Design-Construction of Fox Hollow Pedestrian Bridge

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The basic structure of this $920,000 pedestrian crossing in Calgary, Alberta, Canada, is a two-span symmetrical cable-stayed bridge supported by a single A-frame tower. The bridge deck and tower use precast concrete components. The resulting bridge is an elegant design solution to the functional, aesthetic, structural and budgetary requirements set by the City of Calgary. In addition, the project was completed on schedule and with reduced traffic disruption. This article presents the design challenge, conceptual design and design considerations, as well as the production and erection highlights of the project.

The new $920,000 Fox Hollow Pedestrian Bridge (see Fig. 1) in Calgary, Alberta, Canada, is a two-span symmetrical cable-stayed structure with a total length of 90 m (295 ft). The bridge stays are in a harp or parallel arrangement and are supported by a single A-frame tower at the median. The deck and tower components are all constructed using precast concrete.

The new bridge forms a critical part of the much needed link between the existing urban pathway system in Calgary and the new pathway in the northeast quadrant of the city. The link created by the bridge is the only pathway structure crossing Deerfoot Trail, a major north/south freeway that bisects the city. Because of this significance, the City had a number of specific design requirements for the structure. These requirements were satisfied by a design consisting of a symmetrical cable-stayed bridge constructed of primarily precast concrete components.

This article discusses the conceptual design and design features of the bridge together with the production and erection highlights of the precast concrete components.

Fig. 1. Fox Hollow Pedestrian Bridge, Calgary, Alberta, Canada (looking toward northeast).

CONCEPTUAL DESIGN

The conceptual design of the Fox Hollow Pedestrian Bridge began in 1992. At that time, it was identified that a pedestrian bridge was urgently needed across Deerfoot Trail, a busy six-to-eight lane freeway, to connect the northeast quadrant of the City of Calgary to the rest of the river valley pathway system.

Because of the land use along the freeway, it was also acknowledged that this bridge would be the only pedestrian crossing to the northeast. With this requirement in mind, the City had indicated that they wanted a unique structure that would attract attention to the crossing. Other design criteria that the City identified were:

- Incorporate a tower into the structure to provide an identifiable landmark that pathway users could use to locate the structure.
- Create an aesthetically refined structure that would open a "gateway" to the northeast for pathway users.
- Furnish a durable structure that would have minimal maintenance costs.
- Produce a design that could be constructed with minimal traffic disruptions.
- Devise a design that would not limit or impede the future lateral expansion of the freeway.
- Come up with a design that would not exceed the project budget.

With these criteria in mind, Stanley evaluated the feasibility and the costs associated with several types of structures. These bridge types included:

- A central tower with stays in a fan configuration.
- A central tower with stays in a parallel or harped configuration.
- Twin towers with one set of stays per tower.
- An inclined tower located on the west embankment with stays in a fan configuration supporting a steel bridge structure.

In addition to these bridge concepts, Stanley evaluated a conventional girder on pier arrangements and a long, clear span arch. For both of these options, an independent free-standing tower was added at the west abutment.

City officials initially favored the aesthetics of the inclined tower system. However, the costs associated with this option exceeded the $1.0 million budget available. Also, concern was expressed about the durability and the long-term maintenance of a steel superstructure located adjacent to an area where de-icing salts are applied.

The girder on pier option was the most economical solution. However, it did not produce the landmark structure that the City wanted for this crossing. Of the remaining options, the single tower cable-stayed bridge consisting of precast concrete components was the highest rated option that met all of the design requirements. In May 1995, the decision was made to proceed with the cable-stayed precast design option.

DESIGN FEATURES

The selected structure features a two-span, symmetrical cable-stayed bridge, with stays in a harp or parallel arrangement supported by a single A-frame tower at the median. The two spans are each 45 m (147.6 ft) long, making an overall span of 90 m (295 ft). Fig. 2 shows an elevation of the bridge superstructure and tower.

