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DESIGN OF A POST-TENSIONED BRIDGE AT HIGH SEISMIC RISK REGION, BOTAN BRIDGE

T. Atıcı[1], E.B.Y. Cıplak[2] and M. Kılıc[3]

ABSTRACT

Botan stream - in Siirt, Turkey - has proper landform for series of construction of hydroelectric power plants (HPP) to form an energy network. One of the last HPP projects on Botan is planned to build at the Pervari, Siirt. In the vicinity of this location an old stone bridge exists and it will be completely under water after the construction of the new HPP. Government has funded a road extension work at the same location that includes a possible rehabilitation of the existing bridge. The current decision is to build a new bridge. In this scope, several preliminary designs are performed to determine the best solution. At end, considering the geographic conditions, cost, future maintenance, workability and transportation of necessary equipment, the balanced cantilever post tensioned construction alternative is seemed to be the most suitable one. Bridge is located in a high seismic risk region. And here mentioned some special topic about design of the bridge.

Keywords: post-tensioning; anchors; slabs; walls; high-rise buildings.

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ABSTRACT

Botan stream - in Siirt, Turkey - has proper landform for series of construction of hydroelectric power plants (HPP) to form an energy network. One of the last HPP projects on Botan is planned to build at the Pervari, Siirt. In the vicinity of this location an old stone bridge exists and it will be completely under water after the construction of the new HPP. Government has funded a road extension work at the same location that includes a possible rehabilitation of the existing bridge. The current decision is to build a new bridge. In this scope, several preliminary designs are performed to determine the best solution. At end, considering the geographic conditions, cost, future maintenance, workability and transportation of necessary equipment, the balanced cantilever post tensioned construction alternative is seemed to be the most suitable one. Bridge is located in a high seismic risk region. And here mentioned some special topic about design of the bridge.

Introduction

AASHTO LRFD, 2010 is used as the main design specifications. Local codes; TS500, KGM-Technical Specification for Road Bridges are also used for local differences such as truck loading and earthquake. LARSA 4D software program is used in analysis of the post tensioning and earthquake. SAP2000, Section Builder 8 and Design Response Spectra TR are the other programs that have been used for analysis. Structural computations are based on the analysis results and hand computation verifications.
Fig 1.1 General View of the Bridge

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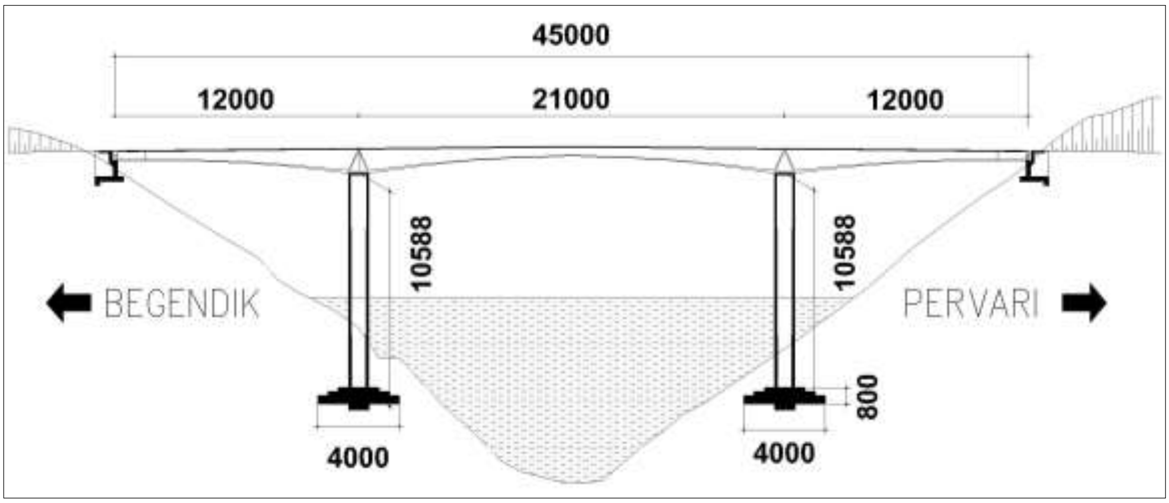
General Information

Name of Bridge : Botan Bridge
Type of Bridge : Balanced Cantilever
Location : Siirt, Turkey
Company : AGM Engineering
Engineers : ATICI Taner, YAZICIOGLU Eylem B., KILIC Mehmet
Advisor : Asoc. Dr. CANER Alp

