Industry Perspectives with Ash:
Past, Present and Future

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Presentation Summary

- Where we have come from
- Design and construction with fly ash and CCPs
- Low carbon concrete, structures and projects
- Where to from here?

Where we have come from

- History of fly ash in Australian standards
- Its changing use
- Durability and sustainability

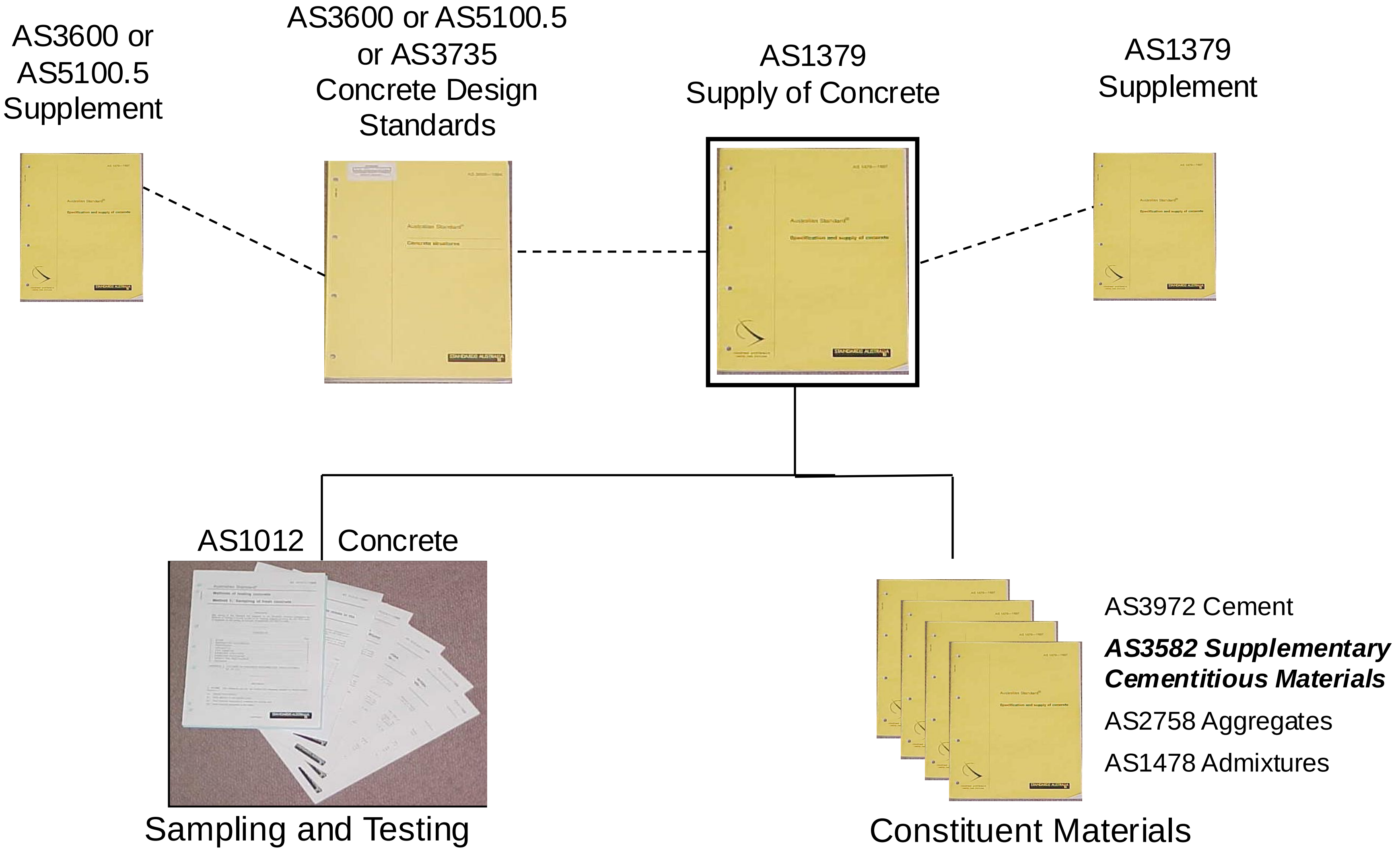
A look at Concrete

Where fly ash has been used as part of the binder

- Structural concrete

- AUSTRALIA
  - 30 million cubic metres of concrete per annum
- USA
  - 400 million cubic metres of concrete per annum
- WORLD
  - 10 billion cubic metres of concrete per annum