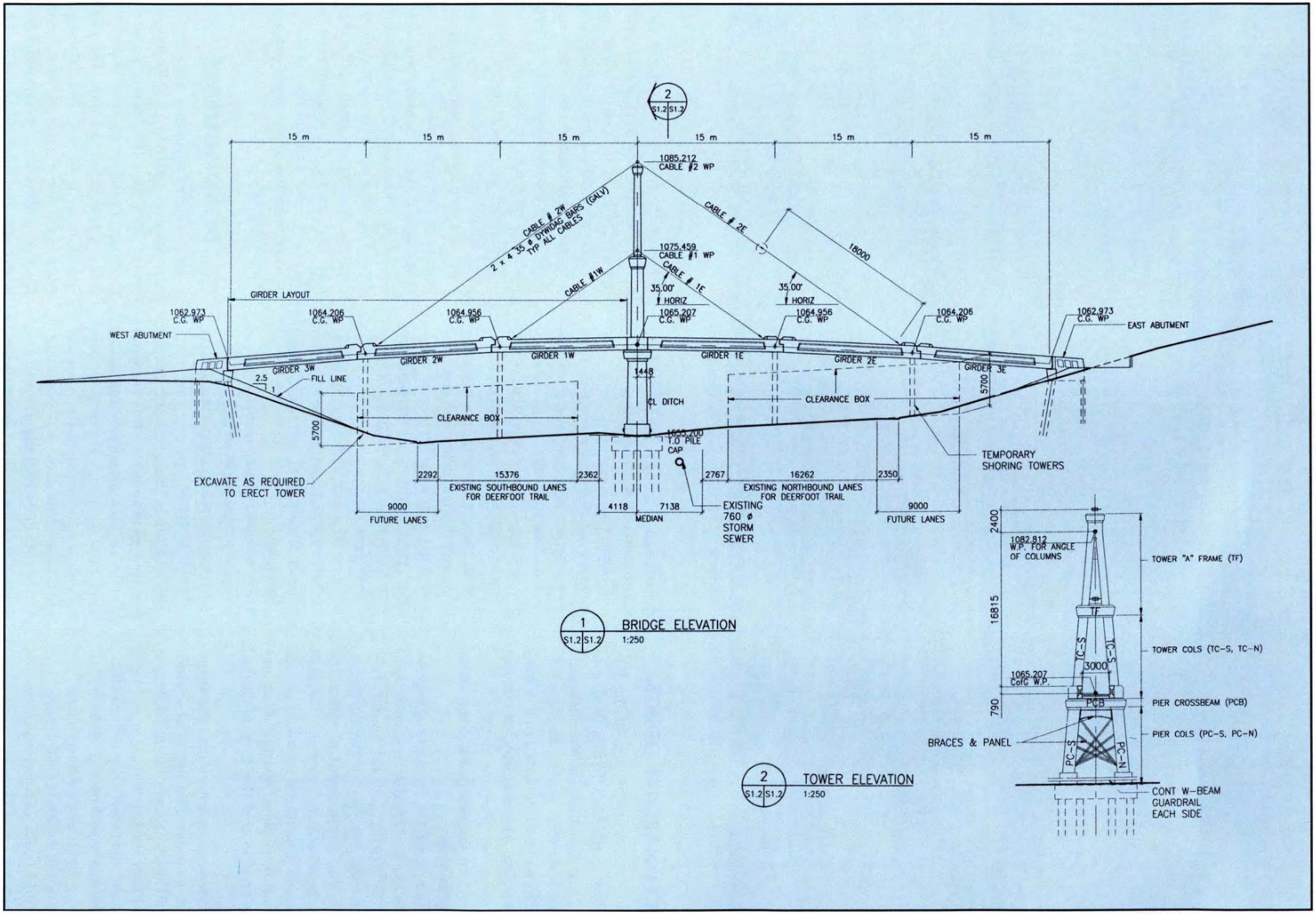

Fig. 2. Elevation of bridge and A-frame tower of Fox Hollow Pedestrian Bridge.

