Small bridge planning can be a very challenging task. The elements influencing the planning process and making up the project program are similar and often equal to those of larger structures, while project budgets are quite limited.

Yakima County, Washington required a replacement of a bridge over Naches River at Nile along a new alignment (Fig. 1). Naches River is in Central Washington on the eastern slope of Cascade Mountains. The bridge site is in a remote area, about 40 miles from the nearest city and about 150 miles from the nearest concrete precasting yard. The road and structure are expected to carry log trucks in addition to other vehicles. The river is a swift mountain stream which at high stages may carry 18,000 cfs (1,000
cfs average) at the bridge site. Flood flows carry also drift and may carry ice.

The river banks are low with about ¼ mile of flood plain—requiring approach roadways on embankments for both sides of the river. The river bed is made of alluvial deposits—sand and round gravel. Obstructions in the stream produce severe scouring and shifting of the channel.

The main channel is slightly more than 150 ft. wide. It was desired to cross it without piers in the channel. It also was felt to be advantageous to keep the bridge superstructure as shallow as practical in order to reduce the height of required approach roadway embankments while preserving vertical clearance for passage of floating matter during floods.

The structural scheme chosen for the above ends is a grillwork consisting of six lines of precast prestressed concrete girders cantilevering 30 ft. over piers which are 155 feet apart. The girder ends are encased in deep, thick and heavy concrete endwalls which retain embankment material and increase dead load cantilever moment over piers; the girder webs are connected with deep diaphragms at 30 and 38 ft. centers. The structure has been designed in accordance with current AASHO Specifications for Highway Bridge Design for H20-S16 loading. The roadway is 26 ft. wide with 1 ft. high and 2 ft. wide curbs on each side (Fig. 2).

The bridge superstructure is 5 ft. 5 in. deep. L/d ratio is 28.5. There are several prestressed concrete yards in the area—all of them about 150 to 200 miles away. Girder transportation over such distances is costly and a difficult item. In order to simplify transport and handling the girders were detailed in three pieces—end pieces 62 ft. long each with cast in ducts for field prestressing tendons and a middle piece 90 ft. long, plant prestressed for it's own moment envelope plus ducts for field prestressing.

In planning a small project in a remote area such as this, overall project economy makes up a large part of the design considerations, requiring choice and arrangement of structural components for the maximum possible efficiency both structural and economic. Of all
available concrete girder shapes the 60 in. "bulb tee" was chosen. This girder section was developed a few years ago by Dr. Arthur R. Anderson, Concrete Technology Corporation, Tacoma, Washington. The 60 in. deep section was found to provide sufficient superimposed load carrying capacity for the required spans (Fig. 3). The standard web thickness for this girder is 5 in. In order to permit more comfortable accommodation of tubes for posttensioning tendon threading, the precast girder piece has a 5⅛ in. web; the end pieces, for resistance to shear over piers, have 7 in. webs. Girder ends have endblocks for distribution of posttensioning anchorage stresses. The precast girder elements are erected over piers and falsework bents; connections are made for the posttensioning steel tubes; some extended mild steel reinforcing bars are welded in the joint, which is 8 in. wide; and then the joints are cast with special concrete in the field (Fig. 4). After curing of the joint concrete the posttensioning tendons, 2 tendons with 12-½-in. 270 K strands and one with 8-½-in. strands are threaded (pulled) through, anchored and stressed from one (alternating) end and restressed from the other (Fig. 5). After posttensioning, the large endwalls are formed and cast (the falsework bents remain in place until completion of all concrete work), then the intermediate diaphragms, the 4½ in. thick roadway slab and the curbs (Fig. 6).

The girder has a wide top flange which improves its properties generally, and also increases lateral stability and reduces roadway slab forming work. With modern concrete casting techniques it is possible to produce precast components which are very uniform dimensionally. In order to maintain roadway slab thickness uniformity, the girders are placed over piers normal to roadway crown.

It is expected that due to the arrangement of superstructure components the bridge will distribute wheel loads more uniformly over its width than the AASHO design specifications assume, i.e., 0.88 wheel lines per girder. The span length/width ratio is high. In lieu of the
Fig. 4—Girder Assembly View

Fig. 5—Girder Prestressing after Splicing
AASHO wheel load distribution recommendation a factor of 0.80 was used in accordance with Hendry and Jaeger transverse load distribution method.\(^1\)

All precast concrete has a mini-

Fig. 6—Roadway Sections

Fig. 7—Shear Diagram

NOTATION

\[\begin{align*}
V_u &= \text{Shear at } 1.5 \text{DL} + 2.5(\text{LL+I}) \\
V_p &= \text{Shear carried by tendons} \\
V_s &= \text{Shear carried by stirrups} \\
V_{ci} &= \text{Shear at inclined tension cracking} \\
V_{cw} &= \text{Shear at web cracking (diagonal tension)}
\end{align*}\]
maximum compressive strength of 7000 psi at 28 days, cast in place concrete, 4000 psi, prestress is applied with ½ in. 270 K strands. Shear resistance, in addition to web thickness variation and effects of prestressing is provided by double No. 4 stirrups at 12 in. along the entire length of girders, which corresponds to both AASHO and ACI 318-63 criteria (Fig. 7).

