The Economics Of Steel Construction

Structural steel framing proved both more economical and faster to design and erect than concrete or masonry for this series of low-rise buildings in Virginia

By S. Keith Rittenhouse, P.E

ITH THE EVER-INCREASING COMPETITION BETWEEN BUSINESS SCHOOLS FOR STUDENTS AND REPUTATION, the recent decision of the Darden graduate School of Business Administration to expand was both appropriate and ambitious. By 1991, the University of Virginia institution had clearly outgrown its facilities, where 500 full-time graduate students studied and more than 4,000 business people annually attended its executive education program. The school is nationally prominent, and in 1996 was rated as the nation's fifth best business school in a Business Week article.

Twenty architectural and three structural engineering firms wre considered for the design of the $35 million replacement facilities. Dunbar, Milby & Williams (Charlottsville and Richmond) was selected by the Darden School Foundation to provide full structural engineering services through construction administration. The project was designed to include classroom, faculty office and library buildings connected to a central Commons building by colonnades and a separate Sponsors Hall residence facility with a gatehouse entry to the complex. The first phase, scheduled to cost $25.5 million, included 220,000-sq.-ft. of new construction.

While modern amenities were critical to the success of the project, it also was important that the buildings complement the overwhelmingly traditional and historic grounds of the University of Virginia, especially from the project's visually prominent hilltop location. As a result, a neo-classic design was envisioned by the architects.

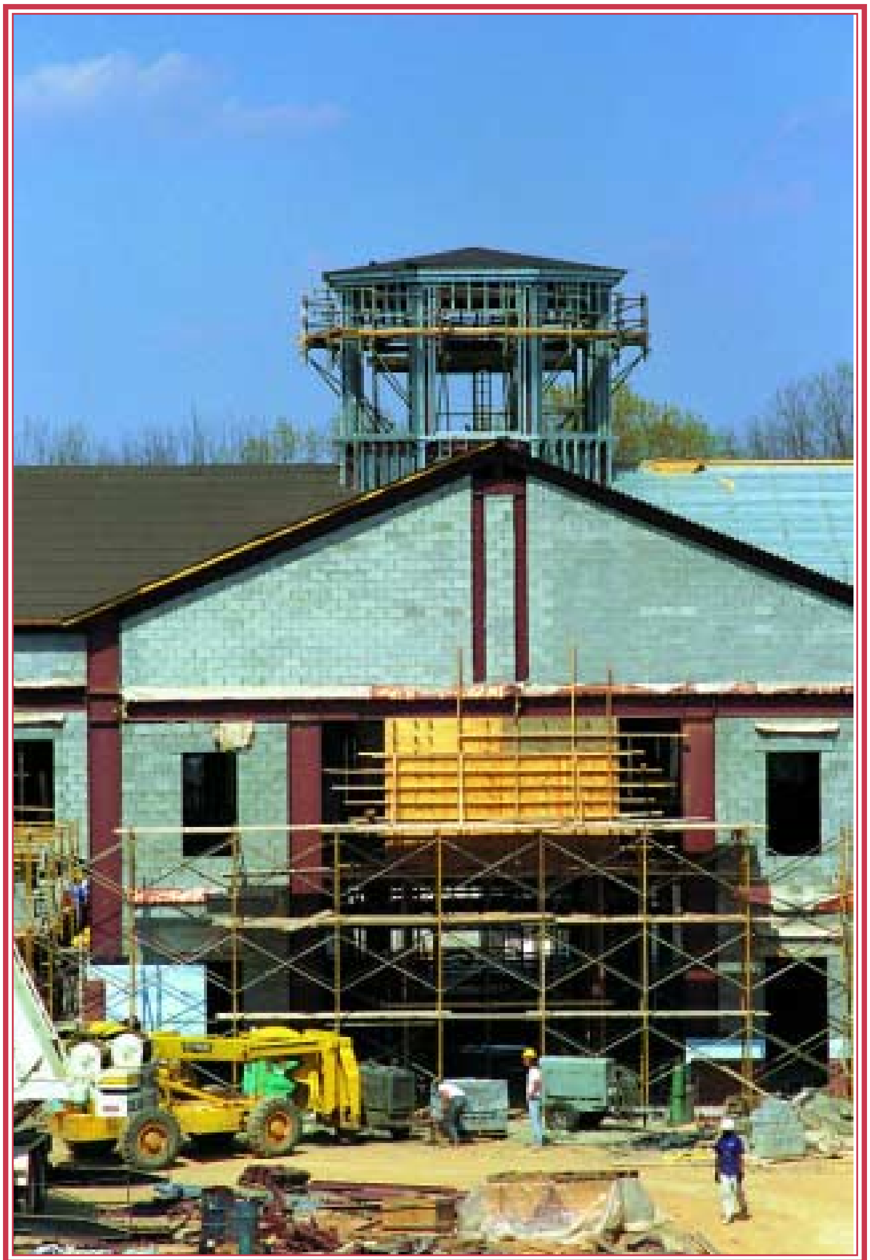
The four interconnected buildings are two- and three-story structures with brick veneer exterior walls, sloping metal roofs and rich detailing throughout. The Faculty Office and Classroom buildings face each other across a central grassy quadrangle with semi-enclosed gardens located between the projecting wings of each building. On the northern side of the complex, the Library faces the site of a future Auditorium building. The Commons building is centrally located as the focal point of the complex and is linked to the Classroom, Faculty Office and Library buildings with one-story colonnades. The Commons building incorporates a two-story lounge with fireplaces, a formal dining room that opens onto the north terrace and an octogonal central space, which projects vertically through the second floor, mechanical attic, and articulated dome ceiling to a framed lantern above the roof.

