CASE STUDY: TOP-DOWN CONSTRUCTION OF ROAD OVER BRIDGE ACROSS A RAILWAY TRACK CROSSING LOCATED IN A DEEP-CUT GROUND PROFILE

Shahrukh Ahmed, Dileepan Ulaganathan, Vasanth Kumar Samyayya
Larsen and Toubro Construction, Chennai, Tamil Nadu, India

Abstract

This case study delves into the strategic use of top-down construction techniques in the development of a Road Over Bridge (ROB) spanning a deep cut designed for railway tracks. Situated near Delhi, India, the proposed ROB features a railway crossing at the base of a deep cut, with an approximate total span of 150 m and a deep cut depth of 20 m. The initial construction methodology proposal involved the conventional sequence of construction which commences with excavation up to the required depth followed by construction of foundation, substructure, and superstructure. Hence, the road traffic is allowed to operate only after all the structural and excavation works are completed. However, this method has some significant drawbacks with regards to the duration of construction, excessive delay in resumption of traffic, unfavourable aspects related to safety and economy of tall and slender substructure components such as piers and abutment. Moreover, owing to the challenges involved in erection of superstructure at considerable heights, the choice of available superstructure types is limited. To overcome these issues, the top-down construction strategy has been adopted. In this method, the structural construction works (construction of foundation, substructure, and superstructure) precede the excavation works and the traffic is resumed on the road immediately after completion of all structural works. Hence, there is no delay on account of the time-consuming excavation work. Also, cost effective and efficient superstructure types like voided slab, PSC box girder can be adopted since the formwork can be supported from existing natural ground level which is at shallow depth. Moreover, provision of slender substructure components is replaced with pile groups which are more efficient and economical.

Keywords: top-down construction, deep-cut ground profile, road over bridge

1 Introduction

Earthworks are the embankments and cuttings that allow a railway track to maintain a certain line, level and grade through the landscape. A cutting is used to carry the railway through ground with a natural level above the line of the railway. The need to cut into natural ground arises from the fact that railway formations have to maintain relatively easier gradients than the prevailing ground slopes. A cutting is a permanently open excavation, and the cut profile (or cutting) may pass through soils, rocks or a combination of both. In cases, where digging or excavation is required to be done for a significant depth into the ground, it is termed as "deep-cut ". Due to the safety concerns, difficulties in construction, increased manpower and resource consumption, special provisions with regards to design and construction need to be adopted.

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Slope stability is one such extremely important consideration in deep excavations and is governed by a variety of factors such as soil composition, slope profile, water table depth, drainage conditions, surcharge loads, liquefaction, and manmade activities [1]. Adequate lateral support system needs to be adopted depending upon the site conditions such as sheet piles, king posts and lagging, contiguous bored pile walls, secant piled walls, diaphragm walls, soil nailing, sprayed concrete, bracings and hand dug caissons. However, in situations where space is available and the ground is sufficiently strong, the formation of side slopes with berms can present a simple and cost-effective solution, offering an alternative to the more expensive and complex earth lateral support systems mentioned above [2]. Due to the extensive amount of excavation work needed in deep cut ground profiles, the conventional bottom-up approach is unfavourable as it leads to significant delays in reopening road traffic. Additional disadvantages include the substantial requirement for substructure formwork (such as piers and abutments), operational challenges for cranes working at considerable heights and distances, increased risk of soil instability and slope failure, higher construction costs due to the need for extensive temporary support systems, and potential disruptions to underground utilities and surrounding structures. Thus, Top-down construction approach is gaining rapid popularity these days and the same has been adopted for the construction of the concerned Road Over Bridge which spans across Railway (Dedicated Freight Corridor) tracks.

2 Bridge location and description

The bridge is proposed to be constructed in the Nuh district of the state of Haryana, near New Delhi. In the vicinity of the bridge, the project alignment runs parallel to the Western Peripheral Expressway, traversing the Aravalli Hills, and closely following the foothills of the mountains (Figure 1). This route intersects various ridges, plateaus, and valleys. A steep negative gradient of up to 1 in 200 is implemented for a stretch of approximately 11 km to match the formation level at its end. Consequently, the provision of a deep-cut bridge is immediately followed by a 2 km-long tunnel and several viaducts on the downstream side, as well as multiple deep-cut bridges on the upstream side, considering the varying landscape of the terrain. As per the seismic hazard map of India [3], this region falls under Seismic Zone-IV and the tectonic elements of the area are considered capable of generating an earthquake of high intensity.

