CALIFORNIA NEW PRECAST WIDEFLANGE GIRDER AND ITS APPLICATIONS

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ABSTRACT

To promote the Accelerated Bridge Construction (ABC), as well as economic design and standard detailing practices of precast prestressed concrete bridges in California, the California Department of Transportation (Caltrans), along with California precast industry experts, have recently developed a new and improved standard precast wide-flange girder shape. This new girder type has the span capability of exceeding 200 ft with or without splicing and its depth-to-span ratios are comparable to those of cast-in-place post-tensioned box girders. The section has a large bottom flange that can accommodate a large number of strands which increases flexure capacity for simple span and provides larger compression area for continuous spans. Combined with the use of high-strength concrete, the spans and girder spacing can be maximized. Two standard web widths, 6 ½-inch and 8-inch, were developed for the girder shape. The 6 ½-inch web is used mainly for pretensioned girders and the 8-inch web is for post-tensioned girders where splicing for continuity is desired. Both girder shapes can be manufactured by making minor modification to the production form with no cost increase. This paper introduces the girder development process, presents the standard typical sections and describes major features of the girder shape. Cost analysis and comparison of the new girders with other existing shapes are summarized. Also, several completed design and construction projects for both pre-tensioned and post-tensioned wide-flange girders are illustrated.

Keywords: Precast Bridge; Wide-Flange Girders; Accelerated Bridge Construction (ABC); Long Span

BACKGROUND

Precast prestressed concrete bridge construction is gaining popularity in California due to its benefits such as speed in construction, minimal traffic disruption, minimal environmental impacts, high quality and durability, and improved worker safety. Furthermore, implementation of Accelerated Bridge Construction (ABC) program[1] in California that requires innovative design and planning, together with materials and construction method, has also made precast concrete girder construction the material of choice in keeping the California highway system up with its steadily growing population and improving economy.

To promote Accelerated Bridge Construction, as well as economic design and standard detailing practices of precast prestressed concrete bridges in California, the California Department of Transportation (Caltrans), along with California precast industry experts, have recently developed a new and improved standard precast wide-flange girder shape.

The new section was developed based on the 2007 AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications along with the California Amendments, which required bridges to be designed for significantly heavier HL-93 and Permit Truck (P15) live loadings in California.

DEVELOPMENT OF NEW GIRDER SHAPE

In summer of 2007, Caltrans initiated a team effort to develop a more efficient girder shape with the goals of extending girder span, reducing number of girders line and structural depth while capable of supporting the new HL-93 and P15 loads. One other goal was to reduce the number of expansion joints in the bridge structure by extending the span length. Using less expansion joint increases the number of structure redundancies and therefore improves seismic performance of bridges. This is an important design feature as most of the bridges in California are located in regions with moderate to high seismicity. The team comprised of Caltrans Management and Engineers and the precast industry experts.

After an extensive study of the existing California Bulb Tee Girders (CA-BT), it was found that capacity of the CA-BT section is often limited by the compression capacity of the bottom bulb. Also, the height of the CA-BT girder is limited to a maximum girder depth "D" of 7'-0 5/8" (2150 mm) primarily due to the concern about stability of the girders during transportation and erection. Figure 1 shows the shape and dimensions of the standard California Bulb Tee Girders (CA-BT).

At that time, several other State DOTs were developing or have developed much more efficient girders and used them successfully. These included the Nebraska NU Girders[2], Florida DOT Girders[3], and Washington Department of Transportation Wide Flange Girders[4]. California wide-flange girders referenced some of desired girder features based on the NU Girders, Florida girders and WDOT wide flange girders.