Fly Ash in Concrete: Standards Roadmap



Australian Standards for Concrete Structures, Bridges and Specification/Supply

CONCRETE STRUCTURES

- 1934: Concrete structures code CA2 first published
- 1974: AS1480 published
- 1988: AS3600 published
- 1994: AS3600 revision
- 2001: AS3735 Liquid Retaining Structures published
- 2001: AS3600 revision
- 2009: AS3600 revision
- 2018: AS3600 revision

BRIDGE DESIGN

- 1992: Australian Bridge Design Code (Austroads ABCB) published
- 1996: ABCB revised
- 2004: AS5100.5 Bridge Design published
- 2017: AS5100.5 revision

SPECIFICATION AND SUPPLY

- 1941: AS(E)A502 published
- 1991: AS1379 published
- 1997: AS1379 revised
- 2007: AS1379 revised

Common Concrete Binder Standards in Australia

CEMENT

- 1925: First cement standard AS-A2
- 1972: Blended cement published
- 1973: AS1315 Portland Cement published
- 1982: AS1315 and AS1317 revised
- 1991: AS3972 Portland and Blended Cements published (no Bogue compositions)
- 1997: AS3972 revised
- 2010: AS3972 revised

SLAG (GROUND GRANULATED (IRON) BLAST FURNACE)

- 1991: AS3582.2 Slag first published
- 2001: AS3582.2 revised
- 2016: AS3582.2 revised

SILICA FUME/AMORPHOUS SILICA

- 1994: AS3582.3 Silica fume first published
- 2002: AS3582.3 revised (Amorphous Silica)
- 2016: AS3582.3 revised

MANUFACTURED POZZOLANS

- 2022: AS3582.4 Manufactured Pozzolans first published

Fly Ash in Australian Standards

- 1971: AS 1129 *“Fly Ash for Use in Concrete”*
- 1971: AS 1130 *“Code of Practice for the Use of Fly Ash in Concrete”*
- 1991: AS3582.1 *“Supplementary Cementitious Materials for Use with Portland Cement, Part 1 – Fly Ash”*
- 1998: AS3582.1 revised
- 2016: AS3582.1 *“Supplementary Cementitious Materials, Part 1 – Fly Ash”* revised

