Technology Triumphs

By Dorian L. Adams, P.E.

Courtesy Intermountain Health Care.

Buckling restrained braces (BRBs) will help limit non-structural earthquake damage at this Utah medical facility near the Wasatch Fault.

The Intermountain Medical Center (IMC), located in Murray, Utah, is the flagship hospital for Intermountain Health Care, one of the leading health care providers in the nation. Approximately five miles east of the hospital campus lies the Wasatch Fault—an active fault capable of producing magnitude 7.3 earthquakes.

In the event of a large earthquake, the eight buildings on the 1.3 million sq. ft campus have to be able to serve the community immediately and with minimal interruption. The structural frame therefore needed to limit damage to non-structural building components and medical equipment by controlling seismic drift while absorbing seismic energy. It also needed to be able to withstand large seismic accelerations without the need for extensive repairs.

Structural steel was selected for its superior seismic performance, economy, and its effect on design flexibility and construction duration. Beyond its seismic advantages, a steel frame would be fabricated and erected quickly, meeting the extremely tight schedule, and would be easily modified during future revisions as the hospital's needs changed.

Buckling Restrained Braced Frames

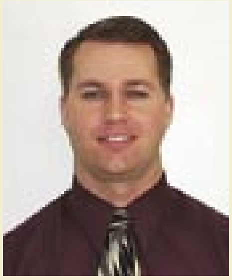
The high strength-to-weight ratio of structural steel made it ideal for seismic design by limiting building mass. Buckling restrained braced frames (BRBFs) and eccentrically braced frames were considered as potential seismic force resisting systems for this project because of their ability to absorb seismic energy while limiting inter-story drift. BRBFs were chosen because they were deemed more reliable and better performing than eccentrically braced frames.

In recent years, there has been a large amount of full-scale testing of buckling restrained braces (BRBs). These tests show that BRBs can withstand many cycles of large inelastic deformations while maintaining strength and absorbing energy in excess of that produced by major seismic events. BRBs are situated to work with the architect's layout of corridors, windows, stairs, and elevators. In many cases, corridors and doorways pass between the braced frame diagonals.

IMC is the largest project to date in the United States constructed with BRB technology. There are 648 BRBs on the Intermountain Medical Center project, all manufactured by Core Brace of West Jordan, Utah. Six large-scale BRB qualifying tests were successfully completed at the University of Utah structures laboratory consisting of two 184 kip braces, two 414 kip braces, and two 920 kip braces. Testing followed the guidelines found in the AISC-SEAOC *Recommended Provisions for Buckling-Restrained Braced Frames*. Two of the test braces experienced cyclical loading at forces above 1.3 million lb.

Foundation and Steel Frames

Approximately 12,350 tons of structural steel were used throughout the hospital campus, which includes a heart center, tertiary hospital, patient care tower, oncology center, ambulatory surgery center, and a women's and newborn cen-



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ter. The largest building in the project is composed of a four-story base that supports the eight-story heart center and the 16-story patient care tower.

The BRBFs from the towers are supported on reinforced concrete shear walls in the lowest two levels. The largest net uplift force on the columns of the 16-story BRBF was 8,000 kips. This magnitude of force is created by the BRBF design procedure that requires the column to have the strength to resist the vertical component of the expected yield strength of each brace in the frame. This design philosophy guarantees the column will remain elastic during a seismic event while the BRBs are yielding and absorbing seismic energy. The BRBF columns were taken through the reinforced concrete shear walls and connected directly to the foundation with up to 20 3″-diameter ASTM F1554 grade 105 anchor rods through base plates up to 9″ thick to resist the high net uplift force.

The interface between concrete shear walls and structural steel created a construction and sequencing challenge. The first tier of BRBF steel columns needed to be erected before the concrete shear walls could be placed. Originally, individual "boxes" were to be erected consisting of the braced frame columns connected to adjacent columns with tie beams. Once steel erection began, it became clear that the building could not be plumbed properly using this method. To solve this problem, additional tie-in steel was shipped for erection to connect the braced frames together and lock the embedded columns into place prior to pouring concrete. Subsequent plumbing problems were eliminated or substantially reduced. This allowed for structural steel erection to continue while concrete work was performed.

Material Procurement and Delivery

The structural steel fabricator was challenged with material procurement and delivery of large steel sections needed for the braced frame columns. Jumbo shapes were purchased from Arcelor International in Luxemburg. Many of these sections needed to be erected a month before the main portion of structural steel erection commenced so they could be cast into concrete shear walls. The early erection schedule conflicted with the delayed rolling of some of the sections, making it necessary to purchase a few of them from Arcelor's warehouse in the U.S. Some of these

Above: Many of the BRBF columns were jumbo shapes. The BRBF design procedure requires the column to have the strength to resist the vertical component of the expected yield strength of each brace in the frame. Photo courtesy Reaveley Engineers & Associates, Inc.

Below: Threaded anchor rods for a BRBF column prior to concrete placement. BRBF columns were taken through the reinforced concrete shear walls and connected directly to the foundation with up to 20 3"-diameter ASTM F1554 grade 105 anchor rods through base plates up to 9" thick. Photo courtesy Reaveley Engineers & Associates, Inc.

sections also required cover plating. To make the early deliveries and still be ready for the primary start of erection, the fabricator found it necessary to sublet the fabrication of the majority of these sections.

Some of the remaining sections that were being rolled to meet the later erection schedule were set back to a later date, challenging the schedule once again. Rolling progress, dock delivery, ship loading in Luxemburg, arrival at one of three ports in California, unloading, and delivery for fabrication in California and Utah was monitored by internal expediters to ensure that deliveries were not postponed.

Fast-Track Schedule

After more than a year of careful programming, the architect turned the design over to the structural engineers in August of 2003, with the structural contract documents put out to bid seven months later in June 2004. A fast-track construction method was implemented by bidding the project in several phases. Earthwork and site utility construction documents were bid so that the work would be completed in time to start construction of foundations and the primary structure in August 2004. Construction of the steel structure was underway while architectural, mechanical, and electrical contract documents were being completed. The architectural and engineering designs were developed and coordinated on a critical path format to meet the schedules of each bid package.

Structural steel allowed for modifications in the event of planning changes and shortened the construction duration. Structural steel detailing began August 2004 and the first of the steel fabrication began in November for erection in December. Detailing was completed in May 2005 and fabrication wrapped up in July.

A weekly structural steel detailing coordination meeting was implemented to solve structural steel challenges in a timely manner and to meet the aggressive construction schedule. The construction manager, engineer, architect, and steel fabricator attended these meetings and were very successful in solving issues before the shop drawings were submitted for approval.

The 16-story tower topped out in July 2005 and the remaining buildings will be topped out by October 2005. Substantial completion for the largest building is expected for the summer of 2007, while the smaller buildings will be finished sooner. ★

Owner
Intermountain Health Care

Architect
Anshen + Allen, San Francisco

Structural Engineers
Reaveley Engineers & Associates, Salt Lake City (executive)
ARUP, San Francisco (associate)

Engineering Software
ETABS
RAM Structural System

Fabricator and Erector
SME Steel Contractors, Inc., West Jordan, Utah, AISC member

General Contractor
Okland Construction Company, Salt Lake City