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Capitol Improvements

$212 million Restoration of Utah State Capitol Highlighted by Base Isolation System

Originally constructed in 1915, the 320,000 square foot, 90-year-old Capitol is undergoing a complete restoration, highlighted by a complex base-isolation system.

Architectural, engineering and construction team members working on the $212 million Utah State Capitol Restoration project all agree that it's a once-in-a-lifetime project.

"I think the (A/E/C) industry really believes that this is an important project," said David Hart, executive director of the Capitol Preservation Board and architect of the Capitol. "I am very grateful to the contractors. These guys are working harder than I've ever seen subcontractors and general contractors work. They're working weekends… they're working holidays. They know what the end game is; they know what the goal in mind is. They're doing everything they can to get the Legislature back in (for the 2008 session).

"I believe that they feel that it's an honor for them to be here," Hart added. It's a legacy for them."

"A project like this is one-of-a-kind," said Lonnie Bullard, president and CEO of Jacobsen Construction, Salt Lake City, who is partnering with Hunt Construction of Phoenix on the joint-venture. "We're very fortunate to be associated with a project that is a historic building that has been here for decades and will be here for another hundred years. It's something that our company and all the individual workers that work on this project are really proud to be a part of. They will be able to show their kids and grandkids what they did on this project."

"It's the kind of project you can build your career around," said Jerod Johnson, project engineer for Reaveley Engineers & Associates, Salt Lake City, who along with structural engineering consultant Forell & Elssesser of San Francisco, designed the base-isolation system. "There are not many structures like this."

Base Isolation

Originally constructed in 1915, the 320,000 square foot, 90-year-old structure is undergoing a complete restoration, highlighted by the complex base-isolation system that features 265 base isolators and 15 sliders that are being installed under 280 of the 380 concrete columns that support the building. This state-of-the-art design strategy essentially de-couples a building from the ground, which in turn limits the potentially catastrophic effects of horizontal earthquake ground motions. It marks the second historical restoration project in Utah to utilize a base isolation system. The first was the City County Building in Salt Lake City in 1987 - also done by Jacobsen - which was the very first historic building in the world to undergo a base isolation process.

Before crews could begin installing the base isolators, soil at the site was reinforced with an extensive micropile suspension system, designed by Jerry Bishop of Geotechnical Design, Salt Lake City. Bishop utilized a Titan Hollow Bar system, which originated in Europe more than 20 years ago, and was initially introduced to the intermountain region in the mid-90's. Bishop said he first used this system during the site reinforcement of the Brigham Apartments in downtown Salt Lake, and since 1995 he has designed tens of thousands of square feet of similar systems on a wide array of projects.

The total weight of the Capitol at the beginning of construction was 130 million pounds. That weight will increase substantially - by an additional 30 million pounds of concrete steel and additional stone.

At the Capitol site, approximately 3,000 individual micropiles were drilled up to 30 feet into the ground. The micropiles are hollow and include a sacrificial drill bit. A water cement mixture (45 percent water to cement ratio) is piped into the bars and discharged out of the bottom of the hole once it's drilled down. The water-cement mixture combines with sand and gravel to form a 3,000 to 4,000 psi concrete shell around each micropile.

"We kind of pioneered the use of this system (in Utah) by default," said Bishop. "Doing it on this type of scale has never been done as far as I know, at least not in Utah. Once they transfer the load outward, it could not have movement more than three-eighths of an inch. Only one (micropile) had any movement at all, and they're about 90 percent done with the load transfer."

"Soil reinforcement on this project - to be able to hold the loads of the transfer -has been a key aspect," said Hart. "Jerry had to make sure that whatever he was putting into the ground was going to be able to support that. To date we've had one or two issues where one of the drilled piers shifted a bit, but it didn't cause any damage."

In June of 2005, crews from Jacobsen-Hunt began installing the first base isolators, cylindrical devices consisting of laminated layers of rubber and steel plates that surround an energy-absorbing lead core. Manufactured by DBI, Reno, Nev., the 265 isolators range in size from 34 inches to 44 inches in diameter with a height of about 20 inches.

