RESEARCHING SANDWICH PANELS

Dr. Ehab Hamed

Senior Lecturer
Centre for Infrastructure Engineering and Safety (CIES)
School of Civil and Environmental Engineering
The University of New South Wales
Sydney, Australia

National Precast Concrete Association Australia
Gold Coast, 28th August 2015

What do we do in the university?

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

Through research we aim to:

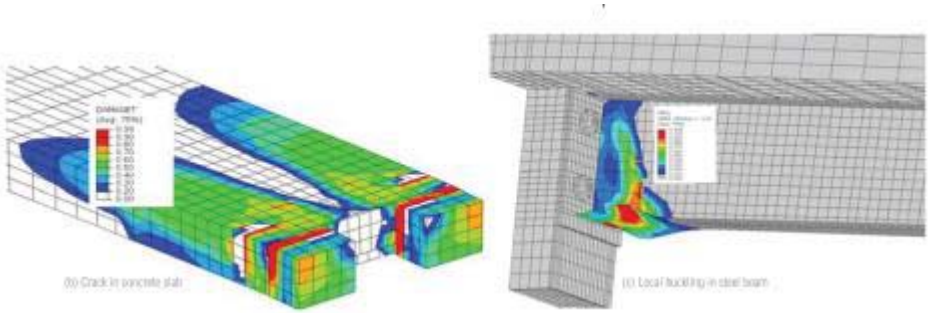
- improve the quality of life by developing new engineering solutions to our structures and infrastructures.
- increase the safety of our structures by investigating the reliability and safety of existing engineering solutions.

"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 $\longrightarrow$ publications

  - Publications of articles in national and international engineering/scientific journals.

  - PhD and Master theses of students.

  - Research reports.

- Outcomes $\longrightarrow$ 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)

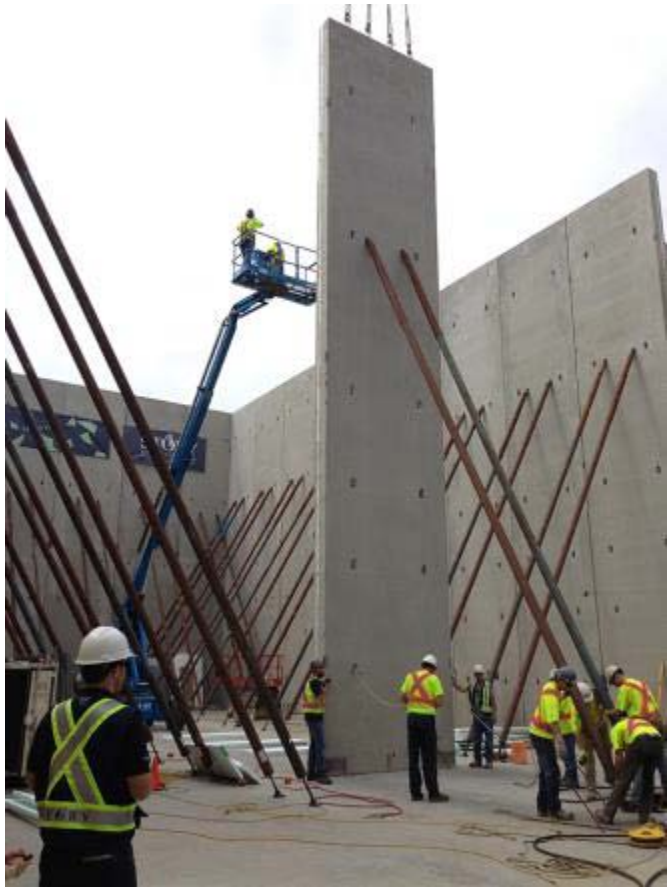
- University

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

- Industry

Previous interest in precast concrete elements

High Strength Concrete Panels

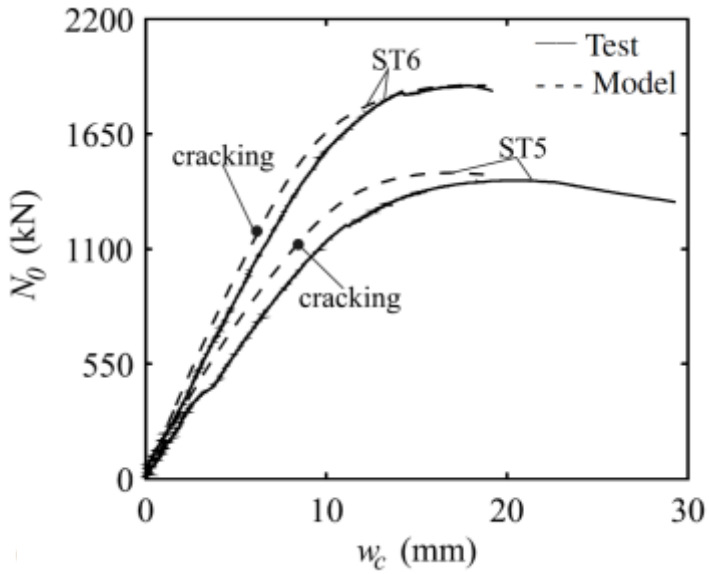


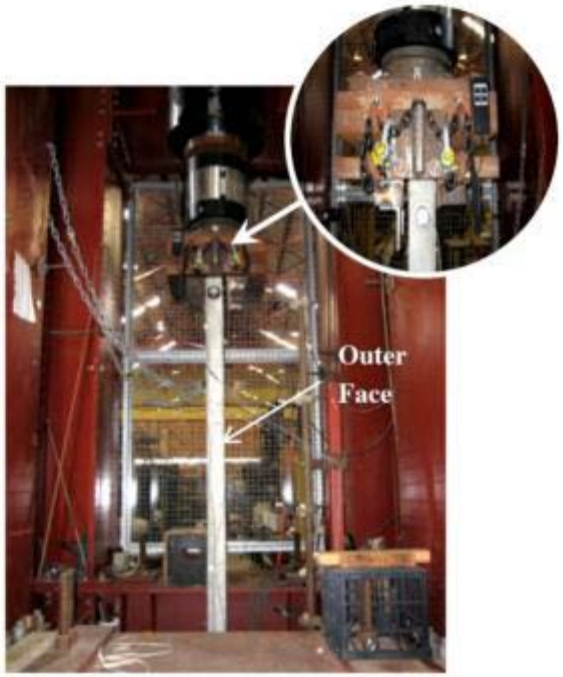
- ***Creep is not accounted for in wall design in AS3600!***
- ***In column design it is included in a very crude and approximate way.***
- ***Also typical buckling needs significant revision!***

"Creep Response of High Strength Concrete Panels" – ARC DP $310,000 (2012 – 2014), *Ehab Hamed and Steve Foster*

