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Report
Offsite Manufacture in Australia
Case Studies

Research Project No: 2005-004-C-03

The research described in this report was carried out by:

Project Leader	Thomas Fussell
Researchers	Nick Blismas Ron Wakefield Peter Bullen Willy Sher Richard Bird Scott Brotherwood
Project Affiliates	Peter Nassau John Reddie Peter Hope Jason Smith Carolyn Hayles Mark Vines Peter Tilley Karyn Ash

Research Program: C
Delivery and Management of Built Assets

Project: 2005-004-C
Off-site Manufacture in Australia

Leaders in Construction and Property Research

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Authors

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Please direct all enquiries to:

Chief Executive Officer
Cooperative Research Centre for Construction Innovation
9th Floor, L Block, QUT, 2 George St
Brisbane Qld 4000
AUSTRALIA
T: 61 7 3138 9291
F: 61 7 3138 9151
E: enquiries@construction-innovation.info
W: www.construction-innovation.info

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1 Introduction

Off-site Manufacture (OSM) has long been recognised, both in Australia and internationally, as offering numerous benefits to all parties in the construction process. More importantly, it is recognised as a key vehicle for driving improvement within the construction industry. The uptake of OSM in construction is however limited, despite well documented benefits. A research project was undertaken to determine the ‘state-of-the-art’ of OSM in Australia.

The project had several objectives, including i) determination of the key economic, social and environmental benefits of OSM within the Australian context, ii) identification of the real and perceived barriers to the use of OSM, and iii) comprehension of the opportunities for future investment and research. Although numerous reports have been produced in the UK on the state of OSM adoption within their country, no prominent studies exist for the Australian context. This scoping study is an essential component upon which to build any initiatives that can take advantage of the benefits of OSM in construction. The Construction 2020 report predicted that OSM is set to increase in use over the next 5-15 years, further justifying the need for such a study. The long-term goal of this study is to contribute to the improvement of the Australian construction industry through a realisation of the potential benefits of OSM.

The report is published as two industry reports:

Booklet 1 **Offsite Manufacture in Australia - A Report on the current state and future directions of offsite manufacture in Australia**

Booklet 2 **Offsite Manufacture in Australia - Offsite Case Studies**

This second booklet presents seven cases of the use of OSM products in Australia. Each case presents background to the project or company, before discussing the OSM aspects of the case. Each case ends with lists of benefits, barriers and lessons learnt from the project.

Booklet 1 provides a more technical report that defines OSM, discusses OSM’s underlying manufacturing principles, and identifies the barriers and constraints of OSM in Australia.

2 Bull Creek Station Project

2.1 Historical Context

The South West Metropolitan Railway in Perth is a large-scale transport infrastructure project. The route extends from Perth CBD to Mandurah and comprises of almost 82 kilometres of track, 15 stations and 20 bridges. This case study focuses on the construction of Bull Creek Station, Leach Highway.

Located at the Kwinana Freeway (north-south) and Leach Highway (east-west) junction it is situated almost 14 kilometres from Perth CBD in an area which is predominantly low density residential land. Categorised as a 'major transit interchange', the Station is forecast to cater for more than 3100 weekday daily boardings, peaking at around 1400 passengers during weekday morning periods.

A range of transport alternatives, including bus and rail services, motor vehicles ('park n' ride' and 'kiss n' ride'), cycling, and walking will all integrate at the station to allow consumer choice. Car parking for 617 vehicles is located on the west side of the freeway.

Designed by Woodhead International / MPS Architects and constructed by John Holland, the structure is a typical station building. It comprises of an elevated bus concourse that spans the Kwinana Freeway and station platform access for railway-passenger from a concourse via escalator, elevator or stairs.

No OSM innovative products were used on the project, being limited to 'tried-and-tested' products, namely:

- Bridge spans;
- Wall abutment systems;
- Lifts;
- Escalators;
- Balustrade.

2.2 Products

The various pre-cast products used on the project are briefly described below.

Leach Highway Bridge T-Roffs

Duplicating Leach Highway Bridge, ten pre-cast concrete T-Roffs were used to span the Kwinana Freeway. Supported on four central columns, each 1.5 metres wide, the bridge comprises two spans: the western span being 36.6 metres and the eastern span, 39.5 metres.

Locally manufactured by Delta Corporation, the pre-cast T-Roffs, weigh between 120t and 145t and were transported onto site with police escort outside peak traffic hours. The beams were then offloaded and stored until they were needed on the project. When the T-Roffs were installed it was necessary to close the freeway for a weekend. Two cranes then lifted the beams onto their bearings working to an accuracy of 2 mm.

Figure 2.1: Leach Highway bridge T-Roffs being lifted into position (Source: New Metrorail 2006a)

Bridge Abutment Walls

In order to accommodate station car-parking and the realignment of the Leach Highway on/off ramps, significant earthworks were necessary. These earthworks were retained by using pre-cast concrete abutment walls. Manufactured locally by Paragon Pre-cast, the concrete panels generally measured 7m x 3m x 175mm and were transported onto site without any transport restriction. Standard tilt-up erection techniques were employed to install the panels.

Platform Retaining Wall

To act as a retainer for the station's platforms, pre-cast concrete panels from Paragon Pre-cast were again used. Measuring 7m x 1.6m x 175mm, these items were transported onto site and craned into position.

Figure 2.2: Leach Highway Bridge: Pre-cast concrete abutment walls

Elevator/Escalator

Manufactured and installed by Schindler Lifts Australia, the elevator at the station was manufactured entirely off-site and lifted into position fully assembled. Otis Elevator Company Pty Ltd, a West Australian supplier, was awarded the contract for escalator supply and installation. Manufactured in China and ordered well before construction of the station started, once onsite the escalators were installed with no problems. They were lifted into place using two mobile cranes, the installation process took around two hours to complete.

Figure 2.3: Bull Creek Station escalator being lifted into position (Source: New MetroRail 2006b)

Structural Steel

The structural steel was supplied pre-fabricated by a local company. The steel was pre-finished with paint before getting delivered to site.

There were a number of design issues which came to light when the steel was on site – the main one being that the internal cavity within the steel components was intended to be a conduit for the electrical wiring/services. However, access points had not been identified at the design process so therefore they were left off during manufacture. The result of this necessitated a consultation with the appropriate electrical services personnel, and significant fabrication delays resulted as a result of having to make changes.

Pedestrian Footbridge Balustrade

The pedestrian footbridge comprises of three spans. The main span is a pre-cast T-Roff beam; the remaining two are Delta Corporation pre-cast concrete slabs. The foundations and support columns were cast in-situ and the Balustrades were OSM items.

The finish of the balustrades was intended to be a hot-dip galvanised finish. However a design specification conflicted with the ability to successfully hot-dip. The hot-dip galvanising process produced a non-uniform finish which was contrary to design specifications. In order to rectify this it was decided to paint the balustrade.

Along the same vein, shop drawings identified the need for 'hit and miss' fillet welds yet the galvanising process required continuous fillet welds. Clearly, confusion existed between drawings and specifications: an issue overlooked by the design team.

Another issue with the balustrades related to both the design and manufacture. It was noted that very detailed design and an inexperienced fabricator combined resulted in a poor product. The fabricator had to carry out many on-site rectifications in order to meet design specifications.

Figure 2.4: Balustrade on footbridge showing installation problems

2.3 Benefits

- All of the pre-cast concrete items were successfully integrated on the project.
- The use of pre-cast components saved time and reduced inconveniences on the existing infrastructure, i.e. limited time needed for road closures. Regarding these components, it was felt that the installation process went very well and progressed without hindrance and according to schedule.
- The other OSM items such as the lift and escalators were also successfully integrated within the build process. Even items such as the escalator – fully manufactured in China were incorporated without any problems. This suggests that the suppliers/manufacturers and the main contractor were well acquainted with OSM items and procedures. Identifying the management complexities associated with the co-ordination of multiple OSM suppliers (e.g. steel fabricators, lift manufacturer etc.) and individual contractors (e.g. concreters, electricians), there were no problems with product quality or component integration.

