出國報告（出國類別：國際會議）

美國混凝土學會 2009 春季年會
技術委員會交流心得

服務機關：國立雲林科技大學
姓名職稱：李宏仁助理教授
出國地區：美國聖安東尼
出國期間：980313～980320
報告日期：980324

摘要

報告人近期擬研究使用高強度鋼筋混凝土之梁柱建築構架耐震行爲，俾利未來相關設計方法修訂之參據。此行赴美國德州聖安東尼市出席美國混凝土學會 2009 春季年會，主要目的參加 352 委員會 (Joints and Connections in Monolithic Concrete Structures)，報告人目前爲 352 委員會准委員(Associate member)，必須每年出席並通過委員會表決才能成爲委員(Voting member)，委員可以建議修訂其技術報告，進一步回饋之 318 規範委員會。此行報告人於 352 委員會報告我國有興趣研究高強度鋼筋混凝土梁柱建築構架耐震行爲，並將研究資訊回饋至該委員會，並期望未來可以成立工作小組(Task group)持續國際學術交流合作。成功邀請 UCLA 教授 John W. Wallace、U of Oklahoma 教授 Thomas H.-K. Kang、及報告人（Hung-Jen Lee）試組一個 Task Group，擬由報告人帶頭啓動高強度鋼筋混凝土梁柱構架之耐震性能研究。

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目的

台灣都市土地開發接近飽和，建築物亦逐漸朝向天際線發展，當前政府大力推動都市更新及擴大公共建設投資，此時推動新世代高強度鋼筋混凝土構造具有多重效益，首先，材料高強度高性能化可節約砂石與鋼鐵用量，具節能減碳之效，搭配先進工法還具有省工、省時、省料之經濟效益。

日本推動高強度鋼筋混凝土構造已有 15 年，其新世代 USD 685 鋼筋具高降伏強度與延展性，適合地震區構造，我們若想效法日本開發新世代高強度鋼筋，必須同步調整其設計方法，然國內建築設計方法源自美國混凝土學會(American Concrete Institute) 318 規範[1]，其適用於地震區之鋼筋降伏強度僅達 420 MPa，使用高強度鋼筋與高強度混凝土於建築業具有結構減重、材料減量、樓層數拉高、棟距拉大、成本降低、節能減碳之效，爲當前國家重要施政方向之一。

報告人學術專長爲混凝土結構，近期擬研究使用高強度鋼筋混凝土之梁柱建築構架耐震行爲，俾利未來相關設計方法修訂之參據。此行赴美國德州聖安東尼市出席美國混凝土學會 2009 春季年會，主要目的參加 352 委員會 (Joints and Connections in Monolithic Concrete Structures)，報告人目前爲 352 委員會准委員(Associate member)，必須每年出席並通過委員會表決才能成爲委員(Voting member)，委員可以建議修訂其技術報告，進一步回饋之 318 規範委員會。此行報告人於 352 委員會報告我國有興趣研究高強度鋼筋混凝土梁柱建築構架耐震行爲，並將研究資訊回饋至該委員會，並期望未來可以成立工作小組(Task group)持續國際學術交流合作。

過程

3 月 14 日星期六 抵達聖安東尼
3 月 15 日星期日 2:00 pm-5:00 pm 出席 352 委員會，李宏仁於會議中簡報。詳附件。
3 月 16 日星期一 9:00 am-12:00 am 至 Session-Research in Progress 聽最新研究報告。
3 月 16 日星期一 2:00 pm-6:00 pm 列席 369 委員會，瞭解耐震評估研究近況。
3 月 16 日星期一 6:30pm-10:00 pm 與 Jack Moehle, Laura Lowes, Ken Elwood, Shyh-Jiann Hwang, Jim LaFave 等著名教授討論梁柱接頭資料庫交流與耐震評估分析模式之研究方向。
3 月 17 日星期二 2:00 pm-5:00 pm 列席 318H 委員會，瞭解耐震規範修訂趨勢。
3 月 17 日星期二 5:00 pm-6:00 pm 出席 Faculty Networking Reception，與 Thomas Kang 及 Adam Lubell 教授相談甚歡，後者也研究加拿大之 MMFX 高強度鋼筋，未來可交流資訊。
3 月 17 日星期二 6:00 pm-10:00 pm 出席晚宴，與著名學者 Thomas T.C. Hsu, John Wallace, Jack Moehle 等人有深入之討論。
3 月 18 日星期三 8:00 am-11:30 am 列席 318E 委員會，瞭解剪力扭矩規範修訂趨勢。
3 月 18 日星期三 2:30 pm-4:00 pm 列席 318H 委員會，瞭解耐震規範修訂趨勢。
3 月 18 日星期三 4:00 pm-6:30 pm 列席 318 委員會，瞭解 318 規範修訂趨勢。
3 月 19 日星期四 返國

