AN OVERLOOKED ASPECT OF ACCELERATED BRIDGE CONSTRUCTION, PROTECTING THE FOREST ON A PEDESTRIAN TRAIL

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BIOGRAPHY

Patrick Gallagher is a Senior Bridge Engineer with Parsons in Raleigh, North Carolina.

Patrick came to North Carolina in 2015 after working for the Washington State DOT for 12 years. In his time at WSDOT, he focused his efforts on Accelerated Bridge Construction. He helped develop WSDOT's policy on ABC and designed two bridges with precast substructures in a high seismic zone.

Some of Patrick's other accomplishments include load rating of long span steel trusses, steel plate girder bridges, a curved fracture critical bridge, and a time specializing in steel sign structure design.

SUMMARY

This presentation will discuss unique opportunities pedestrian bridge design offers engineers. It will give an example of how applying highway bridge design methods can benefit a client, protect the environment, and encourage bridge engineers to pursue design projects that often inspired our careers.

This presentation encourages engineers to consider their own talents before turning to secondary sources for pedestrian bridge engineering solutions.

ABC, specifically Prefabricated Bridge Elements and Systems, were applied to Meadowmont, and provided a solution that met the client's needs while protecting the natural beauty of the Piedmont of North Carolina.

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Introduction

Famous for good music, college basketball, and a center for academic success, the Research Triangle and the Town of Chapel Hill has plenty of good things to offer its residents. Throughout the Triangle there is an intricate series of pedestrian walkways that encourage residents to get outdoors, enjoy the southern sunshine, gaze upon the natural beauty of the area, and stay healthy by promoting an active lifestyle.

Residents in the Triangle have a desire to preserve the natural beauty of their portion of North Carolina's Piedmont. That's why the Meadowmont Pedestrian Bridge Replacements in Chapel Hill, North Carolina are important.

Uniqueness of Pedestrian Structures

At their core, a pedestrian bridge is like any bridge, including highway bridges, and demands the same attention to detail as their larger counterparts. They are built of the same materials, span the same streams and roads, and are built in much the same way as other bridges. Yet, they seem to have a lower status on our natural hierarchy of "exciting" projects. As a result, they often do not get the same level of innovation and attention to detail as other bridge projects.

Look around and take notice of how unique pedestrian structures can often be. Wander the urban landscape of a city and notice how an oddly complex pedestrian structure emerges out of the concrete jungle. You don't usually see a 150 foot long suspension bridge supporting highway traffic, or a highway bridge intertwined intimately with its surroundings. They almost take over the spaces they occupy. But wander through the city and you may find such a structure designed for pedestrians. Pedestrian bridges are often small, narrow, and get very personal with their users and users of the land adjacent to them. They also provide an excellent place for opportunistic bridge engineers to take a shot at recreating the marvels of engineering that inspired us in college, on a smaller level that may actually be obtainable.

By the time pedestrian structures are added to a community, the roadway infrastructure is often established, buildings are constructed, and the path greenways are able to follow are often left to the forgotten spaces developers couldn't gain access to. Greenways may be located along utility easements, across a swamp, tucked between or under bridges in the city, or along creeks that are otherwise inaccessible for development. As a result, greenways are often placed in very unique locations and provide people with a rather special view of the cities they serve.

Meadowmont is such a place; a trail meandering through an otherwise forgotten and inaccessible landscape, providing a unique experience, and an opportunity for an eager bridge engineer to design something truly unique.

Design Codes

While there are codes dictating pedestrian bridge designs, consistent application of loads on these structures has not routinely occurred (1). Historically loads have varied and jurisdictions often take exception to these loads. As a result, our existing inventory of pedestrian bridges have a wide array of design live loads.

Since pedestrian structures and greenways are not often determined to be essential to the commercial value of our networks of roads, the usual environmental criteria do not always apply the same to pedestrian structures as they do roadway bridges. When flooding occurs, pedestrian bridges get damaged first. When a pedestrian bridge gets damaged in a storm, repair of the structure often comes secondary to the roadway bridges or buildings serving the community.

Site Description

Trails near the Meadowmont site are currently composed of very narrow gravel paths meandering through the woods that reside within a wide floodplain. The paths are often elevated slightly on a soil berm. The ground adjacent to the berm is often wet. And the site is often inundated with water when heavy rains occur, especially during the summer months. Trees are very tall, vegetation is thick, and the beauty that makes the trail unique provides an obstacle for conventional means of bridge construction. See Figure 1 for a plan of the site (Figure 1).

