A Review of Recent Australian Bond Test Results and the New Stress Development Design Rules of AS 3600–2009

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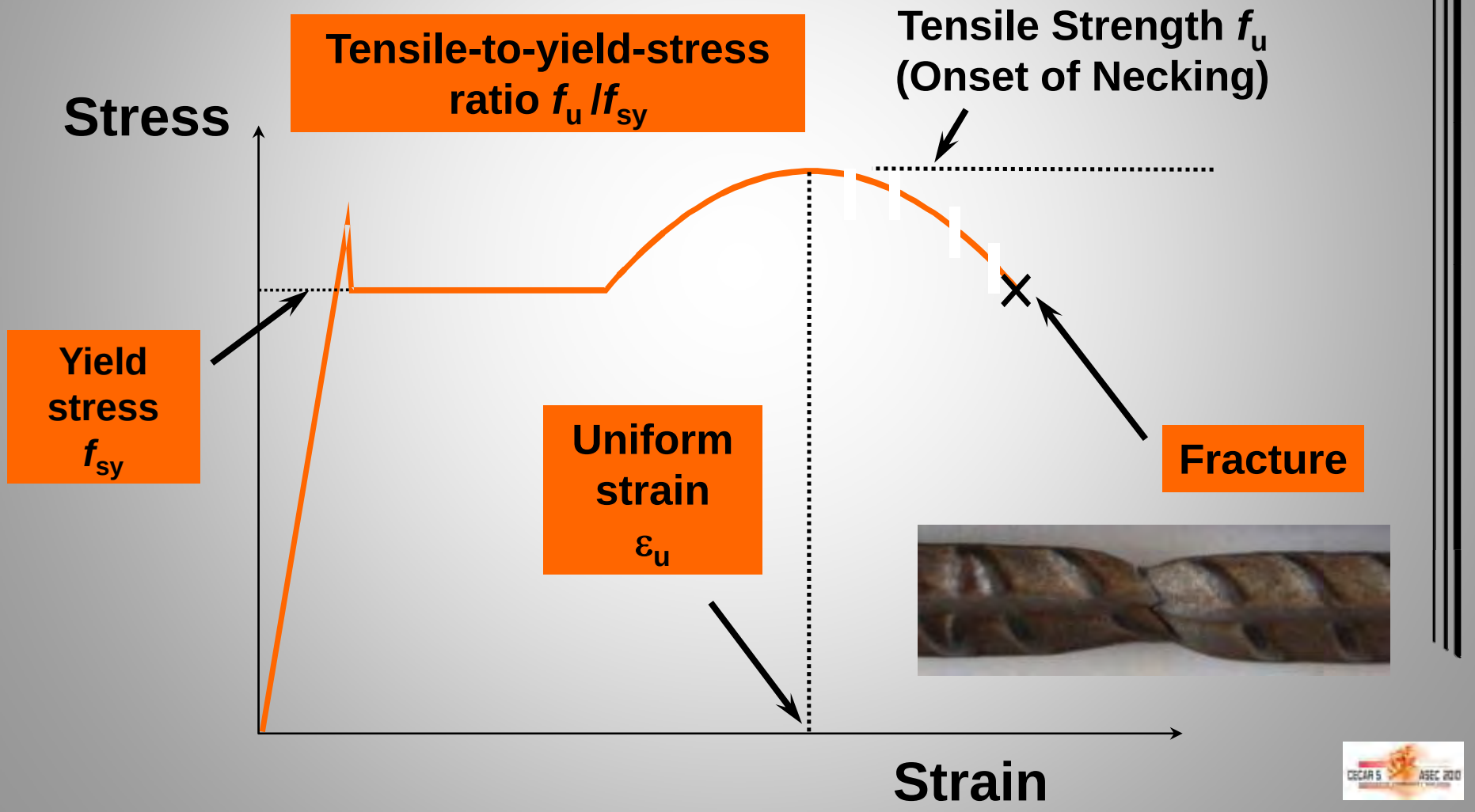
Overview

- **New Design Rules in AS 3600–2009**
  - **Straight D500N bars**
  - **Tensile development lengths**
  - **Tensile lap lengths**
- **Recent Australian Bond Test Series**
  - **University of New South Wales**
  - **University of Queensland**
  - **Curtin University of Technology (SRIA)**
- **Australian Bond Test Results**

New Design Rules in AS 3600–2009

- **D500N Bars to AS/NZS 4671**



New Design Rules in AS 3600–2009

- **D500N Bars to AS/NZS 4671**

Property	*D500N*
Nominal diameter (mm)	10 to 40
Characteristic yield stress (MPa)	
lower	500
upper	650
Tensile-to-yield-stress ratio, min.	1.08
Uniform strain (%) , min.	5.0

DUCTILITY PARAMETERS

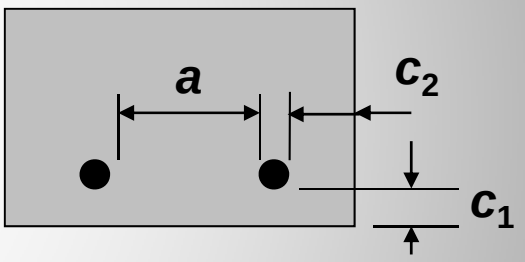
Estimate upper characteristic tensile strength = 1.15x650 = 750 MPa = 1.5f_{sy}

New Design Rules in AS 3600–2009

Basic Tensile Development Length:

$$L_{sy.tb} = \frac{50k_1\left[\left(1.0 - 0.15(c_d - d_b)\right)/d_b\right]f_{sy}d_b}{(132 - d_b)\sqrt{f_c'}} \geq 29k_1d_b$$

c_d = min. (c_1, c_2, a/2) and $d_b \leq c_d \leq 3d_b$



Refined Tensile Development Length:

$$L_{sy.t} = [1.0 - K(\sum A_{tr} - \sum A_{tr.min})/A_s]\,[1.0 - 0.04\rho_p]\,L_{sy.tb} \geq (0.7/k_3)L_{sy.tb}$$

Transverse reinforcement term, k_4

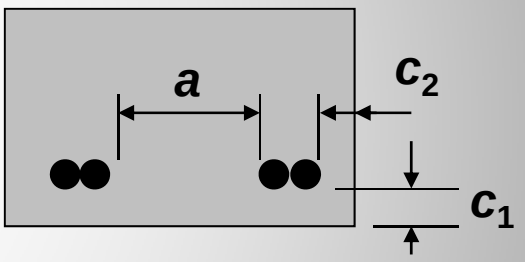
Transverse pressure term, k_5

New Design Rules in AS 3600–2009

Basic Tensile Lap Length:

$$L_{sy.tb.lap} = k_7 \frac{50k_1\left[\left(1.0 - 0.15(c_d - d_b)\right)/d_b\right]f_{sy}d_b}{(132 - d_b)\sqrt{f_c'}} \geq 29k_1d_b$$

c_d = min. (c_1, c_2, $a/2$) and $d_b \leq c_d \leq 3d_b$



Refined Tensile Lap Length:

$$L_{sy.t.lap} = [1.0 - K(\sum A_{tr} - \sum A_{tr.min})/A_s]\,[1.0 - 0.04\rho_p]L_{sy.tb.lap} \geq \max.[(0.7/k_3)L_{sy.tb.lap}, 29k_1d_b]$$

Transverse reinforcement term, k_4

Transverse pressure term, k_5

New Design Rules in AS 3600–2009

What minimum tensile stress should anchored or spliced bars be capable of reaching before failure occurs?