Previous interest in precast concrete elements

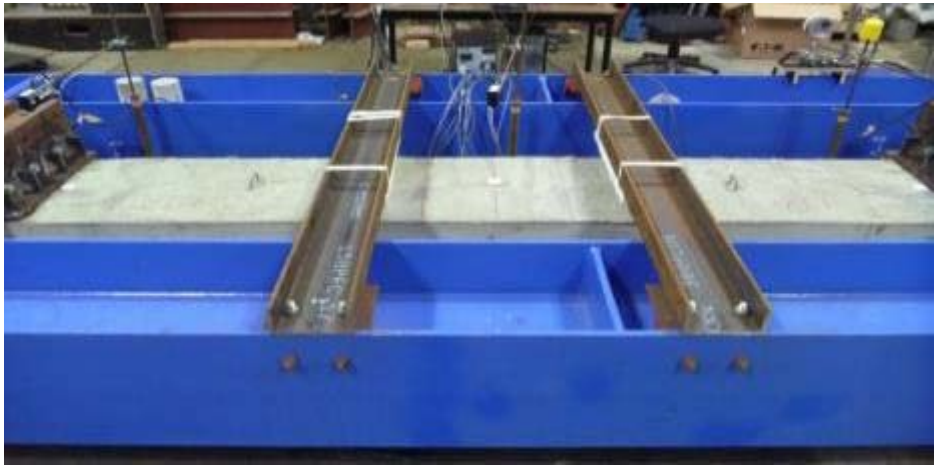
Panel	Model/test	Column design AS3600 (2009)/test	Wall design AS3600 (2009)/test	Column design ACI 318 (ACI 2008)/test	Wall design ACI 318 (ACI 2008)/test
ST1	1.014	0.639	0.619	0.519	0.746
ST2	0.978	0.323	0.603	0.496	0.738
ST3	0.954	0.399	0.581	0.324	0.465
ST4	1.273	1.71	—	1.391	1.997
ST5	1.026	0.888	0.906	0.654	1.085
ST6	1	1.36	1.001	0.942	1.264
ST7	0.967	0.615	0.55	0.485	0.701
ST8	1.019	0.565	0.583	0.504	0.707
Average	1.029	0.812	0.692	0.664	0.963
Standard deviation	0.102	0.486	0.182	0.345	0.486





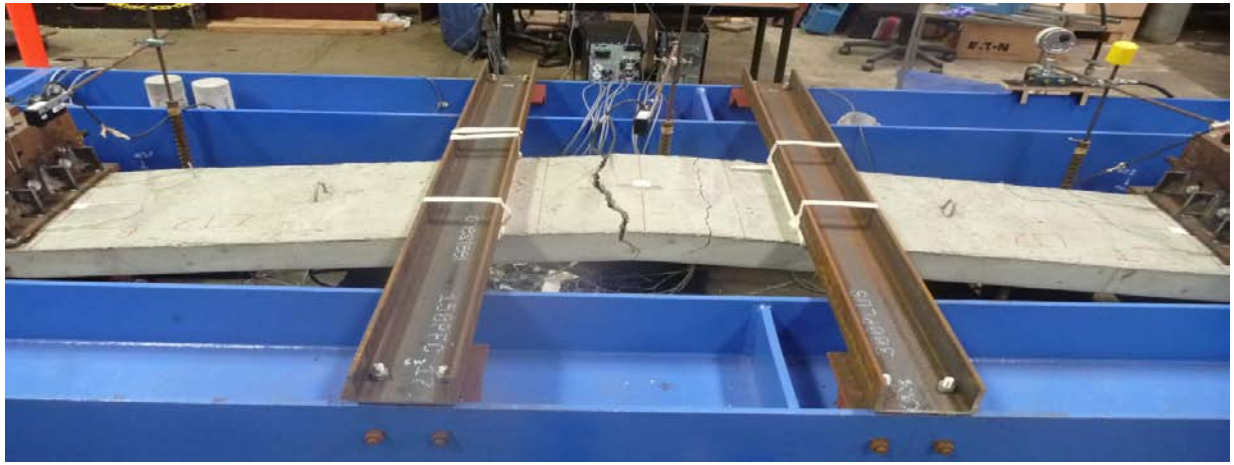
Previous interest in precast concrete elements

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

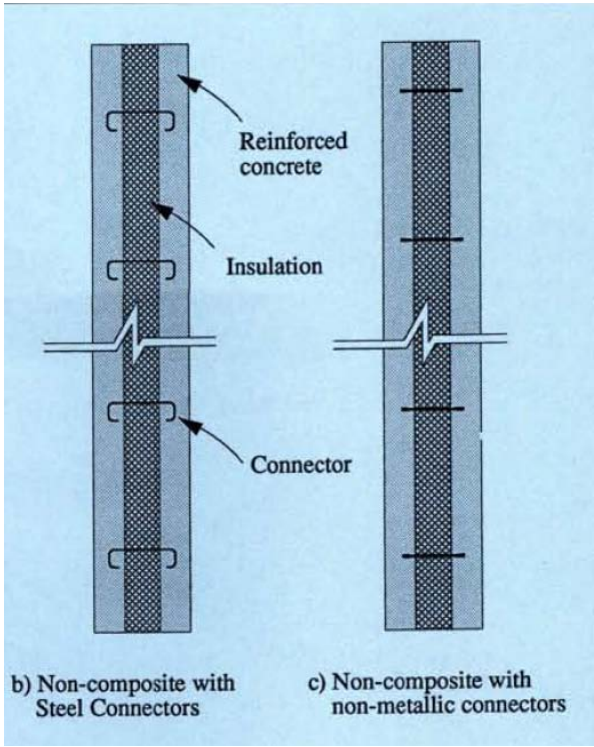
- *Huang, Y., Hamed, E., Chang, Z.T. and Foster, S.J. (2014), "Theoretical and Experimental Investigation of the Failure Behaviour of One-Way High-Strength Concrete Panels". **Journal of Structural Engineering – ASCE**. 141(5): Article number 4014143.*
- *Huang Y, Hamed E (2013), "Buckling of One-Way High-Strength Concrete Panels: Creep and Shrinkage Effects". **Journal of Engineering Mechanics – ASCE**. 139(12): 1856-1867.*