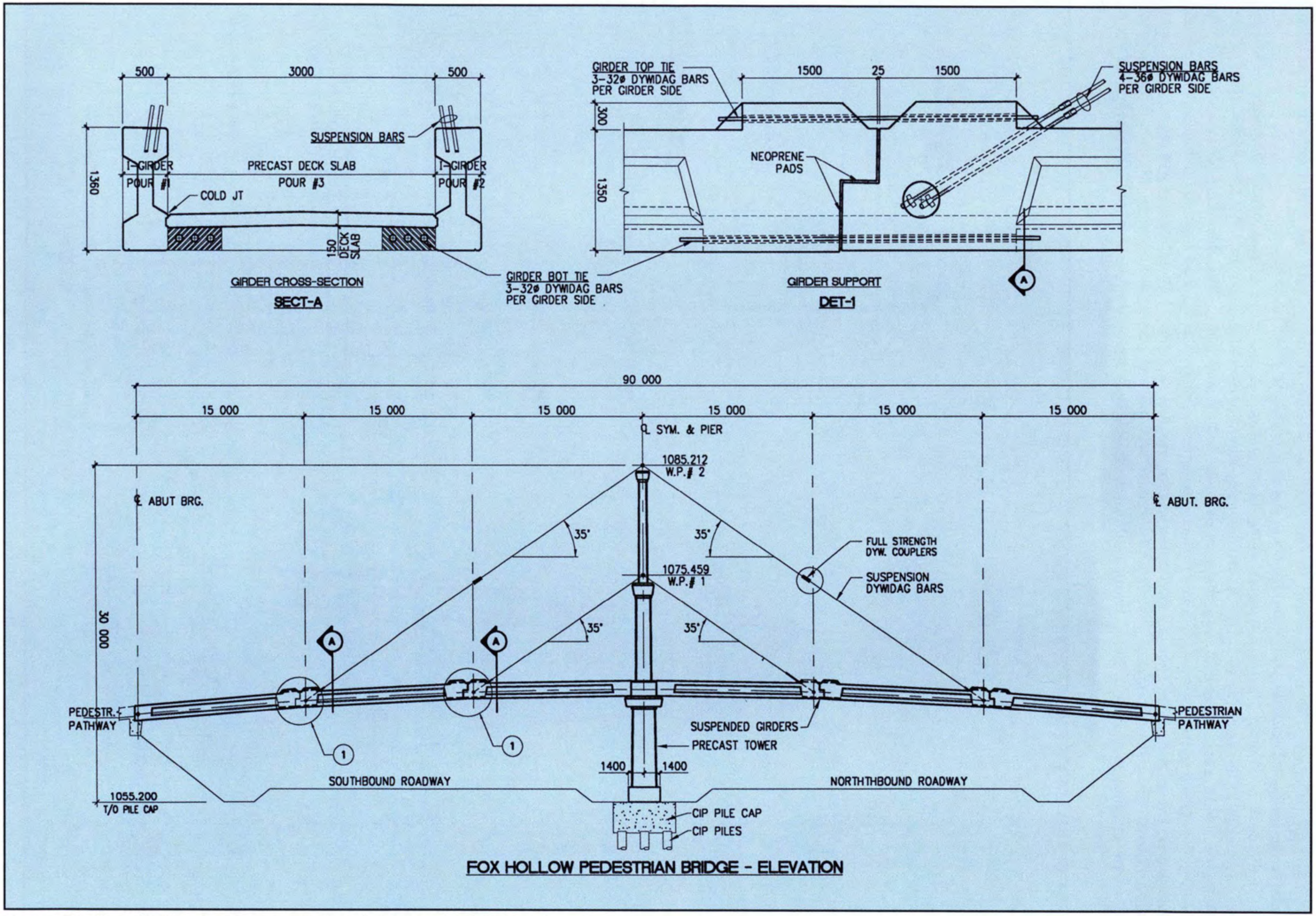

Fig. 3a. Elevation of bridge showing cross section of girder and girder support.

The A-frame tower rises 30 m (98 ft) above the median. The cross section of the deck is channel shaped. The inside width of the walkway is 3 m (9 ft 10 in.) and the area of the deck is about 270 m^2 (2900 sq ft).

Altogether, twelve precast components are used — six deck components and six tower components. Figs. 3a and 3b show various sections of the bridge deck, A-frame tower and other details of the superstructure.

As with all cable-stayed bridges, the stiffness of the tower and the deck had to be evaluated together to achieve the appropriate balance. For this case, the structural response was midway between a stiff tower-flexible deck structure and a stiff deck-flexible tower structure.