In design, it is assumed that the nominal yield stress, f_{sy}=500 MPa, will be reached before the anchorage or splice fails……. but what about in the real structure?

New Design Rules in AS 3600–2009

Clause 13.2.6 *Welded or mechanical splices*

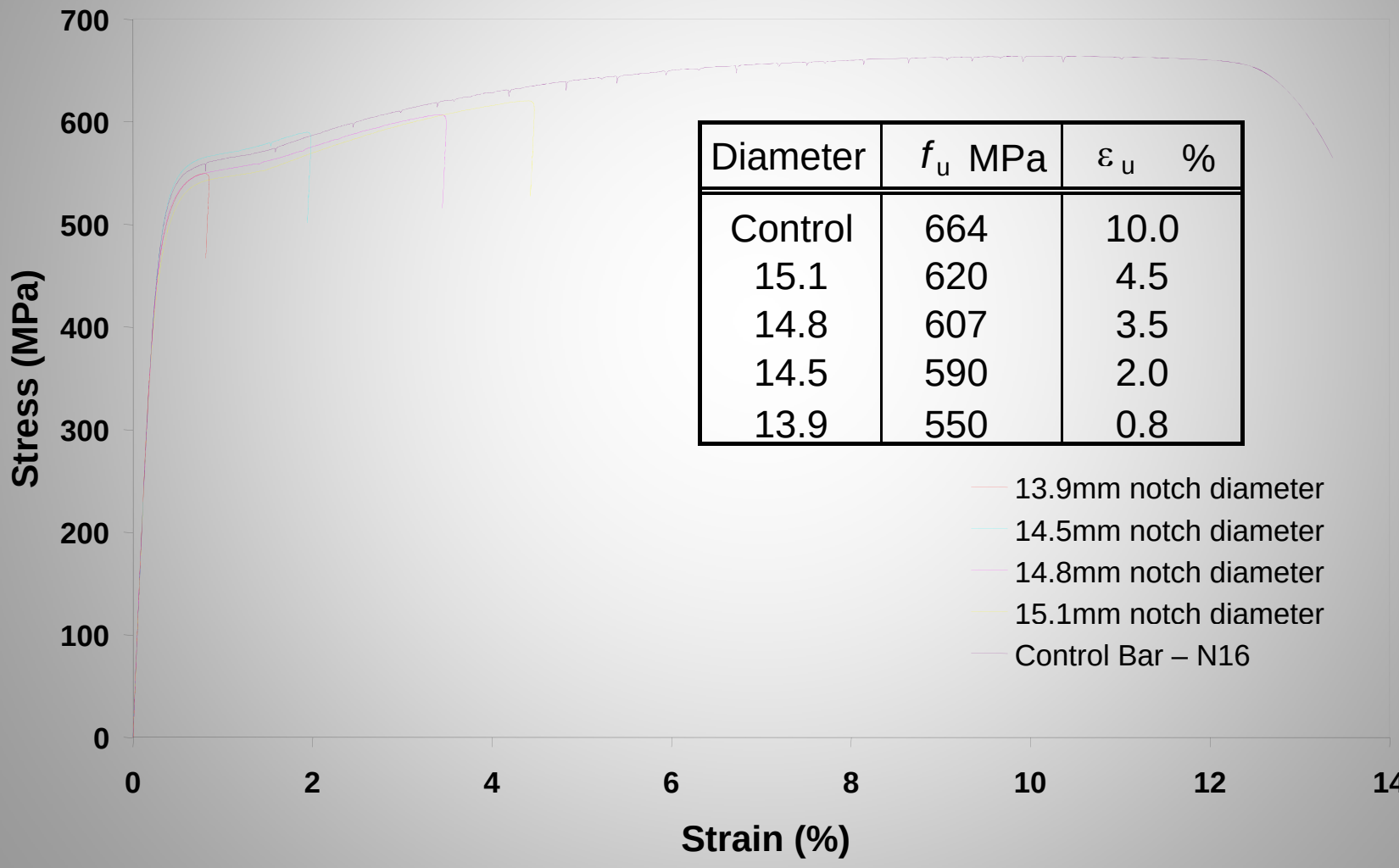
"Welded or mechanical splices formed between Class N reinforcing bars should not fail prematurely in tension or compression before the reinforcing bars, unless it can be shown that the strength and ductility of the concrete member meet the design requirements."

