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Building with Steel

Part One

The Mark

Where design innovation preserves history

BY ALLYN STELLMACHER, AIA, LEED AP,
AND JOHN WORLEY, SE, LEED AP

The Mark

Where design innovation preserves history

Photos © Connie Zhou

IN THE DESIGN OF THE MARK, A NEW 48-STORY COMMERCIAL OFFICE AND HOTEL TOWER IN SEATTLE, THE OWNER AND DEVELOPER HELD THE RIGHTS TO DEMOLISH A HISTORICALLY SIGNIFICANT CHURCH ON THE SITE, ALLOWING FOR THE DEVELOPMENT OF A HALF-BLOCK FOOTPRINT. HOWEVER, THE EMOTIONAL, CULTURAL, AND ALSO HISTORIC SIGNIFICANCE OF THE OLD CHURCH—A FACILITY COMMISSIONED BY ARTHUR DENNY, FOUNDING FATHER OF THE CITY OF SEATTLE—MOTIVATED THE CLIENT AND LOCAL PARISHIONERS TO SEEK ALTERNATIVES.[1]

Working closely with Daniels Real Estate, ZGF Architects looked at numerous design configurations to preserve and celebrate the downtown site while developing a contemporary office building, now one of the city's first quarter-block towers constructed under downtown zoning.[2] Ultimately, the church's preservation and its incorporation into the new development yielded a sustainable solution. This shared commitment and sensitivity to context allowed the structure to be restored for future community use as an event facility, now aptly named the Sanctuary, as well as to maintain the character and history of the block, which also includes the iconic Rainier Club building.

Form and structure

Numerous schemes were initially evaluated for the ability to integrate form, structure, function, and sensitivity to the historic Sanctuary. The design team narrowed the field to three possibilities, including curved, canted, and faceted façades. A faceted scheme was selected and further developed to optimize building height, configuration, and floor-plate efficiency, while responding to the owner's vision for an iconic addition to downtown Seattle's skyline. Amid a historic building boom in the city, the 69,677-m^2 (750,000-sf) high-rise is distinguished by the diagonal steel braces dividing its planes. The faceted scheme is part of a structural system that shifts the load away from the building core and to the exterior walls, thereby eliminating view-obstructing elements like internal columns and reducing the core size to create more efficient floor plates.

With just 1394 m^2 (15,000 sf) of space available on level one of the Mark, floor area had to expand on subsequent floors to maximize leasing potential. Through a joint development agreement with the Rainier Club, over-under property rights were utilized. As a result, the tower subtly slopes over the existing historic structures—with the lower northwest corner cantilevering over the block by more than 6 m (20 ft)—before tapering back through a sequence of triangulated building planes.

The structural lateral system consists of concrete shearwalls around the elevator core and perimeter steel bracing. The perimeter brace system was inspired by and integrated with the architecture of the building, with the braces following the facets in the façade and forming the edge of each folded plate. This allowed for open, configurable floor plates. The lateral stability of a tower like this is often provided by only a central concrete core, but the combined perimeter brace and concrete core system allowed for the core to be only as big as needed to house the building's 12 elevators. This allowed the project team to maximize the building's usable floor space and achieve the requisite lateral stiffness with minimal visual intrusion.

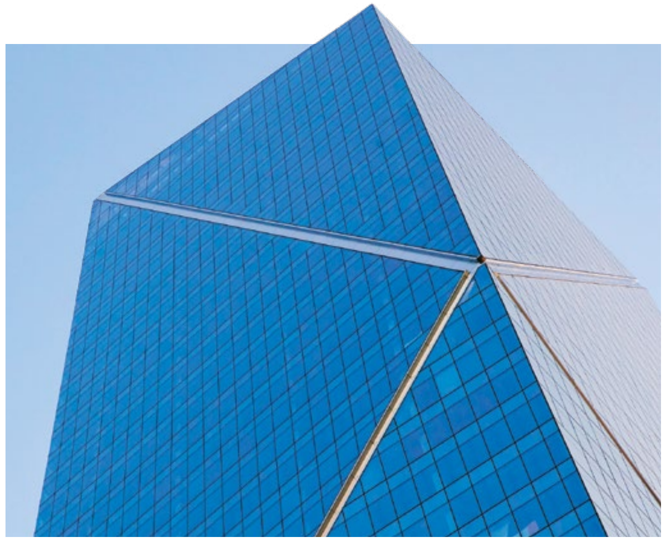
In looking at various frame configurations, the most architecturally satisfying solution was to cross each face of the building with three major diagonal brace elements meeting at key corner points.

These 'megabraces' form the edges of jewel-like facets, with planes angled to create an expanding floor plate over the building height. Most of the exterior columns are canted up to six degrees to support the floor plates, which increase in size through the 18^{th} floor and then vary in shape on the higher levels. Diagonal lines meet at corner points on levels 16 and 28—the latter has the largest floor plate. In order for forces to be transferred between the megabraces and floor diaphragms, the braces meet the floor at the same point, above and below brace intersections where a column or another brace meets the floor (select levels only), to smoothly move loads to the ground.

At these select floors, referred to as nodal floors, lateral earthquake load gets transferred from the floor slabs to the perimeter brace system. At the internodal floors, the concrete core shearwalls resist the lateral earthquake force from the floors and transfer the force upward and downward to the nodal floor levels and then into the perimeter brace system. The geometry of the entire tower is based on the locations of such nodes to ensure a sufficient number of floors participate in the coupling of the core and perimeter frame.

The Mark's unique megabrace structural configuration produced several important outcomes that included:

- a highly geometry-driven design;
- an unusual interaction between the core and external braces;
- a redundant system with distributed ductility; and
- an architecture defined by the bold expression of structure.



The faceted scheme, with fewer lateral elements configured at open angles, eliminates view-obstructing components like columns and has created more floor-plate efficiency by reducing the building's core size.

