Widening of an Existing Bridge to Accommodate Two Traffic Lanes – Al Bustan South Project in Qatar

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Abstract

Driven by Qatar National Vision 2030 and catering to the 2022 FIFA World Cup, Qatar is undertaking an extraordinary and ambitious programme of infrastructure development to deliver a world-class new and upgraded road infrastructure network. Projects designed to improve highway capacity, connectivity, and safety through the urban and rural parts of Qatar and to meet current and future demands of population and economic growth.

In this paper, the authors discuss some of the most critical and challenging considerations in putting a planning and design process on a path to deliver successfully a bridge deck-widening project, implementing a collaborative approach. The case study of upgrading an existing ramp bridge will be presented, where the one lane deck was converted to two lanes to accommodate the heavy traffic flow. The fast-track construction schedule necessitated the widening from one side by 1.15m, while the extended slab was supported on a steel strut connected monolithically on the concrete box girder web (bottom) and extended part (top) through shear dowels. To meet the tight construction schedule and the local market material constraints, built-up sections were utilized with variable configurations along the length of the bridge. Further, several epoxy resin products were studied and utilized for the drilled bars on the extension part and the drilled dowels of the web. The replacement of the existing bearings was necessitated due to the additional weight of the extension.

Keywords: Deck widening; Steel-concrete composite; Bridge assessment

1 Introduction

The requirement of accommodating a second lane in the 350m long Ramp Bridge was aimed to improve the traffic flow that was observed during the operation of the structure as a single lane bridge. Several options were studied (See Figs. 1 & 2) to conclude on the preferred option, which would meet the fast-track schedule set by the client, and at the same time adhere to the site constraints, the required road geometry on the bridge, approaches and the local market availability of material resources.

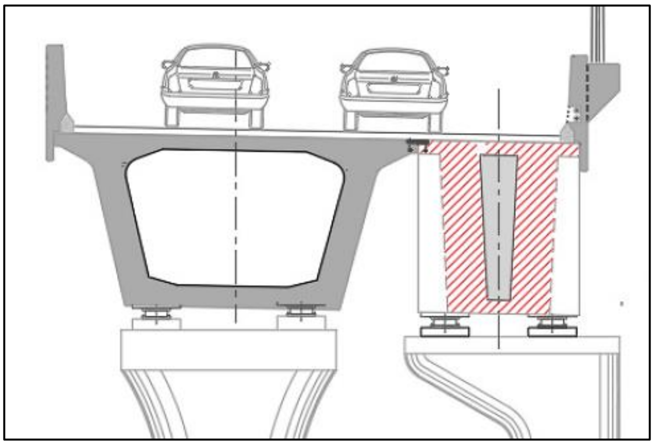

Fig. 1: Option of Adding a New Bridge Deck

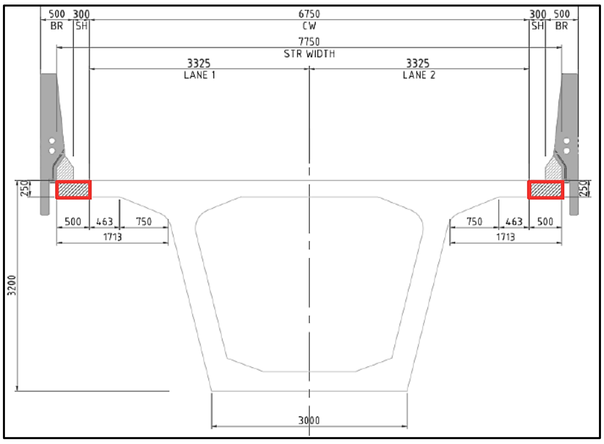

Fig. 2: Option of Extending Both Sides of the Deck (dimensions in mm)

In the preferred one-sided widening option (See Fig. 3), the addition of one lane on the bridge increased the cross-section width from 6.75m to 7.90m. The proposed 1.15m deck widening consisted of cast-in-place reinforced concrete deck slab supported on steel strut. The newly casted concrete of the extension was monolithically connected with the existing deck slab through additional rebar that was drilled and bonded to the deck slab using suitable epoxy resin. During the design, the number of rebars to be installed, the embedded length, and safe distance from the existing tendons were taken into consideration, to ensure the construction feasibility and safety. A key consideration was to keep the number of post-installed bars to a minimum and reduce the invasive operations on the existing deck flange. The steel strut was originally designed as the hot rolled section, but during construction stage the section was altered to built-up section to compensate for the local market constraints in obtaining the standard sections. The built-up section proposed by the contractor was not identical to the hot rolled section, as a result the design was checked once more utilizing the actual section to be installed.