2.4 Barriers

- Product handling issues resulted in damage to pre-painted finish on the OSM steel components. However these were rectified by on-site touch-up painting of the damaged areas.

- More importantly, relating to the steel OSM items a design oversight failed to recognise the need for access to electrical conduits running through internal cavities. As a result, significant fabrication delays were encountered while rectifying the design fault.

- Lastly, fabricating the pedestrian footbridge balustrade highlighted differences between design expertise, product knowledge and local workmanship quality. Detailed designs failed to fully comprehend galvanising requirements and processes thus altering the overall finish. Poor workmanship required significant on-site modifications.

2.5 Lessons

The problems highlighted by this case study suggest greater communication is required earlier with all stakeholders involved with the steel OSM manufactured items. If design issues had been sorted before manufacture of the OSM components commenced, most of the issues could have been solved or minimised.

2.6 Acknowledgements

Malcolm Wilkinson – Project Manager, John Holland J.V.

Peter Bifield – New MetroRail

3 Melbourne East Link Project

3.1 The project and company

The East Link Freeway project in Melbourne, Victoria was undertaken by the Theiss John Holland Joint Venture. The project was awarded in October 2004 and manufacture of precast commenced in July 2005. Completion of the project is due in mid 2007. Its design necessitated a significant number of pre-cast concrete components, and therefore a manufacture yard was required.

A location was sought that could accommodate manufacture on such a large scale, have readily available labour, with little to no impact on the actual construction site. Morwell was selected as the location. Although the location was approximately 130 kilometres away from the construction site, it had a reasonably high rate of unemployment from which to access labour. Among the reasons for the award of the contract, the joint venture presented to the Government that if successful the project would provide employment to the region.

The pre-cast manufacturing plant was located in a disused steel fabrication plant for the duration of the project. Converting the existing plant into one suitable for pre-cast manufacture presented its own problems. There was significant work around ground consolidation, providing new gantries, and production of assorted casting beds for both internal and external areas.

Prior to award the joint venture elected to appoint a Precast Start-Up Manager for the precast operation to ensure a reasonable level of readiness once the project was awarded. In the first four months after award the work packing of all aspects of precast operation was developed and major contracts for long lead items such of prestressed moulds from China were designed and the procurement process started. As part of the pre-cast operation the joint venture then appointed a senior person as the Precast Facility Manager (PFM). The PFM had little prior knowledge of the pre-cast industry, but exhibited skills in the management of people through his experience as a manager of one of the local power stations in Morwell. The two managers then worked together in an effective handover phase. Initially the PFM employed some seven staff with different skills in pre-cast concrete. These employees spent many months developing the existing plant into a working pre-cast concrete manufacturing plant. The PFM also employed various senior engineers experienced in the manufacture of prestressed concrete. Employment of approximately 200 workers followed. The PFM was advised not to employ those with concrete experience, opting rather to skill them up over a three week period, providing potentially superior quality of product. This reduced the likelihood of bringing potentially bad practices from site to the factory.

Transport

The newly opened rail network through Morewell provided a possible means for delivering components to site. However this proposition was quickly dispelled as the cost of loading and unloading the concrete pre-cast elements would have been prohibitive compared to trucking the elements by road with only one lift onto the carrier, and one lift into the final position. The train option would require four lifts in total. The 130km distance from the factory to site did not pose any problem as pre-cast elements would require loading onto trucks for transport regardless of distance. Consequently, in dollar terms, the extra time involved in actual transport on the road was the only consideration, and in context was deemed minor.

3.2 The Process and Products

The system and process allowed manufacture of concrete pre-cast bridge components and assorted sound barriers off-site whilst earthworks were underway at the main East Link site. The components were ready for use when the construction team required them on-site.

Bridge beams

The largest and heaviest components manufactured by the plant were the pre-stressed beams of weights exceeding 90 tonne. Much of the plant's capacity was designed around these products. Manufacture of large pre-stressed beams was fairly standard and consisted of:

- Setting-up steel strands in the moulds;
- Pouring 50 MPa concrete and curing ready for lifting the next morning;
- Curing, carried out by pumping hot water through pipes on the outside of the moulds utilising a new hot water plant specifically designed for the curing process;
- Attaching safety platforms and rails before loading onto the 'jinker'.

Figure 3.1: Boiler system used to accelerate curing of the moulded concrete.

Manoeuvrability of these heavy components required specific attention and necessitated the mobilisation of a 85 tonne Straddle Carrier, 50 tonne rail mounted portal gantry cranes and 70 tonne mobile sling crawler for handling pre-stressed beams from the moulds and various operations leading up to loading and dispatch. Due to this weight the base on which the rubber tyred straddle carrier operated had to be consolidated with approximately half a metre of stabilised crush rock at significant cost.

These heavy pre-stressed beams, forming part of the numerous bridges, were loaded onto ‘Jinkers’ late in the afternoon. They were then transported, in twos, stopping at Officer (just outside the East Link site) around 10.00pm, recommencing the last section of the trip at 6.00am. The transport often slowed to 20kms per hour on the highway.

Figure 3.2: Safety rails fitted to beam and loaded onto ‘jinker’ for transportation.

Figure 3.3: ‘Jinkers’ being loaded with post-tensioned bridge beams

Sound barriers

Apart from the bridge beams, smaller sound barriers were also produced at the plant, using Vertical (battery) moulds. Utilising the gantry, these were easily transported outside for storage. Reusable impression moulds were also used for many of the barriers.

Figure 3.4: Vertical sound barrier moulds (Battery Moulds).

The larger ‘rock face’ sound barriers were produced horizontally. The ‘rock face’ mould was made utilising a continuous pour method. The latex moulds had an estimated life of 150 pours although they were able to last beyond 200 pours. The cost of producing these moulds was about one third that of the more traditional supplier with an original $1.5million price tag. Polystyrene was also incorporated into the cast to reduce the overall weight of the panel. Concrete cost savings were not realised through the polystyrene moulds, as these were offset by the increase labour costs associated with laying the styrene.

3.3 Lessons

- Use of battery moulds worked exceptionally well. The space occupied by vertical moulds, casting up to 56 panels per day, was greatly reduced by implementing the vertical mould design.
- Coordination between on-site and off-site operations was difficult, particularly regarding the coordination of panel delivery to site. Some large panel and beam sections were made and stored, but were not required as stated on the original production schedules until much later in the project. Further, beams were stored on top of other beams due to storage area shortages. Access to particular beams became problematic. The control of inventory was therefore an area that could be improved, perhaps with the use of electronic tracking devices. The use of radio frequency identification (RFID) technology was investigated during the start up

phase and was abandoned due to the high cost. However, in hindsight the RFID system step up costs would have been recovered.

The set-up of the temporary production pant was highly successful, producing components to a very high standard, at a rate exceeding demand, and to a lower cost than anticipated. The case clearly demonstrated that offsite options were not restricted to fixed, long-term facilities, but rather were more about understanding the concepts of production and manufacture.

3.4 Acknowledgements

John Reddie – Precast Start-Up Manager, John Holland (Pty) Ltd.

4 Newcastle Mercure Apartments Project

4.1 Historical context

The Mercure apartments are a new development in Newcastle NSW. It is a mixture of new build and the adaptation of an older structure. The finished building will be 14 floors and consist of a number of Mercure branded hotel apartments.