New Design Rules in AS 3600–2009

- **Any form of splice can reduce bar strength**

Recent Australian Bond Test Results

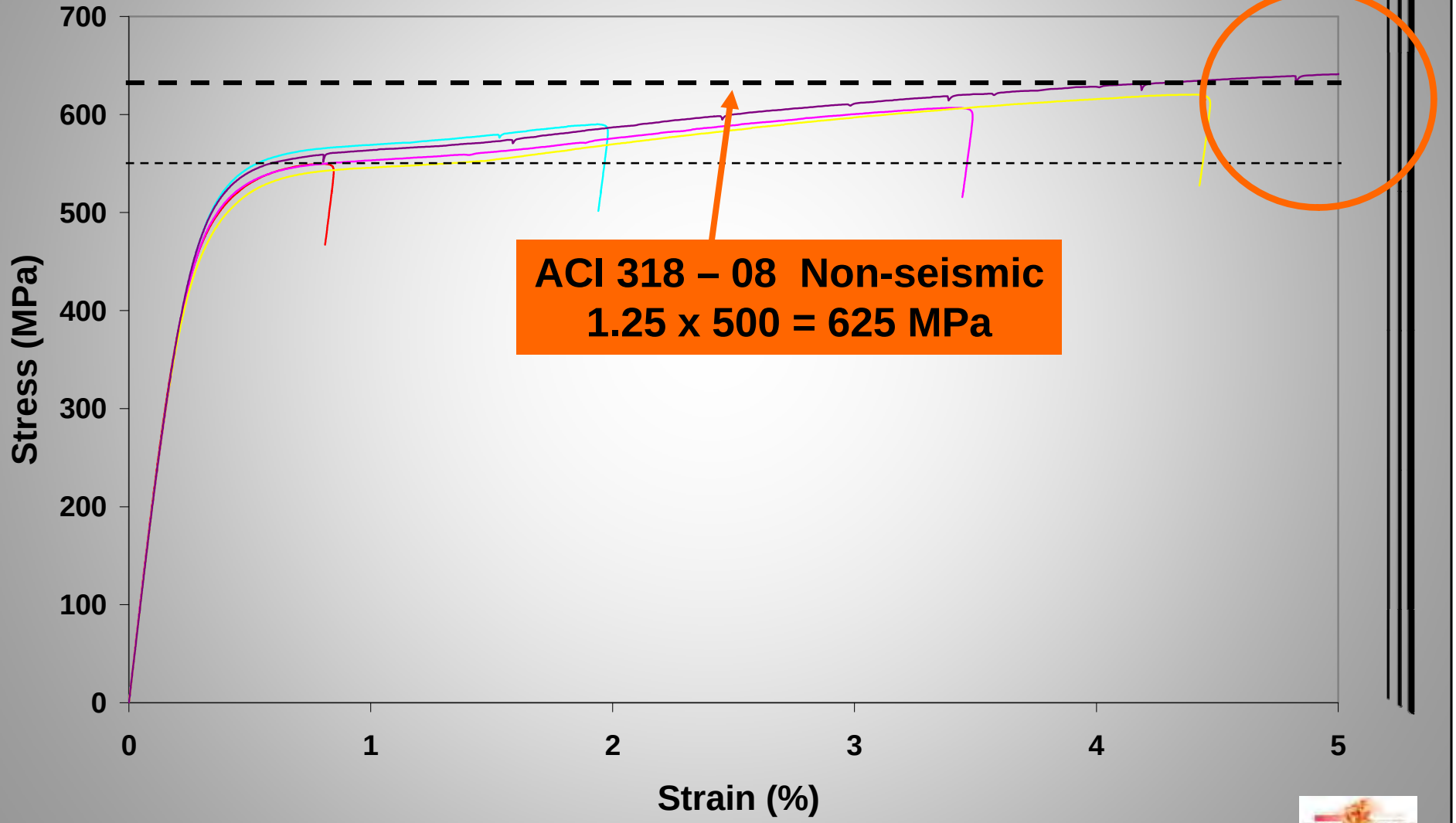
New Design Rules in AS 3600–2009



Diameter	f_u MPa	ε_u %
Control	664	10.0
15.1	620	4.5
14.8	607	3.5
14.5	590	2.0
13.9	550	0.8

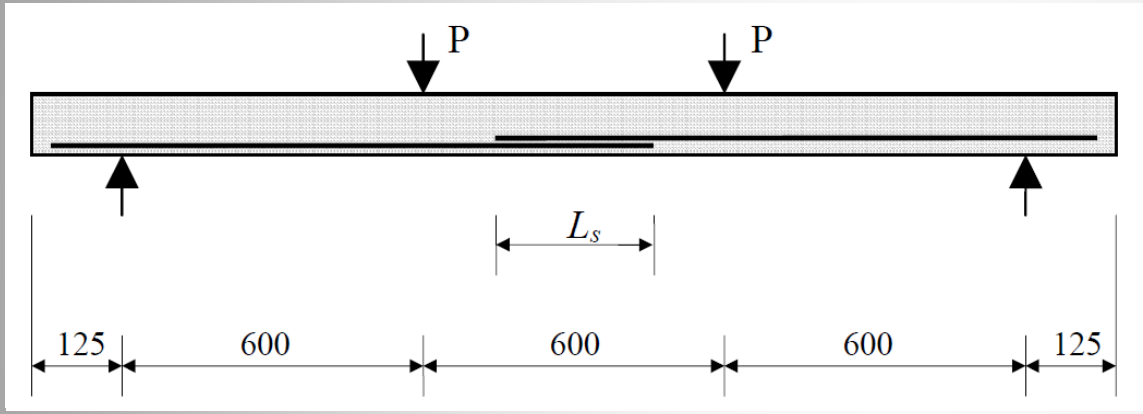
Recent Australian Bond Test Results

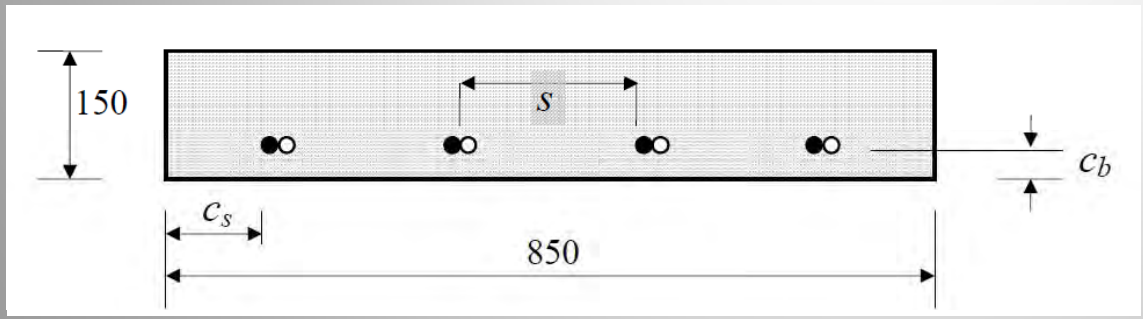
Design principles



Recent Australian Bond Test Series

- **University of New South Wales**

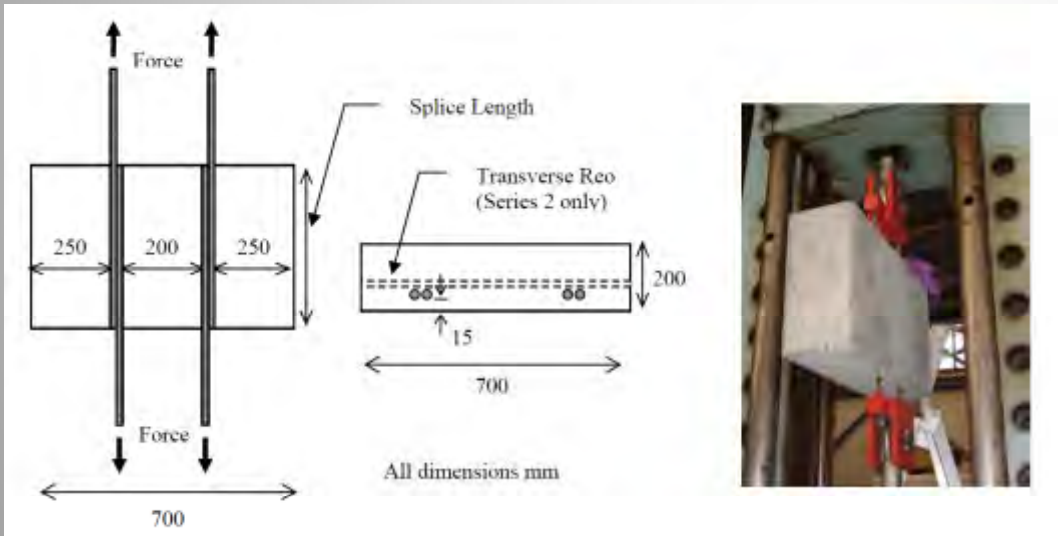




- **10 conventional slabs in flexure**
- **Small diameter, widely-spaced D500N12 or N16 bars representative of slabs or walls (min. clear distance 157 mm)**
- **No staggering**
- **No transverse reinforcement**
- **Short lap length (max. approx. $18d_b$) for bond failure**

