Precast Prestressed Cable-Stayed Pedestrian Bridge for Bufalo Industrial Park

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An all-precast, prestressed concrete cable-stayed pedestrian bridge was constructed to transport workers across a busy four-lane highway to a major industrial park complex in San Pedro Sula, Honduras. In designing the 30.8 m (101 ft) long structure, special attention was given to creating an aesthetic harmony between the bridge and the entrance canopy as well as the other buildings in the industrial park. The purpose of this article is to present the design options, architectural concept, design considerations and particularly the design of connections, construction highlights, and especially the role that the nearly 150 precast concrete components played in erecting the bridge. It is concluded that the design concepts and construction method, which proved to be efficient and economically successful in Honduras, can be applied in other parts of the world.

In the last decade, the Bufalo Industrial Park in San Pedro Sula, Honduras, has grown steadily in both size and population. Today, there are more than 10,000 persons working in this industrial center. Most of the workers have the same hourly schedule and, therefore, it was important to provide efficient and safe passage to and from the facility. It is anticipated that in the next few years the number of people working here will continue to increase.

In front of the industrial park there is a busy four-lane highway with a green median strip in-between. For functional reasons as well as safety precautions, there was a critical need to provide a pedestrian bridge across this highway (see Figs. 1 and 2). The purpose of the bridge would be to link the existing bus station (that serves the urban transportation system) with the entrance to the industrial park on the opposite side of the highway. A site plan showing the pedestrian bridge in relation to the main highway, bus stop and sidewalk is shown in Fig. 3.

Once authorization was granted to construct this bridge, several design criteria were established for this structure based on location and existing conditions:

- Clear height (from road surface to soffit of bridge): 5.6 m (18.4 ft)

Fig. 1. Completed pedestrian bridge in San Pedro Sula, Honduras. Nearly 150 precast concrete components were used on this project.

Fig. 2. End view of bridge showing folded arch form in middle and both sides of structure.

- Net length of bridge superstructure: 29.0 m (95.1 ft)
- Net width of bridge superstructure: 3.00 m (9.84 ft)
- Two points of access at each end of bridge
- Adherence to quick construction schedule
- Working within budget constraints
- Compliance with structural provisions of building code

In addition to the above criteria, it was important that the bridge would be aesthetically attractive. The entrance canopy and buildings inside the Bufalo Industrial Park were purposely designed to have architectural appeal and be environmentally sensitive. Many of

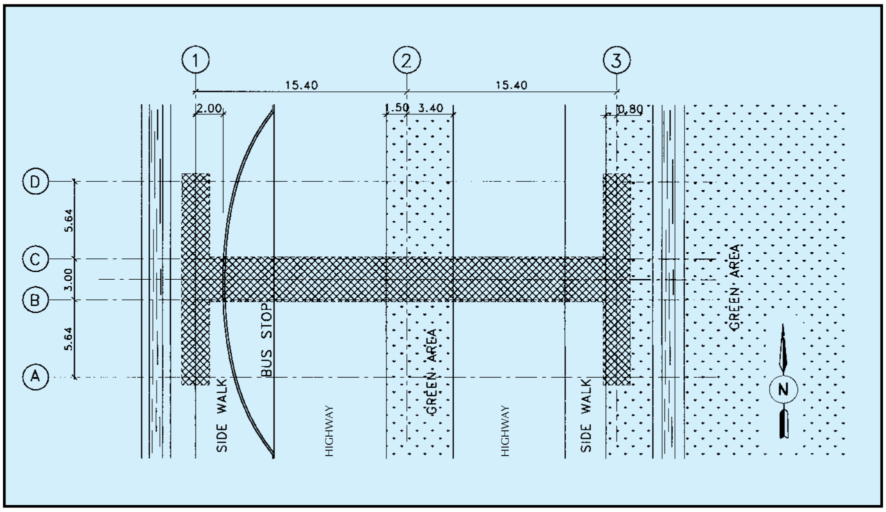

Fig. 3. Site plan of project showing pedestrian bridge in relation to highway, sidewalk, bus stop and green area.

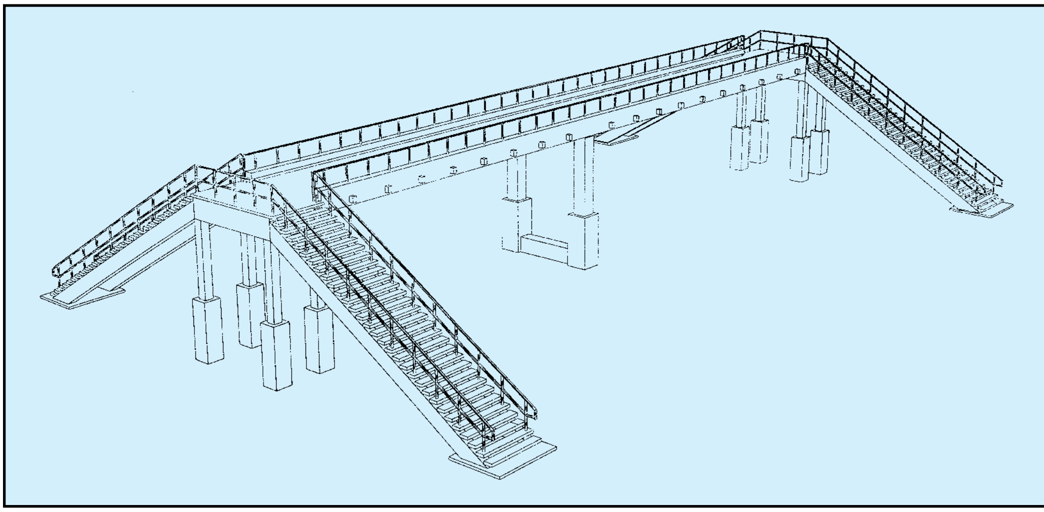

Fig. 4. Preliminary design of bridge (Design Option A).

the buildings have distinctive precast wall panels and folded plate roofs. In the compound, there are also pavilions with beautiful umbrella-shaped precast folded plate roofs. Therefore, it was important that the proposed bridge would be aesthetically compatible with the structures in the industrial complex.[1-4]

The purpose of this article is to present the design options, architectural concept, design features and erection highlights of the project. Particular attention is given to the precast concrete components and how they are connected together.

