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Upgrading Existing Infrastructure – The Case Study of Industrial IC Bridge

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Abstract

Doha, the capital of Qatar, has been facing phenomenal growth of vehicular traffic owing to rapid development which has resulted in traffic congestion causing significant rise in travelling time in some areas. To mitigate these problems, upgrading existing intersections and consequently retrofitting the contained structures along significant corridors is a strategy implemented by the Public Works Authority in some cases. A case study presented herewith, is a project awarded as a *Design & Build* Contract by the PWA to upgrade the infrastructure at the junction of a major corridor (Junction 101 – Industrial Interchange). This paper covers the tender stage and the final design solutions, outlining the simulation models, assessment of the existing structures, the design analysis and the construction methodology adopted to address the operation and maintenance conditions as well as the project specific requirements and constraints.

Keywords: Steel-concrete composite; Condition assessment; Retrofitting; Bridge expansion joints

1 Introduction

The Industrial Interchange is located at the junction 101 of the Salwa Road and Furousiya Street. Salwa Road is categorized as an expressway and the Furousiya Street as a major artery before upgrading and shall be categorized as an expressway in the future. The junction is a 4-level grade-separated junction (Figure 1) with Furousiya Street at -1 level, existing roundabout bridges at-grade (level 0), Salwa Road bridges at +1 level, and left turn directional ramp at +2 level.

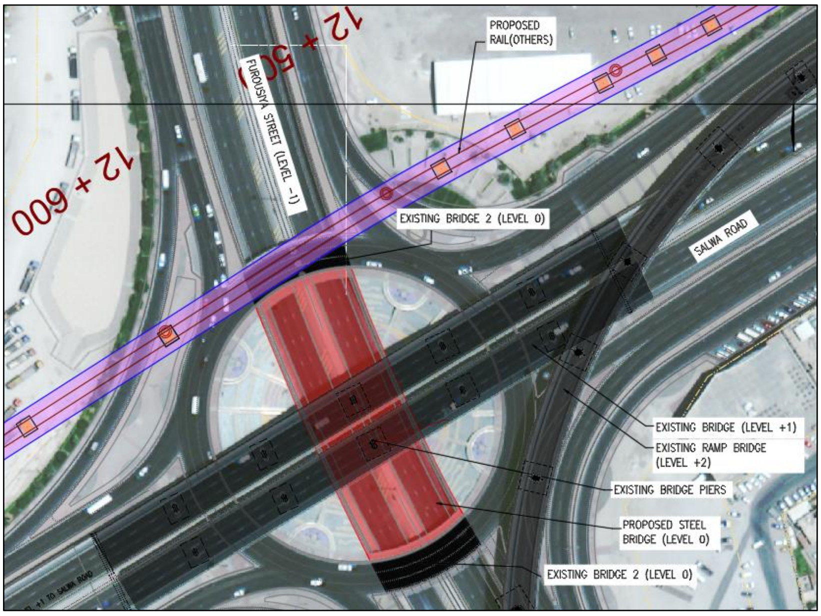

Fig: 1: Layout of Junction 101 with the existing and proposed bridges

The scope of the project was to upgrade the at-grade (level 0) portion of the intersection to improve the traffic performance and to accommodate the future demand. The reference design in the tender stage (Figures 2 & 3) proposed/dictated the construction of a single span bridge with steel-concrete composite decking over the Furousiya Street extending between the two existing roundabout bridges, converting the current signalized roundabout to a signalized junction.

2 Tender Stage

At the pre-design/tender stage the design approach considered a single-span steel-concrete composite bridge, with 37.80m width and 104.48m length approximately, supported on the existing retaining walls with the necessary retrofitting (Figure 2), to carry safely the additional loads due to the new configurations and accommodate the installation of the new bridge bearings. The bridge was initially designed as a steel- concrete composite bridge with steel tub girders spaced in a nominal distance and concrete slab on top. The monolithic/composite connection of the two structural elements was achieved with shear studs projecting at the tub girder top flanges. The two existing piers of the Salwa ramp bridges (level +1), maintain their structural independence through openings in the newly proposed deck.