Originally the client who owned the building looked to find a company which could develop the site into private apartments to a specific budget. Timwin Construction – a Chinese construction company with offices in Sydney - was selected to construct the building. In order to keep to budget Timwin decided to develop the idea for the using a number of different factory made modules for the bathrooms, en-suites and kitchens in the development. Together with another company in China they established a factory in China to build these modules.

After construction of the building had commenced the client decided to brand the building into the Mercure Brand – and therefore its original use as private apartments changed to that of a hotel/serviced apartments. To ensure that the decor and therefore the design and construction of the kitchens and bathrooms fitted in with the Mercure branding the client contacted Duc Associates to assist in altering the design of the modules to fit in with the new branding and use. Duc Associates have a reputation for specialising in the design of large scale hotel projects. Their work ensured that standards are met and the designs to fit in with the Mercure brand.

During the construction of the building Timwin were taken over by the company making the modules.

4.2 The Product

The building uses the following modules:

- Bathroom;
- Kitchen;
- Laundry;
- En-suite.

There are many variations in design so they are by no means standard modules. There are approximately 100 modules of each type of room.

4.3 Construction

The modules consist of 75mm steel tubular chassis in which a concrete reinforced floor is poured. The finished floors are approximately 80mmm thick. The chassis provides the structural rigidity for the module which allows them to be craned out of the containers, and also provides protection against damage while shipping.

Once the chassis is built the frame is lined internally in a conventional way with plaster boarding and internal finishes.

- All services are plumbed in using Australian standard water pipes which are supplied to China.
- All Kitchen cupboards are pre-fitted.
- Wiring conduits are fitted and some wiring pre-done but most lighting and sockets/switches are fitted once on site.

4.4 Transportation

The modules are manufactured in China and loaded into standard shipping containers. They are then shipped to Sydney. The containers are off-loaded at port, placed on a truck and driven to the site. Once on-site the modules are craned out of the containers directly to the floor in which they will be fitted. They are then shifted by hand using rollers to place them into the correct position. Once in place they are levelled and plumbed. Once on site many of the modules have to have an in-situ built ‘extension’ on them to bring them to the size necessary for the room.

4.5 On site

Because half the building is in a 50 year old structure, adapting it to its new use and incorporating the modules within has been challenging. In the existing building the floor slabs have a very thick topping on them and this has had to be chiselled out in order to take the thickness of the module floors. Once the modules are in place a new screed is poured. In the new parts of the building the floor slabs have been designed with a set down to incorporate the thickness of the modules.

Once onsite the modules are craned to the desired floor using a static power crane, then manhandled off onto rollers and moved to the required position. At this stage they are then integrated within the building systems. No (minimal) service ducts were constructed in the in-situ floor slabs. Holes to accommodate vertical service pipes were drilled through the slabs at a later date. There was a sizeable space between the top external side of the modules and the underside of the concrete slabs of the ceiling above. This void was used to run horizontal service mains that the modules connected to.

Figure 4.1: Modules in position (note void above for services).

4.6 Benefits

- The completed modules are very cheap – a typical completed kitchen module installed on site cost less than a traditional kitchen replacement;
- Materials which are perceived to be of a better quality in Australia actually cost less than conventional materials in China – so its more cost effective to use 'higher quality' materials;
- By making the module off site, it allows the structure of the building to be completed while modules are being manufactured at the same time, which should theoretically reduce the total build time of the project.

4.7 Barriers

The main disadvantages of this project have seemingly stemmed from the history of the project and how things have changed during its build history.

The thickness of the module floors has caused considerable construction problems with the existing building and the new build. The requirement for step changes in the floor slab to take the modules has resulted in an inefficient building process and restricted any future changes to the building's use.

One of the current problems is that modules have been supplied and fitted on the site before the building structure is complete. At the time of the site visit there were still a number of floors which were being built on the new build section. As a result of this the structure has no windows and is not yet water tight. The modules are therefore exposed to rain egress and damage by splashes of concrete and general workers being in the vicinity. This would have been minimised if the modules had been temporarily covered but no attempt had been made to do this. However this was not perceived to be a problem as such items as cabinet doors can easily be replaced at little cost.

Figure 4.2: Kitchen module in place by window (note drop down floor).

4.8 Lessons

The project has been earmarked as a learning curve for the various stakeholders – with the plan to use the system on future projects.

One of the key areas that needed improvement was document management. It is considered that any future projects will have a fully established documentation system for recording all aspects of the construction process stage by stage.

Because the modules are being manufactured in China and because the main construction company on site is Chinese there have been many cultural differences between the Chinese and the Australian stakeholders which have had to be overcome in order for the project to succeed. To help drive this process an external consultant has been employed by the client to act as a facilitator on the project. However, as all parties involved wish to get to the same end point - and indeed use the experience as a platform to expand the availability of Chinese-made modules on other projects within Australia - a great deal of effort has resulted in many lessons being learnt.

As a result of a Newspaper article about the project Duc Associates have been contacted by another hotel group and they are currently working with the module manufacturer to refine the design/production/integration process for new projects.

4.9 Acknowledgements

Edward Duc – Duc Associates

KK Yeung – Project Manager, Timwin Construction Pty Ltd

John Smolders – Facilitator, Global Developments (Asia Pacific) Pty Ltd

5 Prep School Capital Works Project

5.1 Historical context

Prep is a new school year which has been introduced into Queensland. Getting ready for Prep has meant Queensland State Government has taken on one of the largest ever capital works programs in the education department's history. It involves providing approximately 400 new build classrooms and a similar number of refurbished classrooms together with numerous smaller upgrades of pre-school classrooms and small schools.

Queensland Department of Works managed the project. A government-led review team undertook the original scoping for the project and established the project budget. This was then handed to the Education Department for delivery. One of the key suggestions from the review team was to use modular transportable buildings as a means of meeting the tight deadlines set by Government policy. From the go-ahead in mid 2004, the prep facilities were required for the start of the 2007 school year for the first cohort of children with the balance to be completed for the start of the 2008 school year – giving approximately 2.5 years to complete the bulk of the new builds and refurbishments. Another factor favouring OSM was the large geographic spread of the sites, which would have been logistically difficult to manage and challenging to resource given the limited number of contractors available.

As nothing had been done on this scale before it was also seen as a test case, with its concomitant pressure to succeed.

5.2 The product

A risk assessment was initially carried out to establish the procurement packages and how to manage the different types of new build and refurbished work, together with how the new classrooms would be integrated into the existing school site. One of the recommendations of this was to reduce the risks of non-supply by using two contractors to produce the classrooms and two contractors to do site ground works. It was also decided to combine the refurbishment projects in the same contract package as the new build works because in many cases both types of work were required at the same site.

The transportable building suppliers were Bendigo Relocatable Buildings (BRB Modular) and Ausco Building Systems (Ausco). The ground works contracts went to Bovis Lend Lease and the Department of Public Works – Joint Venture. The Joint Venture was formed from personnel within the commercialised business units (Project Services & Q-Build) of Department of Public Works.

Another key requirement was that it was necessary to provide the new buildings with an appearance of permanence so that they blended well into the existing school infrastructure. The buildings were also briefed not to be moved once in position so all joints could be permanently covered.

Obviously the wide number of different sites and requirements dictated that a number of different options would have to be made available. As this would put the cost up an effort was made to limit the options. Where space was a premium however it was necessary to build two storey in-situ buildings, but this was kept to a minimum. Generally no more than three classroom blocks were installed on each site.

Figure 5.1: Classroom onsite and in use.

5.3 Design

The basic design of the classrooms was developed by the Queensland Department of Works. The manufacturers were responsible for the engineering design and resultant production drawings. The design took the form of a rectangular, 7 bay module with a classroom at each end. Kitchen and storage facilities were located in the central module. A 5-bay offset version of the above was also offered. Originally there had been in the region of 12 different designs to cater for different site requirements but ultimately two designs were sufficient to cover almost all situations.

