Review of Australian Support-Settlement Tests on Continuous, One-Way Reinforced-Concrete Slabs incorporating Low-Ductility Reinforcement

Scott Munter – Steel Reinforcement Institute of Australia
Mark Patrick – MP Engineers
Vijay Rangan – Curtin University of Technology

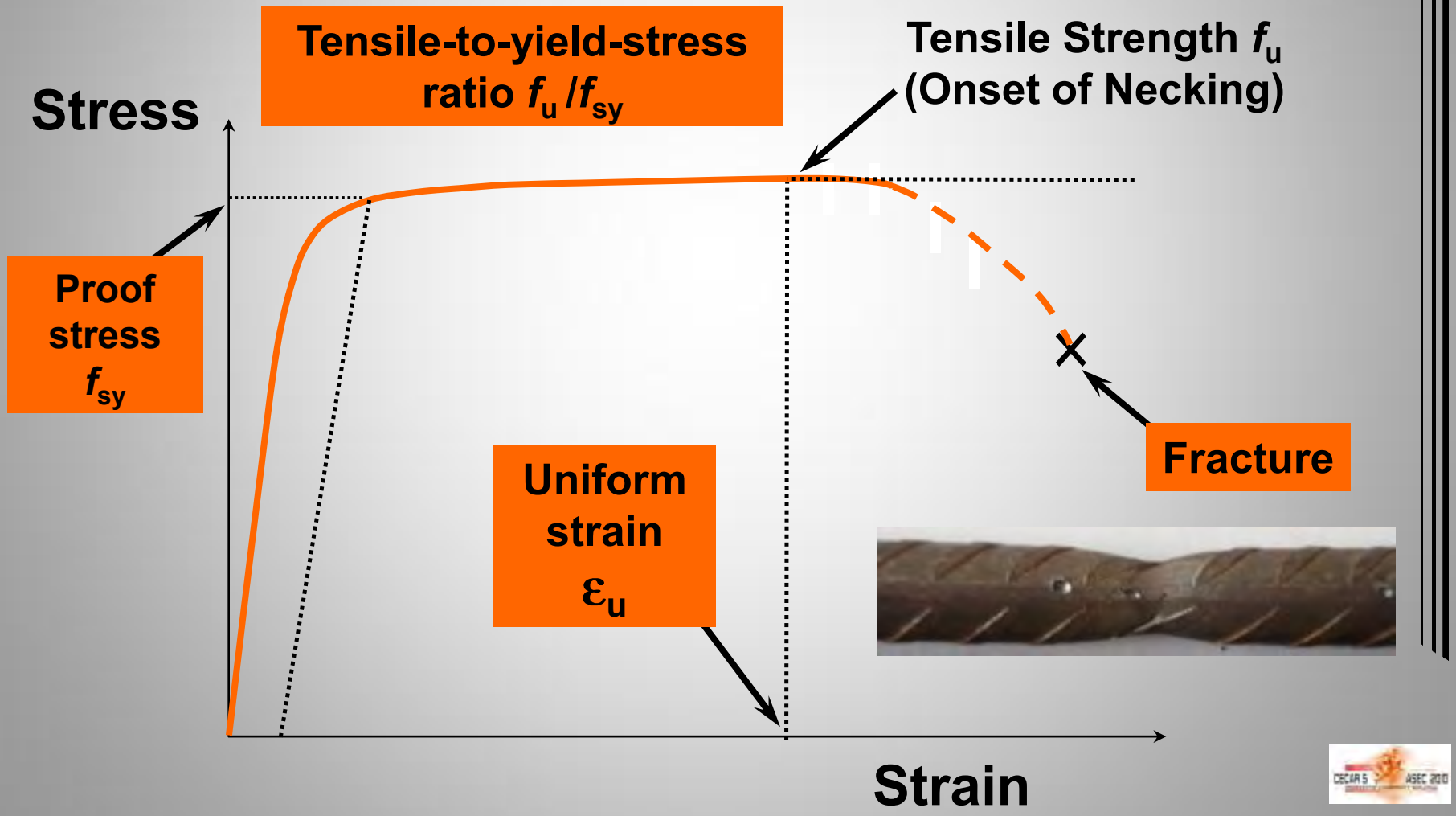
CECAR 5 ASEC 2010
INNOVATIVE COMMUNITY BUILDING

Overview

- Class L Mesh Main Reinforcement
  - Design to AS 3600–2009
  - SRIA Technical Note TN6
- Moment Redistribution
- Australian Support-Settlement Tests (1-Way)
  - University of Melbourne
  - University of New South Wales
  - Curtin University of Technology (SRIA)
- Review of Support-Settlement Test Results

New Design Rules in AS 3600–2009

- D500L Bars to AS/NZS 4671



New Design Rules in AS 3600–2009

- D500L Bars to AS/NZS 4671

Property	*D500L*
Nominal diameter (mm)	5.0 to 16
Characteristic yield stress (MPa)	
lower	500
upper	750
Tensile-to-yield-stress ratio, min.	1.03
Uniform strain (%) , min.	1.5

