Yesildere Intersection Bridge

Design Challenges and Solutions

A. Yagcioglu, A. Yavuzcan, O. Kokten, T. Solak, I. Çetin

Temelsu International Engineering Services Inc., Ankara, Turkey

Abstract This paper presents the design challenges behind the Yesildere Intersection Bridge, a 24 span, multi sectional, precast prestressed "I" girder concrete bridge with exceptionally curved plan layout. Yesildere Bridge, located in Yesildere District, Izmir, Turkey, plays an important role in a complex transportation infrastructure solution system, covering also the Konak Tunnel with two special portal structures located at two ends of the tunnel. Mentioned transportation system solution, namely "Konak-Yesildere Connection Road", acts as a key element of Izmir City's near future transportation network as being connecting Konak and Buca districts in a more comfortable way within much shorter period.

Within this paper, structural and geotechnical aspects of design approach and construction related design solutions adopted for Yesildere Bridge, such as bridge structural element sizing and positioning, geotechnical improvement solutions, optimization and diversion of the on-going traffic during construction, providing road alignment continuity with the connection roads and bridges, secondary element considerations such as near field river bed arrangements and secondary access bridges, retaining wall configurations, slope/bench stability solutions and considerations for protecting nearby urban areas and historical buildings during construction stage will be summarized. Following these considerations, brief information about design challenges and applied solutions for engineering structures covered within the adjacent Konak Tunnel Portal Structures, including specific culverts, cut-and-cover type approach structures and related retaining structures will also be given.

1 Introduction

Yesildere Intersection Bridge, along with connecting Konak Tunnel and Portal Structures represents one of the recent significant transportation projects designed and constructed in Turkey.

Among the constituents of this distinguished project, there are several major engineering structures that spread over a large project site. General layouts and plan views for these project components are shown in the below figure.

Figure-1: Overall project site showing engineering structures

While the main focus of this paper will be on the design studies performed for Yesildere Intersection Bridge and Konak Portal, brief information for the remaining structural components that required specific considerations during design stage will also be summarized.

1.1 Geotechnical Assessments

Before proceeding into the design stage, besides separately performed detailed geotechnical assessments for the tunnel alignment, total of 24 borings were performed with the total drilling depth of 500 meters for the Intersection bridge and 14 borings were performed with the total drilling depth of 400 meters for the Konak Tunnel Portals, to be able to assess the geotechnical condition of the Intersection Bridge area and general project site.

Under the light of these bore logs and performed laboratory and site tests, a very generalized ground profile around foundations from top layer to bottom is determined as:

- Fill material and medium-stiff clay with low plasticity,
- Medium to highly weathered sedimentary rock with low strength,

where sedimentary rock is classified as sandstone, gravel stone and silt stone.

2 Yesildere Intersection Bridge

The main structure within the Yesildere Intersection complex is the "Yesildere Intersection Bridge". The overall plan geometry of the bridge showing the separate bridge segments forming the overall bridge are indicated in the below figure with the necessary segment definitions.

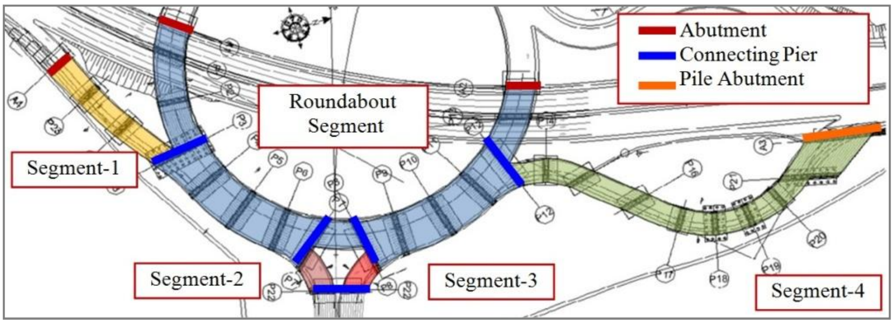

Figure-2: Yesildere Intersection Bridge General Layout

The main structural and geometrical characteristic of the bridge superstructure and substructure systems are given in the below table.

