SPECIAL FOCUS: BRIDGE INNOVATIONS

Continuous for Live Load Steel Girder Construction in the Northern Panhandle of West Virginia

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ABSTRACT

This paper presents two recently constructed steel girder bridges in the northern panhandle of West Virginia featuring simple for dead load–continuous for live load (SDCL) construction. The design, fabrication, construction and maintenance of this structure type are explored in addition to positive impacts on traffic control.

Keywords: steel bridges, steel girders, SDCL, simple for dead load–continuous for live load.

INTRODUCTION

The West Virginia Department of Transportation recently investigated the benefits of simple for dead load–continuous for live load (SDCL) bridges through the construction of the Three Springs Drive Bridge and the Washington Avenue Bridge in the northern panhandle of West Virginia. SDCL structures minimize or eliminate flange transitions for steel girders, provide the simplicity of simple span structures for fabrication and erection and eliminate problematic deck joints, as in typical continuous structures. These factors reduce costs, improve performance, reduce maintenance and accelerate construction.

STRUCTURE

These projects involve the replacement of the Three Springs Drive Bridge over U.S. Route 22 in Weirton, West Virigina, and the Washington Avenue Bridge over Interstate 70 in Wheeling, West Virginia. Both projects consist of replacing existing four-span bridges originally built in the 1960s with two-span steel SDCL structures. The existing Three Springs Drive Bridge was a prestressed concrete I-beam structure. The existing Washington Avenue Bridge consisted of rolled steel beams.

The final deck geometry of both replacement structures was very similar, with five 12-ft traffic lanes and two 3-ft-wide shoulders on an 8-in.-thick concrete deck at each location. A 5-ft-wide raised sidewalk is also present on one side of each structure, as shown in Figure 1. The only difference in deck width results from a slightly wider sidewalk barrier at the Washington Avenue location. The new Three Springs Drive Bridge was opened to traffic in 2007. The bridge at Washington Avenue was completed in 2008.

For Three Springs Drive, as shown in Figure 2, the deck is supported by seven 54-in.-deep weathering steel plate girders spaced at 11 ft 2 in. with spans of 125 ft 6 in. and 95 ft. Span lengths were dictated by the configuration of U.S. Route 22, and the 54-in. girder depth was based on preliminary depth studies. K-type cross frames are provided at intermediate locations.

The Washington Avenue Bridge, as shown in Figure 3, is supported by seven 45-in.-deep weathering steel plate girders spaced at 11 ft 2 in. with spans of 96 ft and 112 ft. Span lengths were dictated by the configuration of Interstate 70, and the 45-in. girder depth was limited by vertical clearance requirements. Bent plate diaphragms are provided at intermediate locations.

The steel girders were placed as simple spans to resist noncomposite forces. After placement of the deck in both spans, flange splices were connected over the pier to provide continuity for composite dead and live loads, and an integral concrete diaphragm was cast in place concurrent with the deck closure pour. Both structures are supported at the ends by jointless, integral abutments founded on steel H-piles. Mechanically stabilized earth (MSE) walls surround the integral abutments at the Washington Avenue location.

It was desirable to maintain traffic throughout construction at both locations; therefore, partial-width staged construction was used to allow on-alignment replacement of each bridge.

Girder Design

The steel continuity splice over the pier allows for simple span girder construction, which is then made continuous for

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composite loads. SDCL construction shifts negative moment from the interior support (typically higher for conventional girder structures) to the positive moment regions, as shown in Figure 4.

By shifting a portion of the load to positive moment regions that can develop resistances above yield and have compression flanges that are continuously braced by the deck, the mid-span and interior support cross-sections are similar. This reduces the number of flange transitions. For structures with smaller, more balanced span arrangements, transitions can be entirely eliminated, and the use of rolled sections becomes more economical.

At these West Virginia locations, span lengths dictated the use of plate girders rather than rolled beams. However, at the Washington Avenue Bridge, with a maximum span of 112 ft, flange transitions were completely eliminated, with 20-in.-wide plates of constant thickness used for both the top and bottom flange.

The maximum span length at the Three Springs Drive Bridge is 125 ft 6 in. The positive moment in this span dictated two flange transitions for economy. The bottom flange remains a constant 20 in. wide, while its thickness varies from 1 to 1½ in. The top flange remains a constant 1 in. thick, while varying in width only for each span.

