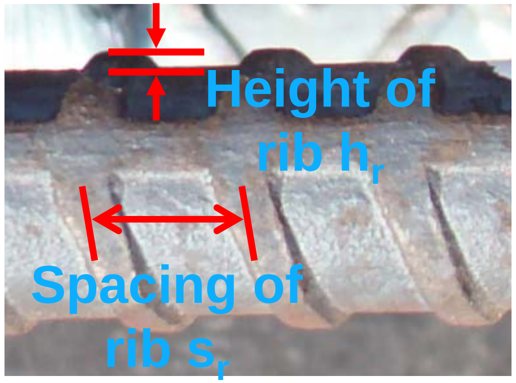
Section 8.1.2

(本設計手冊建議)

Development length in compression following ACI 318 code (unit : SI)

$$l_d = 0.24 \frac{f_y}{\sqrt{f_c'}} d_b \geq 0.043 f_y d_b$$





$$R_{r,ave} = \frac{h_r}{s_r} \geq 0.17$$

$$R_{r,ave} = \frac{h_r}{s_r} \geq 0.10$$

Limitations for Bond Equation

- $f_y \leqq 690$ MPa
- $f_{yt} \leqq 420$ MPa
- $f_c' \leqq 100$ MPa

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Outlines

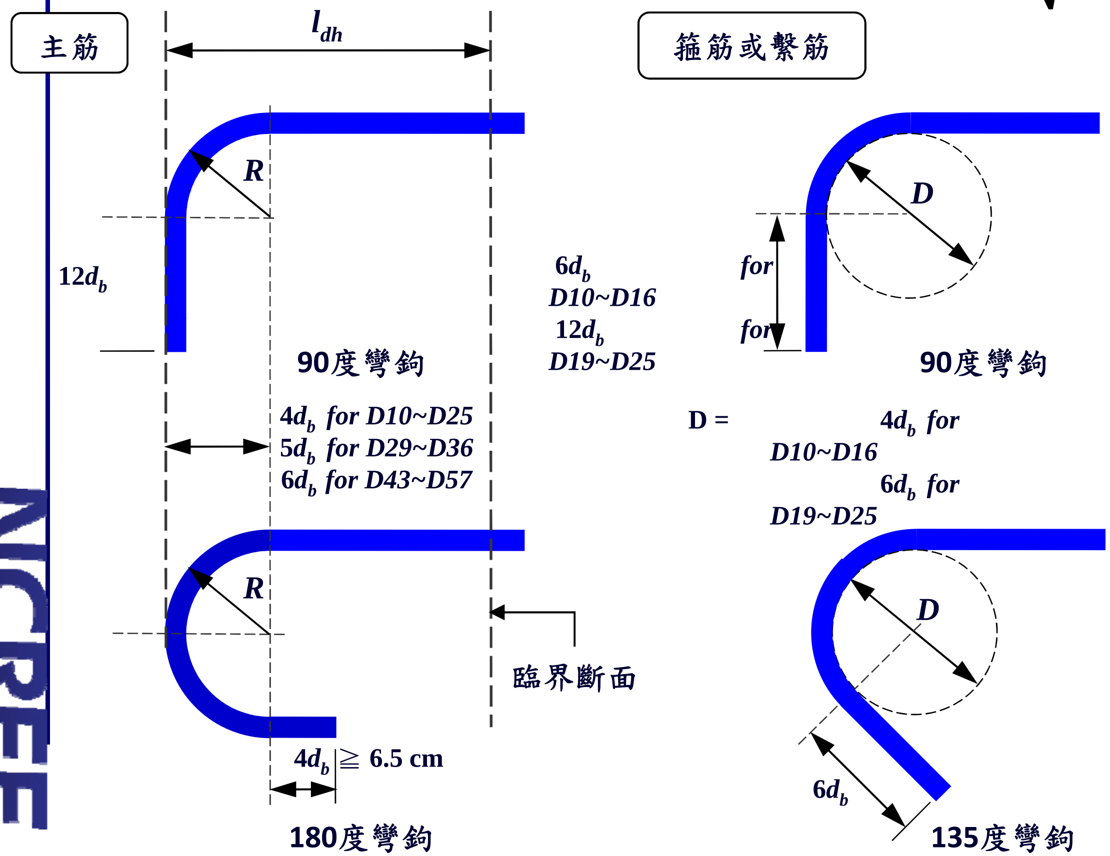
- Introduction
- Properties of Reinforcement
- **Development Length of Reinforcement in Tension**
  - Straight bar
  - **Hooked bar**
  - Headed bar
- Splices

Development of Standard Hooks

Section 8.1.3

Development length in tension following ACI 318 code (unit : SI)

$$l_{dh} = 0.24\frac{f_y \psi_e \lambda}{\sqrt{f_c'}} d_b$$



Limitations for Bond Equation

- $f_y \leqq 550$ MPa
- $f_{yt} \leqq 420$ MPa
- $f_c' \leqq 100$ MPa
- 彎鉤不計受壓

修正因子詳設計手冊之表8-3

Outlines

- Introduction
- Properties of Reinforcement
- Development Length of Reinforcement in Tension
  - Straight bar
  - Hooked bar
  - Headed bar
- Splices

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Introduction of Headed Bars

銲接式錨定頭鋼筋

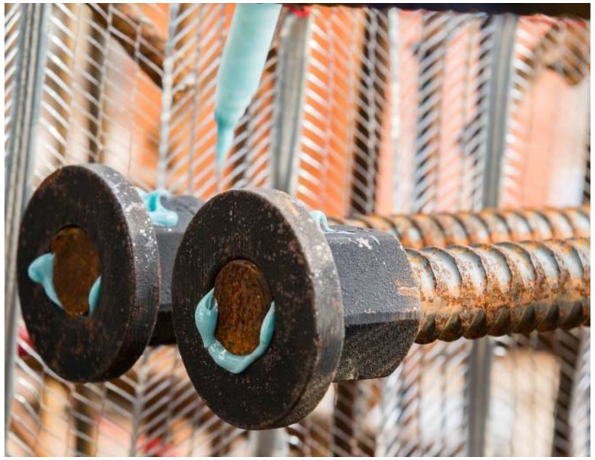
(東和鋼鐵)

銲接螺紋式錨定頭鋼筋

熱軋擴頭式錨定頭鋼筋

(日本DHF)

灌漿式套筒錨定頭鋼筋



(日本TTK)

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Related Provisions for Headed Bars

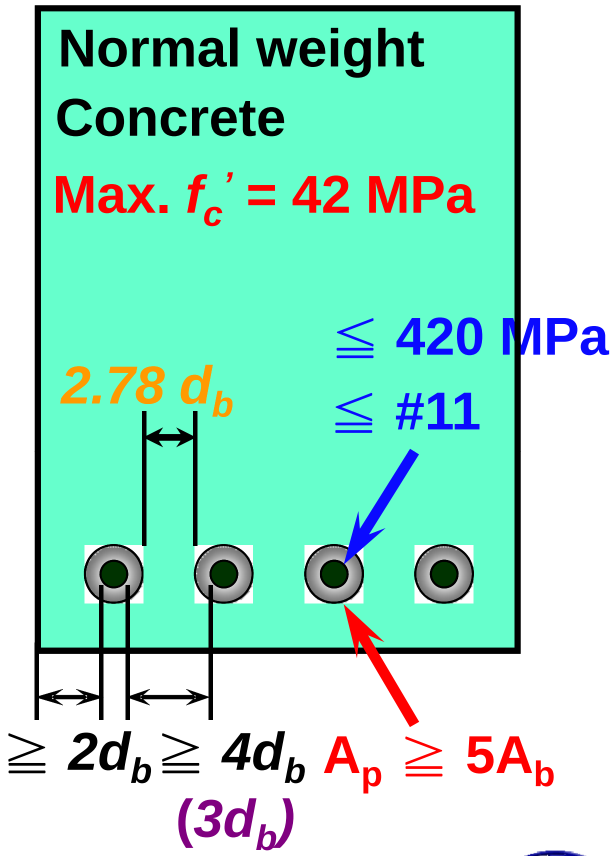
18.8.5.2 (Earthquake-Resistant Structures, 2014)

ACI 318-14 (2014)

25.4.4 Development of headed deformed bars in tension

25.4.4.1

(a) Bar shall conform to ASTM Rebar;
(b) Bar f_y shall not exceed 60,000 psi;
(c) Bar size shall not exceed No. 11;
(d) Concrete shall be normal weight;
(e) Net bearing area of head A_{brg} shall not be less than $4A_b$;
(f) Clear cover for bar shall not be less than $2d_b$;
(g) Clear spacing between bars shall not be less than $4d_b$.
$3d_b$ for seismic design. (18.8.5.2)



Related Provisions for Headed Bars

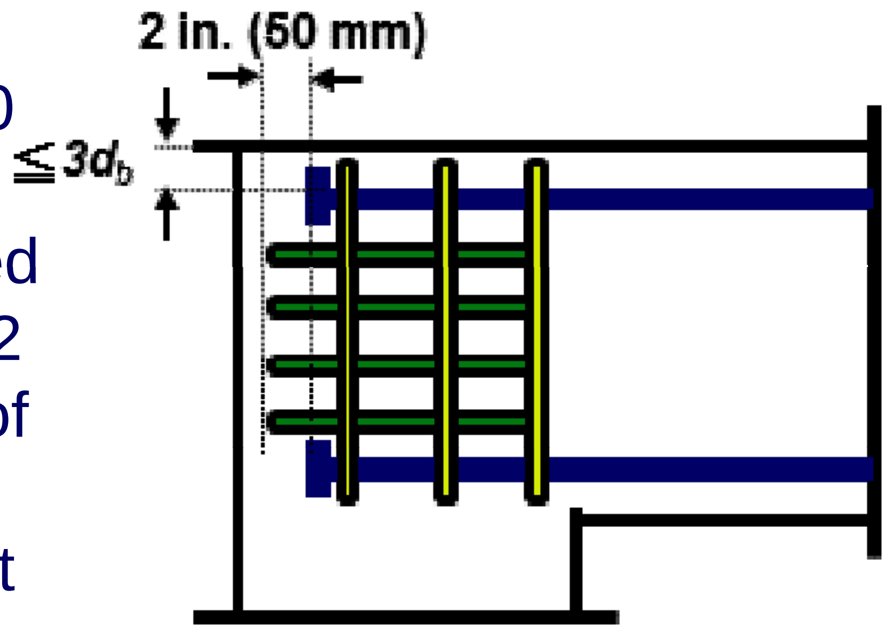
ACI 352-02 (2002)

4.5.3 Headed bars terminating in the connection

(a) Net bearing area of head A_{brg} shall meet ASTM A970 standard.

(b) Bar heads should be located in the confined core within 2 in. (50 mm) from the back of the confined core.

(c) Clear cover for bar shall not be less than $3d_b$, otherwise transversely restrained stirrup or hoop leg is needed.



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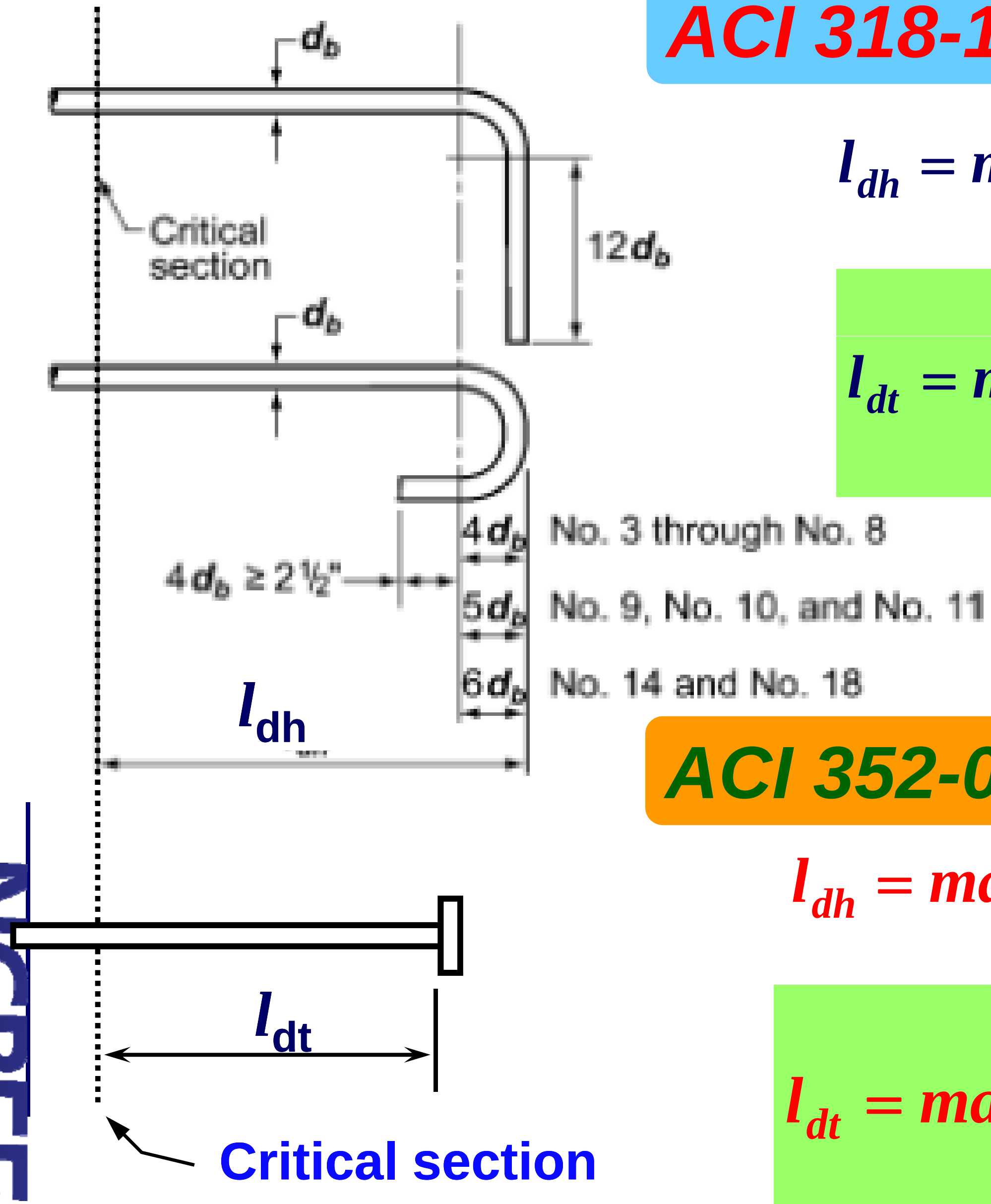
Development Length of L_{dh} and L_{dt}