Concern has been maintained about expected superstructure deflections due to all causes. Dead load and construction effect deflections are provided for by geometric control during girder component precasting, erection, stressing and completion of the structure. The live load deflections as calculated are \( \frac{1}{150} \) of the main span and \( \frac{1}{500} \) of the cantilever spans. The actual expected live load deflections will be considerably less. Because of the location and prospective use of the structure, the probability that the main span will have full design live load applied to it is about 1 in 10,000; normally the maximum load will be one fully loaded log truck traveling in one lane, an empty one may be in the other lane and even those will seldom meet in the maximum load position. From observation of a steel girder bridge with a similar geometric configuration, and considering the effects of considerably larger mass in the concrete superstructure and its inertia during application of bridge live load, the actual expected live load deflections are estimated to be about one-third of those estimated in the design calculations (Fig. 8).

![Diagram of Girder Camber and Deflection](image-url)
It is also expected that interaction of endwalls with embankment soils will further dampen the live load effects (Fig. 9). The roadways at both ends of the bridge are to be paved with asphalt which will permit small movements and small grade misalignment without impairment to the function of the bridge.

The described scheme was developed to provide low first cost, low maintenance costs and the required serviceability. The girders had to be hauled 200 miles over the Cascade Mountains; cast-in-place concrete, workmen and equipment came from 40 or more miles away. Nevertheless, the total structure cost is $115,012, or $17.83 per sq. ft.; superstructure only cost is $76,477 or $11.86 per sq. ft.; all representing reasonable (or low) first cost for the improvement in the location.

As an outgrowth of considerations made in planning this and other prestressed concrete bridges, comparisons were made between various available precast girder shapes and their adaptability to economy and structural efficiency requirements. Fig. 10 provides a comparison sketch of three locally common sections: the “bulb tee”, the Washington State Standard 100 ft. series girder and the AASHO—PCI Type IV.

Since part of prestressed concrete construction scene is formed by component handling and transportation convenience, and 6000 psi precast concrete can be made in nearly every part of the country (for last 4 years the author’s office has consistently been calling for and getting 7000 psi) it would be easier to plan, to design and to effect economies in construction of prestressed concrete.
### Table: Highway Bridge Girder Comparison

<table>
<thead>
<tr>
<th>Girder Type</th>
<th>Girder Weight</th>
<th>Precast Conc.</th>
<th>C.I.P. Concrete</th>
<th>Prestress</th>
<th>Posttensioning</th>
<th>Cost, Concrete</th>
<th>Cost, All Prestress</th>
</tr>
</thead>
<tbody>
<tr>
<td>54° BULB TEE</td>
<td>34 T</td>
<td>10 C.Y.</td>
<td>6 C.Y.</td>
<td>14 Str.</td>
<td>24</td>
<td>$ 2,400</td>
<td>$ 1,220</td>
</tr>
<tr>
<td>WSHD 100</td>
<td>36 T</td>
<td>10 C.Y.</td>
<td>10 C.Y.</td>
<td>14 Str.</td>
<td>24</td>
<td>$ 2,700</td>
<td>$ 1,600</td>
</tr>
<tr>
<td>AASHTO IV</td>
<td>53 T</td>
<td>24 C.Y.</td>
<td>16 C.Y.</td>
<td>16 Str.</td>
<td>36</td>
<td>$ 3,400</td>
<td>$ 1,870</td>
</tr>
</tbody>
</table>

**Fig. 10**—Comparison of Three Prestressed Concrete Highway Bridge Girders—120-ft. Simple Span

**Fig. 11**—Proposed Forming Components for Long Span Precast Prestressed Concrete Girders
girder bridges if design offices would not be bound to only one type of girder. Versatility could be achieved by developing and using girder forming component parts which would allow more freedom and choice in design. As a suggestion towards that goal, Fig. 11 is a sketch of one way of doing it—permitting a selection from two top flanges, and providing a variable girder web height and web width. The only variable form element in this system is the height of the web side forms—all other forms parts can be used for any girder.

**SUMMARY**

It is feasible and economical to plan and build small prestressed concrete bridges with spans longer than ordinary by precasting the girders in parts and posttensioning in the field over bridge falsework. The importance of structural efficiency of chosen girder type increases with the increase in bridge span length.

**REFERENCE**


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*Presented at the Eleventh Annual Convention of the Prestressed Concrete Institute, Miami Beach, Florida, December 1965.*