



Structural Woven Formwork

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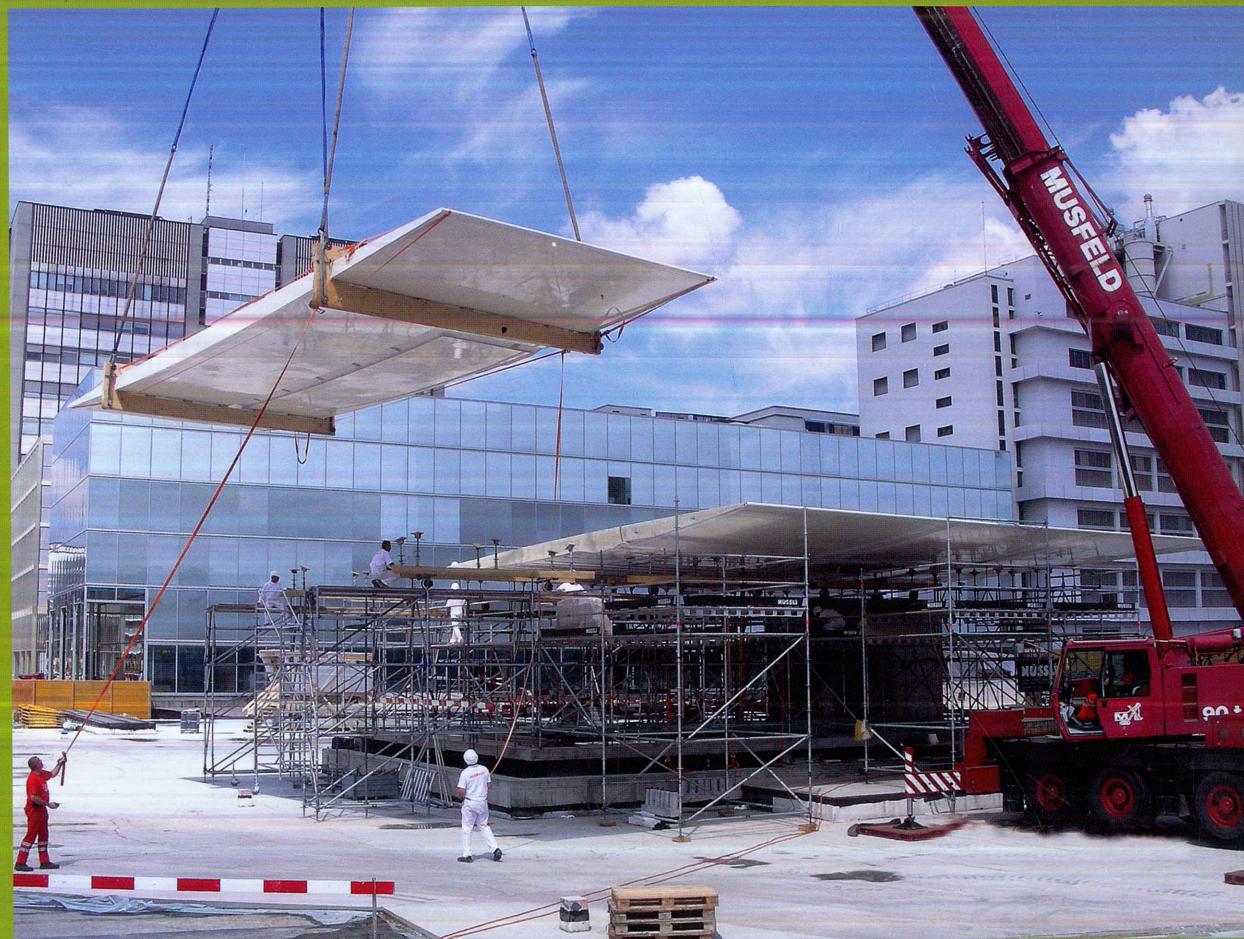
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Workshop follow up activities

The mission teams are working on research proposals for submission to EPSRC and other funders, in particular FP7 Energy Efficient Buildings Call July 2012. The detailed research challenges identified in the workshops will be presented in a report.