心得及建議

1. 報告人成功於美國混凝土學會 352 委員會報告，引起主席與秘書對高強度鋼筋混凝土應用表示期待，希望未來可以持續與台灣來的研究人員保持合作，首先邀請 UCLA 教授 John W. Wallace、U of Oklahoma 教授 Thomas H.-K. Kang、及報告人（Hung-Jen Lee）試組一個 Task Group，擬由報告人帶頭啓動高強度鋼筋混凝土梁柱構架之耐震性能研究。
2. 美國學者仍持續投入老舊、未作妥適耐震設計之建築耐震評估與補強研究，在耐震評估方面，已發展至非線性歷時分析，除梁柱元素之外，接頭如何模擬是一個重要課題。UW 教授 Laura Lowes 帶頭開發，報告人會持續關注其研究變化，並回饋至國內之耐震評估方法。
3. 加拿大也有降伏強度 690 MPa 的新型 MMFX 鋼筋問市，可見發展超高強度鋼筋是先進國家的趨勢，U of Alberta 教授 Adam S. Lubell 對於台灣研究 USD 685 鋼筋極感興趣，希望未來可以進一步與報告人交流資訊，爲此行之意外收穫。
4. 結構設計方法必須隨材料更新作適當之變革，方可將新型高性能材料應用於未來新建築上，然而發展一部新的設計規範需要非常多人力物力才可能達成，這需要大家共同努力，非個人獨立研究能達成。
5. 報告人著眼於按 ACI 方法[2]設計普通 RC 接頭已經在工地造成鋼筋壅塞施工困難，一旦將材料提昇至 USD 685 高強度鋼筋，將無法使用現行 ACI 方法設計梁柱接頭，設計條款必須修訂，尤其是握裹條件限制與接頭箍筋量亦必須適當放鬆，這需要不同的設計模式。
6. 參加美國混凝土學會年會，對於瞭解最新研究進度、規範變革趨勢、學術人際交流均亟有幫助，有助於提升台灣學術研究成果於之國際能見度。除了發表國際期刊論文之外，建築科技研發必須落實之設計法規與工程界，而美國混凝土學會之技術委員會提供一個非常好的交流平台，全世界相關專長者齊聚一堂討論與表決，遠比期刊論文打筆仗更有效率。
7. 建議政府應補助國內學人出席相關技術交流會議，將國內研究成果國際化，提升能見度。

參考文獻

[1] ACI Committee 318, “Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary,” American Concrete Institute, Farmington Hills, MI, 2008, 465 pp.

[2] Joint ACI-ASCE Committee 352, “Recommendations for Design of Beam-Column Connections in Monolithic Reinforced Concrete Structures (ACI 352R-02),” American Concrete Institute, Farmington Hills, MI, 2002, 37 pp.

附件一

美國混凝土學會 2009 年春季年會 352 梁柱接頭委員會議紀錄
簡報講義，報告人李宏仁

Minutes of ACI-ASCE Committee 352 Meeting
"*Joints and Connections in Monolithic Concrete Structures*"
Sunday, March 15th, 2009; 2:00p – 5:00p
Meeting Room "Conference Room 14"; ACI Spring 2009 Convention
Marriott Rivercenter; San Antonio, TX

ATTENDANCE

Members Present: Sergio Alcocer, John Bonacci, Marvin Criswell, Luis Garcia, Mary Beth Hueste, Thomas Kang, Mike Kreger, Jim LaFave, Gustavo Parra-Montesinos, Ian Robertson, Jorge Segura, Myoungsu (James) Shin, Loring Wyllie

Members Absent: Jim Cagley, Jeff Dragovich, Catherine French, Russell Gentry, Ted Krauthammer, Douglas Lee, Dawn Lehman, Roberto Leon, Cheng-Ming Lin, Don Meinheit, Nilanjan Mitra, Jack Moehle, Voula Pantazopoulou, M. Saiid Saiidi, Bahram Shahrooz, John Wallace, Jim Wight

Associate Members: G. Appa Rao, Sung Chul Chun, Kara Hartleib, Hung-Jen Lee, Bohwan Oh

Visitors: Lou Colarusso, Rex Donahey, Ken Elwood, Damon Fick, Shyh-Jiann Hwang

1. Call to Order and Introductions

Committee 352 Chair Jim LaFave called the meeting to order at approximately 2:05p, after distributing copies of the meeting agenda. All individuals in the meeting room then introduced themselves.