ACI 318-14

$$l_{dh} = max\left\{0.24\frac{f_y}{\sqrt{f_c'}}d_b\ ,8d_b\ ,150mm\right\}$$

$$l_{dt} = max\left\{0.19\frac{f_y}{\sqrt{f_c'}}d_b\ ,8d_b\ ,150mm\right\}$$

$$L_{dt} = 0.8\ L_{dh} \quad (ACI\ 318-14)$$

$$L_{dt} = 0.75\ L_{dh} \quad (ACI\ 352-02)$$

ACI 352-02

$$l_{dh} = max\left\{0.16\frac{f_y}{\sqrt{f_c'}}d_b\ ,8d_b\ ,150mm\right\}$$

$$l_{dt} = max\left\{0.12\frac{f_y}{\sqrt{f_c'}}d_b\ ,8d_b\ ,150mm\right\}$$

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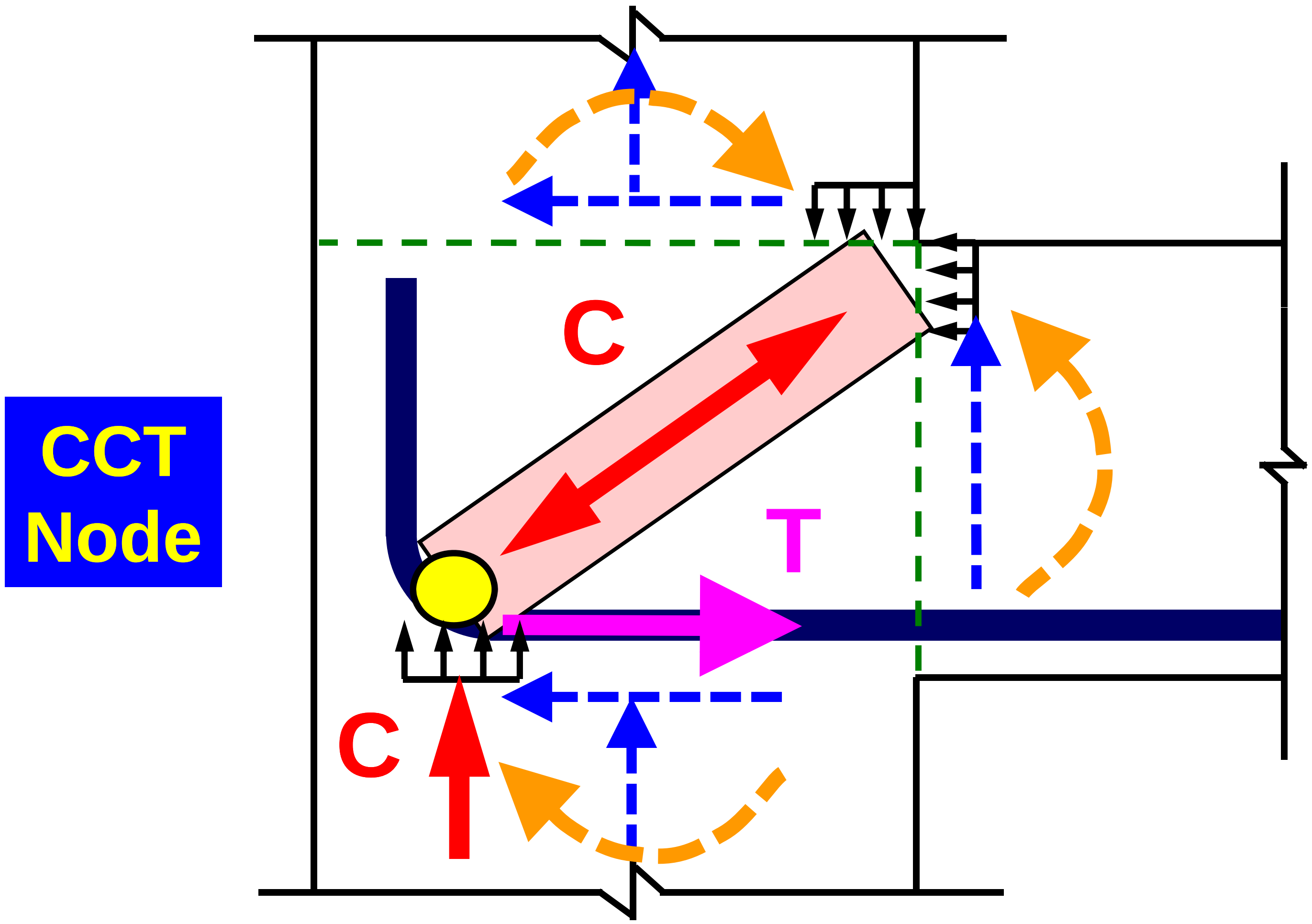
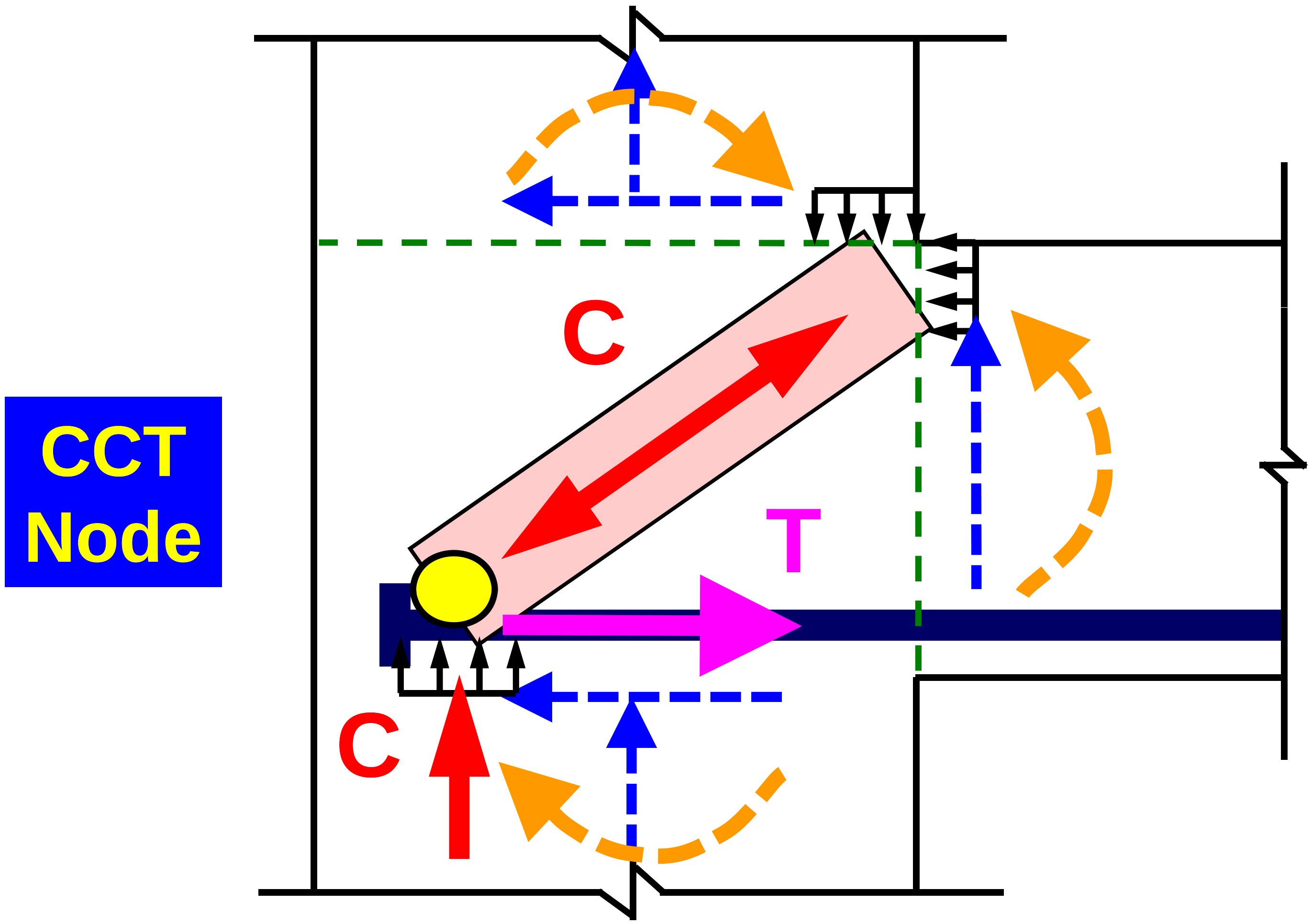
Force Mechanism of Hook