DESIGN OPTIONS

For preliminary design considerations, two concrete design options were submitted. Note that for aesthetic and economic reasons, a structural steel design or cast-in-place concrete option was not considered feasible.

Option A — This design comprises two independent post-tensioned, prestressed concrete segmental I-beams supporting a precast concrete deck for the main span, and two reinforced concrete inclined beams with prestressed concrete stepped slabs for the bridge approach spans (see Fig. 4).

Option B — This design is basically a cable-stayed structure consisting of a central tower with two columns and stays in the middle. Twin prestressed concrete beams support a precast concrete deck for the main span while one precast-cast-in-place reinforced concrete arch and a third stairway form the landing to the bridge deck for the bridge approach spans (see Fig. 1).

In analyzing Options A and B, it soon became apparent that Option B offered more advantages than Option A. For example, four columns in each landing will limit the length of the bridge approach spans and will be reduced to more than 40 percent of Option A. The level of the stair landing slab of the bridge approach spans is almost 2.0 m (6.56 ft) lower than the bridge scheme of Option A. In addition, Option B offers several structural advantages; for example, the overall span of the bridge is shorter than that for Option A.

The volume of concrete of the major elements of the bridge for Options A and B are listed in Table 1. By comparing the concrete quantities under Options A and B, it is apparent that Option B provides the more economical structure, i.e., 46.7 percent less concrete than Option A. It is assumed, of course, that construction costs will remain the same.

Therefore, when all of the design-construction aspects, including also the economics and aesthetics of the project were considered, it was decided to adopt Option B, i.e., a precast, prestressed cable-stayed bridge.

Table 1. Comparison of concrete volume of various components of Bridge Options A and B.

	Concrete volume (m^3)	
Description	**Option A**	**Option B**
Central tower	12.70	16.21
Main bridge	16.38	14.57
Approach spans	76.82	25.65
Total	105.90	56.43
Percentage	100 percent	53.30 percent

Note: 1 m^3 = 1.308 cu yd.

DESIGN FEATURES

Architectural, structural and aesthetic considerations, together with plant cast precast/prestressed concrete construction, made this pedestrian bridge unique.

Architectural Concept

For aesthetic reasons, the selection of a concrete arch and suspended deck system for the bridge proved to be a wise choice because the structure complemented the entrance canopy and other buildings of the industrial park.[2]