Design and Construction with Fly Ash and CCPs

- Role of designers
- Role of contractors in major infrastructure projects

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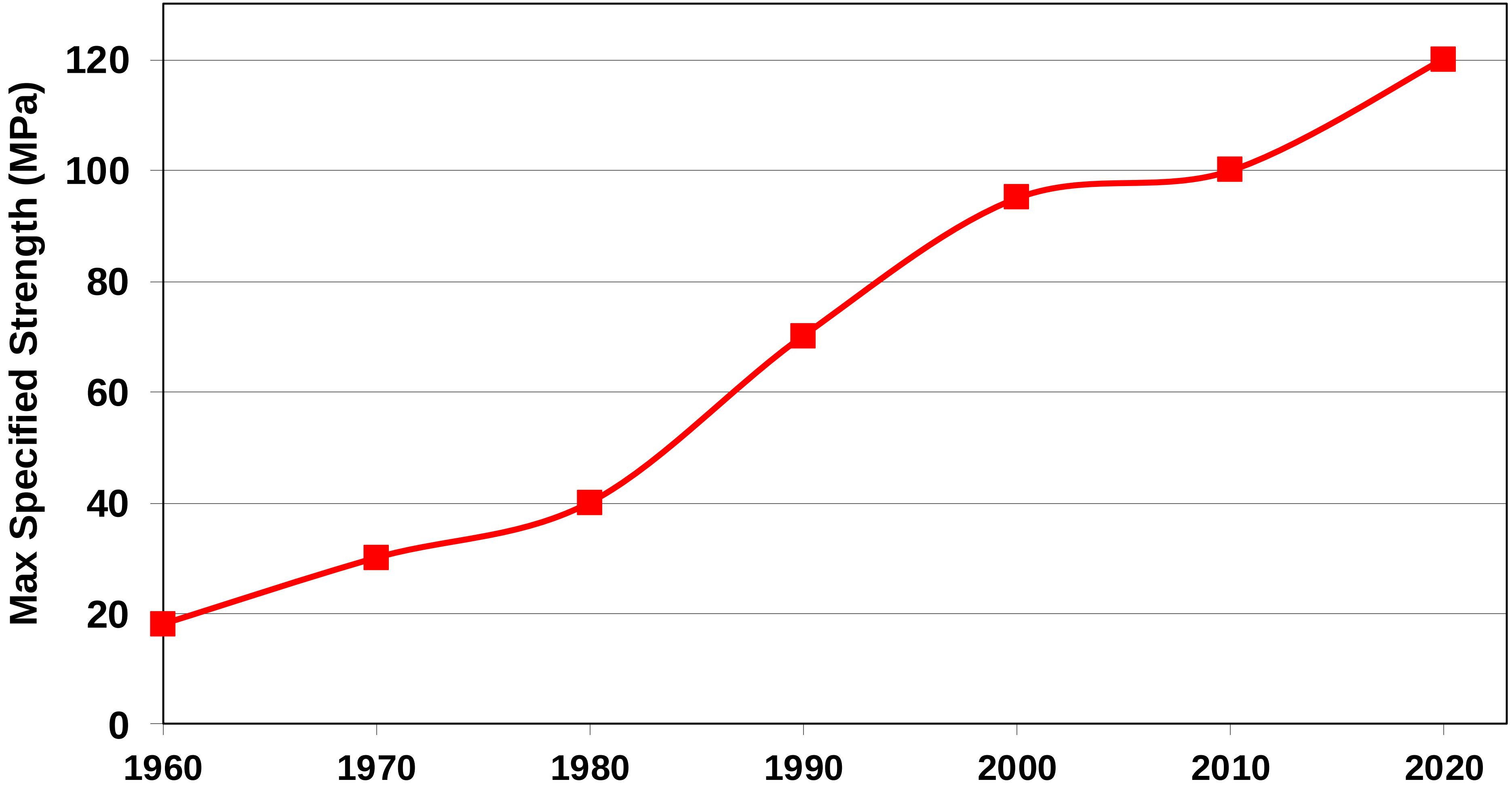
“Traditional” Concrete:

- N Class or S Class – AS1379
  - 20 MPa
  - 25 MPa
  - 32 MPa
  - 40 MPa
  - 50 MPa
- S Class – AS1379
  - 65 MPa
  - 80 MPa
  - 100 MPa
  - 120 MPa

- Fly ash included in most concretes commercially since about 1966
- Constructability benefits
- Have been “rationed” because of potential lack of supply (AS3582.1 conforming)
- Imported from overseas in the last 10 to 15 years to supplement requirements

Growth in Specified Concrete Strength

(on your projects)



Project Specifications

- Infrastructure
  - Mostly transport authorities
  - Long history of specification development
  - Long term durability critical – call for minimum cement contents
  - 100 year design lives
  - Design (structural) efficiencies sought
  - Efficient construction required
  - Combination of prescriptive and performance based specs
  - Sustainability (work in progress)

- Buildings
  - 50 year design lives
  - Require efficient design
  - Must be cost effective
  - Require efficient and low cost construction
  - Design usually optimised for cost and efficient structural elements (e.g. columns, slabs and walls)
  - Sustainability (work in progress)

Fly Ash Use in Concrete - Historical

- 1940's – Bureau of Reclamation Structures, USA
- 1949 – Snowy Mountains scheme
- 1953 – East Perth Power Station fly ash in concrete structures in Perth
- 1958 – Wangi fly ash in Keepit Dam, NSW
- 1966 – Became commercially available in premixed concrete in Australia
- 1970's – Significant uptake in concrete
- 1980's – Significant research done on durability
- 1990's – Becomes a benchmark in Normal Class concrete
- 2000 to 2005 – First indications of shortages of AS3582.1 compliant fly ash in construction in Australia
- 2010 – Sustainability further drives fly ash and SCM use in concrete in Australia