C：Compression

T：Tension

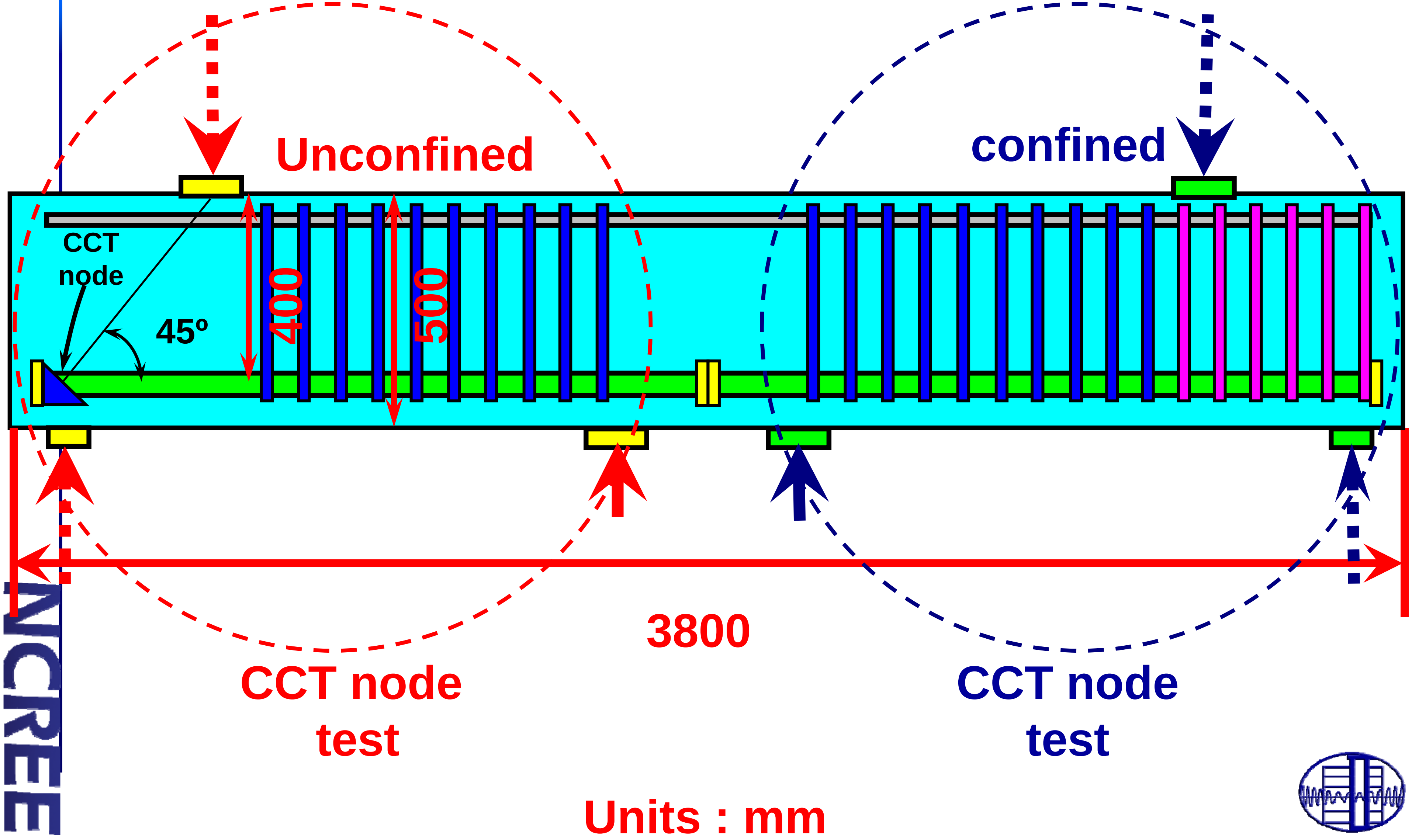
Force Mechanism of T-Head



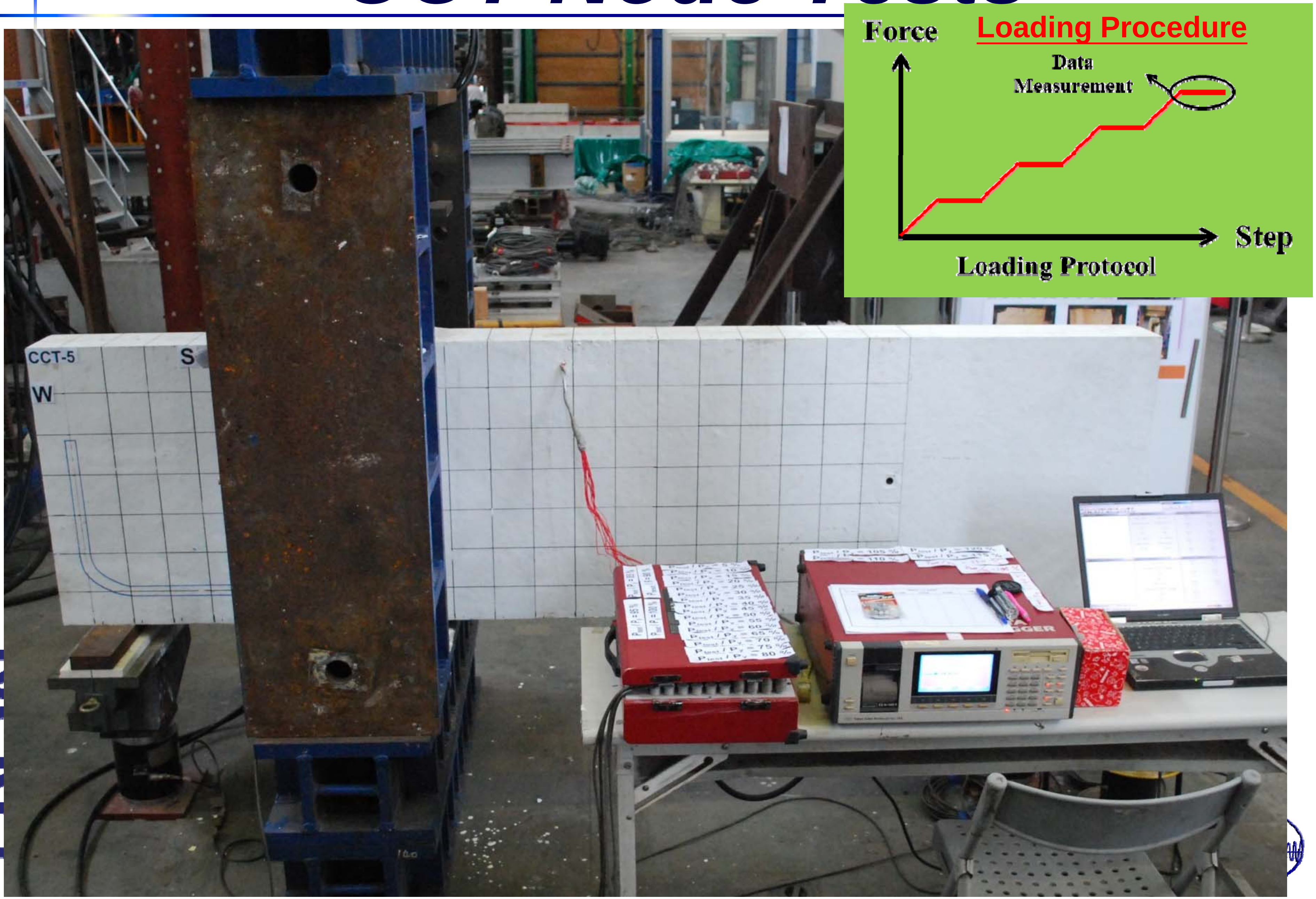
C：Compression

T：Tension

Experimental Program (CCT Node)



CCT Node Tests



Design Variables of Specimens (I)

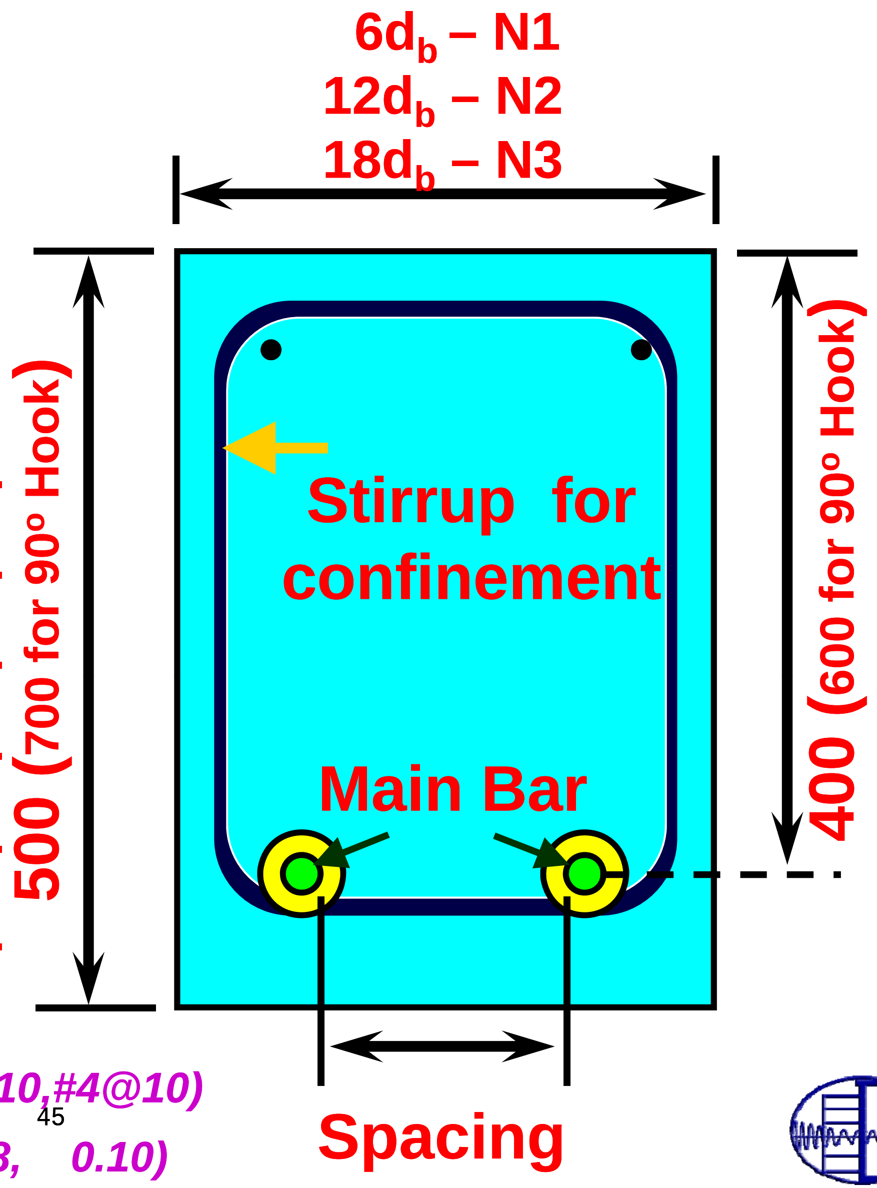
紀凱甯 - 2010

Number of Specimens:

- *43*

Variables:

Type	*Hook(90º,180º)* *Head(no, yes)*
Main bar	*#8,#10,#11*
A_p/A_b	*1,3,5,7*
No.of bar	*1,2,3*
Spacing	*$1.5d_b$,$4d_b$*
f_c'(MPa)	*42,56,70*
Confine	*no* *yes(#3@20,#3@10,#4@10)* *(0.04, 0.08, 0.10)*



Units : mm

Design Variables of Specimens (II)

紀凱甯 - 2014

CCT Node for Hooked

CCT Node for Headed

Spec.	Width B (mm)	Depth D (mm)	Bar d_b (mm)	Anchorage Type	f_y (MPa)	f_{yt} (MPa)	f_c' (MPa)	Confine (mm)
CCT-1	150	700	25	90º Hook	690	790	70	X
CCT-2	150	700	25	90º Hook	690	790	70	D10@100
CCT-3	150	700	25	Plate Nut	690	790	70	X
CCT-4	150	700	25	Plate Nut	690	790	70	D10@100
CCT-5	160	700	32	90º Hook	690	790	70	X
CCT-6	160	700	32	90º Hook	690	790	70	D10@100
CCT-7	160	700	32	Plate Nut	690	790	70	X
CCT-8	160	700	32	Plate Nut	690	790	70	D10@100

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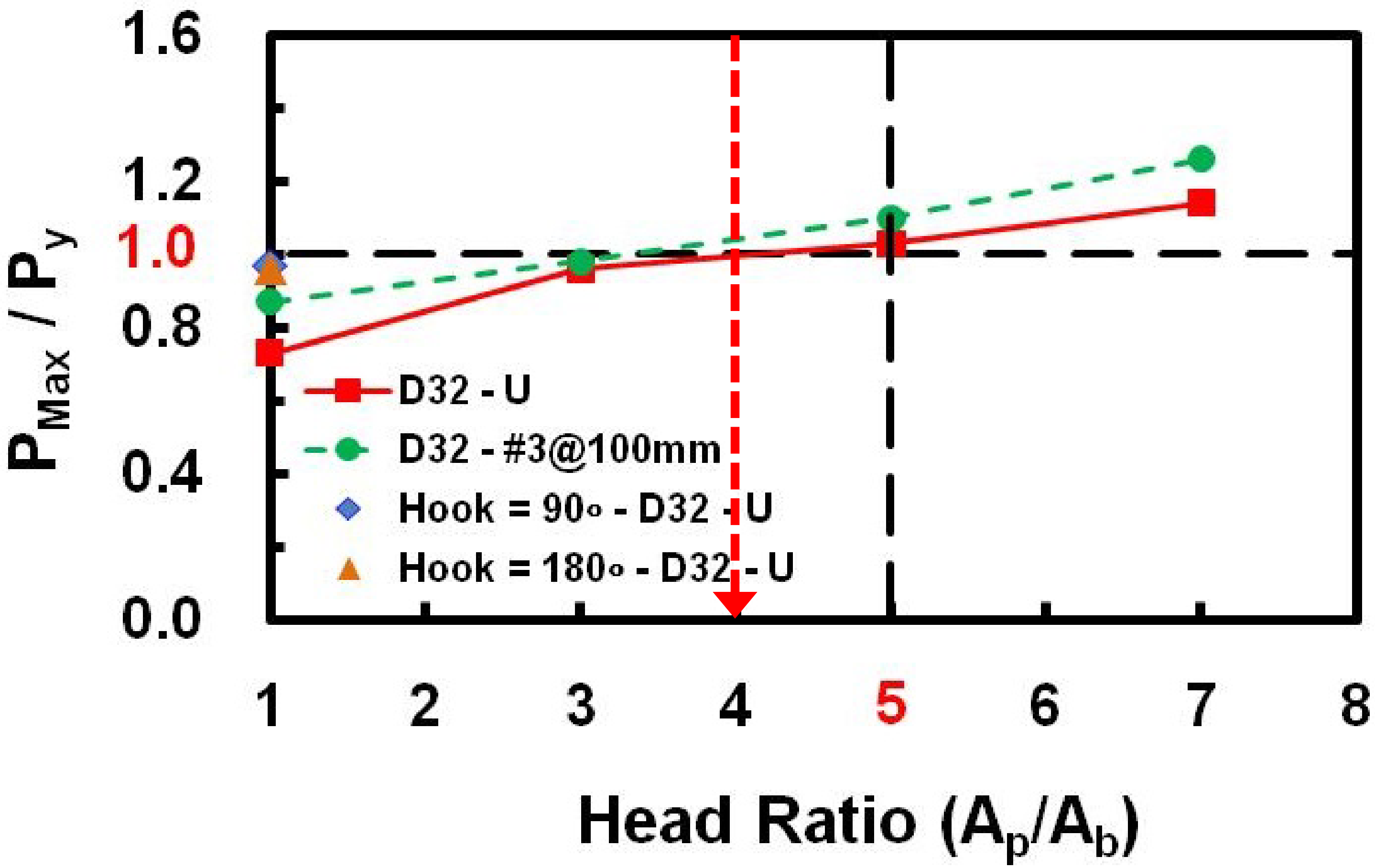
Anchorage Strength – Head Ratio (I)