To further ensure that the products did not have the portable ‘temporary classroom look’, two specific features were incorporated into the design. Firstly, a sloping roof was designed incorporating vertical windows near the apex; and secondly the external joints between modules were effectively covered by a deliberate design detail that used full cladding sheets. Theses were a combination of compressed fibre cement sheeting and corrugated colourbond cladding.

Figure 5.2: Completed roof sections assembled at ground level.

Internally, the walls were clad with varnished plywood below dado level to protect them from every day classroom activities. Above dado level the walls are painted. Again, the design called for full cladding sheets to hide the joints. A further benefit of wood sheeting is that they provided a high level of flexibility to the modules whilst they were transported to site.

The ‘feel’ of the interior is very light which is partly due to the light colour scheme and the abundance of windows. Ventilation has been provided by louvers in large wall panels as well as in the high level roof windows. In practice this has been found to keep the classrooms cool in summer.

5.4 Manufacture

The two manufacturers had similar approaches to the construction of the modules – but with some differences. The following describes the method in which the classrooms are built.

A mock-up and two prototypes were built to test out the initial designs. After consultation with stakeholders a number of items were changed to generally improve the structure by stiffening the floor beams to give a more permanent feel. It was also found that rain caused excessive noise within the classrooms, which necessitated the inclusion of additional insulation in the roof space and walls.

At the outset a design team inspection was held at each site, with representatives from the individual school, to formulate a design brief. Following agreement, the necessary documentation was developed and submitted for building surveying approval with the respective local authority. On approval, plans were sent to the building supplier for foundations and the specification was sent to the manufacturers. The designer developed a bill of materials including all requirements for each building, enabling a streamlined ordering system. This also ensured better inventory control.

The basic structure consists of a hot rolled steel skeleton with light gauge steel framing in-fills, designed to the appropriate wind resistant category.

Production line methodologies were used in the construction of the roof sections. They were manufactured indoors at ground level to remove any risks of working at heights. The roof structure was manufactured complete with external finishes, wiring, insulation and internal ceilings. At the same time the 7 modules of the floor were bolted together and levelled before the basic skeleton was built which included the posts for the roof support. With this in place the roof sections moved outdoors and attached to the framework. Once the roof section was attached, the walls and interior were fitted-out onsite. Elements of the building were excluded at the module interfaces to allow the covering of joints onsite using full sheeting. All the necessary components for finishing the module interfaces, down to screws and glue, were supplied attached to the module floors.

Once completed the modules were separated and dispatched to site. By fully assembling the building before delivery, the manufacturer guaranteed that the complete building could be assembled onsite without any interface discrepancies and associated delays.

Figure 5.3: With competed roof in place the framework and fitting out commences.

Figure 5.4: Completed classroom at factory showing cladding left off at module joints.

Figure 5.5: Completed classroom at factory showing cladding left off at module joints and transportation supports (blue steel).

5.5 Onsite installation

Two processes take place on installation:

Modules

Once onsite the installers organised the set out of the building on site and supervised installation. Thereafter trades (electricians, plumbers etc) followed to complete the fitting out of the class rooms and removed all evidence of the individual modules. The following main items were finished onsite:

- Battening under the building to hide the foundation stumps (Education Queensland does not normally do this with temporary buildings).
- The roof sheeting at the joint (referred to as the complex joint) were left off so that standard roofing could be fixed onsite ensuring no joints could be seen.
- Likewise the exterior walls received a full cladding sheet between windows or doors to hide joints.
- Internally, flooring panels completed onsite to conceal joints.
- Full length guttering was attached onsite.

Ground works

Having completed the logistics for the installation of the modules the ground works teams undertook services connections and integrated the new building with the rest of the school - while also completing refurbishment in other areas of the school.

The main task was to provide walkways, ramps and stairs to the classrooms and fitting these with appropriate hand rails for safety. Rails and balustrades were manufactured beforehand and were adaptable to the differing needs of the site. One of the main reasons for pre-manufacturing these items was the limited amount of galvanising facilities in the area which could have led to a supply shortage.

There had been pressure on the project to address individual requirements for the different sites; however this was restricted due to cost. The only situations where alteration were permitted related to works undertaken on or near historically listed buildings, where more appropriate colour schemes were necessary to meet planning legislation.

5.6 Benefits

- Quality - highly consistent product.
- Well received by users.
- Good aesthetic properties – does not look like a ‘prefab’.
- Large scale manufacturing enabled the process to be very efficient.
- Buildings delivered onsite quicker.
- Less time spent onsite which could disrupt the school.
- Easier to access difficult sites.

- Costs in the current market were marginally cheaper than in-situ new build. At the time there was substantial overheating of the local market and significant shortages of skilled trades in Queensland.
- Underwent a learning process during the first few weeks, but times were reduced to a 'start-to-hand-over' period of 3 weeks.
- Factory building in controlled environment with dedicated work centres improved efficiency.
- Much safer working environment.
- Provided a stable and static workforce.
- Repetitive manufacturing process reduced the requirement for skilled trade labour.
- Sub-assemblies were also manufactured off-site arriving ready to install and saving time, e.g. doors complete with sills and frames.
- Reduced waste and increased recycling of materials.

5.7 Barriers

- Statutory approval process – Approval system of such items as services was mainly a documentation issue. Also different Shire authorities were found to have slightly different requirements.
- Due to the large up-front investment needed by manufacturers to start manufacture, an 80% payment was made on initial installation and retentions released on practical completion.
- Ancillary supply chain supply problems, such as window supply, limited galvanising facilities in regional areas, loss of suppliers.
- There was a concern that the labour market would restrict the project timetable.
- Quality was an initial concern – however the prototypes resulted in significant improvements. One manufacturer continued to have problems until a QA plan was put in place, thereafter quality continued to improve over the life of the project.

5.8 Lessons

- Managing logistics, 'lots of people in lots of locations installing lots of buildings'.
- Getting the process right up front – making sure that everyone talked the same language (e.g. contractors and suppliers talk structural dimensions and architects talk external dimensions and they are different).

- Considering the track record of companies involved helped lay the foundations and reduced risk.

- Cost – treasury may have seen some cost savings initially but in reality the costs of the in-situ build classrooms were about the same as the OSM versions.

- Prototyping allowed accurate schedules to be produced, enabling the whole Organisation to be more efficient.

- Continuous improvement and learning allowed improved time cycles and reduced snags.

- The sheer volume of the program made it 'do-able'.

- The products had been designed for a 50 year life; however this is an unknown quantity.

- Confidence to use the model again – one of the key messages from the Government was that they saw it as a trial for further work and they wanted to make sure it would work because they can see lots of advantages to this type of program in the future.

5.9 Acknowledgements

Martin Miles – Project Manager, Department of Public Works Queensland.

Luis Biaggini – Construction Manager, Bovis Lend Lease.

Andy Jacka – Project Director Prep Year Capital Program, Dept of Education and the Arts Queensland.

Andrew Jones and Glen Goodfruit – Ausco Building Systems Pty Ltd

Justin McNamara – BRB Modular

6 Skilled Park Project

6.1 Historical context

Skilled Park stadium at Robina is currently being constructed by Watpac for the Queensland Government’s Major Sports Facilities Authority. The project has successfully utilised OSM products throughout.

Watpac has a history of constructing stadiums in Queensland (Ballymore Stadium extension, Queensland Sport and Athletics Centre extension, Brisbane Cricket Ground and Suncorp Stadium) and therefore has a good knowledge base for this type of construction. The project’s Principal, the Department of Public Works, has utilised a Single Select Negotiated Guaranteed Construction Sum Managing Contractor contract to procure the project. Watpac were engaged shortly after the announcement of the stadium design competition outcome to assist the design development process and expedite the submission of a guaranteed construction sum (GCS). A GCS was submitted by Watpac at the completion of the Schematic Design stage. Upon completion of the GCS negotiations, the contract was let and the design team was novated to Watpac. Since letting of the contract, Watpac have been responsible for managing the design development and construction process to the agreed GCS.