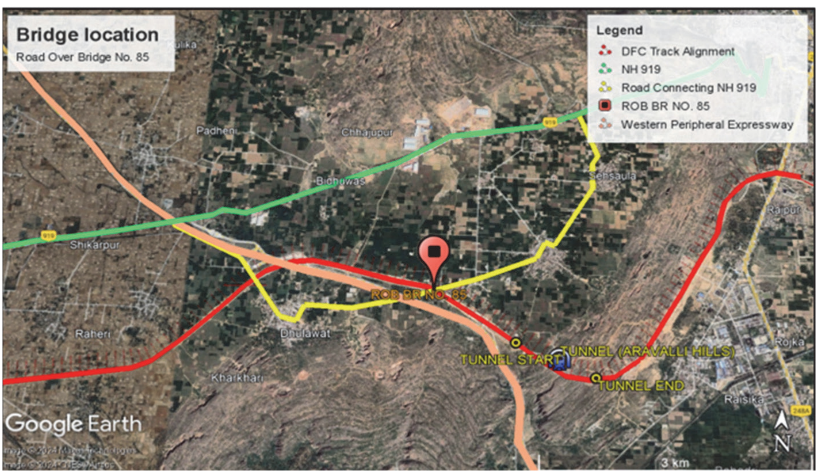

Figure 1 Satellite Imagery (Google Earth) Showing Bridge Location and Vicinity

The road passing over the bridge with a carriageway width of 10m connects National Highway 919 with nearby villages (Dhulawat, Ghusbethi & Sehsaul). The railway track crossing, with a radius of 875m at the bridge location, is positioned at a skew angle of 51° relative to the road crossing (Figure 2). Therefore, effective survey control is integral to the construction process. Boreholes which are available near each foundation offer valuable insights into the subsoil strata essential for a reliable geotechnical design. It can be observed that the ground water table is significantly below the formation level and that 'Medium Dense' to 'Very Dense' silt and sand (based on SPT N value results) are consistently present throughout the depth. These considerations are essential to ensure satisfactory slope stability.

Figure 2 Site Photograph Displaying Bridge Location, Track Crossing, and Deep Cut Ground Profile

Table 1 Salient features of the bridge

Particular	Value/Description
Span configuration	3 x 50 m (EJ-EJ)
Vertical Clearance	21.285 m (Rail level to soffit of PSC box)
Horizontal alignment	Curve radius – 875m, skew – 51 degree
Vertical alignment	1 in 238.961
Type of Superstructure	PSC Box Girder (Cast-in-situ) of depth 2.5 m
Deck width and carriageway	12.5 m deck width with 10m carriageway width
Type of Bridge bearings	POT-PTFE (Polytetrafluoroethylene), Elastomeric Bearings for Seismic stoppers
Number of traffic lanes	3
Loading standard	Class A & 70R (Wheel & Track) loading as per IRC 6
Type of Crossing	Dedicated Freight Corridor Railway tracks
Substructure and foundation configuration	Abutment- Diamond shape pilecap with 9 nos. of 1.2m diameter piles. Pier pilecap with 11 nos. of 1.2m diameter piles.
Exposure condition	Very severe as per IRC 112:2020 [4]

3 Construction methodology and design considerations

The sequence of construction along with relevant design considerations in each stage are mentioned below.

3.1 Traffic diversion, setting out and site preparation

Prior to commencing construction, a traffic diversion plan must be devised and executed. This plan details how existing traffic will be safely rerouted, potentially involving temporary routes, signage, or traffic signals to maintain smooth traffic flow during construction. Diversion of existing road is made as per this traffic diversion plan. After this, survey setting out is carried out to mark the coordinates of piles exactly as per the Good for Construction drawings (Figure 3 and 4).