Structural Characteristics	**Bridge Segments**				
	Roundabout	**Segment-1**	**Segment-2**	**Segment-3**	**Segment-4**
Sprstr. Type	Precast Prestressed RC I-girders with 120 cm height				
Nr of Spans	14	3	1	1	9
Span Lengths	17,3~25,9 m	25,0~29,0 m	16,9 m	18,2 m	15,9~32,6 m
Pier Type	Single/double oval shaped piers	Singe oval shaped piers	Singe oval shaped piers	Singe oval shaped piers 5x2 m	Singe oval shaped piers
Pier Heights	8,2~20,3 m	10,6~17,5 m	20,3~22,6 m	20,3~22,6 m	3,2~18,5 m
Found. Type	Single/ piled (d=120 cm) RC footing	Single RC footing	Single RC footing	Single RC footing	Single RC footing
Abutment Type	RC Cantile-ver Abutment	RC Cant. Abut. / Con-necting Pier	Connecting Pier	Connecting Pier	RC Cant. Abutment with piled footing

Table-1: Structural Characteristics of the Yesildere Bridge Segments

2.2 Structural Design Requirements

Besides from the greatly irregular plan layout of the bridge, the individual bridge segments and the formed overall bridge structure can be identified as a general multi-span bridge with prestressed precast I girder superstructure system and RC pier, abutment and foundation substructure system.

With this respect, for the superstructure and substructure design studies, design code of "AASHTO Standard Specification for Highway Bridges 2002" is referred along with the additional inputs from "General Directorate of Highways - Engineering Structures Design Criteria Report". Among many other detailed design requirements, main requirements referred during superstructure and substructure design are listed below.

Superstructure Design:
- Vehicle Load : H30-S24 truck as per KGM Design Criteria Report
- Rest of the design requirements: AASHTO SSHB 2002

Sub-Structure Design:
- Bridge type: "Not Regular" as per AASHTO SSHB DIV-1A Section 4.2
- Analysis Type: Multimode Spectral Analyses Method as per AASHTO SSHB DIV-1A Section 4.5
- Bridge Importance Classification: Essential Bridge IC-1 as per AASHTO SSHB DIV-1A Section 3.3
- Site Effects: Soil Profile Type-2, S= 1.2 as per AASHTO SSHB DIV-1A Section 3.5.1
- Acceleration Coefficient: A0 = 0,4 g as per Izmir Earthquake Map
- Elastic Seismic Response Coefficient: Cs calculated in accordance with as per AASHTO SSHB DIV-1A Section 3.6.2
- Seismic Performance Capacity: SPC-D

2.3 Geometrical Design Requirements

Besides from considerably common and typical design requirements followed for the intersection bridge structural components, some very strict geometrical requirements are automatically dictated by the complex geometry of the intersection bridge complex and other connecting elements such as connecting highway road alignment and elevation, connecting bridge, nearby Yesildere riverbed arrangements and newly designed retaining walls around this riverbed.

Some basic geometrical design requirements referred during design in accordance with aforementioned geometrical limitations are listed below:

- The plan alignment of the Roundabout(RA) Bridge Segment is formed to be in exact conformance with the road plan and profile alignment. All the pier axes of the RA bridge segment are rotated to accommodate roundabout road interchange section. All the precast prestressed bearing support elevations and corresponding bridge deck pavement elevation are studied one-by-one for each pier axes to maintain road interchange plan and profile.
- Due to the irregular plan alignment of the RA bridge segment and connecting other bridge segments, some piers are detailed as Connecting Pier that accommodates separate I girders from separate bridge segments. Precast beam plan alignments, directions, beam fan angles and supporting distances on cap beams are determined separately for each Connecting Piers for each different connecting geometries.
- With respect to the circular plan alignment of RA bridge segment, some considerably large cantilever deck sections are geometrically formed at the side extremities of the bride deck in the deck span mid-sections. The effect of this additional cantilever deck sections to superstructure calculations are implemented into each beam design studies.
- The abutments of the RA Bridge Section are detailed as RC cantilever free standing abutments that takes place in between long retaining wall alignment positioned on the West side of the RA Bridge Segment. Top elevations of these abutments are detailed so that to have exact conformance with the road interchange plan and profile and also with the adjacent retaining wall top parapet profile.
- In the East of the interchange, Yesildere Bridge connects with an another bridge called as "Flying Road", which is detailed and constructed separately from this project, through a Connecting Pier that acts as a mutual structural element between Yesildere Bridge and Flying Road. While determining geometry and elevation of the related Connecting Pier and supported bridge superstructure deck elements, constant discussions are being held between two design teams to provide exact match in this connection part.
- The plan layout of Segment-4 is directly dictated by the adjacent Yesildere riverbed. Since Segment-4 is crossing over the Yesildere river on two different locations, the plan alignment of the Segment-4 is bended two times that forms a considerably curved bridge segment over this riverbed.
- Due to this interference with the segment layout and riverbed, the axes of piers and foundations that are adjacent to the riverbed are rotated so that to have these element's layout parallel to the river flow direction. The elevations for these pier foundations are also determined so that not to interfere with the riverbed bottom arrangement.
- In accordance with the limited space between the Segment-4end axis location and adjacent riverbed width, a cantilever RC abutment supported by the two rows of 120 cm diameter piles are detailed. Top elevation of this piled abutment is detailed so that to have proper match with the adjacent piled retaining wall which is again formed by two rows of 120 cm diameter piles.

2.4 Conclusions on Design

For the various sub-structural elements forming the complete Yesildere Intersection Bridge structure, related design studies are performed on many sub-headings varied for each structural element.

With respect the structural behaviour of the overall bridge under the seismic excitation defined by the related codes, various independent FEM models for the bridge segments were analysed both separately and connected to each other with the necessary interface definitions to verify the structural performance of entire bridge elements separately and as a whole. Design verifications dictated by the referred design codes which are required for the overall structural behaviour, such as modal participating mass ratios etc., and for each individual elements specifically such as verification of ductile behaviour through confinement reinforcement are performed explicitly by reporting each analysed verification.

For the geometrical design of each bridge elements, utmost attention were paid for providing exact match between the aforementioned geometrical design requirements such as connecting road alignment, riverbed arrangement, curved layout of the bridge segments, connecting bridge and pier geometries etc. During the very early phases of the design stage and before the construction stage, constant discussions were performed with the contractor to verify the geometrical design conformance with the required final geometry of the structure complex.

3 Konak Portal

Konak Portal is designed at the other end of the Konak Tunnel connecting to the intersection bridge location. The construction site for the Konak Portal, which is intended to be designed with the implementation of cut-and-cover construction method, takes plane in the downtown area of the city, at an area with intense development. There are many buildings, historical registered structures and existing roads adjacent to the construction site of the cut-and-cover portal. Five-storey historical masonry museum building, the registered buildings at the excavation bevel, represents the most critical structure amongst the adjacent buildings.

3.1 Design Requirements

During the design of the excavation support system for the cut-and-cover structure to be constructed adjacent to the old and historical masonry museum building, selection on the excavation support system presented significant importance as the horizontal and vertical settlements to be generated at the foundation soil of the museum and registered buildings should be restricted by considering the said museum building, the registered structures and Damlacik mosque are considerably old masonry buildings, thus doesn't have any remarkable foundation system.

The principal design requirement during excavation was considered to be preventing the instant and consolidation settlements that would occur at the foundation soil of the adjacent structure due to increase at the effective stress induced by the excavation at the underground water level and the swellings that would occur at the excavation bottom due to excavated and removed soil. Therefore, any decrease at the underground water level due to excavation must be prevented.

Other significant design requirements taken into account during the designs are as set forth hereunder; ensuring overall and bottom stability, preventing hydraulic failure, the priority that concern completion of the project in a short time, the time constraint on the construction works, minimum impact on the daily urban life during construction activities to be carried out at the downtown area of the city.