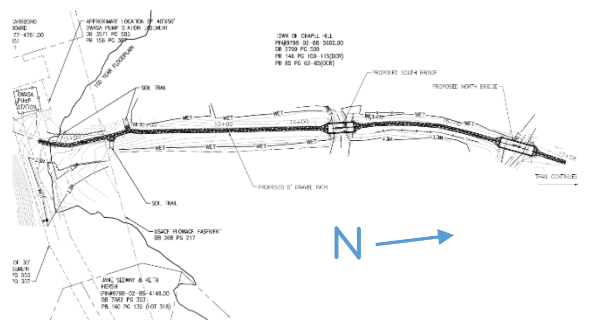

Figure 1: Site Plan

The site traverses from south to north across the floodplain. The pedestrian trail enters the floodplain near an elementary school, at the edge of a forest. The landscape dips slightly as you enter the forest. As you travel to the north, you come across the first bridge (Figure 2), titled "South Bridge" in this report. As you continue down the path, you come across the second bridge, titled "North Bridge" (Figure 3). The existing South Bridge is five feet wide and 22 feet long. It's too narrow to support the maintenance vehicles the Town uses to access its trail system. The existing North Bridge is 11 feet wide and 35 feet long. Both bridges are made of wood.

Figure 2: Existing South Bridge

Both bridges have scour critical, spread footing type foundations. The banks have been reinforced to protect the foundations, and those repairs are vulnerable to flood damage since they do not extend far beyond the ends of the bridge.

Figure 3: Existing North Bridge

Selected Design

To simplify maintenance, the Town of Chapel Hill specifically did not want wood to be used on the new bridges. They wanted a structure that was as close to maintenance free as they could obtain. That meant concrete and galvanized steel were the materials of choice. Furthermore, they did not want the new bridges to be scour critical.

Both bridges are designed with galvanized steel piles, galvanized rolled beams, and galvanized steel rails. They are also designed with precast concrete bent caps and deck panels. Except for the piles, each part is prefabricated and brought to the site. Figure 4 shows a partial rendering of the design for the South Bridge (Figure 4). The North Bridge is nearly identical.

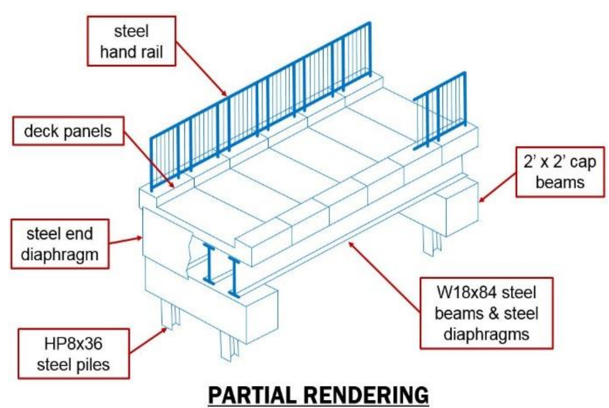

Figure 4: South Bridge Rendering

By using materials heavier than wood for the bridge construction, heavy equipment was evaluated for moving bridge elements. In an effort to keep the size and weight of elements made from these heavy materials as small as practical, prefabrication of smaller pieces was considered.

Both bridges are on the same path through the woods and there is no reasonable detour, requiring one be replaced right after the other. The new South Bridge spans 34 feet, the North Bridge spans 45 feet, and both provide a 12 foot wide usable deck.

With the linear fashion of the site, the first bridge along the path was designed to withstand the loads of the somewhat heavy construction equipment needed to cross the bridge to construct it and the second one.

Prefabricated concrete bridge elements are often more costly than constructing the elements in place. (This is not necessarily the case for steel elements.) These elements require custom forms that may or may not be reused after the project is complete. After fabrication, prefabricated elements have to be picked up and hauled to the site. And then they have to be installed and fitted to elements previously installed. In order to absorb the costs of these extra activities, good utilization of prefabricated elements required many identical elements, with only slight modifications made to differing elements when differences are necessary. It required the formwork be as simple as possible, and any item added to the precast element be a permanent installation.

Forming the deck panels was expected to be done on a concrete slab with nominal 2x thick lumber used as the sides of the forms. The slab would likely have to be off site, perhaps in the contractor's shop. And then, the panels would be shipped to the site on a flat-bed truck or trailer.