Benefit：Hook → T head
Suggestion：T head ratio = 4

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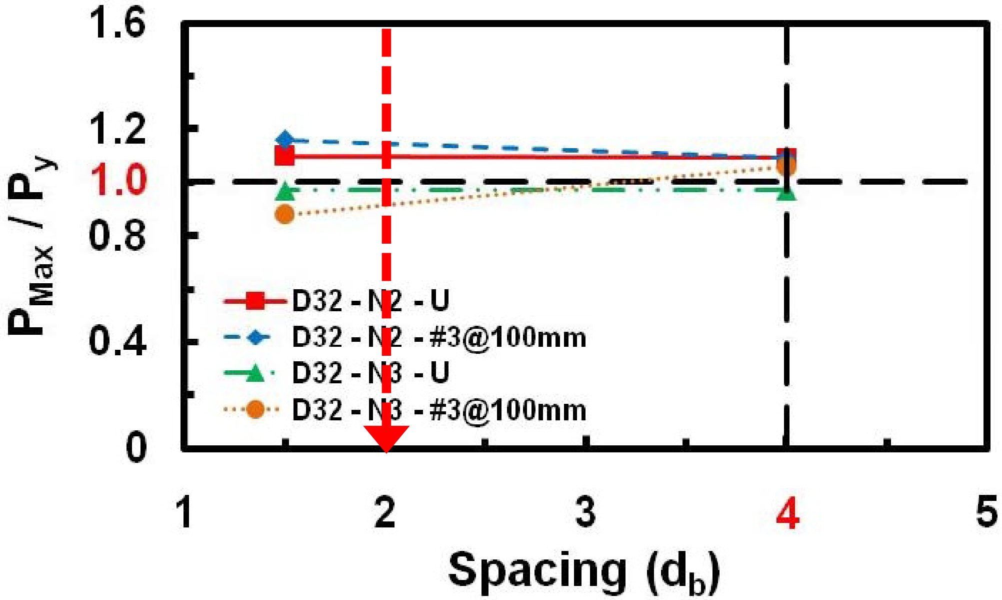
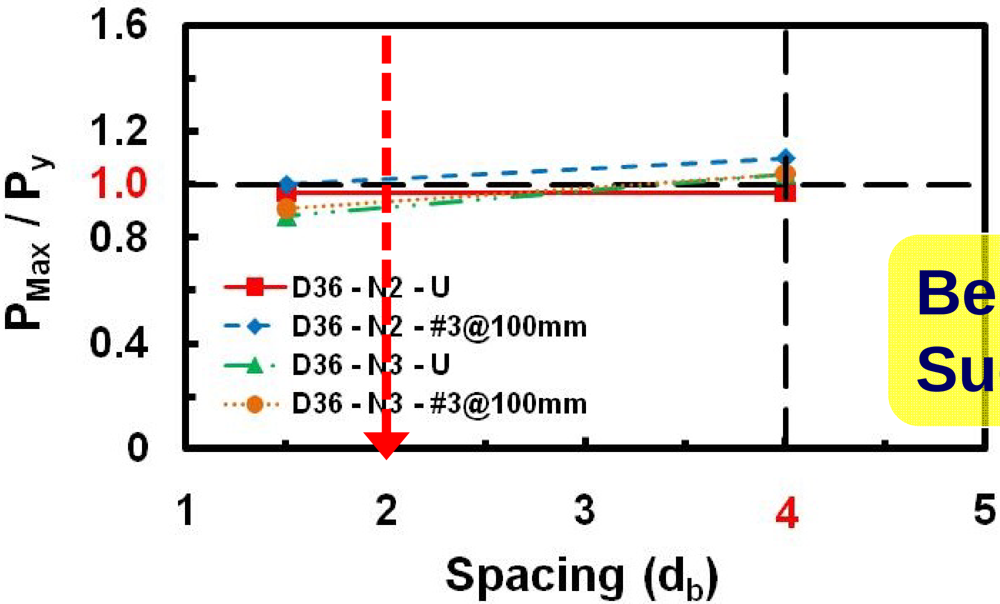
Anchorage Strength – Spacing of bars (I)





Benefit： break $4d_b$ limit

Suggestion：Spacing ≒ $2d_b$

Summary

- 當擴頭鋼筋搭配端鈑面積為3A$_b$時，其錨定強度與標準90°彎鉤鋼筋相當；當擴頭鋼筋搭配端鈑面積為5A$_b$與7A$_b$時，其錨定強度分別較標準90°彎鉤鋼筋提升6%與18%。
- 本研究建議採用擴頭鋼筋進行錨定時，擴頭端鈑面積應為4A$_b$。

- 擴頭鋼筋淨間距1.5d$_b$與4d$_b$之錨定強度相當。
- 本研究建議採用擴頭鋼筋進行錨定時，擴頭鋼筋之淨間距應至少2d$_b$。

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Exterior Beam-Column Joints (I)

陳政宇、高文良、許書豪 - 2010、2012、2014

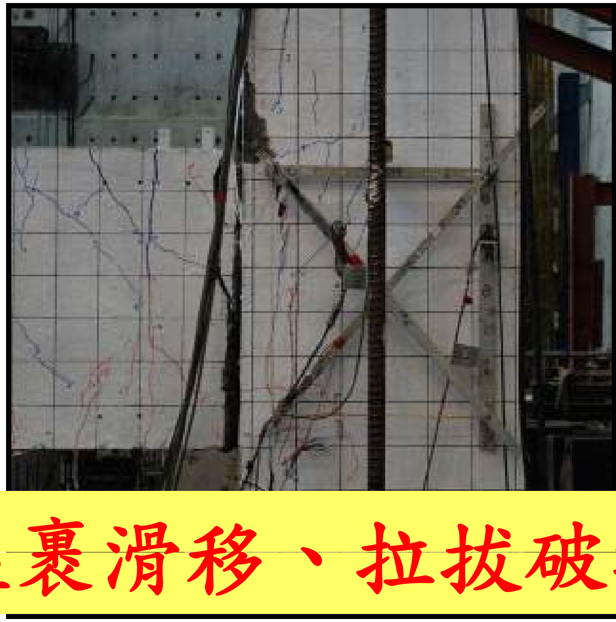
Specimens	f_c / f_y (MPa)	f_{ca} / f_{ya} (MPa)	Column b / h (mm)	Beam b / h (mm)	Beam Main bars	Beam s (d_b)	Joint End Type	Joint l_{test}/d_b	Joint $V_{jh,u}/V_{n,ACI\ 318}$
JT6_TB528_IV_L	42	46.8	650	400	T 6-#8	2.2	IV	21.1	0.59
	420	445	650	700	B 6-#8	2.2	IV	21.1	
JT6_TB528_V_L	42	49.4	650	400	T 6-#8	2.2	V	21.1	0.58
	420	445	650	700	B 6-#8	2.2	V	21.1	
JT6_T309B216_IV_L_1	42	50.0	650	400	T 6-#8	2.2	IV	12.4	0.61
	420	445	650	700	B 6-#8	2.2	IV	8.6	
JT6_T309B216_IV_L_2	42	50.2	650	400	T 6-#8	2.2	IV	12.4	0.61
	420	465	650	700	B 6-#8	2.2	IV	8.6	
JT6_T450B380_IV_L	42	53.8	650	400	T 6-#8	2.2	IV	18.0	0.61
	420	465	650	700	B 6-#8	2.2	IV	15.2	
JT6_TB309_IV_L	42	50.0	650	400	T 6-#8	2.2	IV	12.4	0.61
	420	465	650	700	B 6-#8	2.2	IV	12.4	
JT8_TB358_IV_H	42	41.5	550	400	T 8-#8	2	IV	14.3	1.01
	420	456	600	600	B 8-#8	2	IV	14.3	
JT8_TB358_IV_M	42	47.8	650	400	T 8-#8	2	IV	14.3	0.85
	420	456	600	600	B 8-#8	2	IV	14.3	
JT8_TB358_IV_L	42	44.6	750	400	T 8-#8	2	IV	14.3	0.74
	420	456	600	600	B 8-#8	2	IV	14.3	
JT8_TB323_IV_H	42	42.6	550	400	T 8-#8	2	IV	12.9	1.01
	420	456	600	600	B 8-#8	2	IV	12.9	
JT8_TB323_IV_M	42	47.5	650	400	T 8-#8	2	IV	12.9	0.85
	420	456	600	600	B 8-#8	2	IV	12.9	
JT8_TB440_IV_H	42	38.8	550	400	T 8-#8	2	IV	17.9	1.01
	420	456	600	600	B 8-#8	2	IV	17.6	

End Type:

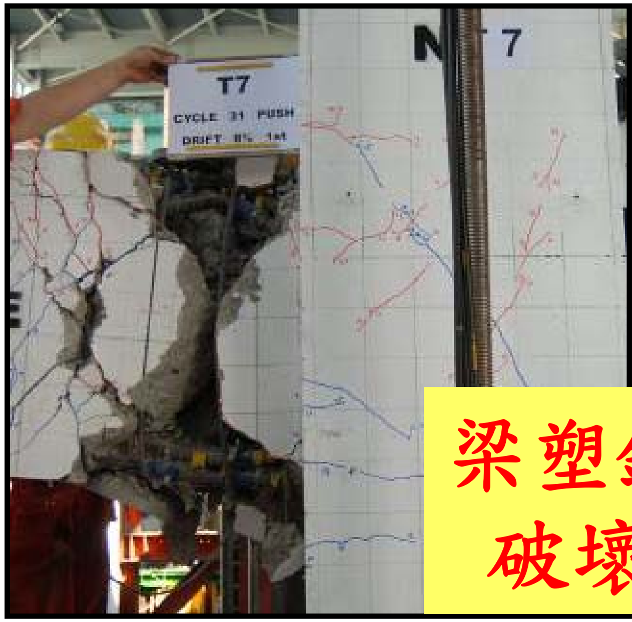
IV：headed

V ：Hooked

Failure Modes



握裹滑移、拉拔破壞



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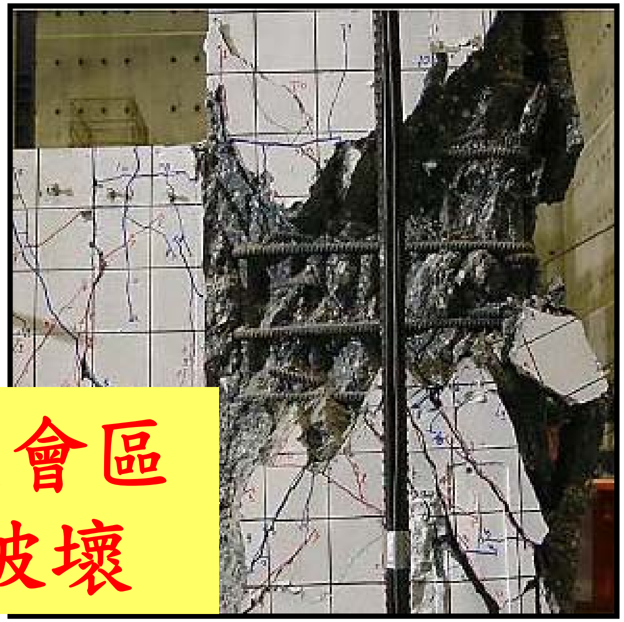

