Classic Revival

By Beth S. Pollak with Kenneth E. Dahl, P.E.

Photo © Fred Housel/Housel Photography

Seattle's Marion Oliver McCaw Hall, originally built in 1927, was given a major structural and architectural overhaul that included designing to achieve a silver LEED™ rating.

The Marion Oliver McCaw Hall in Seattle, home of both the Seattle Opera and the Pacific Northwest Ballet, originally was built in 1927 as a civic arena. In 1960, the building was extensively remodeled as a concert hall for the 1962 Seattle World Fair, and other smaller additions and renovations changed the space and design over the years. However, by the mid-1990s, space limitations, seismic requirements, outdated interiors, and an undersized lobby pushed owners to consider a new renovation.

"The City of Seattle wanted seismic upgrades for most of its public assembly buildings," said Kenneth E. Dahl, P.E., project manager for structural engineer Magnusson Klemencic Associates. "But the arts groups that used the venue wanted to update the appearance of the building, and update the production facilities to meet the current industry standards. As a result, the public and private parties shared the cost of the entirely renovated building."

The $127-million expansion and renovation created the required seismic upgrades, stage amenities for current scenery and production technology, a new lobby space, additional seating and lounge space, practice rooms for performers, staff offices, and a 400-seat lec-

Steel is Sustainable Construction

Five new balconies framed with structural steel cantilevers were added on each side of the auditorium. Photo courtesy Michael Dickter and Magnusson Klemencic Associates.

ture hall, and provided additional public-access corridors to the Seattle Center (a sports, theatrical arts, and civic gathering venue).

As part of the City of Seattle's plan for all new city-owned buildings of more than 5,000 sq. ft to achieve a silver LEED™ rating, the opera house was designed with "green" features to make it an efficient and environmentally friendly building. The renovation used structural steel framing, which has near 100% recycled content. The use of locally fabricated, recycled structural steel can earn points toward a LEED rating in the recycled and locally manufactured materials categories.

Behind the Scenes

Structural steel framing was used for much of the renovation. The lateral system was a hybrid of concrete shearwalls and structural-steel braced frames. "In the existing building, there was a lot of brick façade that needed to be seismically braced," Dahl said. "So we placed the shearwalls to entomb those walls. That took care of seismic loads in one direction, and in the other direction, we used braced frames in locations that were not going to be people areas, like elevator shafts, stair shafts, and within walls."

The new lateral-resisting elements in the project were designed to meet the 1997 UBC, Zone 3 requirements. Existing building elements used as part of the seismic-load distribution were evaluated and reinforced to conform to FEMA 310 and FEMA 356, *Prestandard and Commentary for the Seismic Evaluation of Buildings*.

Flying High

The stage's existing fly loft was not tall enough to be used with many of the modern scenery sets commonly used around the country. To bring the facility to current standards, the existing fly loft was removed, and a new one was constructed 25′ higher. The flyloft was raised by adding structural-steel column and braced-frame extensions to the existing lower structure. Atop the new flyloft, a full-width rigging gridiron was introduced to provide flexibility for line sets and individual point loading. The gridiron consists of heavy-capacity steel grating supported by W8 sections at 5′ centers. The W8 members are supported by dual C12 members at 12′ o.c. The C12 members are gapped, allowing individual line sets to access the stage below. The C12 members are supported by hangers at 20′ centers, hung from 8′-deep trusses that span the 75′ depth of the stage.