Further, a special issue of the Proceedings of the Institution of Civil Engineers Journal of Construction Materials is planned in which key mission-led outcomes will be published to present the state-of-the-art in materials-related ground and structural engineering research worldwide.



LimesNet Research Workshops

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LimesNet Research Workshops

During April and May 2012, LimesNet held four two-day research workshops to: provide a forum for feedback presentations by LimesNet mission teams and invited key-note speakers; provide a forum for networking and community building; develop future research agenda (challenges) through open-space workshop activities; and, develop high-quality transformative research ideas and proposals. Over the four workshops, a total of 155 LimesNet members participated in the workshop events.

The workshops followed the four material themes of the network, although inevitably there were overlaps and linkages between workshop presentations and discussions. Day 1 of the workshops comprised a series of presentations by the international research mission teams and invited speakers, many of whom had established links through the missions. Presentations were accompanied with Q&A's and broader discussions. On the morning of day 2 workshop delegates participated in 4½ hour open-space workshops. Setting their own agendas, the workshops aimed to discuss and develop transformative research ideas. Finally, the mission teams gathered together on the final afternoon to further develop their research proposals.

The following outline summarises the presentations and discussions held at the workshops. Research proposals noted here are those discussed in the workshops and are not necessarily those being currently developed. A full report of the research workshops and other activities will be produced by LimesNet.

General themes to come from the workshops included:

- Wide recognition from international missions of the under-investment in UK research infrastructure compared to other/competing countries.
- Need for standardisation of terminology across both academia and industry.
- Research needs to consider end use, not just functionality but how industry and the general public are going to learn about new materials and products, understand them and use them.
- A product must be cost effective compared to anything currently on the market, and for sustainability concerns this must include a LCA approach.
- Construction industry is conservative in adopting change and this must be addressed.
- A need to understand and acknowledge the barriers of working with industry.
- Consider the long term sustainability of all feed stocks, including water, previously taken for granted.

Workshop 1: Advanced Composites and Nano-Materials

Presentations were delivered by representatives from industry, academia and not-for-profit organisations, across a wide range of themes relating to advanced composites and nano-materials in construction. The programme included 13 presentations, including three from LimesNet mission teams. These include notable presentations by Dr Yolanda de Miguel of Technalia (Spain), Liesbeth Tromp from Royal Haskoning (Netherlands), and Dr Mark Evernden and Dr Antony Darby (both University of Bath). Comments and key points raised in the workshop presentations and discussions on day 1 included:

- Lack of understanding about the impact damage on FRP and coatings, including both physical and environmental (in particular for marine and wind applications).
- Concerns about a lack of understanding about how mortars and coatings react to surfaces, especially on timber and heritage surfaces, as these are more complex to model.
- Nano-coatings are often seen as the 'answer' for everything, but more work is required to understand their use, whether this is single or multi-functional.

Themes forming the agenda of the open-space workshop on advanced composites and nano-materials were as follows:

Self-healing materials; and durability	Health monitoring	Multi-functional coatings for facades
What are the best applications for Nano-Materials?	Structural reliability and material characterisation	Composites for fabric formwork
All in one coatings	Reliable methods of joining pultruded FRP sections	Construction uses for graphene
Composites for Impact	Heat resistant adhesives for bonding FRP to timber	What are the barriers to market penetration?
Do we need to know anything more about FRP strengthening?	Compatibility; materials, materials and the environment	Nano materials in FRP
Stiff natural fibre composites	Insulation materials	Composites in ground engineering

Summary of workshop:

Discussions on self-healing materials and durability identified a need to develop benchmarking based on surveying of existing FRP materials and structures. Construction sector should consider lessons learnt from the off-shore industry, including: proving surface is reliable; salt ingress and thermal cycling; effect of environment on durability; degradation of material on structural performance; scope for self-healing coatings.

The fire protection of FRPs for both strengthening and as structural systems was identified in discussions, as was the potential for the use of fabric technology to lead the use of fabric formwork developments. Related factors included: resistance against stiffness and strength degradation; potential use of protective surface or coating; and, the use of mortars for strengthening with textiles. Moving forward key research objectives were identified: coatings or resins; fire resistance requirements; fabric formwork opportunities; potential for use of nano-scale additives; and, understand mortar resistance to fire as replacement for adhesives.