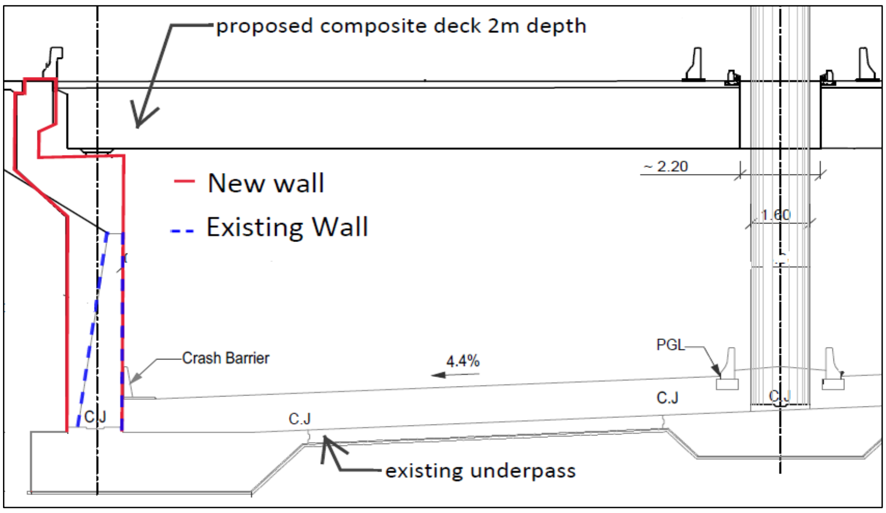

Fig. 2: Reference Design Typical Section

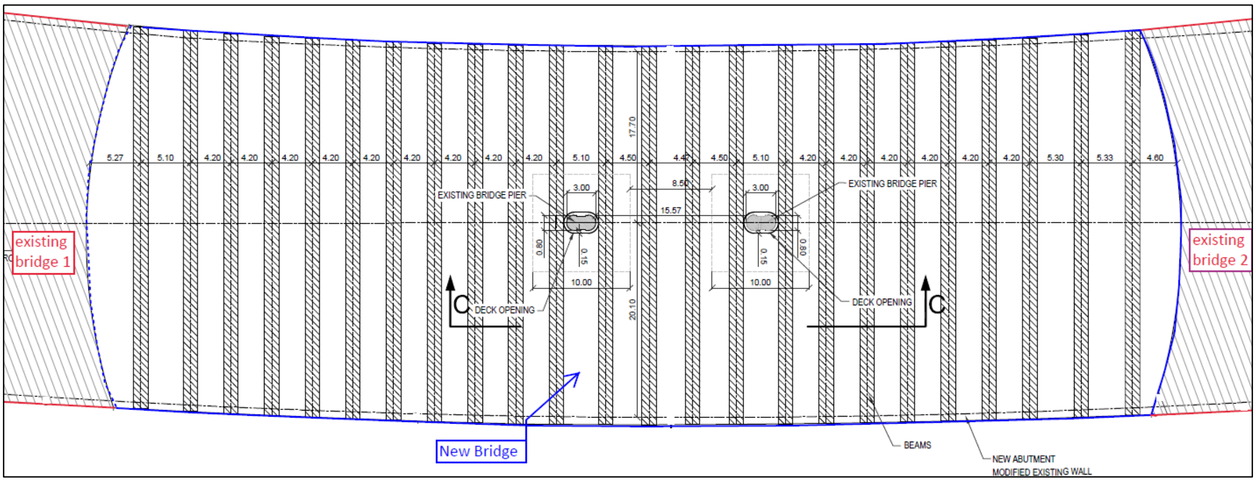

Fig. 3: Reference Design Layout

Due to the challenging site conditions, a number of constraints had to be considered in the preliminary design stage which included the following:

- **Vertical Clearance**: As the newly installed deck is bound by the existing underpass at -1 Level and the existing Salwa Road Bridge deck at +1 Level, the design was constrained by the fixed total height to provide vertical clearances below and above the proposed deck. To provide acceptable vertical clearances, the new deck depth had to be optimized.
- **High Groundwater Table**: Due to the consideration for high groundwater table present at the site, particular attention was given to ensure the watertightness of the existing underpass structure by avoiding penetration of the bottom slab.
- **Existing Salwa Bridges Piers**: Piers for the existing Salwa Bridges are present behind the proposed abutments and founded at a higher level than the existing underpass. The design was required to mitigate against the risk of undermining the piers' foundations and complications of installing temporary shoring to support the piers during construction.
- **Unknown Existing Structure Capacity**: There is an inherent risk in relying on the capacity of the existing structure. The design considered minimizing additional load transfer to the existing underpass.