Seismic design

The potential of a large seismic event due to Seattle's proximity to the Cascadia Subduction Zone—where the offshore Juan de Fuca tectonic plate is pushing beneath the North American plate—added a layer of complexity to the project's structural design challenges. Given the building code limitations (2006 *International Building Code* [*IBC*] with City of Seattle Amendments) in prescribed lateral systems for high-rise buildings of this scale, the project's engineering team, had to justify the structural configuration through a very rigorous performance-based seismic design (PBSD) approach.[3]

Some of the critical structural elements evaluated as part of the PBSD included:

- steel perimeter braces (limited the amount of yield strain the brace experienced);
- concrete core walls (checked to ensure axial compression capacity is never exceeded);
- concrete core wall reinforcing (limited the amount of rebar tension strain beyond yield);
- concrete core beams over door opening's 'coupling beam'(limited the rotation of beam due to bending);
- nodal floor collector beams (checked to ensure beam and beam-to-wall connection capacity is never exceeded);
- nodal floor diaphragms (checked to ensure the concrete floor shear capacity is never exceeded); and
- perimeter steel columns (checked to ensure the column capacity is never exceeded).

One of the challenges of the analysis modeling was to capture the effect of the structural lateral system extending down 29 m (93 ft) into the ground, like a pole embedded in the earth. The lateral structure can push against the soil below grade and cantilever off the mat foundation slab at its base. To ensure the effects of both load paths were captured, all

The lobby of the Mark emphasizes daylight and transparency.

To preserve the former First United Methodist Church, built in the early 20th century, ZGF Architects designed a tower that cantilevers over it instead of taking its place. Last year, the church building made its reintroduction as the Sanctuary, a space for events and meetings in Seattle.

analyses were run twice—once with stiff soil laterally restraining the below-grade structure and again with soft soil.

The PBSD process demonstrated that the structure meets or exceeds the intended performance of *IBC* with regards to strength, stiffness, ductility, life safety, and collapse prevention. This project consisted of running seven simulated earthquake ground motions through a non-linear dynamic analysis of the tower structure to demonstrate that all components meet performance criteria to ensure structural integrity is maintained. The simulation validated the Mark could withstand a 2475-year quake registering as high as 9.0 on the Richter Scale. Slight yielding of the perimeter steel braces and concrete core reinforcing steel is expected, but there would be zero loss in integrity of any structural elements or connections.

This approach has led to a better understanding of structural seismic performance and, for this project in particular, resulted in enhanced performance above code-designed buildings. By wrapping around the entire structure, the perimeter bracing system acts as a closed tube that engages the axial stiffness and strength of all the perimeter steel columns. It also enabled Arup to design the steel for the structural lateral and gravity system most efficiently and with the least amount of material. In fact, it saved 750 tons of steel—a 10 percent saving over other structural systems—while providing superior seismic performance.

Details and amenities

Inspired by the composition lines of classical figures such as Michelangelo's David and the Venus de Milo, the Mark's design is balanced and proportional with nearby buildings. At the tower's base, an elegant and highly transparent entrance lobby and lower-level façade complements the adjacent buildings. A glass connector serves as an enclosed transition between the Mark and the former church building.

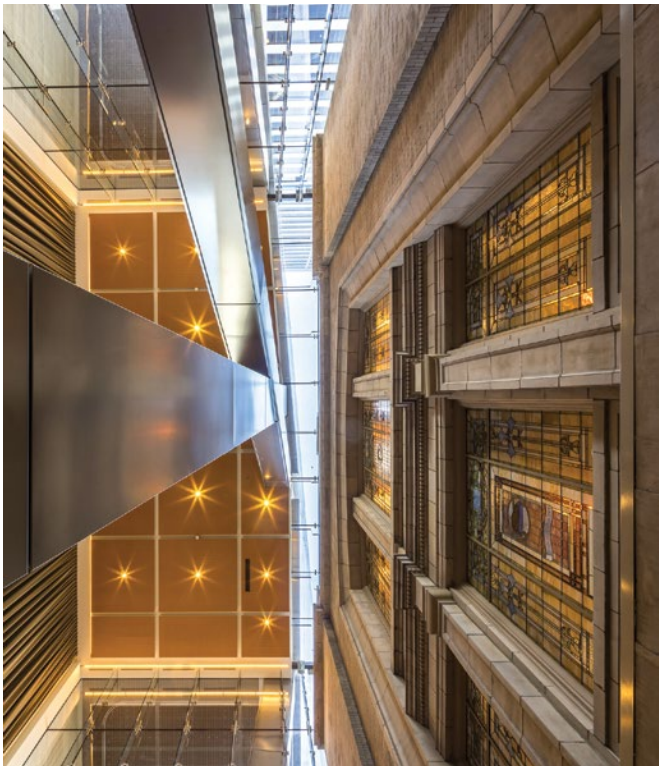
In the Mark, the faceted glass exterior is light and luminous, designed to be as transparent as possible to maximize daylight opportunities, while contrasting with the surrounding buildings. It is one of Seattle's first towers with column-free floors and floor-to-ceiling windows (more per square foot than in any other building in the city) which create light-soaked spaces for tenants. With fewer lateral elements configured at open angles, the faceted scheme draws the eye upward, increasing the vertical emphasis of the tower.

The scheme also offers subtle variation in plane from facet to facet: a soft expression to avoid overpowering the delicate detail and scale of the nearby church and the Rainier Club. Depending on the time of year, weather, and the observer's point of view, the Mark reflects both adjacent high-rises and the historic buildings at its base, thereby paying homage to Seattle's past and present.

Just off the lobby of the Mark, a travertine wall hand-selected by the Daniels Real Estate team in Italy creates a podium of natural beauty complementing the century-old Byzantine architecture of the Sanctuary. Due to its weight and size, the wall is structured by freestanding hollow structural section (HSS) frames, four stories in height. This was done to ensure it could move independently of the main building structure in a seismic event. The HSS tubes were infilled with structural studs, which were then sheathed. The stone itself was attached as a rainscreen, set on continuous horizontal rails fixed to the sheathing.