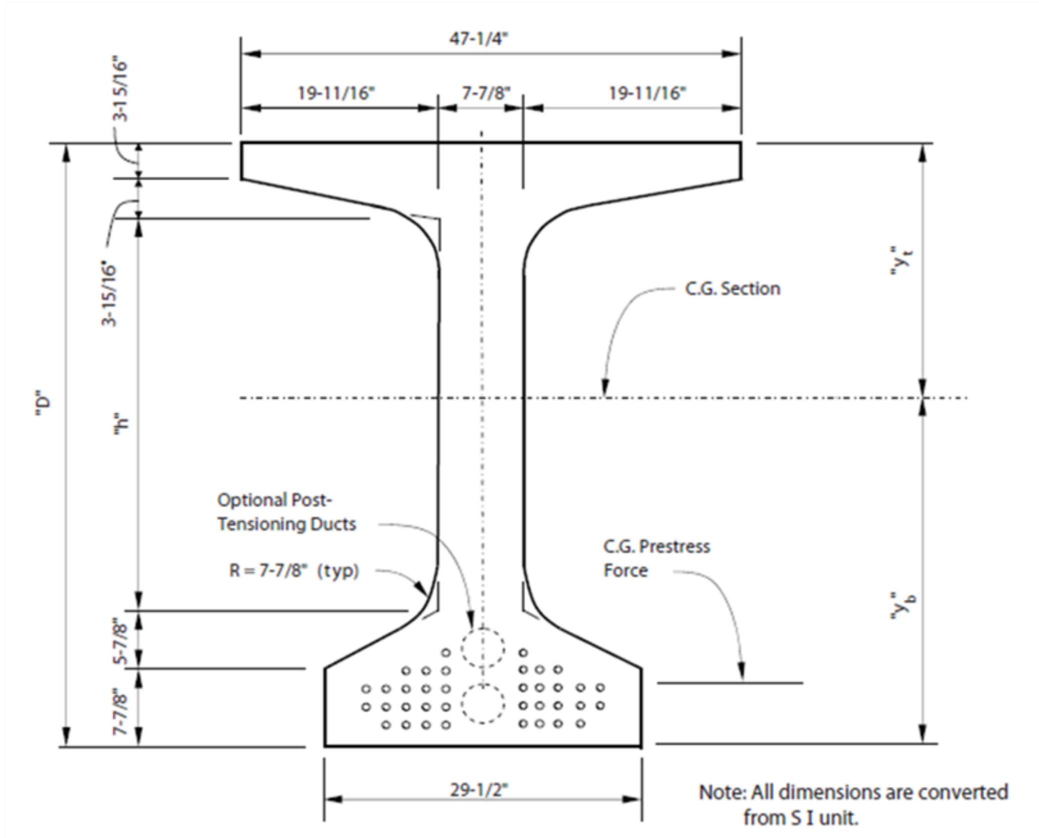

Fig. 1 - California Standard Bulb Tee Girders (CA-BT) [5]

FEATURES OF NEW WIDE-FLANGE GIRDERS

This new girder type has the span capability of exceeding 200 feet with or without splicing and its depth-to-span ratios are in the range of 0.040 to 0.045, which is comparable to those of widely-used cast-in-place post-tensioned box girders in California. The section has a large bottom flange that can accommodate a large number of strands which increases flexure capacity for simple span and provides larger compression area for continuous spans. Combined with the use of high-strength concrete and debonding features, the spans and girder spacing can be maximized.

GIRDER SHAPE

Two standard web widths, 6 ½-inch and 8-inch, were developed for the girder shape. The 6 ½-inch web (Fig. 2) is used mainly for pretensioned girders and the 8-inch web (Fig. 3) is for post-tensioned girders where splicing for continuity is desired. The 6 1/2-inch web pretensioned girder is designated as Wide Flange Girder (WF) and the 8-inch web girder is called Wide Flange Post-Tensioned Girder (WF-PT).

The new shapes show several improvements in structural efficiency compare to the old Bulb Tee section. Some of the important features are:

- Bottom flange width increased from 29-1/2" to 45" & 46 ½"
- Girder web reduced from 7-7/8" to 6-1/2" for WF
- Girder web increased from 7/7/8" to 8" for WF-PT

Both girder shapes can be manufactured by making minor modification to the production form with small or no cost increase. The 8-inch web is needed to accommodate the post-tensioning ducts. California Amendments to AASHTO LRFD Bridge Design Specifications increases the limit of duct size to the web thickness ratio from 40% to 50%. The 8-inch web can accommodate a maximum 4-inch outside diameter ducts, which can fit a large 21-0.6" strands PT system.