Another important objective of the

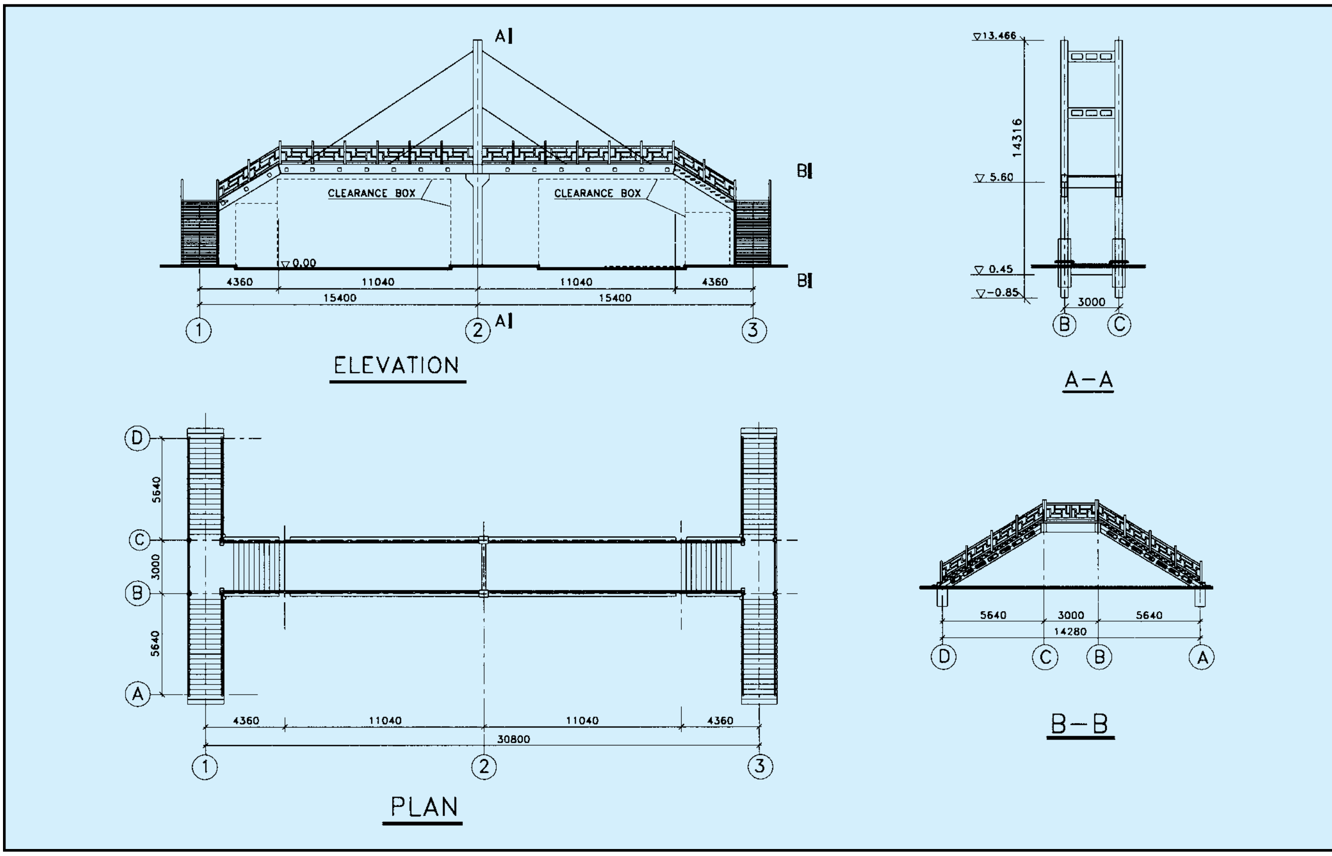

Fig. 5. Plan, elevation and typical sections of cable-stayed bridge (Design Option B).

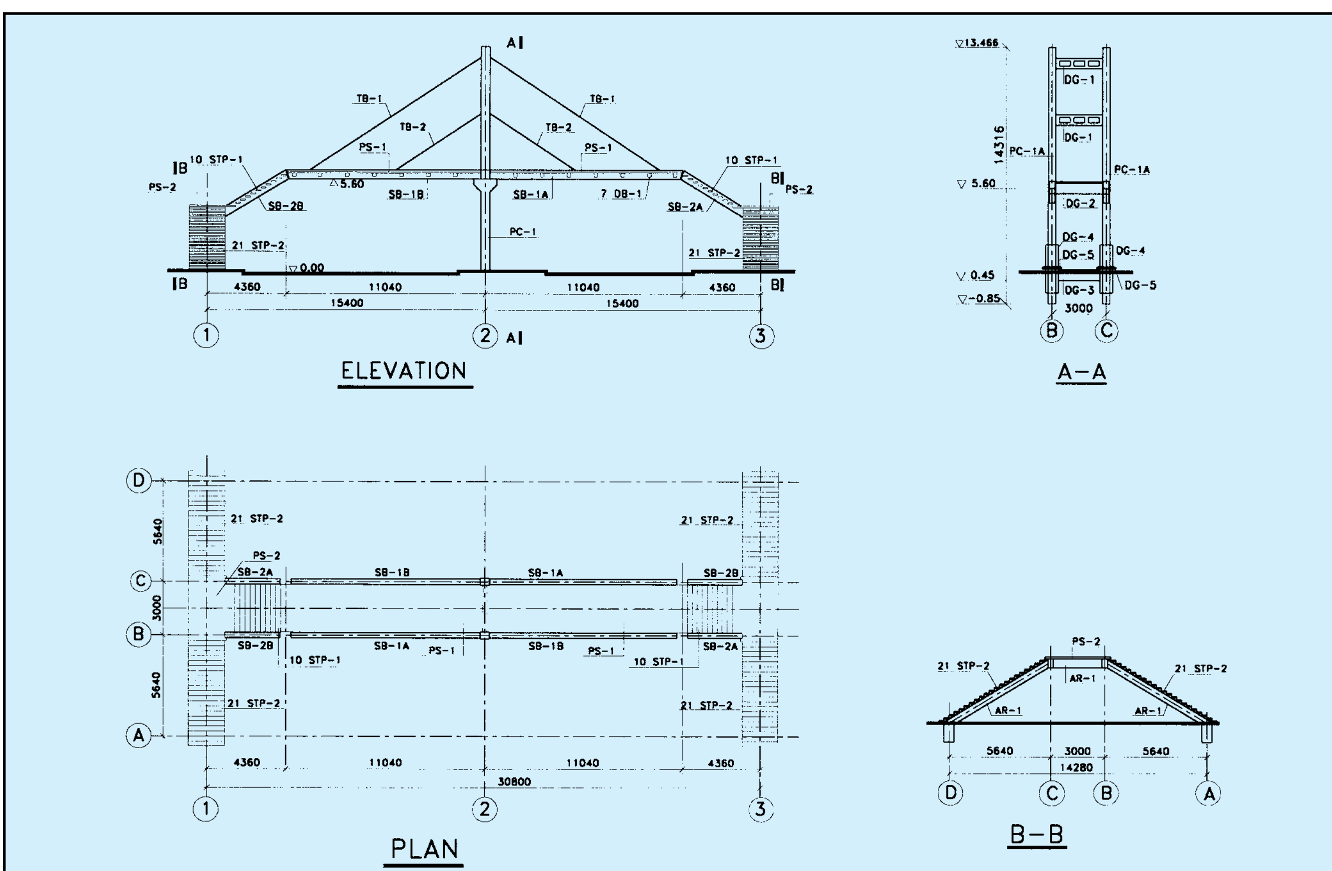

Fig. 6. Plan, elevation and sections of bridge showing a breakdown of the various precast concrete elements in bridge (see also Table 2).

architectural design was to reduce the distance between the pedestrian level and the top line of the clearance box (see Fig. 5). The bridge superstructure was designed to cross the main highway at a right angle along two lines. The approach spans passed by the bus parking area and sidewalk at the west and east ends of the bridge. Thus, the clear height of the bridge soffit near the ends was lower than that over the main highway. This facilitated having a third stairway from the landing to the bridge at each approach.