To highlight the building's many amenities and to clearly guide tenants and visitors throughout the space, ZGF created a branded identity for the Mark. Elevators in the hotel and office cores include a custom-designed pattern etched on an oil-rubbed bronze overlay, a detail to highlight the tower's vertical expression and distinguish between the Mark and the Sanctuary.

Network technology company F5 Networks has leased all 47,938 m^2 (516,000 sf) of available office space at the Mark. A luxury, 189-room hotel is located on the first 16 floors and repurposes the former church into a meeting, event, and



An interior view of the enclosed connection between the Mark and the Sanctuary.

amenity space with a restaurant, bar, spa, and a 1858-m^2 (20,000-sf) ballroom.

Conclusion

The goal of preserving and celebrating adjacent historic structures, while creating a bold and distinctive form, drove the design of the Mark. It was clear from the start if the design did not respond to these criteria, the Sanctuary would be lost to other development opportunities. Today, the Mark offers an inspired response to a unique context, incorporating design innovation, stewardship, and historical integrity to maintain two existing structures and maximize development potential in one of downtown Seattle's skinniest high-rises. **CS**

Notes

[1] For more information, visit www.zgf.com/project/daniels-real-estate-the-mark.

[2] See Note 1.

[3] *IBC* does not have defined requirements for an earthquake lateral load-resisting system for a building of this height consisting of a combination of a concrete core shearwall and a perimeter steel brace frame. Therefore, this system needed to be justified to meet the building's performance requirements. Get more information at www.arup.com.

ADDITIONAL **INFORMATION**

Authors

Allyn Stellmacher, AIA, LEED AP, is partner at ZGF Architects. Stellmacher provides design leadership for a wide variety of projects in both the public and private sectors, including healthcare, higher education, and technology applications. Stellmacher's project involvement has demonstrated his sensitivity to the use and detailing of appropriate materials, building systems, and technologies to optimize design quality. He graduated from the University of Oregon with a bachelor's degree in architecture. Stellmacher can be reached via e-mail at allyn.stellmacher@zgf.com.

John Worley, SE, LEED AP, is a principal with Arup and is the office leader for Oakland, California. Worley has more than 30 years of experience in structural building design and project management on a wide range of projects, including office towers, hospitals, schools, laboratories, airports, and theatrical and industrial facilities. Leveraging technology and a team-integrated approach, he orchestrates projects from conception through final construction. Worley also has extensive experience in seismic analysis and performance-based design. He can be reached at john.worley@arup.com.

Abstract

A striking addition to downtown Seattle's skyline, the Mark, an office and hotel tower, is distinguished by its exposed diagonal steel braces that divide the building's planes. The faceted façade scheme is part of a structural system that shifts the load away from the core and to the exterior walls, eliminating view-obstructing elements like internal columns, maximizing natural daylight, and allowing more open, configurable floor plans. To preserve the adjacent former First United Methodist Church, the tower cantilevers over it instead of taking its place. As a result, the Mark is one of the first high-rises in downtown Seattle to be built on a quarter-block site.

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05 12 00–Structural Steel Framing
08 81 00–Glass Glazing

UniFormat No.

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B2010–Exterior Walls

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Concrete
Glass glazing
Seismic performance
Steel braces
Structural steel

