High Performance Economics

By Paul W. McMullin, Ph.D., S.E.
and Ronald H. Dunn, S.E.

South elevation showing steel framing and interior shear walls.

It is not every day that your client knows enough about structural engineering to require a certain type of connection and insist on a higher level of seismic protection. But that is exactly what Workers Compensation Fund (WCF) did when they built their new corporate headquarters in Sandy, Utah, in the south portion of the Salt Lake Valley. After a seismic study indicated their offices did not meet current seismic codes, and unsatisfied with the time and interruption of a retrofit, WCF embarked on a journey to build a new home that would meet their needs for years to come and ensure continued operation under demanding environmental conditions.

WCF is a sophisticated client who understands the economic loss of not being operational. A driving desire for them was to serve their clients after a major seismic event, and not spend time scrambling to take care of themselves. To do this required significant contribution from all parties involved. The owner, contractor, and design team collaborated closely throughout the design and construction process to satisfy WCF's challenging goals. The end result was a high-performance building that met WCF's aesthetic and functional needs.

Project Goals & Criteria

Knowing this would be a one time opportunity, WCF approached the project with a thirst for understanding their options. They had developed several other buildings and parking structures as investments, but this time it was for keeps. From finishes to foundations, they pushed the design team and contractor for information in order to weigh their many options and desires. Their hunger for knowledge, and back and forth design interactions, defined the project.

In addition to goals common to office type projects, WCF wanted a building that would structurally perform far beyond a traditional IBC design. Two key goals grew from this desire: Immediate Occupancy seismic performance and Progressive Collapse resistance. The first goal was a requirement of the design. The second was not explicit, just a desire to have as much protection as possible through prudent design decisions. These two goals influenced a myriad of structural and other design decisions.

Finished, southeast elevation.

With an understanding of seismic performance options from their previous building study, WCF knew that the traditional building code only provided life safety and that higher levels were available. The question was how much more performance could they afford in light of escalating construction costs. To assist the owner in their decision making process, the structural engineer and contractor developed a number of structural options with associated costs, and compared these to a typical office building design. From this iterative process, the owner selected Immediate Occupancy for a 5%/50 seismic event and Life Safety for a 2%/50 year event. The return period for the Immediate Occupancy design interestingly corresponded with WCF's standard risk interval of 1 in 1000 years.

Although the threat of terrorist activities against this type of owner is believed to be low, WCF desired to have as much Anti-Terrorism/Force Protection (AT/FP) resistance available, without negatively affecting the project budget. In other words, they essentially asked that the team make design decisions that would provide as much protection as possible. This posed a significant opportunity to be creative.

In addition to the high-performance structural system and back-up systems to ensure continued operation, aesthetics and energy efficiency were paramount to the owners. This resulted in utilizing an attractive and durable stone and curtain wall cladding system, pursuit of a LEED Gold rating (which WCF is on track to receive), 10-foot ceilings, and an open floor plate.

Structural System and Design

WCF executives overseeing the project do not like braced frames. Their current board room only has two small windows next to a large, furred-out frame bay, effectively obstructing the view of the Salt Lake valley. It was a nuisance to them and they were determined not to go there. With braced frames out, a perimeter moment frame became the most logical choice for the lateral force resisting system. This presented several advantages:

- Open interior floor plates
- Unobstructed views
- High seismic energy absorption capacity
- Significant Progressive Collapse resistance

When presented with the dog-bone connection option, WCF found it strange to remove a portion of the beam. One of the executives remarked, "It doesn't make sense to take a perfectly good beam and cut a

big piece out of it." It was counter intuitive enough that they insisted on utilizing a different connection. Given the high seismic zone and desire for progressive collapse protection, the SidePlate™ connection was a natural fit. With the decision to use a SidePlate moment connection, steel became the material for the gravity system as well.

With the lateral system and material decided upon, Dunn Associates Inc. set out to design the perimeter moment frame. Preliminary frame sizes required 800 pound-per-foot column sections, which attracted the contractor's immediate attention. Sizes over 400 pounds-per-foot come from overseas and, at the time, had a minimum six month lead period with no firm delivery date. To meet the schedule, the team decided to utilize the perimeter moment frame with a concrete shear wall core. The concrete core drew enough seismic force to reduce the frame column sizes such that they were available in the United States.

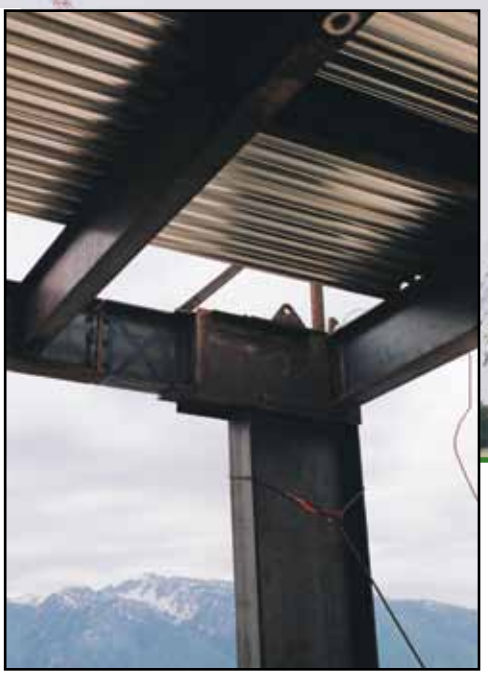
The final lateral system design consisted of:

- Moment frames with 36-inch series columns and 21-inch series beams.
- Concrete shear wall core that was continuous around the first two stories, then individual wall segments for the remaining five levels. The wall thickness varied from 14 inches in the basement to 8 inches at the top two stories.
- Mat foundation to support the core walls and several interior columns.
- Grade beams around the perimeter to carry the moment frame reactions.

The design basis for the lateral system was ASCE 41 *Seismic Rehabilitation for Existing Buildings*. While originally developed for retrofit of existing structures, this Performance Based approach is applicable to new building design. A linear dynamic model provided the structural analysis which was used in combination with spreadsheets developed specifically for shear wall and moment frame design, according to ASCE 41.

For added progressive collapse resistance design the final documents included:

- Reinforced slabs over metal deck with #3@18 inches each way in lieu of the welded wire reinforcing.
- Hooked slab reinforcing at the perimeter frame beams and shear wall embeds.
- Double clip angle steel to steel connections.



Corner SidePlate™ connection at roof.

Conclusion

WCF, the contractor, and the design team have met the goals set out at the beginning of the project. Together, they have delivered a high-performance, aesthetically pleasing, energy efficient building that will serve the user for decades to come. Without the close cooperation of all involved, these goals would still be on the drawing board.

The high-performance structure of WCF's new home added a mere 3% to the overall cost of the building; a small price to pay to be operational immediately after an earthquake.

When an owner looks at their building as being critical to their ability to stay in business, the entire discussion changes. The building goes from being an expense, or even an asset, to a vital part of their operation. This opens up the ability to create a truly high-performance building that will help protect the owner's economic security.▪

Structural framing, showing moment frames and interior shear walls.

*Paul McMullin, Ph.D., S.E. (**pmcmullin@dunn-se.com**) is a Principal with Dunn Associates Inc. and directs their high-performance building work.*

*Ronald Dunn, S.E. (**rdunn@dunn-se.com**) is the President and owner of Dunn Associates Inc.*