Recent Australian Bond Test Series

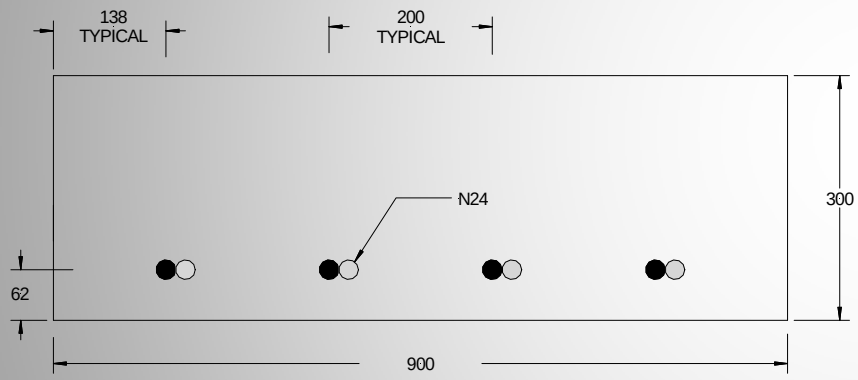
- **University of Queensland**



- **Unconventional pull-out tests, without flexure to cause bar prying, etc.**
- **Small diameter, D500N16 bars representative of slabs or walls**
- **Contact lap splices**
- **No staggering**
- **Transverse bars present in 3 of these tests, but presence should be ignored in design since on wrong side of main bars**

Recent Australian Bond Test Series

- **Curtin University of Technology – SRIA tests**



4 N24 contact lap splices without transverse reinforcement

Recent Australian Bond Test Series

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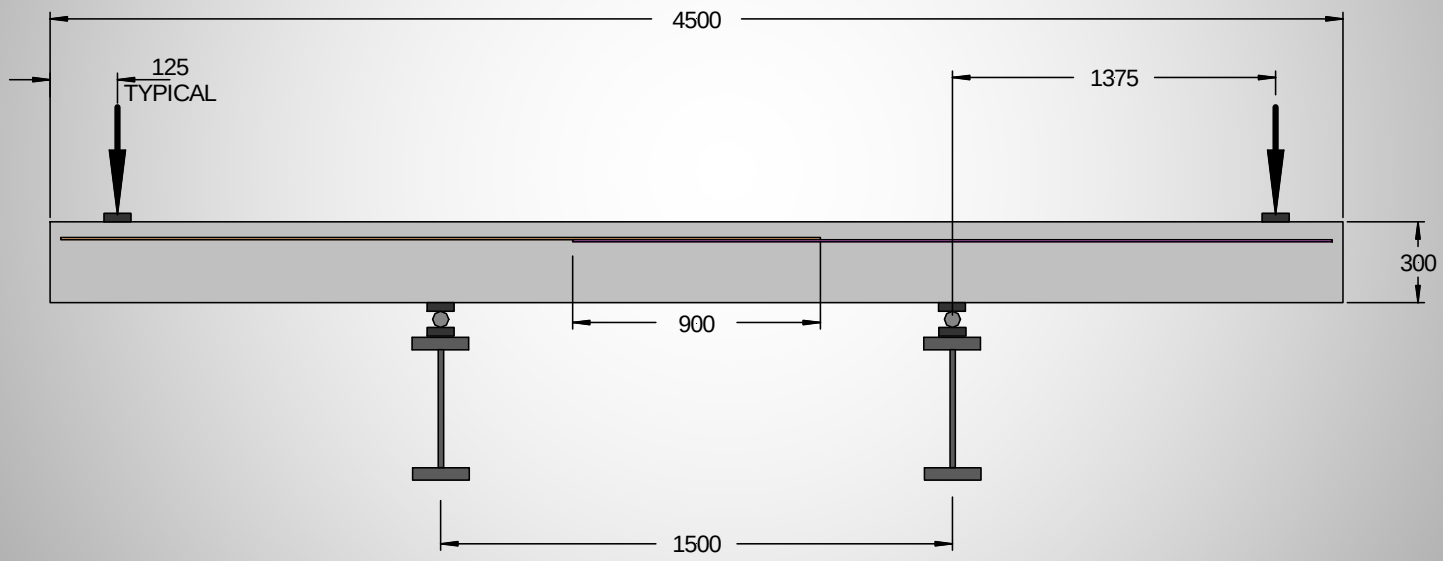

Test lap length =900 mm, while AS 3600–2009 design $L_{sy.tb.lap}$ = 930 mm if use nominal f'_c and k_7=1.0

Recent Australian Bond Test Series

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Recent Australian Bond Test Series

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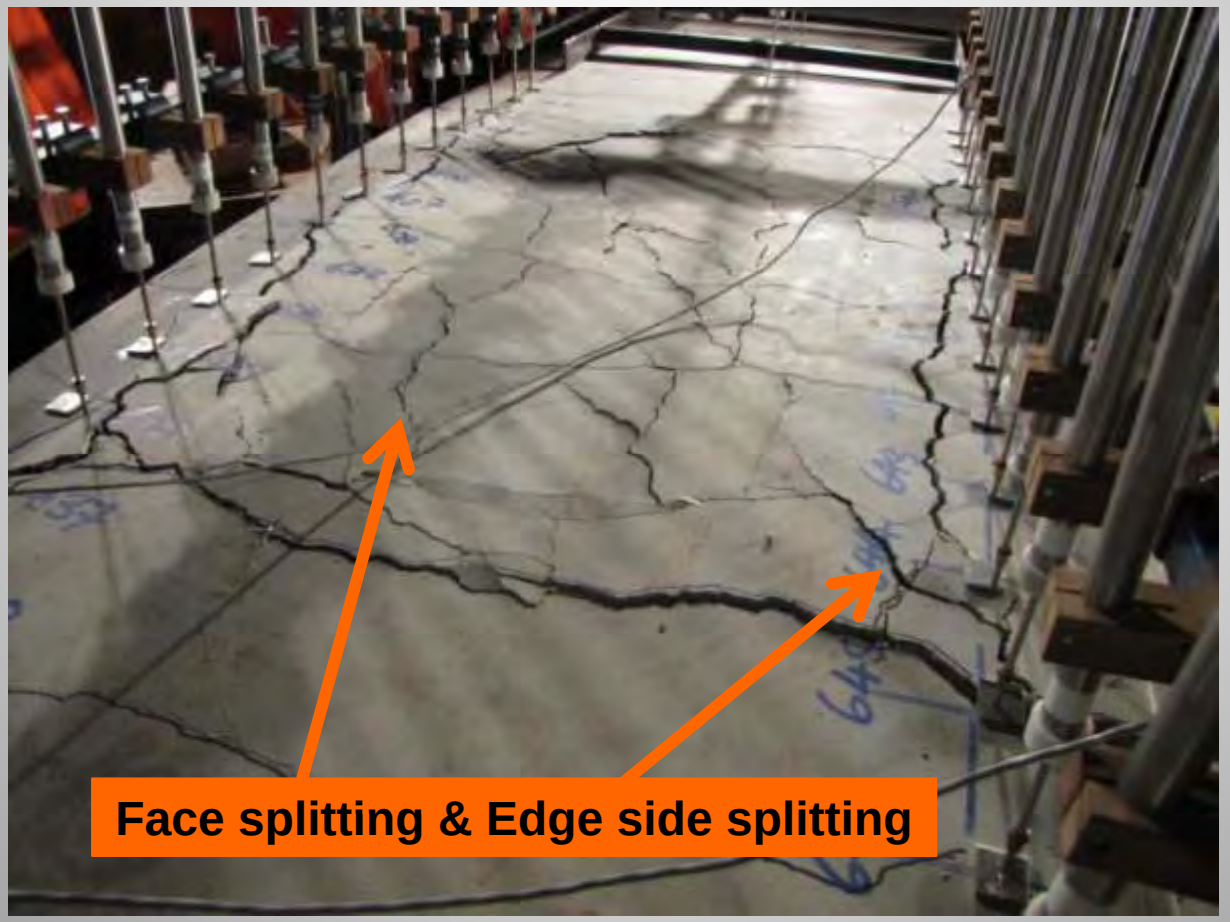