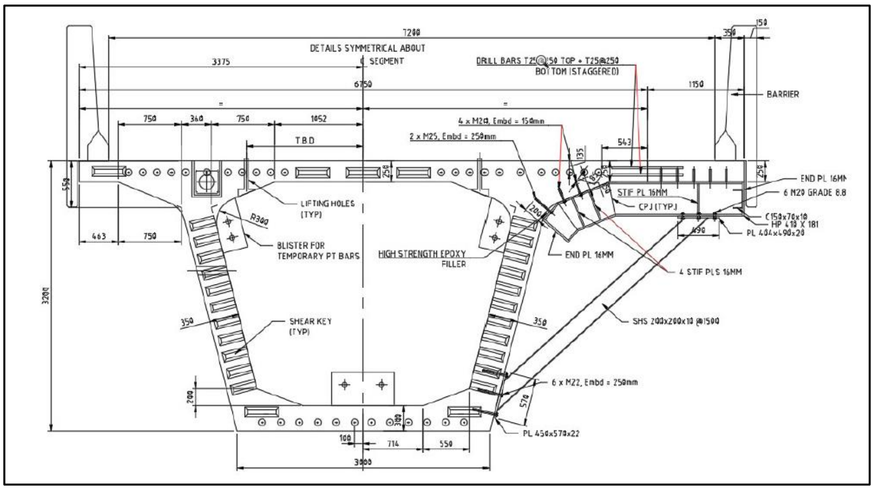

Fig. 3: Bridge Deck Cross-section (dimensions in mm)

2 Design Approach

The design was separated in two main stages and those were the positive assessments of the existing bridge to carry the additional loads (Stage 1) and the design of the new components for the widening of the existing bridge deck to accommodate the extra traffic lane (Stage 2).

The activities listed below were conducted for the preparation of the preferred option. Those were the following for each one of the above-mentioned stages:

2.1 Stage 1 (Existing Bridge)

- Check the structural safety of the existing Ramp Bridge (substructure & superstructure) for the widened deck slab.
- Provide the updated bearing schedule due to the increased permanent loads. These loads necessitated the bridge bearing replacement, an activity that was conducted by jacking of the existing deck (See Fig. 4) and replacing the bearings with larger capacity bearings.

Fig. 4: Caption of Bearing Replacement

2.2 Stage 2 (New Components)

- Design of the steel strut installed at a maximum spacing of 1.5m.
- Conduct all the necessary checks on both connection points of the strut.
- Design of the steel corbel at the abutment diaphragms. Due to the different geometry of the abutment diaphragm compared to the typical section (solid rectangular beam), a different detail was developed for this location, which proposed three rectangular hollow sections (RHS) closely spaced, supported to the side of the diaphragm segment. The RHS were developed in a horizontal plane, as opposed to the typical section strut, which was inclined.
- Provide the details of the extended expansion joints.
- Design of the new approach slab with the 1.15m projection corresponding to the deck extension.
- Provide the necessary construction steps/sequence of works.

The structural elements as listed below and form part of Stage 1 as it is mentioned above, were identified as affected by the deck widening and checked to confirm that no retrofit is necessary due to the increased dead, live and seismic loading:

– Foundations.

– Columns.

– Abutment.

– Bridge deck (Service Stress, Flexure, Shear & Torsion, and Transverse checks were performed).