DUCTILITY PARAMETERS

Class L Mesh Main Reinforcement

- **Design to AS 3600–2009**

Capacity reduction factor, ϕ for calculating ϕM_{uo}:

- **Bending without axial tension or compression, for members with Class L reinforcement:**

$$0.6 \le \{\phi=(1.19 - 13k_{uo}/12)\} \le 0.64$$ **(i.e. =0.8×0.8)**

Common methods of analysis for calculating M^*, etc.:

- **Clause 6.10 – Simplified Methods for beams or one-way slabs; and two-way slabs supported on four sides.**
- **Clause 6.2 – Linear Elastic Analysis of any type of framed concrete structure, but ignoring moment redistribution**
- **Support settlement no longer required to be considered**

Class L Mesh Main Reinforcement

- **SRIA Technical Note TN6 (to AS 3600-2001)**

SRIA STEEL REINFORCEMENT INSTITUTE OF AUSTRALIA

July 2008

TECHNICAL NOTE 6

DESIGN to AS 3600:2001 of SUSPENDED CONCRETE FLOORS REINFORCED with CLASS L MESH

1 SCOPE

This technical note addresses the design of suspended concrete floors reinforced with low-ductility Class L mesh in accordance with the current edition of the Concrete Structures Standard AS 3600:2001[1]. Changes to the Standard made in two amendments (1 & 2) that concern using Class L mesh as main reinforcement are fully accounted for.

An example of a suspended concrete floor constructed using Class L mesh as multi-purpose main and secondary reinforcement, which comprises reinforced-concrete beams and slabs, is shown in **Figure 1**.

Design for serviceability and ultimate strength are addressed. Important aspects of design not directly addressed in AS 3600 are clarified.

FIGURE 1 *Suspended Concrete Floor Construction using Class L Mesh*

2 BUILDING CODE OF AUSTRALIA (BCA)

The two complementary Australian Standards AS 3600:2001 *Concrete structures* and AS/NZS 4671:2001 *Steel reinforcing materials*[2] are both given legal status by being referenced in the current Building Code of Australia (BCA)[3]. Designs developed using these Standards comply with the Deemed-to-Satisfy Provisions of the BCA and accordingly fully satisfy its Performance Requirements.

These two Standards define the minimum properties, and design and construction requirements for Class L mesh used as reinforcing steel in suspended concrete floors.

3 AS/NZS 4671:2001

The standard grade of ribbed reinforcing mesh sold, referred to in AS/NZS 4671 has a nominal yield stress, f_{sy}, of 500 MPa and is designated as having low (L) ductility.

Its ductility is characterised by uniform strain, ε_{suf}, and tensile-strength-to-yield-stress ratio, f_{st}/f_{sy}, for which compliance with Appendix A of AS/NZS 4671 must be demonstrated. Minimum lower characteristic values for Class L mesh are $\varepsilon_{suf} \geq 1.5\%$ and $(f_{st}/f_{sy})_k \geq 1.03$, on which the design rules in AS 3600 are based. Significantly higher values can be achieved in practice[4]. As well as confirming satisfactory mechanical properties, weld-shear strengths and geometric measurements must also be confirmed.

Cross-sectional areas of commonly-available Class L mesh sizes used in the construction of suspended concrete floors like that in **Figure 1** are given in Table 1, where A_{sl} and A_{st} are the cross-sectional areas of the longitudinal and transverse bars, respectively, based on

www.sria.com.au

INSTRUCTIONS: Click on any item in BLUE to go to it, use Return Button to come back to previous place

Advises that support settlement does not normally need to be considered in design, as it is adequately catered for using the lower value of ϕ =0.64 for under-reinforced sections

Moment Redistribution

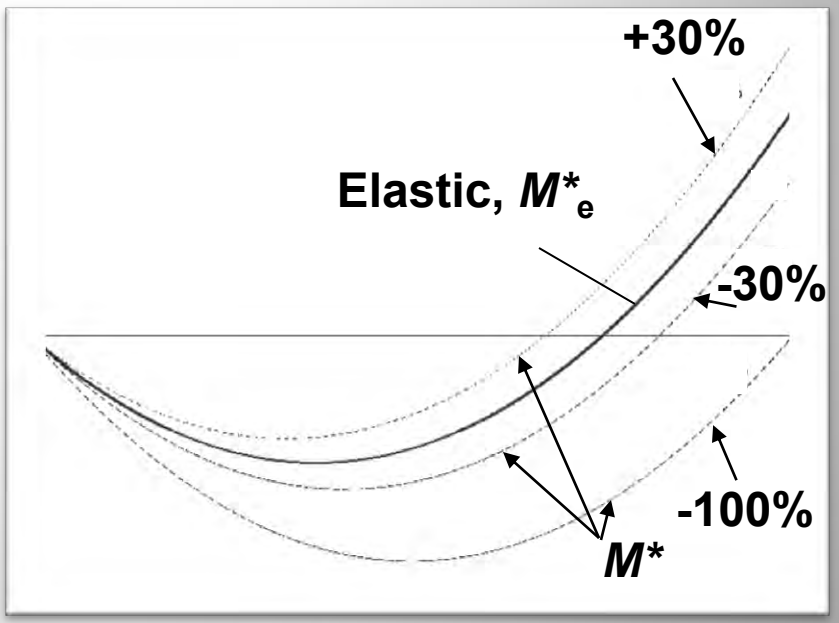
- **For design of a cross-section, the amount of moment redistribution:**

