

# BUILDING ENVELOPE TECHNOLOGY SYMPOSIUM

## MODULAR CONSTRUCTION – SHOULD WE PRE-INSTALL WATERPROOFING SYSTEMS?

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## ABSTRACT

Modular construction is a fast and rising trend in the building industry. Prefabricated units or recycled shipping containers are stacked together to create a multiplex. The various delivery methods for these types of projects ask for pre-installed waterproofing and building envelope membrane systems, which require some level of finishing in the field. Consultants are challenged with alternative design processes, product approvals, and construction sequencing committed to expedited schedules.

There is an urgent need to evaluate the pros and cons of pre-installed waterproofing systems in the context of quality-control measures for modular construction. Walls, windows, and roofing assemblies are components of the conventional building envelope for which consultants are used to designing and detailing flashing on paper. When these systems are selected for modular construction, the manufacturing team decides and designates the best practices for the waterproofing assemblies. How are design decisions made, and are the correct performance criteria being reviewed? Who will ultimately be responsible if waterproofing issues arise in the future?

The consultant's role as an on-call advisor becomes essential in a modular design and prefabricated project setup. Lessons learned from Walker Consultants in modular-unit construction will be shared and discussed, with ideas to improve our building envelope and waterproofing approach to this type of work.

## SPEAKER

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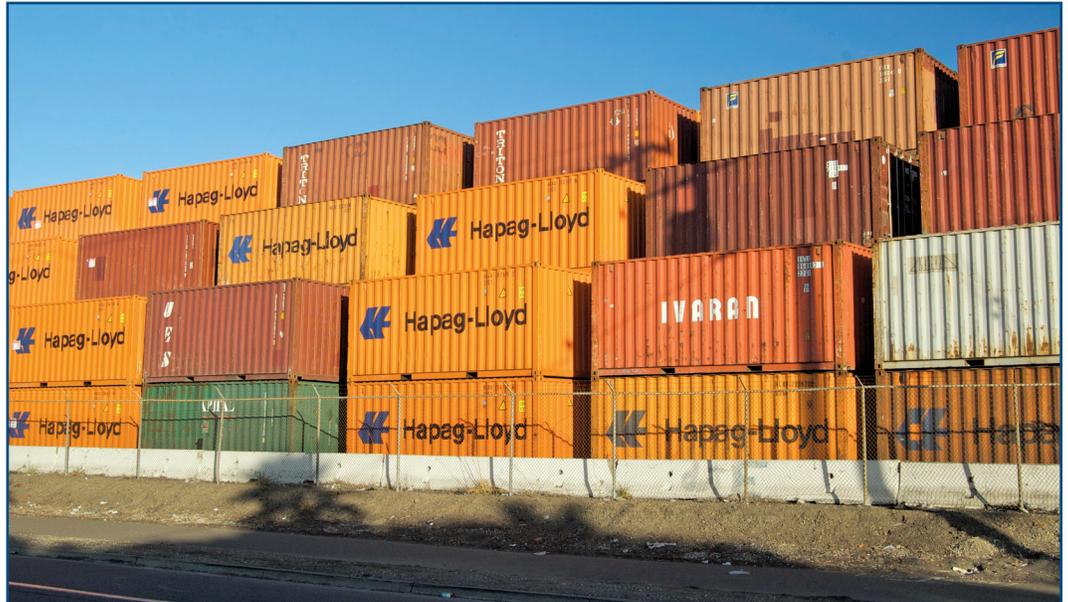


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# MODULAR CONSTRUCTION – SHOULD WE PRE-INSTALL WATERPROOFING SYSTEMS?

Modular construction is a fast and rising trend in the building industry. Prefabricated units or repurposed shipping containers are stacked together to create a multiplex (Figure 1). The structures are typically housing complexes in which the exterior envelope waterproofing design is a critical component. The various delivery methods for these types of projects are set up such that the waterproofing and building envelope membrane systems are preinstalled in a factory. The completion of these systems requires some level of finishing in the field. Consultants are challenged with alternative design processes, product approvals, and construction sequencing committed to expedited schedules.

There is an urgent need to evaluate the pros and cons of preinstalled waterproofing systems in the context of quality control measures for modular construction.