3 Advantages of the Selected Option

The option of implementing the extension on one side of the bridge (i.e., eccentric) and supporting the newly casted extension with a steel bracket and strut was selected due to the below advantages:

- Minimization of the negative moment on the overhang.
- No local effects on the web of the existing bridge (i.e., strut supported on the height of the bottom slab haunch).
- The steel beam functioned as a shoring for widened deck construction (i.e., sacrificial formwork supported on this beam) thus the reduction of time for temporary works.
- One-sided widening minimized the traffic and utilities diversions. It also required the removal of the existing precast barrier and drilling of the deck slab on one side only. This reduced the construction duration.

4 Risk Mitigation Approach

The strut anchor bolts and steel reinforcement were detailed aiming to reduce the risks during the construction. Below are the locations that the anchor bolts and steel reinforcement were designed with particular attention to reduce the risk of adverse impact on the existing structure and ensure constructability.

4.1 Bracket Anchorage to the Bridge Deck Haunch (Soffit)

The anchor bolts embedded depth was designed to ensure a minimum of 55mm clearance to the post tensioning tendons (See Figs. 5 & 6). Further, the number of rows of the anchor bolts was reduced from 3 to 2, to avoid the embedment of a row of anchor bolts in the curved part of the bridge box girder deck. This increased the number of bolts in the 1st & 2nd rows as shown in the snapshots below.

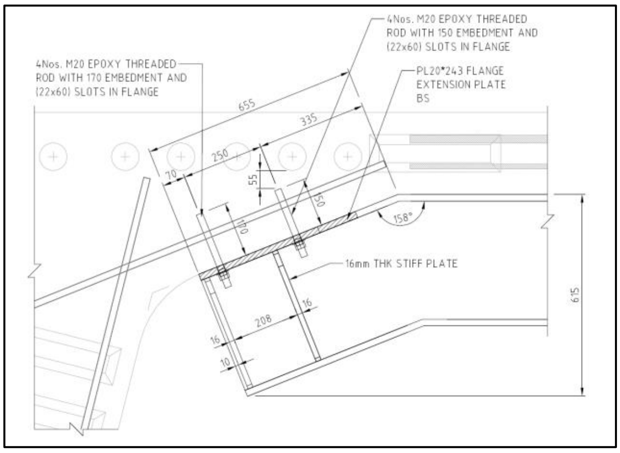

Fig. 5: Bracket (Section) (dimensions in mm)

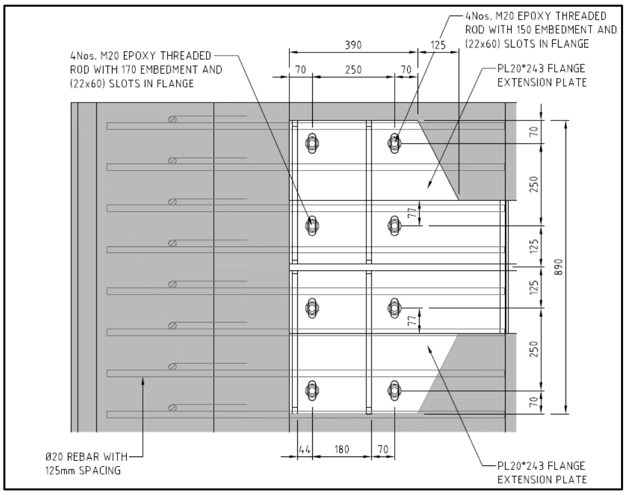

Fig. 6: Bracket (Plan view) (dimensions in mm)

4.2 Anchor Bolts providing the Connection of Strut Support and the New Extended Deck

The number of anchor bolts was increased and distributed on the bracket top flange to decrease the embedment depth to 150mm. This allowed the development of the anchor bolts within the 250mm deck slab extension to avoid crossing of the anchor bolt heads with the top mat of slab reinforcements for ease of construction (See Figs. 7 & 8).