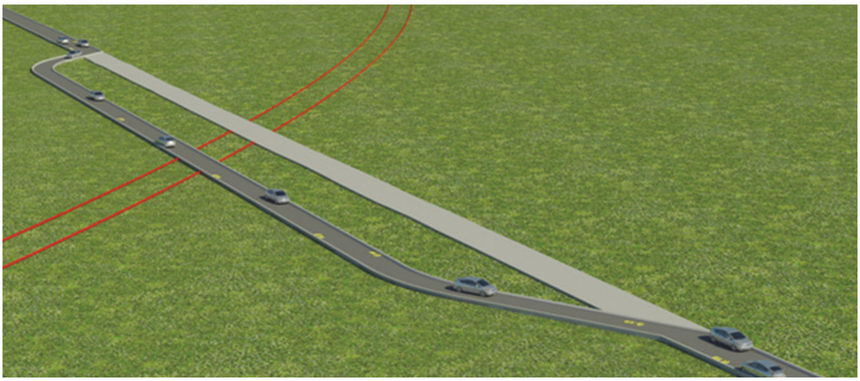

Figure 3 Traffic diversion, setting out and site preparation

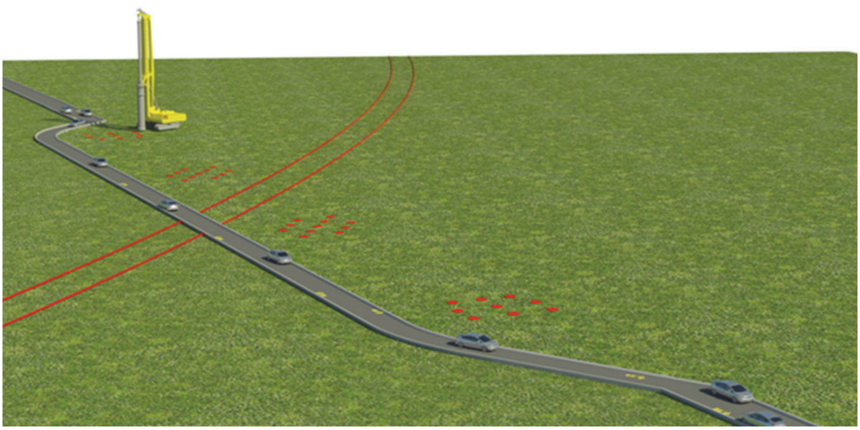

Figure 4 Survey setting out, marking of pile coordinates and commencement of piling operations

3.2 Design & construction of substructure

Following the setting out, piling is commenced, with boring conducted to the specified depth (Figure 5). The depth of pile required is evidently higher for the piers than for abutments because of their longer exposed pile lengths. Liner of suitable thickness is provided for the

exposed lengths extending up to the formation level of railway tracks to protect against environmental degradation thereby enhancing its durability. After the piles have been cast, the next set of activities include reinforcement fixing and casting of pile and pile cap including bearing pedestals. Each span of overall length 50m being simply supported on the substructure is subjected to significant horizontal forces (lateral and longitudinal forces) and movements. Consequently, the application of POT-PTFE type bearings of the required capacity positioned atop the completed pedestals becomes imperative [5].
With regards to the structural design, a three-dimensional space frame model is developed in Finite element modelling software (STAAD Pro). Pile and pile caps are modelled with appropriate structural and soil stiffness. It should be noted that soil springs are calculated below lowest level of ground where pile intersects ground level. Loads are applied at appropriate levels on pile and pile cap system to effectively simulate loading conditions (Figure 6).