Therefore, a folded arch form was used for both the main beams and the third stairway approach spans on each side. The approach spans add a triangular arch form and, thus, a harmonious symmetry to the entire structure. This unique feature of the bridge, in which a folded arch style is displayed in the middle and both sides of the structure, is shown in Fig. 2.

Precast Components

A major feature of the structure is use of the precast/prestressed concrete components, which provide both structural stability and aesthetic appeal to the bridge. A total of 147 precast concrete components, weighing 135 tons (122 t), were used. These components comprised the columns of the central tower, the main beam, secondary beams, deck slabs, secondary beams, star landing slabs, stair steps, arch beams, footing beams, and a reinforced precast footing. These elements are listed in Table 2 and are also shown in Figs. 6, 22 and 23.

The precast concrete components were fabricated by CONHSA-PAYHSA at their plant in San Pedro de Sula. They were delivered by truck the short distance to the project site.

Table 2. Concrete volume of various components of bridge (see Fig. 6).

	Components	Number of components	Concrete volume, m^3	
			Single component	Total
1	PC-1	2	2.91	5.82
2	DG-1,2,3,4	1	4.188	4.19
3	SB-1A	2	1.48	2.96
4	SB-1B	2	1.48	2.96
5	SB-2A	2	0.48	0.96
6	SB-2B	2	0.48	0.96
7	AR-1	4	1.30	5.20
8	AR-2	2	0.47	0.94
9	DB-1	14	0.093	1.30
10	PS-1	2	2.04	4.08
11	PS-2	2	0.36	0.73
12	STP-1	20	0.067	1.35
13	STP-2	84	0.067	5.63
14	F-1	2	3.10	6.20
15	F-2	4	2.69	10.76
16	BE-1	2	1.17	2.35
	Total	147		56.43

Note: 1 m^3 = 1.308 cu yd.

Main Span Design

In order to make a symmetrical bridge, the H-frame tower must be located in the middle of the structure on the median green area. The bridge is basically a symmetric two-span cable-stayed structure with stays arranged in parallel and supported by a single H-frame tower. The two main spans are each 11.04 m (36.2 ft) long, making an overall span of 22.08 m (72.4 ft). A plan and elevation of the bridge, with typical sections, is shown in Fig. 5.

The H-frame tower rises to a height 13.47 m (44.2 ft) above the highway. The inside width of the walkway is 3.0 m (9.84 ft). The deck is composed of secondary beams and slabs.

Similar to the design of large-scale cable-stayed bridges, the stiffness of both the tower and the deck had to be evaluated together in order to obtain the correct value. Four 30 mm (1.2 in.) diameter cables per stay were used to support the girders. Two pieces of the cable were connected by bolts to the above stays. Also, connecting bolts were used in the joints between the stays with the tower at the top and the joints between the stay and the main beam below.

To simplify the connection details, the precast concrete components were connected by inserting steel tubes through preformed holes. The steel boxes were recessed in the columns and the main beams.

As shown in Figs. 7 and 8, three concrete closure pours had to be made with the H-frame:

First Pour — At the plant, a connection was made between the two columns and rectangular section on the long line prestressing bed (see Detail PC-1A in Fig. 7).

Second Pour — At the plant, three frame girders between the two columns were connected (see Details DG-1 and DG-2 in Fig. 7).

Third Pour — As shown in Figs. 9 and 10, one frame girder at the bottom and two reinforced collars were aligned and connected to the columns in final position (see Details DG-3 and DG-4 in Fig. 7).

The bridge deck members comprise two rectangular girders that are connected between each other by the secondary beams (see Fig. 11). They are also connected with the columns of the

H-frame by a rigid joint at the end. A total of 14 secondary beams were supported in the holes of the main beams. The deck slab [10.93 m long, 2.67 m wide and 70 mm thick (35.9 x 8.76 ft x 2.75 in.)] is supported on secondary beams (see Figs. 12 and 13). The small secondary beams, in turn, transfer their loads to the main beams.

The above configuration results in reducing the distance between the pedestrian level and the top line of the clearance box. It also reduces the size of the hand railing. The geometry of the members and their connections were purposely made a major feature of the design.

Bridge Approach Spans

The bridge approach spans add a harmonious symmetry to the structure. Each approach span comprises two stairways culminating in a landing and a third stairway from the landing to the bridge deck. The stairways have a 30-degree pitch.

Below the landing, a two-hinged arch structural frame is used in the bridge approach span. Four precast concrete components are used for each arch. The upper chord of the arch is composed of three elements while the bottom chord comprises a precast, prestressed concrete tension footing beam, which is located below grade (see Figs. 14 and 15). The three inclined upper chords function as stringers, supporting the stair loads.

The third stairway from the landing to the bridge deck is supported on the inside by two inclined beams. Every stair component with a tee section is supported on steel plates embedded in the inner face of the inclined beams as shown in Figs. 12 and 19. The three protruding cubiforms on the outside are for decoration purposes only.

A rectangular slab [3.64 m long, 2.56 m wide and 90 mm thick (11.94 x 8.40 ft x 3.54 in.)] forms the landing for each bridge approach span. Two layers of straight and parallel prestressing tendons were used in the slab. The slab itself is supported on the upper chord of the arch.