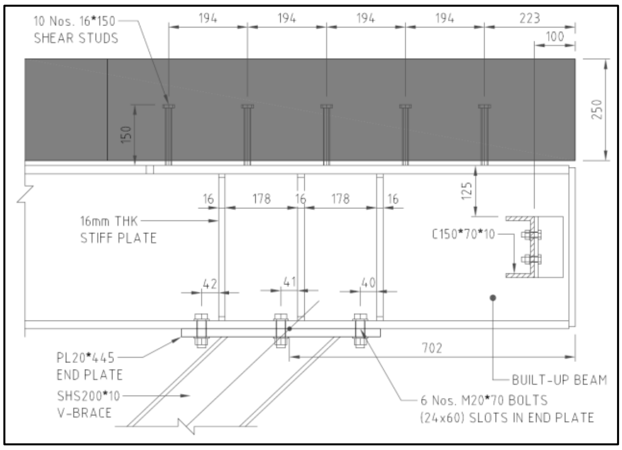

Fig. 7: Strut & Bracket (Section) (dimensions in mm)

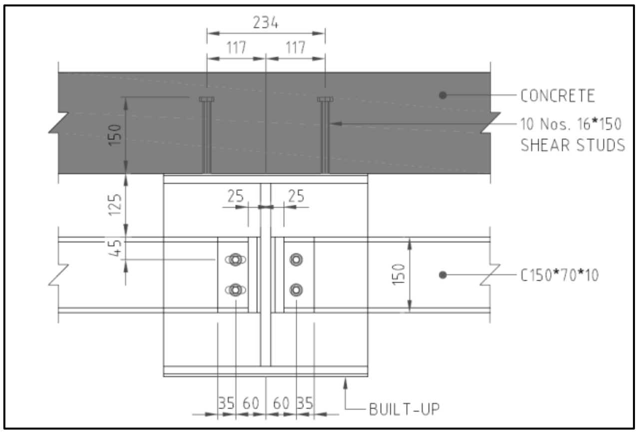

Fig. 8: Struct & Bracket (Section) (dimensions in mm)

4.3 Anchor Bolts of the Strut Bottom Connection with the Box Girder Bottom Slab Haunch

The number of anchor bolts increased to 6 and the embedment depth was optimized to reduce the risk of clashing with the bottom slab post-tensioning ducts. Further, the location was selected to ensure suitability to carry the straining actions transferred from the strut support. The design considered small deviations due to the uneven surface of the concrete, allowing grouting up to 15mm thickness (See Figs. 9 & 10).

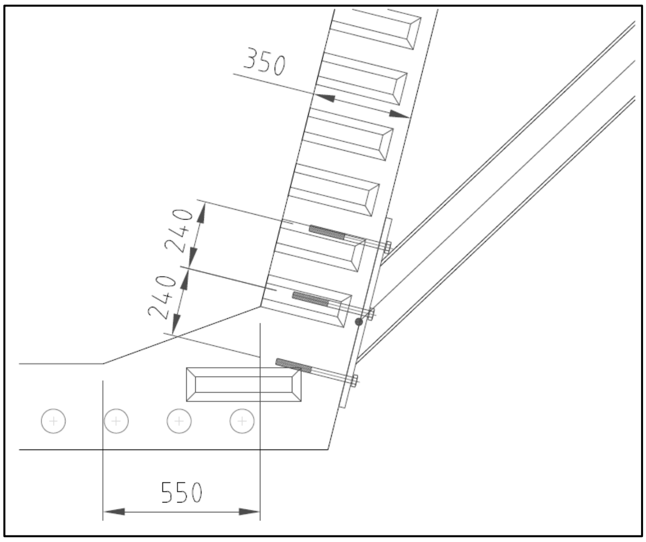

Fig. 9: Strut-Girder connection (Section) (dimensions in mm)