The design of Skilled Park differed from other stadiums that Watpac had constructed. The winning designers, HOK Architect’s, are specialists stadium Architects that had worked with Watpac on Suncorp Stadium. The Department of Public Work’s initiative to engage an experienced managing contractor early in the design process enabled the team to consider buildability, OHS and industrial strategies and tailor the design to accommodate OSM. The system of construction was selected based on experience gained during the Brisbane Cricket Ground and Suncorp Stadium projects. OSM is particularly suited to stadium construction as they inherently have large repetitive elements, with large volumes, spaces and heights, all of which introduce particular construction and OHS risk.

At Robina the main driving forces for OSM were;

- the limited time available for construction within an under resourced labour market, the client requires the stadium to be completed in time for the commencement of a nationally televised sports code season
- the minimisation of onsite work and to utilise more efficient offsite fabrication methods
- the reduction in construction quality risks
- the reduction in OHS risks

Construction was started onsite in June 2006 and it is anticipated the stadium will be complete in late 2007.

Figure 6.1: Robina Stadium site January 2007 (Source: Watpac Construction).

6.2 The product

Structural steel was selected for the main structural frame as it is traditionally constructed quickly and easily offsite in many sections. Early in the design process, Watpac considered incorporating further off site manufactured items into the development, eventually deciding to undertake the majority of the stadium's structural elements production processes off-site. The structure consisted of the following OSM components:

- Structural steel for the main structure of the stadium including seating support members, curved roof beams and the 4 level west stand facilities building;
- Seating plats, being the main precast concrete beams that support the stadium seating;
- West stand building floors consisting of precast planks forming the load-bearing floor structure that is placed on the structural steel frame before a topping is poured in-situ to tie the planks into the structure;
- All concrete vertical elements including wall panels, stair shafts, lift shafts and vomitories (spectator exit points) are precast;
- Roof and wall cladding consisting of a fabric membrane manufactured in Germany and fabricated in Poland.

6.3 Steel

The main Steel fabricator, Beenleigh Steel Fabrication (BSF), provided valuable industry input early in the design process. BSF's input into the project team value engineering process enabled options for key steel design elements to be reviewed and resolved efficiently. This initiative ensured the early bulk steel ordering of key structural elements from industry suppliers whilst simultaneously allowing the refinement of design details prior to commencement of shop drawings for manufacture. This key initiative reduced the potential of being delayed at a later stage.

BSF tend to use shop detailing companies who work exclusively for them to ensure good levels of communication. BSF had two main roles on the Robina project: fabrication and erection.

Figure 6.2: Steel fabrication.

Fabrication

The steel was constructed in a controlled environment to eliminate any adverse weather effects. BSF have two factory locations that, among other things, enable them to have a stable workforce of boiler workers. All sections were made-up on the bench and then broken-down into transportable sections. The overhead cranes in the factory make it possible to easily move larger items around when required. Theses were then stored until they were dispatched for protective finishing and painting. From then the items went directly to site. All items were labelled for identification and could be referenced back to the shop drawings if required.

Erection

BSF erected its steelwork together with the precast concrete elements. The company owns its own cranes and supplies crane drivers and riggers onto site. Combining the erection of steelwork and pre-cast elements under one package has streamlined BSF's erection methodology, reduced demarcation risk and aided the project programming.

Erection began immediately the in-situ foundations had been placed. The erection process had very low tolerances – typically a couple of mm, requiring precision in the onsite and offsite elements fabrication, thorough shop drawing co-ordination and accurate survey and set-out work.

6.4 Concrete Plats

Precast concrete plats (long beams to which the seating is attached) have for a long time been used as a standard element of stadium construction, as these are both cost and time efficient. Casting the seating tiers in-situ would take considerable time, be costly and also expose a large number of people to high levels of risk during the construction process.

Precast Elements manufactured the seating plats. Previously seating plats were cast with a large exposed surface area being steel trowelled. The Plats for this project are ‘T’ shaped and were moulded at 90 degrees to the final orientation to reduce the amount of trowelling required. This gave the maximum amount of off-mould surface, which results in the a high quality seating bowl surface finish – typically a class 1 or 2 surface.

Figure 6.3: Pouring the concrete plats.

The T shape (on its side section) was designed to overcome a perceived problem that was considered by the architects and engineers (normal plats are L-shaped). It was feared that a crowd jumping on the plats simultaneously would induce a natural frequency in the elements, hence the introduction of the T-shape to stiffen the plats.

Precast Elements have four, 60m moulds and can make different length plats by using adjustable end plates. Using these moulds they have the capacity to make up to 24 plats a day. Steel reinforcements were laid and tensioned in the moulds before pouring the concrete. Magnets are used to hold the fully-adjustable mould sides in place.

To speed up the production process quick-curing high strength concrete was used in conjunction with steam curing. The steam increases the temperature of the moulds to around 55-60C and reduces the cure time. The process took around 18 hours from start to finish, with pours commencing at 2pm and finishing by 8pm. By 6am the following morning, the plats could be removed from the moulds and stacked. Generally the plats required no patching or repair. The pre-stressing of the plats necessitated a half inch cut in the steel to tension the concrete on removal from the moulds. Once cut and trimmed the ends of the steel were then painted with an epoxy paint to seal them and prevent corrosion.

The connection systems and fasteners, together with stencils for product identification, were cast into the product allowing easy installation and product identification.

Figure 6.4: Steel structure and concrete plats onsite.

6.5 Benefits

- The biggest benefit in this type of stadium construction is reduced overall project time and the associated cost savings.
- Reduced time and labour levels on site.
- Safer site – an in-situ approach would have required a large infrastructure of platforms, scaffolding etc. to be set-up. Using precast items has significantly reduced the exposure to risk.
- Better quality control – easy to control and obtain a better finish.
- Coordinated interfaces and reduced trade conflict – allowed different trades to be present at anytime without competing for common workspaces.
- Better environmental performance – reduced amount of wastage and better recycling has been achieved both on and off site. All items brought onto site were used in the construction. The OSM providers also minimised waste as they were able to order materials more precisely reducing off-cuts, left-over concrete etc.

6.6 Barriers

- Mistakes made at the drawing stage may not have been discovered until the item was installed onsite. The consequences of mistakes are more significant.
- Less control of individual onsite. (?This was not intended to be a barrier; the intent was that due to lesser numbers on site this allowed greater control)
- In automated systems, single component break-down has a significant impact on other aspects.
- Even with prefabricated elements appropriate labour and workshop space and access are still challenges.
- In-situ solutions have the flexibility to adjust elements on-site – this ability is largely lost with OSM.
- The number of engineers that are comfortable designing precast components is limited, tending to be conservative in their designs.
- Fastenings are a substantial cost of pre-cast concrete elements – problems arise if the engineer does not understand pre-cast or has limited technical knowledge. Knowledge in connection systems and their capacities is required.

6.7 Lessons

- Co-ordination and documentation flow is critical and normally the main contractor's responsibility.
- Spend more time getting the drawings right in the first instance. Delays in finalising engineering and architecture designs for the detailing of the steel and precast concrete elements cause fabrications delays.
- Negotiate and award the contract to a builder early – this allows better co-ordination and earlier commencement of offsite works.
- Allow architects and engineers enough time – they have been surprised at the speed of installation onsite – a basic stand structure being completed within a few weeks. There is significant pressure on the design consultants to develop the design and provide construction documentation at a much earlier stage when OSM is utilised.
- A large amount of trust is required – by using people who have worked together before reduces this risk.
- Ability to discuss options and aspects with clients throughout the project is highly beneficial.