Several design options were considered which included the modification in the following structural features:

- **Number of spans**: A single-span structure would eliminate the need for placement of the median support; however, this will require an increased deck depth, which would make the vertical clearances unacceptable.
- **Abutment types**: Modification of the existing underpass retaining walls to support the new deck as envisaged in the tender design would require major retrofit of the walls and enlargement of the existing footings, including complicated shoring to support the existing Salwa Bridge piers during the construction. Installing a piled abutment behind the existing underpass walls would mitigate this risk.

After consideration of the above factors, the design option as presented in the following sections was selected.

3 Design Stage

3.1 General Description

The optimal solution finally adopted in the design was a two-span composite bridge with a median support integrated with the existing base slab and new abutments at both sides with piles placed behind the existing retaining walls (Figure 4). The challenge of this solution is the construction of the foundation of the median piers, without overstressing the existing 400mm base slab and maintaining the integrity of the slab and the underlying waterproofing membrane, considering the high-water table in the area. Further, the proposed solution of the independent piled abutments eliminated any need for temporary shoring walls that would be necessary to support the existing Salwa Piers located behind the existing underpass walls.

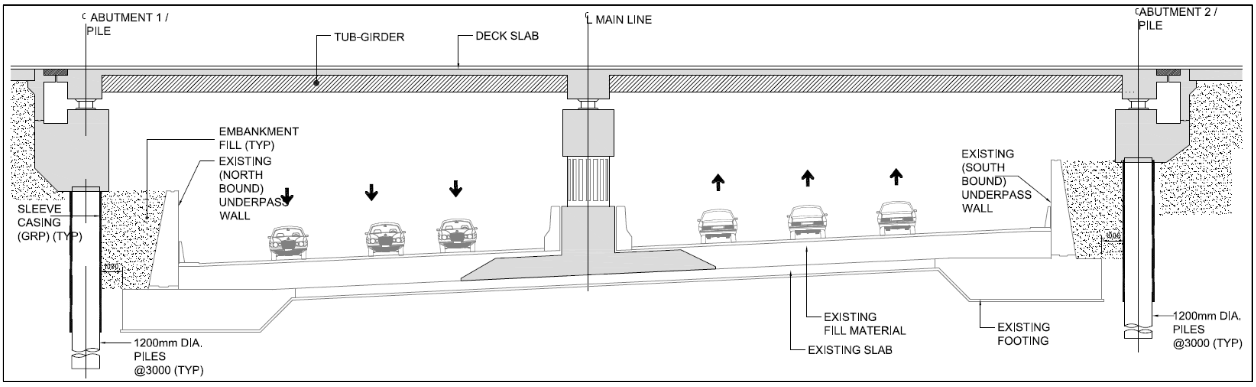

Fig. 4: Final/Adopted Bridge Section

3.2 Advantages

The preference of this option was based on many advantages in regards to the feasibility and constructability of the bridge, as well as its minimal impact to adjacent structures in a compressed construction schedule as presented below:

- Achieved maximum vertical clearance below the deck (min 5.7m).
- Achieved maximum vertical clearance between the proposed deck FRL and Salwa Bridge deck soffit.
- Deck depth is reduced to 1.0m in total.
- The durability requirement of 120 years is satisfied.
- The bridge is supported on new abutments and piers.
- No loads transferred on the existing retaining walls and therefore avoided extensive and complicated retrofit works.
- Applied stresses on existing slab within allowable code limits.
- No major temporary shoring system is required.
- Excavation and backfilling activities are significantly reduced.
- Eliminated the requirement of extensive de-watering activities that would be necessary if the underpass wall would be converted to a bridge abutment.

3.3 Existing Structures Assessment

A condition assessment of the existing structures has been conducted at the early stages of the design in order to understand the properties of materials incorporate any strengthening actions and determine the feasibility of the proposed solution. All the tests/measurements/site inspections/verifications of as-built configurations required by the codes have been conducted and the results were analyzed and provided in assessment reports. The results have shown that the existing trough structure and the roundabout bridges are in a good condition and no strengthening was deemed necessary. In addition, the base slab of the underpass and the foundation of the Salwa Bridge piers could accommodate the additional loads due to the construction of the median support.