Typical Connections

The following sections describe some of the most important connections used in the bridge:

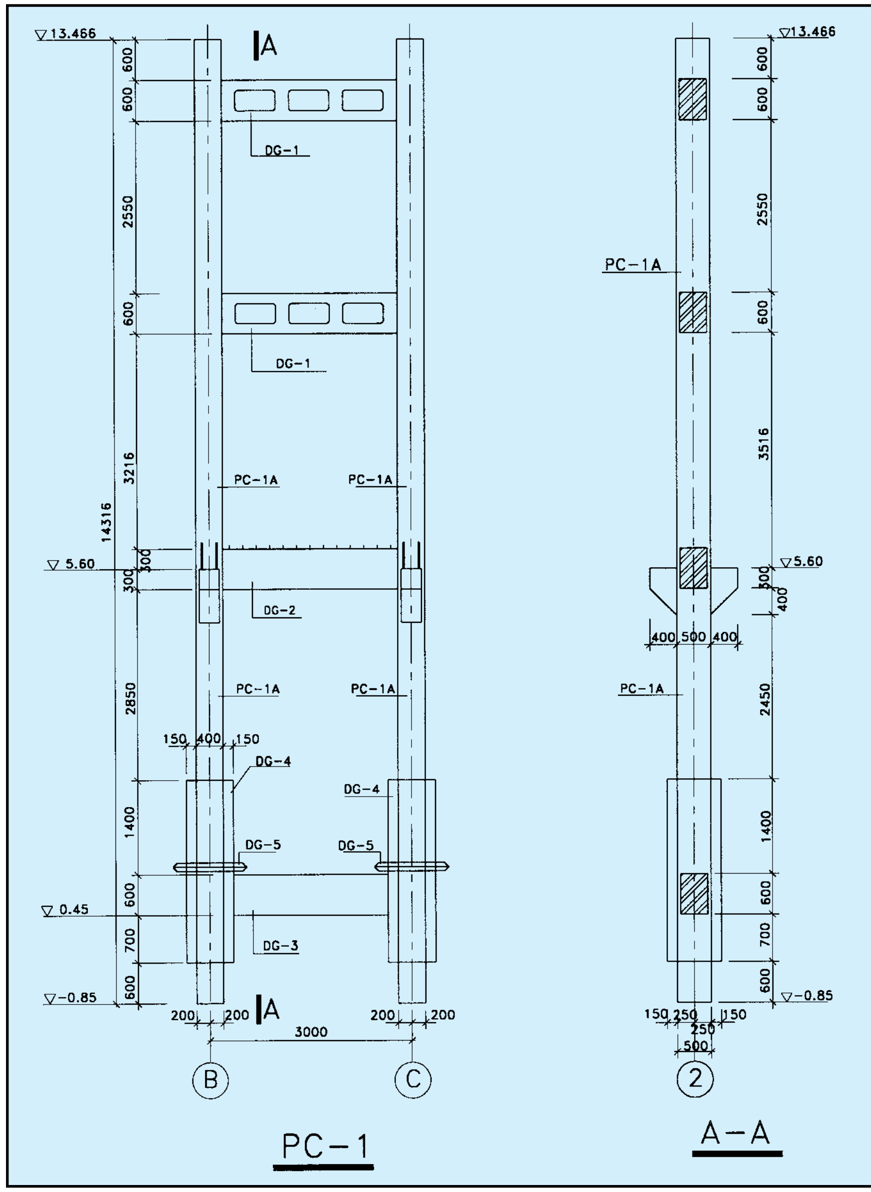

Fig. 7. Elevation and section of H-frame showing precast elements.

Fig. 8. Erection of H-frame.


Fig. 9. Precast pocket footing of H-frame in final position.


Fig. 10. H-frame columns being fitted with two reinforced concrete collars for strut girder.


Fig. 11. Main beams and secondary beams in final position.

Column-to-Foundation Connection — A precast pocket footing with a long neck is used for the foundation of the H-frame. The bottom level of the foundation is supported on the existing soil.

A composite section between the 2 m (6.56 ft) high column collars and the footing is achieved by a cast-in-place concrete closure covering reinforcing bars protruding from the footing. The column section was increased from 400 x 500 mm to 600 x 800 mm (15.75 x 19.69 in. to 23.62 x 31.50 in.) not only to increase the structural capacity of the section but also to ensure the column would withstand any damage from a possible vehicle collision (see Fig. 10).

Beam-to-Column Connection — As shown in Figs. 16 and 17, before the permanent tension diagonal cables were installed, the main beams were initially connected using a corbel and thrust bearing arrangement at the stay connection location. Four dowel bars protrude from the top of the cable to an insert in the beam. The hidden reinforcing steel is assumed to act as a simple support.

Four additional reinforcing bars pass through the holes in the column and are welded with the upper reinforcing bars of the beam. Finally, by grouting the hole and pouring concrete on the upper half of the beam, the moment-resisting connection is achieved. This joint produces a continuous deck structure from the abutment bearing to the tower.

Beam-to-Beam Connection — As shown in Figs. 18, 19 and 21, the connections between the main beam and inclined beam have two functions, namely, to perform as a hinged and rigid joint for various construction stages.

The hinged joint, which is needed during erection, is controlled by a 30 mm (1.2 in.) gap and three reinforcing bars in the ends of both beams. Two 25 mm (1 in.) diameter reinforcing bars, 250 mm (10 in.) long, are welded on one end of the beam. A large 30 mm (1.2 in.) diameter reinforcing bar, located in the middle, is welded on the opposite end of the beam. Some allowance for torsional movement can be accommodated by the flexible steel plates, which are welded above and below the two beams.