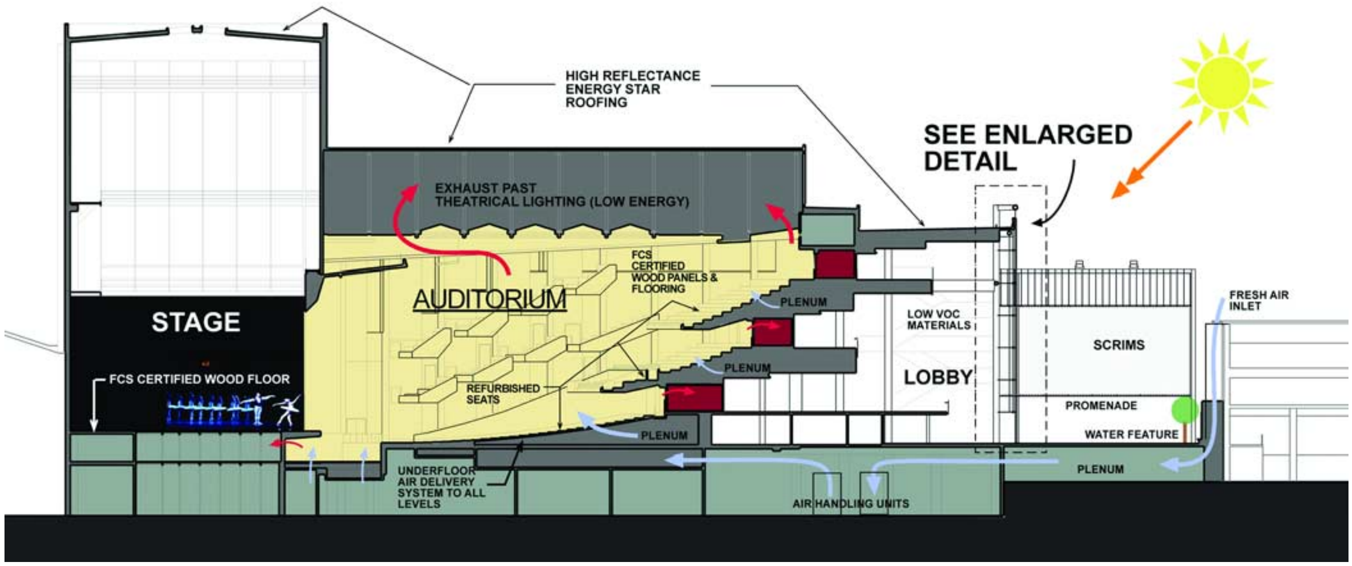
The stage also was replaced entirely. The old facility/stage had a capacity of 125 psf, but most stages today have a live load of 250 psf. The new stage was upgraded to meet this capacity. In addition, the original 1927 stage had only a small "trap" area that had been removed in later renovations. The new stage includes a large trap room. Half of the new stage is removable trap area. The trap system consists of twenty-one 5′-by-7′ wood-framed panels supported by a grillage of HSS beams and posts. The panels and their supporting beams and posts can be removed individually or in groups depending on the trap needs of the production. A second trap level, also removable, is located 10′ below stage level, giving even more flexibility for productions.

A 45′-high adjacent stage area was created for scenery assembly, future set preparation, and extra handling during large productions. To provide column-free access throughout the scenery-handling area, W30 roof girders spanning more than 60′ were used to support W16 cross beams above. The W16 beams were equipped with plate connections to the bottom flanges, which were used as fixed-rigging points for the scenery supports. The fixed-pick locations provided hanging locations approximately 15′ apart in each direction.

Dramatic Entrance

The building entrance is marked by a 60′-high-by-200′-long serpentine glass curtain wall on the west façade. "This was part of the design concept, to break the barrier between the inside of the opera house and the outside, so it would be welcoming and approachable," said Peter Locke, AIA, project architect for LMN Architects.

The five-story curtain-wall system is backed by exposed, horizontal, curved C channels. The channels are supported by hanging rods supported from the roof beams above. Round steel HSS columns filled with concrete support the lobby roof. The columns also act as the primary lateral support for the curved channel-backup system. 3″-diameter pipe struts link the channels and pipe columns, pro-



"Green" features throughout the building helped are designed for a silver LEED™ rating. Drawing © LMN Architects.

viding a visual decoupling between the columns and wall. Outside the building, nine 60′-by-60′ exposed steel HSS frames support stainless-steel 20′ by 60′ "scrims" or screen-like posters. Various colored lights are choreographed on to the scrims via a sophisticated computer program as part of an art installation project by lighting artist Leni Swendinger.

The building's public-access areas were renovated and expanded significantly. A new three-story atrium was added to replace a confined and dark one-story lobby. "There wasn't much public-access area on either side of the auditorium," Dahl said. "To add needed public areas, new construction was planned on either side of the original auditorium for bathroom space and reception rooms for the donor groups."

A 1970 addition had created a rehearsal hall and practice room for the opera's orchestra, which, along with a loading dock, was poorly located near the main entrance. Designers worked with the contractor to find a way to recapture the space without demolishing the existing structure.