3.4 Structural Type & Design Approach

The superstructure for the Industrial Interchange Bridge extends between the two existing roundabout bridges with an overall length of 107m approximately (Figure 5). The 1.0m composite deck depth consists of 0.25m of cast-in-place concrete slab and of 0.75m steel girder with a typical spacing of approximately 3.0m (Figure 6). The steel tub girders are connected at the abutments and median supports through concrete diaphragms. The connection of those elements is monolithic and is achieved through shear studs (Figure 6).

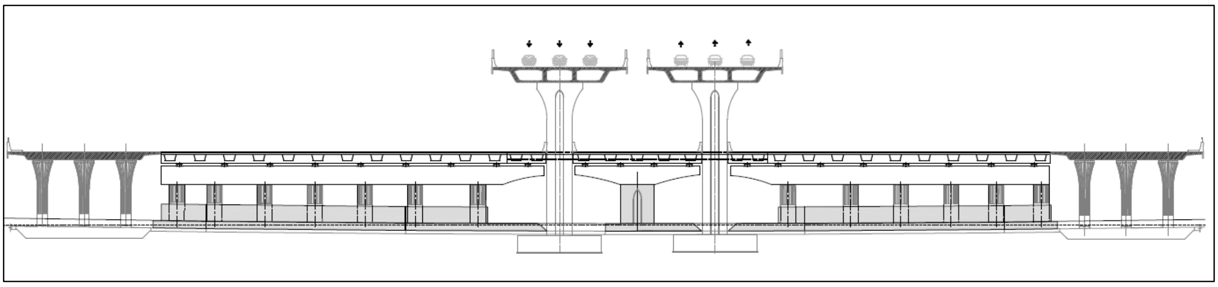

Fig. 5: Longitudinal Section

The bridge deck rests on spherical bearings at all supports. The articulation over the middle support consists of free sliding bearings in order not to transfer additional moments at the bottom of the median piers. In accordance with the new road layout, the traffic direction is not always perpendicular to the expansion joint axis between the parts on the bridge (Figure 7). For this reason, flexible plug joints were chosen to connect the parts of the bridge to allow the movement in both directions and accommodate the altering super-elevation throughout the 107m deck width (Figure 7).