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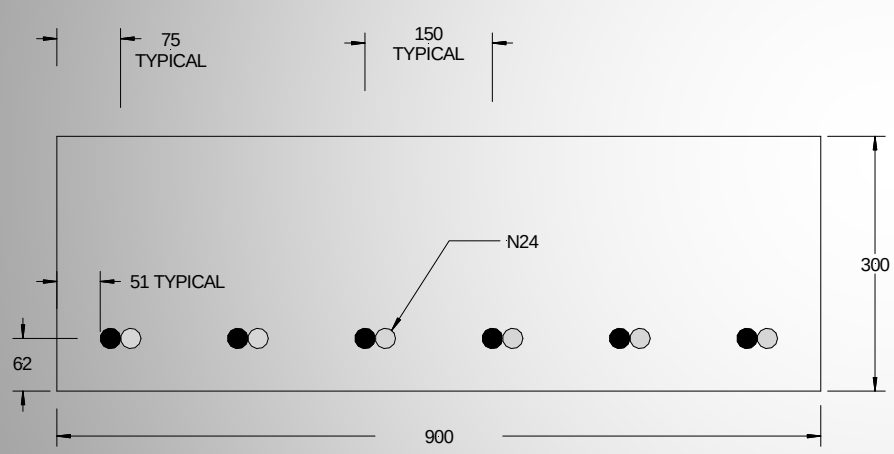