$$\beta = -100\left(1-\frac{M^*}{M_e^*}\right)$$

where:

M* = **the design bending moment, and**

M^*_e = **the elastically-determined design bending moment ignoring moment redistribution**



Australian Support Settlement Tests

- **University of Melbourne (2005)**

Two two-span continuous one-way reinforced concrete slabs containing Class L mesh were tested to investigate the impact of support settlement on ultimate strength.

"Moment redistribution occurred throughout the tests due to changes in relative stiffness caused by the gradually evolving crack patterns."

"The slabs were able to resist loads considerably higher than the ultimate limit state design loads before failure (using ϕ=0.8)."

ε_u varied from 1.7 to 3.4%

Upward movement of L/294, or downward movement of L/235

Australian Support Settlement Tests

- **University of New South Wales (2008)**

- ***"A series of full range load tests is described on two-span continuous one-way reinforced concrete slabs containing Class L welded wire fabric (WWF). Five specimens were tested to investigate the impact of support settlement on ultimate strength."***

- **There were 2 control slabs without any settlement. The centre support of the other 3 was lowered by L/215, L/422 or L/426.**

- ***"The imposed support settlements did not affect the strength of the slabs and the reinforcement was able to accommodate the settlements without compromising the strength."***

- ***"The WWF used in the experiments had a uniform elongation ε_{su} typically in excess of 3.4% and a strength-to-yield stress ratio (f_{su}/f_{sy}) in excess of 1.05. …….Therefore, the observations concerning the effect of support settlement on the strength of the one-way slabs may not be applicable for Class L reinforcement that just satisfies the minimum limits."***

Australian Support Settlement Tests

- **SRIA at Curtin University of Technology:**
  Universal testing frame

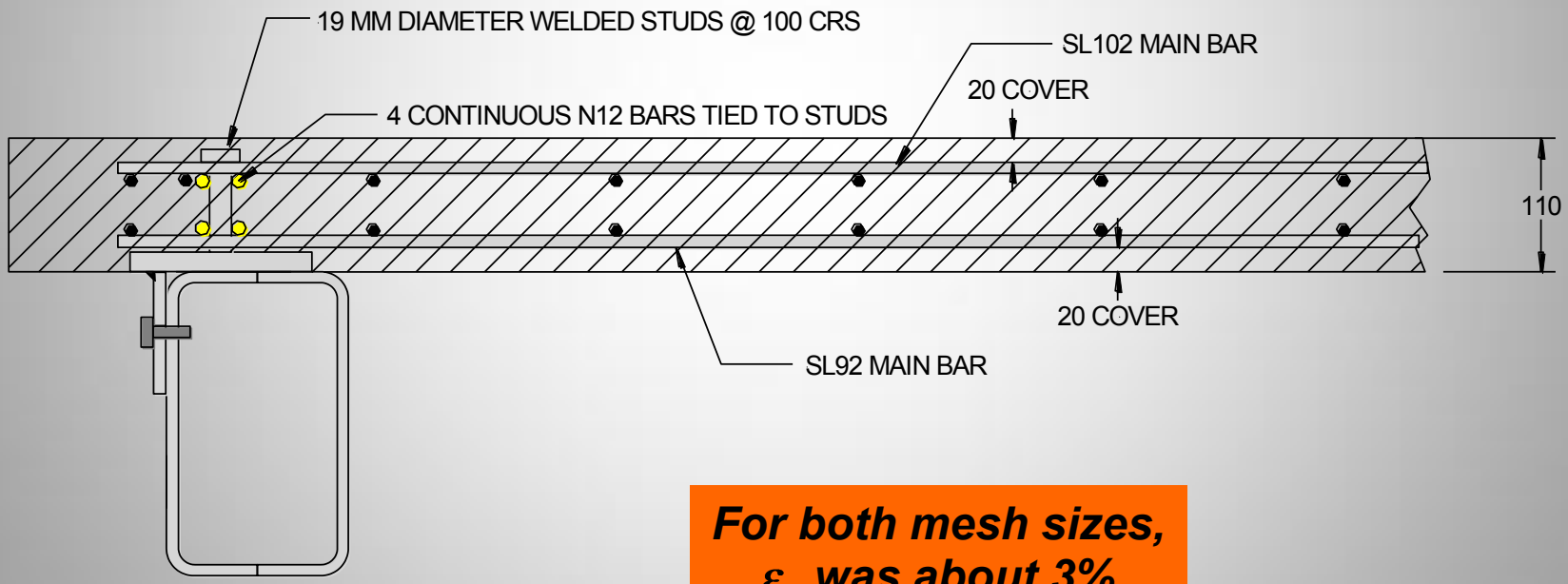
Australian Support Settlement Tests

- **SRIA at Curtin University of Technology:**
  Four double-span support settlement tests:

Australian Support Settlement Tests

- **SRIA at Curtin University of Technology:**

Main reinforcement:



For both mesh sizes, ε_u was about 3%

Australian Support Settlement Tests

- **SRIA at Curtin University of Technology:**
  Different end support conditions: FIXED

DSOW–ST1 & ST2

Australian Support Settlement Tests

- **SRIA at Curtin University of Technology:**
  Different end support conditions: ROLLER

DSOW–ST3 & ST4

Australian Support Settlement Tests

- **SRIA at Curtin University of Technology:**
  Testing DSOW–ST4 : holding down ends

Australian Support Settlement Tests

- **SRIA at Curtin University of Technology:**
  Testing DSOW–ST4 : flexural cracking over middle support after initially jacked up 5 mm

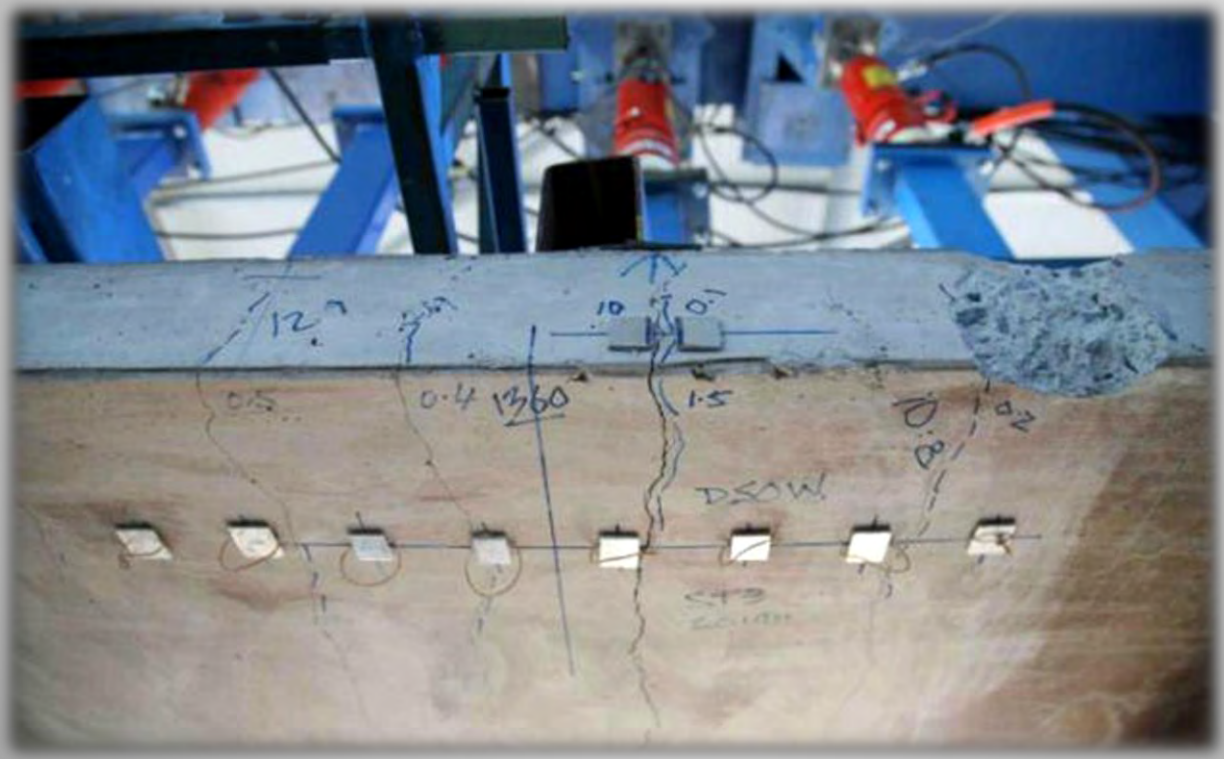
Upward movement of L/460

Australian Support Settlement Tests

- **SRIA at Curtin University of Technology:**
  Testing DSOW–ST4 : near maximum load

Australian Support Settlement Tests

- **SRIA at Curtin University of Technology:**
  Testing DSOW–ST4 : +ve bending region