In order to keep prefabrication costs low, both bridges were designed with very similar prefabricated parts, and identical connection details. The only variability was within the precast panel lengths. Reinforcing, deck thickness, curb details, etc. were all consistent between the two bridges. The same philosophy was applied to the precast cap beams, with no variation between the North and South Bridges. Anchor bolts for bearings and handrail posts, and reinforcing in the deck panels were designed for lifting and moving the precast element, as well as their final intended connection use, See Figures 5 and 6.

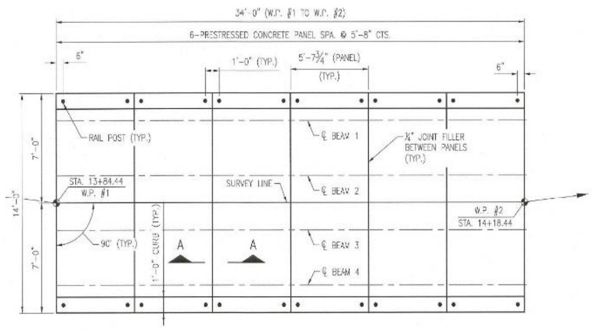

Figure 5: South Bridge Framing Plan

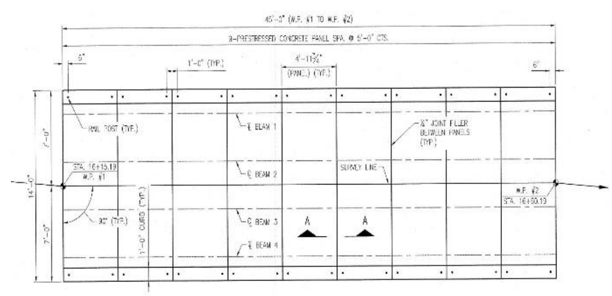

Figure 6: North Bridge Framing Plan

Aside from length and a few subtle details, both bridges are identical. In Figure 4, you will notice nearly every deck and rail segment is identical, with minor exception being given to the ends of the bridge. Similarities are provided between the two bridges, such as identical end bent caps, identical steel beam sections, and only a slight variation in precast deck panel length to accommodate the differing span lengths.

Steel is a simple material to use in a repeated fashion. The only variables in the steel details are length of beams used for the South and North Bridges, and the fact that the North Bridge required cambering to account for the dead and live load deflection of the bridge while in service.

Connections were made with conventional means. Cast-in-place anchor bolts were used for beam to bent cap connections, and handrail connections. Concrete inserts were installed on the bottom of the deck slabs to allow familiar construction methods to be used to connect them to the steel beams. Concrete inserts also simplified the deck panel construction by allowing the connecting elements to be entirely contained within the concrete pour for the panels. Cutting the forms was not required to make way for an anchor, and nothing protruded from the bottom of the panel, making construction of the panel simple.

In order to prevent difficult shear connections between the deck slab and the steel beams, the deck was designed as non-composite with the steel beams. This allowed the deck panels to simply be bolted to the steel beams. In order to ensure proper fit-up, the deck panel connection was designed with some room for construction tolerances. Furthermore, steel diaphragms were installed between the beams to ensure beams would remain properly braced in the event a deck panel connection would not provide adequate bracing.

Steel was used for the piles, beams, and handrails. Steel piles are readily available in North Carolina, and easy to move and install. The beams are the most primary structural element of the bridge, and steel provided the lightest weight material for the element doing most of the work. A concrete beam would have been massive by comparison and negated the entire suggested construction process. Due to its versatility and light weight, steel was the natural choice for the handrails. Due to its durability, concrete was used for the deck and bent caps. The end diaphragm was designed with steel, and a rugged and durable coating material was specified to protect the steel from the approach fill.

A Case for Prefabrication

Prefabricating bridge elements was selected to address two concerns, access and environmental concerns.

Access to, and construction within the site is a delicate operation. For a pedestrian, access is as simple as going for a walk. But access for construction equipment would typically require destroying part of the forest to provide wide and open access roads.

The most striking reason for prefabrication is the ability to pour concrete in the floodplain. Pouring concrete at a location where a seasonal high water elevation is above the deck elevation could pollute the streams the bridges cross if uncured concrete is washed into the stream during a storm.

Prefabrication resolved both of these concerns. In order to eliminate the need for heavy equipment and large staging areas disrupting the forest, prefabricated pieces were designed to be small enough, thus light enough, not to demand a large piece of equipment to place, eliminating that concern. Construction activities are moved out of the wooded floodplain and does not disrupt the forest. Pouring concrete in an otherwise dry location, and bringing precast pieces to the site eliminated the concern with the flood waters interfering with the concrete pours.