Steel Continuity Splice

SDCL construction was accomplished by splicing the top and bottom flanges of the simple span girders at the interior support location after placement and curing of the deck, which was poured to within 5 ft of the centerline of bearing at the abutments and pier (pouring the deck as near as possible to the supports minimized noncomposite forces on the continuity splice). The girders were placed on elastomeric bearings with preformed joint filler between the remaining

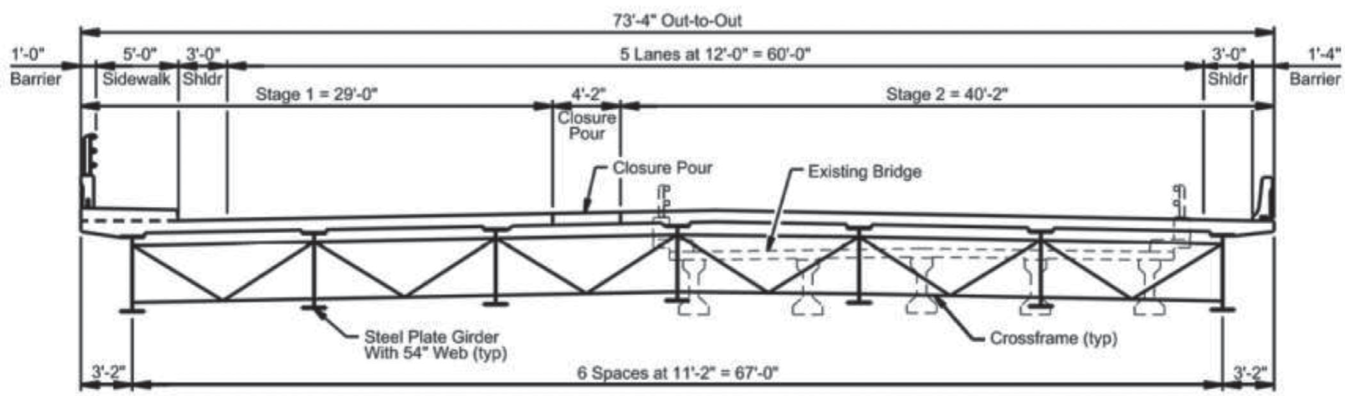

Fig. 1. Three Springs Drive typical section. Washington Avenue is similar with 45-in.-deep girders and bent plate diaphragms.

Fig. 2. Three Springs Drive.

Fig. 3. Washington Avenue.

portions of the girder bottom flange and top of pier cap. The remainder of the pier cap was covered with a ½-in. layer of preformed joint filler to allow rotation of the concrete diaphragm under live loads after completion of the structure, as shown in Figure 5.

Design of the steel continuity splice was accomplished by resolving the factored moment at the pier into a force couple. Flange to web welds in the vicinity of the splice were sized to allow the portion of the moment resisted by the web to be transferred into the top and bottom flanges. An outside bolted splice plate in single shear was used to transmit the top flange tension force of the composite section. The connection was considered slip-critical. The contribution of deck reinforcement was not included in the tension capacity of the splice, providing redundancy in the system. To transmit the compression force of the bottom flange, steel-bearing plates were placed between the bottom portion of the girder webs and flanges. At the Three Springs Bridge, this was achieved through the use of steel end plates welded to the girder web, with bearing plates and shims filling the void between the end plates, as shown in Figure 6. A slightly simpler detail was used at the Washington Avenue location, with the bearing plates welded directly to the web without a steel end plate. At both locations, steel shims were placed between the bearing plates after placement of the deck, with the majority of dead load rotations realized.

