THE POTENTIAL FOR PREFABRICATION IN UK HOUSING TO IMPROVE SUSTAINABILITY

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Abstract

Off-site, factory production of dwellings has the potential to lead to significant improvements in both the quality and speed of construction compared to traditional site-based construction. The technical benefits include increased speed of production, reduced levels of defects and waste, greater efficiency in the production process, and improved environmental performance. These are all generated as a direct result of moving more of the construction process from the building site where efficiency is poor and management difficult, into the relative safety of factory conditions, where efficiency and control can be better managed. This can also lead to social benefits including improvements in health and safety, more stable employment and investment into machinery and development of skills. Greater stability in the manufacturing process also generates potential economic benefits.

All of these contribute to environmental, economic and social benefits of sustainability. This paper will review the sustainability benefits of prefabrication, and look at the various alternative ways that prefabricated building systems are beginning to have an impact on the way residential buildings are constructed in the UK.

Keywords: prefabrication, off-site manufacture, modular construction, speed

1. Introduction

In the UK, government predictions suggest that 3.8 million additional new dwellings will be required over the next 20 years. Current replacement rates are minimal, with most new housing adding to the stock rather than replacing old, outdated housing. Within the social housing sector it is estimated that from 2000 to 2016 one million new dwellings will be required. These are expected to be mainly high-density, terraced houses and purpose built flats. This presents a significant challenge to the UK construction supply chain with its diminishing labour force and increased business performance demands. Furthermore, client requirements for higher building standards and the industry’s increasing regulatory improvements, particularly in thermal and acoustic performance, and health and safety issues are pushing the industry to reconsider on-site methods of construction and to investigate other ways of building homes.

Increasingly, concern about the impact of the construction process, and of the additional 3.8 million new homes, on the environment and local communities is beginning to push clients to take more account of the sustainability impacts of how we build, operate and maintain our buildings. For example, the Housing Corporation which funds much social

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housing now requires a Ecohomes [1] environmental rating for all housing schemes they finance and 50% should achieve a rating of "Good".

A further factor leading to change in the industry is government's construction policy, which is now dominated by the report of the Construction Task Force "Rethinking Construction" [2] published in 1998 and the subsequent report "Accelerating Change" [3] published in 2002. These encourage the industry to address market demands for improved efficiency, better quality, faster construction and better cost control. This has led to a greater interest in off-site manufacturing technologies and many house builders are currently investigating a variety of innovative ways of building dwellings. Recent reports [4] have identified considerable areas of overlap between the agenda of improved industry efficiency through prefabrication and partnering and the sustainability agenda.

To date prefabrication in housing in the UK has not been a commercial success. It has often been associated with a reduction in flexibility and choice for the designer, client and end user, and with higher costs. Until recently, perceived market resistance has prevented significant uptake of such technology in the UK despite examples here and from abroad illustrating its technical feasibility. However, off site fabrication both volumetric construction and panelised construction has received a great deal of attention in recent years. The trend began with the hotel sector, where quality and repeatability of units lend themselves to volumetric buildings. This technology is now being increasingly applied to apartments, houses and sheltered accommodation.

2. Off-site manufacturing systems

In the UK, there are three principal approaches to off-site production of buildings using lightweight construction currently being used. These are discussed below:

2.1 Volumetric systems

Three-dimensional units are manufactured in the factory with a high degree of services, internal finishes and fit-out installed in controlled, factory conditions prior to transportation to site.

This has many benefits including improved quality, reducing defects and snagging on-site, increased speed of construction on site, better working conditions, increased predictability and efficiency in the production process. This approach is particularly suited to highly serviced areas such as kitchens and bathrooms, which have a high added value, and cause disruption and delays on site, but may be less appropriate for other rooms which have less internal fit-out.

Volumetric systems have the disadvantage that each unit has to be transported separately, and the maximum size of the unit is determined by the practical problems associated with transportation by road. The factories operate most efficiently when a large number of similar units are made to the same dimensions. Both of these factors work to reduce flexibility in layout and design. For these reasons most volumetric construction in the UK to date has been in the hotel, hospital and fast food chain sectors, where repetition of units is possible. Increasingly, they are also being used for student accommodation.
Since the units have to be self-supporting and are craned into place on site, the strength and rigidity must be sufficient to allow this process to occur without damaging the unit. The strength requirements for the lifting operation may exceed those for in-use service, thus the structure may be over-designed for its end-use, leading to wastage of materials.

2.2 Panellised systems

Flat panel units are manufactured in a factory, and fixed together on site to produce the three dimensional structure. Services, windows and doors, internal wall finishes, and external claddings can potentially be installed in the factory but in most current systems in the UK the services installation, external cladding and internal finishing occurs on site.