The 15 sliders - used in locations where the columns are not carrying the extreme loads supported by base isolators - are quite a bit bigger since the entire building can displace about two feet in any director. A slider is a Teflon pad bearing mechanism that rests on a stainless steel plate, approximately 18 inches in diameter. The building has to be able to slide 24 inches in any direction on the steel plate, which is about five feet in diameter.

The isolators and sliders are designed to dramatically reduce the seismic impact of a major earthquake. For example, an earthquake that measures 8.0 on the Richter scale would have an impact on the Capitol equal to a much-less harmful 5.5 earthquake.

When the lateral force of an earthquake pushes against the isolator, it stretches in an oblique shape in any horizontal direction. So rather than shaking apart, the Capitol would move back and forth on the isolator bearings - up to two feet in any direction - reducing the impact of the seismic forces on the structure.

"Base isolation is driving the entire ship," Hart said. "The reason for base isolation is to allow the building to experience an earthquake at a much lower force. The period of time it takes to go through one complete (earthquake) cycle is greatly reduced. When base isolation is completed the building will be subjected to only 1 G of force as opposed to 7 G's of force. It reduces all the elements within the building from having to be designed to meet that half-second (seismic) impact."

Johnson said the structural design team studied other base isolation projects - the most similar to the Capitol being San Francisco City Hall, which was designed 15 years ago by Forell & Elssesser - and fed various bits of criteria into a computer model to predict how the Capitol might react during an earthquake with the base isolation system in place.

"Every building is unique," said Johnson. "But one thing that helped us out is the nature of structural dynamics. Whether it's a new building or an old building, an earthquake tends to want to shake things and follow the general Newtonian laws of physics. So we were able to create a very elaborate computer models that predicts how the building wants to move naturally. With that computer model we can add the base isolation system and gauge how well the system is performing. We can actually tune the system to get optimal performance.

"For every retrofit project that approach is different," Johnson added. "There are no two historic buildings that are identical, but there are some that are similar. The building that is most similar to this one that had (base isolation) done is the San Francisco City Hall. (Forell & Ellsesser's) input has been invaluable - they've really helped with the design of the isolators themselves."

The process of installing the isolators has challenged Jacobsen-Hunt's crews immensely. A concrete load transfer solution was decided upon as the logical approach since the Capitol is a concrete building. Jacobsen-Hunt crews cast a new five-foot wide concrete load transfer beam around existing columns and used temporary loading jacks for support. Upon opening that jack, the loads from the column will come down through the load transfer beams and into the jack, temporarily taking the load off of that column.

The column is then cut off below the load transfer beams. The base isolators are then brought in under the load transfer beam and lifted into place, which means they are effectively hanging from that load transfer beam.

An area below the isolator is excavated so that a new footing and pedestal can fill the gap between the footing and the isolator. The load path from that column is transferred into the isolator and new footing. Any remaining space is then filled, using a flat pancake jack that is inflated using water to transfer the load of the column onto the new mat footing. Eventually, the water in the flat jack is transfused with epoxy under full load for permanent structural support.

"It's quite a complex process," Johnson said. "One of the biggest challenges is to incorporate the necessary retrofit items, including the new concrete walls and the base isolators, without interrupting the character or the original historic layout of the building. We were told right from the very beginning that our primary objective with this project is that when somebody walks in the building when all of this is done and says, 'Boy, they didn't do anything at all.'

"Fortunately we've had great team members that have come up with some very creative ways to incorporate the new retrofit elements in very inconspicuous ways," Johnson said.

Kevin Brown, project manager for Jacobsen, said crews are approximately halfway done isolating the four large rotunda columns and 80 percent done with the isolation of the remainder of the smaller columns.

The reason for utilizing the base isolation system was simple - public safety. History patterns show major seismic events occur in the area around the Capitol about every 1,300 years. Most geological experts agree that it's merely a matter of time before the next 'big one' strikes the Wasatch Front.

"Initially when we were looking at the building, the number one concern was life safety," said Hart. "And as we looked at life safety issues, we realized that to save the building it would basically need to be gutted. All interior and exterior walls had to come down."

Historical Integrity vs. Modern Conveniences

Base isolation is just one of many challenging design and construction aspects on the Capitol restoration. Hart said that when the Capitol Restoration Group (CRG) architectural team - which consists of Salt Lake firms VCBO and MSJA, along with Schooley Caldwell Associates, Columbus, Ohio - initially set up the criteria for the building, three main items were recognized. They included life safety, high functionality and preserving the original historical aesthetics.