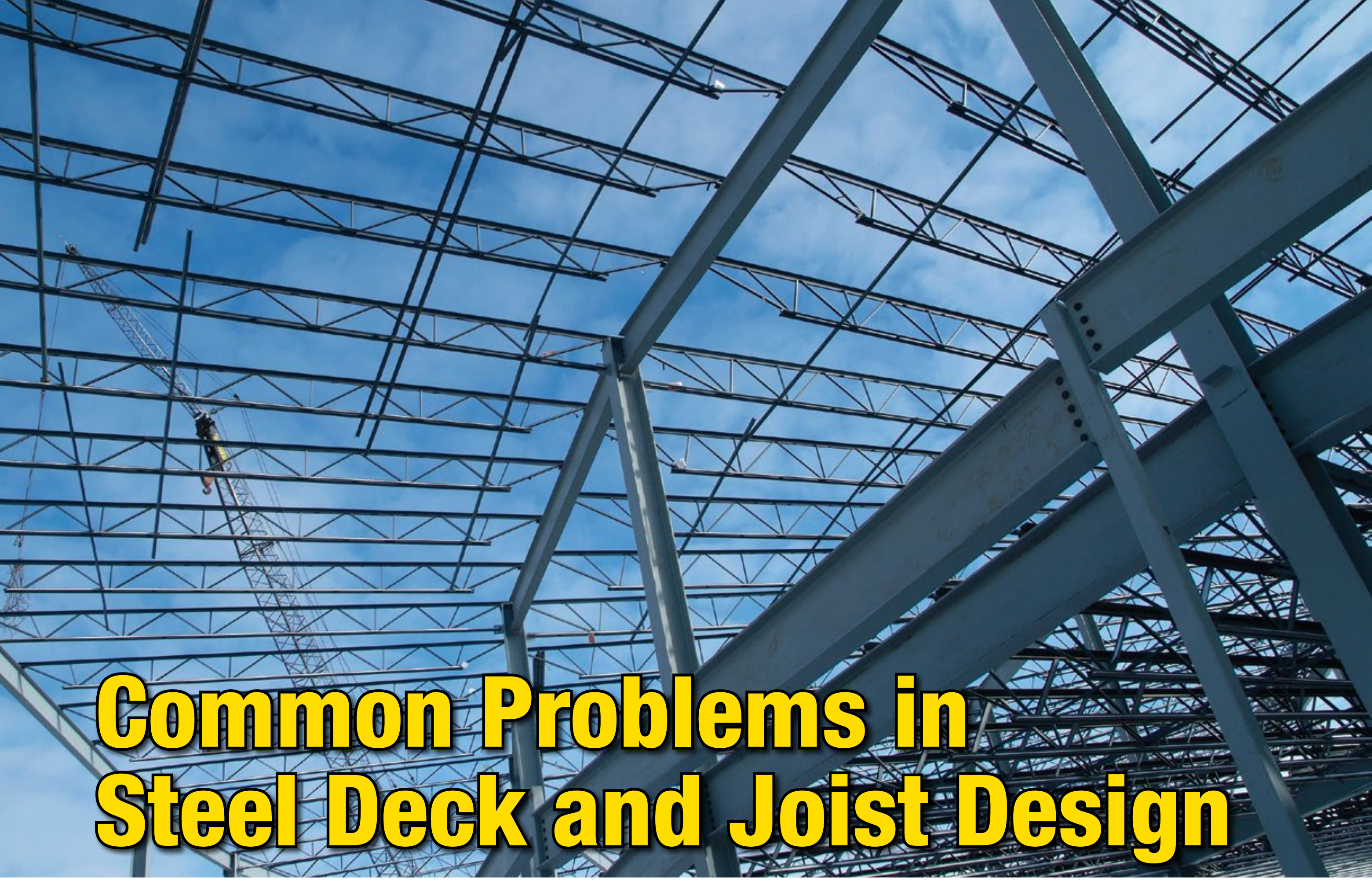
Building with Steel

Part Two

Common Problems in Steel Deck and Joist Design

Early communication and collaboration can streamline the construction process

BY PHILLIP KNODEL, LYNDSAY CROSS, AND CHRIS RODES



Common Problems in Steel Deck and Joist Design

Early communication and collaboration can streamline the construction process

Images courtesy New Millennium Building Systems

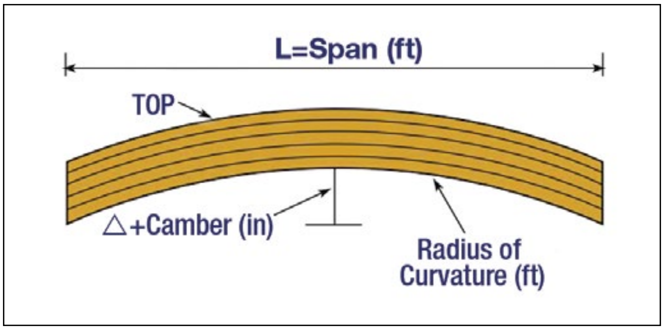
AGGRESSIVE TIMELINES ARE CREATING A SCOURGE OF INCOMPLETE CONSTRUCTION DRAWINGS, LEAVING MANUFACTURERS AND FABRICATORS OF JOISTS AND STEEL DECKING GUESSING AT THE DESIGNER'S INTENT AND UNCLEAR ABOUT CRITICAL DETAILS. WITH COMPRESSED PROJECT TIMELINES, THE SPECIFICATION OF CRITICAL DETAILS CAN GET PUSHED DOWNSTREAM TO THE STRUCTURAL ENGINEER, WHO PUSHES THEM TO THE FABRICATOR. IN REALITY, THIS METHOD OF SAVING TIME UPFRONT BY LEAVING OUT INFORMATION IN THE DRAWINGS JUST TRANSFERS THAT WORK TO A DIFFERENT STAGE OF THE PROJECT AND CAN LEAD TO MISTAKES, REQUESTS FOR INFORMATION (RFIS), AND COST OVERRUNS. THE ANSWER: UPFRONT COLLABORATION WITH ALL MEMBERS OF THE TEAM AND A SHIFTING OF RESPONSIBILITY BACK TO THE APPROPRIATE TEAM MEMBER.

Specifically with regard to the manufacture of steel joists, incomplete construction drawings and a lack of the specifics required by subcontractors can slow down a project. This article addresses some common areas of concern for steel decks and joists.

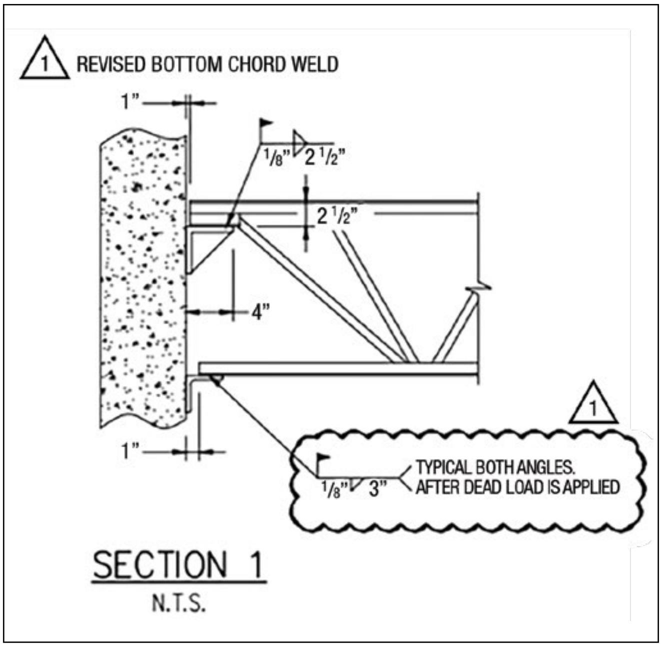
Avoiding the RFI

While often a necessary part of construction projects involving multiple teams, RFIs complicate and slow down project timelines. Pushing critical decisions to later in the project cycle to compress schedules can lead to more RFIs, which, ironically, slows the project down even more.

Poorly labeled sections, incorrectly labeled sections, or conflicting information on drawings is all fodder for RFIs. It is a good practice for the manufacturer or subcontractor to try and identify all problem areas at once, prior to sending construction drawings out for approval, so that all of the team's concerns can be addressed simultaneously. If the drawings come back from approval and not all of the concerns were addressed, or the answers are unclear, then an RFI is



Engineers of record should solicit the expertise of joist engineers when specifying cantilevers. Camber can play a significant role in the structural effectiveness of joists designed in cantilever applications.