Why we Use Fly Ash in Concrete

- Lower chloride diffusion
- Manage carbonation (with appropriate mix design)
- Resistance to sulfate attack
- Resistance to chemical attack
- High resistance to ASR
- Managing DEF

- Lower shrinkage
- Potentially lower cracking
- Increased constructability
- Lower creep
- Lower joint movement
- Improved serviceability
- Lower carbon structures *with appropriate design – not simply to replace cement in concrete*

Low Carbon Concrete, Structures and Projects

Learning from the past – high performance concrete

Conflicting requirements for managing carbon in materials versus carbon in structures/projects

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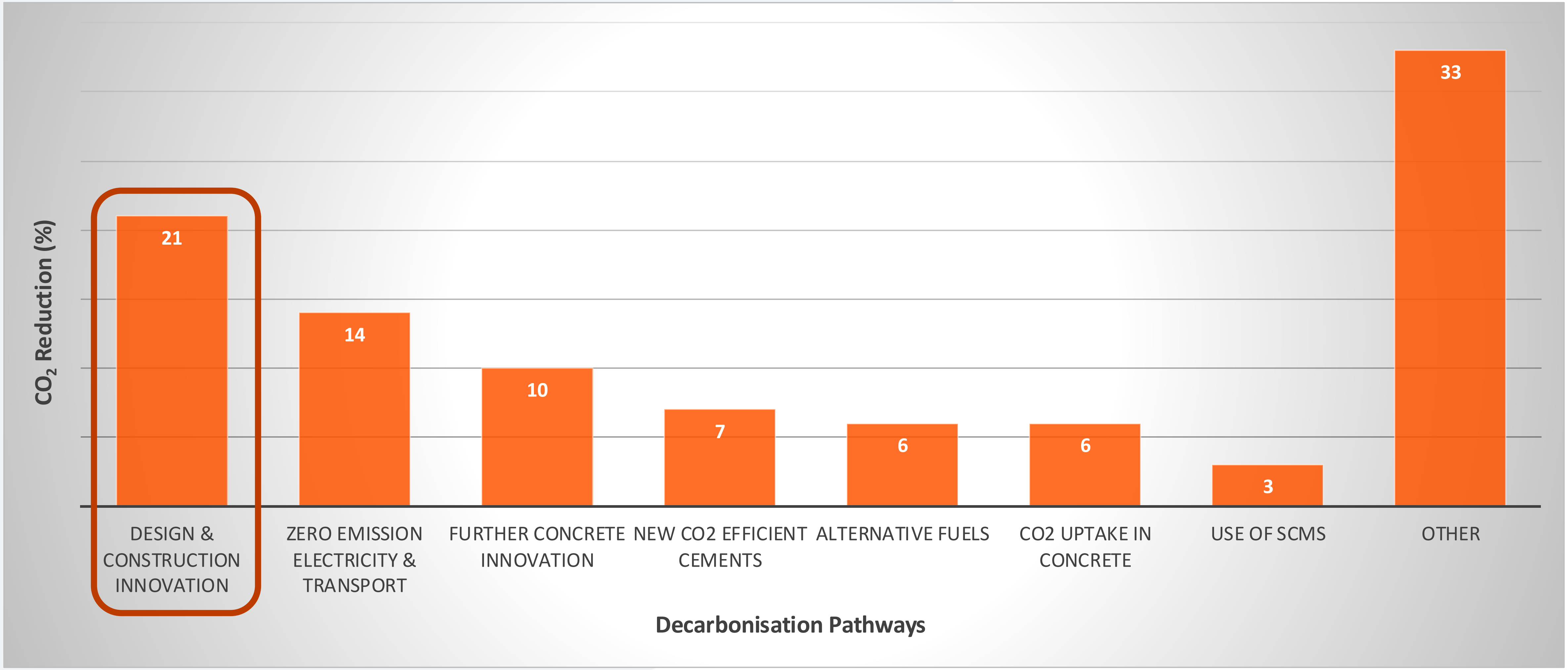
“Concrete” Hot Topics

