Geotechnical design of the Izmit Bay Suspension Bridge

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Summary

The Izmit Bay Suspension Bridge, app. 50 km east of Istanbul, crosses the Sea of Samara with a main span of 1550 m. The foundation of the bridge poses interesting challenges in that the bridge site is in a highly seismic region. Moreover the ground profile ranges from Dolomitic Limestone to a thick sandwich of silty sand and clay layers overlying the bedrock.

Keywords: Earthquake; Foundations; Pile inclusions; Suspension bridge.

1. Introduction

The Izmit Bay Bridge will feature the world's 4th longest suspension bridge, main span of 1550 m, by the slated time of inauguration in 2016.

The bridge site is located app. 50 km east of Istanbul and crosses the Sea of Samara. This is a highly seismic region in close proximity to the North Anatolian fault which caused the 1999 earthquake. Moreover, the ground profile ranges from Dolomitic Limestone at ground level on the northern side to kilometre thick sandwich of silty sand and clay layers overlying the bedrock moving south. The top soil deposits are very loose/soft and susceptible to liquefaction. The foundation structures are therefore different when moving from North to South.

The paper focuses on the geotechnical and soil-structure interaction aspects of the design and construction. It describes the design process allowing the foundation challenges to be met by innovative solutions.

2. Foundation solutions and challenges

The foundation solutions adopted for the Izmit Bay Bridge are shown schematically in Fig. 1 with gravity structures for the anchor blocks and a hybrid gravity/pile inclusion solution for the two towers.

The very high ship impact loads, 246 MN from the 160,000 DWT design ship and particularly the seismic load cases with horizontal forces typically of the order 400 MN, posed very significant challenges for the pylon foundations.

Direct foundation was obviously not an option and traditional piled foundations would be very hard to verify for the seismic NCE event.

Fortunately the ground conditions and the magnitude of loading were similar to the conditions for the Rion-Antirion Bridge in Greece and through 2D and 3D FEM calculations it proved possible to verify this foundation type solution to the tower foundations for the Izmit Bay Bridge.

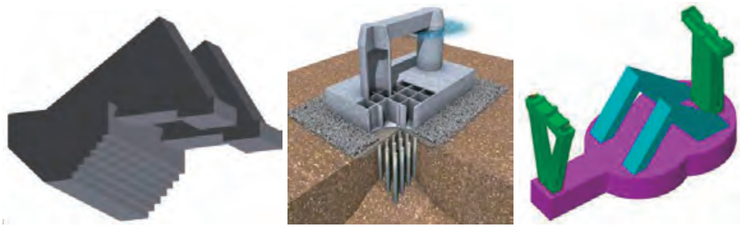

Fig. 1: Foundation concepts; (a) North anchor block; (b) Tower foundations; (c) South anchor block

The North anchor block was initially considered the simplest and most straight forward of the foundation structures. However, it turned out to produce by far the most comments from the Independent Design Checker and proved to be very challenging in terms of both design and execution due to a perceived possible kinematic failure mechanism. To manage the perceived residual risks from this failure mechanism, the design was also verified for a considered worst case scenario and a programme of additional investigations and specialist laboratory tests were initiated to confirm the assumption. The reporting from the additional testing did (fortunately) confirm that the worst case scenario was unjustified and the design could be approved.

The North and South towers are hybrid solution each with 195 Ø2.0 m tubular steel pile inclusions for soil improvement and a gravel bed acting as a horizontal load fuse between the caisson base and the free-standing piles. The most challenging part of the tower foundation design was the verification for the seismic events applying the base isolation concept which was previously used for the Rion-Antirion Bridge. This involved a very comprehensive calibration exercise in order to provide a match between the global IBDAS model and 2D plane strain Plaxis finite element modelling (vertical load) and ABAQUS 3D finite element modelling to determine the load-displacement behaviour of the gravel bed springs.

The application of an advanced non-linear model with distributed springs allowed implementation in a practical manner of a displacement based verification for high magnitude earthquakes with dissipation of seismic energy by rocking as well as a controlled and limited sliding.

The South anchor block was in the Tender Design in line with the North anchor block using two front pads and a rear pad. However, as the shallow ground conditions were relatively soft alluvial deposits the pads needed to be founded on piles to provide sufficient bearing capacity and acceptable settlements. This solution was, however, not without difficulties and as the detailed design progressed the loads changed (in part due to the relocation of the anchor block) and in view of the conceived risk of possible secondary faults, it proved beneficial to include the South side span pier in the anchor block structure. Thus, very late in the design process it became clear that H/V was now considerably lower than unity and “overnight” the concept was changed to direct foundation at level -15 m. The very robust design of the anchor block as one big gravity structure had the added advantage that it could be verified even when subjected to severe oblique-slip fault movement.

3. Conclusions

This extremely interesting project posed a multitude of geotechnical challenges. The project re-emphasized that in geotechnics you must expect the unexpected. By dedicated cooperation between geotechnical and structural engineers and very fruitful cooperation with the Contractor IHI it was possible to overcome the challenges using innovative solutions and readiness to adapt to changing conditions brought about by the ground conditions, the construction programme and economy.

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