Proprietary Products

Proprietary products were explored in the design process. The weight of a prefabricated truss necessary to cross the creeks weighed considerably more than the prefabricated pieces designed for this project. Obtaining proprietary products can be cumbersome, and a government entity often has to go through a special process to justify using one specific supplier.

In an effort to keep engineering fees and potential risks low, engineers often turn to proprietary products when designing pedestrian bridges. But that negates the value and creativity the engineer could bring to the design process. Proprietary products have a well-deserved place in the repertoire of bridge design potentials. But installing them everywhere is not it. This engineer believes an engineer ought to consider their own talents first and see what special experiences and abilities they can bring to the design process. And if the engineer can’t provide a better product than these producers, then turn to proprietary products. Seek the best solution, without selling yourself out.

With an interest in prefabricated systems, this engineer took advantage of the opportunity and took some time to experiment and see if ABC elements could be borrowed from highway construction and applied here.

Construction Process & Engineering

Design engineers do not normally get involved with means and methods a contractor might wish to utilize. But for sake of designing and planning, a Suggested Construction Sequence was proposed and that suggested construction sequence was accounted for in the design. The project's specifications allowed the contractor to use other methods if they chose to. However, with narrow access provided in the civil engineering plans and concrete being placed below the normal high-water line, other methods would have been risky. More on specifications is described below.

Designing for the suggested construction sequence required the existing bridges be analyzed and the plans suggested heavy equipment be sized to fit within the existing bridge's capacity.

Access to the site is adjacent to an elementary school at the south end of the job site. The bridges are expected to be built from south to north with the South Bridge being built first, then the North Bridge. After the trail is widened slightly to give the selected construction equipment access, a 4 ton piece of equipment would install piles for the first end bent. The existing South Bridge would then get a new, temporary deck that would make it wide enough to support the 4 ton piece of equipment. That equipment would cross the South Bridge and then install piles at the second bent. It would then move to the North Bridge and repeat the process.

After the piles are installed, a crane on rubber tires weighing 40 tons would be used to demolish and construct both new bridges. The crane would have a long enough reach to place a 3.5 ton cap beam at the far shore and each 4 ton deck slab. It would only have to cross the South Bridge to access the entire site (Figure 7).

In order for the existing bridge to be used to support the 4 ton piece of equipment, and have enough space for the piece of equipment to drive onto the existing bridge, the end bent was designed to be founded on two piles located to the side of the existing trail. To ensure the existing bridge would not be affected by the piles or interfere with the piles, the new bridge was made 10 feet longer than the existing bridge.

Almost by accident, the steel beam size utilized for the North Bridge worked well for the South Bridge. The North Bridge is 11 feet longer than the South Bridge, requiring a larger steel section be used to support the pedestrian live load. By using that steel section on the South Bridge, a crane weighing 40 tons can be supported by the shorter span, and still support the pedestrian live load. The design team investigated the picking capacity of a number of cranes weighing 40 tons, and there are many available that can pick and place the prefabricated elements. As a result, the suggested construction sequence suggested a crane with an 4 ton weight that can be used for construction of the bridges, and only cross the South Bridge. A worst case axle configuration was considered in the design and listed in the plans.

