Parking Goes Green – Literally – at Miami University

By Jun Ye, P.E. and Michael Haney, P.E.

Who says a parking garage cannot be green? Certainly not the faculty, staff and students of Miami University in Oxford, Ohio, where the construction of a parking garage was recently completed. The garage – 175,000 square feet of cast-in-place, post-tensioned concrete – features a 450-space underground parking garage capped with a 90,000 square feet structured and landscaped quadrangle. When university students, faculty and staff walk across the quadrangle, complete with its beautiful lawn, planters, benches and special light fixtures, they might never guess hiding beneath is a two-story garage.

Introduction

Located 35 miles north of Cincinnati, Miami University is a unique and wonderfully historic college campus. Set in the sloping hills of Ohio's picturesque town of Oxford, Miami University is known as one of the most beautiful campuses in the United States. The university boasts lush quadrangles – the centers of student life – framed by Georgian red brick architecture. That beauty is one of the major reasons 16,000 students attend Miami University to study every year.

Though the formal name for the parking structure is the North Campus Parking Garage, the great lawn and new quadrangle space constructed above has given rise to its nickname: "The Green Garage." The term "Green

Figure 1: Site rendering by 360 Architects and MSI Design.

Garage" in this instance does not imply LEED certification, nor does this article focus on sustainability. Instead, this article addresses the unique challenges associated with the design and construction of an inviting and efficient underground parking structure supporting a large planted public space.

Design Challenges and Solutions

The project team developed a design that not only provided an efficient, durable and inviting structured parking garage, but also a new creative outdoor space above. The project was not without its unique challenges, however. Following are four design challenges and the solutions provided for each:

Structured Plaza

The weight of landscaping and soil on the plaza had a significant impact on the garage structure. To control the depth of soil it was decided early in the project that large plantings and trees would be kept off the supporting structure. The initial soil depth was set at 18 inches. To further reduce load on the structure, MSI Design, the project landscape architect, developed a lightweight soil and drainage system which required a total depth of only 10 inches. Figure 3 below shows a cross-section view of the soil assembly used above the plaza slab. This shallow system not only reduced soil weight but also reduced the overall depth of the garage.

In addition to supporting the lawn, the plaza structure also supports walking paths, planters, benches and light poles. The light poles were anchored to the structure, while all other elements of the plaza

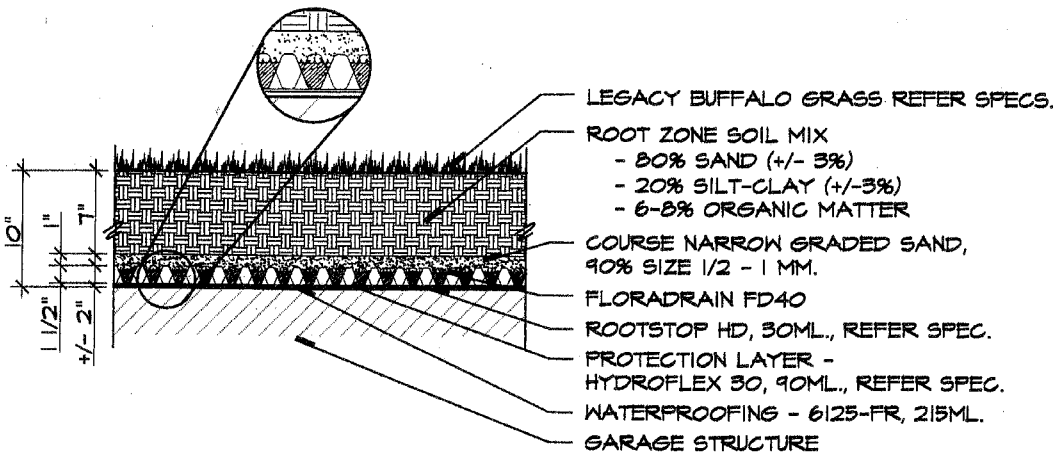
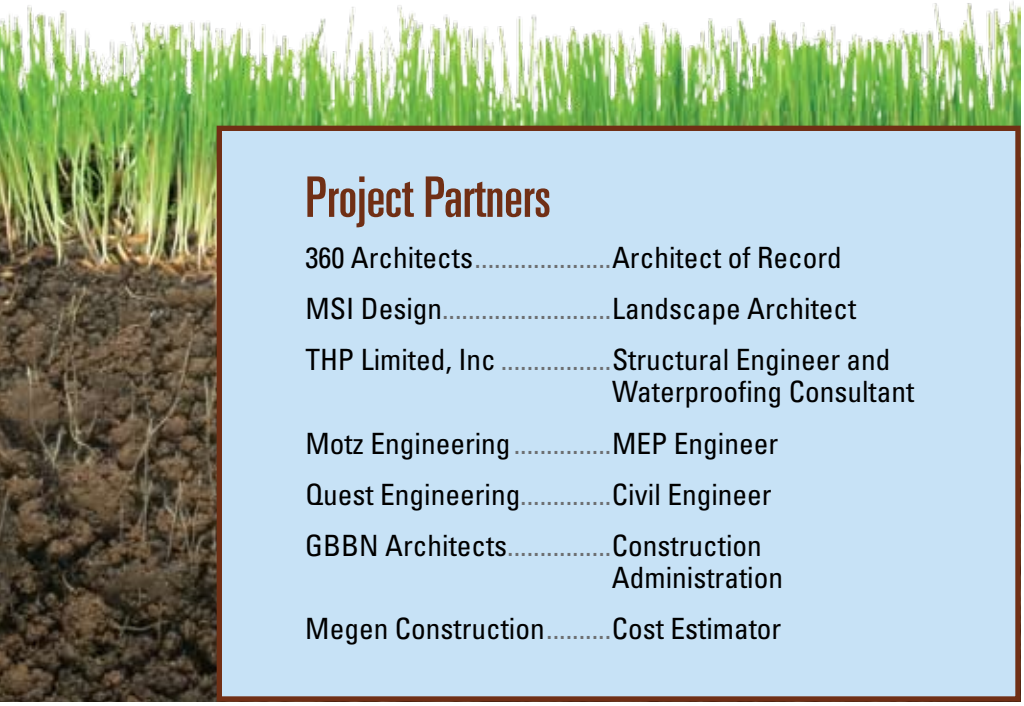