Indicating revisions with clouding can save project time by making it easier for trades down the line to locate the change.

sent. Frequent areas of concern for subcontractors with respect to steel roofs and decks are: net uplift value, rollover forces, fatigue design, diaphragm capacity, cantilevers, and welds.

Uplift

On ballasted roofs, uplift is not generally a concern once the construction is complete. But with other roof types, when uplift is a concern, in the authors' experience, it is often provided as a gross value right out of the American Society of Civil Engineers (ASCE) 7-10, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* code, instead of the net uplift required for the joist design. It is then up to the subcontractor to calculate net uplift using the actual roof dead loading, which may not be specified in the design loading.

If no uplift is indicated, it is up to subcontractors to determine whether uplift needs to be considered or not, and to do the calculation. It then needs to be confirmed with the engineer of record (EOR). This ends up being more work on the back end of the project.

Rollover forces

Vague references in the design documents to rollover forces create similar problems for subcontractors. For roofs and decks, it needs to be clearly stated on the construction drawings if the joist seats need to be designed to handle the rollover forces. If it is not clear how the rollover forces are going to be resolved, it adds time to the process as the subcontractor has to determine the best method to address these forces. For example, if the design does not indicate channels, tube steel, or something similar in between the joists to pick up the diaphragm, then the joist seats must be designed to handle the rollover. This can become challenging, depending on the size of the forces.

Fatigue design and cranes

Another example of introducing uncertainty into a project because of a reluctance to make a decision early in the process is related to the use of cranes. This function is controlled by the American Institute of Steel Construction (AISC) *Design Guide 7*. When crane loading on the joists is specified, the joist design must account for the cyclic loading, otherwise known as fatigue. Joist specifiers need to know the crane's classification, the type of crane, and how it is being controlled. These factors determine the impact and fatigue factors that are used in the joist design. The fatigue experienced by joists supporting a crane is similar to bending and unbending a paper clip repeatedly. Eventually the paper clip will snap. If the EOR does not have details about the crane at the time of design, it is advisable to provide the information as soon as it is available.

Diaphragm capacity

Another area in which drawings often lack critical specificity is transferring diaphragm capacity through deck attachments. The Steel Deck Institute (SDI) has standard practices regarding diaphragm transfers. SDI's *Code of Standard Practice 1.4.2* and its commentary explicitly state that deck attachment is to be specified by the specifying professional (often the EOR). That lack of information could easily lead to RFIs on the issue. Instead of trying to delegate the design of diaphragm transfers, it would be more efficient if the EOR or other professional would design it at the outset.

Cantilevered joists

The joist manufacturer is the expert on the capabilities of joists and joist girders. Joists with cantilevers are situational and there can be a knowledge gap on the part of the architect and engineer. Joists can have a significant cantilever, but in most cases, if there is a long cantilever, it is not advisable to camber the joist. If a long cantilever joist is cambered, before it is even loaded, the curvature of the joist would cause the end of the cantilever to dip significantly, which is likely not what the EOR expects. In this case, the subcontractor would likely question the design and send out RFIs or approval notes. Earlier collaboration may avoid these types of errors.

Rooftop units and snow

Snow drifts are often specified around rooftop units (RTUs). When there is a square mechanical air conditioning unit on a roof, it is advisable for the EOR to look carefully at the specifications for snow drift requirements all around those units. In accordance with ASCE 7-10, Section 7.8, "If the side of a roof projection is less than 15 feet long, a drift load is not required to be applied to that side." The authors have experience with one project in which the manufacturer was able to save the client approximately $70,000 while still remaining within the code, by carefully considering the details of the rooftop units and the need (or lack thereof) for drift load. It is possible that some design software may not account for exceptions regarding drift load.

Longer welds

Specifying welds is another area that often leads to unnecessary costs when early project team collaboration is skipped. Specifically, unnecessarily large weld sizes are often specified on chord toes or on chords attaching to columns or tie plates. Weld size can drive material thickness. For example, if a 9.5-mm (3⁄8-in.) fillet weld at 102 mm (4 in.) long is specified on the bottom chord of a joist with 8-mm (5⁄16-in.) thick chords, the chords would have to be bumped up to 11 mm (7⁄16 in.) thick to receive the weld. To save money, an EOR could specify a smaller weld that is longer: instead of 9.5 mm, a 6.3-mm (1⁄4-in.) weld could be specified. A 6.3-mm weld only has to be 50 percent longer to be the same strength and would use one-third less welding material. Having a conversation with the joist manufacturer about chord thickness and weld size early in the project can save time and money.

Revisions on drawings

The quality of construction drawings goes a long way in determining the overall outcome of a construction project both in terms of quality and project length. This includes the proper designation of revisions using clouding. When revision marks on drawings are not called out with clouding, finding revisions becomes a tedious process. As a result, a trade may miss something. Additionally, Section 3.5, "Revisions to the Design Documents and Specifications," of the AISC *Code of Standard Practice for Steel Buildings and Bridges 15th edition*, states, "… all revisions, including revisions that are communicated through RFI responses to RFIs or the annotation of the approval documents … shall be clearly and individually indicated in the contract documents." Hunting through 100 pages of detailed drawings to find one changed area requires a lot of unnecessary time and effort.

Conclusion

In the authors' view, attempts to save time and money by compressing project timelines will often have the reverse effect. In the case of deck and roof design, leaving critical decisions until later often leads to additional questions and avoidable RFIs from manufacturers and subcontractors. Early collaboration can streamline the process. **CS**

ADDITIONAL **INFORMATION**

Authors

Phillip Knodel is a design engineer with New Millennium Building Systems, a manufacturer of steel joints and metal decking.Lyndsay Cross is an engineer with the company, and Chris Rodes is a design supervisor.

