Over the Top

By Richard C. Pennock, P.E. and Ronald E. Thompson, P.E.

Steel canopies offer a lighter and brighter view at several new stations for the Washington, D.C.-area rapid transit system.

From its opening day in March 1976, to the present, Washington, D.C.'s Metro commuter rail has maintained a uniform architectural appearance. The at- and above-grade stations feature distinctively arched, reinforced-concrete canopies at trackside to protect commuters from rain, snow and sun. The canopies' design mimics the column-free openness of the barrel-arch vault design of Metro's underground stations. Some Metro riders, however, will soon notice a subtle change: new, above-ground stations scheduled to open in December 2004, use steel "umbrella" canopies instead of the cast-in-place or pre-cast concrete canopies traditionally built at the system's 31 other surface stations.

The use of steel canopies at the new stations constituted a big change in engineering design but only a subtle departure from the original architectural concept. The change was partly a response by the Washington Metropolitan Area Transit Authority (WMATA) to feedback from commuters and elected officials that some of the concrete-canopy stations were dark and uninviting. Acordingly, WMATA's architects worked to develop a new station design to address community concerns.

WMATA's consultants, Capital Transit Consultants (CTC) began considering steel for canopy design in order to achieve a lighter and more delicate structural appearance. The conceptual design that developed called for exposed arched trusses spaced on 6'-8" centers. Although the structures were to be designed for the code-mandated loading conditions, WMATA conducted wind tunnel tests and determined load forces in the truss members using STAAD.Pro 2002.

Because one of the three new stations would be built within the District of Columbia, the new design concept required review and approval by the U.S. Commission of Fine Arts and the National Capitol Planning Commission.

With their approval in hand, WMATA was ready to move forward with the detailed design and construction of the steel-canopy concept for the new stations, providing bridging-type documents in its "Design-Build Request-For-Proposal." The two new stations discussed here (Morgan Boulevard and Largo Town Center), are part of a 3.1 mile lengthening of the commuter rail system's Blue Line that extends Metro beyond the Capital Beltway east of the city.

In fall 2002, WMATA awarded a design-build contract to Clark-Kiewit Largo, a joint venture of Clark Construction Group, Inc. of Bethesda, MD, and Kiewit Construction of Omaha, NE. The \$92 million contract includes designing and constructing two stations, ancillary parking facilities, and, at Morgan Boulevard, a childcare center. Morgan Boulevard is located just outside Washington's eastern city limits, while the next station, Largo Town Center, is the new line terminus at Largo, MD, just outside the Capital Beltway. Clark-Kiewit subcontracted the project's design to HSMM/STV Largo, a joint venture between Hayes, Seay, Mattern & Mattern, Inc., of Roanoke, VA, and STV Incorporated, New York City.

The HSMM/STV Largo team tackled the challenge of developing construction documents from the WMATA-provided design-build documents. Working closely with the design-builder and the structural steel subcontractor, the design-build team created a workable design, fabrication, and erection solution that met WMATA's vision for the canopy. Largo's platform canopy covers 385′ of the 600′-long structure and spans 44′-6″ over the 34′-wide platform, providing approximately 5′ over-the-track protection on each side. The Largo station design also included a 69′-2″ by 84′-8″ pavilion-roof structure, providing a station gateway from the south parking area. This stand-alone structure's design was relatively straightforward.

In contrast, at Morgan Boulevard, the pavilion design is cruciform. It overlaps with and draws commuters to the linear concourse canopy. Morgan's cruciform pavilion is 184′-8″ long by 69′-2″ wide on its long axis parallel to the concourse, while the right-angle intersecting section runs 111′-4″ by 69′-2." The concourse canopy is 251′-4″ by 40′-8."

The design-build team had to address critical fabrication and erection issues along with the complex design requirements. HSMM/STV structural engineers worked hand-in-hand with the design-builder, the structural steel fabricator, the steel erectors and WMATA to achieve an optimal design and construction solution at each station.

Structurally, the design called for triangular box girders to support trusses on the canopies' long axis. The unusual shape and relatively long length (from 33′-4″ to more than 75′), coupled with their thin (½″) plate sections, made handling the girders during fabrication, shipping/handling, and erection a tricky process at best. Controlling distortions in the fabrication shop was also a major concern. On-site erection, handled by AISC-member Williams Steel Erection Company, called for extensive field welding to provide an essentially seamless sightline for on-site appearance by Metro users, with erection connections cut-off and ground to a smooth finish for final coating. To avoid extensive field welds, the girders were fabricated to longer-than-usual lengths where possible.

Strict specifications applied to other tolerances affecting visual impact, including welds, cambers, member sweep and final alignments. The combined "forces" made erection a difficult exercise. Moreover, the design-build team had to carefully coordinate erection logistics at the Largo Town Center site, since the platform steel was erected simultaneously with erection of pre-cast panels and structural members of two multi-level garages flanking the platform.

Fabrication differed between the stations, but in general, the canopies are made from a pair of parallel, hollow triangular steel girders on the long axis, with a series of plate trusses spanning between the girders, and cantilevering beyond the girders and over the tracks. The girders are made from ½″ plate, with either a 1′-4″ or 2′ width at the base, depending on location. Each side tapers inward as it rises by 10 degrees from the vertical.