- *Huang Y, Hamed E, Foster SJ (2014), "Creep Effects in High Strength Concrete Panels". 10th International Symposium on Innovation & Utilization of High Performance Concrete. 16-18 Sep, Beijing.*
- *Huang Y, Hamed E, Foster SJ (2014), "Creep Testing and Analysis of High Strength Concrete Panels under Eccentric Loading – Buckling Effects". Proc. of the 23rd ACMSM, 9-12 Dec, Byron Bay.*
- *Huang Y, Hamed E (2013), "Effect of Supporting Conditions on the Long-Term Load Capacity of High Strength Concrete Panels". Proc. of the 22nd ACMSM, Sydney, pp:287-291.*
- *Huang Y, Hamed E (2012), "Effect of Reinforcement Ratio on the Creep Buckling Behaviour of High Strength Concrete Panels". Proc. of the 7th Int. Conf, Comp. Mech. Spatial Struct. Bosina and Herzegovina, pp:131-134.*

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

Motivation

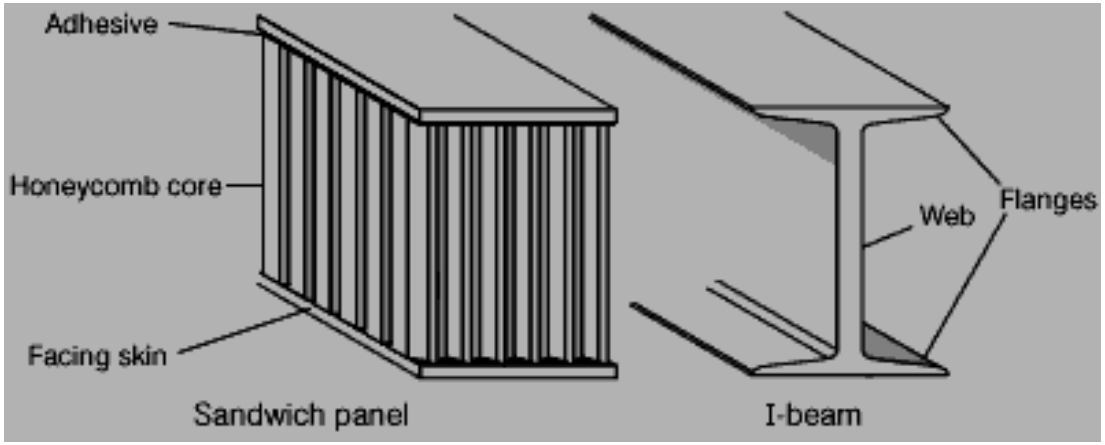
- Popularity of precast concrete walling.
- PCSPs provide an excellent solution to significantly reduce the energy needed for the heating and cooling of buildings. Thus, taking the precast industry a step towards sustainability and green buildings.



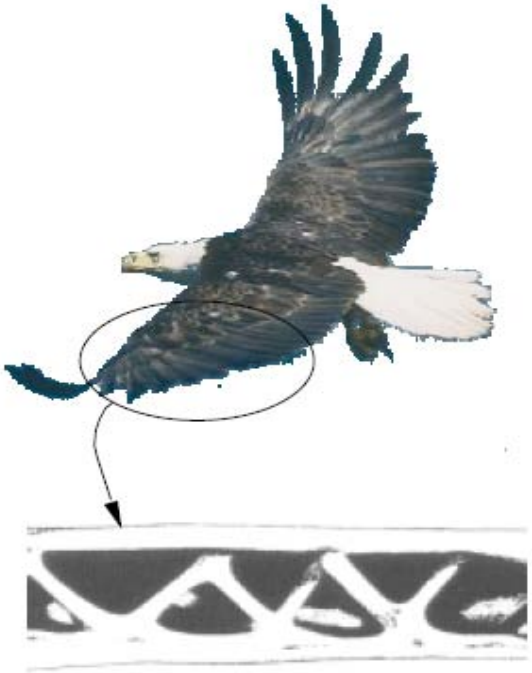
Motivation

Concept of sandwich panels:

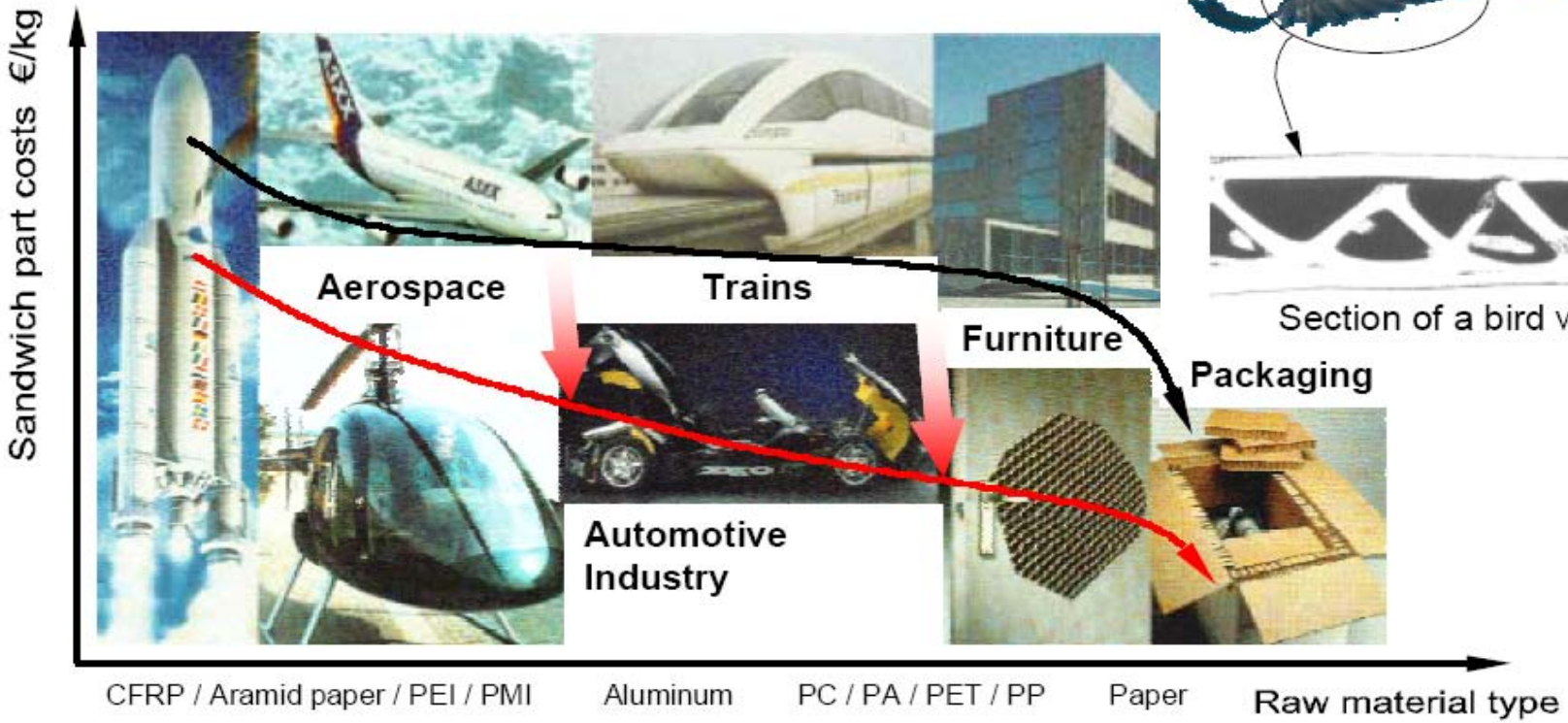
- Thin stiff skins bonded to thicker, lightweight core.
- Large increase in stiffness without weight penalty