Figure 3: Plaza soil assembly section by MSI Design.

Figure 2: Plaza level, looking east with SEAS building on the right. *Photo by GBBN Architects.*

"floated" above the structure. Such a design avoided adding extra complexities to waterproofing detailing and installations.

The simplified waterproofing can be seen in Figure 4 below. Note the lack of steps, corners and protrusions that often complicate the application of the waterproofing. The drainage system for the entire plaza was designed to be simple and efficient. A high ridge was located in the middle of the plaza with the slab sloped towards the two sides. Surface drains were installed along the side walls. This approach allowed surface and subsurface water from the plaza to be collected quickly by the top drains. No drains were installed through the plaza slab and waterproofing assembly.



Project Partners

360 Architects	Architect of Record
MSI Design	Landscape Architect
THP Limited, Inc	Structural Engineer and Waterproofing Consultant
Motz Engineering	MEP Engineer
Quest Engineering	Civil Engineer
GBBN Architects	Construction Administration
Megen Construction	Cost Estimator

Short Span or Long Span Structure

Generally, a cast-in-place concrete structure is selected for structured parking garages that must consider durability and economics. The project team wondered: should a short span or long span structural system be used for this project?

Initially, a 30-foot span, conventional two-way flat slab was considered, as the North Campus Parking Garage was connecting to the existing, three-story School of Engineering and Applied Science (SEAS) parking garage that used the same short span structure. A short span system would allow the two garages to relate to one another in terms of grid and elevation. In addition, the short span structure would efficiently support heavy landscape loads.

But a long span structure using post-tensioning (PT) and 60-foot column spacing had significant advantages over the short span system:

- better parking garage layout and openness due to fewer columns
- lower construction costs for columns and foundations

Figure 4: Plaza level waterproofing being tested before placing soil and landscape. *Photo by THP.*

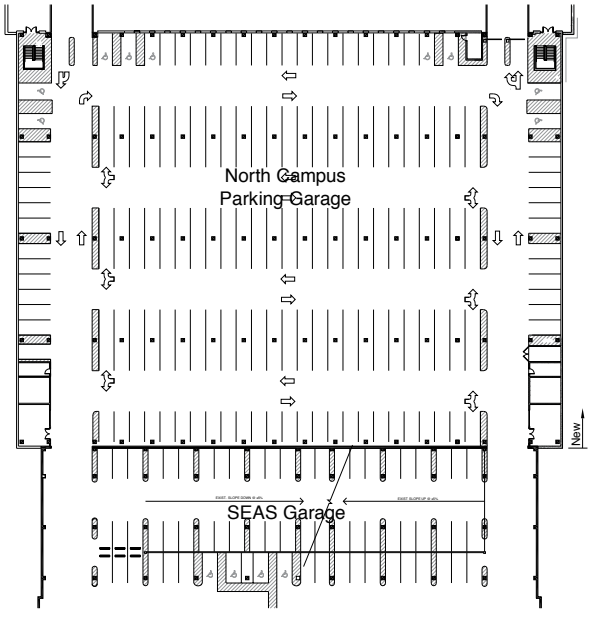


Figure 5: Parking level plan by 360 Architects. Note the grid for the new garage was set to assure the drive lanes line up.