At the plant, the various components of the H-frame were assembled together and given a second concrete pouring closure (see Fig. 22). The assembled frame was then delivered to the project site by truck over a distance of 1 km (0.62 mile). The four main beams were installed on temporary scaffolding (see Fig. 12). Similarly, the inclined beam and three upper chord components of the arch were installed on temporary scaffolding (see Figs. 20 and 21).

The last phase of the erection process was in converting the structure from a temporary condition into a permanent stable bridge. To make this possible, four tension cables on each side of the structure were installed to support the main beams. Load was transferred to the eight stays by nuts at both ends and a steel-coupling sleeve in the middle of the cables. When this step was completed, the temporary scaffolding was removed.

CONSTRUCTION SCHEDULE

The structural design for this pedestrian bridge began in the fall of 1998. The precast concrete components were fabricated during September and October of 1998 (see Figs. 22 and 23).

Erection of the precast elements was delayed until January 1999 because of the severe wind and flooding conditions caused by Hurricane Mitch. When the storm conditions subsided, erection of the bridge was completed in only one week. During erection, at least one lane of highway traffic was maintained in each direction. This very short erection period could not be matched by any other construction method.

Figs. 8 through 14 and 17, 19 and 20 show various phases of the erection of the H-frame and bridge deck.

The total cost of constructing the bridge, including prefabrication and cast-in-place concrete closures, was about $62,000.

The cost breakdown was as follows:

- Volume of concrete:$1100/m^3
- Linear length of main bridge: $1327/m
- Surface area of main bridge: $402/m^2
- Linear lengths of bridge approach spans: $1114/m
- Surface area of bridge approach spans: $429/m^2

Fig. 12. Four main beams were installed on temporary scaffolding.

Fig. 13. Deck slab being lifted into place.

Fig. 14. Upper chord elements of arch, tension footing beam, and pocket foundation connection during erection.

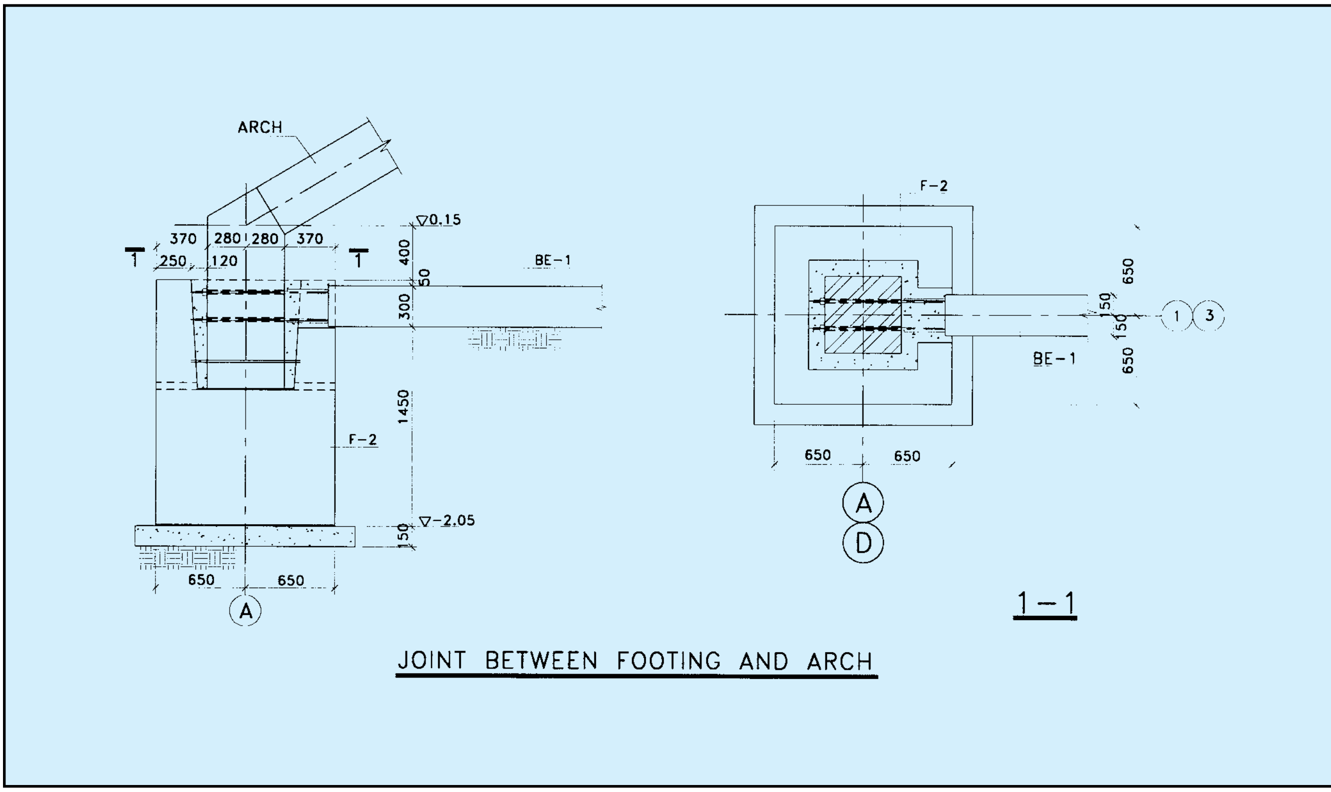

Fig. 15. Connection detail of upper chord element of arch, tension, footing beam and pocket foundation.