3.2 Design Stages and Parametric Studies

Based on the design principles set forth in the previous sections, parametric studies and hundreds of finite elements analyses were conducted in order to identify different alternates for the support systems and to select the most adequate ultimate excavation support system for the cut-and-cover structure.

The most critical excavation cross-section has an excavation height of 20 m, and is located at the cross-section where the horizontal axes of the museum building and the excavation portal intercept. The horizontal distance of the masonry museum building to the excavation limit is 6 meters at the most critical cross-section.

The excavation bracing system selected for excavation of the cut-and-cover structure as a result of the parametric studies conducted in this respect is set forth hereunder:

<u>Vertical Bracing Elements:</u>

- Secant Bored Pile Wall with diameter of 1000 mm (SBPW),
- Continuous Bored Pile Wall with diameter of 1200 mm (CBPW), designed as an integral part of the cut-and-cover structure,

<u>Horizontal Bracing Elements</u>

- Permanent Prestressed Anchorage with repeated grouting and corrosion protection

<u>Structural System Configuration</u>

- Reinforce Concrete Culvert with Top-Down construction method

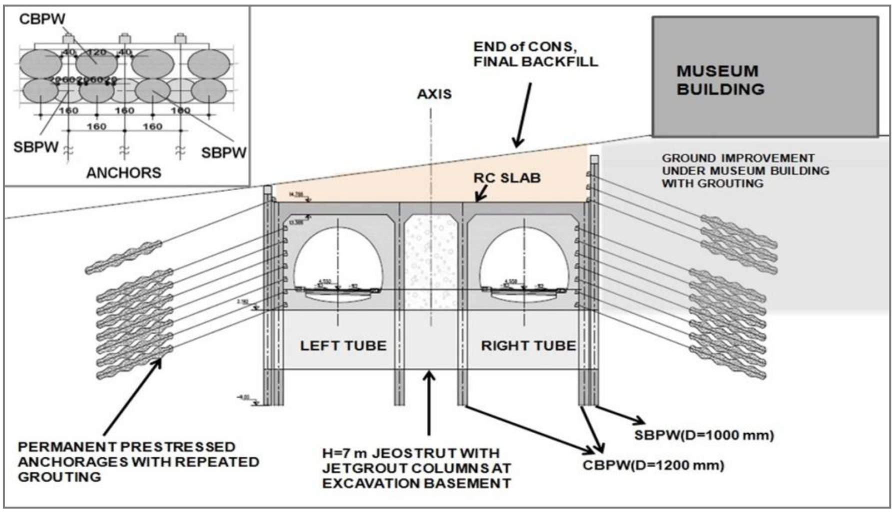

Figure-3: Konak Portal Top-Down Culvert Typical Section

3.3 Conclusions on Design

The performance of the designed excavation support system was checked by 2D and 3D FEM analyses modelled in compliance with the progressive construction.

Based on the results of the analyses, it is demonstrated that the geostrut formed at the excavation bottom with jet grout columns, and the soil improvement works conducted at the museum foundation soil through grouting prevented variations at the underground water level, thus the settlements. Conformity of the design was observed on-site during construction works.

The results from 2D and 3D analyses are coherent with each other. Maximum wall lateral displacement is calculated in the order of 7.1 – 7.3 mm and maximum vertical displacement is calculated in the order of 1.0 – 1.3 cm, both of which remain within allowable limits. The amount of settlement observed at the museum building during construction works is also coherent with the design calculations.

Based on the analysis results, the permanent prestressed anchorage loads remained under the critical design load during all phases of excavation studies. The results from the acceptance and conformity tests performed on-site during construction are also coherent with the design assumptions.

The cross-section behaviour of the vertical support elements, the piles, and at the deck of the cut-and-cover structure remained within the allowable limits.

The displacements that could occur during construction, the water pressures and stresses occurring at the support elements are instantly monitored using inclinometer, piezometer, tiltmeter and settlement gauges, verifying their conformity with the design requirements.