The design of the bridge was based on the CAN/CSAS6-88 Bridge Code. The controlling load combination was dead load and unbalanced live load. Wind velocity was not a critical factor in the design. Maximum factored moments on the deck were 2700 kN-m

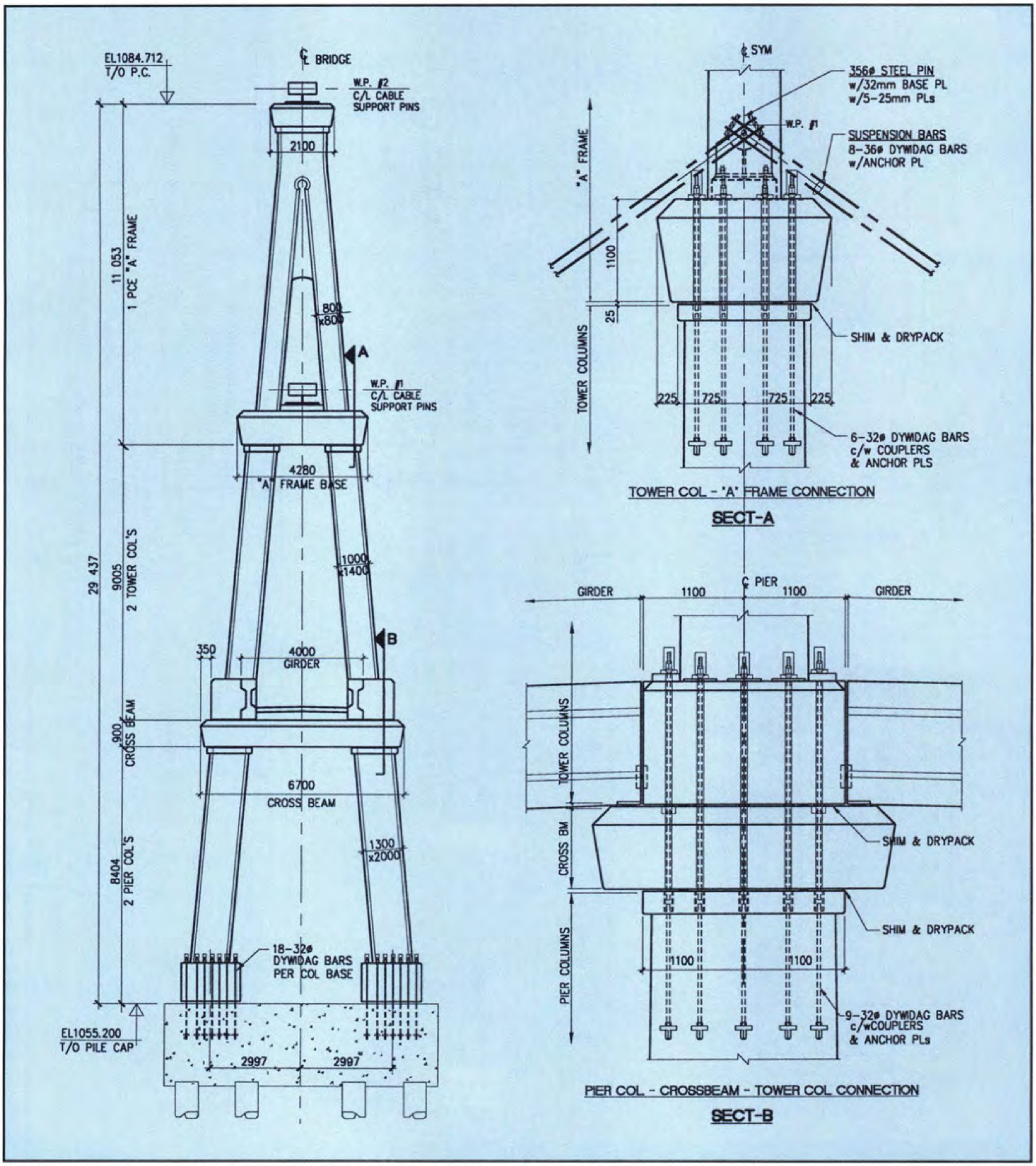

Fig. 3b. A-frame tower showing tower column and pier column cross-beam connections.

Fig. 4. Erection of upper tower column.

Fig. 5. Erection of tower A-frame.

Fig. 6. Erection of last bridge deck component on west span.