"The building originally was built on auger-cast piles, so we came up with plan where they could undermine the existing building by using these piles as shoring stilts," Dahl said. "The soil beneath the building was excavated down 30′ and then a new foundation system was installed. Two levels of infill structural-steel framing were added between the foundation and existing building. The steel system was then used to support the existing columns above it. The contractor then cut off the existing piles. So we ended up putting in a new structural steel base to a building that had been built 25 years earlier."

The original rehearsal hall was retained on the top floor, and the loading dock was moved to the other side of the building. The excavated space is now a two-story building with offices, dressing rooms and lounges for staff and performers. "It doesn't look like a separate building, it looks like part of the whole complex," Locke said. "We've also added a lecture hall to the space, that goes down to the basement level, at 17′ below grade, and rises to the ground floor."

Auditorium Additions

The original auditorium space had a flat floor and a small stage. The 1960 renovation expanded the stage and added balcony levels, but it was designed as a concert hall, with emphasis on acoustics rather than sight lines. As the opera and ballet became the auditorium's main tenants, poor sight lines became an obstacle for audience members and for staging shows.

To remedy this, as part of the current renovation, walls were narrowed about 15′ on each side. To maintain good acoustics, the upper part of the sidewalls were left open, so the volume of the original room was maintained. Grillwork separates the auditorium from the back area. Five new balconies were added on each side, with structural steel cantilevers to hold them in place. Structural steel also was used to extend existing concrete balconies closer to the stage, adding three rows of premium seating.

Green Scene

The project team designed the building to achieve a silver LEED rating. "For a silver rating, you really need to spread sustainable design across all aspects of building," Locke said. "It was difficult on this project, because it's not a commercial office building, for which the LEED system was originally designed."

Designers retained 25% of the original building. A salvage program prior to construction allowed reuse companies to salvage materials of value from the existing building, like marble, carpet, wood paneling, mirrors and fixtures. The theater rigging and systems now are used in various other theaters. All 2,900 existing auditorium seats were salvaged and sent to other theaters in the city. A construction-waste management plan diverted 90% of construction-waste material from landfills, including demolition waste.

The building uses innovative heating and cooling systems to save energy. An underfloor air-supply system cools the auditorium. Conditioned air surfaces just below the seats, and rises up only about 8′ high. This saves energy because it cools only occupied areas, instead of trying to cool the entire auditorium space. Consequently, warmer air rises to the ceiling, where the auditorium's main exhaust system removes it.

An underfloor conditioning system also is used in the orchestra pit. "Orchestra pits are usually the most uncomfortable place to be in an auditorium, because you're between a stage system and an audience system," Locke said. "But we used an underfloor system there too. The floor of the pit is perforated like an air hockey table, with flexible ducts underneath."