Panellised systems are more flexible and can more easily accommodate variations in unit plan and detail design than volumetric systems. Spaces such as bedrooms and
living spaces lend themselves to panel construction systems, providing greater choice to the client and designer, with few restrictions on room size and layout. Furthermore, the advantage of panellised systems is that they can be stacked flat, so more of the structure can be transported in one journey, reducing transport impacts. However, the levels of finish, and services, which it is practical to install into panels prior to shipping to site are reduced compared to volumetric. This leads to more work on site and requires further deliveries of other materials, components and labour to site. This may not be much of a problem for plain walling but would be a disadvantage for highly serviced areas such as kitchens and bathrooms. Also, there is a greater likelihood of damage to the finishes applied to the panel during transportation or on site.

2.3 Hybrid (semi-volumetric) systems

A third option, which maximises the benefits of prefabrication, is to use volumetric units for the highly serviced areas such as kitchens and bathrooms and construct the remainder of the building using panels or by another means. This offers the opportunity of removing the highly serviced areas from the critical path of the project, and potentially brings together the benefits of different construction systems. It can also address the issues of providing flexibility and consumer choice.

Figure 3 A UK housing scheme using a mixture of panellised and volumetric construction

Thus, some schemes have used volumetric modules for bathrooms and kitchens in hot rolled steel frame or concrete frame buildings. Alternatively, volumetric units are used in combination with panels for the less serviced areas (Figure 3). Also, volumetric units have been used to extend buildings and provide additional accommodation with minimal disruption.

Such an approach may combine the benefits of economies of scale and the economies of scope, utilising mass production, factory production and standardisation to provide flexibility of options offering customisation. A kit of parts can be used to provide flexibility yet maintain the benefits of standardisation.
3. **Sustainability benefits**

3.1 Site benefits

The key feature of prefabrication is that much of the process is removed from the site to controlled factory conditions. This reduces the amount of time spent on site, which leads to less detrimental impacts on the locality. Experience in the UK shows that prefabricated hotel buildings can be constructed on site in half the time (or less) of a traditionally built hotel of a similar size, and this could be reduced further with the use of factory applied claddings. In the catering industry clients have claimed a factor of 10 improvement in installation and commissioning timescales for a typical fast food restaurant when using volumetric construction. This means that the locality around the site is disrupted for a shorter period reducing noise, pollution emissions and local traffic disruption. In addition, the lightweight nature of the buildings can often result in smaller foundations and therefore less groundworks, also reducing local disruption as well as reducing the volume of materials used in the groundworks and spoil to be removed.

Furthermore, prefabrication generally leads to fewer deliveries to site compared to traditional construction methods. Some monitoring of a site in London suggested that deliveries to a volumetric site were reduced by up to 60% compared to a similar building nearby. This will also reduce local disruption, although, volumetric sites will generally have larger lorries delivering bulky, awkward volumetric units which require cranes to off-load. Thus, careful management is required to ensure minimum disruption when deliveries are made.

The wider transport implications of prefabrication are difficult to measure. SCI hope to carry out meaningful comparisons of volumetric, panellised and traditional sites for transport impacts. Volumetric deliveries often come from considerable distances from the factory. However, there are generally fewer deliveries than with traditional construction. In addition, the shorter period on site and the nature of the work means that less labour is required on site and for a shorter period. Panellised construction can be more efficient in delivery to site, but more subsequent work on site to finish the building off can lead to additional transport movements. In general it is likely that a well managed site using prefabricated components can significantly reduce the impact of transport.

The additional transport movements related to the factory should be considered. However, the workforce in a factory is more likely to be local than at a building site, and thus will travel shorter distances, and is more likely to use public transport, where possible. Secondly, material deliveries to a factory can be planned so that full loads are always delivered, and local suppliers can be used.

3.2 Process benefits

A building site does not provide an ideal environment for achieving quality construction or safety. Construction work on site can be a dangerous activity and leads to significant numbers of casualties and fatalities. Allowing much of the process to be carried out in more controlled and comfortable factory conditions enables safety requirements to be more easily met and policed, and healthy and comfortable working conditions are more readily maintained. More demanding health and safety requirements are pushing many builders to consider off-site manufacturing techniques.
Conversely, the use of heavy lifting equipment to locate the prefabricated components on site requires careful management.

The use of scaffolding is a particular safety concern. Some schemes in the UK have tried to eliminate the need for scaffolding completely by integrating claddings in the factory. The perceived market preference for brickwork is seen by many as a potential obstacle for further off-site manufacturing. Nevertheless, several companies are developing options for alternative claddings to traditional brickwork, with improved detailing which avoids the need for scaffolding, and some of these can be installed in the factory. Many UK schemes using prefabrication use alternative cladding systems such as cedar boarding, polymer based renders or rain-screen cladding.

