



Buried side by side during the Late Cretaceous period on a subtropical coastal plain in what's now Montana, the Dueling Dinosaurs are among the most complete skeletons ever discovered of two iconic dinosaurs: *Tyrannosaurus Rex* (inset top) and *Triceratops* (inset bottom). The Dueling Dinosaurs have taken up permanent residence at the North Carolina Museum of Natural Sciences, where a laboratory exhibit area is being built to house the monumental discovery.

Dueling Dinosaurs!

Floor Reinforcement Needed for Monumental Exhibit

BY JOHN R. HUGHES

Montana's Hell Creek Formation, a barren, rocky landscape of sandstone, shale and clay, is an unforgiving land, but the area has produced some of the most important dinosaur specimens ever discovered. One of its most famous discoveries is the "Dueling Dinosaurs," a spectacularly preserved juvenile *Tyrannosaurus Rex* and *Triceratops* intertwined in a single fossil estimated to be approximately 67 million years old.

Dueling Dinosaurs on Display

The Dueling Dinosaurs have taken up permanent residence at the North Carolina Museum of Natural Sciences in Raleigh, N.C. The dinosaur carcasses remain entombed within sediment from the Montana hillside where they were discovered, giving scientists access to biological data



typically lost in the excavation and preparation processes. Entombing sediment preserves extraordinary features such as body outlines, skin impressions and other soft tissues as well as injuries and potential evidence of interaction, such as *T. rex* teeth embedded in the *Triceratops* body. This distinct preservation will provide museum paleontologists with an unprecedented opportunity for research and education as they work to uncover the fossils and learn from them in the years to come.

HH Architecture in Raleigh is working with the museum's exhibits team to construct a laboratory exhibit area to house the monumental discovery. Scientists will be able to study the fossil for the first time, and visitors will have a one-of-a-kind, hands-on experience.

The exhibit, which is expected to open in late 2023, will include high-tech display spaces; an area where visitors can explore the tools and techniques used by paleontologists; and an exemplary science laboratory dubbed the “SECU DinoLab,” where scientists will research the specimens live in front of the public. Museum guests will have a unique opportunity to enter the SECU DinoLab and talk directly to the paleontology team. The state-of-the-art facility also will feature video feeds and research updates so the public—both onsite and online—can follow along live as paleontologists work to reveal and share their Dueling Dinosaurs discoveries.

Construction Details

The impacted area is approximately 4,000 square feet, featuring a highly visible glass enclosure with stone fenestration at the base. The renovation will be an iconic addition to the museum’s streetfront.

Raleigh-based Lynch Mykins, the structural engineer for the Dueling Dinosaurs project, is tasked with ensuring the new and existing structural systems are designed and reinforced as needed. The project added 1,200 square feet and functionality to the existing main exhibit space, including a bridge crane, state-of-the-art workspaces for the paleontologists, and a new means of egress from the renovated exhibit space.

During design, the biggest challenge the structural engineering team faced was to reinforce the existing concrete floor system with steel beams to support the weight of the 30,000-pound dinosaur fossils. Originally designed to

support 100 pounds per square foot (psf), the reinforced floor now supports up to 400 psf—a four-time increase in live load capacity.

The design team used Revit from Autodesk as its BIM software to create a 3D model of the existing building with the new addition. With the Revit model, the design team could collaboratively solve problems and conflicts as they arose as well as predict and avoid future issues.

In addition, Lynch Mykins used a combination of RAM Structural System and RAM Elements from Bentley Systems, PROFIS from Hilti, and ENERCALC software to create a structural design model of the renovated building as well as design the structural components.

Strengthening Support Structures

Although Lynch Mykins routinely tackles renovation, addition and change-of-use projects, not many are tasked with increasing a structure’s load capacity to the same degree as the Dueling Dinosaurs project. The first step was to work collaboratively with the design team and museum to define how the new space will function when the project is complete. From there, the Lynch Mykins team took the project requirements and began developing the schematic plan for how to support the new use of the existing space and how the new structure will integrate with the existing building.

After the schematic plans were approved, the team began determining if the existing structure had the capacity to support the increased loading, which it didn’t. The team had to design a reinforcing system that allowed the existing



Within the museum's new SECU DinoLab, visitors will be able to get up close and personal with the fossils and meet some of the scientific team as they uncover long-buried secrets.



To supplement the shear capacity of the museum's existing reinforced concrete floor beams, the project team oriented a unidirectional carbon fiber system in a "U-Wrap," with the primary fibers running transversely to the axes of the beams.

structure—with minor modifications—to support the new programming. The chosen reinforcement system had to balance constructability concerns within the existing building, geometric limits and height restrictions for the parking garage below, conflicts with the existing building's stormwater system, and cost efficiency to maintain the project's budget.

In the end, the primary reinforcement of the existing concrete floor combined structural steel framing and fiber-reinforced polymer (FRP) to strengthen the existing concrete beams. The primary structural steel reinforcement structure will halve the span of the existing concrete beams from 30 feet to only 15 feet and carry the added load from the exhibit floor directly into the existing concrete columns. With the span of the existing concrete beams reduced and new support provided at their original midspan, a Tyfo SCH-41 system from Fyfe FRP was used

to supplement the shear capacity of the existing reinforced concrete floor beams by orienting the unidirectional carbon fiber system in a "U-Wrap," with the primary fibers running transversely to the axes of the beams.

The FRP strengthening system was selected because of its cost-effectiveness, ability to make up the required capacity and ease of installation. The design team explored alternative methods, such as increasing the shear capacity of the existing beams with conventional steel schemes or reducing the shear demand on them, but those options were either difficult to install, added significant amounts of structural steel tonnage to the project; created a deficiency in the project's overall requirements, such as maintaining head clearance in the parking garage; or were unable to provide the required increase in shear capacity of the existing concrete beams.

As an added challenge, the existing concrete beams were coated in a fire-protection system that needed to be removed before installing the Tyfo SCH-41 system. Adhesion testing was performed to confirm an adequate bond between the substrate and the system. In addition, witness panels were created onsite and sent to an independent laboratory for ASTM D3039 testing to confirm the system's design properties.

Each project has its own unique qualities and opportunities for innovation, so the specific combination of reinforcement systems used for the Dueling Dinosaurs project isn't used regularly. However, Lynch Mykins does specify

FRP for strengthening and repair applications for many concrete and masonry structural systems.

The significance of this one-of-a-kind project to the people of North Carolina as well as the magnitude of the renovation, addition and reinforcement of the building required a high level of collaboration, teamwork, creative thinking and problem solving. It's anticipated that the Dueling Dinosaurs and SECU DinoLab will become a "must-see" icon at what's already the state's most-visited attraction. The way the entire experience is designed—inviting the public to follow the scientific discoveries in real time and participate in the research—will set a new standard for museums.

II

John R. Hughes is a freelance writer specializing in issues related to urban planning and sustainable development; email: jrhughes@springsips.com.