(1990 ft-kips), while maximum factored moments in the tower legs were 3900 kN-m (2880 ft-kips). Four galvanized $1^3/_8$ in. (36 mm) diameter rods per stay were used to support the girders. The size and number of bars were based on reducing the live load deflections and decreasing the positive moments in the girders.

During the initial stages of the design, it became apparent that the connection of the individual components would have a large impact on the construction duration and on the appearance of the structure. Therefore, personnel from Con-Force Structures Ltd. were asked to comment on the component sizes, the erection sequence, and the connection details. Lorne Simpson, a partner in the architectural firm of Simpson Roberts Wappel, was retained to provide advice on the aesthetics of the structure and on the proportioning of the components.


Fig. 7. Erection of bridge deck components.


Fig. 8. Bridge deck stay connection.

Based on these discussions, it was agreed that in order to simplify the connection details, the precast components would be connected by inserting Dywidag rods through preformed holes. Instead of trying to recess and hide the connections, which would have complicated the reinforcement in the components, the connections were exposed and made a feature of the structure. In addition, for the tower elements, the connection had an impact on the size of the elements because the rods from the element below had to be anchored in a corbel attached to the element above.

This scheme (see Fig. 3b) resulted in progressively smaller column sizes in the tower. Six precast components were used in the tower — two lower legs, the lower cross-beam supporting the bridge, the two middle legs, and the upper A-frame. The joints between the elements were grouted prior to stressing the anchors.

The bridge members consist of two I-shaped girders that are connected by the deck slab at the bottom flanges (see Fig. 3a). This configuration provided a solid barrier that would reduce the likelihood of snow, ice or debris falling into the freeway. It also reduced the size of the handrail. The bridge girders utilized similar connection details as the tower. Dywidag bars were installed through sleeves located at the top and bottom flange levels. Again, these connections were purposely made a feature of the bridge.

Before the permanent Dywidag bars were installed, the girders were initially connected using a corbel and thrust bearing arrangement at the stay connection location. These joints were later grouted with Dywidag bars installed across the joints to produce a continuous deck structure from the abutment bearing to the tower. At the tower, a permanent thrust bearing was used to create a pinned connection.

Table 1. Details of precast concrete components.

Tower
- One tower located at center of overpass
- Six-piece component vertically post-tensioned A-frame tower
- Total height: 30 m
- 16 – 32 mm diameter Dywidag bars from tower to deck girders on each side

Bottom of tower
- Two-pier columns
- Size: 2.2 x 1.3 x 8.4 m
- Weight: 64000 kg each
- Volume: 26.7 m^3 each
- Reinforcement: 1200 kg (non-prestressed)
- A-bolts: 18 – 32 mm diameter Dywidag A-bolts each into substructure

Lower cross-beam
- Size 6.7 x 3.3 x 0.9 m
- Volume: 18.7 m^3
- Reinforcement: 1420 kg (non-prestressed)
- Connection: 7 – 32 mm diameter Dywidag bars to tie each lower pier to each upper pier column

Middle tower columns
- Size: 1.5 x 2.2 x 7.5 m
- Weight: 35600 kg
- Volume: 14.83 m^3
- Reinforcement: 680 kg (non-prestressed)

Top A-frame on tower
- Height: 11 m
- Size: 2.1 x 1.2 m at top to 4.3 x 1.9 m at bottom
- Consists of two columns with top and bottom cross-beam all in one piece
- Weight: 51600 kg
- Volume: 21.5 m^3
- Reinforcement: 2060 kg (non-prestressed)

Inverted channel girders
- Number: six components
- Length: 15.5 m
- Width: 4 m
- Depth: 1.36 m
- Volume: 27 m^3 each
- Weight: 6600 kg each
- Reinforcement: 3500 kg each (non-prestressed)
- Post-tensioning
- Three-part casting (two sides and deck)
- Beam is supported from the tower with 8 – 36 mm diameter Dywidag bars suspended from the end farthest from the tower only with the other end resting on the tower or previous girder with a ship-lap joint

Note: 1 mm = 0.039 in.; 1 m = 3.28 ft; 1 m^3 = 35.4 cu ft; 1 kg = 2.2 lbs.