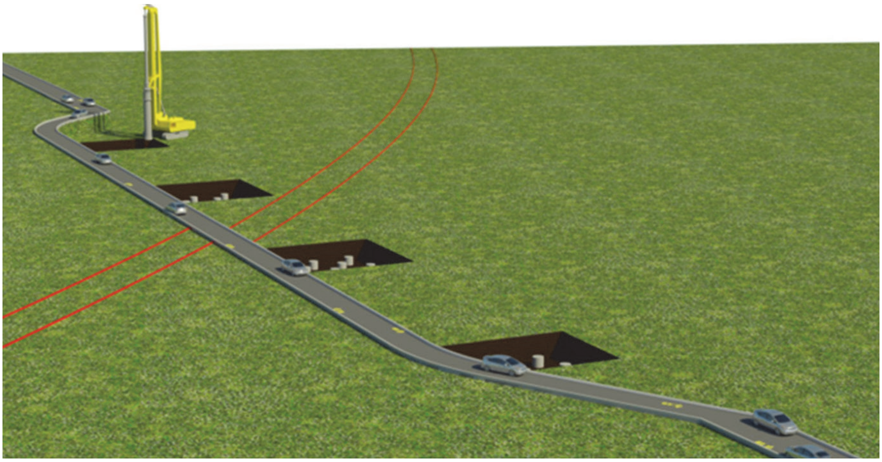

Figure 5 Excavation till bottom of pile cap and chipping of pile head

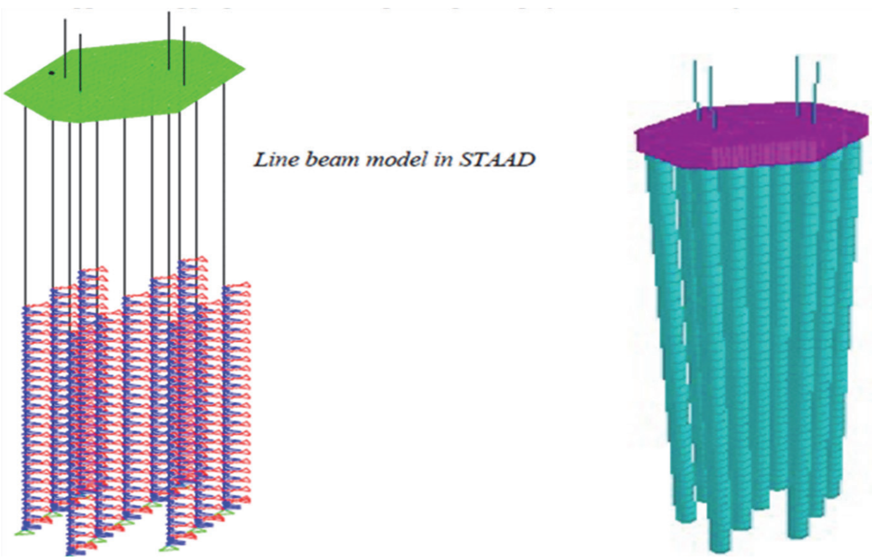

Figure 6 Pile and Pile Cap model in Finite Element Method(FEM) software

3.3 Design and construction of superstructure

The formwork for the superstructure shall be erected on the sides, and the ground shall be prepared as the soffit for superstructure construction. This is followed by concreting of superstructure (Figure 7). The selected superstructure is a cast-in-situ post-tensioned box-type design, known for its exceptional strength, stiffness, and cost-effectiveness, particularly suited for intermediate to long spans [6]. (Figure 8). Critical load combinations are considered for the given number of lanes as per IRC 6:2017 [7] with the maximum axle and vehicle loads as 17 t and 100 t respectively. The superstructure is modelled as a beam except the diaphragm portion which is modelled using strut and tie model because of non-linear strain distribution. The casting of superstructure is done in stages as elucidated below:

Stage 1: At the end of 14 days (after casting) subjected to a minimum attainment of compressive strength of 50MPa, prestressing commences as per the approved stressing sequence.

Stage 2: At the end of 24 days crash barrier, footpath and wearing course are cast.

Stage 3: Live load (Traffic) is allowed to operate at the end of 39 days after casting (Figure 9).

Overall, these stages are carefully planned to ensure the safe and efficient construction of the project while considering the time-dependent properties of concrete and the sequence of construction activities.

Next, the superstructure load shall be transferred to bearing after the pedestal and pile cap achieves the required strength.

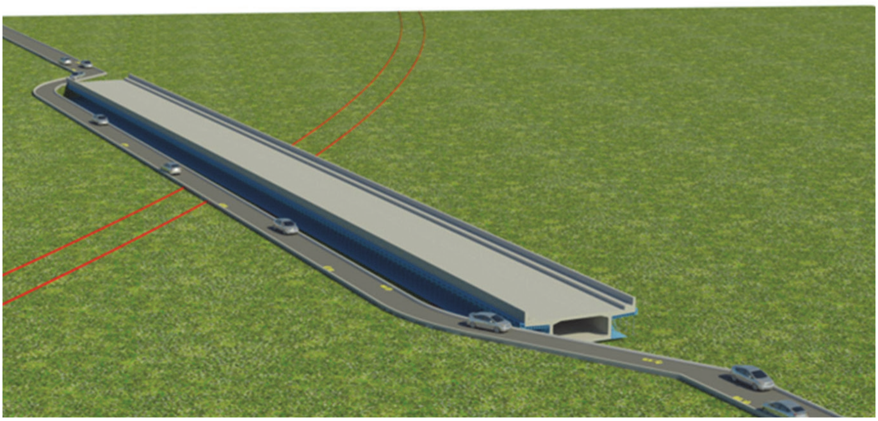

Figure 7 Construction of superstructure with formwork directly supported on ground.