**Figure 1 – Typical steel shipping cargo containers.**

Walls, windows, and roofing assemblies are components of the conventional building envelope for which consultants are used to designing and detailing flashing on paper. When these systems are selected for modu-

lar construction, the modular manufacturing team decides and designates the best practices for the waterproofing assemblies. It is important to consider how design decisions are made, and if the correct performance criteria are being reviewed. In the end, who will ultimately be responsible if waterproofing issues arise?

## PROJECT DELIVERY

A couple of project delivery methods are currently in place for modular construction. One follows the traditional design-bid-build setup in which a design team, including a modular unit manufacturer, is selected to assemble the architecture of the overall project (Figure 2). An architect puts forth the preliminary design, and the modular manufacturer supplies the prefabricated units. The division of responsibility is typically separated between the fabricator of the modular units and the design team who oversees the remaining building components that will be built on the site. Elements such as façade cladding, exterior stairs, and walkways are detailed by the architect. These components follow the traditional design process in which construction documents and technical specifications are provided by a design team.



**Figure 2 – Modular construction units in progress.**



**Figure 3 – Modular unit delivered to the site.**

The modular manufacturer might select their own waterproofing systems, or they may follow recommendations supplied by the architectural team. Generally, this should be discussed up front with the modular manufacturers during selection, since it will reveal what quality control measures they have in place alongside the production of their units. Some companies will be resistant to waterproofing recommendations beyond their own organization, and they may not provide the flexibility and willingness to accommodate technical suggestions that a consultant and design team have to offer.

Another delivery method consists of one company assuming all responsibility as the developer, architect, and builder of the modular project. In this delivery method, there is one entity that oversees the entire project from design through construction, and they may even go on to manage the building and property after construction. In the San Francisco Bay Area and Southern California regions, numerous companies are being established with this model as their goal. They have their own in-house architects and engineers who provide the overall design and construction documents for their modular units, which are then stacked together to become a building complex (Figure 3). Also, they have their own general contractors who run and manage the construction of the project.

Companies who specialize in designing and building modular projects typically select all the waterproofing systems on their own. They determine which membrane products to use on the walls, what type of flashing products will go in the rough openings for windows and doors, and they select

the roofing membrane for the project. Their building envelope design and choices will only be as strong as the technical knowledge of their architectural team, unless a separate building envelope and waterproofing consultant is hired to review the assemblies.

### CONSULTANT'S ROLE

Modular construction is changing the building industry, as well as the role that the architect and building envelope consultant plays on a project. In the more traditional design-bid-build setup for modular projects, the architect or developer may hire their own waterproofing consultant.

Compared to conventional building projects, the building envelope consultant

should ideally remain in close coordination with the architect and the modular manufacturer throughout all design phases of the project. Especially critical is the preliminary design phase in which the modular manufacturer is brought on board. Most manufacturers are partial to certain waterproofing systems based on their previous history of projects that have steered their production and cost estimates. Because of this, the decision-making process and focus of the building envelope consultant shifts from being the entity who initially recommends and selects the appropriate products. Instead, the consultant is put in the position of reviewing the products that have been predetermined by the modular manufacturer. Thus, the role of the building envelope consultant is somewhat confronted by the modular company and their predefined specifications.

In some scenarios, there is no waterproofing consultant on a modular project if the building is driven by one modular company acting as the developer, architect, and general contractor. Companies such as these have their own internal team who will be responsible for the exterior envelope design of their units. This may or may not be a good setup depending on the technical waterproofing knowledge of that team. Since modular construction is rather new, it may be a while before we know more about whether this team setup is successful.

Building envelope consultants are often



**Figure 4 – Modular construction with steel containers.**

brought on board during the construction phase to help resolve waterproofing issues in the field related to the modular units. They are challenged in this scenario when the full history of the design is unclear and knowledge of the products that were installed on the modules is lacking. One specific challenge facing building envelope consultants involves windows that are already installed. There may be a construction question about how the rough opening flashing can be applied, but if the consultant was not involved during the design phases, this and other sequencing issues become apparent.

Instead of providing peer review feedback on details during the design phases, the building envelope or waterproofing consultant's role often evolves into that of an on-call advisor during the construction phase for modular projects. With challenging waterproofing details, the potential risk increases when consultants are responding to issues instead of designing appropriate solutions.

## WATERPROOFING SYSTEM SELECTION

For steel shipping containers that are repurposed and reused for modular construction, there are typically only a few industry-standard waterproofing systems that will be applied to the exterior of the units—window flashing, joint waterproofing, and the roofing membrane. If cladding is installed over the exterior façades of the steel containers, a separate waterproofing membrane is generally not required since the container can be a watertight interface on its own, and only treatment or sealing of fasteners or any other penetrations through the steel will be necessary. Typically, the exterior of steel modular units is just painted (Figure 4).

