RESEARCHING SANDWICH PANELS

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What do we do in the university?

- Teaching (30%)
- Research (50%)
- Service (20%)

Through research we aim to:

- improve the quality of life by developing new engineering solutions to our structures and infrastructures.
- increase the safety of our structures by investigating the reliability and safety of existing engineering solutions.

“In most cases the industry is going faster than research, and many technologies are used blindly to some extend without sufficient research to support methodologies”
How do we achieve our research goals?!

- Developing new mathematical models that are capable of predicting the structural behaviour of new or existing design solutions. Finite element or developing in-house codes.

- Validate our models through comparison with actual testing of specimens in the laboratory.
How do we achieve our research goals?!
What are the outputs and outcomes of our research?!

**Outputs → publications**
- Publications of articles in national and international engineering/scientific journals.
- PhD and Master theses of students.
- Research reports.

**Outcomes → design guidelines and ideas for new technologies**
- Participating in and chairing design standards committees.
- Publication of handbooks of design recommendations.
- Registered patents (IP)
From where do we get funding to do our research?!

- ARC – Australian Research Council
  - *Discovery Projects* (success rate 18%, up to $500,000 per year for 3 to 5 years project duration)
  - *Linkage Projects* (success rate 35%, up to $300,000 from the ARC per year (2 to 5 years) that need to be matched by 25% from the industry partner)

- University

- Other joint research funds (Australian-China, Australian-USA,....)

- Industry
Previous interest in precast concrete elements

High Strength Concrete Panels

• Creep is not accounted for in wall design in AS3600!
• In column design it is included in a very crude and approximate way.
• Also typical buckling needs significant revision!

“Creep Response of High Strength Concrete Panels” – ARC DP $310,000 (2012 – 2014), Ehab Hamed and Steve Foster
Previous interest in precast concrete elements

<table>
<thead>
<tr>
<th>Panel</th>
<th>Model/test</th>
<th>Column design AS3600 (2009)/test</th>
<th>Wall design AS3600 (2009)/test</th>
<th>Column design ACI 318 (ACI 2008)/test</th>
<th>Wall design ACI 318 (ACI 2008)/test</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST1</td>
<td>1.014</td>
<td>0.639</td>
<td>0.619</td>
<td>0.519</td>
<td>0.746</td>
</tr>
<tr>
<td>ST2</td>
<td>0.978</td>
<td>0.323</td>
<td>0.603</td>
<td>0.496</td>
<td>0.738</td>
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<td>ST3</td>
<td>0.954</td>
<td>0.399</td>
<td>0.581</td>
<td>0.324</td>
<td>0.465</td>
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<tr>
<td>ST4</td>
<td>1.273</td>
<td>1.71</td>
<td>—</td>
<td>1.391</td>
<td>1.997</td>
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<tr>
<td>ST5</td>
<td>1.026</td>
<td>0.888</td>
<td>0.906</td>
<td>1.654</td>
<td>1.085</td>
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<tr>
<td>ST6</td>
<td>1</td>
<td>1.36</td>
<td>1.001</td>
<td>0.942</td>
<td>1.264</td>
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<td>ST7</td>
<td>0.967</td>
<td>0.615</td>
<td>0.55</td>
<td>0.485</td>
<td>0.701</td>
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<tr>
<td>ST8</td>
<td>1.019</td>
<td>0.565</td>
<td>0.583</td>
<td>0.504</td>
<td>0.707</td>
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<tr>
<td>Average</td>
<td>1.029</td>
<td>0.812</td>
<td>0.692</td>
<td>0.664</td>
<td>0.963</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.102</td>
<td>0.486</td>
<td>0.182</td>
<td>0.345</td>
<td>0.486</td>
</tr>
</tbody>
</table>
Previous interest in precast concrete elements

Creep tests
Previous interest in precast concrete elements

Creep Buckling under 60% of the failure load!
Previous interest in precast concrete elements

Outcomes and Outputs


“The results of this study are currently considered to be included in the revision of AS3600 for walls design”
Motivation

- Popularity of precast concrete walling.
- PCSPs provide an excellent solution to significantly reduce the energy needed for the heating and cooling of buildings. Thus, taking the precast industry a step towards sustainability and green buildings.
Motivation

Concept of sandwich panels:

- Thin stiff skins bonded to thicker, lightweight core.
- Large increase in stiffness without weight penalty
Motivation

- Researching Sandwich Panels – *Ehab Hamed (UNSW)*

![Diagram showing various industries and raw material types with Sandwich part costs in €/kg](image)

- Sections of a bird wing
- Raw material type
  - CFRP / Aramid paper / PEI / PMI
  - Aluminum
  - PC / PA / PET / PP
  - Paper

Industries:
- Aerospace
- Trains
- Automotive Industry
- Furniture
- Packaging
Motivation

- Potential to rely on the sandwich panel to act as a load-carrying member.