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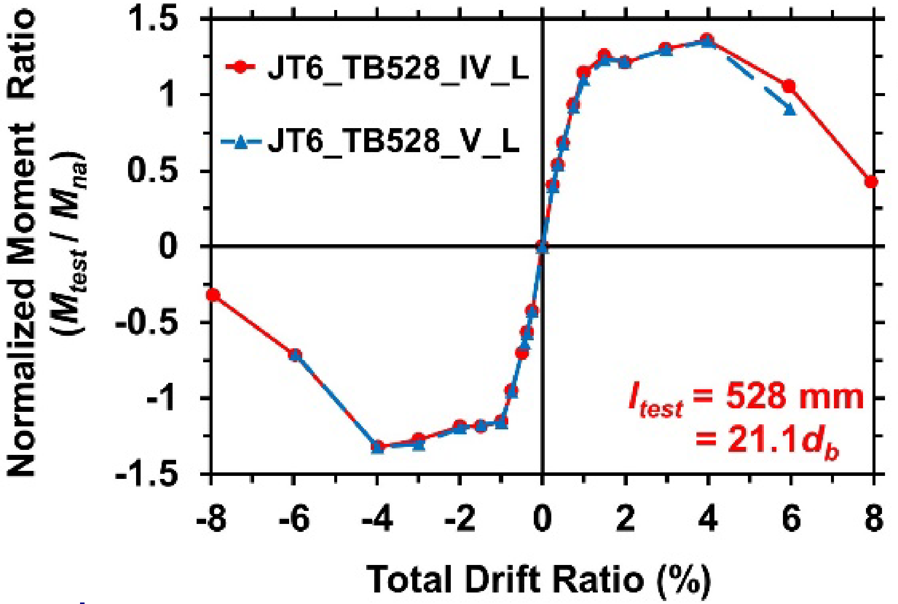
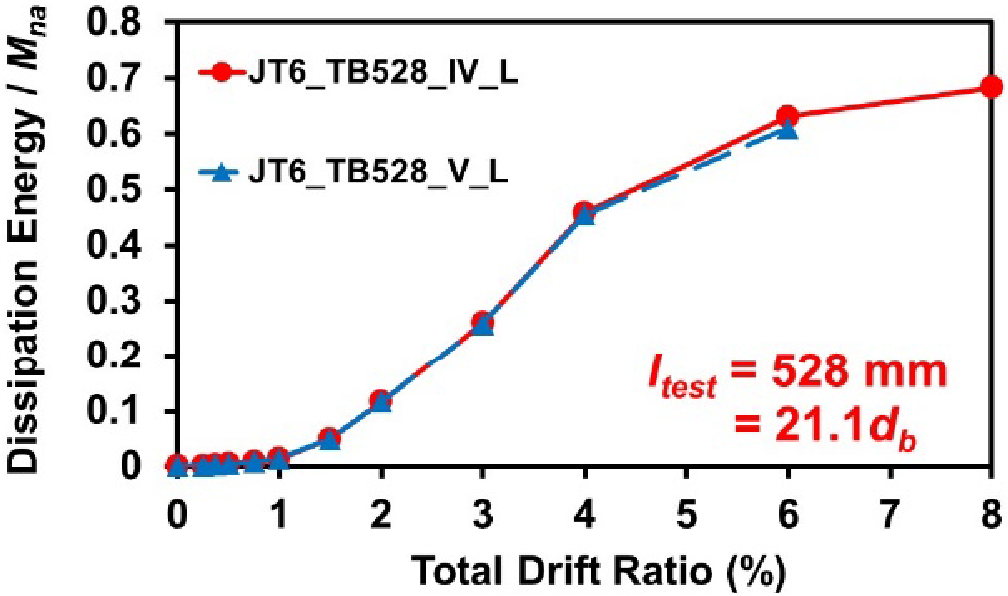
Comparisons of Headed and Hooked





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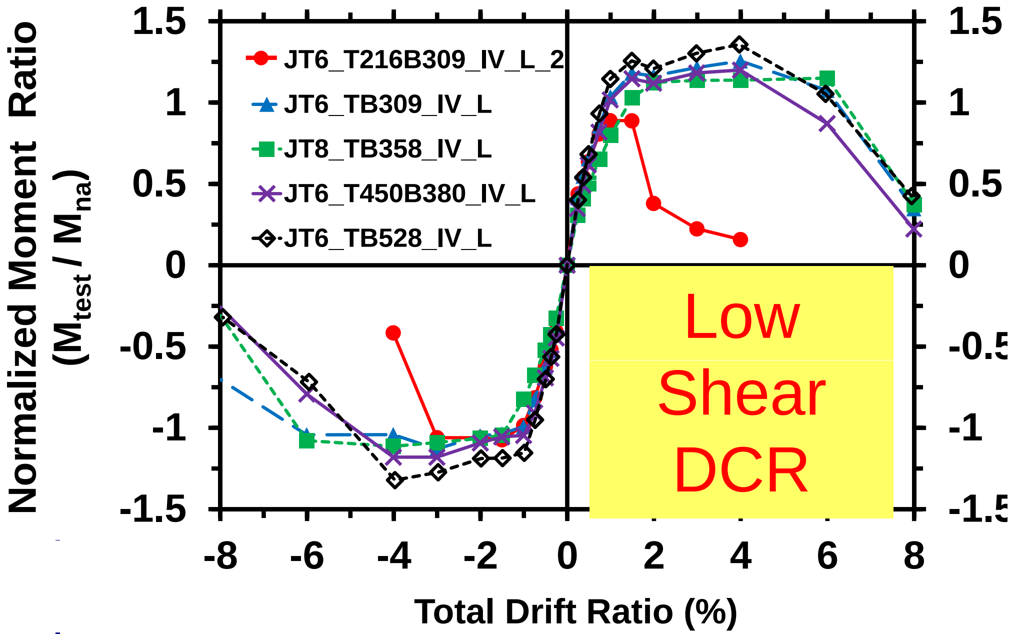
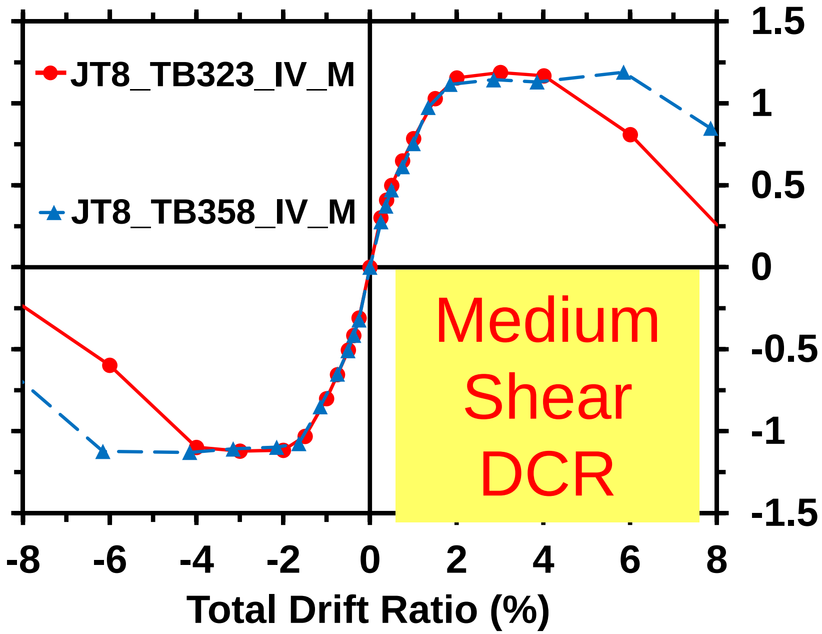
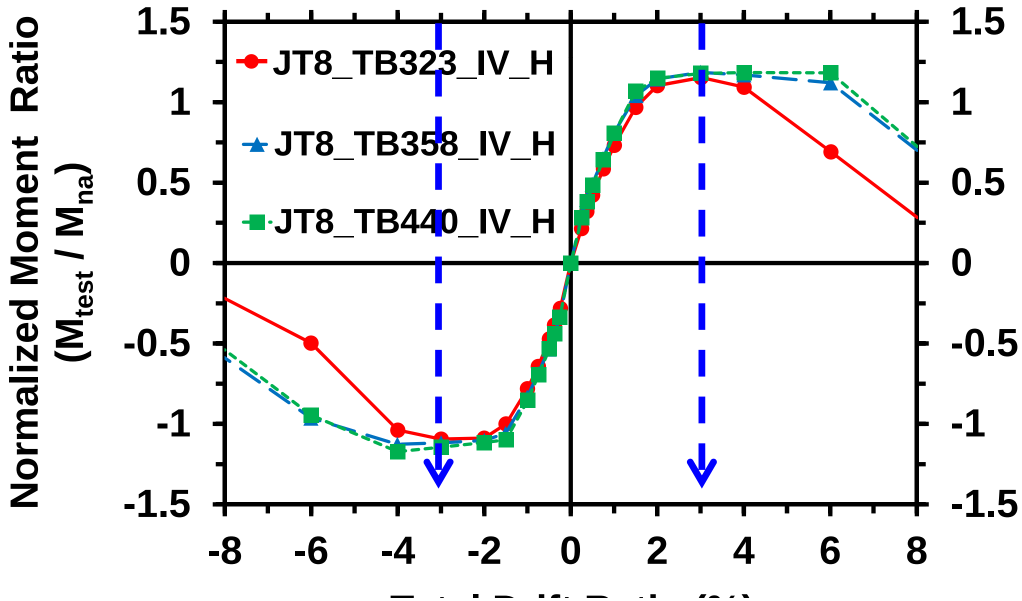
Different Shear Demand at PZ