Building sites are also notoriously inefficient in the use of labour and materials. Studies in the UK have shown that site based activities have a considerably lower efficiency in the use of labour compared to factory based activities. In some cases the useful activity on site can be below 50% of full potential. Furthermore, it is estimated the between 13% and 18% of materials delivered to UK construction sites are wasted and never used properly. Manufacture in a factory allows far better management of the waste stream with more efficient use of materials and ordering of exact amounts, more careful storage, and the possibility of design to suite standard sizes. In addition, any waste that occurs can be more easily collected and reused or recycled. Many off-site manufacturing plants have recycling facilities installed, as this reduces the costs of disposal of waste. There is further potential for reducing waste when using prefabrication if the designer is prepared to co-ordinate sizes so that materials such as timber and gypsum sheets are used in their standard sizes without generating many off-cuts.

**3.5 Improved final product**

Moving work off-site also leads to various quality benefits resulting from better working conditions and an opportunity for better quality management. Factory based activities allow testing and checking procedures to be more easily implemented. For example, volumetric units can have electrical and water installations fully tested prior to leaving the factory. General experience in the UK suggests that far less call-backs are necessary to make good defects after completion for buildings using a lot of prefabrication. This is a significant cost and efficiency benefit to the builder and leads to satisfied customers. It also reduces wastage of resources.

The correct and careful installation of the elements of the fabric, in particular insulation materials and air barriers are important to the thermal and acoustic performance of the building in use. Thermal and acoustic performance is very dependent on the quality of workmanship and supervision. Factory manufacture allows operatives to be better trained and supervised in these tasks, and allows regular checking and testing of performance. Problems such as omitted insulation and badly fitted air barriers are less likely to occur. Comparisons from North America suggest that better energy efficiency in use is achieved in homes that use off-site manufacturing techniques with a similar specification to site built homes.

In addition, volumetric construction allows building to be potentially dismantled and the modules reused at a different location. Modular hotels in the UK have been dismantled and removed to a different location when found to be uneconomic at their original site. Traditionally, many volumetric buildings were used as temporary
buildings and removed for reuse when no longer necessary. Thus, the technology for reuse is well established. Many of the materials used in this type of construction such as the steel framing can also be extracted for recycling at the end of the life of the module. This is made easier by the lightweight, dry construction methods that are generally used. This is likely to become more significant in the future when EEC legislation about producer responsibility encompasses the construction industry.

3.6 Benefits to the workforce and community

Building sites are temporary employment locations, so they generally offer little long-term amenities for the local community. Manufacturers in factories are often closely linked with the local community, with much of the workforce coming from the locality. They provide a long term economic and often social service for the community. Many manufacturers of prefabricated modular or panel units in the UK are well-established in particular locations and have developed a highly trained, local workforce, and strong links with the local community.

Employment at a factory manufacturing prefabricated building component is generally more stable and long term than site based employment, which is intrinsically transient. As a result, factory based employers are generally more willing to invest in training for their workforce. Furthermore, to function efficiently prefabrication requires high levels of skill and flexibility in the workforce. This necessitates greater training by employers.

From a financial point of view the shorter construction period allows a quicker return on investment by the client, and reduced overhead costs.

4. Conclusions

There is an increasing interest in off-site manufacture in the UK house building industry. House builders are beginning to realise that there is a need to improve standards and that new regulatory requirements such as the changes to the Building Regulations dealing with energy efficiency and acoustics will be more easy to satisfied by increasing the amount of off-site manufacture. Health and safety issues are driving many changes in approach.

There is an established sector of the construction industry manufacturing volumetric units for hotel construction, key worker accommodation, the education sector and budget restaurants. The economics of this type of construction relies on repeatable units so that large production runs can be set up. A figure of 40 repeatable units (of similar size and layout) is sometimes quoted as a minimum number required for such systems to be cost competitive. The volumetric manufacturers have developed technical systems and construction processes to maximise the benefits of this type of construction.

Panellised systems are more commonly in use in UK housing, but with relatively little finish off of the panels in the factory. Several builders are looking to move towards significantly more integration of finishes in the factory.

The management of the construction process has been identified as a particularly important area, and the interaction of the prefabricated components with site processes such as foundations, service connections and cladding are critical. It is essential to consider the process of manufacture and assembly when considering the building
design. Technical decisions can lead to process problems, and so both must be considered together.

The objectives of sustainability and the 'Rethinking Construction' agenda of improving efficiency in construction overlap in several areas, notably waste minimisation, process integration, a commitment to people and a quality driven agenda. Prefabrication offers an opportunity to address both these agendas, and improve both efficiency and sustainability. However, the industry has much to learn to fulfil the potential of this technology.

References


