Packaging design of unitized curtainwall plays a pivotal role in the time frame between production of the unit and its being installed on the building. A good design should allow for the units to be secured easily, protect the unit from damage during shipping and lifting, and be easy to handle with a forklift or crane. Typically, unitized curtainwall is packaged in wooden bunks fastened together with nail or screw fasteners. In addition to not being reusable, wooden bunks have a tendency to fail if not designed and built properly. Steel bunks have greater structural integrity with the bonus of being highly recyclable. Most importantly, steel bunks designed with bolted connection allow for the bunks to be reused over and over again, even for different projects. Here, we will describe our efforts to promote sustainability through the use of reusable steel bunks that also offer additional advantages such as cost reduction and product safety. Work on reusable bunk design and their implementation was carried out by the Applications Engineering group consisting of Brian Koons, Jim Casper, and Carlos Otterners under the advisement of Darryl Sorens.

In a curtainwall manufacturing facility, parts and components are delivered from vendors in order to be assembled. The majority of the parts come prefabricated and ready to be installed, such as the glass, gaskets, fasteners, and thermal isolators, while some require some degree of cutting and drilling, such as the aluminum extrusions, using a computer numerical control (CNC) programed EMAG. Smaller parts that can be pre-assembled prior to being installed in the unit are grouped together to form sub-assembled parts. Starting with the aluminum framing, the parts, materials, and sub-assemblies are strategically installed in the unit followed by the addition of the glass, or architectural spandrel panel, and subsequent caulk, which are the last steps in the production line. However, a very important step in producing unitized curtainwall comes after each unit is successfully built: packaging. Proper packaging protects the units during shipping and lifting which ensures the units are delivered to the job site in good condition.

In the past, curtainwall units have been packaged in wood bunks consisting of two to four units. The units are placed on a wood base, glass facing up, and then stacked on top of each other with padded wood in between. When complete, the bunk is flipped on its side such that the male or female vertical mullion is at the base. The structural basis of the wood bunks is that of a moment frame. The wood and connections maintain stability of the truss to prevent any distortion due to lateral unit loads that are primarily induced during shipping. Currently, we have moved towards using steel re-usable bunks which have proved to reduce costs, improve product safety, reduce labor and time, as well as promote sustainability.
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jobs in succession if painted to prevent rust. A construction project and even for multiple steel parts can be reused over the duration of due to the material and fabrication, however, its availability in standard shapes and sizes, it is an obvious choice of material to use.

Additionally, the price of steel parts vary drastically by section type which influences bunk design greatly. Channels and angles can be procured for a fraction of the price of W-sections and HSS. In order for the bunks to be reusable, they must also be able to be assembled and disassembled to a certain degree. Consequently, the majority of part connections must be bolted assemblies. Wood bunks are not able to be taken apart without destroying the integrity of the wooden members and fasteners. Although stainless steel fasteners will last longer since they provide better corrosion resistance than tempered steel, they have reduced strength and would require a higher quantity to be used. Also, the wood construction side bolts can easily be misplaced. Therefore, it is better to use zinc-coated steel fasteners due to their increased temper and rate of corrosion resistance. Additionally, steel or zinc-coated steel fasteners are generally less expensive than stainless steel.

Reducing the time it takes to bunk units is another advantage of using steel reusable bunks that saves money. Wood bunks require constructing the bunk around the units as they are stacked by cutting down the wood to size and nailing in place. This requires a lot of time. Steel bunks, on the other hand, are pre-engineered to fit the unit exactly and only require fastening together with the specified bolts. The reduction of time spent bunking units helps with costs since it enables units to be bunked and moved to storage faster, freeing up space and personnel to perform other tasks.

Steel bunks may have a higher upfront cost due to the material and fabrication, however, steel parts can be reused over the duration of a construction project and even for multiple jobs in succession if painted to prevent rust. Furthermore, having a reusable design allows for fewer bunks needing to be produced per project since the bunks are sent back from the job site to the manufacturing facility to package new units. Due to the durability and corrosion resistant paint, the bunks can also be used for several jobs consecutively before being retired and recycled yet again.

