STRUCTURAL OPTIMISATION OF TIMBER OFF-SITE MODERN METHODS OF CONSTRUCTION

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ABSTRACT (for oral presentation)
Efficient and sustainable building systems are required in order to achieve the UK government’s target of building three million new homes by 2016. Given the current lack of activity in the housing construction market to achieve this target, increased levels of off-site modern methods of construction (MMC) need to be adopted which conform to future regulatory and code requirements, are environmentally sound and structurally robust.

The dominant form of timber construction for housing in the UK is open-panel platform frame construction (approximately 25% of the UK market share). In order to meet future market and building regulatory requirements, this form of construction needs to evolve and become an efficient closed-panel system solution. The system solution needs to be capable of being manufactured off-site to the highest possible specification in terms of mass customisation, inclusion of services, application of cladding and to achieve a high standard of building performance (thermal insulation, reduced cold bridging, acoustic separation) whilst remaining cost-effective. An example of wall panels being produced in a factory is shown in Figure 1.

Figure 1: Off-site construction of wall panels for two-storey residential buildings

Thus far research on off-site MMC has primarily focussed on the understanding of the market, the conceptualisation of modern building systems and products, and the adaption of production theories to construction. Attention has also be turned to the implementation of modern business processes to construction by means of adapting information and communication technologies and micro-renewable solutions (photovoltaics, ground source heat pumps etc) to provide additional energy. However, the focus of this research work is to ensure the developed systems solutions are robust, safe and serviceable conforming to European Structural design requirements.
It has been recognised that sustainable building envelopes should start with improving the efficiency of the building fabric. The evolution of timber platform frame from an open-panel to a closed-panel system solution requires increased levels of off-site MMC and improved building performance. This impacts upon the structural performance and requires the derivation of novel technical solutions and incorporation of innovative products. Running concurrently with this, is the need to structurally design and certify all new building systems in accordance with the new European Code of Practice as a result of the British Standard Code of Structural Practice now being obsolete.

The research reported in this paper is on a project at the Centre for Offsite Construction and Innovative Structures (COCIS) at Edinburgh Napier University which is delivering through testing in isolation, and in combination, novel technical solutions and innovative products for the timber closed-panel system solutions of the future. These derived solutions are being used in pilot projects to demonstrate their application and, through post-completion testing, overall system efficiency. Further to this, the work is creating a generic product family architecture in accordance with Eurocode design requirements providing industry confidence in the code and the ability to specify the derived solutions or adapt them for their specific market or clients’ needs.

Among the main objectives of the research project, which are further explained in the paper, is the resolution of the structural performance issues identified as stability, robustness, durability, standardisation, design life, movement and fire resistance, evolving open-panel timber frame to a closed-panel engineered system solution. Other major goals are the derivation of novel technical solutions to overcome specific structural requirements without impinging upon the overall system efficiency and the creation of a Whole House Engineering (WHE) mechanism from test information capable of structural optimisation and cross correlation with Eurocode.

The research work being undertaken is part of a wider scale research movement and therefore provides the necessary outcomes for the implementation of sustainable and efficient methods of construction required to address the existing UK housing shortage. This paper explains how this work will support the UK timber frame industry and its suppliers in terms of both raw materials and services (i.e. consulting engineering practices).

The above-mentioned objectives will be achieved by completing work packages with several specific tasks. One of them will consist in benchmarking current open-panel timber platform frame construction in accordance with the new Eurocode design procedures. The performance of connections, elements and assemblies will be determined in isolation and then when acting in combination as part of a system. This will create a whole house engineering tool set capable of structurally analysing open-panel construction in accordance with Eurocode design procedures.

Key components and connection details will be identified where novel technical solutions are required due to building performance, manufacturing and construction requirements. This will form the product family architecture to be structurally optimised without impinging upon the other key system performance criteria. Conceptual ideas will be derived and tested which solve the identified problems in order to structurally optimise the product family architecture. In addition, closed-panel system solutions will be developed for wall, floor and roof elements with standardised connection detailing at critical junctions, e.g. foundations, intermediate floor, wall head, ridge detail. The closed-panel system solutions will be structurally analysed and tested. This information will then be incorporated within the whole house engineering mechanism in order to determine full structural system performance. The whole-house performance will be analysed by testing full scale systems. This process will be facilitated by on-going and future research activities taking place at Edinburgh Napier University in collaboration with industrial partners. Finally, a platform will be created for innovation by disseminating the information generated to create a culture of cross-industry collaboration.

This research originates and develops from other projects which are currently being carried out at the Centre for Offsite Construction and Innovative Structures and which investigate timber construction from different, but complementary, perspectives. For instance, structural stability, with the development of a series of hybrid racking panels; material characterization and innovation, with the analysis of acetylated timber beams behaviour in outdoor environment and thermal performance of lumber construction aimed to reduce energy use.

With regard to the other researchers in the field, Eurocode is harmonising structural engineering practice in Europe, therefore there is the opportunity to collaborate more readily with academic partners in the Eurozone as identified.

The systematic approach to the research of looking at the component parts in isolation and in combination will provide information which can be interpolated for the requirements of other research in timber engineering and create opportunities for advanced computer modelling of systems such as finite-element analysis.

This project will also serve as part of a process to defragment the industry in order that it can make progress in other fields such as the implementation of business improvement processes including Enterprise Resource Planning (ERP) and Building Information Modelling (BIM).