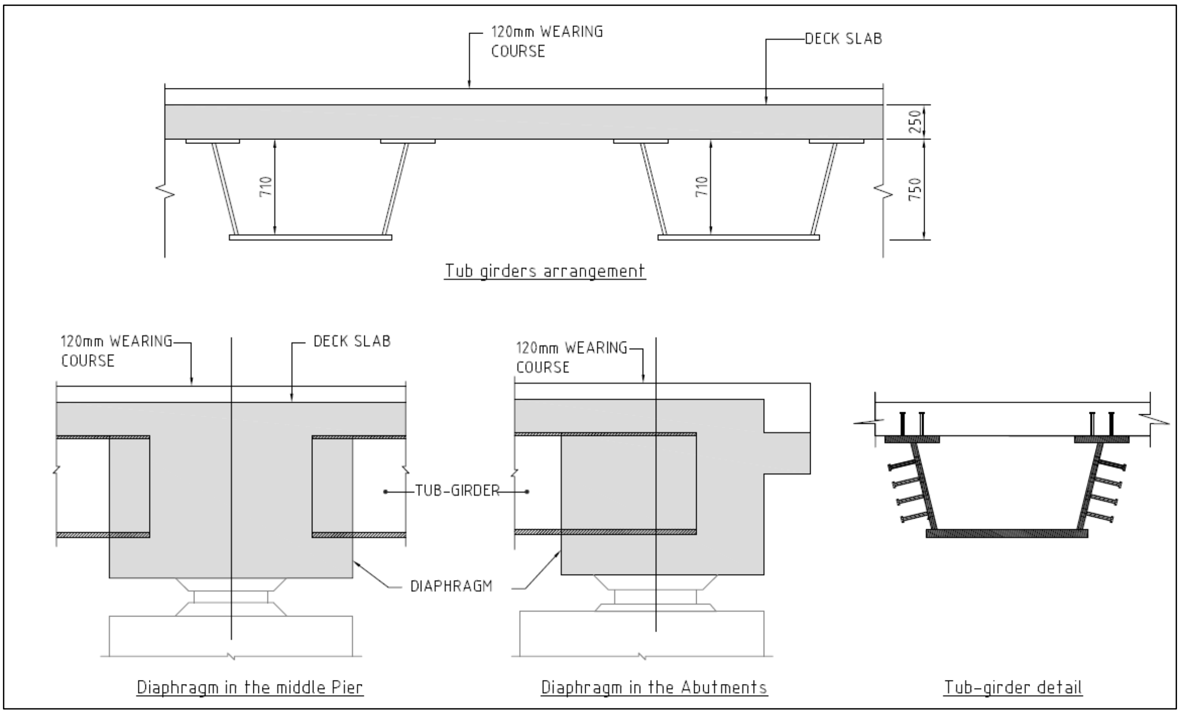

Fig. 6: Typical deck details

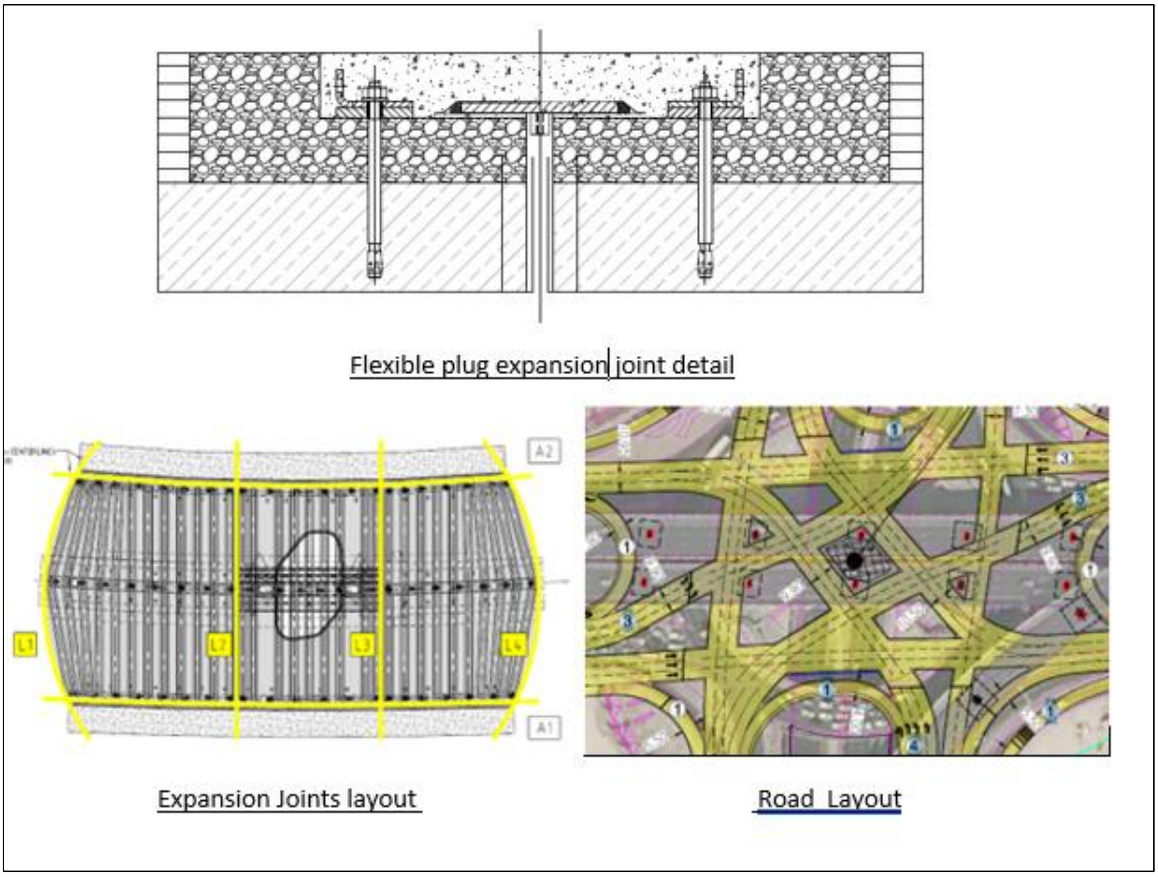

Fig. 7: Flexible plug expansion joints details and layout

The abutments are designed as piled supports with pile cap. The piles are sleeved for the top 5.5m to avoid transferring loads on the existing retaining Underpass walls. The median pier is designed with pad strip footings of 11,000 to 12,000 mm width and 850mm to 900mm thickness, integrated with the 400mm existing base slab with shear studs (Figure 8) in order to accommodate the additional loads transferred from the pier. By implementing these substructure types the risk of damaging the existing Underpass walls is avoided and the amount of temporary works is minimized.

