A Structure That Teaches

BY LIZ REHWOLDT AND ZACK STUTTS

Opus Architects & Engineers, Inc.

Instrumentation in Marquette University's new engineering building will give students a real-world look at concepts in action.

LOCATED IN MILWAUKEE, Marquette University is home to a College of Engineering with a philosophy of learning by experience. The first phase of the $100 million, two-phase Discovery Learning Complex has been equipped with strain gauges, pressure plates and other instrumentation to provide just that. The 115,000-sq.-ft structural steel facility will provide all engineering disciplines a place to study engineering concepts and their real-life applications with data from the instrumentation.

The five-story building is set to open in August 2011 and consists of classrooms, offices and laboratory space. The 5,000-sq.-ft Engineering Materials and Structural Testing Lab (EMST) in particular will see plenty of use from civil engineering students. A student commons area also will be included with a goal of fostering communication and cooperation among different engineering disciplines.

The selection of steel for the framing system not only enabled the structure to be a laboratory for civil engineering students but also was the most economical choice. Other advantages to the selection of steel framing include BIM and instrumentation considerations. BIM is more conducive to modeling a steel structure than one constructed with concrete, which allows the college to have a virtual model of the structure after construction, making the demonstration of stress effects much easier. Also, it is less labor intensive, and therefore generally cheaper, to attach strain gauges to a steel beam than to reinforcement steel in a concrete beam.

Instrumentation

The instrumentation for structural engineering purposes includes more than 120 strain gauges located on bracing and column members in braced frames, on beams in moment resisting frames, at the mid-span of a crane runway beam, and in a composite floor beam, among other locations. Also two Geokon pressure plates have been installed, one in a spread footing and the other centered below a braced column in a combined footing. An anemometer will be installed to gather information about wind speed and direction. Other engineering departments have plans to model and monitor environmental building aspects, such as energy use and water consumption. More detailed plans for those analytical tools will be made post-construction.

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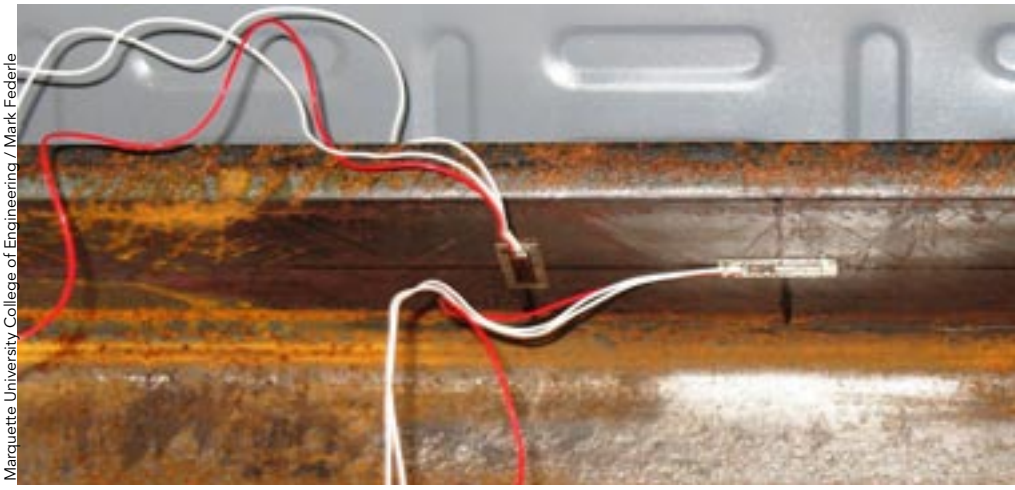
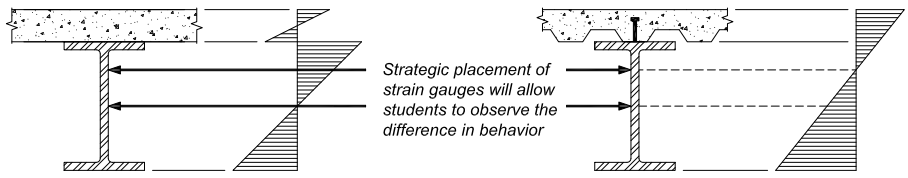
◀ Marquette University's new Discovery Learning Center now under construction will allow various engineering disciplines to use the building itself as a lab.



Marquette University College of Engineering / Mark Federle

➤ The Discovery Learning Center on the campus of Marquette University in Milwaukee will provide real-time structural response data so engineering students can see evidence of principles in action.