- reduced slab cracking and improved long-term durability of the garage structure

After careful comparison of the two options, the design team concluded that a long span PT structure would be a better solution. This was especially important once the lightweight soil scheme solution for the plaza was proposed, making the landscape load lighter than originally anticipated.

Column Grid and Elevation

Choosing the long span structure created another issue: how to coordinate the grid and elevation between the North Campus Parking Garage and the existing SEAS garage. The existing SEAS garage had a typical 30-foot grid and 17-inch-deep structure with a floor-to-floor height of nine feet and nine inches. The new two-story underground North Campus Parking Garage required a 32-inch-deep elevated garage structure, a 44–inch-deep deep plaza structure, and 60-foot by 20-foot grid. There also needed to be two column-free drive lanes running north/south on both sides of the garage to connect the new garage to the existing SEAS Garage.

After thorough studies by the design team, a 27-foot-long span slab was chosen for the two north/south drive lanes. This selection provided three major benefits: It eliminated the need for heavy transfer girders between columns; allowed all column grids between the two drive lanes to be equally spaced at 18 feet apart; and enabled the forms to be used repetitively.

The North Campus Parking Garage was expanded 16 feet on both the east and west sides. The added short bays improved the overall parking efficiency of the garage by providing end-bay parking. This also improved the structural efficiency of the 27-foot span over drive lanes. Refer to Figure 5 for the garage layout.

The elevation adjustment proved to be a bit tricky. Due to the very hard grey shale on site, extra excavation would

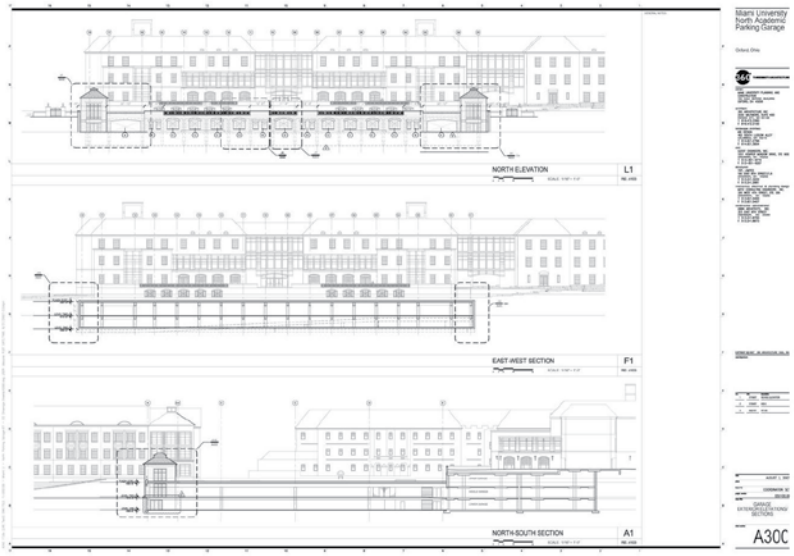


Figure 6: North/South section by 360 Architects. Note the elevation transition at intermediate level.

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have significantly increased the cost of the garage. To avoid that cost, the North Campus Parking Garage's lowest level was made to align with the SEAS garage. The structure depths were adjusted four inches – to 32 inches and 44 inches, respectively – so that the high point of the plaza level would not exceed or block the ventilation openings in the existing SEAS garage wall. This made the elevated garage level 15 inches higher than the SEAS garage level.

The elevation difference was later resolved by adding a 15-foot-long slope transition slab at the end of the main drive lanes. Tendon layout and installation in the local area were studied and the feasibility of using this approach was approved. Refer to Figure 6 above for garage cross section.

Structure Shortening and Perimeter Walls

Large post-tensioned garage structures move due to temperature changes and shortening produced by post-tension forces. Restricting this movement will result in unwanted distress in the garage structure. To allow the structure to move more freely, two main actions were taken. The first action was to separate all perimeter walls from the main garage structure. The second action was to make some perimeter columns more flexible. A special column base detail was added underneath the perimeter columns to force the base joint to serve as a pin.

It was determined that a traditional retaining wall would work fine for the north wall because it was only one story high. But the use of free-standing retaining walls along the two-story east and west walls were found to be cost-prohibitive.