6.8 Acknowledgements

Gilbert Gouveia – Design Manager, Watpac Construction

Mark Finney – Beenleigh Steel Fabrication

David Cullen-Ward – Managing Director, Precast Elements Pty Ltd

7 Hollow Core Concrete Pty Ltd.

7.1 Historical context

Hollow Core Concrete Pty Ltd (HCC) was established in Melbourne in 1987 after the managing director had seen the use of hollowcore floor slabs in the Middle East. Production of hollowcore commenced in 1988 at their specially built manufacturing facility in North Laverton.

Hollowcore slabs are precast prestressed concrete elements that are designed to be used as floor slabs or industrial walling. The manufacturing process was developed in Europe in the 1950’s and first used in Australia for industrial walling in the 1960’s.

The Company initially just produced hollowcore slabs, but found that their use generated a demand for a prefabricated flooring system including the support structure.

This prompted the company to investigate what options and systems were available for a complete support structure. These investigations identified a potential demand for skeletal frame structures that allowed the whole structure of the building to be prefabricated. Systems being used in USA and Europe were not suitable for the types of buildings and construction methods used in Australia.

Through their in-house design team HCC developed a product range that suited the smaller buildings and low levels of repetition that are common in the Australian market. The result is a precast skeletal frame system of which hollow core planks are an integral part. The remaining elements are precast columns, precast beams and other precast elements that make up the complete building structure.

The degree of precast use depends on the nature of the design, although the elements the company produces can be used in conjunction with other construction processes and techniques.

The current range of products focuses on all the main skeletal framing elements of a building. Their manufactured products include:

- Floor slabs: Hollow Core and solid slabs;
- Columns;
- Beams;
- Stairs and landings;
- Wall panels;
- Stadium seating units;
- Small bridges;
- Balcony units.

HCC markets are principally the commercial and civil engineering sectors, although a recent development has seen increased use of hollowcore planks for the transfer floor in domestic housing where basement car parking facilities are required. This is still considered a small market.

A large percentage of HCC work results from the in-house design team producing precast alternatives to insitu concrete or steel frame designs. This allows the Company to offer a 'design, manufacture and installation' package.

Figure 7.1: Example of a building using Hollowcore system.

7.2 Hollow Core production

Hollowcore is essentially an extruded hollow concrete plank that incorporates tensioned steel multi strand reinforcement. It is possible to manufacture the hollow core planks in different widths, depths and lengths.

The company has four under cover casting beds each approximately 120m long. These act as forms for the bottom of the hollow core planks. Steel strands reinforcement is laid out along the length of the bed and then stressed to a pre-determined force. The number of strands and force can be altered depending upon the specification of the hollowcore plank.

Concrete is then fed into an extrusion machine that travels down the bed extruding the hollowcore section. The extrusion machines are fitted with a number of dies, each of which has a cone shaped screw on the front. These screws rotate, compressing the concrete and extruding it as the machine moves along the bed. This also removes all air and most of the water from the concrete mixture. The concrete is fed into the machine by overhead hopper with the whole process being computer controlled. As the machine moves along the bed the area behind the dies become the hollow centres of the extruded section.

The concrete mixture is very dry and keeps its shape after extrusion without having to be tampered or trowel finished (it is quite possible to walk on it shortly after the machine has passed).

Once extruded the planks are left to cure before being cut to pre-determined lengths and removed from the mould. All slabs are manufactured as individual components for specific projects. The planks are stored outdoors for further curing before being delivered to site for erection.

The extrusion machines, cutting saws, concrete conveyor system and lifting clamps are sourced from Finland or manufactured by HCC.

Figure 7.2: Hollowcore in production

7.3 Pre-cast skeleton frame system

In order to assemble the precast elements into a structurally stable building a number of solutions have been developed. The basic system consists of precast columns, precast beams and hollowcore floor slabs.

Columns are erected over steel dowels projecting from the foundations or column below and temporarily braced. The column bases incorporate dowel tubes, filled with high strength grout after erection. In a similar manner beams are erected over steel dowels projecting from the top of the supporting column. These dowels project above the top of the beam to provide the dowels into the column above. Dowel tubes through the beams are filled with high strength grout. In order to stop the grout escaping at the edges where the two structural members contact, a flexible foam strip is placed on top of the columns before the beams are erected. Beams are typically inverted Tee sections and are design such that no temporary support is required.

The Hollow core planks sit on the ledge of the inverted Tee beams. On a typical system an 80mm thick screed is used over the top of the hollowcore and beams to tie them the structure together. Once the structure is tied together the temporary braces on the columns can be removed.

The key to the success of this system is to use standard profiles and simple connections that are easy and quick to implement on site. This is critical to the speed of the project.

Figure 7.3: Hollowcore planks, beams and columns (showing support) onsite.

7.4 Example in practice – GPO Building Melbourne

A new six-level glass façade building was to be constructed next to a historic building in the centre of Melbourne. The new building, although having connecting foot traffic and services was to be structurally separate from the original building.

Although originally designed to be built in-situ concrete, the builders (St. Hilliers) and the consulting engineers (Arup) in conjunction with HCC decided prior to the commencement of the project to investigate the use of pre-cast concrete components. One of the main drivers of this decision was the difficulty of using insitu construction in the confined central city location with its associated access and time constraints.

Hollow Core was asked to propose a suitable construction technique to overcome the technical difficulties of cantilevered floors on three sides and, due to the glass façade, the lack of shear walls to provide lateral stability.

The HCC solution incorporated the basic precast column, beam and hollowcore skeletal frame solution as well as solid cantilevered planks. Lift-shaft walls, together with stair-shafts and stair flights within the original building were also included as precast concrete.

To provide lateral stability a pre-cast moment resisting frame was incorporated at the West end of the building.

Constructed almost entirely out of pre-cast components the new building has approximately 2300m² of hollow core plank floor area. The cantilevered sections are pre-cast solid slabs and incorporated a small up-stand section on the external edge. This was to act as a 'shuttering' for the screed, which was poured to tie the cantilevered panels in with the rest of the structure. This up-stand also enabled temporary railings to be fitted for the safety of the construction team and following trades and avoided the need for external scaffolding during erection. These up-stand sections also incorporated fixing points for the glass curtain wall, further reducing the time to install the façade.

Figure 7.4: GPO Building Melbourne

7.5 Benefits of the project

- Speed of construction and therefore less impact on the surrounding area.
- Rapid access available for following trades.
- Showed that Hollow Core planks and pre-cast construction can be adapted to suit an architecturally complex project.
- Significant formwork and scaffolding systems to handle the large floor to floor heights was required for the original scheme. This was completely eliminated using the precast system.

- Safety concerns were significantly reduced due to the reduction of on-site labour required.

7.6 Typical Benefits

- Hollow Core enables spans up to 17m. This reduces the need for beams and columns and is very suitable for car parks or open plan areas.
- No need to have scaffolding or form work so there is a reduced onsite labour cost.
- Speed of construction.
- Early access of following trades.
- The process of hollowcore manufacture is highly mechanised resulting in high quality products.
- Reduced onsite labour.
- Excellent surface finishes.

7.7 Barriers

- Over the years precast concrete has been associated with low-cost housing blocks that have affected its image and restricted its uptake – ‘Grey Box’ mentality.
- The construction industry is traditionally very conservative so the introduction of anything perceived as new or different faces barriers.
- There is need to realise that precast concrete is not suitable for every project. If more people were aware of its capabilities they could identify particular projects that suited the system.
- There is a lack of knowledge and understanding of precast concrete in Australia. Engineers think that precast is a new system. Many in Australia have little understanding of hollowcore, yet it has been used in Europe since the 1920s and is by far the largest flooring system used in Europe.
- It is suitable for domestic project housing, however it cannot compete on costs with traditional light weight wooden joist construction.
- Many building design codes and specifications are not written for precast. They are not restrictive but extra design time is required to ensure systems used are compliant with the codes.