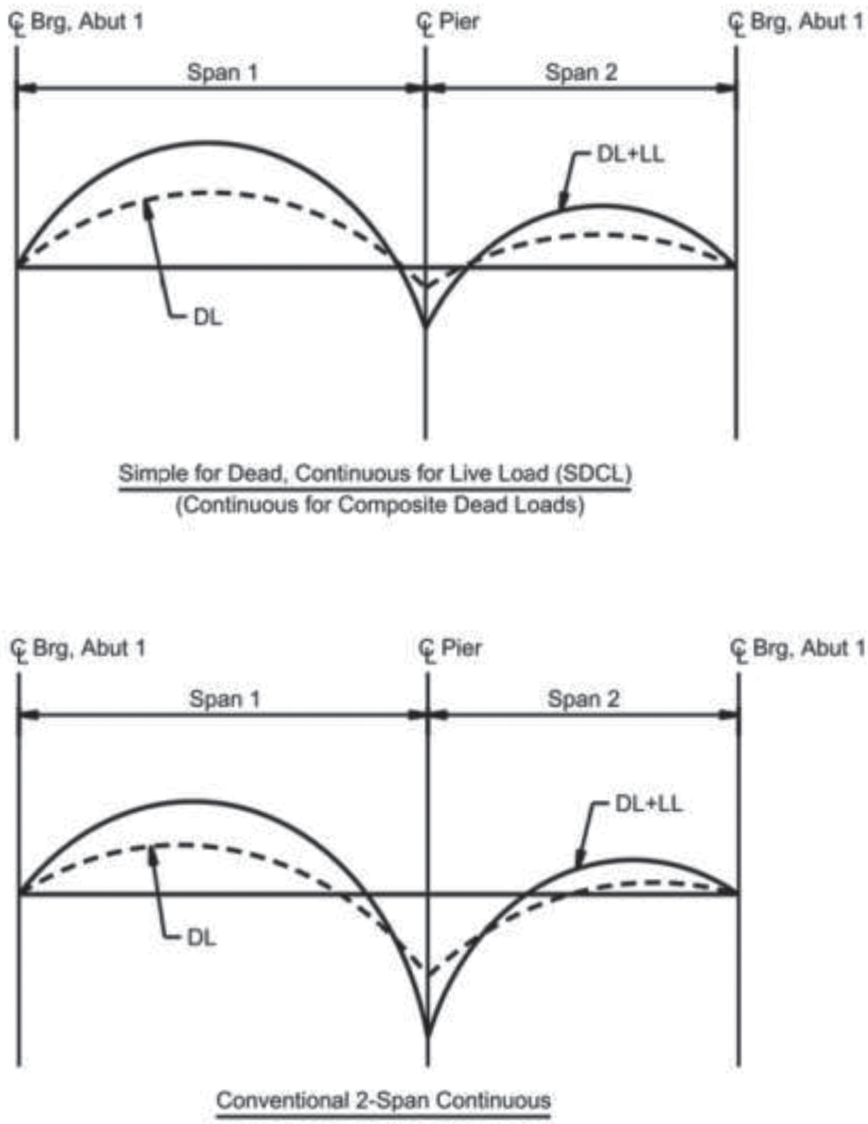

Fig. 4. SDCL and continuous-span moment diagrams.

To anchor the superstructure at the pier, reinforcement bars were used as dowels extending from the pier cap into the concrete diaphragm. Transverse bars were placed through holes in the girder webs, and shear stirrups were used to form a cage extending from above the pier cap into the deck. After completing the reinforcement, the diaphragms, including the deck within 5 ft of the centerline of pier and abutments, were placed. The completed diaphragm is shown in Figure 7.

To provide stability at the supports during placement of the deck, temporary cross frames, as shown in Figure 8, and consisting of threaded bars with turnbuckles for the diagonals were used. After the deck was cured, these temporary cross frames were removed to allow space for completion of the steel continuity splice and minimize the possibility of corrosion and voids within the concrete diaphragm.

FABRICATION BENEFITS

SDCL girder designs provide potential cost and time benefits during fabrication. Based on preliminary design studies, it is believed that balanced span lengths less than 100 ft provide the optimal situation for efficiency by reducing steel weight and eliminating full-penetration welds in the flanges. As the span lengths increase or become unbalanced, evaluating the construction, traffic and maintenance benefits of SDCL structures plays a greater importance in determining their efficiency.

Because of its increased and unbalanced span lengths (125 ft 6 in. and 95 ft), the Three Springs Drive structure required welded plate girders with two bottom flange transitions in the longer span. The structure's steel weight of 24 lb/ft^2 was comparable to conventional continuous girders. However, the number of plate thickness transitions was reduced.

The Washington Avenue structure's steel weight of 25 lb/ft^2 was comparable and also in line with conventional continuous girders. However, with a more favorable span balance (96 and 112 ft), flange transitions were completely eliminated from the design.

Thus, while the steel weight for each of these structures was in line with conventional continuous steel girders, the elimination of welds associated with flange transitions did offer some advantage.

In addition to advantages in girder fabrication, the use of concrete diaphragms at the piers eliminates the need for larger, more complex steel cross frames at the supports to transmit lateral loads. The use of concrete diaphragms also leads to simplified bearing pads, which don't require steel sole plates welded to the girder flanges.