Motivation

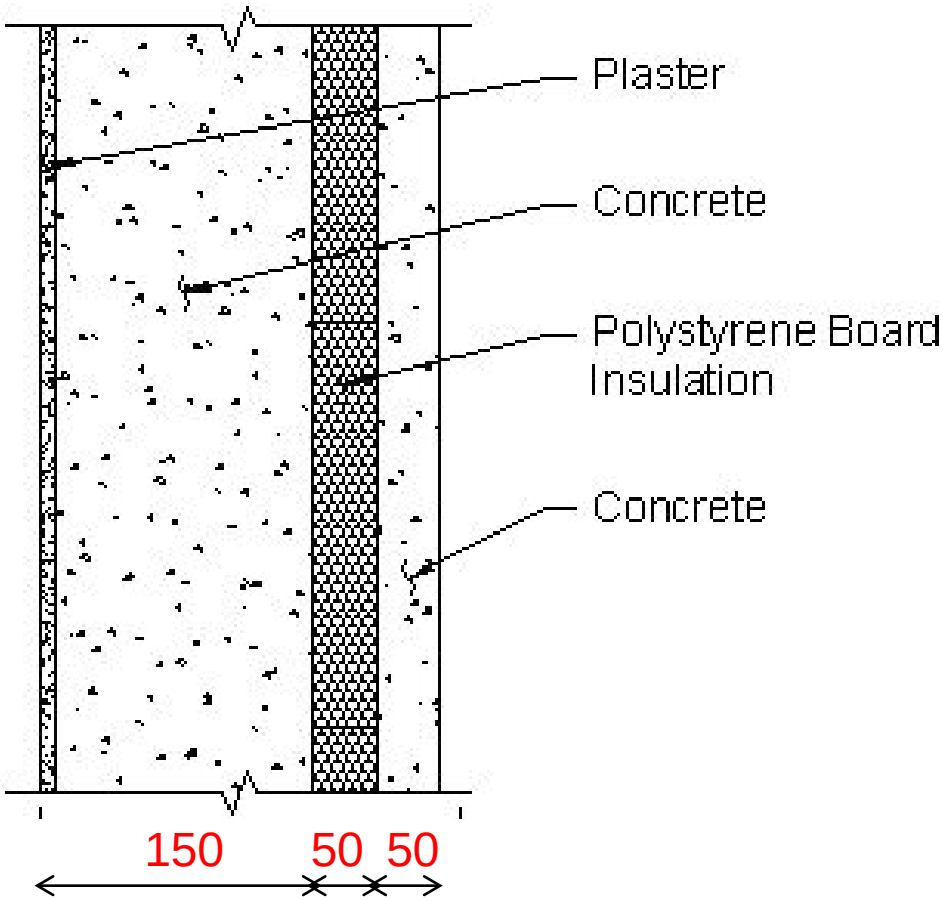


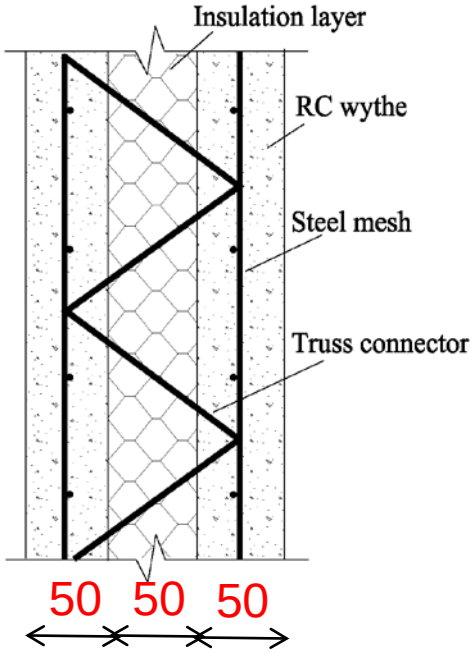
Section of a bird wing



Motivation

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

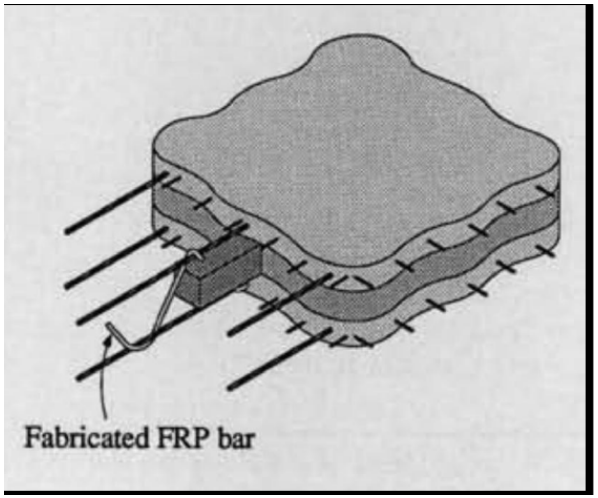


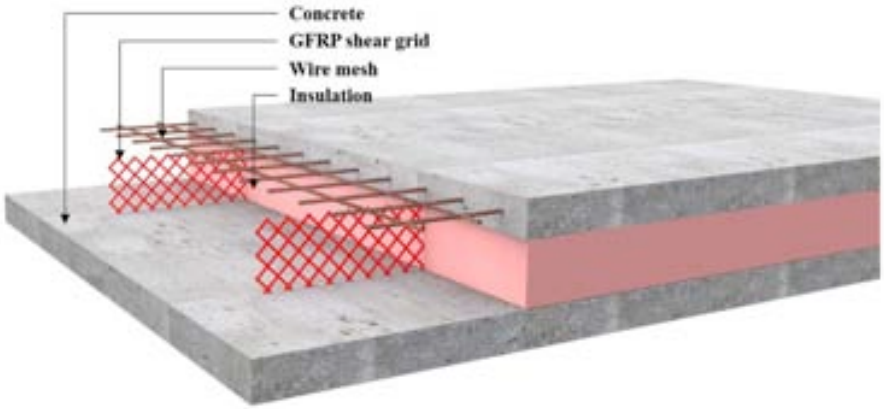


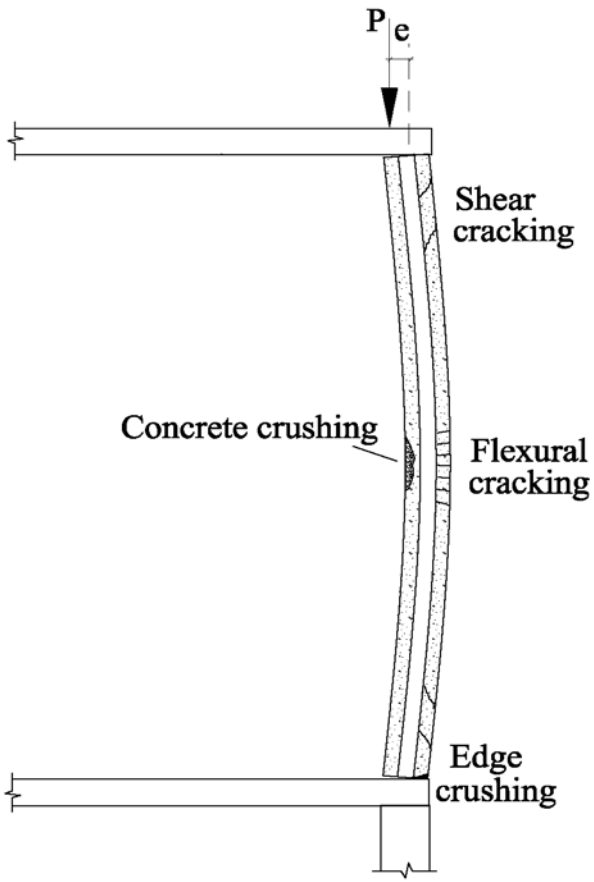
(Einea et al. 1994)

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:

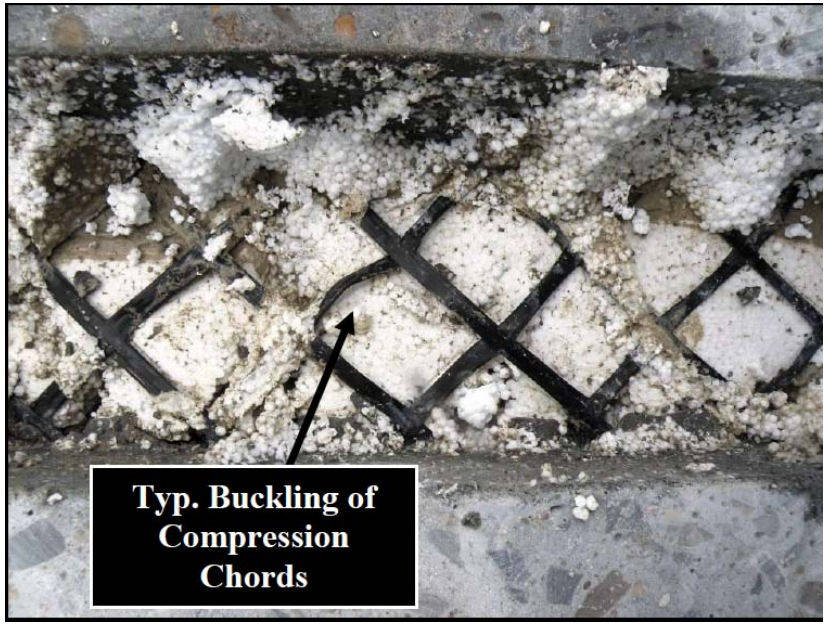
