UNT's Business Leadership Building

A complex structural solution for a world-class educational building.

By Thomas Taylor, P.E., Rodolfo D'Arlach, P.E. and Lee Christian, P.E.

Business Leadership Building at University of North Texas.

Owner - UNT
Architect of record – Jacobs
Design architect – Ennead
Structural engineer – Datum Gojer
Civil engineer – Datum Gojer
MEP engineer – Jacobs
Landscape architect – Caye Cook & Associates
Audio visual/telecom – Applied Tech Group
Food services – Bosma Design Solutions
General contractor – Hunt Construction Group
Concrete subcontractor – Capform
Post-tensioning contractor – Suncoast
Steel fabricator – Basden Steel
Steel erector – Basden Steel

Several years ago, The University of North Texas (UNT) in Denton, Texas, began a journey to establish a new building to accommodate the school's growing admissions. UNT has about 5,000 students in the business program and expects that number to reach 8,000 in the next 10 years. The new Business Leadership Building is four stories, 180,000 square feet, with a budget of $70 million, and a goal of LEED gold certification. The design schedule was 13 months and the construction schedule was 16 months.

The Business Leadership Building's architectural team included Ennead (formerly Polshek Partners) and Jacobs as the architect of record. The structural and civil services were provided by Datum Gojer Engineers LLC. The general contractor was Hunt Construction.

Embracing human scale

The architectural vision was based on an academic village concept in which a group of campus-scaled buildings within the building surround a marketplace atrium. The third floor faculty level acts as a parasol above the atrium, providing weather protection and sun control. Skylights *(image on next page, top)* lighten the high-volume space created by the marketplace atrium. Exposed, cast-in-place columns support the atrium roof. The atrium links all the different teaching levels together visually. Exterior cladding is composed of brick, Texas limestone, curtain wall and metal panels.

The skylights were installed around the third floor heavily loaded green roof to allow light into the atrium, but created high-stress and congestion issues in the 60-by-60-foot waffle slab. The skylights are adjacent to the columns and the ribs are extended through the skylights. The joists were post-tensioned in both directions to resist the stresses and to control dead load and creep deflections. The architect was very specific about the desired look. Ribs could not frame into the column. Instead, they framed into the beam at the back of the column. The rib was formed to be round at the column and square above it.

The roof is composed of light structural steel. The various functions in the building, including classrooms, atrium, auditoriums, and offices, are stacked vertically. This design created the need for irregular column spacing, varying from a typical 40-foot module to a 60-foot module in the atrium.

Skylight around the Market Place atrium.

Classroom box.

Research and ingenuity

The grand marketplace atrium and spiral stairs, the green roof of the atrium, the steel V-columns, the irregular column spacing, the long cantilever corners, the classroom box, the short-span steel roof, and the desired building module were all resolved with a simple primary structural system that used a cast-in-place concrete waffle slab. The upper floor levels were also constructed with a cast-in-place concrete, conventionally reinforced waffle slab.

The structural engineers and architects performed an exhaustive study of framing systems and selected a waffle slab to eliminate costly and deep-transfer girders. In the more regular and independent auditorium area, a slab and beam system frames the sloping floor.

A square module for the waffle slab of 6 feet, 8 inches, by 6 feet, 8 inches was chosen to work with the functional module of the building. The waffle slab was constructed with 20-inch deep steel forms combined with a 4-5/8-inch thick slab to create a typical 24-5/8-inch deep system with 10-inch wide ribs.

The architectural design of the atrium mandated a column-free marketplace. Consequently, a deeper system of 32-5/8 inches supporting the 60-by-60-foot long span green roof was required. This system was constructed by adding an 8-inch deep plywood "hat" on top of the steel waffle forms. The green roof over the atrium was designed to support insulation, soil, paving, a 150-pound-per-square-foot live load, and several 7,500-pound planters. In areas where the waffle slab is exposed, the entire waffle form is constructed of plywood. Also, the northwest corner of the green roof is open to allow rain and light down to the ground floor entry.

Diamond in the waffle

To resist punching shear at the columns, a diamond-shaped concrete panel was formed in the waffle system. Special spacing of stirrups was used around the columns in the slab panel. The ribs are 20 feet wide at the narrow end of the diamond to reduce stirrup requirements.

The classroom box sits in the middle of the east side of the building and is clad in stone similar to that found on the exterior façade. It is surrounded by skylights with bridges at entries on every level, thus creating a dramatic separation and architectural effect.
(see image at left)

The perimeter V-shaped columns were constructed of 1/2-inch thick galvanized steel and painted with intumescent paint for fireproofing. The columns were installed before casting the concrete floor, since the floor is supported by the columns. Coordination between the concrete contractor and the steel erector was a model example of construction trades working together. The steel columns had a temporary tension tie rod attached across the top of the column for erection purposes. Once the 5-foot deep concrete beam was cast at the top of the V columns and gained its strength, the concrete beam provided the tension tie for the columns. *(see image, below right)*

The steel columns vary in radius from 14 inches at the base to 26 inches at the center. They were designed using Stephen Timoshenko's "Theory of Elasticity" as a reference. The text has a section devoted to columns with varying cross sections. In short, a geometry-dependent modification factor is applied to the Euler buckling equation. Using the modified Euler equation, the critical buckling stress of the column was determined and the design was completed using the AISC code equations.

The architectural expression created a 20-foot long concrete double-cantilever at the corners of the building. Post-tensioning of the cantilevers closely balanced the dead load of the structure, cladding, partitions and ceilings to control deflection and long-term creep.

Significant stairway

The monumental steel stairway in the atrium connects all levels. The structure cantilevers off of the bridge at levels 2 and 3 and spirals down to level 1 with HSS 10-by-10-inch-by-1/2-inch stringers. The bridges, at each floor, laterally brace and support only one end of the stairs. The steps are X-braced and the landings are diagonally braced to laterally brace the stairs to the supporting landing at the floor line. Rods centered on the stairs hang from the roof to provide extra support. *(see image, below left)*

At level 3, the office partitions follow the 6-foot, 8-inch module of the concrete ribs. The visual expression of the umbrella required a shallow roof system combined with a lower floor-to-floor height. The thin structural roof framing was accomplished by restricting the span to a maximum of 26 feet, 8 inches and by using light structural steel. The steel roof columns are supported on the third floor waffle slab at the intersection of the concrete ribs. The short spans allow the steel beams and joists to be no deeper than 14 inches.

Software assistance

Various software packages were used in the analysis and design of this project. Revit 2010 assisted the team in modeling and architectural coordination. The waffle slabs were modeled using ADAPT Floor Pro. The roof was designed using Ram Steel and the Atrium stairway was analyzed using Risa 3D.

This structure, with so many unique and varying conditions, required a major team effort by the structural engineer. Many Datum Gojer staff members provided their special talents and expertise for this project.

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Market Place atrium stair.

Detail of V columns used at the corners of the building.

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