2. Approval of Minutes from the Fall 2008 Committee 352 Meeting

The Fall 2008 meeting minutes (from the convention held in St. Louis, Missouri), which had previously been posted to the committee website and were also available in hard copy format at the meeting, were approved by acclamation.

3. Discussion of ACI Conference Session Organization & Sponsorship Opportunities

Jim LaFave first reminded everyone about the committee's session (entitled "New Developments for Practical Analysis and Design of Structural Concrete Frame Connections") at the upcoming *ASCE/SEI 2009 Structures Congress* on May 1st in Austin, Texas (see our Fall 2008

meeting minutes for more details). In order for the committee to focus more attention on sponsoring sessions at future ACI conventions, there are no plans right now for us to organize a session at the 2010 Structures Congress.

Mary Beth Hueste then led a brief discussion about opportunities to sponsor sessions at upcoming ACI conventions – for Spring 2010 (in Chicago), a complete session proposal (with all speakers and talk titles identified) would need to be submitted by the end of this convention week, whereas for Fall 2010 (in Pittsburgh) there is still time to arrange session(s) including an open call for some of the presentations. With respect to slab-column connections, a session was envisioned that might at least include a couple of talks about the committee's updated design recommendations, perhaps along with something about recent testing of such connections with different shear reinforcement details, structural concrete system modeling for proper drift prediction of such connections, etc. For a beam-column connection session, the talks could include something about the use of headed reinforcement, use of high-strength materials, performance of existing connections, analytical modeling of connections, etc. In each case, opportunities likely exist for coordination and/or co-sponsorship with Committee 374 in regards to including talks about joint and/or connection performance characterization for design. Ian Robertson and Sergio Alcocer volunteered to assist Mary Beth in organizing these session(s).

Sergio also briefly described an idea for a series of four sessions at the ACI Fall 2011 (Cincinnati) convention in honor of Jim Jirsa. The plan is to have them co-sponsored by Committees 352, 369, 374, 408, and 445 – members of our committee present at the meeting endorsed participation in this effort. Sergio and Jose Pincheira will keep us posted as this effort proceeds.

ACTION ITEM: Mary Beth Hueste will lead an effort to develop proposed ACI convention conference session(s) sponsored (or co-sponsored) by the committee and to formally initiate the session request.

4. Task Group Updates Related to *ACI 352R-02*

Following are brief summaries of the reports (and ensuing discussions) made on behalf of the two active task groups the committee has about issues pertaining to our reinforced concrete beam-column connection design recommendations report:

a) Thomas Kang noted that the task group on headed reinforcement applications in beam-column joints & connections for seismic design has produced a manuscript summarizing their work to date (see the Fall 2008 meeting minutes for more details), which has been accepted for publication by the *ACI Structural Journal*. They also have a conference paper / presentation that will be part of the committee-sponsored session at the *ASCE/SEI 2009 Structures Congress*. This task group will report in more detail about their

latest findings (especially including some additional consideration related to bar slip) at a future committee meeting.

b) Myoungsu Shin then gave an update about the work of our task group on beam-column connections with eccentricity at the joint. In a 2005 *Concrete International* article, members of this group had taken a look at nearly a dozen new eccentric connection test results beyond the five or so that had been available when *ACI 352R-02* was published. They have now been considering the test results from about five more recently available connections, including a couple of corner connections (the rest have been cruciform edge connections). Based on simple estimates of the actual "effective" joint width in each case, some proposed (reduced) effective joint width definitions for design were presented, and particular effects of floor slabs and corner connections were noted. Key members of this task group also have a conference paper / presentation that will be part of the committee-sponsored session at the *ASCE/SEI 2009 Structures Congress*. This task group was asked to present a final set of eccentric connection design recommendation proposals for consideration at the next committee meeting.

ACTION ITEMS: These two task groups will continue their work and report back to the entire committee at the next meeting; their respective *ASCE/SEI 2009 Structures Congress* conference papers will be posted to the committee web site so that all committee members can get a better flavor of these task groups' findings to date.