STRUCTURAL SYSTEM

Structural steel framing was selected over reinforced concrete

The desire to minimize interior columns, combined with a need for a high design live load and fast design and construction, pointed to steel framing. LRFD was used for the design to reduce the total steel tonnage on the project without increasing fabrication costs.

Photo at left by Peter Aaron/ESTO; construction photography (right and below right) by Garland & Company, Charlottesville, VA.



as more economical and efficient for the Faculty Office, Classroom, Library and Commons buildings.

Many functional considerations for the various building uses influenced the selection of a basic structural system. It was desirable to minimize the number of interior columns in the Faculty Office building, and it was essential to eliminate columns in the lecture rooms in the Classroom building. In addition, multi-story clear spaces at exterior walls were required for both the Commons and Library buildings. Design live loads included basic 100 psf floor loads for the Faculty Office, Classroom and Commons buildings and 150 psf for the Library floors.

Design for lateral stability needed to accommodate heavy fenestration in the exterior walls. The rich architectural detailing also created budgetary pressure to minimize floor-to-floor heights. In addition, foot-induced floor vibrations had to be kept within acceptable limits. Finally, both the design and construction schedules needed to be aggressively executed to accommodate academic teaching schedules and the planned reuse of the existing Darden facilities, which were being acquired by the UVA School of Law.

By mid-April, 1992, design of the buildings had proceeded

Peter Aaron/ESTO

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from the schematic phase into design development. After consideration of various framing schemes, structural steel was selected for the Faculty Office, Classroom, Commons and Library Buildings. During the design development phase, Allowable Stress Design (ASD) methodology was used to evaluate framing plans and member sizes. However, during final design and the preparation of construction documents, the Ramsteel analysis and design software package was used to investigate building designs for both ASD and Load and Resistance Factor Design (LRFD)-First Edition. The comparison showed a reduction in steel tonnage with LRFD, which was ultimately used for the project design. The software was used for both member selection under gravity loads and to design the floor framing to meet the vibration requirements. Using this approach, potential floor vibrations were limited to the "slightly perceptible" range of the Modified Reiher-Meister scale.

The typical framed floor slab is 2½" of normal weight concrete on 2" deep, 20 or 22 gage, formed composite steel deck, for a total thickness of 4½". Structural W-shape steel beams and girders up to W30x116 in size act compositely with the slab. Connection of the slab to the steel members was accomplished with ¾" diameter x 3½" headed stud shear connectors field welded through the steel deck. Typical beam and girder connections use simple shear connections. Connection angles are shop-welded and field-bolted with 3/4"-diameter ASTM A325-N bolts.

In order to provide the desired column-free spaces, floor beams span up to 39'-10" in the Faculty Office building, while first floor beams over a large lecture room in the Classroom building clear span 52'-10" and have web openings for mechanical duct penetrations. A mix of ASTM A36 and A572 Gr. 50 steel was used.

Framing for the Library and Commons buildings presented challenges due to the architectural design and detailing. Two-story high spaces at the Library east exterior wall and the Commons south lounge exterior walls required exterior beam-columns to resist axial loads and components and cladding lateral wind loads. Framing in the central portion of the Commons building is geometrically complex with a vertical clear space extending from the first floor through an octagonal second floor balcony opening to a larger octagonal attic floor opening. From the attic level, an articulated dome ceiling extends to the open bottom of a lantern structure projecting through the intersection of four orthogonal gable roofs. The dramatic architectural effect of this central focal space required five levels of floor and roof framing.

The gable and hip roof shapes at the Faculty Office, Classroom and Commons buildings utilize steel W shapes to support beam and open web joist rafters. Similar framing is used in the Classroom, Library and Commons flat roofs.

Structural steel framing also provides building stability to resist lateral forces. Multi-story rigid frames accommodate the heavy fenestration at exterior walls. Steel braced frames are used at interior locations in the Library and Commons buildings where architectural finishes hide the frame diagonals.

PROJECT COORDINATION

As the project entered its construction phase in late October, 1993, it was essential that shop drawing review and fabrication and delivery of structural steel proceed quickly. The Darden School construction was subject to the Special Inspections provisions of the 1990 BOCA National Building Code. Project specifications required that the structural steel fabricator have an approved quality control program and maintain an agreement for periodic in-plant inspections by an independent agency. The project fabricator, AISC-member Southern Iron Works, Inc., met the quality control requirements through its participation in the AISC Quality Certification Program (for more information on this program, see the December issue of MSC or point your favorite web browser to http://www.aisc.org). As a result, structural steel fabrication commenced without delay, allowing simultaneous construction on multiple buildings.

The school occupied the new facilities in January 1996. Structural steel proved to be an excellent framing system for the Darden School of Business' new facilities, providing both the economy and flexibility needed for the buildings' neo-classical architecture and varied functions. The use of LRFD enabled a reduction in structural steel weight of nearly 13%—a savings of more than 65 tons—when compared with a parallel design using ASD. It is appropriate that the Darden School, with its reputation for excellence in business education, should receive the functional and economic benefits of structural steel and LRFD design technology in its new facilities.

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