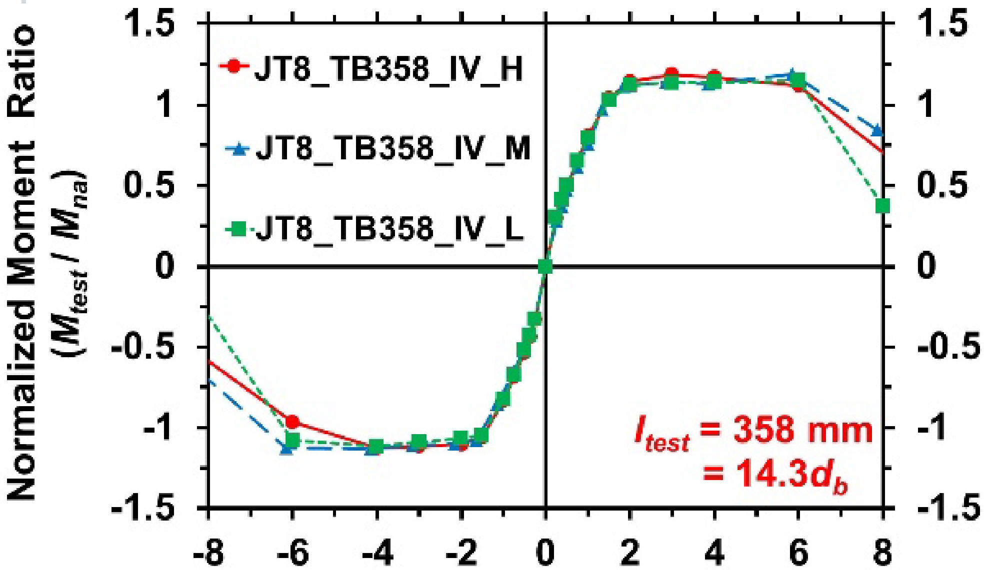


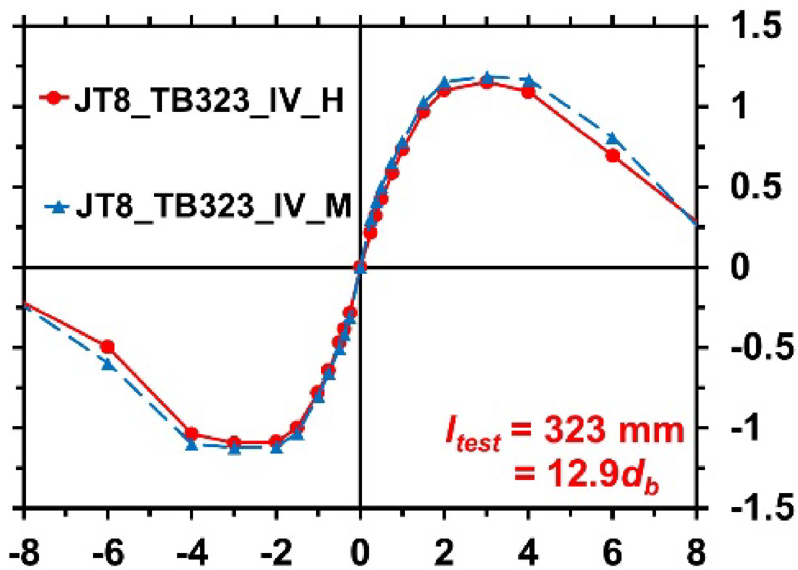
High Shear DCR

3%前

行為相當

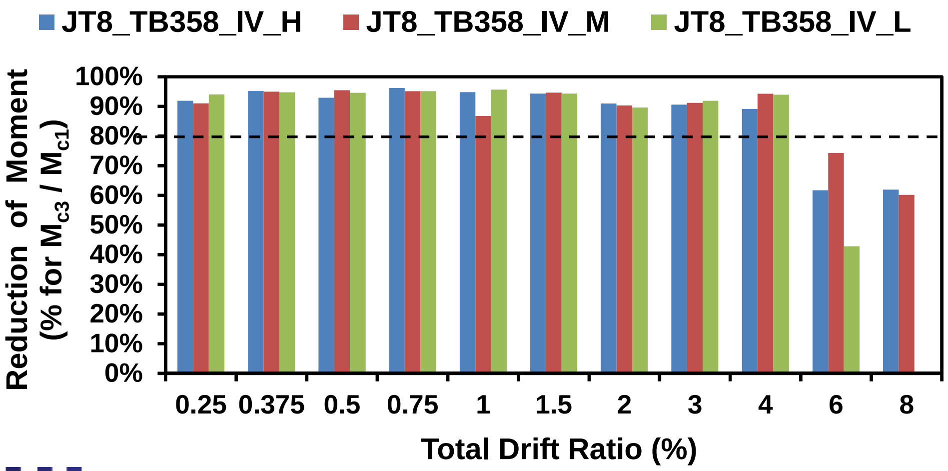
l_{dt} and Shear Demand at PZ

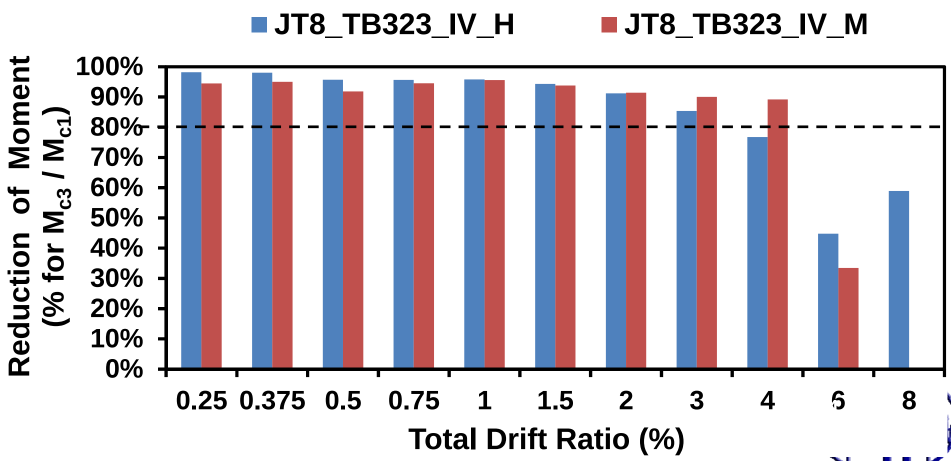




L_{dt} 滿足<u>ACI 318</u>規定

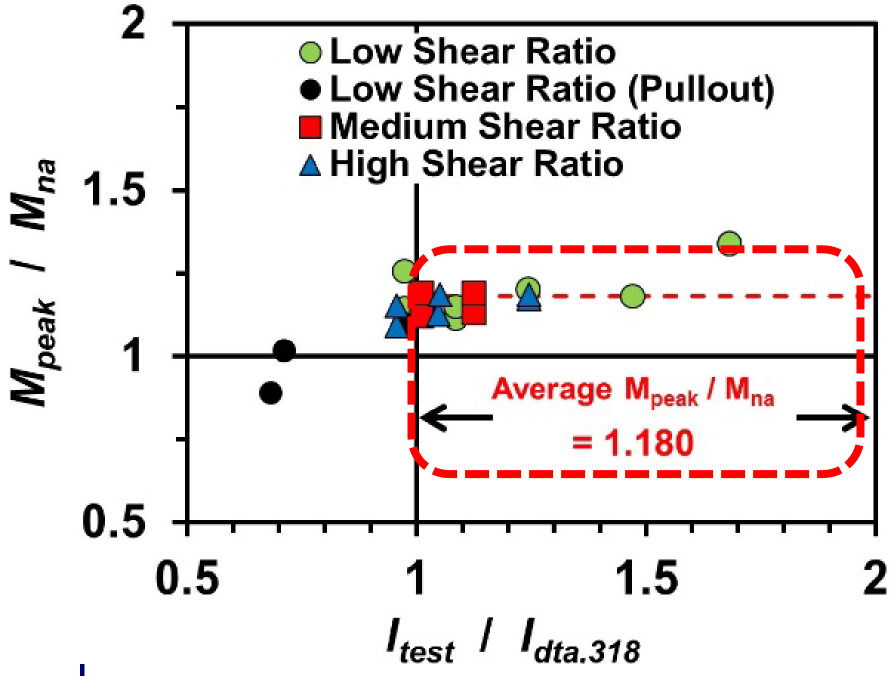
L_{dt} 滿足<u>ACI 352</u>規定



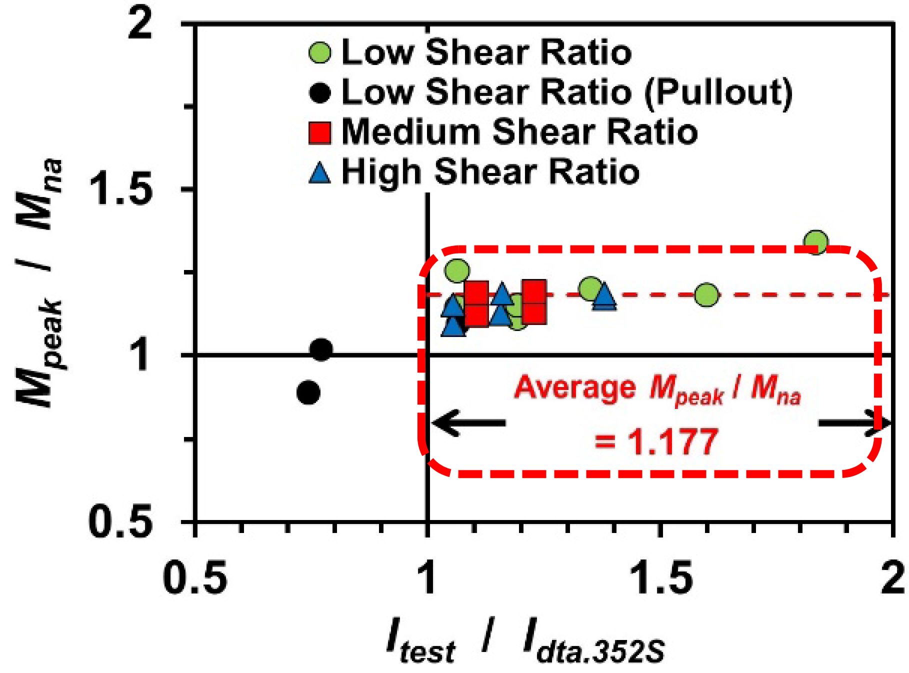


Flexural Strength

ACI 318



ACI 352



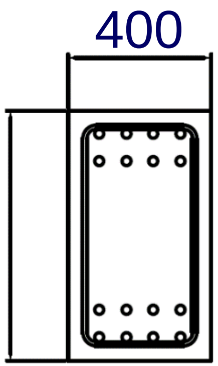
SH OS

1.77 x 1.084 = 1.28 > 1.25

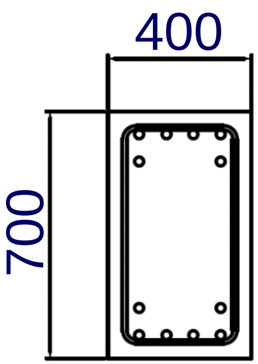
Exterior Beam-Column Joints

P-δ effect (趙偉帆 – 2015)

Variables	LAHV (11/2)	LAMV (11/5)	HAHV (11/19)	HAMV (11/24)
F_c' (MPa)	93.8	81.2	89.8	84.1
F_y (MPa)	710			
V_{jh} / V_n	**0.907**	0.729	**0.928**	0.716
L_{dt} (mm)	**390 (ACI 318-14 Code)**			
$P / A_g f_c'$	**0.10**	**0.10**	**0.45**	**0.44**