The challenge is that when modern technological advances - highly efficient and functional mechanical and electrical systems for example - meets with historical architectural integrity, it oft >> times is like combining oil and water.

"If we restore this building and it's not functional, what did we really accomplish?" Hart mused. "We realized early on that this was a great opportunity - probably the only opportunity we'll ever have - to put the Capitol back the way it was originally. That's when the restoration of the building really came to fruition. If you're tearing everything out to make it an operable, functional building, we thought 'why not put it back the way it was'?"

To make sure that design and construction members were all on the same page right from the get go, and to ensure that the wishes of CRG were not misconstrued in any way, a Project Definition Book was created, which then translated into a series of 17 weeklong design workshops for all design team members. Hart said the creation of the Project Definition Book by 3DI, Salt Lake City, has been critical to the success of the project thus far.

"As an architect, one of the things I have always struggled with is how information is handed off and dealt with," said Hart, a Salt Lake native and former principal with HFS Architects. "Unless the owner can give you good information, you can spend a lot of time going in circles, wasting your time and energy and not coming up with anything the owner really likes.

"We thought in the initial stages that it would be good to hold a variety of workshops," he continued. "The Project Definition Book, in effect, talks about everything we care about. It broke the project into two areas - things we cared the very most about, and things we cared about secondly. We documented everything graphically and verbally, which produced a very comprehensive book. It talked about historic preservation, the aesthetics, zones of restoration…everything you could imagine."

Hart said 60 or so ideas were then combined into the 17 different weeklong workshops, including everything from mechanical and electrical systems, exterior and interior finishes, etc. Architects, engineers, the general contractor and all subcontractors attended these meetings. If a specialty subcontractor was needed, they would be brought on and retained as a design-assist contractor. Hart said the process, which started 18 months before construction began in September 2004, has proved to be invaluable.

"The benefit of all of that work was that over the course of three years, without any reduction in quality, we absorbed all the increases in energy costs and construction materials," said Hart. "We have only $500,000 to $600,000 in change orders so far - less than one-half of one percent. That shows you that it is possible, in my opinion, to identify a budget and stay within it."

"(The Capitol) mandates a different approach when you have the kind of intense pre-construction process that we had," Bullard said. "On a project like this the engineering elements are so critical, especially in terms of the seismic base isolation. It's critical as a general contractor that we get the best team we can and put them on the project and make sure they have the proper support in the fields."

Early construction required the entire building to be gutted. Drop down ceilings were stripped down to the original plaster, while old plaster walls were demolished and replaced with new exterior and interior shear walls, which also help the building withstand the lateral forces of a seismic event, as the building will function more as a single mass.

One major design challenge for the mechanical and electrical engineers was designing utility systems around strict mandates from the architects. Since all drop-in ceilings were torn out and the original plaster is only a few inches thick, running HVAC ducts and electrical conduit horizontally simply wasn't an option.

Hart said in the last 40-plus years buildings have been generally designed with electrical and mechanical systems running through interstitial space - the area between the ceiling and the structure. For the Capitol project, engineers were forced to come up with alternative routes and pathways.

"Running all services and utilities through an interstitial space is not in keeping with the aesthetics of the building," said Hart. "To go back to a more historic framework we had to look at alternate, unique ways to make this happen."

The eventual solution was to run the majority of large HVAC ducts and electrical conduits vertically, in between new concrete wall spaces. Spectrum Engineers, Salt Lake City, is designing all the electrical and technological systems, and is teamed with Heath Engineering, Salt Lake City, on the mechanical system design. Dave Wesemann, project manager for electrical engineering, said the architects held firm to their requirement of having no dropped ceilings, which challenged Wesemann and his staff to come up with other pathways.

"We asked the architect for more space and they said absolutely not," said Wesemann. They said 'Go back and figure out another way.' If they could have given us two more inches then we could treat it like more of a standard building. So we came up with a system of running our ducts and conduits in a vertical distribution system rather than horizontally - running ducts through stacked thickened walls from the attic down and the basement up and distributing out the walls.