In selecting rough opening flashing, steel containers present numerous challenges since flanged window or door assemblies cannot be used when the steel panel is the exposed façade material. The interior wall is usually furred out so that thermal insulation and finishes can be incorporated on the inside of the unit.

When some depth is configured at the rough openings, block-framed window assemblies without a nailing flange can be installed with waterproofing and sill pan flashing. Anchoring of the windows can be achieved like a conventional building



**Figure 5 – Metal mounting straps installed along window perimeter will disrupt the continuity of the perimeter sealant joint.**

assembly with clips or anchors installed along the edge of the rough opening, in conjunction with perimeter sealant joints. Varying configurations may be proposed by the modular manufacturer, including a system of metal straps that end up disrupting the continuity of the perimeter sealant joint (Figures 5 and 6).

For wood-framed modular units, manufacturers have been using a variety of products for the walls and windows, often selecting mainstream manufacturers of waterproofing products. Synthetic, sheet-wrap products such as the weather-resistant barrier assembly, and self-adhered membranes for flashing at the rough openings are popular (Figure 7). It seems that fluid-applied waterproofing products are not as



**Figure 6 – Metal mounting straps installed along window jamb.**



**Figure 7 – Synthetic wrap installed at walls of modular units.**



**Figure 8 – Rainscreen furring channels installed over modular units in preparation for wall cladding.**

In the field, review and testing of the transitions and connections between the modular units should happen. This includes spray testing of the exterior wall systems, especially at the transition between the modular units.

Also, a percentage of windows ought to be water tested in the shop prior to the completion of all modular units and prior to any units being delivered to the site. Having a testing protocol in place will help to protect all project team members involved so that any issues are identified early in the manufacturing and preinstallation process. The design can be adjusted prior to completion of all modular units, and prior

readily considered for modular construction, but perhaps they ought to be, since field touch-up and transitions may be more easily achieved with these systems.

Single-ply roofing materials are typically selected for modular construction.

Since the membrane material is installed in the shop, the simplest, cleanest, and most cost-effective method is chosen. Often, however, roofing material is wasted if the modular manufacturer preinstalls the roofing membrane over each individual module. Without the knowledge of which units may end up at the top level of the building, the material can be wasted on a sufficient percentage of modules at the lower levels of the building.

### **WHAT GETS PREINSTALLED IN THE SHOP VERSUS IN THE FIELD?**

Windows, rough opening flashing materials, and roofing membranes are often preinstalled at the modular company's shop. The benefits of this include having a more controlled environment that can offer better protection for the waterproofing materials. Products can be better protected from con-

struction debris and shielded from ultraviolet (UV) exposure versus being left out in the open at a jobsite.

With this installation, there is less opportunity for objective quality control measures. It is likely that the level of review varies radically from one company to another. In the future, it would be good to see some standards established for the third-party review and inspection of the units.

At a minimum, the preinstallation of waterproofing systems ought to be coordinated with manufacturers, and this should take place when the initial modular units are constructed for a project. Quality control testing that is usually conducted in the field for conventional construction should be moved to the shop assembly phase for modular construction. This includes window water testing, sealant pull tests, and any adhesion and compatibility tests. There is room for improvement during this phase of the project. Since modular manufacturers do not specialize in the technical detailing of building envelope and waterproofing components, they usually do not know the importance of performance testing.

to them being shipped to the site.

The exterior wall membrane for framed modular units is typically installed in the field, as well as any finish cladding materials or rainscreen systems (Figure 8). It is recommended that a qualified installer with waterproofing experience be utilized since there will be critical tie-in transitions that need to be completed at and between each of the modular units. For example, a watertight interface will need to be achieved between the weather-resistive barrier at the walls and the rough opening flashing at each of the windows. Also, additional detailing at each of the joints between the modular units will need to be treated after installation; this also adds to the overall waterproofing quality control measures.

Finishing of the roofing membrane installation is also done in the field, which varies on each modular construction project. Some will only require completing the membrane transition between units, and some projects will require that the full roofing assembly be installed in the field, as well as any specialty roof elements such as heating, ventilation, and air conditioning (HVAC)



**Figure 9 – Elevated walkways are added after modular units are installed at the site.**



**Figure 10 – Exterior stairs are installed to the walkways connecting modular units.**

equipment or photovoltaic (PV) panels.