Discussion in the workshop also covered broader barriers to market penetration. Key challenges highlighted need to convince contractors to use composites; develop culture of 'learn by doing'; define risk, and improve/develop a realistic cost perception; specify accurately life cycle costs; and further design guidance for use of composites. Contracts should change to highlight and acknowledge the benefits of composites in constructions. Define life-cycle costs, health monitoring can develop a cost model for life cycle evaluation.



Workshop 2: Cement and Concrete

The programme included 13 presentations, including three from LimesNet mission teams. These included presentations by Dr Jacqui Glass (Loughborough University), Dr Tim Stratford (University of Edinburgh), Prof. Rod Jones (University of Dundee) and Prof. Nick Buenfeld (Imperial College). General comments and key points included, need to perceive how cement and concrete will be used in 25 years' time, and turn disadvantages into advantages, for example the innovative use of waste materials.

Themes forming the agenda of the open-space workshop on cement and concrete materials were as follows:

Intelligent Sprayed Cementitious Coatings	Zero Portland Cement Concrete	Design for durability, then sustainability	High Tensile Concrete
Self-healing Concrete	All concrete sourced from waste?	Carbon Sequestration	Taking Concrete Beyond Civil Structural Engineering
Hygrothermal behaviour	A world without concrete?	Should we be using shells?	What Impacts?
Fabric Formed Concrete	Intelligent Concrete	A roadmap for the next 25 years	Overcoming the barriers to LC concrete
Life Cycle Assessment	Self-Compacting Cement	Concrete – but not as we know it!	Concrete at the nano scale

Summary of workshop:

Discussions about self-healing concrete considered different approaches (self-sealing and self-healing) and approaches (bacteria, shape memory, polymers, polyurethanes). Questions posed included 'Does self-healing need to recover strength?' For durability need to maintain cover to reinforcement, but with self-healing can reduce cement contents and use of steel. Concluded that self-healing should not be treated as solution for poor practice or introduce unnecessary redundancy. Ideally we seek a concrete that is responsive to its environment. Key aspects are ITZ (between healing agent and old concrete). Solution to problems may need only be on the surface only. Is it possible to add the agent to the formwork?

In response to challenge to deliver all concrete from waste stream materials, discussions focussed on whether if there is enough waste and is the waste where we need it? Consider future waste streams in current applications. There is a need to accept higher level of risk in innovation. This aspect covered the topic of the use of fabric formwork too, which was considered to represent an opportunity for a step change in structural concrete design and research.

Concrete at the Nano-scale: Challenge is to create a more homogeneous cement matrix. Nanoparticles provide a template on which hydration products can develop. Potential use in combination with cement with fewer hydration products, reducing heterogeneity. Need to change the characteristics and behaviour of cement matrix. Nanoparticles (in small proportions) 'chain reaction' and need to have a large sphere of influence. Need to identify suitable nanoparticles. Should look at biological solutions: clams and molluscs have shells that are significantly stronger than cement materials but are 99.5% CaCO₃ and 0.5% organic matter: what is the organic matter and how does it work?



Workshop 3: Geo-Materials

The programme included nine presentations, including three from LimesNet mission teams. Presentations demonstrated a wide variety of uses for geo-materials in construction, from new forms of grout to bindings for railway ballast to seismic support for rammed earth buildings. Stimulating programme included talks by Dr Andrew Heath (University of Bath), Dr John Provis (University of Melbourne), Dr Julie Soden, (University of Ulster) and Professor William Powrie (University of Southampton). General comments and key points included from day 1 included:

- Need to understand different soils in global context, therefore appropriate of use concrete or geo-material for that soil.
- Cost price analysis to prove competitiveness.
- Problem of salination, especially within historic built environment.
- Increasing use in UK of geo-polymers.
- More appropriate use of on-site or off-site production
- Limited research funding in geo-materials such geo-polymers.