7.8 Lessons

- HCC works across all procurement methods but they have found that where they are involved in the project from the conception stage it has proved more beneficial to the whole project.

- Working together with all stakeholders within the project team gives greater efficiency and leads to more economical buildings.

- HCC have products to suit a number of different applications but there are a number of misconceptions in the industry of the limitations of hollow core and pre-cast. HCC needs to generate greater publicity about the large number projects they have successfully completed.

- More education is required to inform the industry of the advantages of precast concrete and prefabrication. Much is this education relates to understanding precast as a system rather than a combination of a series of individual components.

- Recent industry skills shortages in the standard trades (such as concreters, steel fixers, carpenters, crane operators) have necessitated more training and a shift to greater use of precast component. Internal corporate expertise in the products and OSM, more broadly, are used to train new staff. HCC also run training on other items such as industry standards, OHS, QA requirements and on-the-job training which are specific to precast.

7.9 Acknowledgements

Simon Hughes – Hollow Core Concrete Pty Ltd

8 Monarch Building Systems

8.1 Historical context

Monarch Building Systems (Monarch) has experience involving many hundreds of building modules and panelised buildings including several large projects involving over 100 accommodation units produced within tight production timetables. Monarch position themselves at the top end of the traditional ‘pre-fab’ market and are able to provide for a market where clients are demanding better quality housing, particularly in the mining sector.

Monarch Building Systems consist of two main organisations which came together to offer a total package:

- Pantex – is a construction company mainly specialising in building housing and multi-residence buildings, and more recently dealing with OSM products.
- Monarch – established in 1979 to manufacture transportable buildings based around a steel frame system.

Both organisations complement each other and are kept separate to maintain independency with regard to standards and building requirements and regulations.

8.2 The Product

For the purpose of this case study, the focus will be on Monarch Building Systems and the construction of its different products. Within Monarch itself there are two key areas, namely Monarch Panelisation and Monarch Modular.

8.3 Panelisation systems

The panelisation system has been developed to allow whole houses to be built to lock up stage within a few days. The system comprises of a number of whole wall panels which are built in the factory and include all frames and sheeting ready for onsite erection.

The process

The wall panels comprise of a proprietary roll formed steel frame to which an external lightweight concrete panel is attached. When developing the exterior cladding system key considerations were that the panel had sufficient rigidity and long term stability, as well as sound ‘solid’ when hit by the hand (no ‘drumming’).

The cement-based panels are 26mm thick and comprise a light weight concrete of proprietary composition and a water proof membrane. The board has been tested for impact, fire, water proofing and insulation. The finished panels meet most QLD insulation requirements without the need for additional bulk insulation. The cladding is screwed to the steel frame. The external surface of the cladding is pre-finished with robotically applied render and paint.

All windows and doors are then installed and sealed before the frame is stacked into a rack for loading onto the truck. Specialised trailer units have been developed by Monarch allowing a single truck to transport an entire typically-sized house in one journey. This includes the wall frames, roof frames, internal frames and all cladding. The modular wet rooms of the houses are loaded onto a separate truck for delivery.

Where wet area modules are included in the house these are generally supplied to site before the panels. They are placed on a prepared base, and tied into the concrete slab, which is poured around them. The installation of panels as described above is then commenced.

Once onsite the frames are craned off the truck and assembled onto the pre laid foundation slab. Within about a day, a typical crew of three carpenters would expect to have completed the construction up to installation of trusses. After this point the crane is no longer required. Subsequently the roof structure and internal wall frames are fitted together, including the anchoring of all wall frames to the slab. The roofing and guttering are fitted together with the facia and soffit linings, achieving lock-up stage.

Figure 8.1: Lifting completed wall panels onto site (Source: Monarch).

Figure 8.2: Construction onsite (Source: Monarch).

Once at lockup stage the follow-on trades can get access. The house is plumbed and wired using pre-stamped holes in the frame system for routing, and then the interior is plaster boarded conventionally. At this stage such items as push-fit pre-finished window/door architraves help to reduce fit out time and painting further.

Figure 8.3: Completed house (Source: Monarch).

8.4 Modular

The modular system which has been developed is based on the construction techniques used in the panelised system. They have a steel frame on a pre-cast concrete floor, to which cladding is fixed. As the modules have to be lifted onto trucks for delivery, cranage points, durability for transportation and such issues as balance points all have to be considered at the design stage.

The manufacturing system of the company is based on that of vehicle manufacture and relies heavily on the use of robotics and other process philosophies such as just-in-time supply-chains.

The module systems which have been developed to include:

Whole unit transportable buildings

Modular buildings are typically fully completed in the factory including all plumbing, electrical items, internal and external wall linings and finished floors.

The buildings have a steel frame and are clad depending upon requirements, typically either panelised wall colourbond steel pre-finished weather board or corrugated profile. This gives durability and long life.

There are a number of different types made:

- Single person accommodation facilities for such sites as mining towns, comprising of two, three and four bedroom modules each typically with its own en-suite for privacy;

- Residential homes of conventional architecture;
- C Commercial office buildings. Applications have been in remote area;
- Tourist Accommodation which has been designed to provide tourist park operators with three and four star standard facilities.

Wet room modules

These comprise of bathrooms, toilets, en-suites, laundry rooms and linen cupboards. Depending upon the design requirements of the building, these can be stand alone or fitted back to back within the building.

As with the building modules the wet room modules consist of a concrete floor and steel frame to which an external cladding is attached (if required) and the interior is fitted out with conventional materials. Once again all plumbing and electrical items are pre-fitted. These have been used in single story, as well as, multistorey developments.

Figure 8.4: Bathroom modules in production (Source: Monarch).

8.5 Benefits

- The manufacturing process enables the production to be very efficient and cost effective.
- Quality-controlled construction delivering a consistent product.
- Short delivery times and very quick onsite construction time.
- Minimal trades requirement onsite, particularly in remote areas.

- The overall look of a completed house is that of an in-situ built product, eliminating the negative stigma attached with ‘pre-fab’.

- Suits low-rise multi-residential applications in remote areas and regional centres where access to trades can be difficult.

- Minimal on-site disturbance therefore giving a tidy work site with minimal waste or pollution.

- Minimal disruption due to weather delays.

8.6 Barriers

- Need volume to make OSM competitive.

- The structure has to be stronger than is necessary to survive the transportation with no damage.

- Processes differ from conventional building, requiring all stakeholders to modify site processes and techniques.

8.7 Lessons

- Monarch has developed a strong engineering and project management skills base which enables it to operate more efficiently. Aspects such as the IT systems use fully integrated building design programs, which allow for thorough design work, steel roll forming and robotic assembly.

- Trust is required between builder and supplier – a certain degree of confidence is required.

- The nature of OSM requires more accuracy – the builder who installs the product must be able to work within these tight tolerances.

- Each project needs to be considered on its own, often adapting previous designs. This allows more efficiency.

- This type of manufacture requires management and engineering overhead.

- The most successful projects have been where Monarch manages the project from the early stages – after the architect has provided the concepts. This way the project management can be optimised to use the building system and vice versa.

- Works best on large scale projects where there are many standard units.

8.8 Acknowledgements

Nathan Warner – Projects Manager, Monarch Building Systems

9 The Way Forward for OSM in Australia

A recommended action-plan for driving OSM through the industry is presented in Table 9.1 below. This is an extraction of the recommendations from Booklet 1, and includes the views of respondents within the case studies of this booklet.