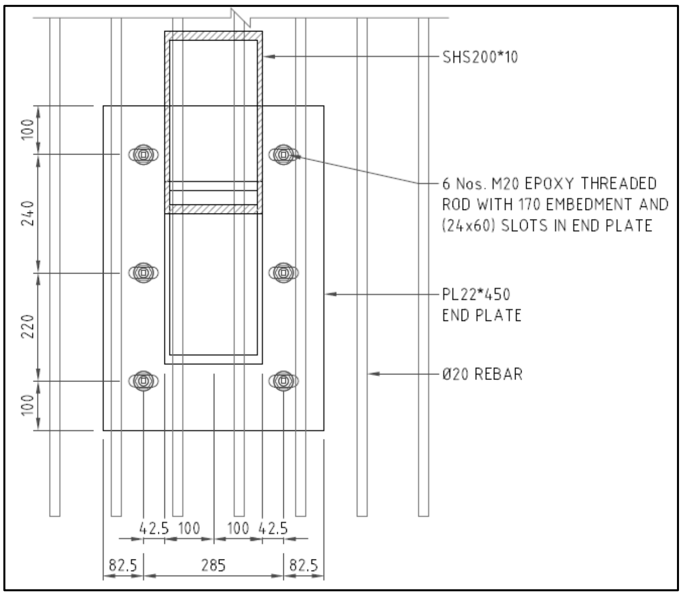

Fig. 10: Strut-Girder connection (Plate details) (dimensions in mm)

4.4 Drilling and Bonding of the Steel Reinforcement on the Existing Deck Slab to Accommodate the Extension

The steel reinforcement diameter and spacing were selected based on the required embedment depth, minimizing the number of drilling locations along the 250mm thick slab, while keeping a safe distance from the top slab post-tensioning ducts (See Fig.11).

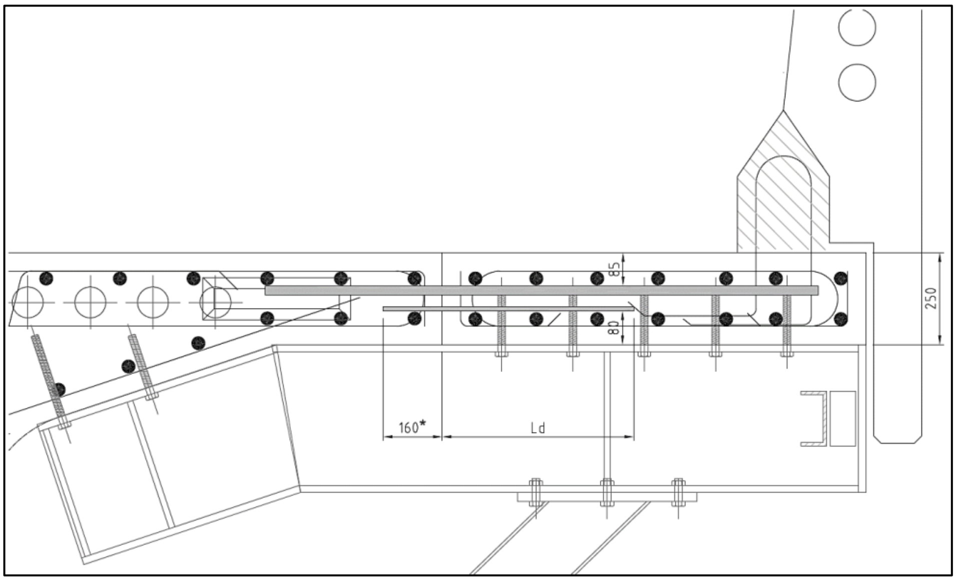

Fig. 11: Caption of Embedded Reinforcement (dimensions in mm)

5 Conclusion

The Ramp Bridge 8 of the Al Bustan South Project required the extension of the existing bridge deck by 1.15m to allow the placement of a second traffic lane. The design of this extension aimed to create a robust solution that would be constructed in a fast-track schedule with tight deadlines for delivery while considering the site constraints and market material availability.

The challenges that were encountered in the proposed one side deck widening were mainly the installation of the steel strut in the existing post-tensioned concrete deck, considering that the anchorage of the steel strut in both top and bottom plates, would have to be done in such a way to avoid any potential damage to the existing post-tensioning tendons. Further challenge was the jacking up of the bridge deck for the replacement of the spherical bearings, that would carry the increased loads due to the deck extension. The design proposal, the contractor’s execution plan and the continuous engagement of all project stakeholders (Client/Contractor/Designer), were factors that enabled to overcome the above challenges and provide a robust structural design, speedy construction, with an aesthetically unintrusive configuration. Fig.12 shows the completed bridge deck.

Fig. 12: The Completed Deck Extension (site photo)

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