”Because present knowledge of the behaviour of sandwich panels is primarily based on observed phenomena and limited testing, some difference of opinion exists among designers concerning the degree of composite action and the resulting panel performance, the effectiveness of shear transfer connectors, 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".

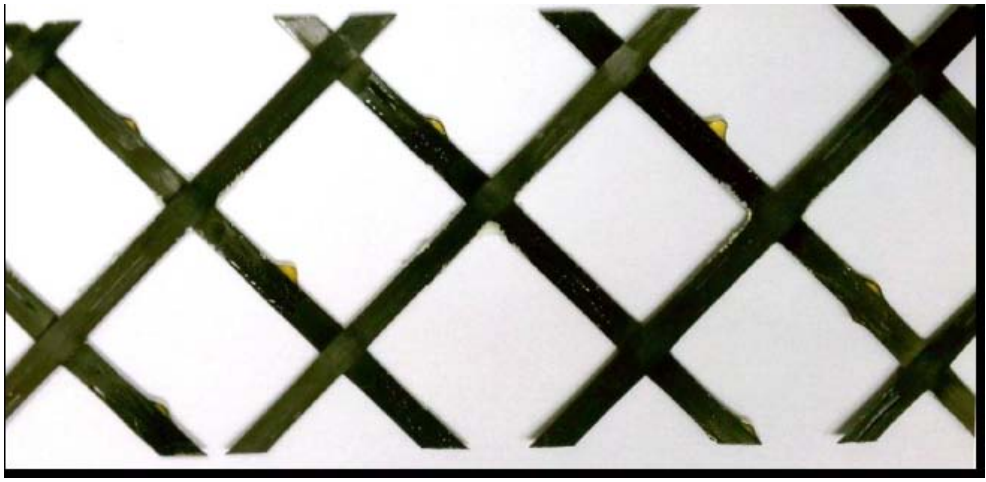
Literature review

Works from the literature:

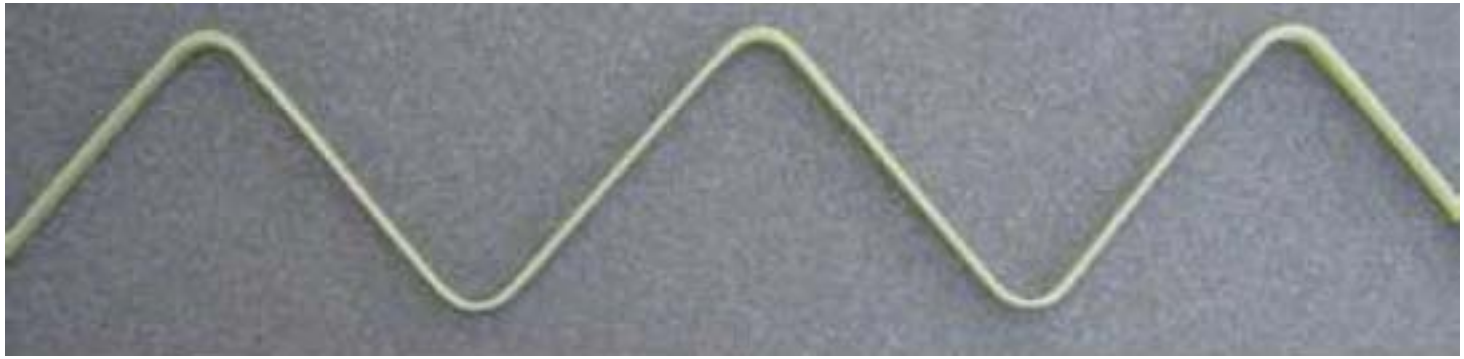
Benayoune et al. (2006)