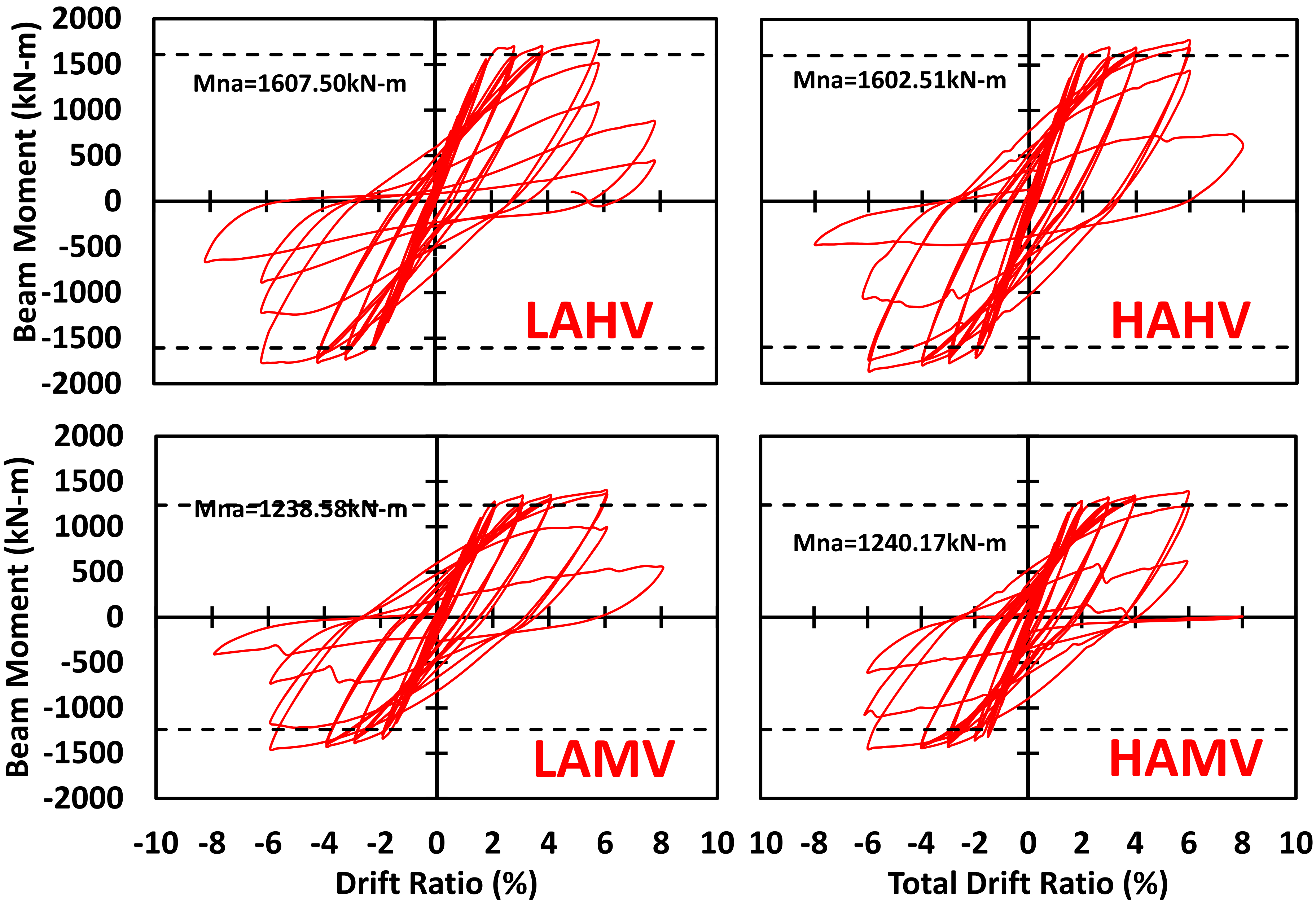


LAHV、HAHV
主筋16-#8
箍筋#4@100
繫筋#4@100

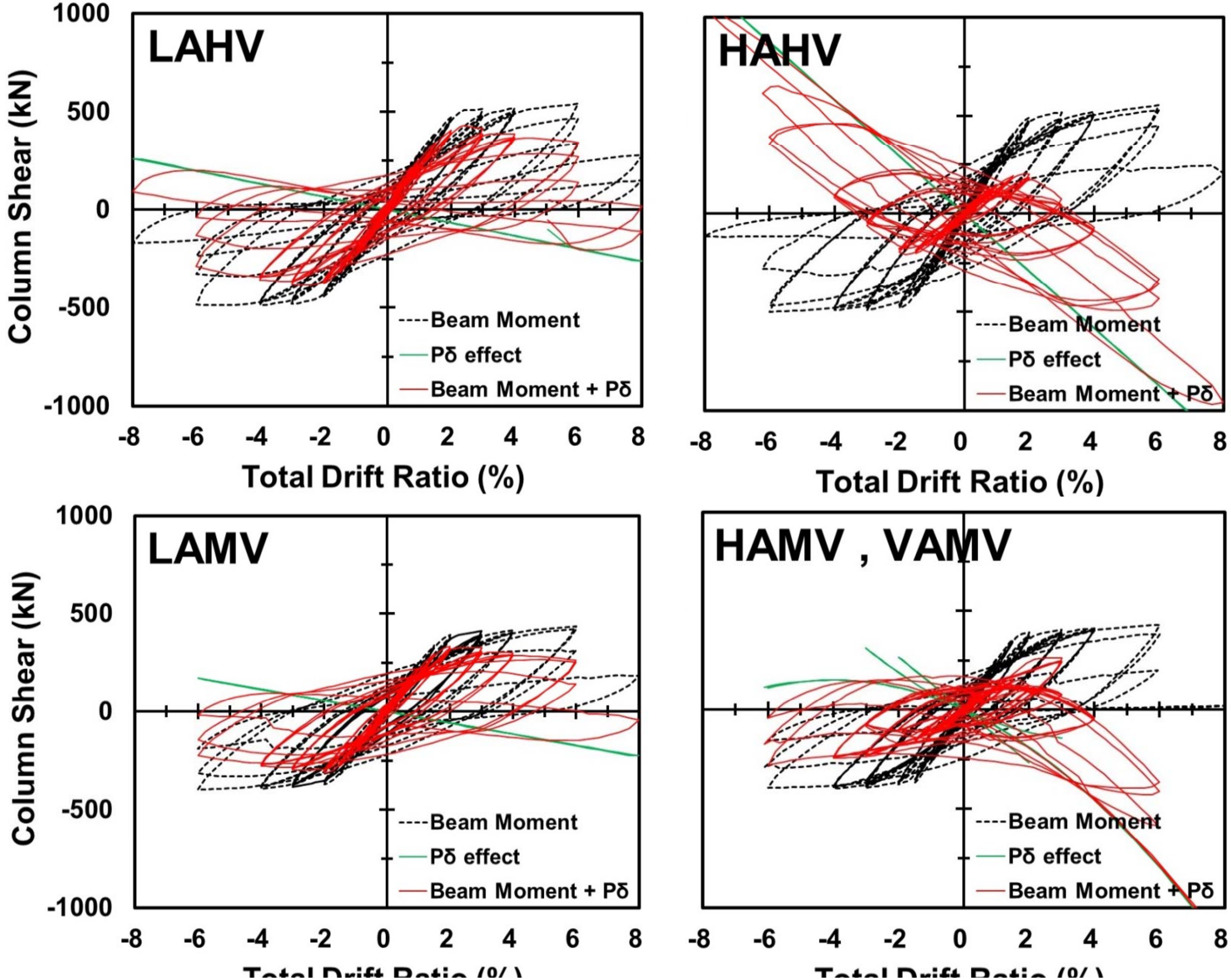


LAMV、HAMV
主筋12-#8
箍筋#4@100
繫筋#4@100

Tests Results for P-δ effect of BC Joints



Tests Results for P-δ effect of BC Joints



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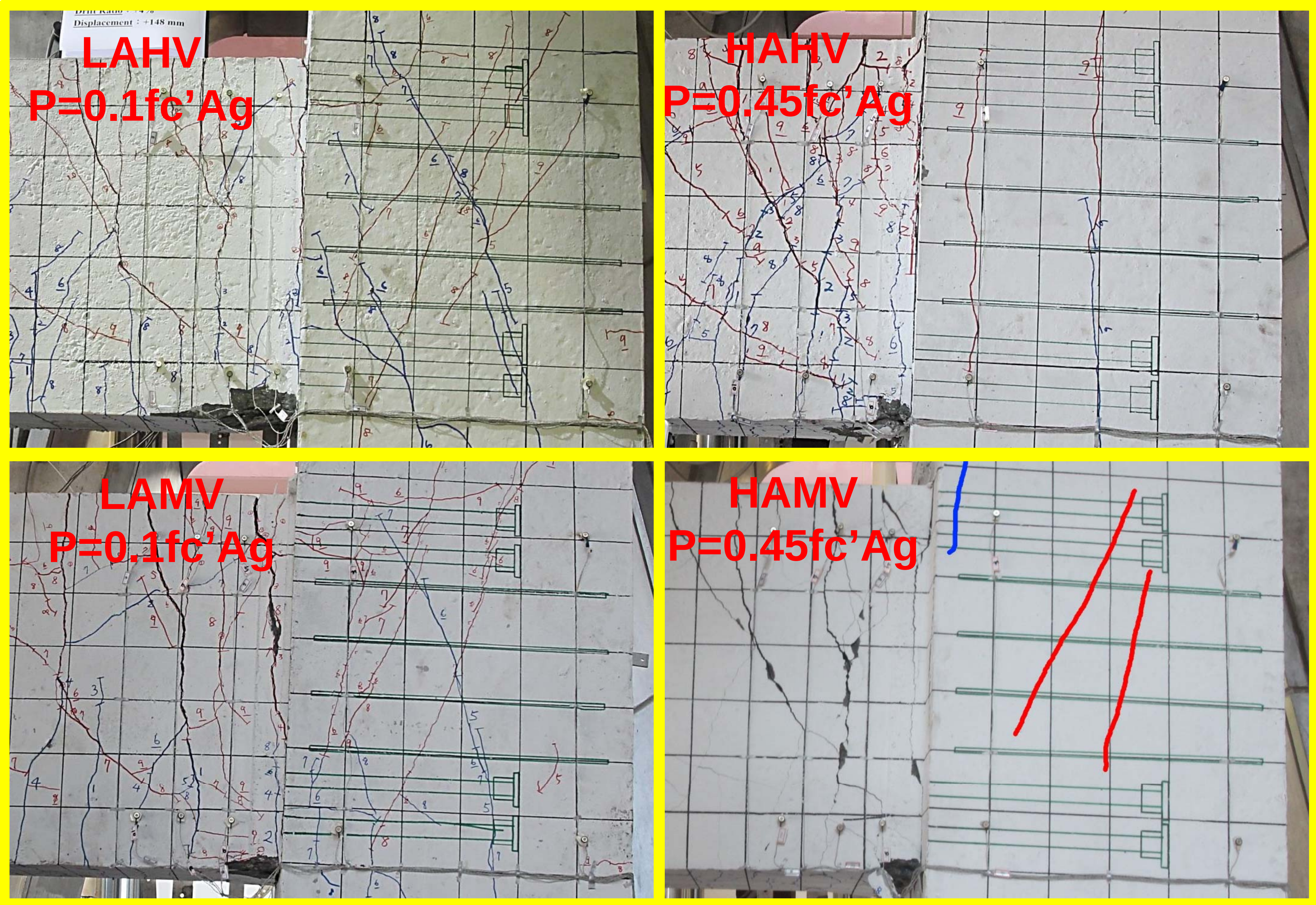
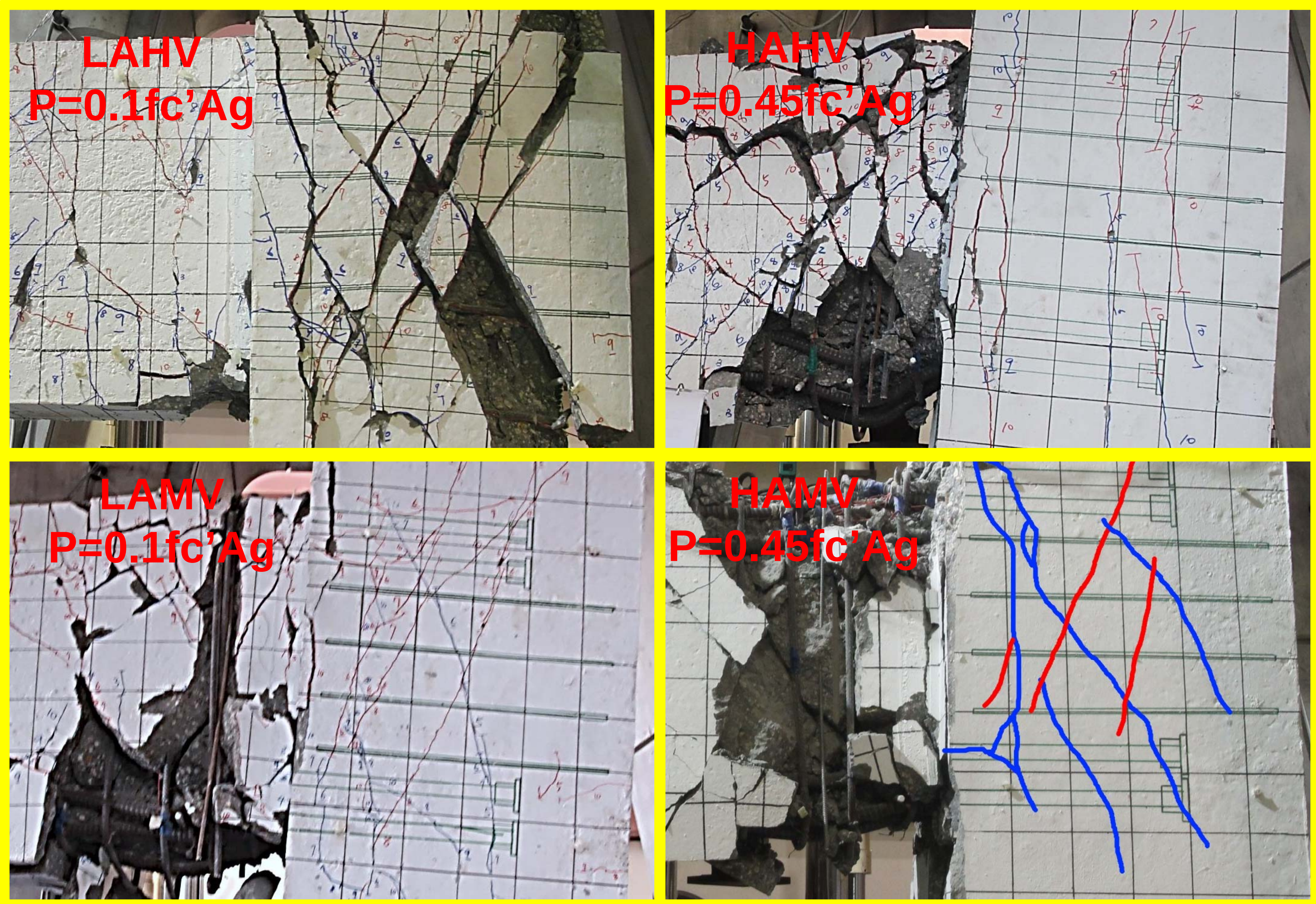
Crack at 4%


Displacement : +148 mm
LAHV
P=0.1fc'Ag
HAHV
P=0.45fc'Ag
LAMV
P=0.1fc'Ag
HAMV
P=0.45fc'Ag

Failure at 8%



Summary (I)

- 當梁構件主筋淨間距為2.2d_b且錨定長度配置充分並相同時，採用擴頭鋼筋與傳統標準90度彎鉤鋼筋錨定於交會區之試體，其耐震性能相當，顯示可採用擴頭鋼筋取代標準90度彎鉤鋼筋錨定於交會區。
- 本研究結果顯示，只要梁構件主筋採用擴頭鋼筋且錨定長度符合ACI 318-14規範建議之發展長度時，擴頭鋼筋淨間距配置2d_b之梁柱接合試體可滿足ACI 374.1-05之接合性能評估準則。

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Summary (II)

- 當擴頭鋼筋錨定於交會區長度均至少滿足ACI 318-11規範建議之發展長度者，可符合強度、勁度與能量之耐震性能評估準則，為耐震接合；滿足ACI 352-02規範建議之發展長度者，僅能符合強度性能評估準則。
- 當擴頭鋼筋之錨定長度配置符合規範ACI 352-02規定之發展長度時，其鋼筋應變硬化因子平均值約為1.177，若同時考慮鋼筋材料平均超強因子1.084，則鋼筋實際發展之強度約可達鋼筋設計降伏強度之1.28倍，滿足耐震設計規範之1.25倍。

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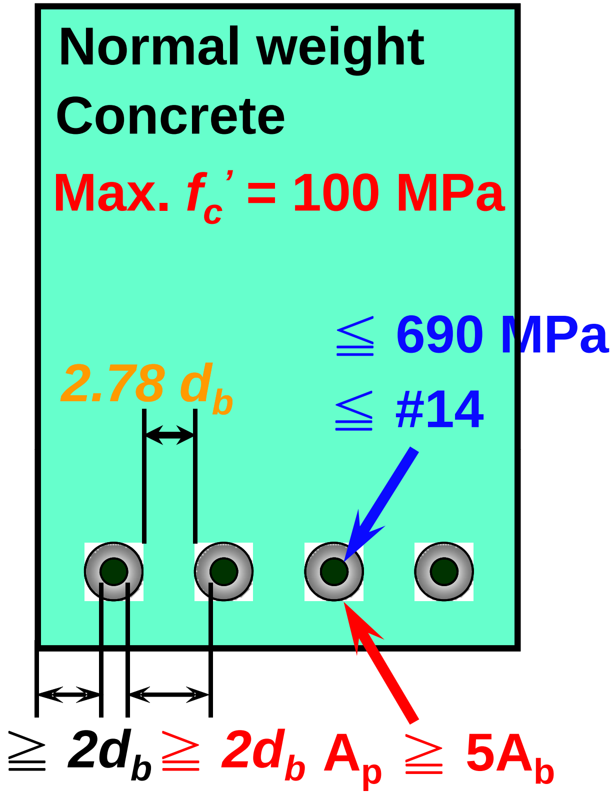
Summary (III)