Themes from the past that guide us into the future

- 1983: The Durability Debate
  - No standard had specific provisions for durability
- 1985: Concrete Cancer
  - *“The cancer that is eating our city buildings”*
    Financial review
- 1997: High Performance Concrete
  - *“The concrete we want but can’t talk about without being misunderstood”*
    RJ Potter, Cement & Concrete Association of Australia
- 2022: Net Zero
  - *“achieving an overall balance between greenhouse gas emissions produced and greenhouse gas emissions taken out of the atmosphere”*
- 2023: The Sustainability Debate
  - No standard had specific provisions for sustainability
- 2024: Low Carbon Concrete
  - Concrete that has a reduced embodied carbon
  - *“The concrete we want but can’t talk about without being misunderstood”*

Decarbonisation Pathways for Australian Cement and Concrete Sector

VDZ – CCAA, CIF SmartCrete and Race for 2030

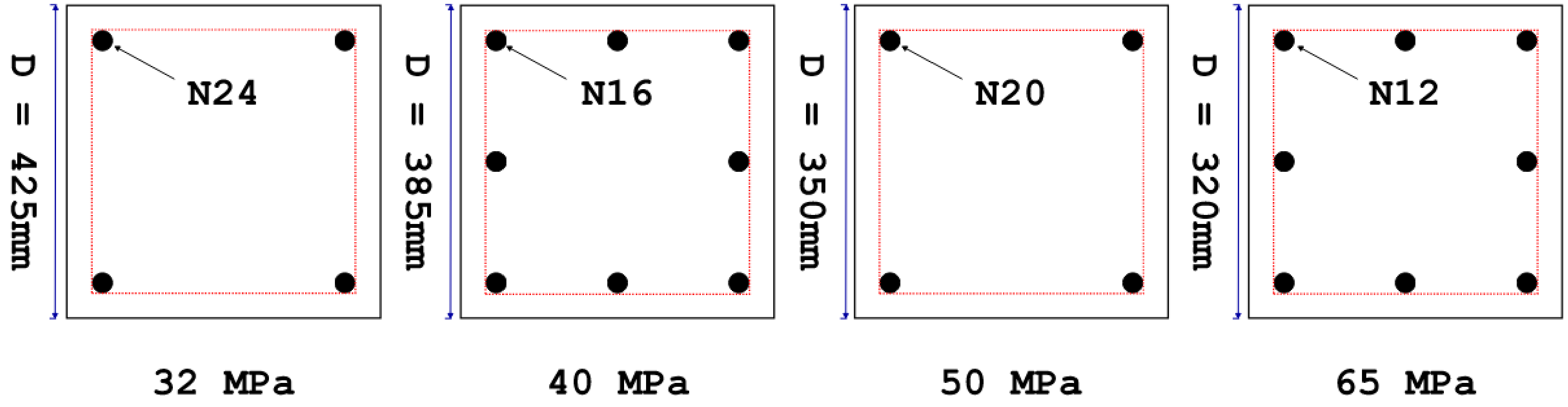


“Environmental” efficiency, reducing carbon and *“net zero”*

- What does this mean?
- Currently achieved by reducing cement
- Considered a purely materials issue
- No consideration for impacts on design and construction
- No consideration of structural and constructional efficiency
- Needs also to consider structure reuse