SAFETY

Another major advantage of using steel bunks is that units are less prone to being damaged in transport in comparison to wood bunks. The wood members and screws are relatively weak and may fail during transport. Additionally, wood may come into contact with the unit which causes scratches or other visible marks. Steel bunks, on the contrary, are preassembled and placed in position using a bridge crane. Since each steel bunk type is designed to accommodate specific units, the only manual task required is fastening the parts together with an impact driver. OSHA specifies that such changes can greatly reduce physical demands on workers which can lower injury rates. This also leads to an increase in work productivity.

COST REDUCTION

Unit weights can range from 500 pounds to over 2500 pounds, depending on unit dimensions, glass composition, and presence of steel reinforcement. Due to the large weights, wood bunks require high strength wood to be used. Normally, visually graded No. 3 (minimum) treated Southern Pine is used, or an equivalent wood species. Due to the quality of lumber and the fact that it is unable to be re-used, material costs are very high. To achieve structural adequacy, wood screws must also be used in lieu of nails. Although nails are inexpensive and can easily be inserted with a nail gun, they are relatively weak and tend to pry-out over time. Wood screws provide a much higher tensile strength, however, due to the quality of lumber and the selection of reusable materials. The U.S. Green Building Council evaluates buildings and promotes Leadership in Energy and Environmental Design (LEED) ratings, which is a big incentive to use sustainable materials in all aspects of business operations. A typical Manhattan skyscraper is cladded with thousands of curtainwall units. Each unit was shipped to the construction site bolts. The reduction of time spent bunking units helps with costs since it enables units to be bunked and moved to storage faster, freeing up space and personnel to perform other tasks.

SUSTAINABILITY

A big focus for buildings and architecture is achieving a high level of sustainability. This is accomplished through energy efficient designs and the selection of reusable materials. The U.S. Green Building Council evaluates buildings and awards Leadership in Energy and Environmental Design (LEED) ratings, which is a big incentive for building developers to pursue sustainable buildings. A building with a high LEED certification does not only reduce energy costs, but also serves as a marketing tool to promote a company’s brand, recruit and retain employees, and promote sustainability. In this day and age, people are more environmentally aware and aim to take the necessary measures to preserve the environment.

Although a LEED certification only pertains to the building and its components, it is important to promote sustainable designs and measures in all aspects of business operations. Using steel reusable bunks is also safer for workers since they improve ergonomics and allow the bunking process to be less labor intensive. Wood bunks require the use of hazardous tools, such as table saws and nail guns, and manually placing and fastening members to the bunk frame. Steel bunks, on the contrary, are preassembled and placed in position using a bridge crane. Since each steel bunk type is designed to accommodate specific units, the only manual task required is fastening the parts together with an impact driver. OSHA specifies that such changes can greatly reduce physical demands on workers which can lower injury rates. This also leads to an increase in work productivity.

FIGURE 1
Wood bunks are not reusable and a high quality of wood, screws, and nailing is required to create a structurally stable bunk.

FIGURE 2
Bunks from the San Francisco Museum of Modern Art FRP wall.
Capital One Block B was one of the first projects to utilize the reusable bunking concept. The bunk design revolves around the concept of suspending the unit within the bunk frame. For this project, the vertical mullions had notches specifically designed into the extrusion profile solely for bunking. The notches allowed a foot long aluminum hat channel to slide along the mullion length. The hat channel acts as a connection point for a double angle assembly back to the steel bunk frame. The first angle, connected directly to the hat channel, is aluminum while the back angle, connected directly to the bunk frame, is steel (Fig. 4).

The bunk frame design is modular in that each bunk is composed of three tiers of frames that are bolted together (Fig. 5). Each bunk frame consists of four columns composed of C4x5.4 ASTM A36 channels. A L3x2x3/16 ASTM A36 angle runs along the side of the unit between adjacent channel columns and bolts to the channel webs. Another L3x2x3/16 ASTM A36 angle runs across the unit width and is welded to each channel flange. The length of the welded angle changes with respect to the unit width while the bolted angle length remains constant for all unit types. At the top of the channel, a 1/2” ASTM A36 plate picking eye is welded to the interior of the channel web. When the frames are stacked on top of each other, the hole in the picking eye allows each frame to be bolted together.