5. Unresolved Ballot Issues for the Revised & Updated *ACI 352.1R*

Jim LaFave reminded the committee that, at our last meeting, we addressed many of the remaining negative votes (and affirmative votes with substantive comments) related to Chapters 5-8 of the latest version of our "Recommendations for Design of Slab-Column Connections in Monolithic Concrete Structures". Due to a low turn-out of voting members at that meeting, however, the final recommended resolutions (noted in the Fall 2008 meeting minutes) were not then able to be voted on. Therefore, facilitated here by Thomas Kang, meeting ballots were conducted to finally resolve all of the items noted below (with the document page and line numbers referenced to the version most recently balloted):

a) Chapter 5:

i) Saiidi negative – p. 37, line 3 – A motion (by Robertson, seconded by Kang) was approved (12 for, 0 against, 0 abstaining) to find Saiid's negative vote (related to the repetitive nature of calling out the definition for γ_f) persuasive; this repetitious definition will be removed.

ii) Alcocer negative – p. 38, line 13 – A motion (by Robertson, seconded by Bonacci) was approved (12 for, 0 against, 0 abstaining) to find this negative vote nonpersuasive; the language "at the connection" and the recommended maximum slab bar spacing will remain here as they are

(for use in conjunction with the definition of connection provided elsewhere in the document).

iii) Saiidi negative – p. 38, line 23 – A motion (by Robertson, seconded by Kang) was approved (12 for, 0 against, 0 abstaining) to find Saiid's negative vote (regarding the need for clarifying the definition of *h*) persuasive, but with no change in the equation itself; the $0.00075*h*l_2$ equation will remain as it is, with "*h* is the slab thickness not including any drop panel or shear cap" being added right after here to replace "*h* is the slab thickness, including drop panel".

iv) Alcocer negative – p. 41, line 2 – A motion (by LaFave, seconded by Kang) was approved (12 for, 0 against, 0 abstaining) to find this negative vote nonpersuasive; the "2*h*" back in Section 5.1.5(b), on p. 39, line 16, will remain as it has always been.

v) Saiidi negative – p. 48, lines 20-21 – A motion (by Garcia, seconded by Robertson) was approved (12 for, 0 against, 0 abstaining) to find Saiid's negative vote (regarding the efficacy of this commentary statement) persuasive; this sentence will be clarified by replacing it with: "Within the depth of the joint of exterior connections, column longitudinal bars should be restrained laterally by spirals or ties per these recommendations, which can be more stringent than ACI 318."

vi) Saiidi negative(s) – A motion (by Garcia, seconded by Robertson) was approved (12 for, 0 against, 0 abstaining) to find the remainder of Saiid's comments about this chapter under his umbrella negative vote above to be persuasive – they are essentially editorial in nature anyway and will be addressed as such.

b) <u>Chapter 6:</u>

i) Alcocer negative – p. 57, line 13 – A motion (by Robertson, seconded by Kang) was approved (12 for, 0 against, 0 abstaining) to find Sergio's negative vote (primarily related to clarifying shear force nomenclature) persuasive; "factored gravity shear force" will be made universally consistent with V_{ug}, and mention of the phi factor will be relocated for clarity.

c) <u>Chapter 7:</u>

i) Bonacci negative – p. 65, lines 2-17 – A motion (by Garcia, seconded by Wyllie) was approved (12 for, 0 against, 0 abstaining) to find John's negative vote (regarding the "commentary" nature of certain aspects of the language in Section 7.2) persuasive; the occurrences of "are effective for increasing" in Sections 7.2.2 & 7.2.3 will be changed to instead read "can be designed to increase".

ii) Alcocer negative – p. 68, line 7 – A motion (by Robertson, seconded by Kang) was approved (12 for, 0 against, 0 abstaining) to find Sergio's negative vote (regarding an undefined term in this equation) persuasive – the undefined term was just a typographical error, so it will simply be addressed as an editorial change.

iii) Alcocer negative – p. 70, lines 2-3 – A motion (by Robertson, seconded by Hueste) was approved (12 for, 0 against, 0 abstaining) to find this negative vote nonpersuasive; for the

minimum connection shear capacity that should be provided by shear reinforcement, the value of $(3.5\sqrt{f'_c})A_{cs}$ employed from Chapter 21 of ACI 318 should indeed also be used here in these recommendations.

iv) Alcocer negative – p. 71, line 4 – There was consensus agreement with Sergio's negative vote that the value 0.85*d* does imply excessive precision – further discussion led to an additional consensus that the maximum recommended *s* should not exceed *d*/2, which in conjunction with another requirement that the first line of shear reinforcement should be at *s*/2 would then effectively require a second line of shear reinforcement at 3*d*/4 from the column; although the original point of the negative vote was in fact persuasive, these other suggested changes are well beyond the scope of just finding that negative persuasive, so the revised version of this small section will need to be re-balloted.

At this point, there was neither enough time nor a quorum to resolve any more negative ballots; still remaining are a few negative votes on Chapter 8 (for which tentative resolutions were reached at the previous meeting) and a handful more from Chapters 1-4.

ACTION ITEM: The subcommittee will continue their work on the draft document in accordance with the above negative vote ballot resolutions; resolving negatives may also continue via web ballot between now and our next meeting.