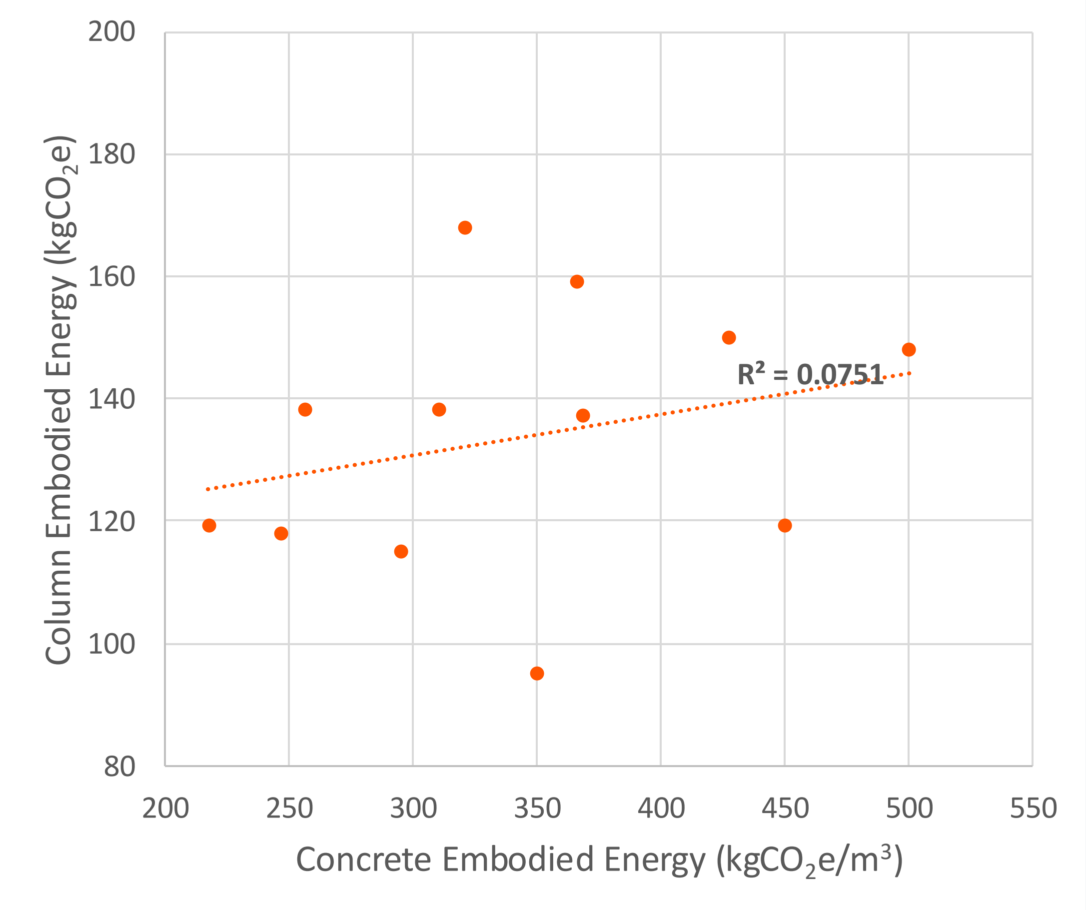
Column Design

- AS3600-2018
- Combined load = 2814 kN
- $A_s = 0.01A_g$
- $\sigma_{y_{steel}}$ = 500 MPa
- Cover = 25 mm
- Length = 2.5 m



The “S” word

Column Design Example – <u>NO CORRELATION</u>



- The current solution to sustainability is to reduce cement in concrete
- Simple column with applied load and normally designed
  - <u>**Column embodied energy ≠ concrete embodied energy**</u>
- Goes against design and construction principles
- We need research to determine how to reduce carbon in:-
  - Structural elements
  - Structures
  - Projects

Where to from Here?

- How best do we use fly ash and CCPs?
- What are the industry challenges?
- What role should power producers take in facilitating?

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Fly Ash

- Ungraded fly ash
  - Run of station ash (90% vol)
    - Ash stored in dams
    - Repository ash
    - Can be used as an aggregate supplement
- Graded Fly ash (AS3582.1)
  - Grade 1 (concrete grade)
  - Grade 2
  - Special grade (ultrafine)
- Ungraded furnace ash (10% vol)
  - Can be used as an aggregate supplement

- Graded fly ash restricted to traditional “structural” concrete
  - Extensively used
  - First used in Australia in 1949 and in NSW in 1958
  - Offers significant design and constructional benefits to concrete and roadbases
  - Should not be used to solely replace cement
- Ungraded fly ash provides massive future opportunities

Concrete Redefined

Concrete Compressive Strength Class	Opportunity for CCPs	CCP Type
<2 MPa	• Modification and stabilisation of subbases • Drainage layers • Granular courses in pavements • Non-structural fill materials	• Ungraded fly ash • Ungraded furnace ash
2 MPa to 5 MPa	• Lean mixed concrete for pavement subbases • Structural fill materials • Masonry units and components	• Ungraded fly ash • Ungraded furnace ash • Graded fly ash
10 MPa to 15 MPa	• Specialist fill materials • Low grade unspecified concrete	• Ungraded fly ash • Ungraded furnace ash • Graded fly ash
20 MPa to 50 MPa	• Structural concrete (N and S Class) • Major current market	• Graded fly ash
65 MPa to 100 MPa	• S Class High Performance Concrete • Major current market	• Graded fly ash
120 MPa and greater	• Ultra high performance concrete	• Specialist grade CCPs