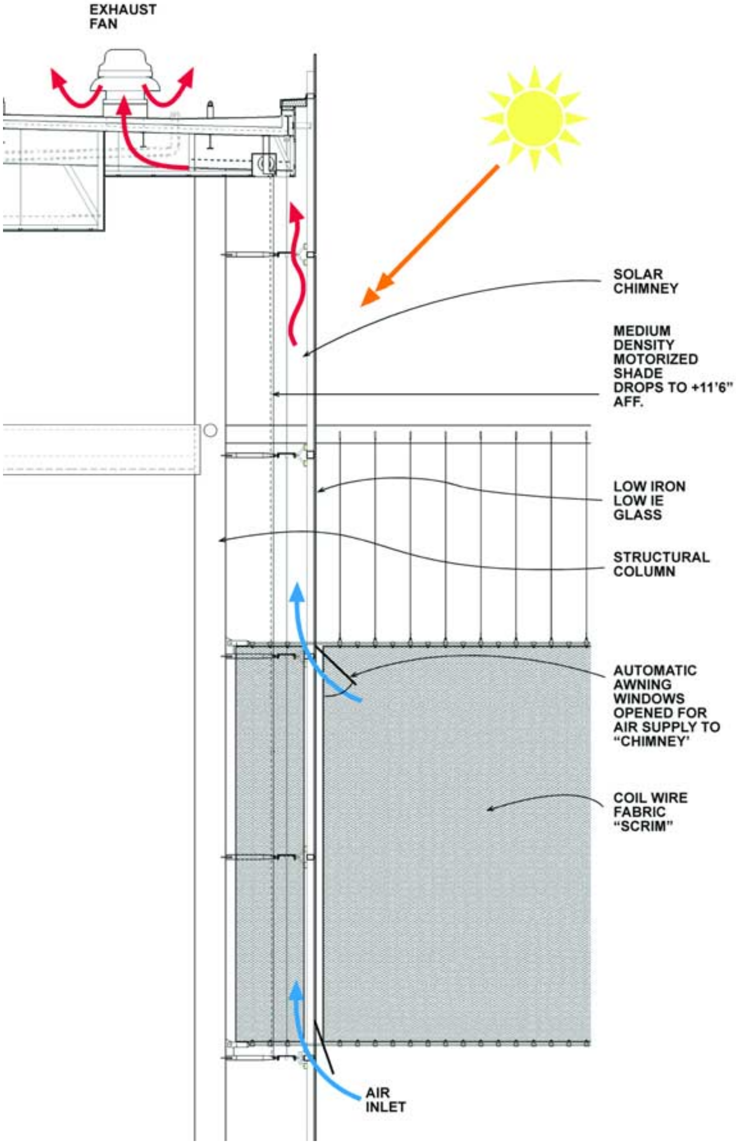
Usually, lobbies also can be difficult to heat and cool, especially if they have large expanses of glass, which permit the penetration of hot sunlight and cold drafts. "We had to maintain a west entrance because of the orientation of the existing stage," Locke said. "But we came up with some innovative solutions to prevent the lobby from becoming an energy drain."

To facilitate cooling, a "thermal chimney" was created as part of the west wall. "We created a 2' air gap between the blinds and the window glazing," he said. "When the sun hits the right place, it instructs the blinds to go down, and tells the windows to open up, creating a chimney that removes the worst heat that you get from the sun. This allowed us to reduce the air-handling units by about half of what they would be otherwise. It saved money in both first cost and lifetime cost in energy use."

Because of the Seattle climate, this is only necessary a few weeks of the year, to prevent solar heat gain. In the winter, the blinds are instructed not to go down, so the building can absorb the solar heat.

For heating, an underfloor radiant system is located under the Main Lobby. "This way, patrons are standing on a radiant floor panel, and feel warm," Locke said. "You don't waste energy by trying to heat the entire 60'-high lobby space."

The office suites also were designed with high indoor-air quality, with features like daylighting, operable windows, and thermal comfort controls. Waterless urinals in all restrooms reduce unnecessary water consumption.



The west curtainwall's "thermal chimney" reduces the cooling loads on the auditorium lobby. A 2' air gap between the blinds and the window glazing helps prevent excessive solar heat gain by opening and closing the "chimney" in response to the sun's rays. Drawing © LMN Architects.

Coordination on Cue

For six months prior to construction, foundation, demolition, and site-utility work was performed, even while the ballet and opera continued to perform. This "early works" package was conceived in order to jump-start construction and to help meet the final project completion date. Once the main construction and demolition work began, an 18-month schedule kept the design and construction team on its toes.

Due to the existing building's multiple past renovations, most of which were not well documented, extensive field dimensioning and as-built dimensional verifications were required in the field to support the concrete and steel detailing efforts, said Martin O'Leary, senior project manager for Skanska USA Building.