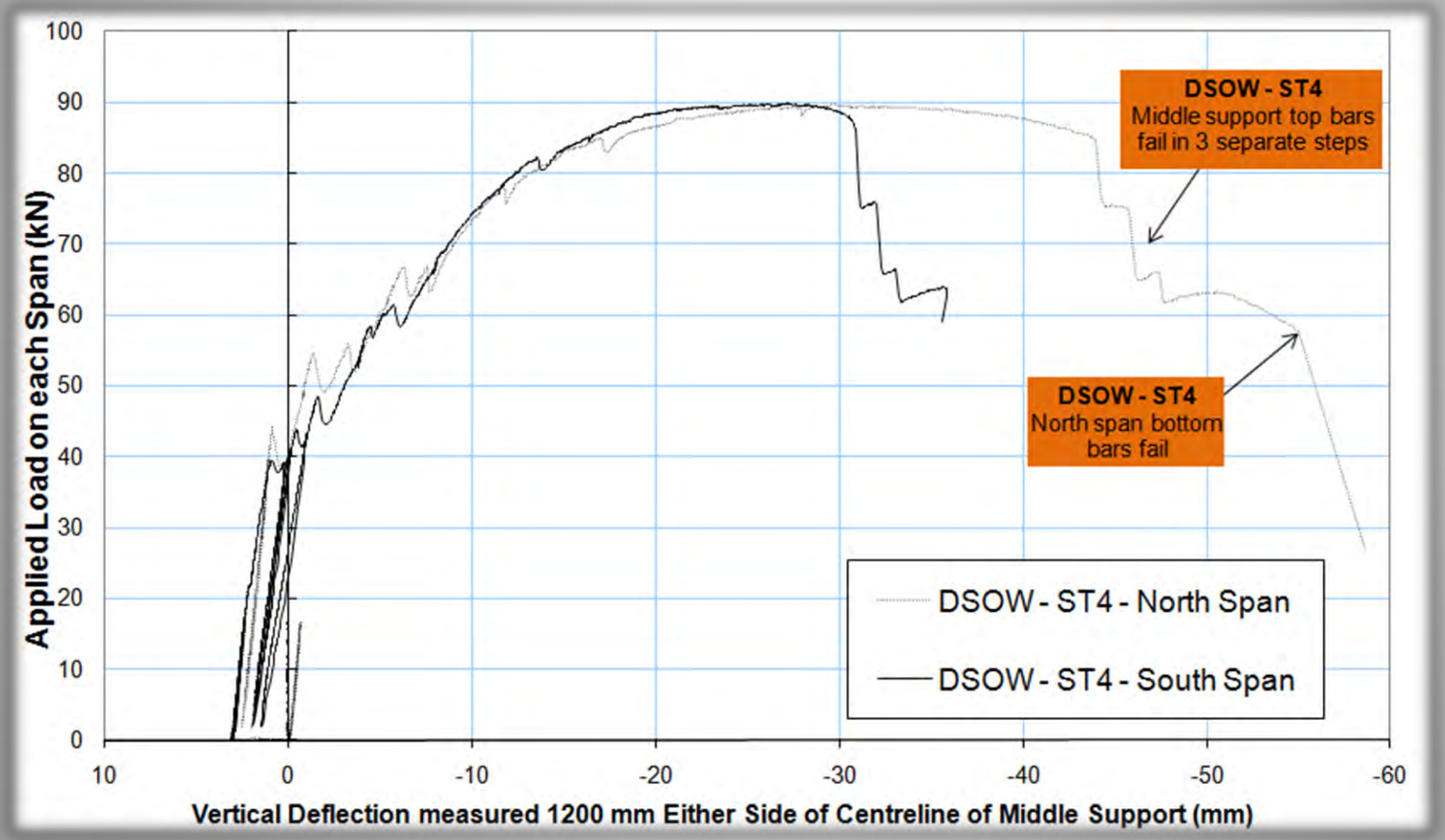


Australian Support Settlement Tests

- **SRIA at Curtin University of Technology:**
  Testing DSOW–ST4 : failing –ve bending region

Australian Support Settlement Tests

- SRIA at Curtin University of Technology:



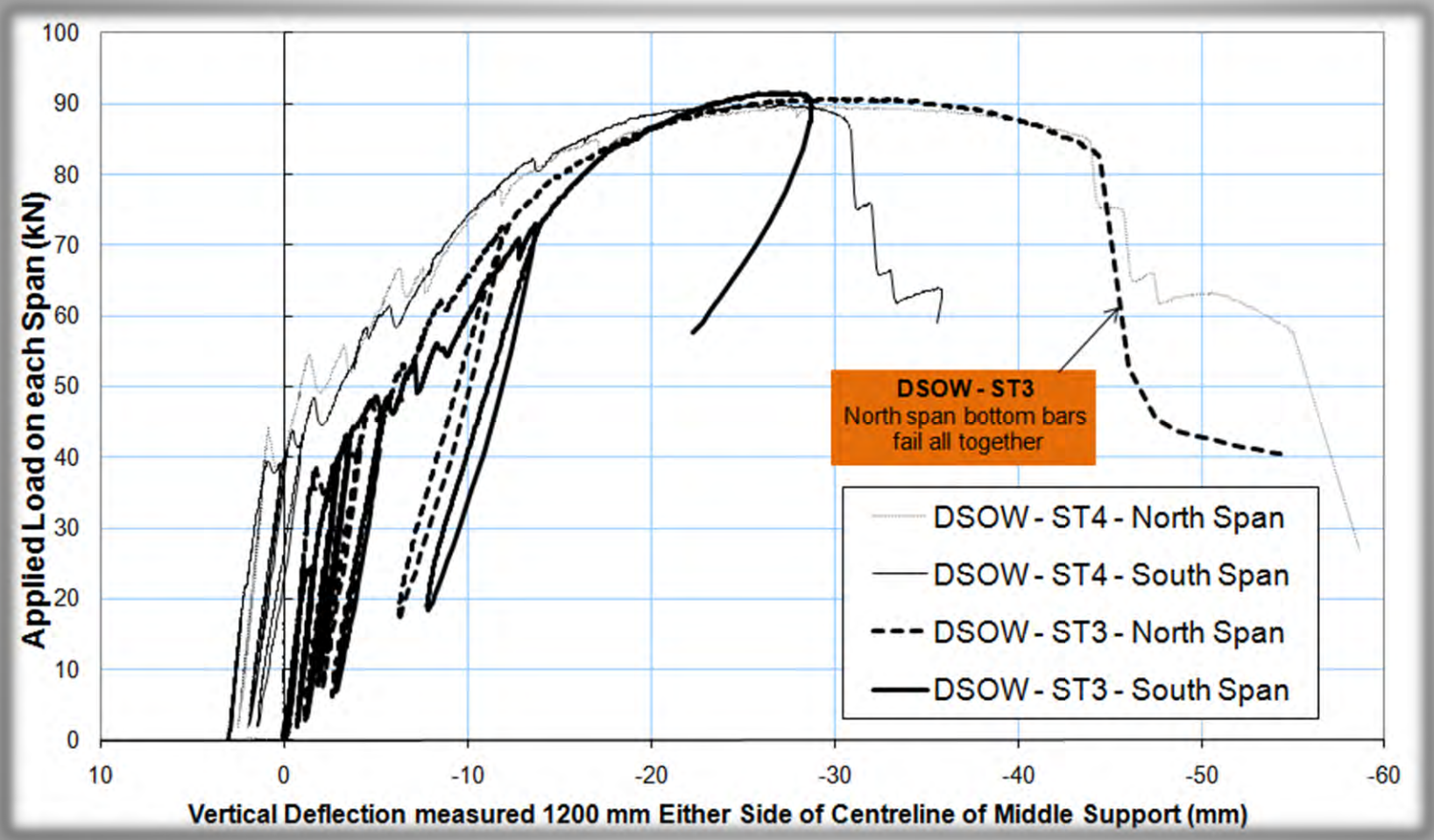
Australian Support Settlement Tests

- **SRIA at Curtin University of Technology:**

Testing DSOW–ST4 : failed +ve bending region

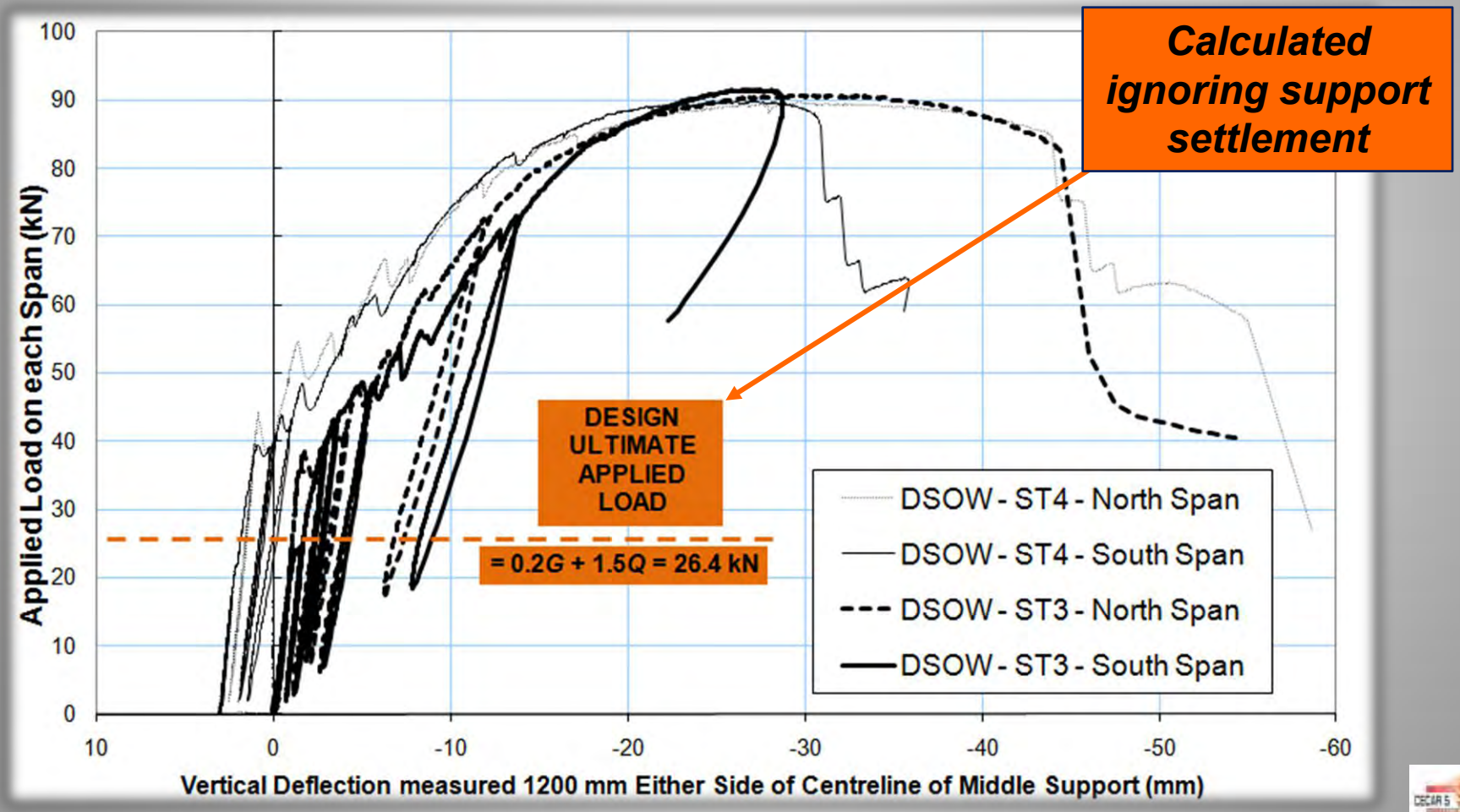
Australian Support Settlement Tests

- **SRIA at Curtin University of Technology:**



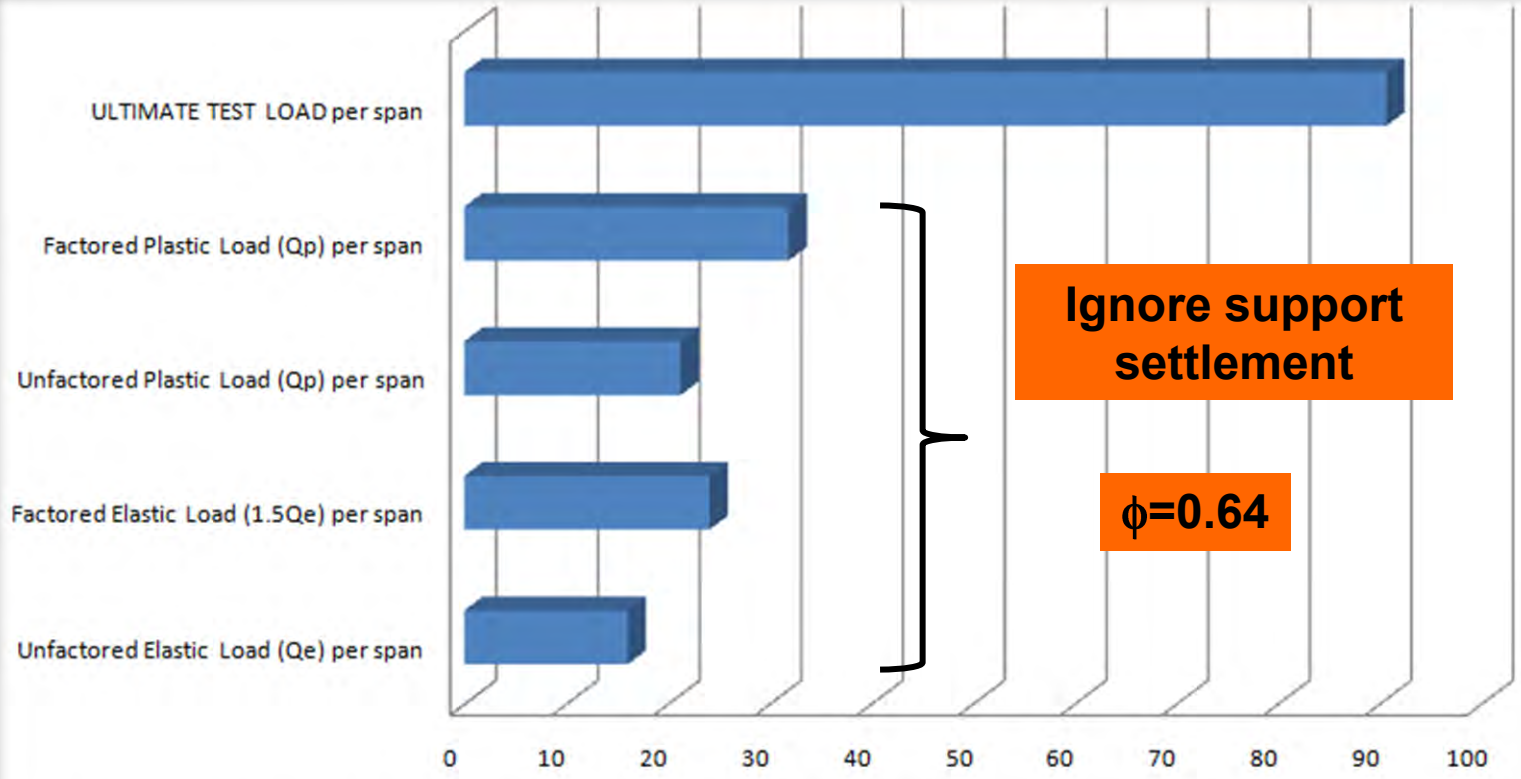
Australian Support Settlement Tests

- **Review of Support-Settlement Test Results**



Australian Support Settlement Tests

- Review of Support-Settlement Test Results

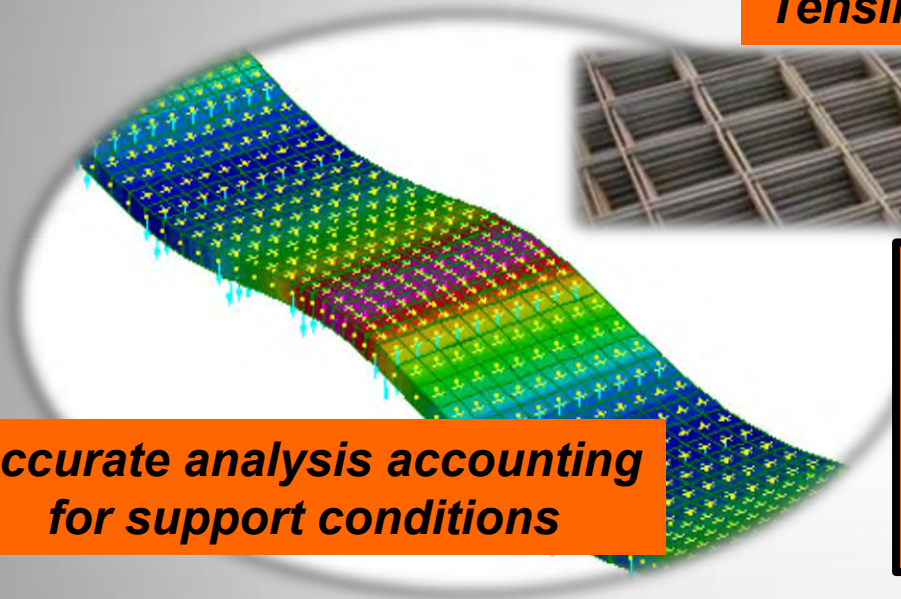


	Unfactored Elastic Load (Qe) per span	Factored Elastic Load (1.5Qe) per span	Unfactored Plastic Load (Qp) per span	Factored Plastic Load (Qp) per span	ULTIMATE TEST LOAD per span
kN	16.08	24.12	21.28	31.92	90.7

Australian Support Settlement Tests

- Review of Support-Settlement Test Results