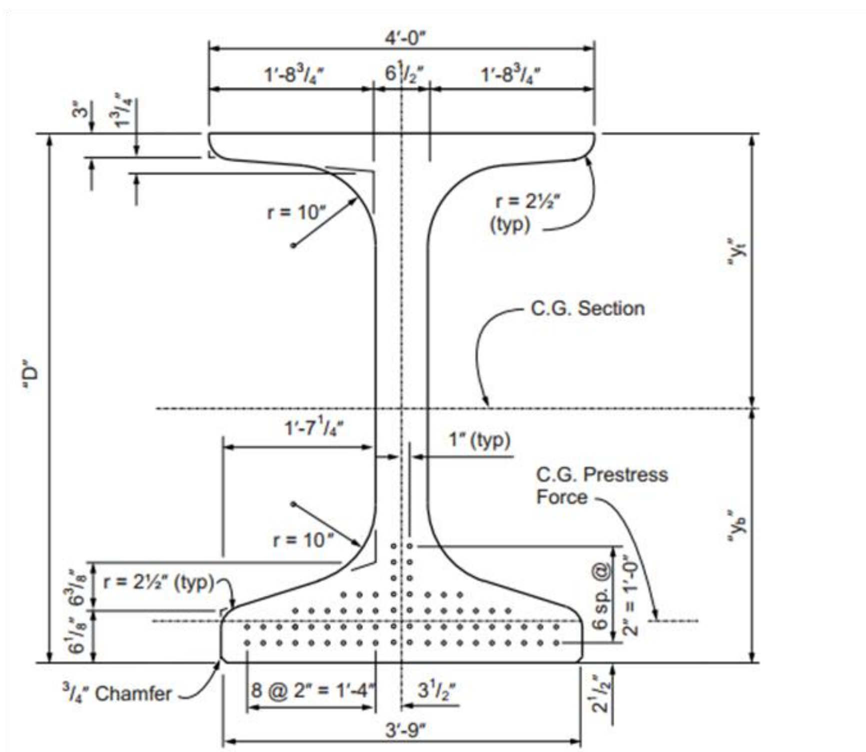

Fig. 2 - Pretensioned Wide Flange Girder (WF)[5]

Weight of the new WF and WF-PT girders is comparable to the Standard Bulb Tee girders. For example, a 1,850mm (6'-0 7/8") CA-BT girder weighs 1,108 lbs/ft[5], 6'-0" WF girder (WF72) weighs 1,080 lbs/ft[5] and 6'-0" WF-PT weighs about 1,190 lbs/ft[5]. Apparently the WF girders are lighter and WF-PT girders are slightly heavier than CA-BT girders. However, due to increase in number of strands that can be placed in the bottom bulb of the

WF girder (50 strands in CA-BT vs. 70 strands in WF girder), the WF girders are capable of spanning larger length, improving structural efficiency, and thus reducing total bridge cost.