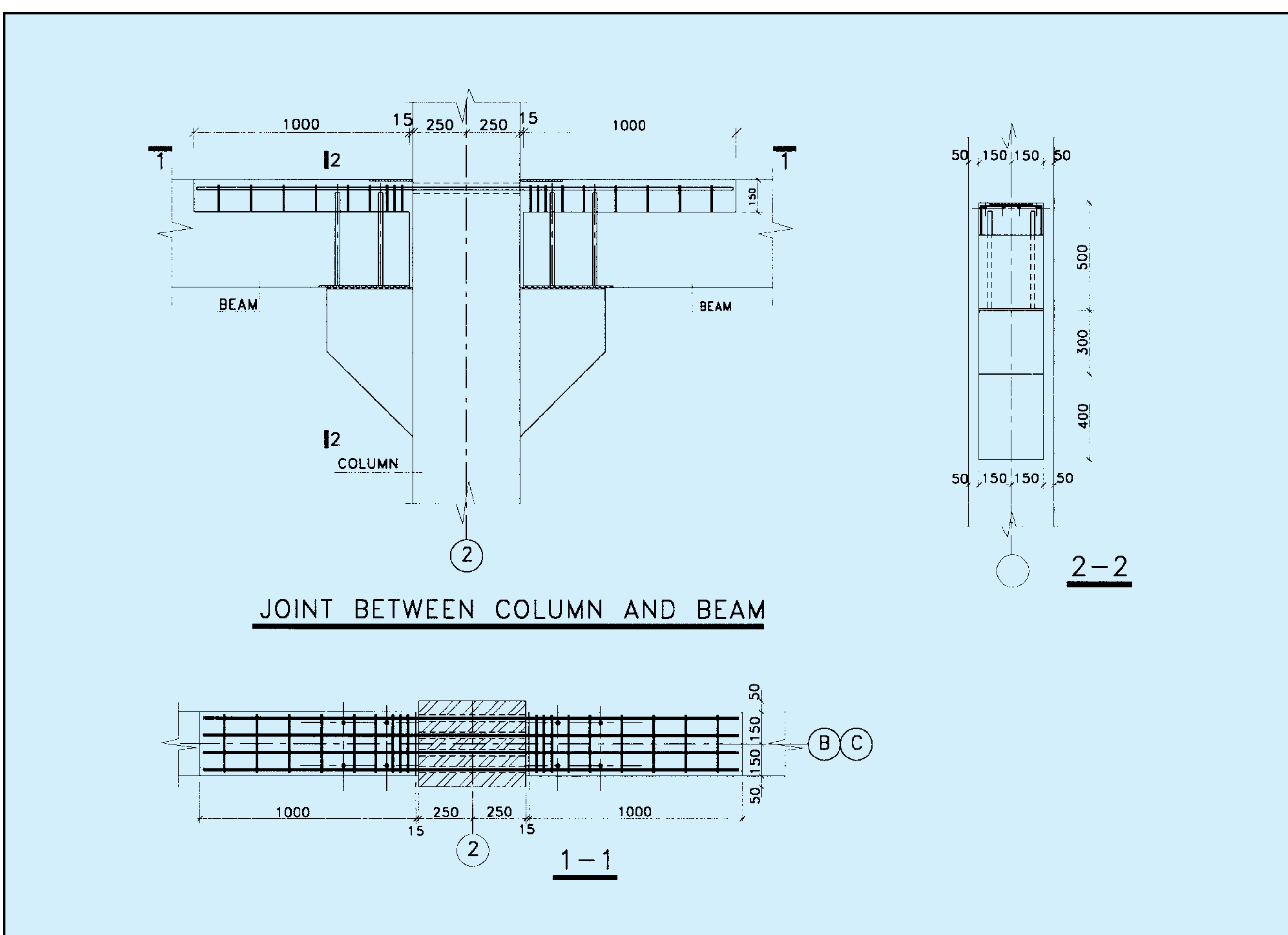

Fig. 16. Connection details between column and main beam.

Fig. 17.
Column, main beam, secondary beam and deck slab connection during erection.

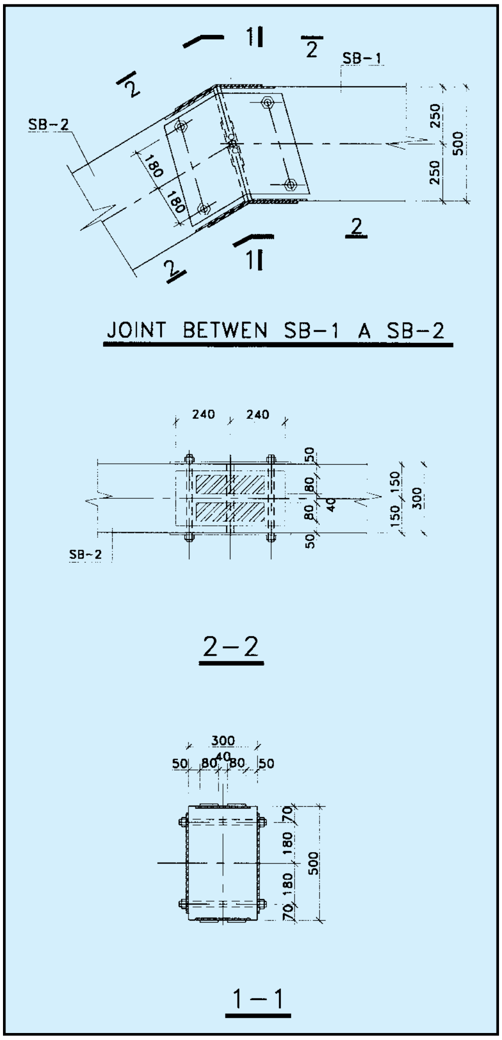

Fig. 18. Connection details between main beam and inclined beam.