(Einea et al. 1994)
Motivation

- Low thermal resistance of steel leads to thermal bridges (R-value)
- CFRP have a thermal conductivity that is about 14% that of steel
Motivation

PCI in 2011 states that:

"Because present knowledge of the behaviour of sandwich panels is primarily based on observed phenomena and limited testing, some difference of opinion exists among designers concerning the degree of composite action and the resulting panel performance, the effectiveness of shear transfer connectors, and the effect of insulation type and surface roughness on the degree of composite action. Current and future research will undoubtedly provide better tools that can be used for more-accurate predictions of behaviour".
Literature review

Works from the literature:

Benayoune et al. (2006)
Researching Sandwich Panels – Ehab Hamed (UNSW)

Literature review

Typ. Buckling of Compression Chords

Bunn (2011)
Literature review

(B. Frankl, G. Lucier, S. Rizkalla, 2008)
Based on the literature, it can be said that:

“The existing numerical models lack the capabilities to describe the structural behaviour and to explain the experimental results”.

“Researchers and engineers mainly rely on experimental findings backed by simplified analytical solutions, that do not reflect the real behaviour of PCSPs”.

“The use of FRP as shear connectors is very attractive. Yet, until numerical models are developed and verified by reliable testing, the potential of PCSPs as a superior energy-efficient, economical, and lightweight construction solution cannot be fully utilized and their safe use cannot be guaranteed”
Mathematical Model

\[
\delta U = \int_{V_{c1}}^{x=H} \sigma_{xx} \delta \varepsilon_{xx} \, dV_{c1} + \int_{V_{c2}}^{x=H} \sigma_{xx} \delta \varepsilon_{xx} \, dV_{c2} + \int_{x=0}^{x=H} bK_u (u_h - u_t) (\delta u_h - \delta u_t) \, dx + \\
\int_{x=0}^{x=H} bK_w (w_{c1} - w_{c2}) (\delta w_{c1} - \delta w_{c2}) \, dx + \sum_{i=1}^{n_{bar}} \int_{x=0}^{x=\bar{x}_{i}} N_i \delta u_i \, dx - \sum_{i=1}^{n_{bar}} \int_{x=0}^{x=\bar{x}_{i}} N_{i,x} \delta u_i \, dx
\]

\[
\sigma_{xx}^c = \begin{cases} 
E_c \varepsilon_{xx}^c & \text{for } \varepsilon_{xx}^c \leq \varepsilon_{cr} \\
\frac{\alpha_2 \varepsilon_{cr} - \varepsilon_{xx}^c}{(\alpha_2 - 1) \varepsilon_{cr}} \alpha_1 f_t & \text{for } \varepsilon_{cr} < \varepsilon_{xx}^c \leq \alpha_2 \varepsilon_{cr} \\
0 & \text{for otherwise}
\end{cases}
\]

\[
\begin{bmatrix}
N_{xx}^i \\
M_{xx}^i
\end{bmatrix} = \begin{bmatrix}
A_{11}^i & -B_{11}^i \\
B_{11}^i & -D_{11}^i
\end{bmatrix} \begin{bmatrix}
u_{oi,x} \\
w_{i,xx}
\end{bmatrix}
\]

\[
N_{xx}^{c2(+) - N_i \cos(\theta_i) - N_{xx}^{c2(+) - u_{oc2}^{(-)} = 0} ; u_{oc2}^{(-)} = u_{oc2}^{(+)}
\]

\[
N_{xx}^i = \int_{-d_i/2}^{d_i/2} bE_i \varepsilon_{xx}^i \, dz_i + E_s A_s \varepsilon_{si}
\]
Researching Sandwich Panels – Ehab Hamed (UNSW)

Mathematical Model
Numerical results

Hamed, E. “Modelling, Analysis, and Behavior of Load-Carrying Precast Concrete Sandwich Panels”. Submitted to Journal of Structural Engineering.
Numerical results

The graph illustrates the relationship between the maximum deflection $W_{\text{max}}$ [mm] and the thickness of the core $d_{\text{bar}}$ [mm]. The graph shows two scenarios:

- **No composite action**: This scenario indicates the maximum deflection without considering the composite action of the core.
- **Full composite action**: This scenario shows the reduced maximum deflection when the core's composite action is fully considered.

As $d_{\text{bar}}$ increases, $W_{\text{max}}$ decreases significantly, indicating improved load-bearing capacity due to the composite action of the core.
Numerical results
Future plan

- Further enhancing the mathematical model
- Testing PCSPs – Building an Environmental room
- ARC DP to investigate the creep and shrinkage effects in sandwich panels (application with Prof. Ian Gilbert)
How can we collaborate?!

- Exchanging ideas! – We can use your materials and construction technologies to verify our models.

- Through PhD and research students that you can support through scholarship and the outcomes can be of benefits to you.

- Through consulting projects. We have the physical and computational facilities and resources to investigate your new technologies! This is based on hourly rate for the academic involved and the use of laboratory staff and resources.

- Through ARC Linkage projects. (Government 75%, Industry 25%)
Thank you!