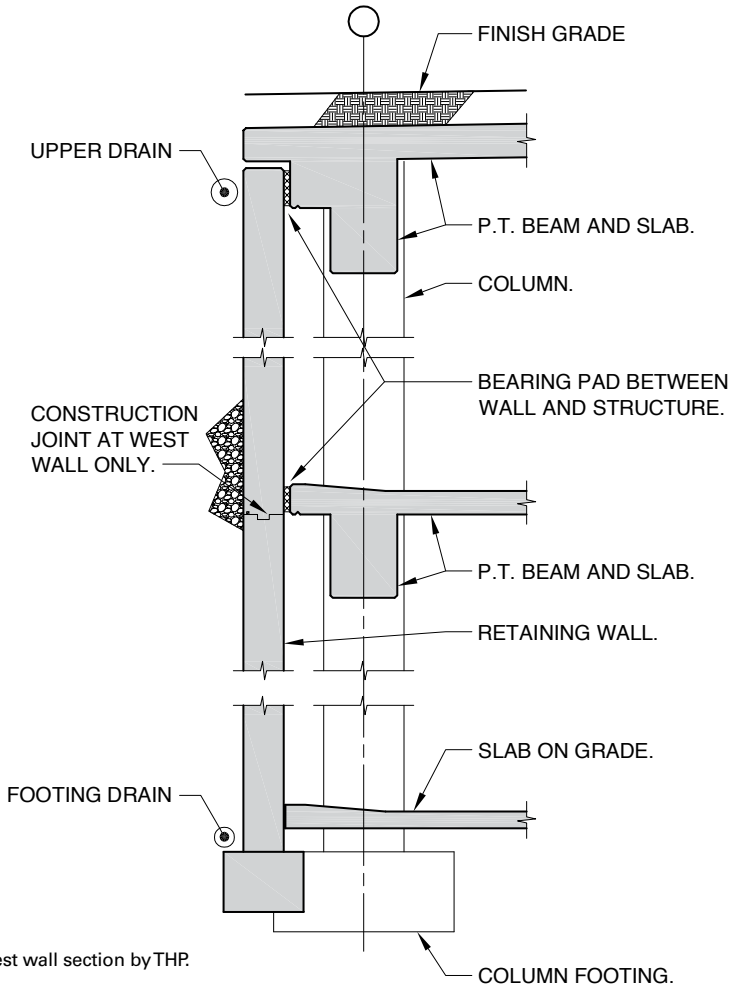

Figure 7: East and West wall section by THP.

Figure 8: Looking south during excavation and footing construction. The SEAS building can be seen in the background. *Photo by THP.*

Figure 9: Looking south during first elevated slab construction. *Photo by THP.*

This problem was resolved by letting the wall lean against the structure, but not tie to it. This design also allowed the two story wall to be built as one piece on the east side, which eased the construction and reduced cost. The top of wall was carefully detailed for easier slab stressing and water protection. The detail of this approach is illustrated in Figure 7 at left.

Other measures were also included in the design to enhance the durability, such as dense concrete mix; protective coating on the reinforcing and embedment; additional concrete cover for the rebar; good drainage inside garage; and a fully-encapsulated post-tensioning system in the elevated parking deck.

Construction

Immediately after the existing Goggin Hockey Arena was demolished, an additional five to seven feet of grey shale was excavated to reach the lowest elevation of the garage. The spread footings and two-story east wall were constructed first, followed by the two levels of elevated slab. A tensioning operation for slab and beams was performed from the north and west sides. The upper portion of west wall was constructed after the elevated parking level was built. Later, the waterproofing was installed on the whole plaza level and tested. Finally, the green roof and all site fixtures were constructed.

Construction began in the summer of 2007 and garage construction was completed in summer 2008. Final landscaping was complete by the spring of 2009.

Sustainable Benefits

Though a standalone parking garage is not eligible for LEED certification, the project indeed provided significant environmental benefits to the campus. The new lawn and landscaped quadrangle replaced nearly six acres of surface parking and building roof, resulting in:

Figure 10: Arial photos taken by Miami University showing the development of the project through its construction process.

North Campus Parking Garage

October 2005

October 2006

October 2007

October 2008

- reduced storm water run-off by replacing hard surfaced roof areas and surface lots with lawn areas
- reduced heat islands effects produced from the previous asphalt paved surface lot

Conclusion

Despite many of the unique design challenges, the completed North Campus Parking Garage is efficient and economical, thanks to the project team's thorough brainstorming process during the design phase. The simplified design eased the complexity of construction, which in turn lowered the cost for Miami University.

The North Campus Parking Garage celebrated its grand opening in the fall of 2008, right before the start of a new academic year. Not only do Miami University students, faculty and staff now enjoy the convenience of the new garage, they also enjoy the magnificent green space located on its roof. The final product is exactly what the university had envisioned and expected to achieve at the start of this project … a true green garage!

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