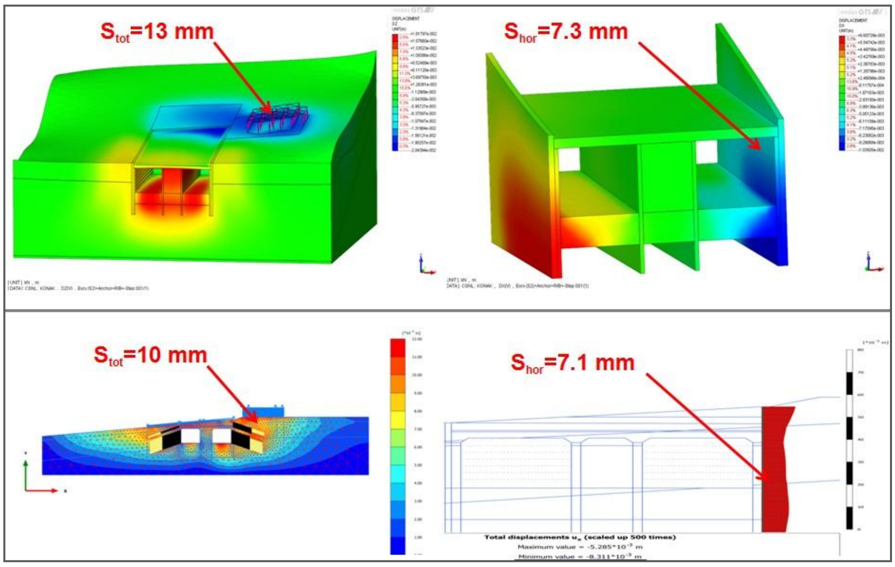

Figure-4: Konak Portal Top-Down Culvert Analyses Results

4 Remaining Engineering Structures

Besides from the two major components of the Yesildere Intersection complex explained in the above sections, there are other various engineering structures that were being considered specifically during the design stage

Major engineering structure under this heading was the Yesildere Portal of the Konak Tunnel and surrounding benches and corresponding slope reinforcements which are located in the direct vicinity of the Yesildere Intersection. Necessary boring studies were performed on the portal region which is formed as an old artificial fill site to determine the necessary ground profile and ground water level. Since there are urban housings in the back proximity of the portal, this artificial backfill was supported by the anchored piles whose anchor roots are formed within the weathered andesite layer under the artificial fill layer. For the slope reinforcement for the below levels and benches, reinforcement design composed of shotcrete, wire mesh and anchored soil anchors are detailed.

Besides these structural elements, below listed engineering structures which takes place in a direct interference of Intersection Bridge are also designed within the scope of the project:

- Total of 600 meters long RC retaining walls with heights varying from 5 to 12 meters were designed within the Intersection Bridge layout. Total of 110 meters long two row piled retaining walls are designed with the pile diameter of 120 cm which also formed the river bench of the Yesildere River.

- Near Segment-4, a single span IZSU-1 pipe crossing bridge with 32m span length and 6m platform width is designed to allow water pipes crossing with diameters 400 and 1800mm over the Yesildere River. All the related connecting utility and pipe displacements on the project site are also planned and designed by the design team.
- A separate single span IZSU-2 bridge with 26,5m span length 15,5m platform width with prestressed I girder superstructure and RC cantilever abutments is designed for the purpose of both 1800mm pipe and vehicle crossing over Yesildere River during both the construction period and following service phase.

5 Conclusions

In this paper, a generally summarized design requirements, studies performed during design stages and conclusions on the performed design activities are given for the various engineering structures forming the complex project compound of Yesildere Intersection Bridge and connecting Konak Tunnels.

Through careful design considerations and by the constant discussions between the various disciplines of the design team and the necessary decision makers, a throughout design progress was achieved for the entire set of separately distinguished engineering structures, both individually and as an constituent of complex transportation and infrastructure design project.

Fallowing this carefully planned design studies, the Yesildere Intersection and Konak Tunnels are now in service for the citizens of Izmir, Turkey, after a equally successful construction phase and supervision process, carried-out and completed without any major setbacks.

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