Replacing Historic Rail Bridge  
Beer Sheba – Ramat Hovav railway Line, Israel  
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Introduction

Two railway bridges were designed and constructed in the town of Beer Sheba, Israel, to carry a single track freight line to the Ramat Hovav chemical disposal site, over the Beer Sheba valley and Road No 25. The bridge crossing the valley is a 9 span structure, 215 m. in length, and the bridge crossing the road is a 4 span structure, of 90m total length. Both bridges make use of the same 24.9 m and 20.0 m. standard spans and typical piers.

The longer bridge over the valley is located east of and parallel to an "Historic Othoman Railway bridge". This is a unique multiple stone arch bridge, officially declared as a “protected structure” due to its nostalgic nature, historic and aesthetic values. It is characterized mainly by its brownish-yellow colors, and low-profile multiple stone arches, that emphasize its length dimension and soft appearance, blending into the desert landscape. There are new plans to restore the old bridge , and use it as a part of the Beer Sheba valley promenade.

Rail levels of the new bridge are app. 8 m. higher than the deck of the historic bridge. The combination of level differences and close proximity of structures, creates an architectural challenge, and call for the design of the new bridge that does not diminish the beauty, elegance, and unique features of the old one.

To meet the challenge, the profile of the new bridge was designed as a single girder medium-span deck, of multiple modular round sided U shape. The deck runs continuously and smoothly over a series of flared columns, keeping the maximum possible open clearance between the top of the old bridge and soffit of the new one, creating a dramatic contrast between old and new. Views are shown on Fig.1 and Fig.2.
The contrast is achieved not only by proportioning the structural elements, but also by choosing and focusing on different styles, materials, and colors.

Due to erection limitations, the deck girder is composed of two round-sided precast "L"-shaped prestressed girders, lying side by side. These are connected by cast-in-place concrete, plus transverse post-tensioning to form the final integrated single round-sided and round soffit U-shape deck girder. Using the U-shape section with its webs pointing upwards increases the clear vertical opening between old and new bridges, enhancing the contrast between structures and emphasizing the slenderness of the new deck.

Using the flared shape columns, of lotus leaf appearance, does not only match with the somewhat oriental nature of this part of the country, but also enables a two-point support of the deck girder at each column, keeping the deck looks like it is detached from pier. This gives a strong impression of lightness, continuity and elegance of the deck profile, stressing simplicity and stability.
**Structural concept**

The typical span is a simply supported single integrated U shape girder, composed of two prefabricated round sided L shape girders, cast on site, post-tensioned and lifted to its final position. Connecting the pair of girders to form the final integrated round shape section, is carried out by cast in place shrink-compensating concrete and transverse post-tensioning, whose anchorages are pre-embedded in the upper part of both side webs. This transverse post-tensioned connection makes use of the lateral drop-down webs, spaced at 5m. centers as shown in Fig.9. It provides both bending and shear strength and structural integrity. A typical section is shown in Fig.3.

![Fig. 3 Typical cross section](image)

The shrink-compensating concrete deck is cast continuously over the piers, to create monolithic continuity of the deck slab for the entire length of the bridge. Since this is done only at the level of the slab and girder webs are not connected, and with the flexibility of the neoprene bearings, longitudinal continuity of the girders themselves is not achieved. This type of deck provides partial and limited continuity of the deck that enables transfer of longitudinal axial forces, but does not provide any longitudinal bending rigidity or bending moments capacity. Therefore, the deck is considered as a series of simply supported spans, as far as vertical loads are concerned, and expansion joints are located only at both ends of the deck.

In case of horizontal longitudinal or transverse loads, the deck is capable of transmitting axial forces and shears from span to span. This applies to braking, traction and seismic forces.
Reinforced neoprene laminated bearings, located on top of the columns and abutments, are used as deck supports and shock-absorbers.

The sub-structure consists of bored vertical piles, 6 per column, connected by a cast-in-place concrete pile cap. Columns are cast in a multi-use steel form as shown in Fig.4. The column is considered to be fully fixed to the pile cap.

![Fig.4 Typical column cast using steel moulds](image)

Horizontal seismic loads are assumed to act at the deck center of gravity, taking into account the rolling stock, ballast sleepers and rails. The lateral force is transmitted to the columns through the elastic properties of the bearings that act as shock absorbers. The bearings are considered here as base-isolators, providing a "period shifting" which is one of the main tools of reducing magnitude of seismic forces.

**Design and Analysis**

Design of the bridge was performed in full compliance with the Israeli Standard I.S. 1227 part 2, which is very similar to the British Standard B.S. 5400.

Loads taken into consideration were:
* Self weight (including super-imposed weight for ballast sleepers and rails).
* Vertical live loads (including dynamic effects).
* Horizontal live loads (braking, traction, nosing).
* Lurching effects.
* Wind loads.
* Seismic loads (according to I.S. 1227 part 1, I.S. 413 and rechecked in accordance with A.A.S.H.T.O. specifications).
* Temperature effects.
* Water pressures on piers, during flash floods.