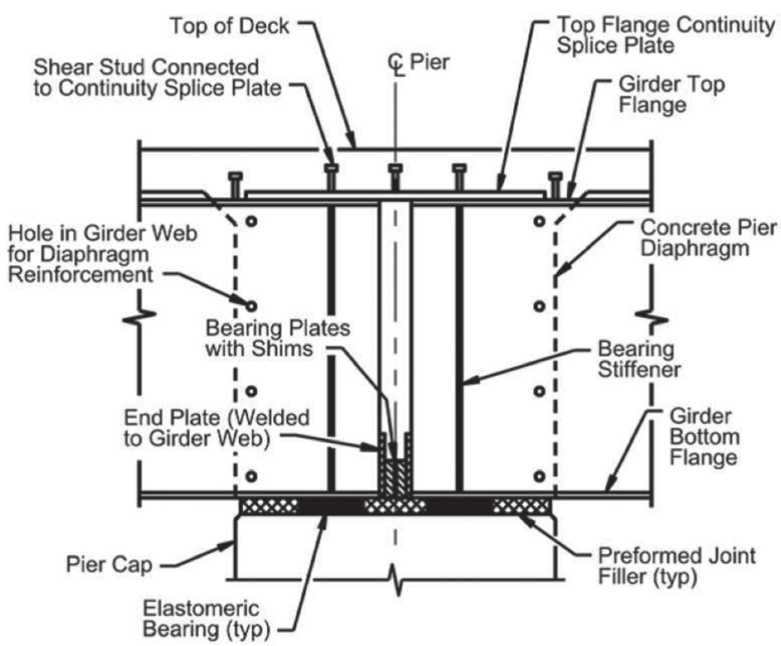

Fig. 5. Steel continuity splice details.

CONSTRUCTION BENEFITS

SDCL girders accelerate construction by eliminating in-span field splices and reducing complex steel details. Moving the splice from a typical inflection point for continuous girders to the pier location eliminates the need for temporary supports and working over traffic, which leads to increased worker safety. The type of splice used for SDCL girders is also less complex, reducing labor and skill-level requirements.

The continuity splice also reduces crane requirements. Because the splice is made at the interior supports, cranes do not have to hold pieces while connections are being made, reducing crane hold times.

Because the structure does not rely on the splice to provide stability for the bridge, the splice is removed from the critical path. Therefore, the construction of the splice can be performed when convenient, possibly when barrier formwork is being installed.

These projects also show SDCL construction's compatibility with partial-width staged construction. Both of these locations required maintenance of traffic with an online replacement.

TRAFFIC BENEFITS

Another benefit of SDCL construction is the positive effect on traffic control. For standard highway overpass structures, such as Three Springs Drive and Washington Avenue, installing girders as simple spans requires the closure of only one direction of a divided highway. If these structures were conventional continuous structures, both directions of traffic would have been closed and rerouted at times. As constructed, entrance and exit ramps were utilized to reroute traffic for closed lanes, minimizing the impact.

Another aspect of SDCL construction is the possibility of complete span-by-span construction. Due to staged construction in conjunction with the existing bridge, this was not possible at these locations. For structures constructed in one stage (such as a new alignment), one direction of traffic below the structure can be rerouted or shifted, and the span can be entirely constructed without live traffic underneath. This includes abutment, pier, girders and deck. If desired, the girder design could also accommodate the placement of the abutment diaphragm and barriers in the span before advancing. After completion of the span, traffic could be shifted from below the second span and the process repeated. The

Fig. 6. Three Springs Drive continuity splice.

final step would be the installation of the continuity splice and concrete diaphragm at the pier(s).

There are several cost and schedule benefits to this construction approach. First, because one entire span is constructed at a time, traffic only needs to be shifted once. This simplifies the maintenance and protection of traffic, minimizing construction time and cost spent on installation and subsequent adjustment of detour devices. Second, shifting traffic away from a span for its entire construction eliminates the time, cost, coordination and public relations associated with overnight or momentary traffic closures for girder erection and shielding. Finally, the removal of traffic under the span during the entire construction allows for versatility in material staging and crane placement, in addition to eliminating the need for shielding.

Also, for small spans and construction sites with large lay-down areas, complete spans can be constructed on temporary supports and lifted into place. This method would limit traffic disruption to a few night closures.