6. Other Business – Presentations

Hung-Jen Lee made a short presentation about ongoing experimental research in Taiwan regarding the use of high-strength materials (both concrete and reinforcing steel) in the joint regions of reinforced concrete beam-column connections. He noted that their high strength beam-column connection specimens are exhibiting higher maximum shear stresses in the joints as compared to the limits provided in the *ACI 352R-02* report on beam-column connections. Furthermore, when high strength concrete and reinforcement are used, the transverse reinforcement requirements may be too strict and the bond and anchorage requirements may need to be increased. However, more careful evaluation is needed before specific recommendations can be made. Hung-Jen also discussed future plans for testing some additional beam-column connections. Overall, this work may inform future efforts of the committee to better address the use of high-strength materials in beam-column connections, perhaps first through a task group and then maybe later by revisions to our beam-column connection design recommendations. Thomas Kang, John Wallace, and other members of the committee will try to work with these Taiwanese researchers toward reaching this goal.

7. Committee Chair and Schedule for the Next Committee Meeting

Jim LaFave announced that his series of terms as Committee Chair will come to a close after

seven years at the end of this convention. ACI TAC has recently invited Mary Beth Hueste to become the new Chair of the committee, for at least one three-year term, and she has graciously agreed to do so, with Thomas Kang continuing on as the Committee Secretary! Mary Beth, Thomas, and the other meeting attendees thanked Jim for his years of dedicated leadership and service to the committee.

The next committee meeting is planned for the ACI Fall Convention, in New Orleans, Louisiana, in November 2009. Given the solid attendance at this meeting, and that about the only other reasonable option would be to try and go for a Monday meeting time slot instead, there was consensus to keep our meetings on Sunday afternoons.

8. Adjournment

The meeting was adjourned at 4:55p.

Respectfully submitted,

James M. LaFave — *Outgoing-Chair, ACI-ASCE Committee 352*

Thomas H.-K. Kang — *Secretary, ACI-ASCE Committee 352*

Mary Beth D. Hueste

Incoming-Chair, ACI-ASCE Committee 352

ACI 2009 Spring Convention
Meeting of 352 Committee, Mar. 15, 2009

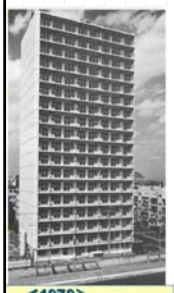
Proposed Studies on Beam-Column Connections utilizing High-Strength Reinforcement and Concrete

李 宏仁 (Harry) Hung-Jen LEE
助理教授 Assistant Professor, Dept. of Construction Eng.
National Yunlin University of Science & Technology, **TAIWAN**

YUNTECH

Outlines

- Background and Needs for HSRC
- High-Strength Reinforcement
- Challenge on the Joint Design



What Made High-Rise RC Buildings Possible ?

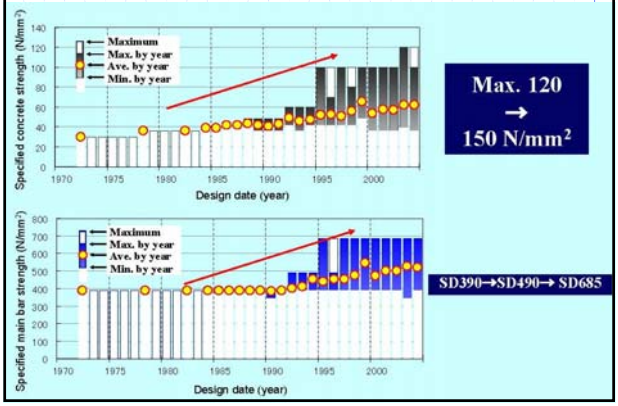
Development of:

- High-strength concrete and steel.
- Techniques to secure ductility of members.
- Analytical tools for design.
- New construction techniques and quality control technology.

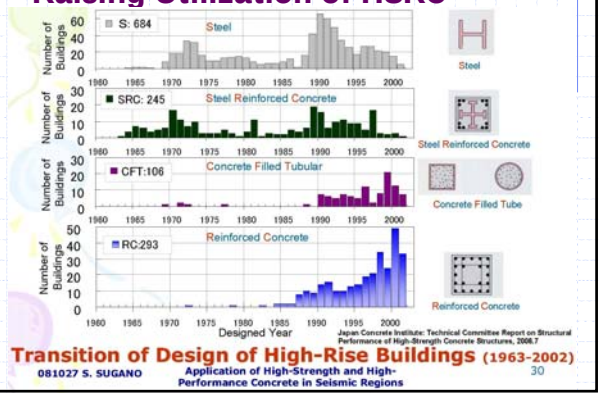
<1972>
- 18 Stories
- fc' 30 MPa
- Small Span frame