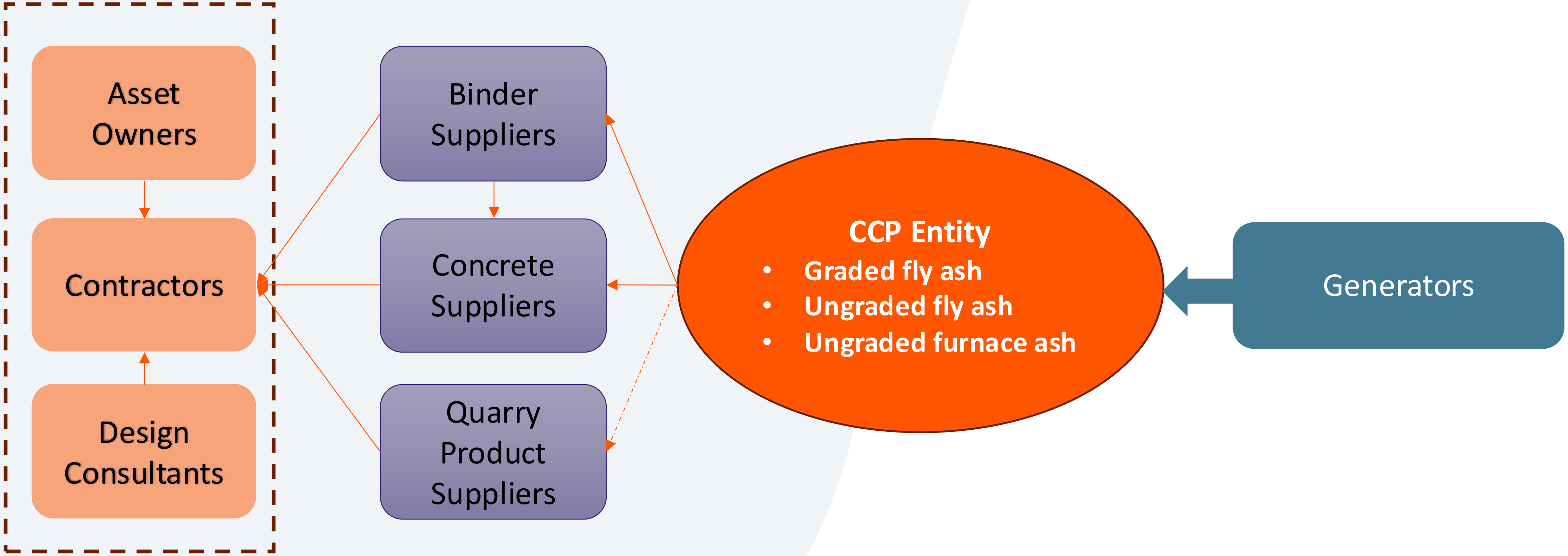
Future considerations for CCPs

- We have been working with graded fly ash in construction for a long time – lots of history
- We cannot keep going the way we are – doing so will result in
  - Waste
  - Unoptimized material use

- We need to rethink how we currently view fly ash and CCPs
- Maintain efforts with graded (AS3582.1 compliant) fly ash materials
- Consider how to use ungraded materials
  - Convert to comply with graded specifications
  - Look at opportunities in other areas (as quarry material inclusions)
  - Look at changing specifications to allow inclusion of lower graded and ungraded materials e.g. in
    - Subbase layers and subgrade modifications
    - Lean mix concrete
    - Structural fill materials and roadbases

Optimised CCP Use

This will require commercial change



Conclusion: We need CCPs

- Construction with concrete is complex
- Supply of construction materials to projects is complex – there is a future need for CCPs in construction
- The approach we have used in the past to get CCPs to market will not work into the future
- Concrete itself needs to be thought of more broadly (from <2 MPa to 120 MPa)
- We need to rethink how we take our CCPs to market