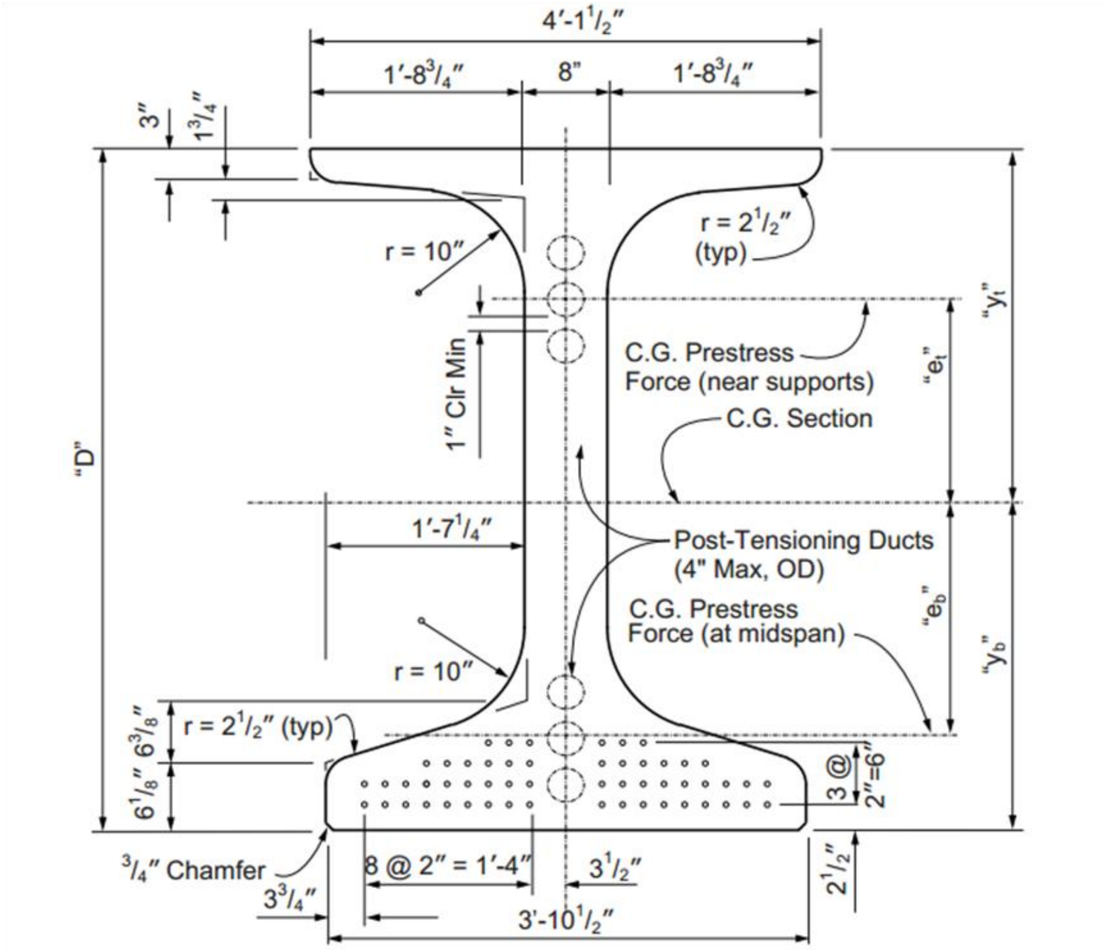

Fig. 3 - Post-tensioned Wide Flange Girder (WF-PT)[5]

DEPTH AND SPACING

There are thirteen girder depths developed for the WF girders. The shallowest girder is 4'-0" deep by Caltrans Standards. Several precast manufactures stated that they could even produce 3'-0" deep girder as well, if required by the job site. The deepest girder is 10'-0" deep. Girder depth increases in 6" increments within this range. To reduce the cost of the forms, the precast producers typically choose to add side forms for the web in incremental heights for producing different girder depth.

Like many other state department of transportation, Caltrans does not have specific requirements for deflections. However, it is a common practice at Caltrans to limit the bridge depth-to-span ratio and girder spacing for typical concrete bridges. The typical depth-to-span ratios for any other pre-tensioned girders are normally 0.050-0.055 for simply supported spans and 0.045-0.050 for continuous spans. For pre-tensioned wide flange girders, the depth-to-span ratio could reduce to 0.045-0.050 for simply supported spans and 0.040-0.045 for continuous spans. The girder spacing for precast bridges is typically set at 1.25 to 1.75 times the structure depth. For example, a 6'-0" structure depth (girder + haunch + deck slab) will have girder spacing between 7'-6" to 10'-6".

SPLICED GIRDER

When considering using post-tensioned spliced girder for longer span bridges, the first thing is to select girder web to be 8” wide to accommodate the post-tensioning ducts. Therefore, when post-tensioning is used to splice wide flange girder segments together, span lengths of over 180-200 feet have been targeted. The depth-to-span ratio for post-tensioned spliced girders is approximately 0.040. The new WF girders have very efficient girder sections and could normally be spaced at the distance of two-times the bridge depth. If girder spacing has been designed closely, the depth-to-span ratio for post-tensioned spliced WF girders even could be in the range of 0.035 to 0.038.

To avoid any congestion of pre-tensioning strands and post-tensioning tendons in the spliced girders, using straight strands is a much more desirable alternative than harping, by allowing maximum up to 33 percent debonded strands, to control tensile stresses at the top fiber of the girder ends. The cross-section, due to significantly wider top and bottom flanges, has a larger lateral moment of inertia. The increased stiffness in the weak direction requires minimal, if any, lateral bracing to prevent buckling failure during transportation.