6 N24 contact lap splices without transverse reinforcement

Recent Australian Bond Test Series

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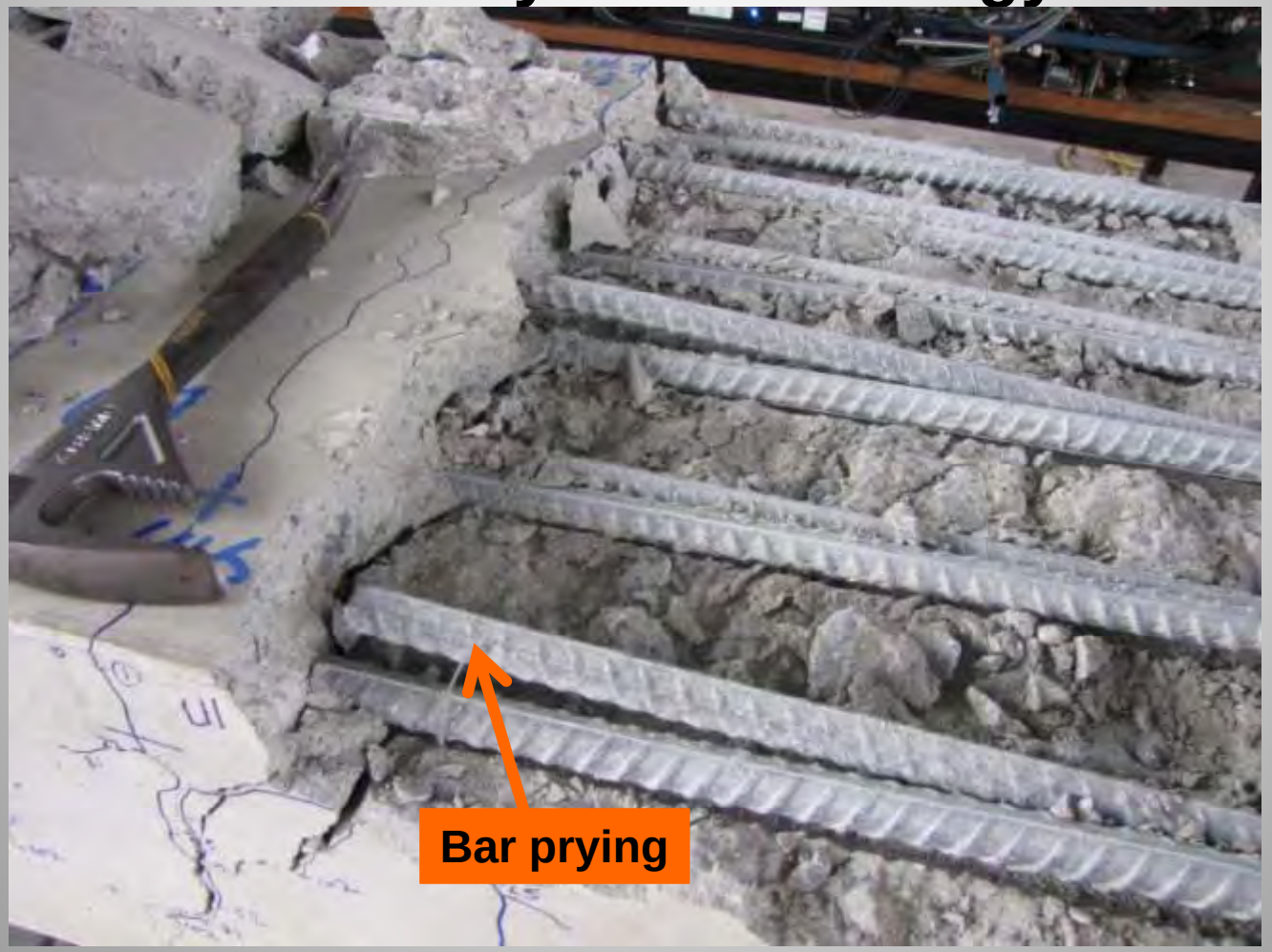
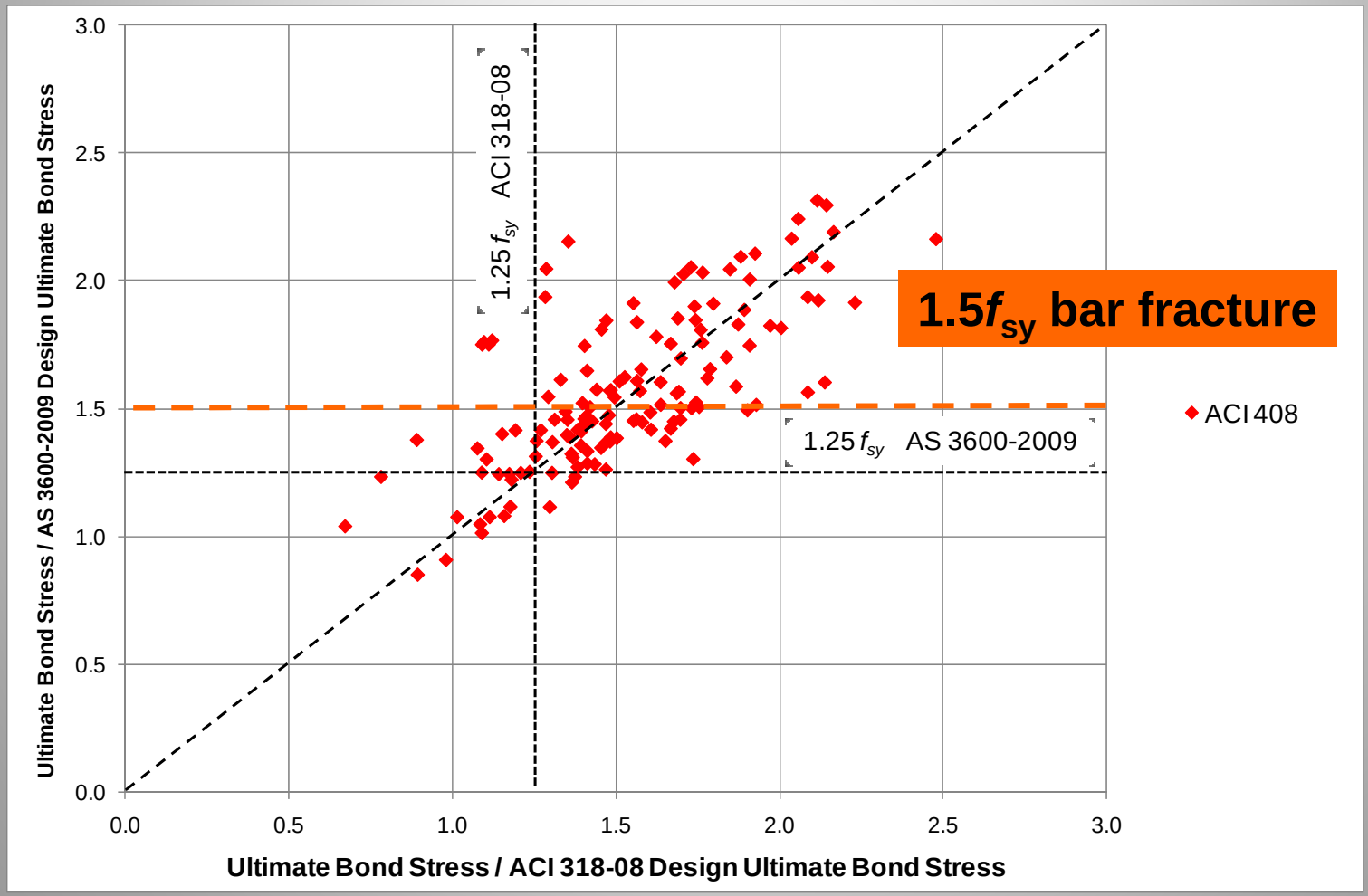