Analysis of the structure, as a whole, was performed assuming a 3D-frame behaviour, for both vertical and horizontal loads, considering the deck as an orthogonal grid of beam and plate elements, and assuming an elastic soil-structure interaction. This was done by taking linear elastic lateral sub-grade reaction coefficients and partly pinned connection between deck and column, taking into account the lateral elastic properties of the bearings. Calculations were performed using the STRAP software package.

Due to the "L" shape non-symmetric cross section of the prefabricated pre-stressed girder, stresses, deformations and rotation analysis took into account bending with respect to the principal axes.

A special dynamic analysis has been performed showing that vibrations exerted by trains using the new bridge will cause only limited soil particle velocities near the historic bridge, that do not exceed around 3 mm/sec (According to Swiss Norm SN-640-312) and using the HMMH attenuation model. This model, that was developed by Harris Miller Miller & Hanson inc. for the FHWA (USA), defines changes of velocity levels in dB as a function of frequencies for various train types.

**Main Bridge Elements**

**Foundations**

6 vertical bored piles of mostly 1.0m, diameter, 18m deep, organized in an orthogonal pattern and topped with a pile cap, constitute the foundation for each intermediate pier. In a few cases, due to stiff ground layers, piles of 1.3 m. diameter and only 13 m. deep have been used instead.

Due to soil properties and high ground water level, piles were executed using a bentonite slurry technique to stabilize the bore hole.

The same piles are also used for abutments, but arranged in different patterns.
Piers

Piers are built as cast-in-place reinforced concrete columns of standard shape and section to enable re-use of the same steel form as shown in Fig.4.

Columns are heavily reinforced due to anticipated seismic loads.

Deck and Deck Girders

Each pair of round edged "L" shape girders that comprise the two halves of the complete rounded U shape deck, was cast on site very close to the designated span, as can be seen in Fig.5.

Fig.5  Partial general view during construction

Each girder weighs around 150 tons. To reduce weight, voids have been created in the lower flange of the girder, using polystyrene blocks. This arrangement called for special measures to be taken to avoid uplift of blocks while pouring the concrete.

Each girder was prestressed from both ends, simultaneously, by 5 X 13 T15S Freyssinet cables of 270 K (super) to a total of 1325 tons per girder. The anchorage zone is shown in Fig.6, and a general view of the "L" shaped girder is shown in Fig.7. Steel tube ducts to be used at a later stage for the transverse post tensioning cables, are embedded in the girders.
After being placed in pairs, upon its final laminated neoprene bearings, the top of girders were temporarily connected transversely to each other, and temporarily fastened to the piers, to avoid lateral accidental overturning, as shown in Fig.8. These temporary connections were removed only after final connections were completed, by means of the cast-in-place concrete deck bottom plate and transverse post tensioning. The cast-in-place concrete follows precisely the round soffit line and is perfectly tangent to the soffit of the prefabricated girders, as can be seen in Fig.9.
Transverse post tensioning is applied using pairs of 2x7T15S Freyssinet cables of 270K (super) tensioned to a total of 280 ton, and spaced at app. 5m. Considerable pre-stress losses were expected due to the sharp curvature of these cables, and duct lubricant was used successfully to reduce the effect. This transverse post tensioning provides the required transverse moment and shear capacity, as well as the overwhole integrity of the superstructure.

**Conclusions**

Two unique railway bridges have been designed and constructed in Israel, as a part of the new chemical disposal freight one-track line, crossing Beer Sheba valley and Rd. No. 25.

The architectural design was aimed to create harmony with the existing disused historic arched railway viaduct, blend into the desert landscape and produce minimal visual obstructions, or any negative aesthetic impact on the existing structure.
The structural solution calls, on one hand, for modular design, ease of construction using repetitive elements and prefabrication, and cutting down costs and construction time to a minimum, and on the other hand for providing structural strength and integrity, excellent structural and dynamic performance, as well as safety.

The result is a remarkable landmark.

**SEI Data Block**

Owner: Israel Railway Authority
Arch. & Struc. Design: Shamir Posner Brown Cons. eng. Ltd. Israel
Contractor: Linom Ltd. Israel
Pre-stressing: Freyssinet Israel ltd.
Site Inspection: Baran Israel Ltd

- Bored piles (app.) 1300 m³
- Piers and abutments (app.) 1300 m³
- Prefabricated deck girders (app.) 1400 m³
- Cast in place deck plate (app.) 400 m³
- Reinforcement steel (app.) 600 ton
- Prestressing steel (app.) 60 ton
- Total cost of two bridges (app.) 3,000,000 $
- Construction time of two bridges 16 months
- Inauguration Summer 2004