The plate trusses are, for the most part, 1¼″ thick at the platforms, and 1½″ at the pavilions The "valley" trusses for the Morgan cruciform are 2″ thick. The plate trusses also have a ½″-by-5″ flange along the top edge to provide a surface for attaching the steel roof deck. As with the other trusses, these are also set on 6′-8″ centers along the girder length.

The girders are supported by 14″- and 20″-diameter steel pipe columns that are, in turn, supported by an understructure of reinforced or pre-cast concrete. Strips of skylights located between the plate trusses run most of the length of the canopy to help create the brighter, more welcoming atmosphere sought by the public. The rest of the canopy is covered by exposed-to-view, painted acoustical Versa-Deck and topped with standing-seam roof decking. The Largo platform also uses acoustical Versa-Deck to minimize the reflective noise from approaching and departing trains.

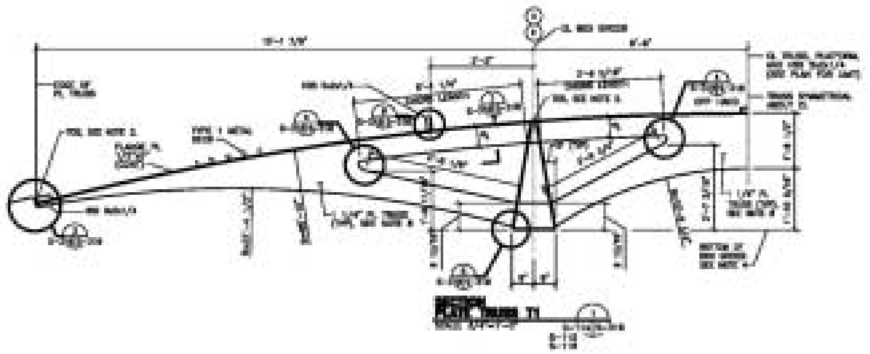
The hollow girders serve another important function in addition to their structural role. They offer an excellent location for recessed lighting, public address system speakers, mounting space for CCTV security cameras, and the electronic passenger information display system signage. The hollow columns provide out-of-sight conduit to support the various safety functions.

HSMM developed the detailed structural design for the Largo station and shared it with STV for the Morgan Boulevard station. STV modified the design for the canopy and detailed it to meet the needs of the cruciform pavilion.

Key to the project's success was the close design-build collaboration by the engineers and contractors with AISC-member fabricator Owen Steel Company. Owen personnel worked with engineers and contractors through every detail of design, fabrication and erection to resolve issues before construction. Some concerns included how to weld the relatively thin girder plates without causing warping; transferring tension and compression forces from the plate truss chords through the hollow girders; and how to provide temporary support to the truss plates before welding them in place to the girders.

The collaborative process led to minimizing weld sizes and to using fillet rather than full-penetration welds to reduce the possibility of heat warping. Contractor Clark-Kiewit demonstrated to the client that the fillet-weld offered the required strength and a better-looking finished product than the client-specified full-penetration welds.

This was particularly significant since the girder side plates were fairly flexible to begin with and lost some stiffness when holes were cut in the plate to accommodate light fixtures. The designers worked with Owen to attack this problem by adding internal stiffeners inside the girders to minimize the possibility of plate warping. The stiffeners



The triangular box girders (at column lines D and E) run parallel to the rail tracks, while the perpendicular plate trusses are attached every 6'-8" along the girder length.

themselves served a dual purpose. The cantilevered roof trusses, spaced on 6'-8" centers along the girder length, created significant tension (top) and compression (bottom) forces in the chords of the plate trusses that had to be transferred through the triangular, hollow girder. The stiffeners were placed inside the girders to match the locations of the truss chords, with a center hole cut to accommodate various system wiring. This solution was chosen after verifying that the welded stiffeners could hold the loads sufficiently.

Owen used Design Data's SDS/2 software to detail the project and used the software's automated downloading capabilities to export data into the SigmaNEST fabrication package. The software dictated the mill plate layout to cut the maximum number of truss plates from a single steel sheet. This "nested" program was imported into the cutting machines to yield a series of identical plate trusses. The equipment used to cut the plate trusses were L-Tec gantry burning tables outfitted with 'Burny' computer numerical controls (CNC). In all, some 1,234 tons of U.S.-made steel was consumed for canopies at the two stations, with much more used in the garages, rails and other features at the two sites.

When the new stations open, the public will enjoy these inviting above-ground stations that maintain the older stations' signature canopy but with a more user-friendly appearance and a brighter appearance. Refined public architecture is meeting the public's will with an "umbrella of steel" that took many collaborative hands to bring to realization.

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Project Owner
Washington Metropolitan Area Transit Authority (WMATA), Washington, D.C.

Design-Build Contractor
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Bethesda, MD

Architect/Structural Engineer
HSMM/STV Largo, A Joint Venture
HSMM, Inc., Roanoke, VA
STV, Incorporated, New York City

Steel Fabricator/Detailer
Owen Steel Company, Columbia, SC (AISC member)

Steel Erector
Williams Steel Erection Company, Manassas, VA (AISC member)

Structural Engineering Software
STAAD.Pro 2002

Detailing Software
SDS/2

Fabrication Software
SigmaNEST

Fabrication Machinery
ESAB L-Tec Steel Industry Products