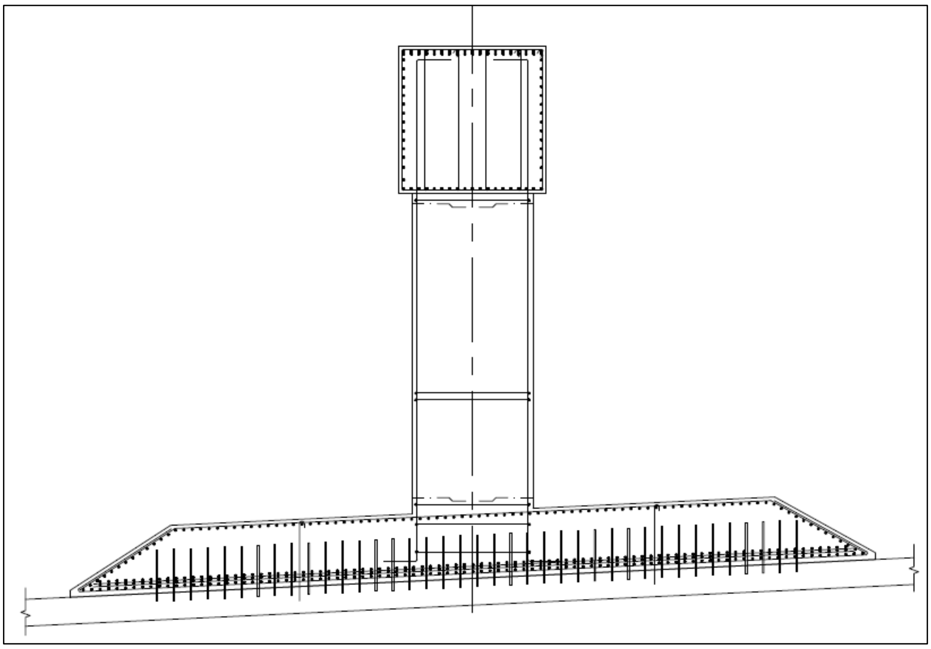

Fig. 8: Median Pier integrated footing

4 Conclusion

The case study presented in this paper, highlights the challenges faced to develop and implement a retrofitting solution to address multiple requirements such as a compressed construction time-frame, constraints in the vertical clearances below and above the new bridge deck due to the presence of the existing structures, as well as efforts to preserve the existing structures without strengthening (Furousiya Underpass/ Roundabout Bridges/ Salwa Road Ramp Bridges).

Further, the need for temporary shoring walls and the extensive dewatering were both eliminated by using piled abutments.

The use of prefabricated steel girders decreased the weight of the bridge deck superstructure, allowed a significant portion of works to be completed off-site, minimized the impact to the existing underpass slab and at the same time it provided an ease of handling in the site space that is limited due to the presence of diverted traffic.

The design proposal that was developed was an integrated and robust solution to accommodate all the site constraints and allow the construction of this complex interchange to be conducted in a safe (for the existing structures) and timely (considering the demanding construction schedule) manner.

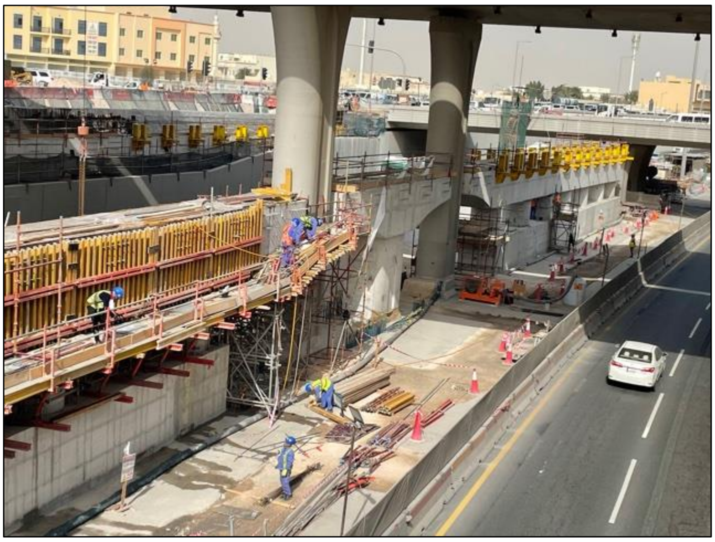

Fig. 9: – Median Piers during construction

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