<2005>
- 59 Stories
- fc' 150 MPa
- Large interior space

HSRC development in Japan



Raising Utilization of HSRC

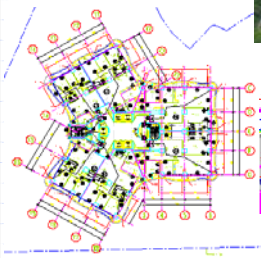


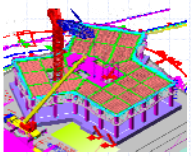
Transition of Design of High-Rise Buildings (1963-2002)

High-rise RC Building in Japan

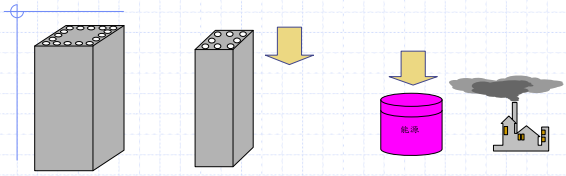
大隱藍海集合住宅(在建案)　簡介-預鑄+隔震

- Level:38F/B3F
- RC PreCast + Seismic Isolator
- Floor area： 62,855m2
- Concrete strength up to 70 MPa
- Reinforcement SD 490 MPa
- Period 2006.12~2009.9, (34 months)
- Site : Taipei County, Taiwan



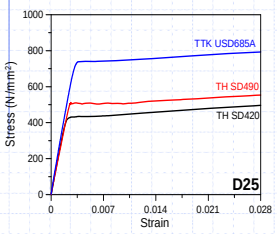


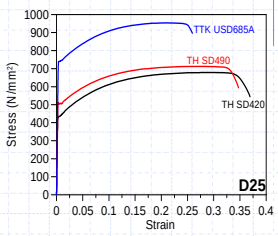
Reduction of member size / materials



Reduction of Energy, CO2 emissions

High-Strength Reinforcement

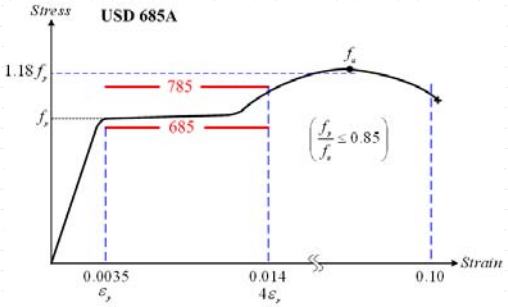




SD420W	490	685 MPa	
~A706	70 ksi	100 ksi	fy

New RC Standard in Japan

USD685A Mechanical Requirement



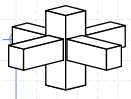
Needs for mechanical splice / anchorage

Design of Beam-Column Joints

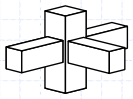
- Shear Strength
- Transverse Reinforcement
- Bond / Anchorage Requirements

when utilizing High-Strength Materials...

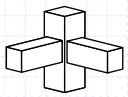
Joint capacity, ACI Sec. 21.5.3



Confined on all 4 faces

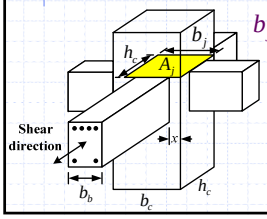


3 or 2 opposite faces



Others

$V_n = 20\sqrt{f_c'}A_j$ $\quad 15\sqrt{f_c'}A_j$ $\quad 12\sqrt{f_c'}A_j$ (lb-in.)



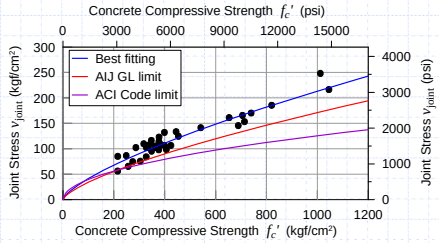
b_j = the smaller of

$\begin{cases} b_b + 2x \\ b_b + h_c \\ b_c \end{cases}$ or $\begin{cases} (b_b + b_c)/2 \\ b_b + \Sigma m h_c/2 \\ b_c \end{cases}$

ACI R21.5.3 $\qquad$ ACI 352R-02

Shear strength of interior joints

50 interior joints without transverse beams (cruciform shape) failed in joint shear before beam yielding (J type)