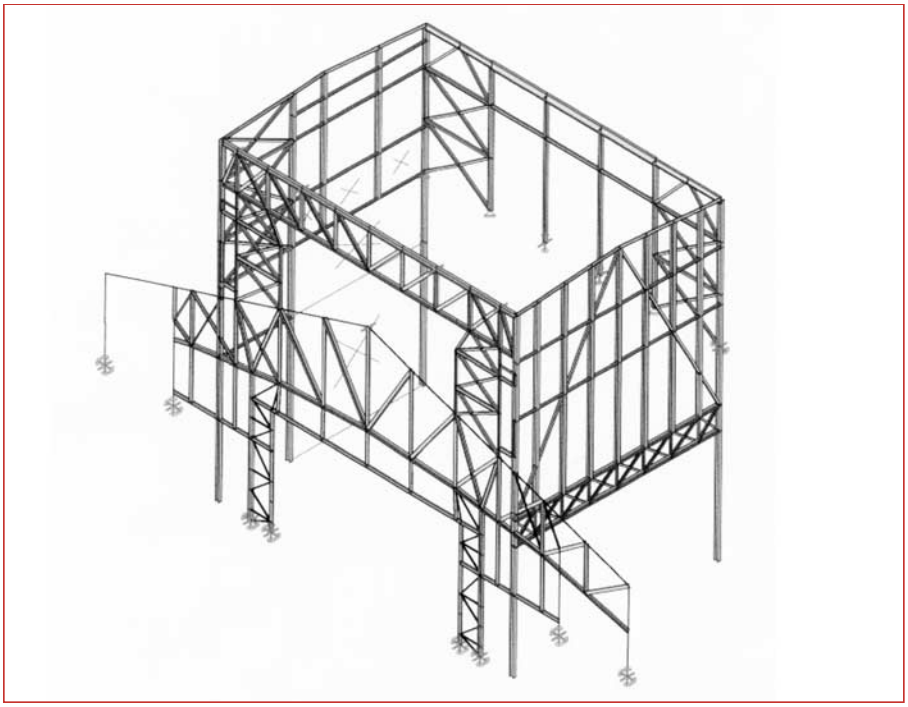
"There had been many elements installed in the existing building, sometime between 1927 and the present, that were not documented," Dahl said. "We'd be installing new elements, and we'd find something hidden, so we'd have to go back and figure out where some of the random pieces originated."

Wherever new concrete or steel elements tied into or connected to the existing structure, field crews surveyed the existing conditions to confirm existing dimensions. "This was to ensure that new steel elements would be detailed and fabricated so that they would ultimately fit into and around the existing structure," O'Leary said. "The most complicated areas were around the perimeter of the auditorium and within the auditorium."

Locke says that's the nature of a renovation project. "We were fitting the steel up to existing members that weren't where they were supposed to be. You think you've measured everything, but there are tens and hundreds of places that are different. It's not a repetitive structure, and it's a complicated structure. It was a process of discovery."

Another challenge was the shoring and bracing of existing structural elements that would remain as parts of the renovated building. Skanksa, MKA and the demolition subcontractor worked extensively for about six months to develop a comprehensive "engineered temporary shoring and bracing plan" to ensure that, as existing elements were demolished or removed, the integrity and stability of the structure was retained until the new structure was put in place. "The eventual plan incorporated concepts such as installing permanent or temporary shoring and bracing elements before demolition and then installing the new structure; or installing the new structure and tying it into the existing structure before demolition," O'Leary said. " The plan was very dynamic and changed regularly as unforeseen as-built conditions were exposed via the demolition process and as the construction sequencing changed to mitigate schedule impacts and reduce costs."

Site logistical issues also created challenges. Construction work was performed in an active public environment at the Seattle Center, and workers had to navigate around ongoing Seattle Center operations. Also, since the auditorium ceiling was not replaced, demolition of the structure and erection of steel proceeded without a tower crane for interior auditorium work. The existing concrete elevated deck was required to be shored to support equipment loads for items such as bobcats, demolition equipment, demolition debris, personnel lifts and booms trucks. Minimal site lay-down areas were available, so the project enforced "just-in-time" material and equipment deliveries.



Above and below: New steel framing creates a larger fly loft to accommodate today's theatrical requirements. The peaked steel truss is part of the original 1927 roof structure. Drawing and photograph courtesy Michael Dickter and Magnusson Klemencic Associates.

Nonetheless, the use of structural steel helped speed the construction process. "Steel is much quicker in terms of erection time, and we had a tight schedule," Locke said. "If we had done it in concrete, it would have exacerbated the schedule. The seismic detailing would have been more complex, and tying into the existing structures wouldn't have been as easy."

As a result, the Hall opened on schedule in June 2003, and performances began a month later. The entire project was completed for about two-thirds the cost of a new building with identical space. The "green" choice to renovate was not only good for the environment, but also an economical, attractive, and practical one.

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For more on structural steel and sustainable design, visit **www.aisc.org/sustainability** or view the article "Structural Steel Contributions Toward Obtaining a LEED™ rating" in the May 2003 issue of *Modern Steel Construction*, available online at **www.modernsteel.com**.