"You have to think outside the box," said Wesemann on this type of project. "You think of things that haven't been done before. You don't limit your thinking to what's already been done or proven. You just think 'How do we get from point A to point B.' You look at every possible scenario and figure out ways to make it happen. When there's a mandate that says you can't do it the traditional way, you have to come up with alternatives. "

Spectrum's Neil Spencer, project manager for mechanical engineering, said he began to understand how vertical pathways could work during a break at one of the design workshops.

"We were in the throes of schematic design, and Max Smith pointed out to me that in this building, we have a lot of individual offices that have more square footage than they typically need," Spencer said. "It was easier for us to eat up some (floor space) in vertical chases than it was to drop a ceiling and have horizontal chases. Once I understood that concept, then it became a lot easier to deal with. Traditionally, you don't want to give up square footage - it's considered sacred space. But on the Capitol it was easier to lose footprint rather than ceiling space."

"It's almost like taking a regular building and turning it on its side for distributing air, power and communications," added Wesemann. "In our documents and specifications, we get the contractor to share the same vision, the same imperatives that are required, and we do that by requiring them to come up to the same level as we had to for design. We require them to provide extra shop drawings and coordination.

We're requiring them to lay it out before they run it, to make sure it will work before it goes in. They understand the importance of nothing being visible."

"They've been innovative," Hart said of the engineers. "Aesthetics had to drive some of the design. It's not an easy task to be told to reduce the size of systems, stuff it in walls, run things around beams. They've done a good job."

One interesting example of how aesthetics drove design was with the smoke detection system. Hart said Rob Pett of MJSA, one of two architects of record on the project, worked closely with Wesemann on figuring out how to incorporate a complex smoke detection system without having a myriad of round smoke detection discs protruding from the ceiling. They consulted with New York lighting manufacturer Rambush Inc. and came up with an ingenious solution by running air sampling tubes through light fixtures.

"We came up with a custom detail where the historic light fixtures could serve as smoke detectors - it's called an air sampling system," said Wesemann. "We designed it so there is an air sample tube coming down through one of the screw holes of the light fixture. The air sample tube vacuums up air, and takes it back to a (computerized detection system) that is located in a closet."

"It's an absolutely wonderful solution," Hart said. "It really is brilliant."

"I'm not aware of any other project where they used a light fixture as a smoke detector," Wesemann added. "That's something we came up with. It stretches your imagination."

"Smart" Offices and Classrooms in Demand

VCBO Principal Peter Brunjes, AIA, said another growing specialty of the firm are buildings for higher education and offices. Brunjes was the lead designer of the new Spencer F. and Cleone P. Eccles Health Sciences Education Building that recently opened on the campus of the University of Utah.

"The demand for office space is starting to come back," said Brunjes. "We have five or six major office developments going on. The real push is for "smart" buildings. The owners want integrated systems so they can get on a computer anywhere and monitor heating, cooling and even the outside irrigation systems."

Brunjes said raised access floors are becoming more and more popular.

"There were some problems with them years ago. They felt like plywood and the panels would come lose but those problems seem to have been overcome now and more people are requesting them.

Brunjes said the owners of class A office space are requesting systems that will make better use of natural ventilation and cooling.

"They are also requesting a LEED (Leadership in Energy Efficient Design) checklist to see what it would take to do LEED certification. Some of the LEED criteria are important to them but generally it is still pushes the cost up past what can be competitive for an office."

Brunjes, said providing LEED documentation is a new service VCBO has added.

"We can do that here in the office. We've had to add that to our work load. It changes how you approach architecture."

The Road Ahead

Valentiner said he expects the firm to continue its growth in the region and there are now plans to open any offices outside of Salt Lake City.

Principal Steve Crane, FAIA, said years ago, the firm decided to invest in an airplane rather than open satellite offices.

"We have transportation when we need it and we can go to more rural places around the region, places that don't usually get high quality architectural services and we can provide that," he said. "As far as other growth goes, I expect we'll expand our educational design work nationally as well as regionally."

Valentiner said the firm finds that in Salt Lake City there are the resources they need to remain competitive.

"We are able to find the well-trained architects we need right here and we look around and find some other areas outside of the state are short on those resources," he said. He said keeping the staff at a central location, they are able to draw on each other's expertise.

"Each partner has a niche and we are able to provide an owner with a large firm attitude and we can handle whatever they want."

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