Table 9.1: Action Plan for OSM in Australia listed in order of relative priority

Theme and Actions
1. Skills & Knowledge Skills training in trades and OSM skills required to ensure the industry is well furnished; Regular conferences/meetings should be arranged to demonstrate OSM projects and benefits; Encourage government to provide improved research incentives to stimulate local innovation and business start-up; Increase appeal for manufacturers to employ apprentices; Encourage location of manufacturing plants in areas with suitable labour source; Conduct career days at schools to interest people in the OSM market; Create online portal to disseminate international trends, products and processes associated with OSM; Conduct market research study to ascertain market opportunities.
2. Process & Programme Disciplines and processes need to be streamlined using integrated IT systems. Including development of IT based project management system to coordinate subcontractors and integrate the process. Need to learn from other industry's systems – from design through order and production; Advice on information and document distribution and management protocols required in high IT environment; Advice on storage and ownership of digital information should be addressed; Encourage design of OSM into the project from concept stage through education and showcasing.
3. Industry & Market Culture Establish annual OSM products and careers expo to showcase and promote OSM. Include trade shows and seminars; Commence initiatives to ensure that tertiary education focuses on future trends and ideas including OSM and manufacturing (CM, engineers and architects); Marketing emphasis should be on mass customisation rather than mass production, includes increased standardisation but not necessarily repetition; Improve government standards for civic architecture intended to improve building quality and longevity, thus, showcasing OSM products in operation and dispelling negative perceptions. Showcasing will demonstrate all benefits of OSM; Establish government funded display centres showcasing OSM products in use.
4. Cost/value Whole-life cost needs to be emphasised with understanding of value rather than purely direct costs. A system or method is required to show and convince clients that OSM is beneficial.
5. Regulatory Energy rating systems to be used to demonstrate that OSM can exceed current standards; Appropriate authorities need to examine the potential for OSM skills accreditation; Appropriate authorities need to examine introduction of separate section to code for pre-cast.
6. Logistics & Site Operations Inventory management research and advice necessary for manufacturers; Advise on location of manufacturing plant close to the project to reduce transport costs and logistics.
7. Environmental sustainability Demonstrate that better efficiency ratings due to better dimensional tolerances are possible; Demonstrate sustainability benefits.

Author Biographies

Richard Bird

Research Associate, School of Property, Construction & Project Management, RMIT University

Richard has an Honours Degree in Industrial Design (Eng) and a post Graduate Diploma in Ergonomics. He has worked for 10 years as a consultant Ergonomist at ICE Ergonomics in the UK (now ESRI), working in many areas including the safety of consumer and industrial products. This work was approximately equally divided between Research and commercial work. The Research work was mainly large scale Government funded research, predominantly relating to the safety of products. More recently Richard has been working in the commercial sector developing new concepts and products predominantly within the toy industry. Since coming to Australia Richard has been involved as a researcher on two CRC projects though his work at the School of Property, Construction & Project Management, RMIT University.

Nick Blismas

Senior Lecturer, School of Property, Construction & Project Management, RMIT University

Nick is a Senior Lecturer in the School of Property, Construction & Project Management, having joined RMIT University from Loughborough University (UK) in February 2004. His main research fields are: construction OHS; multi-project and programme management; and off-site production. His research has always been industry focussed, involving significant numbers of collaborating organisations. In addition to his 10 years construction management research experience, both in Australia and the United Kingdom, Nick also has 3 years industry experience as a project manager.

Scott Brotherwood

Research Associate, Department of Construction Management, Curtin University of Technology

Scott is a third year Urban and Regional Planning student and sessional tutor with Curtin University's, Bentley Campus. A keen advocate of sustainable development, he has previously been involved with Alcoa's Stronger Communities and intends his thesis studies to centre on social capital and local economic development. Recognised by the UDIA for his exemplary work in local planning Scott excels in his academic stream.

Peter Bullen

Lecturer, Department of Construction Management, Curtin University of Technology

Peter Bullen is a lecturer in project management, environmental management, sustainable development and construction technology in the Department of Construction Management in the Faculty of the Built Environment, Art and Design at Curtin University of Technology. He has over thirty years of experience in private and public sector commercial and residential construction project management, quantity surveying and facility management in the UK, Europe and Australia. Peter is currently a doctoral candidate with the Division of Resources and Environment at Curtin University. His PhD research is investigating the adaptive reuse of commercial buildings and he has published several research papers concerning sustainable buildings and adaptive reuse. He is a member of several working for the international research organization the Conseil Internationale du Batiment. He is also a corporate member of the Australian Institute of Building and Australian Institute of Project Management.

Thomas Fussell

Director and Chief Architect, Project Services, Department of Public Works Queensland

For the past fifteen years Thomas has been directly involved in the establishment of Project Services as a successful commercialised business within the Department of Public Works. This process has challenged the business to establish different relationships with its untied clients and to find more effective and more efficient ways to deliver its services. Thomas is focused on the greater use of advanced technologies to enable that improvement to be achieved. He is responsible for implementing the use of “virtual buildings” integrating the contribution of all of the disciplines into a single digital model to be used throughout the design, construction and operation of a building. The Off-site manufacture of components and assemblies has an important place in this new approach and has prompted his involvement in this project.

Willy Sher

Head of Building, School of Architecture and the Built Environment, The University of Newcastle

Willy Sher is Assistant Dean, Teaching and Learning in the Faculty of Engineering and Built Environment at Newcastle University. He is also Head of the Discipline of Building in the School of Architecture and Built Environment. Before coming to Australia he was Senior Lecturer in the Department of Building and Civil Engineering at Loughborough University (UK). He worked at the University of the Witwatersrand (South Africa) in the Department of Building and Quantity Surveying prior to this. He is a Fellow of the Australian Institute of Building and a Fellow of the Chartered Institute of Building.

Mark Vines

Program Director & Senior Lecturer, School of Property, Construction & Project Management, RMIT University

Mark is the Programs Director in the School of Property, Construction and Project Management and has been at RMIT for 16 years lecturing predominantly in the technology areas. Mark is also a registered Building Practitioner with over 20 years of housing experience, and is a member of the Australian Institute of Builders. Current research interests are focused in alternative wall systems for housing with ongoing industry collaboration.

Ron Wakefield

Professor and Head of School, School of Property, Construction & Project Management, RMIT University

Ron is currently Professor of Construction, and Head of the School of Property, Construction and Project Management at RMIT, Australia. He is also Program Director for Program C - Delivery and Management of Built Assets for the Cooperative Research Centre for Construction Innovation. His research and teaching is focussed on construction with particular emphasis on production systems, management of construction operations, use of information technology and whole of life performance of built assets. Prior to joining RMIT in 2005, Ron was the William E. Jamerson Professor of Building Construction in the Department of Building Construction, Virginia Tech, USA. He was Principal Investigator for the Industrializing the Construction Site project (Phases I, II, III, IV, V, Stage V extension) a multi million dollar research effort that lead to the Industrializing the Residential Construction Site series of monographs prepared for the Office of Policy Development and Research, US Department of Housing and Urban Development. Dr. Wakefield has over 20 years experience as an international researcher, consultant, and engineer in construction. Prior to joining Virginia Tech, Dr. Wakefield taught at The University of New South Wales, Sydney, Australia. He was a visiting Fellow at City University of Hong Kong in 1995.

Cooperative Research Centre for Construction Innovation
9th Floor, L Block
QUT Gardens Point
2 George Street
BRISBANE QLD 4001
AUSTRALIA
Tel: +61 7 3138 9291
Fax: +61 7 3138 9151
Email:
enquiries@construction-innovation.info
Web:
www.construction-innovation.info

Established and supported
under the Australian
Government's Cooperative
Research Centres Program