Literature review

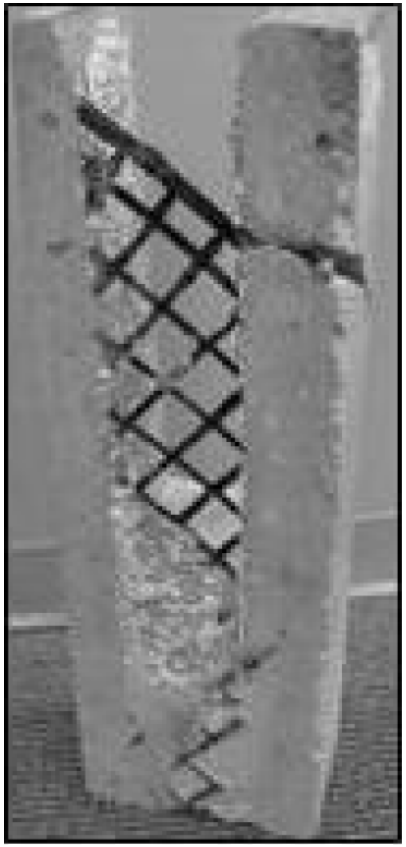




Bunn (2011)



Literature review



(B. Frankl, G. Lucier, S. Rizkalla, 2008)

Literature review

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".

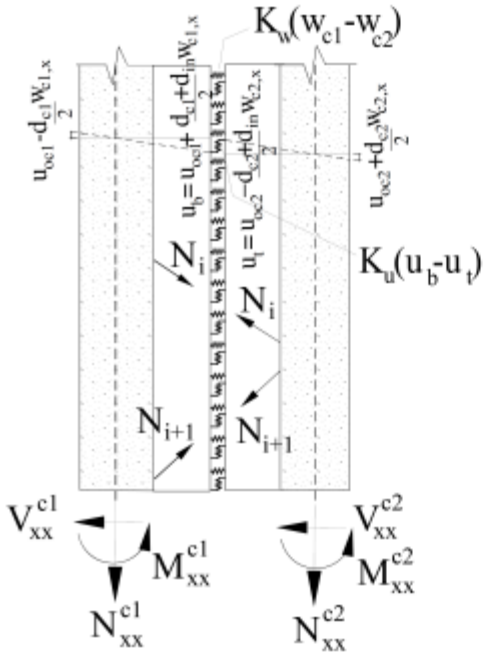
"Researchers and engineers mainly rely on experimental findings backed by simplified analytical solutions, that do not reflect the real behaviour of PCSPs".

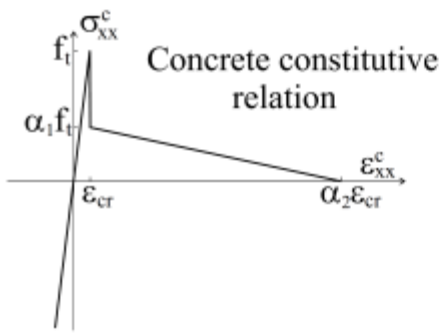
"The use of FRP as shear connectors is very attractive. Yet, until numerical models are developed and verified by reliable testing, the potential of PCSPs as a superior energy-efficient, economical, and light-weight construction solution cannot be fully utilized and their safe use cannot be guaranteed"

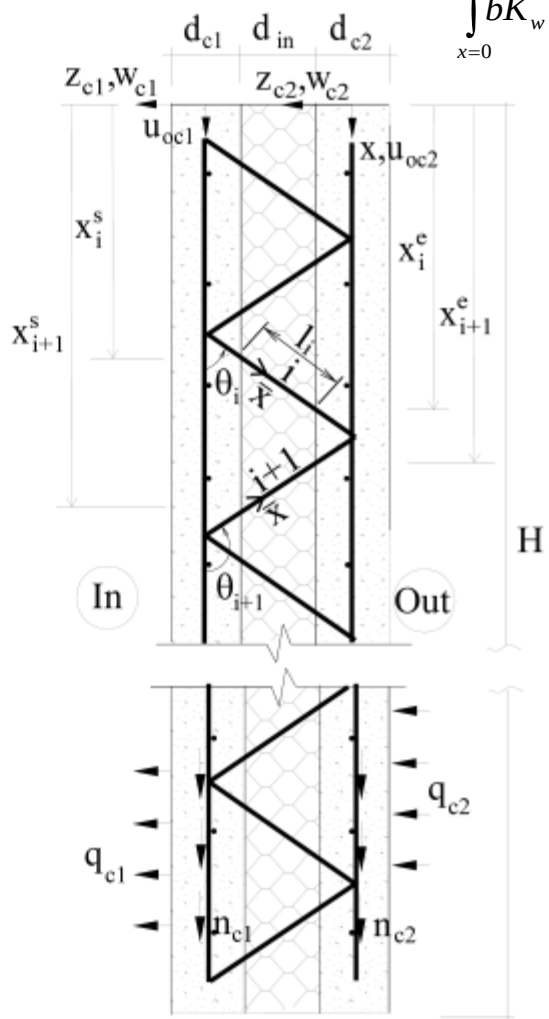
Mathematical Model

$$\delta U = \int_{V_{c1}} \sigma_{xx}^{c1} \delta\varepsilon_{xx}^{c1} \mathrm{d}V_{c1} + \int_{V_{c2}} \sigma_{xx}^{c2} \delta\varepsilon_{xx}^{c2} \mathrm{d}V_{c2} + \int_{x=0}^{x=H} bK_u (u_b - u_t)(\delta u_b - \delta u_t)\mathrm{d}x +$$

$$\int_{x=0}^{x=H} bK_w (w_{c1} - w_{c2})(\delta w_{c1} - \delta w_{c2})\mathrm{d}x + \sum_{i=1}^{n_{bar}} N_i \delta\bar{u}_i \,|_{\bar{x}=0}^{\bar{x}=l_i} - \sum_{i=1}^{n_{bar}} \int_{\bar{x}=0}^{\bar{x}=l_i} N_{i,\bar{x}} \delta\bar{u}_i \mathrm{d}\bar{x}$$