Australian Bond Test Results

- **American Concrete Institute (ACI) Database**



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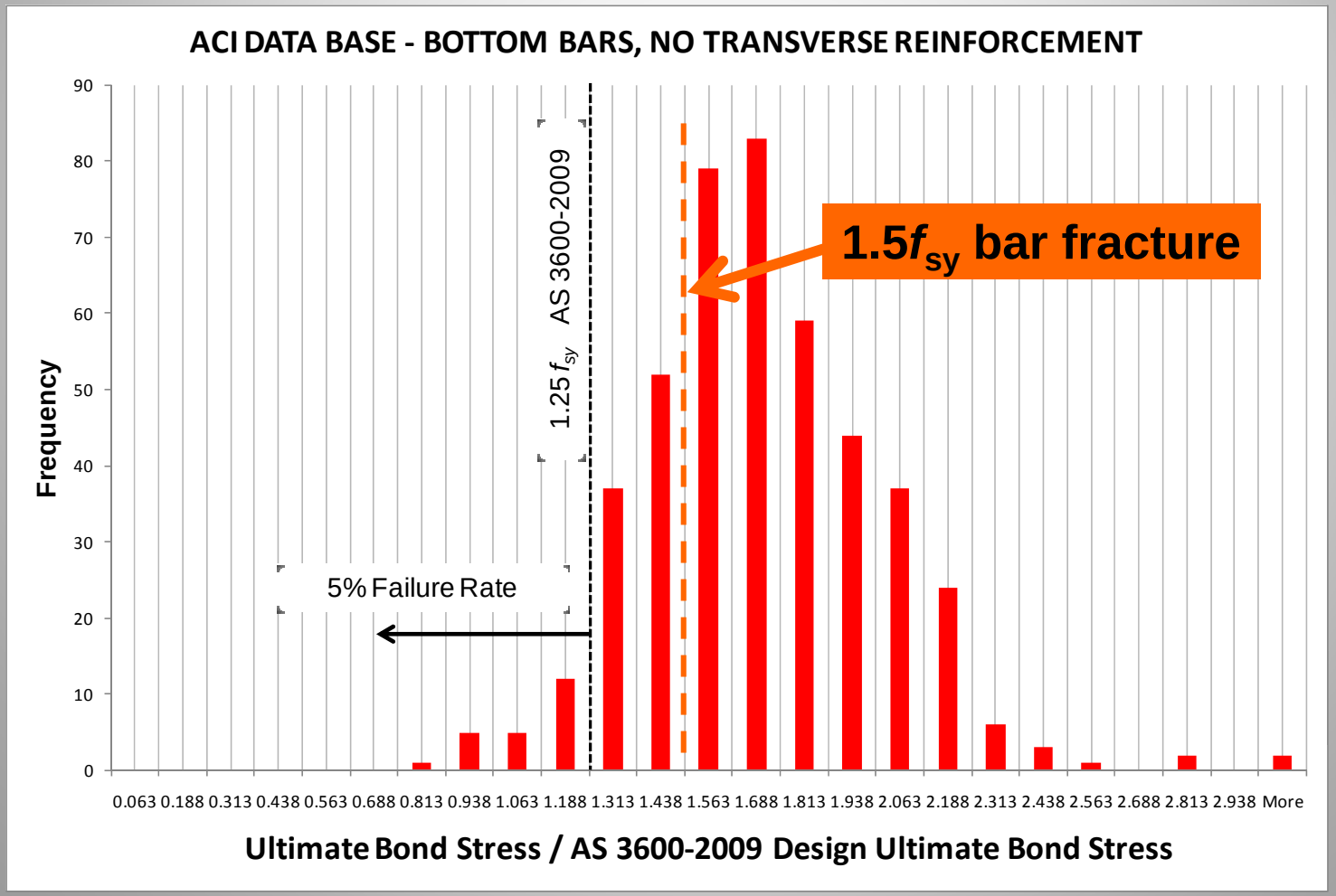
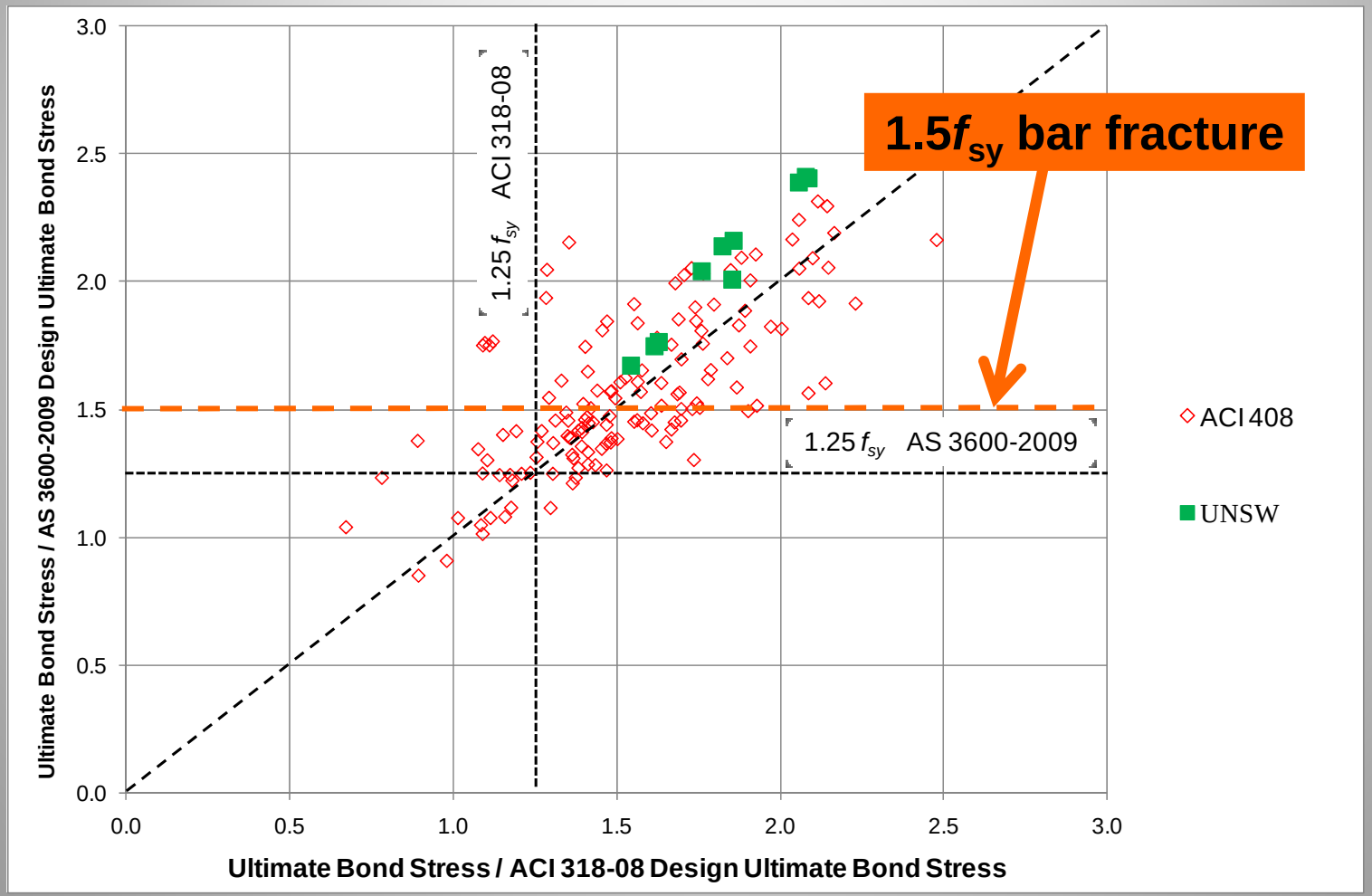