Fig. 19. Connection between main beam and inclined beam using steel plate and bolts.

Fig. 20. Wet connection between upper chords of arch and inclined beam.

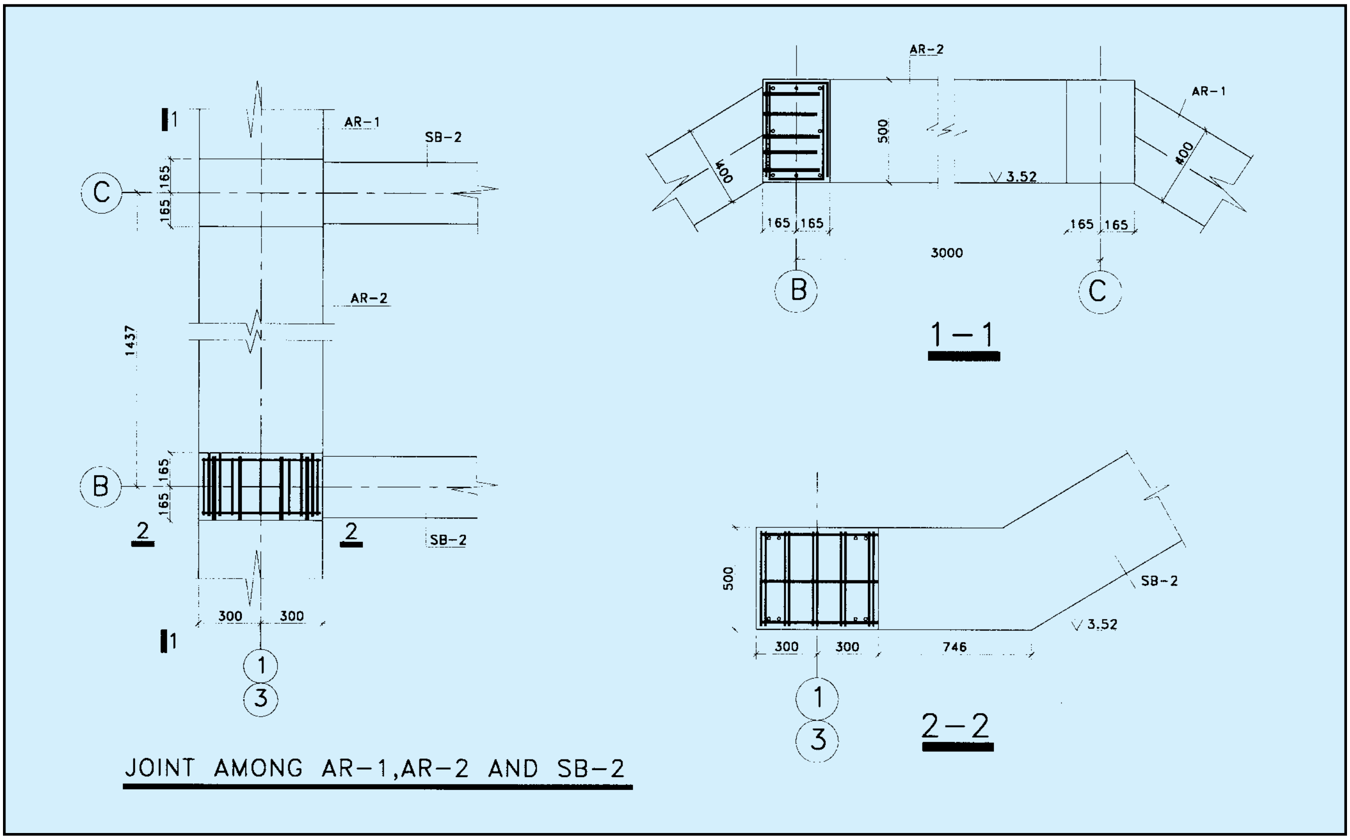

Fig. 21. Connection details between two upper chord elements and inclined beam.

Fig. 22. Fabrication of H-frame in plant.

Fig. 23.
Upper chord elements in plant.

CONCLUDING REMARKS

This project demonstrated that a two-span symmetrical cable-stayed structure is an excellent design option for pedestrian bridges. In particular, when the design-construction method incorporates precast/prestressed concrete components, the resulting structure can be structurally strong, durable, architecturally attractive, economical and easy to build.

The precast components were produced under controlled plant conditions and, therefore, were of superior quality and had accurate tolerances. Erection of the structure took only one week.

The pedestrian bridge was completed on January 24, 1999. Today, the facility is being fully utilized and enjoyed by the workers of the industrial park as well as the general public.

The pedestrian bridge provides a harmonious link to Bufalo Industrial Park and blends aesthetically with the entrance canopy and the other buildings in the park. The owner of this industrial complex is pleased with this new facility.

In retrospect, The design concepts and construction method developed for this project have proven to be efficient and economical in Honduras and can be applied in other parts of the world.

CREDITS

Owner:
Bufalo Industrial Park, San Pedro Sula, Honduras.

Engineer/Contractor:
CONHSA-PAYSHA, San Pedro Sula, Honduras.

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