Typically, each bunk contains three frames stacked on top of each other, each supporting one unit, equaling three units per bunk. Portions of the unit extend past the bunk frame. The max allowable cantilever of the unit is generally three feet to prevent damage to the unit induced from self-weight deflections. Therefore, for longer units, there must be two bunk frames positioned...
on either end of the unit such that the unit is supported at eight locations along the vertical mullions as opposed to four. The bunk is lifted using an eight point steel spreader bar designed according to the dimensions of the bunks. Each pick plate is connected to the picking eyes at the top bunks or at pick locations at the bunk base by wire rope slings. The crane lifts the spreader bar from each corner using a four-leg wire rope bridle.

Unlike the suspended bunks, the reusable steel bunks for 220 Central Park South require units to rest on their side within the steel frame. The base of the bunk was designed to be lifted via forklift, since that was the primary intended lifting method. The base of the bunk is composed of two HSS7x4x5/16 ASTM A500 Gr B tubes connected together by two C5x3 ASTM A572 Gr 50 channels (Fig. 7). The tube shape, size, and spacing were selected to accept the two forks of a forklift. To keep the units upright, vertical HSS2x2x3/16 ASTM A500 Gr B tubes are inserted and bolted into tube sleeves that are welded on the exterior webs of the forklift tubes. There are also plate braces spanning between vertical tubes at the top to maintain stability of the frame.

For long and narrow units, the units rest on their side with either one of the vertical mullions at the base. The steel tubes on either side of the unit keep them upright so that three units fit within a bunk. For short and wide units, the units rest upright with the sill at the bunk base. In this case, there are two aluminum sleeves located on each vertical tube. The lower sleeve is dead loaded to the bottom of the frame. It contains a vertical leg that fits within the chicken head slot.
in the sill. The other sleeve, located at the top, has a notch that securely fits around the chicken head. Together, these sleeves help prevent any lateral movement of the unit during shipping (Figs. 8 – 10).

Due to the unit sizes, another bunk design was used for Pilaster units. In this design, the units stand on their side while resting on a custom steel pallet. Diagonal angle braces are added in the long dimension to maintain stability and prevent distortion. In the short dimension, the units are sandwiched between two channels that span the length of the bunk. The channels are connected to a bunk via a T-bolt connection to a flex-strut anchor channel that is welded to the bunk frame. The anchor channel allows for the unit supporting locations to be adjusted accordingly. These channels also serve as an anchor point to prevent the units from moving during transport. In order to anchor to the channel, a hook shaped plate is bolted to the unit mullion which grabs onto the flange of the channels. Additionally, the design of the bunk allows for unit accessibility which helps with offloading the units. For this job, a custom hydraulic-powered fork-lift boom, coined the Batwing, was used to remove the units from the bunks.

**CONCLUSION**

The use of reusable bunks to package unitized curtainwall has proven to be an effective measure to ensure product quality and successful production operations. The ability to reuse bunks through a project’s life, in addition to multiple projects in succession, reduces long-term material costs relative to bunking every unit in an unpredictable wood frame. Additionally, the inherent strength of steel and its ability to be used in various designs and connection types increases the structural integrity and stability of the bunks, which in turn promote product safety during shipping and handling. Decreases in the physical demands and assembly time of workers is also an apparent result of using pre-fabricated steel. Lastly, the use of reusable bunks emphasizes Enclos’ advocacy towards sustainability since the steel can be easily recycled. Steel bunks are just one example of successful innovations to our standard operations and practices and we hope to proactively seek sustainable solutions in other areas of our company in the future.
This article is a reproduction of the research that comprised a paper — under the same title — delivered at the Advanced Building Skins 2015 conference at Graz University of Technology.