Themes forming the agenda of the open-space workshop on geo-materials were as follows:

Alkalis Activated Materials as low carbon binders	Improved textile reinforcements	Low density geomaterials	Seismic behaviour of geomaterials
Carbon sequestration in earth building foundations	LCA for low carbon building materials	Real life durability requirements	Surviving after the carbon age
Geo-materials in architecture	Low energy construction unit manufacture	Design based methodologies	Hygrothermal behaviours of earth buildings
Reusing sludge as a building material	Foundations using too much concrete	Bugs, bacteria and super bugs	Onsite micro factories

Summary of workshop:

On the theme of 'Bugs/bacteria/superbugs', key challenges included development of GM bacteria for specific applications, use of bacteria for repairing and cleaning, controlling the speed of growth, cost-effective solutions, use of nutrients, and reducing waste products. Biological approaches to control (reduce) moisture in the ground. An important need moving forward is multi-disciplinary working with biologists. Need to match speed of action of biological organism with need for mechanical benefit. Further the use of bacteria to prevent liquefaction during seismic events, scour and erosion. Does bacterially treated land count as contaminated?

Key challenges for LCA and assessing the impact of 'low-carbon' cements included: quality of input data for LCA databases; setting system boundaries; comparing equivalent products; incorporation of durability in LCA studies (cradle to gate or cradle to grave?). Benchmarking and assessment needs quality information available. More detailed LCA is more complex and hard to digest (and expensive), but how far can things be simplified and still be true? A good model needs to produce a useable estimate. This needs to be defined, with consistency in discussion and terminology. A dialogue between the people who make and understand the materials, and the people who assess them, is needed.



Workshop 4: Renewables Materials

This workshop attracted the largest participation, with 50 delegates over the two days. The programme included 10 presentations, including five from LimesNet mission teams. These included talks by David Trujillo (Coventry University), Dr Kate Carter (University of Edinburgh), Prof. Y H Chui (University of New Brunswick), Prof. Richard Harris (University of Bath) and Deb Turnbull (Edinburgh Napier University). Some general comments and key points to come from day 1 of the workshop were:

- There is still a need to convince stakeholders that timber is a 'safe' product, especially concerning fire.
- Total cost analysis for renewable materials is a selling point.
- Need for greater understanding in the UK of 'new' timber already in use.
- Life cycle analysis and sustainability indicators need further development.
- Hygrothermal performance of renewable materials is an important and little understood aspect.

Themes forming the agenda of the open-space workshop on renewable materials were as follows:

'Fabric first'	How will climate change alter design for 25yrs time?	How will climate change alter design for 25yrs time?
Design, detail, skill	Novel uses of round wood	Novel uses of round wood
Embodied carbon vs embodied water	'Form first'	'Form first'
CLT: glue or no glue	Responsible sourcing	Responsible sourcing
High rise timber buildings	What will drive the move to renewables?	What will drive the move to renewables?
Shaping buildings to timber	Carbon capture and offsetting	Carbon capture and offsetting

Summary of workshop:

Need for design for durability, including reliance on robust construction details. Design for replacement rather than eternal life. Need better understanding relationship between moisture contents and moisture movement/ durability. Study vernacular building solutions to understand issues about interconnections between sustainable materials. Consider the whole system.

Technology moving fast, detailing and craft are disconnected, pressure to industrialise construction industry. Do we accept that we treat the materials specially, or do we make them part of mainstream construction? UK needs hundreds of thousands of homes. Research is required to work out what crafts that link the science to the onsite. The major driver in construction is lower and lower costs. Air-tightness is a big issue. Does the loop between construction and design work? Feedback along the supply chain is needed in the construction industry. We should be moving toward industrialization; sensitive materials need to be kept dry. Assembly of components is as important as their production. Every publically funded construction project should have a built in feedback process in it. The research is to define the framework, software, monitoring, and feedback mechanism that would define the feedback system and how we would learn from it. The Canadian recognition that what you do in research is you build skills, and then you recruit those people into industry. There should be a research project on every major public-funded project.

Building systems often develop to increase use of timber are attempting to replicate rectilinear masonry boxes, with lots of waste of material, reduction of timber sections, glue, inappropriate use of timber, durability problems etc.

We should be looking at ways in which the timber can be used with minimum wastage, by using it in positions in a building where its particular properties are required, rather than as a replacement for another material. This means accepting the variations in the geometry, possibly by using it in locations where few connections are needed and continuity of material is not needed. Look to the pragmatic development of use of bamboo as an exemplar of the kind of things that can be done. Explore ways to bring the timber components within the building shell, which is made of a more suitable material.