MATERIALS

To maximize the efficiency of the wide flange girders, high strength concrete in the range of 5.0 ksi to 9.0 ksi is commonly specified as design strength. Since precast girders are produced in a controlled environment, high quality and high strength concrete is much easier to obtain, comparing to cast in place concrete.

PERFORMANCE OF WIDE FLANGE GIRDERS

During the development phase of these new girders, Caltrans contracted with PCI West and Post, Buckley, Schuh & Jernigan (PBS&J) Corporation to conduct two feasibility studies of the new WF girders (previously called "Super Girder"). The first study intended to compare the performance efficiency of the new Pretensioned WF girders with existing California Bulb-Tee girders. The second study aimed to compare the construction cost-effectiveness of the new Post-Tensioned WF Girders with the California most common bridge type, the Cast-In-Place Post-Tensioned (CIP PT) Box Girder.

SUMMARY OF PERFORMANCE-EFFICIENCY STUDY:

In this study, two structural designs were performed for a 2-span precast pretensioned concrete bridge. The first design used the Pretensioned WF girders for the superstructure and the second design utilized the Pretensioned Bulb-Tee girders. The span length was varied and results of the study are plotted in Fig. 4. The additional study of the WF Girders with threaded rods over bent supports for carrying the weight of deck in a continuous span configuration is not presented in this paper.

In the study, the girder depth was kept constant while the girder spacing and span length were varied and optimized for each girder type. In Fig. 4, the red line represents the change in girder spacing for a 72-in. CA-BT Girders, while the blue line represents the change in girder spacing for WF Girders ("Super Girders"), as the span length decreases.

As shown in Fig. 4, for a span length of 170 ft, the required 72-in. CA-BT girder spacing is 6.0' comparing with the much larger 10.7' for the WF girders. This proved that WF girders would require less girder lines for the same bridge width (10.7/6.0 = 178% increase in efficiency). As a result, the cost on per square foot basis for the WF girder bridge would be lower than that for CA-BT girder bridge. Also from Figure 4, with certain girder spacing, say 10.0', the 72" deep CA-BT girder has a span capacity of 150' while the WF girder can span up to 175' for the same girder depth. From another aspect, for the same span, the WF girder requires shallower depth than the CA-BT girder, which is a highly desirable feature for widening projects where the vertical clearance is often limited by the existing roadway profile.