Fig. 9. Completed bridge looking toward the northeast.

CONSTRUCTION SCHEDULE

The need for the Fox Hollow crossing was identified in the late 1980s. However, it was not until 1995 that adequate funding was obtained to move the project forward. With the funding in place and the bridge type selected, the city requested that the project be designed and bid as soon as possible to permit construction to begin in the autumn of 1995.

The design was initiated in May 1995. The design was completed and the bids received in September. The project was awarded in October. Abutment and pier foundation constructions were completed by the end of 1995. The precast components were fabricated during the winter of 1995-96.

Erection of the components could not be started until the spring of 1996 because of the cold weather. Tower erection was started and completed during the last week of April. Poor weather delayed the erection of the girders for 2 weeks. Then on the weekend of May 11 and 12, all six girder segments were erected. During this time, at least one lane of freeway traffic was maintained in each direction.

Figs. 4 through 8 show various phases of the erection of the bridge deck and tower A-frame. The project

Fig. 10. Completed structure looking toward the west from the east abutment.

Fig. 11. Completed bridge looking toward the east along the length of the bridge.

was completed near the end of June 1996. The total cost of construction, including cast-in-place abutments and aesthetic finishes, was approximately $920,000. This cost was well within the allotted budget.

Figs. 9 through 13 show several views of the completed bridge.

PRECASTER'S ROLE

Con-Force Structures Limited entered the time line of the project during the preliminary design phase in mid 1995. The company provided suggestions on component type and size, production and erection schedule, connection details, and budgetary estimates. When the contract was firmed up, Con-Force was responsible for the production, hauling, and erection of the precast components. The company also produced the necessary shop drawings.

In all, only twelve precast components were used on this job — six tower components and six channel shaped components for the bridge deck. Details of these components are given in Table 1.

Standard concrete mixes with air entrainment were used for the components. For reinforcement, all compo-

Fig. 12. Completed structure looking at the east abutment.

Fig. 13. The Fox Hollow Pedestrian Bridge won a design award in the 1997 PCI Design Awards Program. This view is looking toward the northeast.

nents used mild steel reinforcement without any prestressing.

New forms were needed to cast the channel girders, which were made up of two fascia girders placed in the form so a composite deck could be poured to form a channel girder.

The manufacture of the components took place over a two-month period during the winter of 1995-96. The components were delivered to the project site by truck-trailer using a Cometto Trailer 64 wheel trailer flat deck over a distance of 10 km (6 miles).

The erection was done over two weekends in late spring 1996. The tower was erected in one weekend and the six deck girders were installed on temporary scaffolding with the Dywidag support during a later weekend.

The precast contract was $661,000.

CONCLUDING REMARKS

The Fox Hollow Bridge met all of the functional and budgetary requirements of the City of Calgary while providing an aesthetically pleasing and distinctive design solution. Construction was completed within the specified schedule and with a minimum of traffic disruptions. The bridge provides a highly visible "gateway" for pedestrians to access the northeast quadrant of the city from the Fox Hollow Golf Course to the west of the Deerfoot Trail.

In June of this year, the Fox Hollow Pedestrian Bridge won a design award in the 1997 PCI Design Awards Program. The jury's citation was as follows:

> "This project was designed to be a statement as a gateway, and it achieves that goal. It is a very striking structure, and the designers did an excellent job in meeting their needs. The use of precast pylon sections for the main tower, as well as use of precast beams, was quite innovative."

In retrospect, the City of Calgary, the architect, structural engineer, general contractor, and precaster are all happy with the outcome of this project. The bridge has now been in service for about a year and a half and has been operating with complete satisfaction. The users of the bridge are enjoying the new facility and motorists look upon this elegant structure as a "milestone" in their journey. Indeed, Fox Hollow Pedestrian Bridge has fast become a major landmark in the City of Calgary.

CREDITS

Owner: The City of Calgary, Calgary, Alberta, Canada

Architect: Simpson Roberts Wappel, Calgary, Alberta, Canada

Structural Engineer: Stanley Consulting Group Ltd., Calgary, Alberta, Canada

General Contractor: PCL/MAXAM, Calgary, Alberta, Canada

Precast Concrete Manufacturer: Con-Force Structures Ltd., Calgary, Alberta, Canada