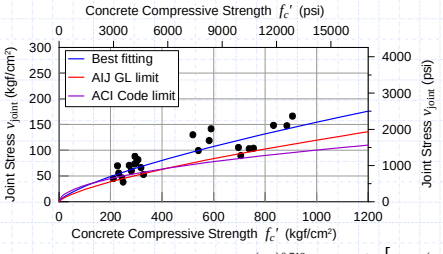
Best fitting $\quad v_j = 1.56 \times (f_c')^{0.712}$ kgf/cm² $\quad [3.35 (f_c')^{0.712}$ psi$]$

AIJ GL limit $\quad v_j = 1.36 \times (f_c')^{0.7}$ kgf/cm² $\quad [3.015 (f_c')^{0.7}$ psi$]$

ACI Code limit $\quad v_j = 15 \times (f_c')^{0.5}$ psi

Shear strength of exterior joints

26 interior joints without transverse beams (T shape) failed in joint shear before beam yielding (J type)

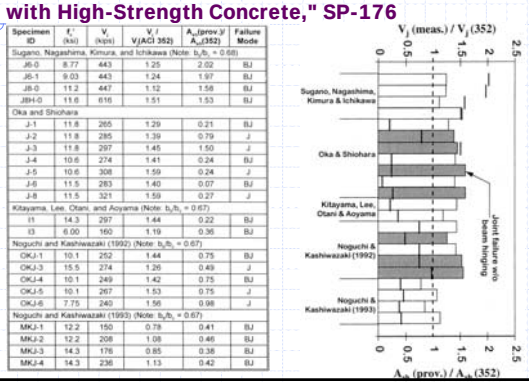


Best fitting $\quad v_j = 1.13 \times (f_c')^{0.712}$ kgf/cm² $\quad [2.43 (f_c')^{0.712}$ psi$]$

AIJ GL limit $\quad v_j = 0.952 \times (f_c')^{0.7}$ kgf/cm² $\quad [2.11 (f_c')^{0.7}$ psi$]$

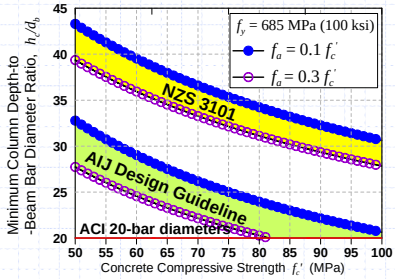
ACI Code limit $\quad v_j = 12 \times (f_c')^{0.5}$ psi

Saqan, E. I., and Kreger, M. E., "Evaluation of U.S. Shear Strength Provisions for Design of Beam-Column Connections Constructed with High-Strength Concrete," SP-176



Specimen ID	f_c' (ksi)	V_n (kips)	V_j / V_j(ACI 352)	A_{sh}(prov.)/ A_{sh}(352)	Failure Mode
Sugano, Nagashima, Kimura, and Ichikawa (Note: b_j/b_c = 0.68)					
J8-0	8.77	443	1.25	2.02	BJ
J6-1	9.03	443	1.24	1.97	BJ
J8-0	11.2	447	1.12	1.58	BJ
J8H-0	11.6	616	1.51	1.53	BJ
Oka and Shiohara					
J-1	11.8	265	1.29	0.21	BJ
J-2	11.8	285	1.39	0.79	J
J-3	11.8	297	1.45	1.50	J
J-4	10.6	274	1.41	0.24	BJ
J-5	10.6	308	1.59	0.24	J
J-6	11.5	283	1.40	0.07	BJ
J-8	11.5	321	1.59	0.27	J
Kitayama, Lee, Otani, and Aoyama (Note: b_j/b_c = 0.67)					
I1	14.3	297	1.44	0.22	BJ
I3	6.00	160	1.19	0.36	BJ
Noguchi and Kashiwazaki (1992) (Note: b_j/b_c = 0.67)					
OKJ-1	10.1	252	1.44	0.75	BJ
OKJ-3	15.5	274	1.26	0.49	J
OKJ-4	10.1	249	1.42	0.75	BJ
OKJ-5	10.1	267	1.53	0.75	J
OKJ-6	7.75	240	1.56	0.98	J
Noguchi and Kashiwazaki (1993) (Note: b_j/b_c = 0.67)					
MKJ-1	12.2	150	0.78	0.41	BJ
MKJ-2	12.2	208	1.08	0.46	BJ
MKJ-3	14.3	176	0.85	0.38	BJ
MKJ-4	14.3	236	1.13	0.42	BJ

Development length requirements in interior joints for different design codes



NZS 3101

$\frac{d_b}{h_c} \le \left(\frac{\alpha_t \alpha_p}{\alpha_s}\right) \alpha_f \frac{6\sqrt{f_c'}}{\alpha_o f_y}$ in N