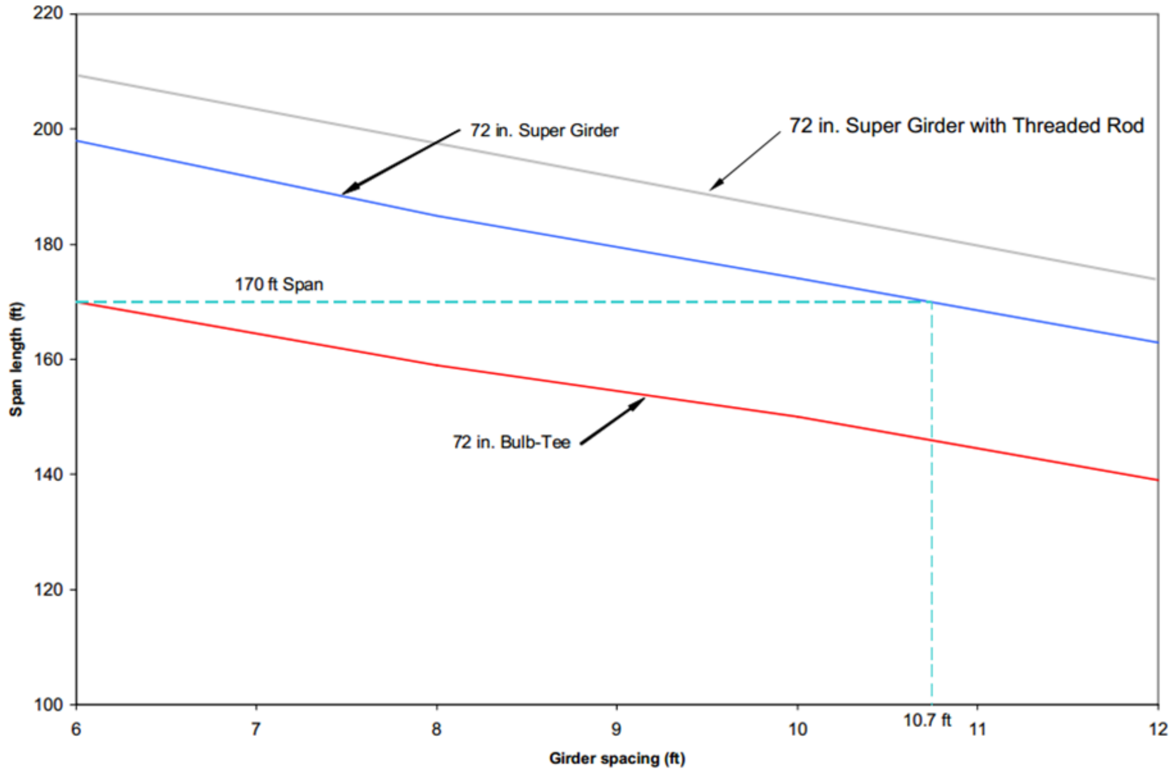

Fig. 4 - Comparison between Bulb-Tee and Wide Flange Girder (Super Girders)[6]

SUMMARY OF COST-EFFECTIVENESS STUDY

A cost comparison of a 2-span bridge using the new Post-Tensioned WF girders and CIP PT Concrete Box girder was conducted. The example bridge has two equal 175'-9" spans with a total bridge width of 70'-0". Results of the study are summarized in Table 1.

Table 1. Cost Comparison[6†]

Item	Wide Flange Girder	CIP PS Box Girder	Ratio (CIP PS/WF)
Superstructure	$2,034,000	$2,515,000	1.24
Substructure	$770,000	$1,055,000	1.37
Other*	$398,000	$304,000	0.76
Total	$3,202,000	$3,874,000	1.21

†Based on 2007 Caltrans Construction Cost Index
*Includes approach slab, concrete barriers and joint seals.

As shown in Table 1, the WF girder has a total bridge cost of $3,202,000 comparing to a total cost of $3,874,000 for CIP PT Box Girder. The construction and material cost of the Post-Tensioned WF girders is approximately 20% less than the cost of the CIP PT box girder bridge.

It can be concluded from these two studies that the new WF girders are more efficient than the existing CA-BT girders and cost less than the conventional CIP PT Box Girders in California. In addition, like all other precast construction, the WF girders also have the benefits of reduced construction time, minimized falsework, and improved worker safety. The WF girder system is well suited for the California Acceleration Bridge Construction program.

APPLICATIONS

Due to its highly efficient shapes, the wide flange girders have been gaining popularity very quickly in California bridge construction. Since its inception, there are several projects already under construction and many in the final design phases today.

Following is a list of several bridges that are currently in construction stage.

- Route 219/99 Separation (Replace) Bridge, Two-Spans, 102' and 102', WF Girders
- Old Redwood Hwy OC (Replace), Two-Spans, 128.5’ and 133.3’, WF-PT Girders
- Butterfield Blvd, Single-Span, 129.5', WF Girders
- SR 4 Cross Town Viaduct, 2870’ long, Span varies from 115' to 165', WF Girders
- Green Valley Road OC, Single-Span, 165.5’, WF Girders
- San Antonio Drive Undercrossing, Single-Span, 159'-0", WF Girders
- Reigo Road Overcrossing, Two-Spans, 154’ and 141’, WF-PT Girders

Fig. 5 - Pretensioned Wide Flange Girder fabricated for Butterfield Blvd

Fig. 6 - Post-Tensioned Wide Flange Girders fabricated for Riego Road OC

SUMMARY

In summary, the California Department of Transportation (Caltrans), along with California precast industry experts, have recently developed a new and improved standard precast wide-flange girder shape. This new girder type has the span capability of exceeding 200 feet with or without splicing and its depth-to-span ratios are comparable to those of cast-in-place post-tensioned box girders. The section has a large bottom flange that can accommodate a large number of strands which increases flexure capacity for simple span and provides larger compression area for continuous spans. Several bridges in California which use the new section are currently in construction or close to completion, and there are more on the way to be constructed. As California moves forward to improve mobility on an unprecedented scale, the new and efficient wide-flange girder type, combined with high performance materials, can provide a cost-effective way to accelerate delivery of bridge improvement projects in California.

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