➤ Strain gauges are placed along both the major and minor axes of the beam flange.



▲ The strain gauges on beams in the Discovery Learning Center will allow students to see how the strain differs between composite and noncomposite beams.

Installation of the strain gauges began in early August 2010 and was estimated to take three to four weeks. The strain gauges were installed by the electrical contractor, Staff Electric, and were welded in place and covered with a silicon sealant to protect the gauges from the fireproofing material. The pressure plates were installed in May 2010 by a team from Marquette headed by civil engineering professor James Crovetti and assisted by the general contractor and his team. The main challenge for the pressure plates was ensuring uniform contact between the plates and the soil and working the plate installation into the general contractor's busy construction schedule.

However, the biggest challenge that comes with all of this instrumentation isn't in the actual installation. It is the coordination of the hundreds of wires that need to be fed through the building to the data collection point. The wires are run through conduit, which should keep them protected and ensure accurate data collection for years to come.

Student Learning and Benefits

Although specific details are still being determined about how data from the building instrumentation will be incorporated into the learning environment, civil engineering professor Christopher Foley envisions that this building in which students study will itself become an analytical model and experimental subject. The wide scale instrumentation provides an unusual opportunity to enhance the engi-

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Dealing With Lateral Loads

After selecting structural steel for the framing material, engineers from Opus Architects & Engineers set to work on designing the five-story Discovery Learning Complex. For the lateral force resisting system, engineers sought to take advantage of stairwell and elevator locations to place braced frames in the north-south direction. One braced frame located in what will be the student commons area was purposely left exposed to allow students to see first-hand what they are learning about in structural design and analysis courses.

Architectural constraints in the east-west direction prevented the use of braced frames so that the building could remain open at key locations. This necessity meant that engineers had to employ moment resisting frames in addition to the cross-bracing and chevron bracing. The diversity of lateral force resisting methods provides a tremendous opportunity for knowledge to be gleaned from instrumentation of systems that serve the same purpose, but behave very differently.

Architects selected a brick façade, hung as precast panels, with glass and aluminum to showcase Marquette's newest engineering building. The prevalent use of glass on the interior and exterior highlights the idea of emphasizing transparent interaction among engineering disciplines. Balconies and an open stairwell will provide students with the opportunity to look in on research projects in laboratories throughout the building.

neering curriculum, enabling students to take the pulse of the Discovery Learning Complex.

Engineering students already familiar with National Instruments' LabVIEW software from their freshman year coursework ideally will be able to enhance their data acquisition and analysis skills by tapping into "data ports" located throughout the building and accessing data for real-time building responses. There also will be a general public display of real-time building responses, but the primary purpose of the instrumentation is providing data for student analysis. Data already are being collected from the successfully installed pressure plates demonstrating how earth pressures change during construction.

When winter winds cause increased deflection of the five-story building, students will be able to estimate the wind loads from wind anemometer data and correlate the two. Strategic experiments using the motion of the overhead crane in the Engineering Materials and Structural Testing Laboratory will demonstrate the abstract concept of influence lines to students in structural analysis classes. The runway crane beam, equipped with strain gauges in both the major and minor axis directions, also will function as an example of a noncomposite beam, providing data for shear and moment analysis as well as mechanical analysis of composite shapes. Data obtained from the instrumentation of composite beams will facilitate a simple strain gradient demonstration, showing students—rather than just telling them—how the strain over the height of a composite beam differs from a noncomposite beam.

The architectural requirements of the building conveniently dictated the use of X-bracing, chevron bracing, and moment resisting frames as part of the structural system. Instrumentation of beams, columns, and brace members at these locations will allow students to compare the difference in axial forces in these bracing options and comprehend the fundamental differences between them. Although many of these demonstration ideas are conceptually simple, the data analysis can be quite complex. Data interpretation skills developed by Marquette students at the Discovery Learning Complex will surely be invaluable. The fact that students will be able to analyze the building in which they study will bring these sometimes abstract classroom concepts to life.

Instrumentation is becoming a relatively low-cost addition to most buildings. The important thing for implementing this idea is having an enthusiastic owner and project team. It would benefit the civil engineering profession if more universities and owners who want to learn more about their structures incorporated this technology into future buildings to gain a new perspective of their surroundings. MSC

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Marquette University College of Engineering

The steel frame of Marquette University's new five-story Discovery Learning Center provides the opportunity to use the whole building as an example of structural behavior.