MAINTENANCE BENEFITS

The pier splice eliminates joints typical in simple span construction. The elimination of this joint prevents corrosion of the steel girders due to water. The concrete diaphragm also protects the girder ends and shields the pier cap from sediment buildup, which can lead to deterioration of the concrete, bearing pads and associated assemblies. These details, in combination with integral abutments, create jointless steel bridges with no exposed bearings or girder ends. This eliminates some of the primary areas of concern for maintenance going forward.

For smaller spans, the compression force in the bottom flange at the pier location could be transmitted through the concrete diaphragm alone, using end plates without steel shims between and relying on the compression strength of the diaphragm concrete. Additionally, the top flange tension splice could be carried through the reinforcement of the concrete deck. However, the use of simple steel connections between the top and bottom flanges in conjunction with the concrete diaphragm provides redundancy in the event of a component failure.

LESSONS LEARNED

The design and construction of these structures leads to several observations about SDCL construction. When integral abutments are used in conjunction with a continuity splice and reinforcement bar dowels at the pier, there is no lateral attachment of the superstructure to the substructure until the pier diaphragm is cast. If threaded anchor bolts through the girder flanges are not provided, then dimensions locating the girder ends relative to each other under the steel and steel plus concrete deck conditions should be provided on the design drawings, which account for girder end rotation under dead loads.

An alternate method would be to provide a temporary linkage connecting the girder webs at the neutral axis of the girders, as shown in Figure 9. A steel bar bolted to the webs could be used to maintain the proper distance between bearing centerlines. The bearing pad should be checked for the resulting deformation at the bottom flange from the deck pour. Additional ways of providing for construction

Fig. 7. Completed diaphragm.

Fig. 8. Temporary cross frames at supports.

flexibility would be to specify field drilling of the holes in the girder web for diaphragm reinforcement and also in the top flange for the splice plate connection.

Additional items of interest include detailing of deck reinforcement in the design drawings. In the vicinity of the top flange splice, reinforcement should be spaced to allow for field drilling and bolting. Also, consideration should be given to installing the pier diaphragm reinforcement cage after the temporary cross-frames have been removed and the steel continuity splice has been made.

Finally, instead of using flat shim plates to provide continuity between bottom flanges at the splice, "wedged kicker plates" could be used (Wasserman, 2005). These wedged shims can be driven in the field and will ensure a more complete contact of the plates.

CONCLUSION

The use of simple for dead–continuous for live load steel girders for the replacement of the Three Springs Drive and Washington Avenue Bridges in the northern panhandle of West Virginia proved successful. While the savings in steel weight versus conventional continuous girder construction proved negligible on these structures, benefits in fabrication, construction and future maintenance were evident. These projects also showed the advantages of SDCL construction regarding traffic control and the compatibility of SDCL construction with staged construction.

REFERENCES

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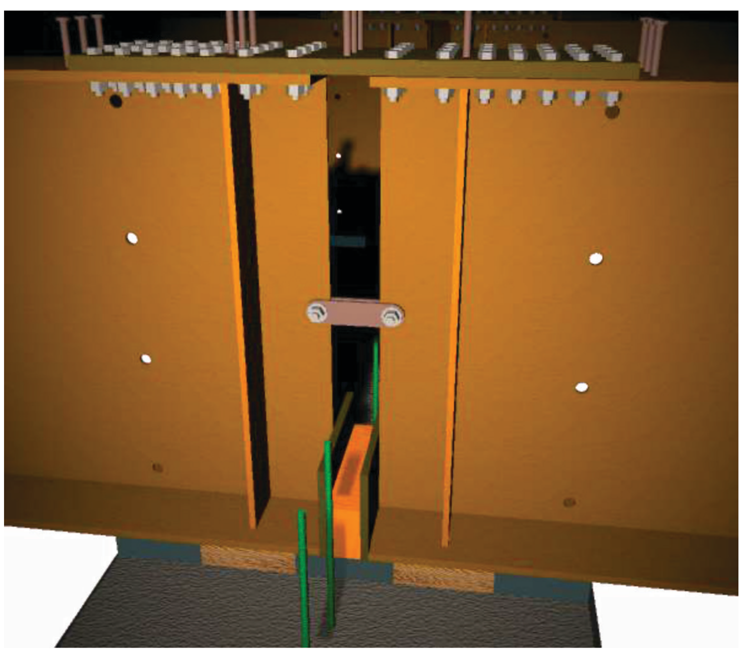

Fig. 9. Continuity diaphragm showing temporary linkage in web.