- 在層間位移角4%弧度之性能評估基準下，當擴頭鋼筋之錨定長度滿足ACI 318-11規範時，即使交會區剪力需求與容量比值高達1.0，其梁柱接合試體之耐震性能均能滿足ACI 374.1-05之耐震性能評估準則，不受交會區剪力需求容量比值大小之影響；
- 擴頭鋼筋之錨定長度滿足ACI 352-02下，只要交會區剪力需求與容量比值大於0.9，其耐震性能可能無法達到ACI 374.1-05之耐震性能評估基準之風險。

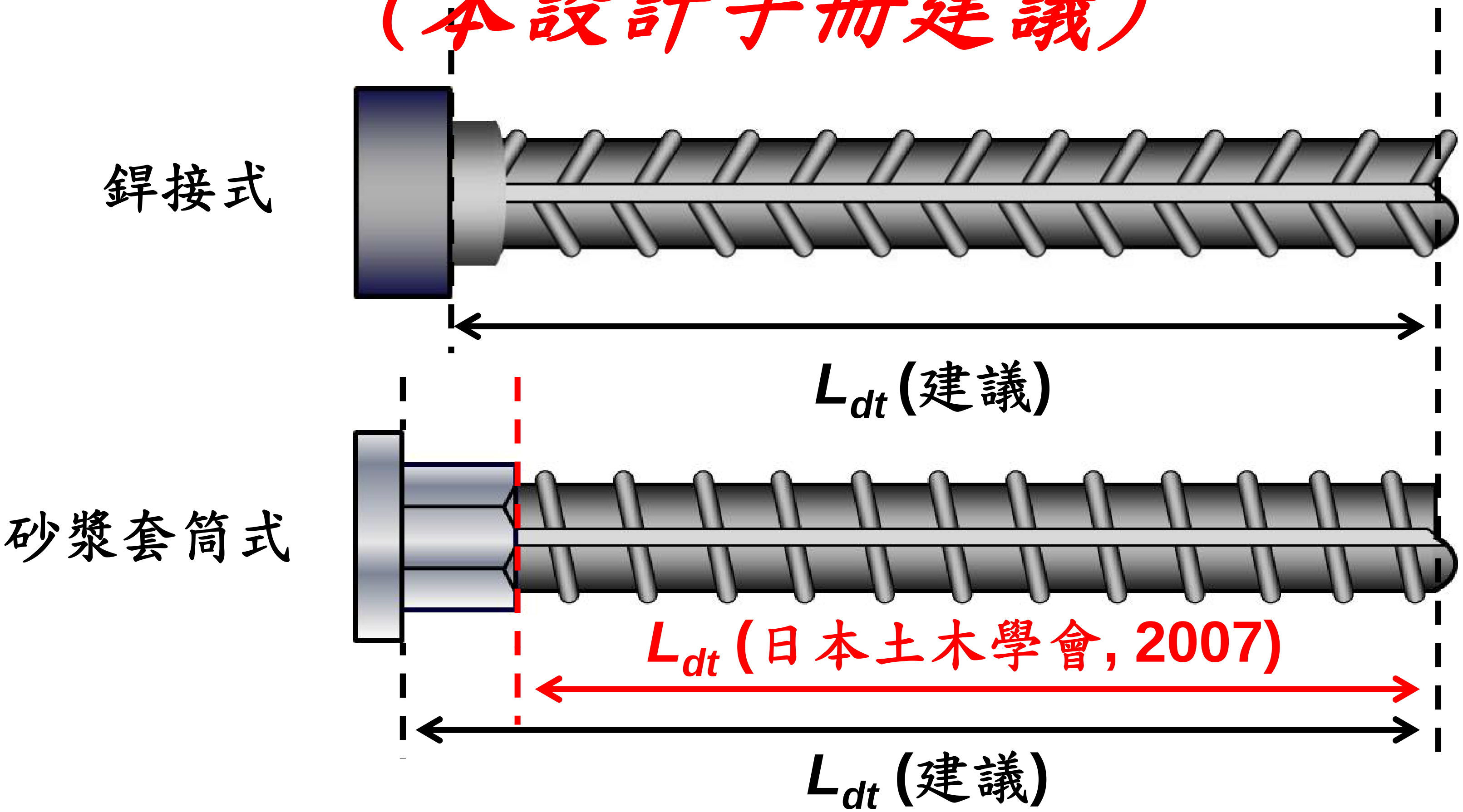
Development of Headed Bars in Tension (本設計手冊建議)

- (a) f_y shall not exceed 690 MPa;
- (b) Bar size shall not exceed No. 14;
- (c) Net bearing area of head $\boldsymbol{A_{brg}}$ shall not be less than $\boldsymbol{4A_b}$;
- (d) Clear cover for bar shall not be less than $\boldsymbol{2d_b}$;
- (e) Clear spacing between bars shall not be less than $\boldsymbol{2d_b}$;
- (f) Concrete shall be normal weight;
- (g) f_c' shall not exceed 100 MPa;



Development Length of L_{dt}

（本設計手冊建議）



$$L_{dt} = max\left\{0.19\frac{f_y}{\sqrt{f_c'}}d_b\ ,\ 8d_b\ ,\ 150mm\right\}$$

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Outlines

- Introduction
- Properties of Reinforcement
- Development Length of Reinforcement in Tension
  - Straight bar
  - Hooked bar
  - Headed bar
- **Splices**

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灌漿式鋼筋續接器種類

無機砂漿螺紋套筒續接器

ACE Joint

樹酯砂漿螺紋套筒續接器

F型螺紋套筒續接器

Free Joint

砂漿填充非螺紋套筒續接器
（兩端均為非螺紋）

Top Joint

砂漿填充非螺紋套筒續接器
（一端螺紋，一端非螺紋）

(東京鐵鋼Tokyo Tekko Co.）

高強度鋼筋續接器續接性能規範

社團法人 台灣混凝土學會

Taiwan Concrete Institute

高強度鋼筋續接器續接性能評估基準

Performance Requirements of Mechanical Splices for High-Strength Reinforcing Bars

(草案)

新高強度鋼筋混凝土技術委員會報告

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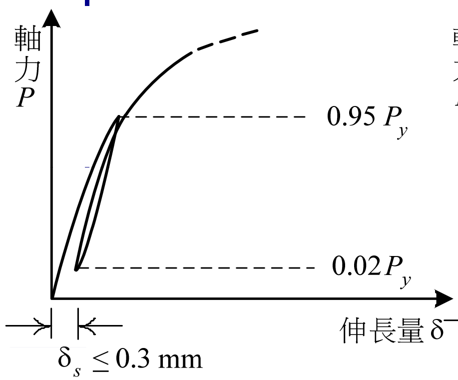
研究助理：王淑真 (按姓氏筆畫順序)

2009年11月30日第02b版

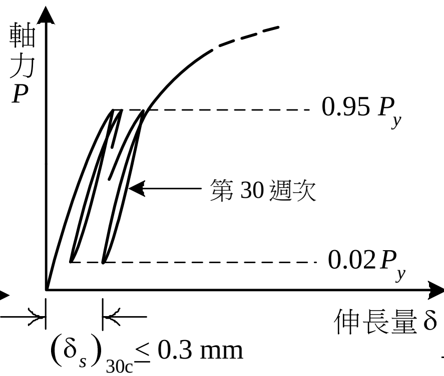
目錄

鋼筋續接器續接性能試驗項目

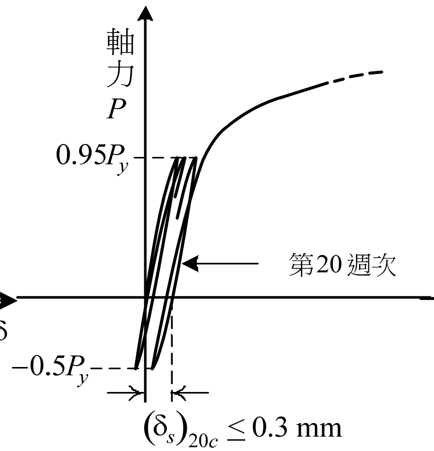
續接性能	母材鋼筋	續接器接合試體			
	拉力試驗	拉力試驗	彈性重複載重試驗	彈性反復載重試驗	塑性反復載重試驗
SA級	●	●		●	●
B級	●	●	●		



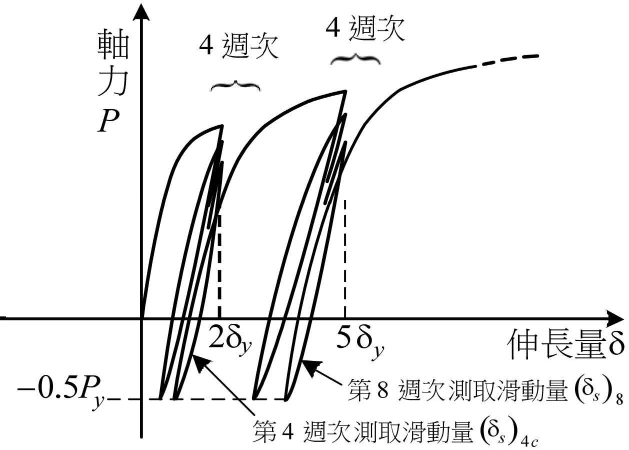
拉力試驗



彈性重複載重試驗



彈性反復載重試驗



塑性反復載重試驗

強度、滑動量和伸長率之合格基準

表 2.5.1　鋼筋續接器續接性能合格基準

<table>
<tr><th colspan="2">試驗項目</th><th>SA 級</th><th>B 級</th></tr>
<tr><td rowspan="3">接合試體
拉力試驗</td><td>抗拉強度 f_{uc}</td><td>$\geq 1.25 f_y$且$\geq f_u$</td><td>$\geq 1.25 f_y$且$\geq f_u$</td></tr>
<tr><td>滑動量 δ_s</td><td>$\leq 0.3\,\mathrm{mm}$</td><td>$\leq 0.3\,\mathrm{mm}$</td></tr>
<tr><td>伸長率 ε_{uc}</td><td>≥ 0.06</td><td>≥ 0.02</td></tr>
<tr><td rowspan="3">接合試體
彈性重複
載重試驗</td><td>抗拉強度 f_{uc}</td><td rowspan="3">---</td><td>$\geq 1.25 f_y$且$\geq f_u$</td></tr>
<tr><td>滑動量 $(\delta_s)_{30c}$</td><td>$\leq 0.3\,\mathrm{mm}$</td></tr>
<tr><td>伸長率 ε_{uc}</td><td>≥ 0.02</td></tr>
<tr><td rowspan="3">接合試體
彈性反復
載重試驗</td><td>抗拉強度 f_{uc}</td><td>$\geq 1.25 f_y$且$\geq f_u$</td><td rowspan="3">---</td></tr>
<tr><td>滑動量 $(\delta_s)_{20c}$</td><td>$\leq 0.3\,\mathrm{mm}$</td></tr>
<tr><td>伸長率 ε_{uc}</td><td>≥ 0.06</td></tr>
<tr><td rowspan="4">接合試體
塑性反復
載重試驗</td><td>抗拉強度 f_{uc}</td><td>$\geq 1.25 f_y$且$\geq f_u$</td><td rowspan="4">---</td></tr>
<tr><td>滑動量 $(\delta_s)_{4c}$</td><td>$\leq 0.3\,\mathrm{mm}$</td></tr>
<tr><td>滑動量 $(\delta_s)_{8c}$</td><td>$\leq 0.9\,\mathrm{mm}$</td></tr>
<tr><td>伸長率 ε_{uc}</td><td>≥ 0.06</td></tr>
</table>

續接器性能分級與使用條件

試驗項目		SA級	B級
接合試體拉力試驗	抗拉強度 滑動量 伸長率	V	V
接合試體彈性重複載重試驗		--	V
接合試體彈性反復載重試驗		V	--
接合試體塑性反復載重試驗		V	--
使用場合		無限制，且 無錯置規定	非塑性 變形區

預鑄結構用續接套管之強度及滑動量符合SA級規定且經構件試驗證明其韌性符合耐震性能要求，亦可視為SA級續接器，或稱之為「有條件的SA級」

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陳政宇、高文良、陳肇宸、許書豪、趙偉帆先生及國震中心技術人員的努力付出。

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東和鋼鐵企業股份有限公司

日本東京鐵鋼(TTK)

潤弘精密工程股份有限公司

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國家實驗研究院 NARL National Applied Research Laboratories

國家地震工程研究中心 National Center for Research on Earthquake Engineerin