### CHALLENGES IN THE FIELD

The transition between modular units and any site-built elements becomes one of the main challenges at the construction site. Tolerances need to be carefully checked and verified as the elements, such as exterior walkways and stairs, come together (*Figures 9 and 10*). Elevations and slope are especially critical at walkways, stairs, and roofing assemblies.

If these calculations are not established in accordance with governing building codes, ponding water on top of the modular units or adjacent to the units can become an issue.

It is recommended that roof slope and drainage for the building be worked out in

design drawings prior to any shop or field construction. Depending on the structure of the modules, it is best to design a roofing assembly that is built up over the entire

structure so that the slope and drainage are handled like a continuous, conventional roof design.

If the roofing membrane and drainage



**Figure 11 – Roofing and drainage system divided per individual modular units.**

system are compartmentalized per each modular unit, or the units are divided by structural components, each module will be developed into a separate and individual roof area (Figure 11). This is not the best approach, and it increases the risk of ponding and water intrusion since additional transitions and roofing barriers are introduced. It is important to address the roofing layout, as well as any horizontal waterproofing elements, during the preliminary design phase so that the approach is clear amongst all team members. If the assemblies and slope configurations are constructed in the shop, there is added potential risk that may lead to field corrections for the slope.

Waterproofing of the interstitial spaces between modular units is a challenge unique to modular construction. The horizontal cavity space between each floor level and the vertical joints between adjacent units require special waterproofing attention. Multiple penetrations are usually made through the modular units to connect mechanical, electrical, and plumbing systems. If these interfaces are

not watertight, there is a direct path for water intrusion into the units.

For the horizontal cavity space, the full perimeter and penetrations through the modular units need to be completely sealed. In the construction of modular steel containers, condensation within the interstitial space is a concern, and the assembly needs to be properly ventilated, insulated, and waterproofed to avoid moisture issues. At

the ground level, modular units are typically installed on top of a concrete foundation stem wall, and they are elevated above the soil or grade line to avoid direct contact with any water or site drainage. Waterproofing at this horizontal interface between the modular units and stem wall is required to mitigate the amount of water that enters the crawl space underneath the units (Figure 12). Also, if the modular units are wood-framed, a vapor barrier is recommended within the ground floor assembly to prevent any moisture vapor drive issues from impacting the interior of the units.

At vertical wall joints, flashing and secondary waterproofing measures need to be implemented along the exterior and interior sides of the joints to prevent water intrusion (Figure 13). Each joint between modular units is an additional risk point compared to conventionally constructed buildings. Construction monitoring of these elements should be carefully reviewed at the site as the modular units come together.



**Figure 12 – Joint between modular unit and foundation stem wall.**



**Figure 13 – Vertical wall joints between modular units.**

**Figure 14 – Modular units being stacked together in the field.**



## CONCLUSION

The desire for modular construction projects is driven predominantly by time and cost savings. In the case of steel units, this includes the repurposing of modular shipping containers. Quality control—especially of the waterproofing systems—often gets overlooked in this type of project delivery. Essential to the success of a modular project is how each unit is constructed, how all the individual units come together in the field, and how the waterproofing is tied into all the components (*Figure 14*). Better quality control measures need to be implemented during the factory pre-installation process, as well as in the field during construction installation.

As the demand for modular construction increases, review and installation of waterproofing assemblies become more critical. This includes the selection and detailing of the products, as well as the tie-in transitions and installation. This overview of the challenges discussed leads us to question, “Should we preinstall waterproofing systems?” The answer is yes—if your team has enough technical knowledge, or if a building envelope consultant is hired to assist with the project. Otherwise, the answer to this question is no—if there is not enough technical knowledge to support the design

process and provide advice when it comes to the waterproofing assemblies. Companies without the technical knowledge put themselves at risk without a consultant, which is the case even for conventional building approaches.

Similar to conventional construction, modular construction proves that not all waterproofing conditions can be resolved in the field during construction; therefore, it is recommended that a waterproofing consultant be engaged early in the design process.

Technical knowledge and experience can improve the quality of this type of building as long as the modular manufacturer does not side-step any quality control measures. Once enough knowledge is gained by the modular companies who deliver these types of projects, the quality of the construction will improve, and a higher level of experience will inform the preinstallation of waterproofing systems. 