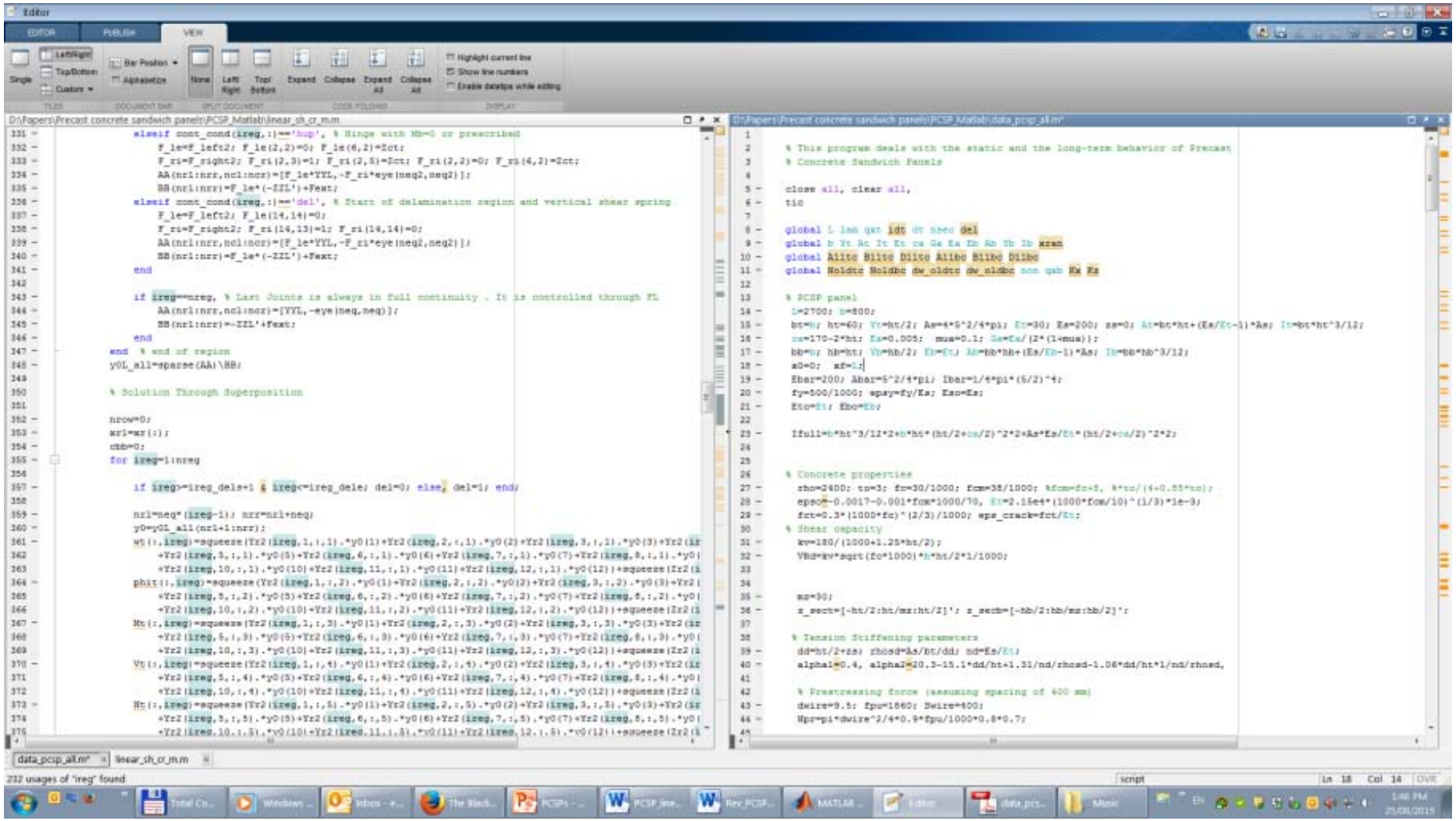
$$\sigma_{xx}^c = \begin{cases} E_c \varepsilon_{xx}^c & \text{for} \quad \varepsilon_{xx}^c \le \varepsilon_{cr} \\ \dfrac{\alpha_2 \varepsilon_{cr} - \varepsilon_{xx}^c}{(\alpha_2 - 1)\varepsilon_{cr}} \alpha_1 f_t & \text{for} \quad \varepsilon_{cr} < \varepsilon_{xx}^c \le \alpha_2 \varepsilon_{cr} \\ 0 & \text{for} \quad \text{otherwise} \end{cases}$$

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

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

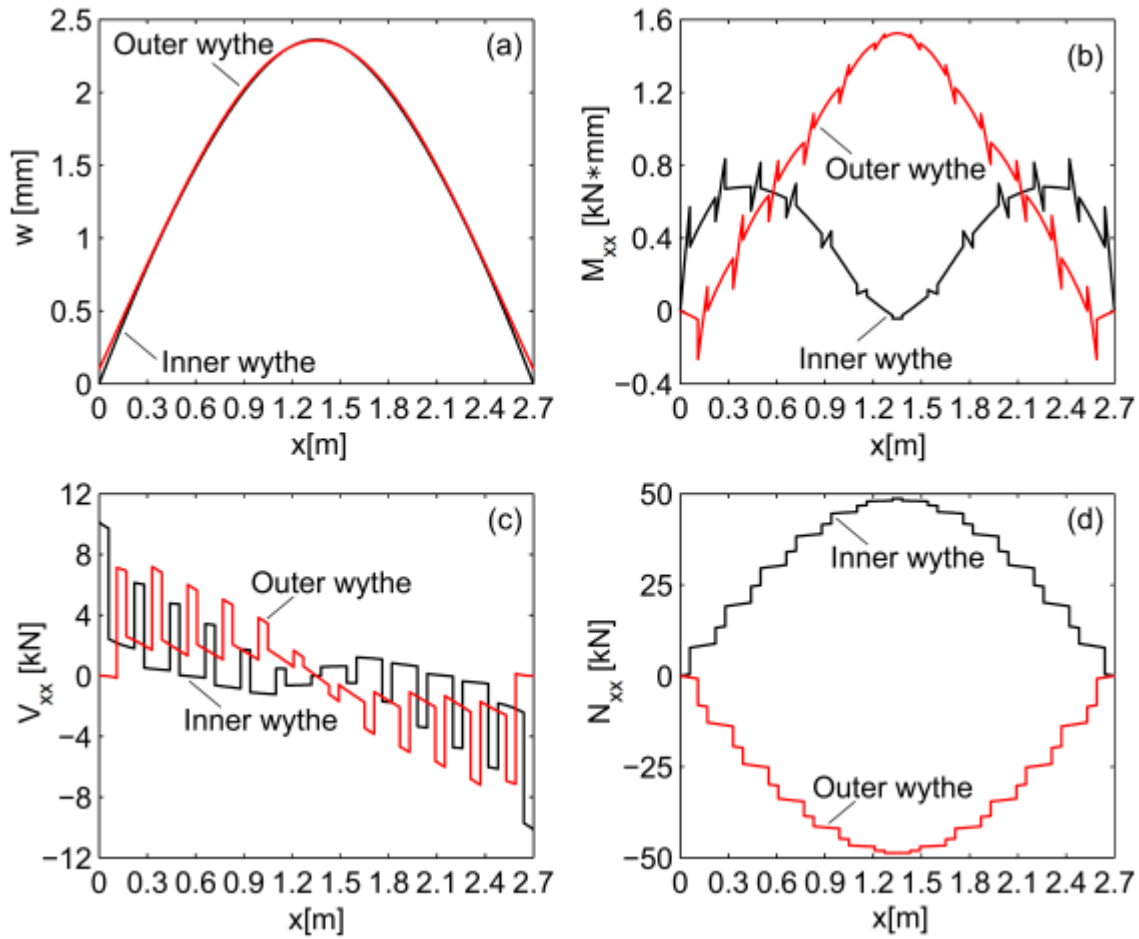
$$N_{xx}^i = \int_{-d_i/2}^{d_i/2} b\overline{E}_i \varepsilon_{xx}^i \mathrm{d}z_i + E_s A_{si} \varepsilon_{si}$$

