Steel Delivers

Structural flexibility and the desire for unobstructed views led to a structural steel solution for the Corporate Express international headquarters in Broomfield, CO.

Richard G. Weingardt, P.E.

The site for the new headquarters for Corporate Express, Inc., an office products and business furniture company, is a high-profile, dramatic location featuring outstanding views of the surrounding countryside and Front Range of the Rocky Mountains. Program requirements centered not only around maximizing those views, but also around meeting the quality requirements specified by the Interlocken Business Park and by the client.

For example, the building incorporates many sustainable design elements with special materials, systems and site orientation selected to minimize energy consumption and to preserve resources. The architect met the program requirements with a multi-faceted building plan incorporating two building modules separated by an atrium.

The owner's requirements included the requirement of a flexible floor plan to accommodate changes in operations, and changes in the functions of various building areas over time. The layout of the building modules and core elements was based on providing this flexibility. As discussed further, structural steel was the structural system of choice.

In addition to the primary office functions of the building, other programmatic features include a 200-seat auditorium, meeting and conference rooms, a large employee cafeteria oriented to an impressive view and a worldwide computer center. Two parking structures offer a total of 309 parking spaces.

A unique design requirement for an office building of this type was the owner's need for a high level of operational security. The data center is placed in a secure environment in the basement of the building, providing both access and protection from disasters. Another facet of this requirement was that the building be designed to resist Uniform Building Code Zone 3 seismic forces even though the Colorado requirement is only for zone 1 forces.

STRUCTURAL PROGRAM

Faced with the design and owner requirements, it was clear that structural

Detail of atrium panel framing and joints including one of the support seats.

steel was the only system that would provide solutions for these criteria. The effectiveness of structural steel in addressing these requirements range from the basic floor plan layout dictated by the design requirement for maximum daylight to the need for maximum structural flexibility and disaster protection.

A composite concrete and steel floor system was selected to provide economic floor framing along with a desire to provide a high strength and vibration resistant floor system. The framing members were selected to provide an efficient combination of load carrying capacities, vibration and deflection control and economic construction. ASTM A572 50 ksi structural steel was utilized throughout using primarily standard high strength bearing type connections. Headed anchor studs provided the composite engagement of the concrete on metal deck floor slab, resulting in best use of the structural steel.

Not only does the composite structural steel framing provide excellent performance as a floor system, it also provides the owner with maximum future flexibility. Should the framing need to be modified to accommodate future stair openings, as an example, this could be easily achieved with steel framing. Similarly, should very high loads be required for a specific area in the future, the framing can be reinforced more effectively and efficiently than other framing systems. These solutions to the owner's design program would not have been achieved without the use of structural steel.

The faceted jewel-like skylight system over the atrium required that structural steel be used. No other system would be appropriate for the combination of load carrying capacity, fire resistance and the complex interconnecting shapes. The tube steel framing design allowed for sections or complete segments to be fabricated in the shop, shipped in whole to the site and erected quickly. Structural steel allowed the construction of the bridges across the atrium and the cantilevered stairs between the bridge levels to be possible.

With the owner's directive that the building be designed to withstand high seismic loads came the requirement that the lateral system be structurally efficient, economical and perform well under these load conditions. The required configurations of the service cores precluded the use of reinforced concrete as shear elements, and exterior moment resisting frames utilizing 50 ksi steel was chosen as the best solution. These frames were effectively integrated into the building perimeter and architectural cladding systems of spandrel and vision glass. The use of structural steel lateral frames provided the owner with the best solution to his design requirements at the highest cost efficiency.

STRUCTURAL HIGHLIGHTS

One of the most distinguishing and unique elements of this building is the complicated, multi-faceted skylight structure over the atrium bisecting the two building modules. In order to achieve the jeweled prism effect, a complex geometry was required. The basic structural design was accomplished using a three-dimensional model of the system including the lateral slip joints along one side.

The structural steel tube sections were selected and designed to provide the required support conditions for the glazing, aesthetic considerations and efficient constructability. By using CAD design and detailing techniques, the skylight elements were broken down into individual face segments and detailed to allow either shop fabrication of the individual segments or larger sections of the framing system.

Since the building is essentially comprised of two completely separated superstructure modules with the skylight bridging the atrium gap between, special consideration was required for the differential movements that would occur between the two superstructures. Lateral differentials caused by normal thermal variations and lateral wind forces were greatly exceeded during design by the owner's requirement for the building to accommodate UBC Zone 3 lateral seismic forces. The resulting movements between the two buildings were accommodated by a series of Teflon slide bearings along one side of the atrium roof structure and slip joints down the vertical sides of the atrium curtain wall below. The structural system of both the horizontal and vertical skylight components had to be rigid enough to

Construction of one of the building segments. Note the moment-resisting exterior steel frame components.

Construction photo showing how the shop fabricated atrium panel segments were completed on the ground with the installation of the glazing system for subsequent lifting into position and final erection on the roof.

effectively isolate differential movements at these slide bearing slip connections.

The same considerations had to be taken with the walkway bridges spanning between the buildings at different levels within the atrium space. The bridges were designed as fixed at one end with freedom to move laterally provided at the opposite end using slide-bearing connections. Further, relative movements between bridge elements required care in the detailing of the stairs between bridge levels.

The requirement for a moment-resisting structural steel lateral frame for much higher than normal seismic forces is unusual in Colorado. To effectively incorporate this requirement, these seismic frames were designed at each of the orthogonal exterior faces. With the superstructure being essentially two independent buildings, each module had to be designed separately with its own direct shear and torsional forces. The performance of the frames had to be carefully controlled to minimize differential movements between the two superstructures while maintaining cost effectiveness. This was achieved by incorporating these moment frames in the overall floor framing and column configuration without needing to add additional structural members.

Richard G. Weingardt, P.E. is chairman and CEO of Richard Weingardt Consultants, Inc., which he founded in 1966.

STRUCTURAL ENGINEER:
Richard Weingardt Consultants, Inc., Denver, CO

ARCHITECT:
Downing Thorpe James, Boulder, CO

STEEL FABRICATOR:
W & W Steel, Oklahoma City, OK (building structural frame) (AISC member)

Central Denver Iron, Denver, CO (atrium framing) (AISC member)

STEEL ERECTOR:
Ridge Erection, Arvada, CO (NEA member)

SOFTWARE:
LARSA (atrium and building lateral), AutoCAD 3D, ICOMPBEAM (floor system)