Abstract

Steel joist and deck engineers have for many years been handed structural steel construction drawings that are incomplete, with dimensions lacking and the intentions of the engineer of record (EOR) left unclear. By taking shortcuts in the architectural and engineering phases, important steel joist and deck load requirements and other mission-critical structural information is not passed downstream to the steel fabricator. This practice of passing the buck is fraught with risk. Early-stage design collaboration will not only aid efficient project flow, it will alleviate many of the cost, performance, and safety risks that confront everyone on the project.

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05 31 00 Steel Decking
05 31 13 Steel Floor Decking

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B1010.10 Floor Structural Frame
B1020.10 Roof Structural Frame

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Division 05
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Roof
Steel deck
Steel joists

Building with Steel

Part Three

Cleaning and Maintaining Stainless Steel

BY CATHERINE HOUSKA, CSI

Cleaning and Maintaining Stainless Steel

Photo © Bigstock.com

WITH APPROPRIATE SPECIFICATION, STAINLESS STEEL CAN LAST THE LIFE OF A BUILDING. HOWEVER, AS WITH ANY OTHER MATERIAL, UNSIGHTLY SURFACE DEPOSITS CAN ACCUMULATE AFTER MANY YEARS OF SERVICE. ACCIDENTS, VANDALISM, USE OF INAPPROPRIATE CLEANING PROCEDURES, AND INSTALLATION ISSUES CAN MAKE SURFACES UNSIGHTLY, CAUSE DAMAGE, OR EVEN LEAD TO RAPID SURFACE CORROSION. SURFACE RESTORATION IS OFTEN POSSIBLE WITH THE RIGHT REMEDIATION APPROACH.

Since its invention over a century ago, stainless steel's durable beauty has been repeatedly demonstrated. In the mid-1990s, more than 30 years of dirt, hydrocarbons, and other deposits had blackened the iconic upper floors of New York's Chrysler (left) and Empire State buildings, but simple cleaning with products commonly found in household kitchens returned them to their original appearance (Figure 1).

The inherent corrosion resistance of stainless steel often makes it possible to restore surfaces after years of neglect when other materials may have suffered too much deterioration to make that feasible. This assumes an appropriately corrosion-resistant stainless steel and durable finish have been selected for the project, which have been the subject of this author's previous articles.[1]

General guidance

Environmental factors influencing the frequency of the routine cleaning required to retain a pristine appearance include:

- the owner's aesthetic standards;
- surface finish roughness;
- airborne particulate concentrations;
- pedestrian traffic levels; and
- exposure to regular heavy rain.

In exterior environments, sheltered areas (*e.g.* balconies or the lower floors on high-rises) can face more aggressive environments

Figure 1

In 1995, the exterior of New York's 150 East 42nd Street (former Socony Mobil Building) was cleaned for the first time in 40 years, removing dirt and hydrocarbon accumulations.

Photo courtesy ATI Allegheny Ludlum

Figure 2

This Chinese museum has a fountain along one side, which sprays water on to the surface. The water's high total dissolved solids (TDS) content is causing staining on both the stainless steel panels and the stone. While this staining can be removed, avoiding the problem by installing a reverse-osmosis (RO) system is best.

Photos courtesy Catherine Houska, CSI

because rainwater cannot wash off corrosive surface deposits. A more corrosion-resistant stainless steel, smoother finish, and increased maintenance may be necessary to retain an attractive appearance.

One should always request the cleaning product's Globally Harmonized System of Classification and Labelling of Chemicals (GHS) information or material safety and data sheet (MSDS), and avoid chemicals containing 'chlor' (*i.e.* chlorides), acids, particulate, and anything potentially corrosive or abrasive. When there are concerns, a stainless steel supplier, industry association, or consultant can review the product chemistry before it is used. (A cleaning company, blogger, or random website does not necessarily understand metal corrosion or specialized finishes.)

Proprietary detergent and water solutions, including those used for automotive or dishwashing, and 'environmentally friendly' cleaning products containing hydrogen peroxide, vinegar, or similar chemicals are also used. The detergent should contain both a surfacent and degreaser, not leave a coating on the surface, and preferably be chloride-free and pH-neutral (*i.e.* non-acidic). Many cleaning products and wipes contain chloride compounds, such as bleach (sodium hypochlorite). If such products are used, the chloride or bleach content should be less than three percent, and thorough rinsing to remove the chlorides is critical. Bleach concentrations of five percent or higher cause corrosion of commonly used stainless steels like Type 304/304L at room temperature, so it is critical not to let solutions dry and concentrate.

Wash water

Clean, potable water is used for rinsing surfaces after most cleaning procedures, but it is important to check the water's chemistry. The U.S. Environmental Protection Agency (EPA) suggests no more than 250 ppm for chlorides and 500 ppm for total dissolved solids (TDS) for human consumption, but there are no hard maximums. In some areas, these levels are much higher, which could add to both corrosion and hard water staining problems.

Suitable water may need to be purchased or a reverse-osmosis (RO) system installed. It is important never to use natural untreated, industrial, or swimming pool water. When acidic cleaning products are used, the rinse water should have a maximum TDS content of 200 ppm or be de-ionized, distilled, or RO water—otherwise, hard water staining occurs (Figure 2). While it can be removed, opting for avoidance is far more cost-effective.

Applying cleaning products

Even durable finishes can be damaged with inappropriate cleaning methods—this is a particular concern for fragile mirror and colored finishes. Too often, 'cleaning' is attempted with abrasives only appropriate for refinishing. One should use a new or clean, soft, lint-free cloth or a clean sponge reserved for exclusive use on stainless steel. It is critical to avoid cleaning products used on other materials, such as carbon steel.

Products that can potentially change the finish appearance, or contaminate the surface with iron, include:

- coarse abrasives pads (*e.g.* sandpaper or non-metallic abrasives);


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Figure 3

A maintenance worker 'cleaned' the hinges in this natatorium room with a household carbon steel wool pad. The corrosion is from the resultant embedded iron particles.

Figure 4

This stainless steel surface has been badly damaged by a maintenance worker's attempt to remove a poster with a metal scraper instead of an appropriate solvent.