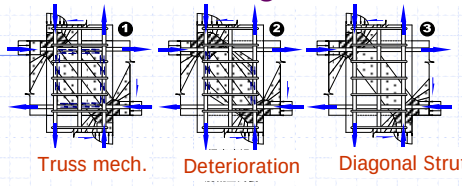
AIJ Design Guideline

$\frac{d_b}{h_c} \le \frac{2.8}{(1+\beta)} \left(1 + \frac{f_a}{f_c'}\right) \frac{(f_c')^{\frac{2}{3}}}{\alpha_o f_y}$

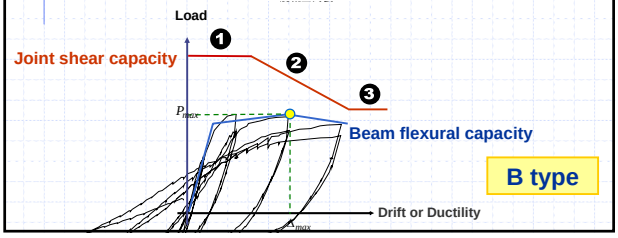
ACI 318 Code

$\frac{d_b}{h_c} \le \frac{1}{20}$

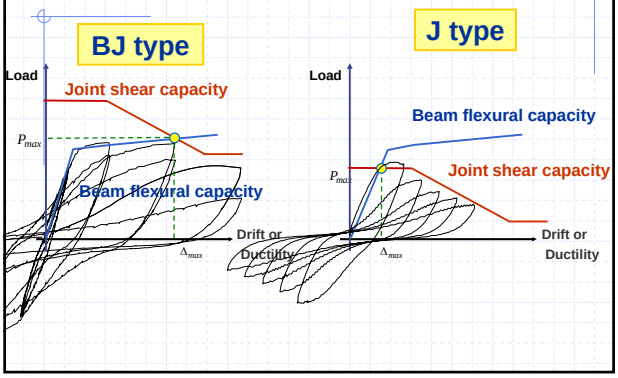
Joint shear-resisting mechanisms



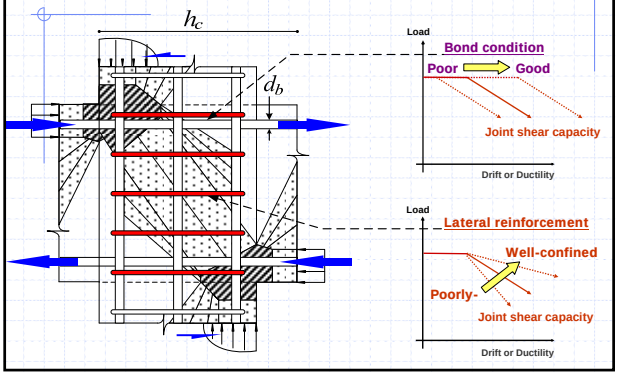
Truss mech. $\qquad$ Deterioration $\qquad$ Diagonal Strut



Joint failure modes



Bond in Joint and Transverse reinforcement



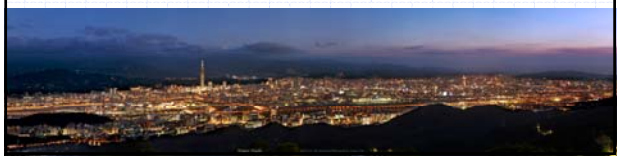
Where to go?

- Shear Strength
- Transverse Reinforcement
- Bond / Anchorage Requirements

when utilizing High-Strength Materials...

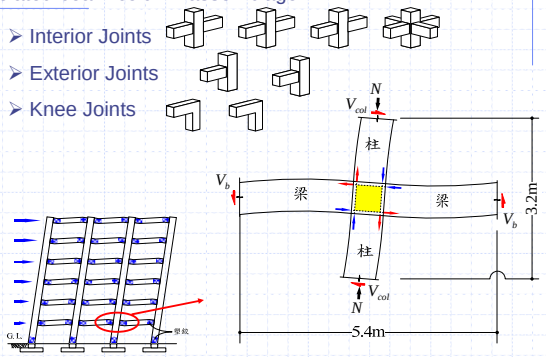
What to do?

- Review available tests of HSRC beam-column connections.
- Additional Experimental Studies
- Task Group ?
- Refine 352R for future



Beam-Column Joints (1/2)

- Isolated beam-column assemblage
  - Interior Joints
  - Exterior Joints
  - Knee Joints



Beam-Column Joints (2/2)

- 600x600-mm column section with 16-D25 bars
- 400x600-mm beam section with varying amount of main bars
- High-strength materials
  70 / 685 / 785 N/mm²