Tensile strength of steel



Accurate analysis accounting for support conditions

So why were the slabs so strong?

Actual depths of slab and steel bars, and actual concrete compressive strength

Australian Support Settlement Tests

- **Review of Support-Settlement Test Results**
  - **Potentially detrimental effects of support settlement up to about span/250 are significantly less than first envisaged based on simple elastic design analysis**
  - **A very detailed Curtin University Test Report about all the DSOW, SSOW and TW slab tests will be published early next year, as soon as it has been reviewed by the SRIA Peer Review Panel of technical experts and industry representatives**
  - **It will have an associated document to explain the design of the slabs in accordance with AS 3600–2009**
  - **SRIA's research results will make a significant contribution to the national test database concerning the use of Class L mesh in suspended slabs**

Conclusions

- **Class L Mesh Main Reinforcement**
  - **Design to AS 3600–2009**
  - **SRIA Technical Note TN6**
- **Moment Redistribution**
- **Australian Support-Settlement Tests (1-Way)**
  - **University of Melbourne**
  - **University of New South Wales**
  - **Curtin University of Technology (SRIA)**
- **Review of Support-Settlement Test Results**

Review of Australian Support-Settlement Tests on Continuous, One-Way Reinforced-Concrete Slabs incorporating Low-Ductility Reinforcement

Scott Munter – Steel Reinforcement Institute of Australia
Mark Patrick – MP Engineers
Vijay Rangan – Curtin University of Technology

CECAR 5 ASEC 2010
INNOVATIVE COMMUNITY BUILDING