Mathematical Model

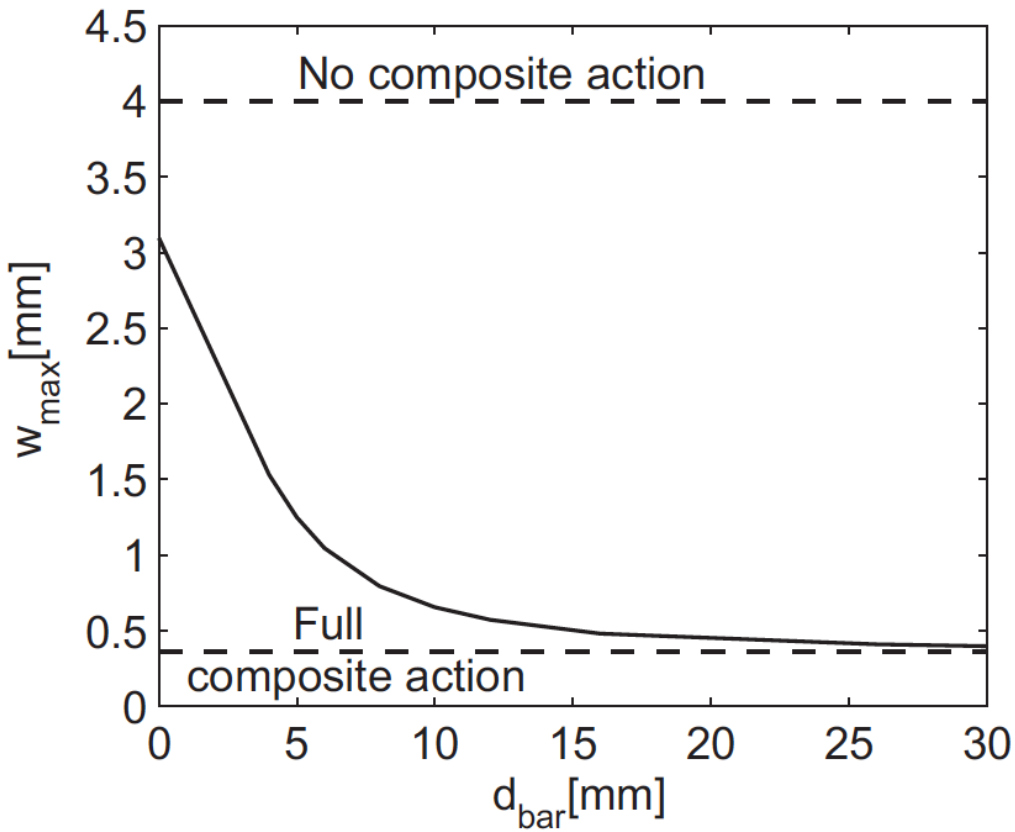


Numerical results

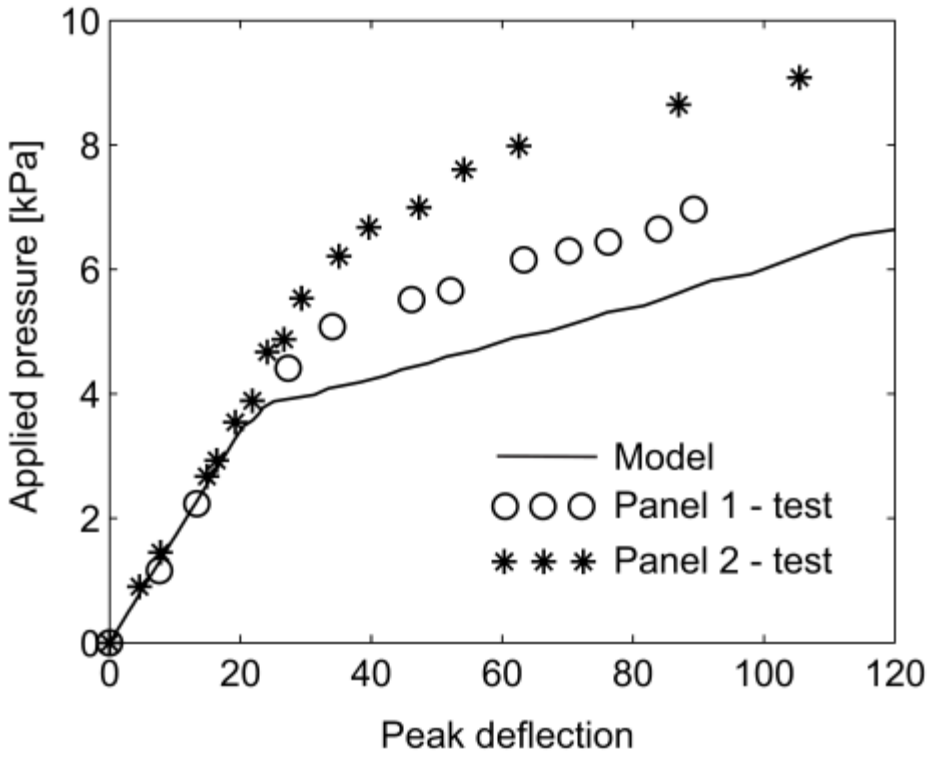
Hamed, E. "Modelling, Analysis, and Behavior of Load-Carrying Precast Concrete Sandwich Panels". Submitted to Journal of Structural Engineering.



Numerical results



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!