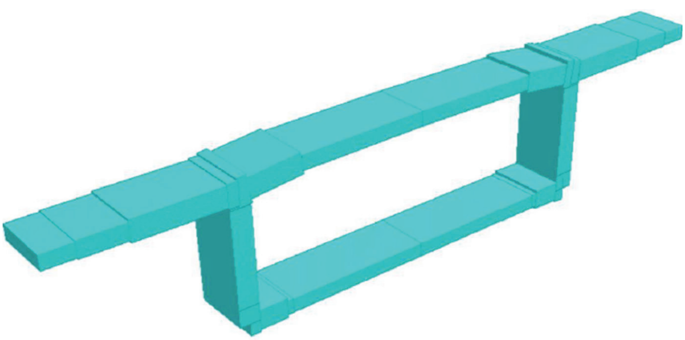

Figure 8 Rendered view of Box type superstructure in FEM software.

3.4 Design and construction of retaining walls and approach road

Retaining walls are constructed at both abutment ends to retain the approach embankment. Backfilling up to required depth and pavement layers is then laid. Strip seal expansion joints are installed at the junction of the ends of bridge segments to allow for thermal expansion and contraction, as well as to accommodate movements caused by seismic activity or settlement of the structure.

3.5 Excavation and laying of track

Ground excavation is commenced only after the preceding activities are completed satisfactorily. Open Excavation is done in stages with berms provided at suitable interval (typically 6m height) along the slope having a minimum width of 1.5m. Side slope ratio of approximately 1:1 (horizontal to vertical) is usually maintained. The above requirements are as per relevant codal provisions unless otherwise governed by site constraints [8]. Additional care shall be considered while excavating near the structural piles. Finally, railway tracks are laid in accordance with the requirements of the Standard Schedule of Dimensions for Western Dedicated Freight corridor (Figure 10) [9].

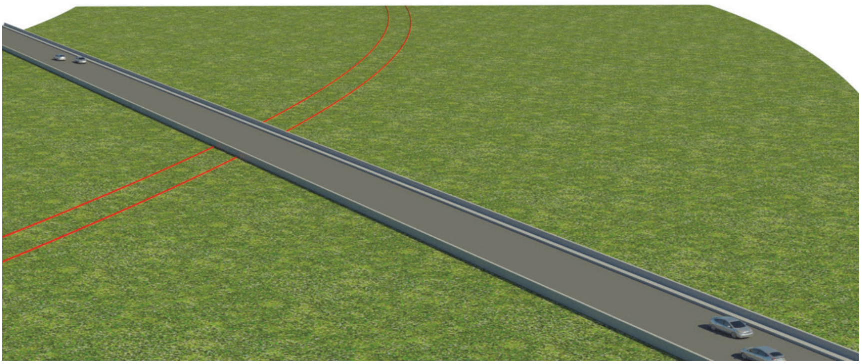

Figure 9 Traffic allowed to operate on the newly constructed bridge superstructure

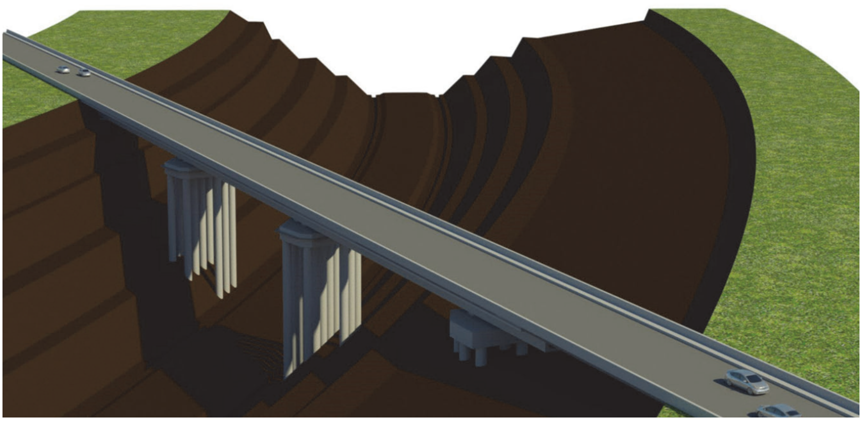

Figure 10 Final completed stage

4 Conclusion

The top-down construction method has several advantages when compared to the conventional method with regards to pace of construction, economy and minimal interruption for road traffic. The foundations are converted to pile only and the pile cap functions as the sub-structure. Piles shall be constructed directly from NGL without any excavation. Also, the Pile cap is constructed with minimum excavation till pile cap bottom. This is advantageous, since all the activities will be performed from NGL itself with proper access and with more efficiency. For constructing new bridge, road diversion will be easier over the NGL than compared to diversion over excavated Deep cut. The Superstructures are converted into Box Girders which are more economical and efficient. These will be constructed directly over the ground, making it easier to access and work effectively. Structural Work need not be held till completion of deep cut excavation.

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