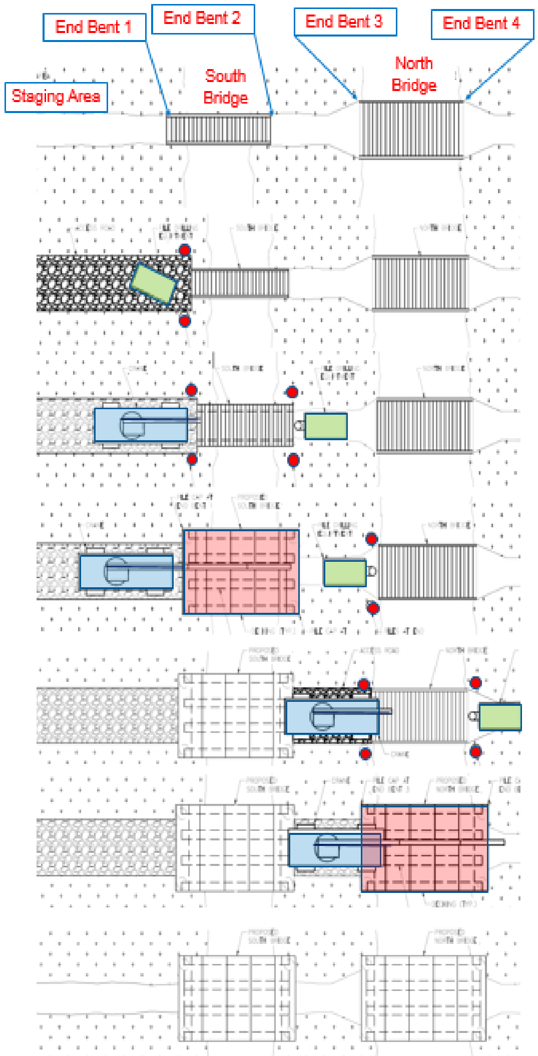

Figure 7: Construction Process

The prefabricated deck panels were evaluated for pedestrian loads, and the loads of the crane. A finite element model was used for analysis of the deck, and to determine load distribution to each of the steel beams and bearings (Figure 8). Deck panels and end bent caps were evaluated for picking and placement using simple beam mechanics. Bearing and rail anchors were used as the pick points, and their capacities verified. These assumed lifting points were indicated in the plans.

At the time this report was written, construction of the bridges had not begun. As with most projects this engineer is familiar with in the Triangle, the engineer's estimate was lower than what the market is providing. The engineer's estimates were approached with three methods, all of which centered around $300,000. Variables such as prefabricated elements and crane mobilization were considered.

A pre-bid meeting was mandatory for bidders. At this meeting, seven contractors expressed an interest in the project and only two contractors provided bids. The low bid was $462,000. The second low bid was $611,000. This is 54% and 103% above the engineer's estimate.

The engineer's estimate was reviewed by the design team during the design process, and after the bids were received. The design team and the owner believed the high bids to be a sign of the times in North Carolina, and an anomaly when weighed against the trends of the previous years. The area is growing, contractors are busy, and their full schedules are reflected in unpredictable bid results.

The team decided to rebid the project with two options for the bidders to consider. Option 1 is to build the South Bridge only. The other is to build both bridges as proposed. At the time this report is being written, the results of that rebid are not known.

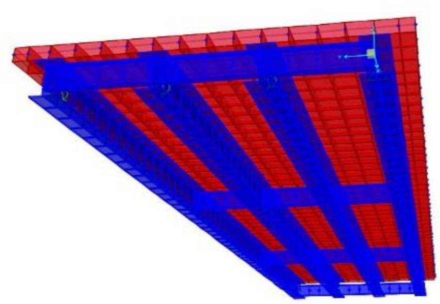

Figure 8: Finite Element Model

Specifications

As stated above, the prefabricated elements of this design are offered to the contractor as a "suggestion." The contractor has little other choice, so the suggested plan is all but required. But officially, the specifications do not require prefabrication. The contractor is required to submit changes to the proposed design and await approval, if they wish to construct the bridge without prefabricated elements or as stated in the suggested construction sequence.

Since the design of these bridges is closely tied to the suggested construction sequence, it's important to protect the integrity of the design if another construction method is implemented. Requiring the contractor to submit changes to the suggested construction sequence assures that the structural design will work with the new method. The suggested construction sequence proposes almost a worst case scenario, and any other method that gets proposed would most likely work within the confines of the design.

Another item addressed in the specifications is the use of micropiles. When this project was being developed, micropiles were expected to be the pile of choice. Connecting the micropile to the bent cap would have been simple. During the design process, it became apparent that obtaining micropile equipment might be expensive for a project of this size. So, the design team preserved the value of our investigation and listed micropiles as an option to the H-Piles we ended up specifying in the plans. As with the precast elements, the decision to use micropiles would be followed up with a submit, review, and approve process to ensure all the load paths are properly developed.

Summary

The Meadowmont project is a far cry from the intricate and glamorous structures we all aspire to be a part of. But when it comes to application of Accelerated Bridge Construction, Meadowmont has it all. With the implementation of Prefabricated Bridge Elements and Systems, the project tackles the challenges of environmental protection, space limitations, seasonal restrictions, and minimal time on site.

Pedestrian bridges are an excellent place for engineers to experiment and explore new ideas. There's a thirst for creativity and ingenuity by owners of these small structures aimed at making their projects more affordable, easy to construct, and protect the special settings they reside in.

For a little bridge project in the woods, the Meadowmont project received more attention that it might have, had it not been for an eye for opportunity and a desire to apply highway bridge construction methods to a little pair of bridges in Chapel Hill. Accelerated Bridge Construction made this project truly unique.

References

1. AASHTO, 2009 LRFD Guide Specifications for the Design of Pedestrian Bridges. Washington, DC: AASHTO.