Figure 5

Dirt and grime are easily removed with simple cleaning of the stainless steel.

- metal scrapers, brushes, or wool pads;
- coarse abrasive powders; and
- abrasive blast media. (See Figure 3 for an example.)

A soft nylon brush or plastic scraper can be used to help loosen adherent surface deposits, but should be tested first to ensure against surface damage. When cleaning directional finishes, one should always rub along the grain (Figure 4).

Light dirt, urine, and fingerprint removal

The choice of cleaning method for removing surface deposits, fingerprints, and other light discoloration depends on the application. Hand cleaning is common, but hot-water power-washing is appropriate for exterior applications where water infiltration is not a concern and a fast, low-cost cleaning option is desired.

Light fingerprints and dirt accumulations are also easily removed with common window cleaning products, such as ammonia and water or vinegar and water solutions. This makes it easy to clean adjoining stainless steel surfaces as windows are cleaned. These products are also suitable for other light cleaning requirements, but they will not remove heavier fingerprinting (Figure 5).

Mild detergent and degreaser solutions will increase cleaning effectiveness. If there are chlorides (coastal or de-icing salts) on the surface, cleaning effectiveness is increased by a proprietary additive specially formulated to improve removal.

Heavy fingerprints, grease, and oil

Heavy grease and oil deposits can be removed with vapor or steam de-greasing, high-pressure water jets, or alkaline or emulsion cleaners. Hot-water power-washing with a mild detergent or oil-free citric acid solution can also be effective. Some household oil-free citric acid cleaners and degreasers effectively remove many heavier fingerprint, oil, and lighter grease deposits.

Proprietary industrial strength degreasers, such as alkaline formulations with surfactant additions, are effective on heavier oil and grease deposits. Any new product should be tested on a small stainless steel surface before use to ensure it does not cause color change. Manufacturer instructions for application and surface rinsing must also be followed.

Clear coatings, oil, and wax

Stainless steel provides the best corrosion resistance when the surface is clean and exposed to oxygen. Clear coatings prevent oxygen exposure and can potentially cause corrosion problems and increase maintenance costs. The most problematic coatings are those that peel or delaminate; they create crevices as they fail, increasing corrosion problems.

Figure 6

After 50 years of oil and wax 'cleaning,' the stainless steel in this lobby was dark from dirt and grime accumulation and had some scratching (left). The panels were taken down, cleaned with dishwashing detergent, refinished with non-metallic abrasive pads, reshaped, and reused in the new design (right). Any unused metal was recycled after the reshaping.

Photo at right courtesy IKM

Coatings increase surface reflectivity and can yellow over time. When applied in the field, service life is typically relatively short; repeated removal and replacement can be more expensive than simple cleaning. Further, some require such hazardous chemicals for removal that contractors frequently remove them by abrasion, which destroys the initial surface.

If a coating must be applied to hide fingerprints or improve corrosion performance, one should select products that naturally dissipate or are easily removed to avoid finish damage—examples include oil, wax, and silicon mixtures. With the exception of lanolin polishes that dry hard and add natural corrosion protection, oils should not be used in exterior applications, swimming pool environments, or any other location with airborne dust or corrosive substances (*e.g.* salt or pollution), as they increase surface accumulations and can cause corrosion. Carnauba wax and similar automotive waxes that dry hard are also acceptable, but do not provide a corrosion-inhibitor.

Oil, wax, and silicon coatings can be helpful in indoor locations where fingerprinting is a concern. It is important to select products carefully since some do not harden and accumulate dirt (Figure 6).

Hydrochloric acid

Hydrochloric acid (*i.e.* muriatic acid) is very corrosive to construction materials; it should never be used for cleaning tile, concrete, or masonry near stainless steel. Concentrations of as little as 0.1 percent can cause room temperature corrosion of Type 304/304L (UNS S30400/S30403).

If there is accidental exposure, the surface should be immediately and thoroughly rinsed with clean water and the acid should be neutralized (Figure 7). Alternative cleaning products are available.

Figure 7

Muriatic (*i.e.* hydrochloric) acid was used to clean the masonry, causing corrosion of the drip edge. Similar damage has been observed by this author on kitchen cabinets after interior tile cleaning and on exterior railings and doors after concrete cleaning.

Adherent deposits

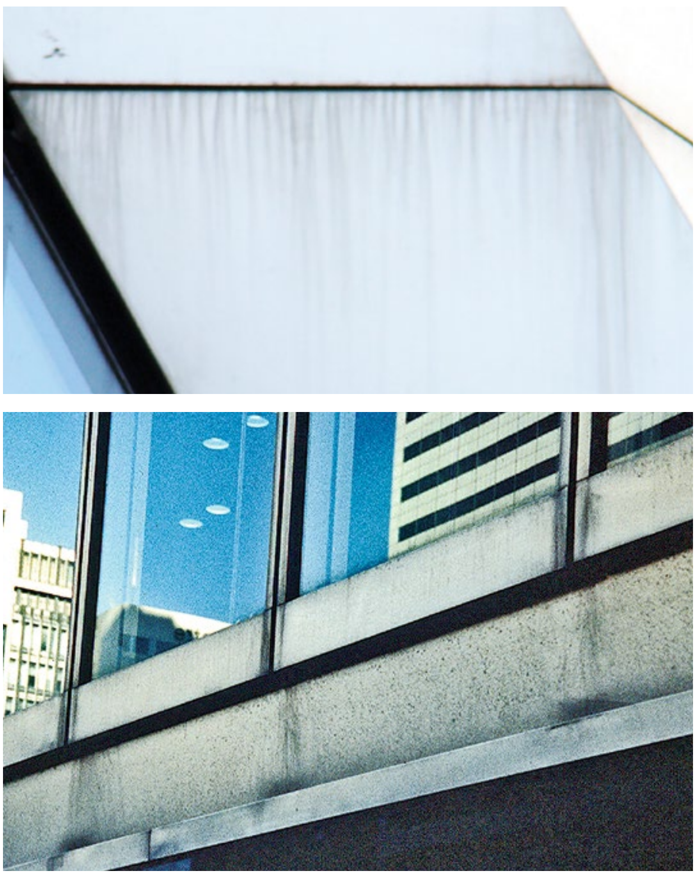
Degreasers can be very helpful in loosening some adherent deposits not involving adhesives. If the finish is not mirror-like, colored, or coated, then very fine abrasive powders suitable for cleaning glass can be effective when made into a paste and gently rubbed on the surface. (They should first be tested on a small area to make certain no surface damage occurs.)