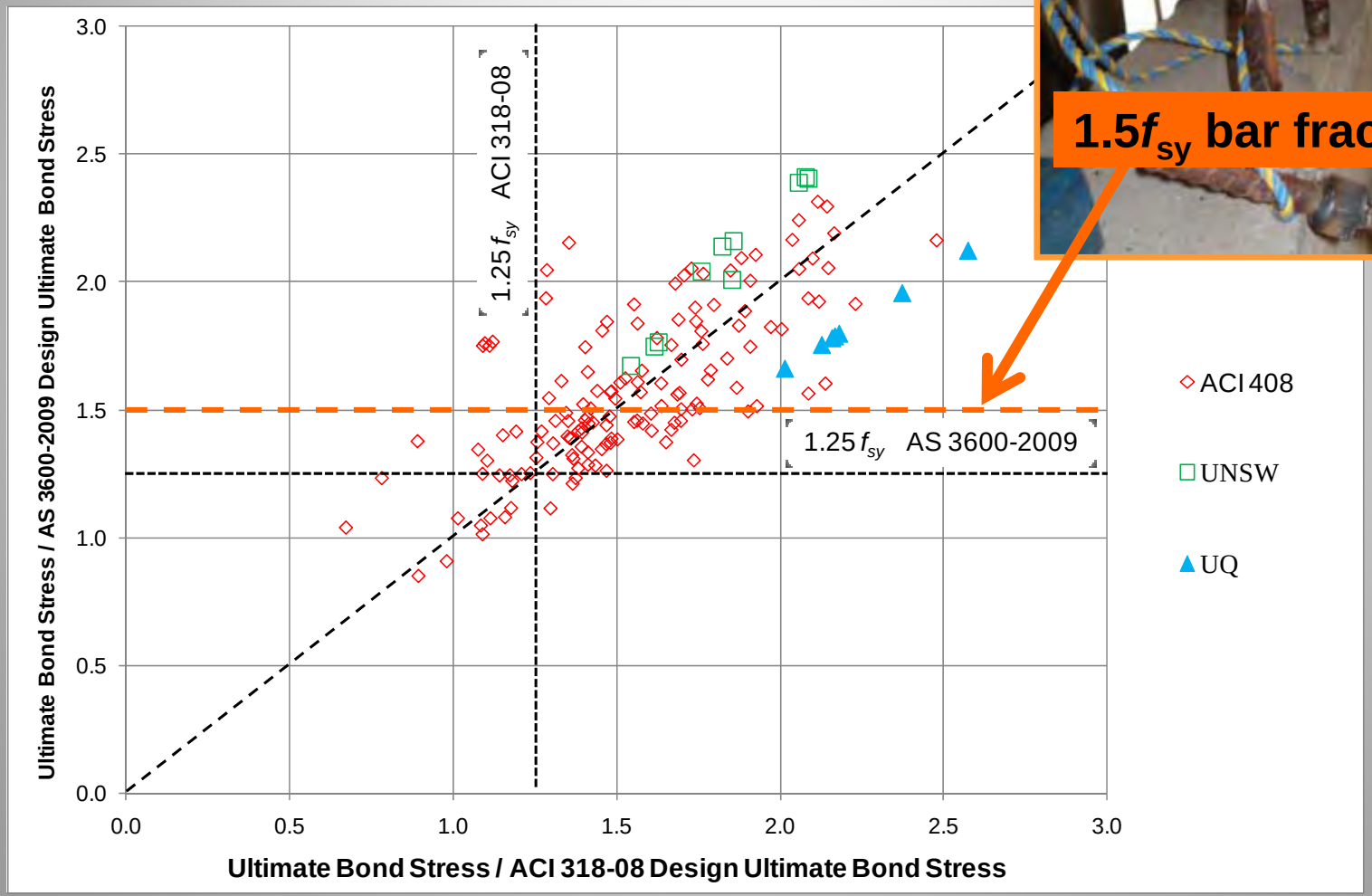
Australian Bond Test Results

- University of New South Wales



Australian Bond Test Results

- University of Queensland



Australian Bond Test Results

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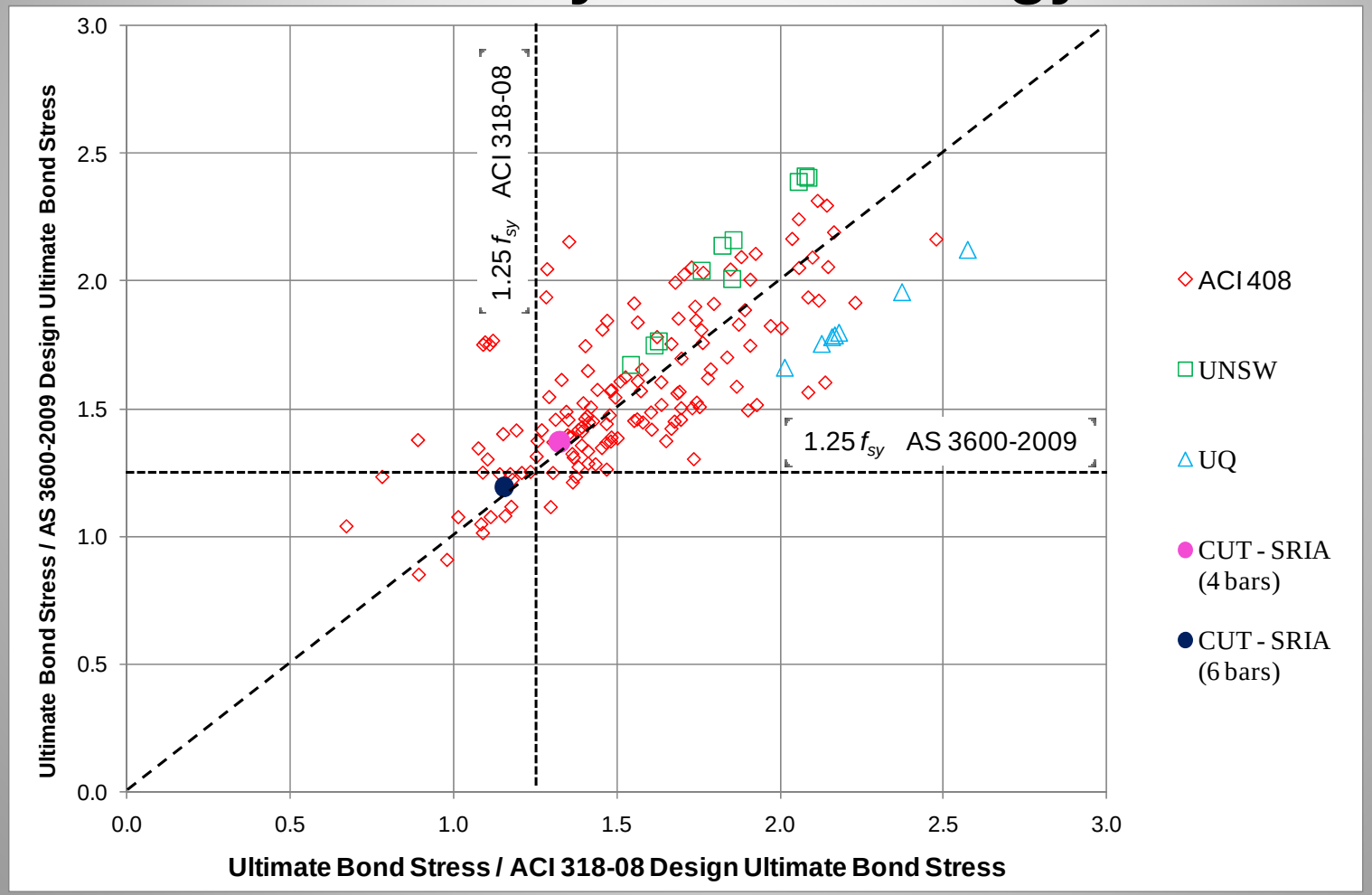

Bond Test Results & Conclusions

- **UNSW & UQ tests were designed to replicate slabs & walls incorporating small diameter bars (D500N12 & 16)**
- **Results of UNSW and UQ tests on small diameter (N12 & N16) bars, with very high mean AS 3600–2009 test/design ratios of 2.1f_{sy} and 1.8f_{sy},respectively, indicate that factor $k_2=(132-d_b)/100$ could possibly be increased**
- **SRIA tests on beams with D500N24 bars performed by Curtin University also indicate 1.25f_{sy} is more realistic**
- **ACI database shows that 1.25f_{sy} is a much more realistic target achieved using AS 3600–2009 under non-seismic conditions, which serves as a *ductility criterion* for spliced D500N bars generally**

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