The surface must be rinsed thoroughly to remove the white powder residue. A soft cloth or nylon brush

Figure 8

This pipe supports a beach park canopy. Unfortunately, the supplier did not use an ultraviolet (UV)-rated strippable film, and the pipe was exposed to the sun for several days prior to removal. The areas with residual adhesive accumulated far more coastal salt than surrounding surfaces, causing light surface corrosion. It was removed with fine abrasive paste suitable for cleaning glass and is now performing well. The test area is shown.

Figure 9



As shown above, fairly consistent dark areas or streaks below a joint are indicative of sealant deterioration and the accumulation of atmospheric particulate on the tacky surface. The stainless steel panels below are very dirty. Rainwater flow patterns or channeling is creating dirt and hydrocarbon streaking in selected areas. This can be corrected with standard cleaning procedures.

can be used to loosen the powder. Calcium carbonate, which is used in toothpaste, is preferred because it does not scratch most finishes and is environmentally neutral. Fine crystalline silica, pumice powders, and baking soda (sodium bicarbonate) are also used. Coarse scouring powders should be avoided as they can contain bleach and can scratch surfaces.

Adhesive removal

Removal of residual adhesive deposits from protective strippable films, posters, and other sources can usually be accomplished without damaging the stainless steel surface. If the supplier can be identified, it should be contacted for removal advice. Several different adhesives are used in construction, and the appropriate removal products vary.

When recently applied, some can be removed with an eraser, mild detergent, vinegar (or ammonia), and water mixture. Plastic bristle brushes and scrapers may assist in removal, but anything that could scratch the surface should be avoided. Non-toxic household adhesive removers are also often very effective. If the finish is not mirror-polished or colored, fine abrasive cleaners suitable for glass can be made into a paste and then gently rubbed on with the grain to assist in removal. A strong solvent may be required, but it should be tested on a small area in advance and washed off completely afterward (Figure 8).

Sealant failure

'Rundown' occurs when fluids are released from sealant, producing dark areas or streaks below the joints as dirt, hydrocarbons, and other substances in the air collect on the tacky surface. The causes can range from poor installation to chemical exposure to normal end-of-service-life deterioration.[2]

Discoloration color is determined by the type of particulate adhering to the sealant. This aesthetic problem is different in appearance from the normal rain/dirt runoff patterns occurring at window corners or directly under a joint (Figure 9). The appropriate removal product depends on the sealant type.

Paint and marker pens

Paint and marker pen stains can be removed using proprietary alkaline or solvent paint-strippers after testing the product on a stainless steel sample or in a low-visibility area to ensure it does not cause any surface discoloration. A soft, nylon bristle brush can be helpful in loosening residue. Some proprietary chemical cleaners can damage sealant—care should be used to prevent inadvertent damage.

Figure 10

Outside an Indian airport, concrete spilled off the sides of these bollards when they were filled. Unfortunately, it was not washed off immediately. Power-washing may be effective in removing the deposit.

Cement and mortar

If cement or mortar is accidentally spilled onto stainless steel, it should be washed off immediately with adequate water before it can set. Otherwise, removing solidified material can be difficult without causing surface damage. If the surface is smooth, it may fall off as it dries. Low-power-washing can also be tried, with the water stream angled to loosen the deposit edge.

If the cement or mortar has been allowed to dry on the surface, dark multi-color alkaline staining may be apparent on the stainless steel surface after the deposit is removed. This can be removed by rubbing a paste of fine abrasive powders and water on the surface. However, if the stainless steel surface is colored or coated with metal, permanent surface damage may occur (Figure 10).

Conclusion

Appropriate cleaning of stainless steel can frequently restore the original appearance of stainless steel. There is generally no reason to use products damaging to the environment or hazardous to workers. Cleaning frequency is determined by the owner's expectations, site conditions, and appropriateness of the stainless steel and finish.

Generally, only occasional cleaning is required to remove surface deposits. However, care should be taken in applying coatings since some can adversely affect corrosion performance. With appropriate procedures and products, stainless steel can stand the test of time.[3] **CS**

Notes

[1] Previous articles by this author for *The Construction Specifier* include "Proving its Long-term Mettle" (August 2016), "Avoiding De-icing Salt Corrosion" (January 2015), "Designing on the Waterfront" (November 2007), "Stainless Steel for Severe Coastal Environments" (September 2011), "Architectural Metal Corrosion: The De-icing Salt Threat" (December 2006), "Preventing Corrosion in Soil" (April 2006), and (co-authored with James Fritz), "Swimmingly Stainless Pool Design" (December 2005). Visit www.constructionspecifier.com. See also this author's articles for the International Molybdenum Association (IMOA) e-newsletter, *Stainless Solutions*, along with *Architectural Metal* magazine.

[2] See the Failures article from the April 1997 issue of *The Construction Specifier*, "Premature Sealant Failure," written by David H. Nicastro and Joseph P. Solinski.

[3] The author would like to acknowledge the support of the Nickel Institute and IMOA in the preparation of this article.

ADDITIONAL **INFORMATION**

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Abstract

The inherent corrosion resistance of stainless steel often makes it possible to restore surfaces after years of neglect when other materials may have suffered too much deterioration to make that feasible. However, it is important one knows which tools to use to clean the surface and which to avoid in order to ensure long-term beauty.

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