Technical Details

Total Length : 450m (120m - 210m - 120 m)
Deck Type : Single Cell Box Girder
Deck Width : 14 m (2m - 2*5m - 2m)
Deck Depth : 12 m above piers,
4.5m at middle of the span
Pier Dimensions : 10m *10m outer length
7m*7m inner length above foundation (wall thickness = 1.5m)
8m*8m inner length below the 12m diaphragms (wall thickness = 1.0m)
Pier Length : 105,88m for both piers (from top of foundation to bottom of supper structure)
Foundation : 40m*40m*4~8m for both piers
Abutment Height : 7,75m for both abutments (top of foundation to bottom of bearings)+5,00m
Tendons : 19 strands (1 strand=7wire=150mm^2=62’’)
Upper tendons : 58 + 6 (stressed + slackened for future facts)
Bottom middle tendons : 26 + 4
Bottom side tendons : 20 + 4

Fig. 1 – Overview Dimensions



SOME FIGURES

Fig. 2 - Bridge Location View from Google Earth

Fig. 3 - Excavation Plan

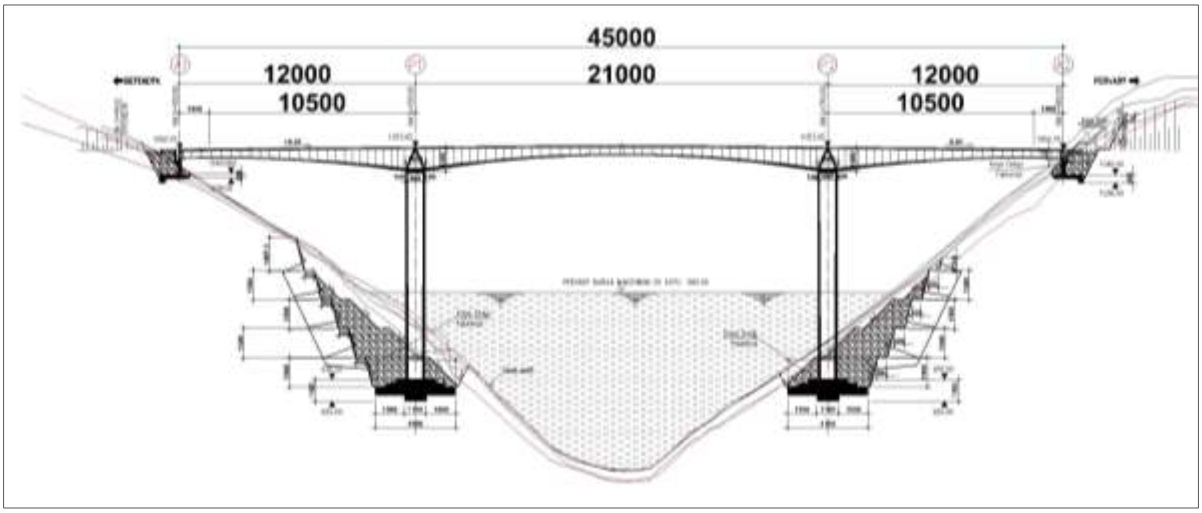


Fig. 4 - General Layout

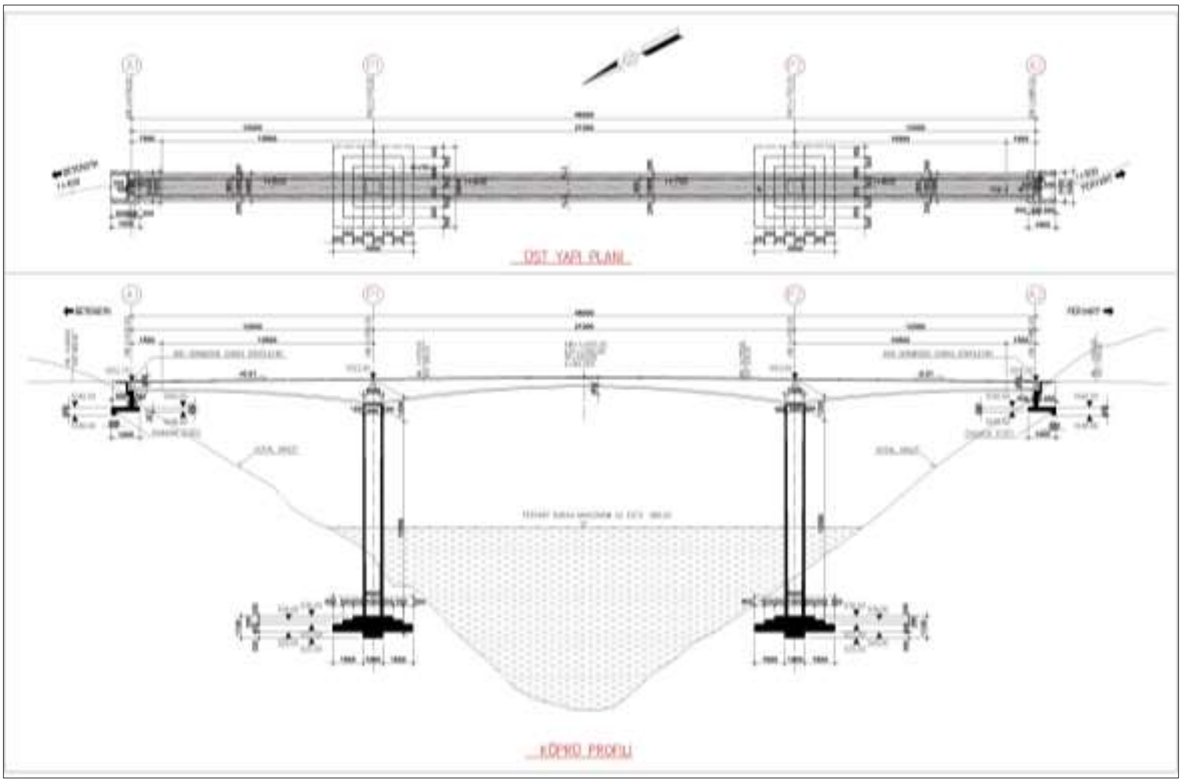


Fig. 5 - Tendon Layout Drawings

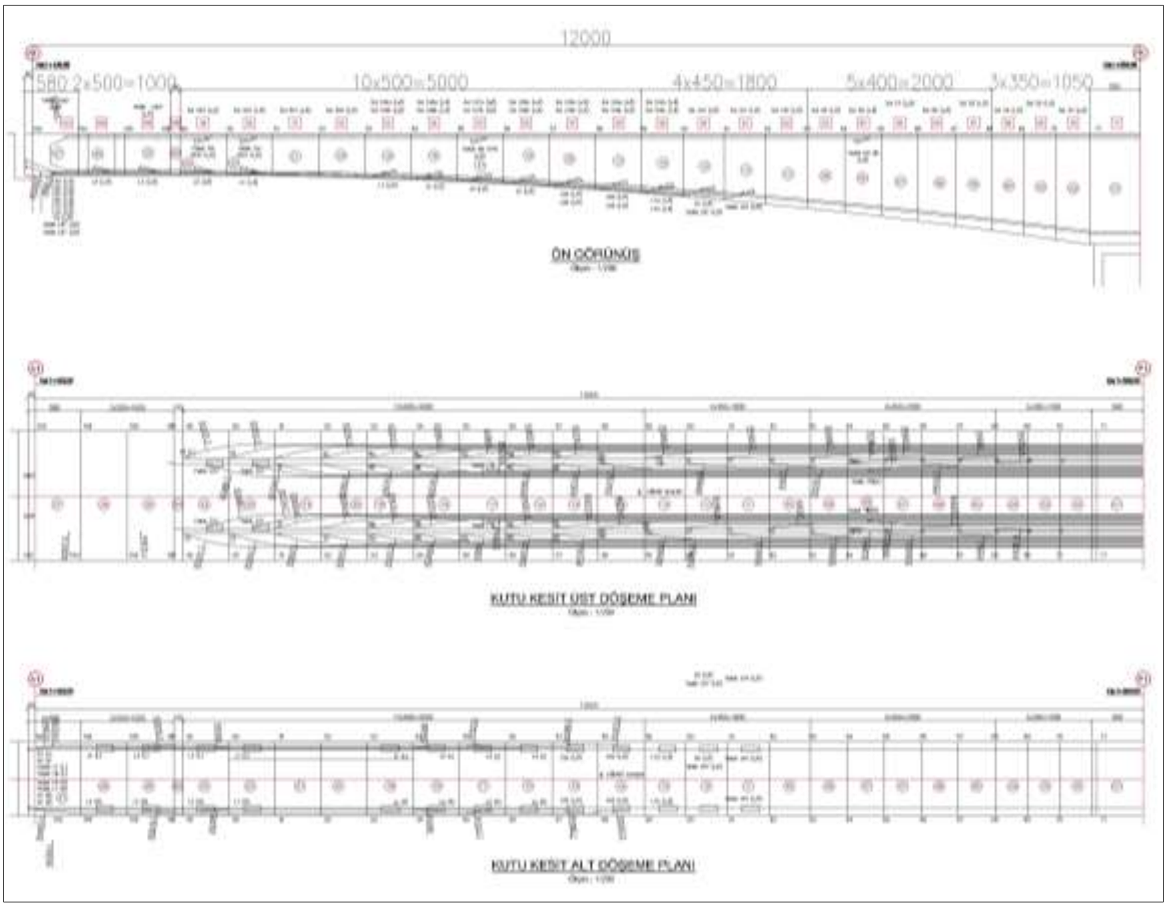


Fig. 6 - Deck Section on Top of Pier

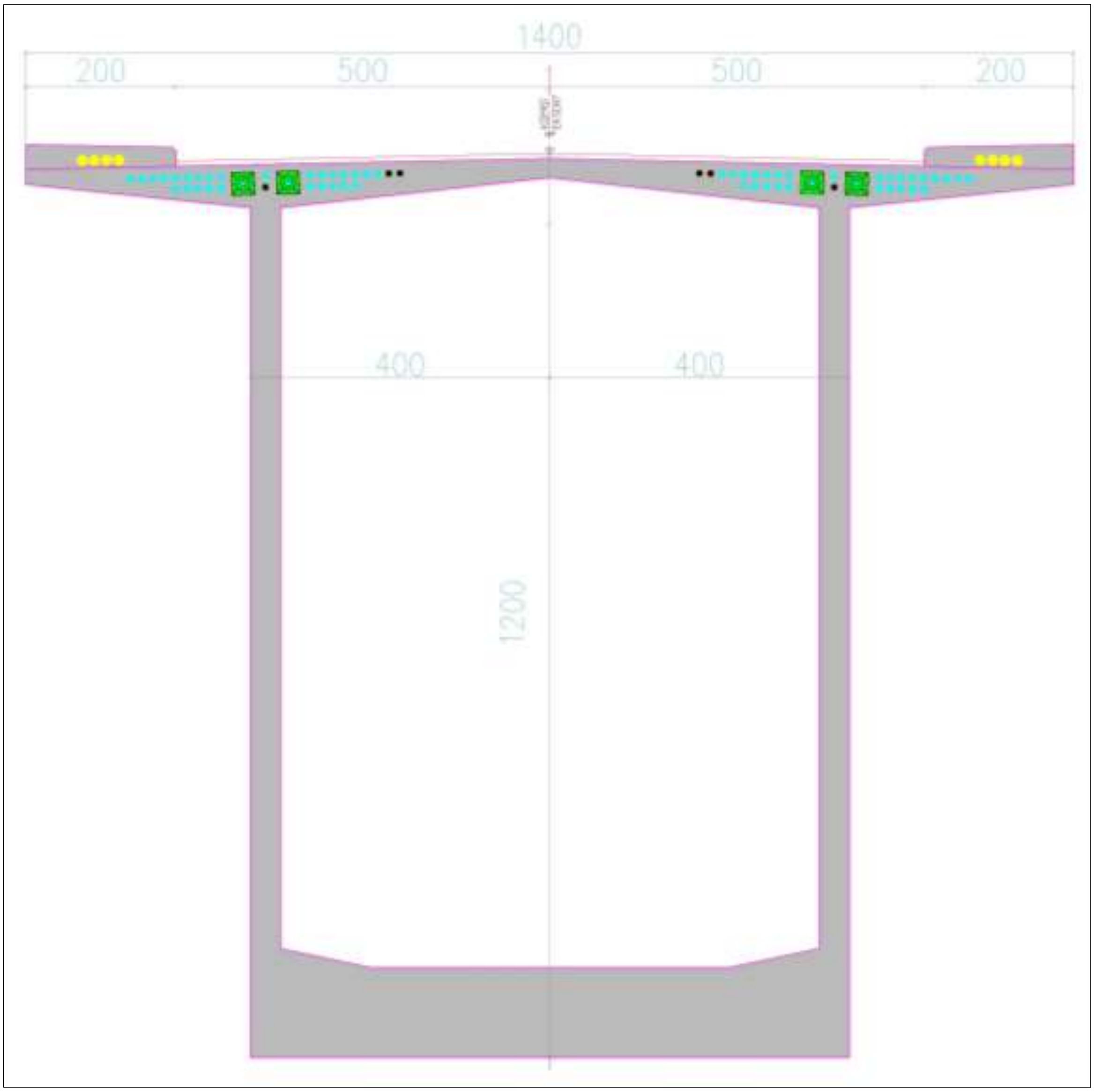


Fig. 7 - Deck Section at The Middle of The Span

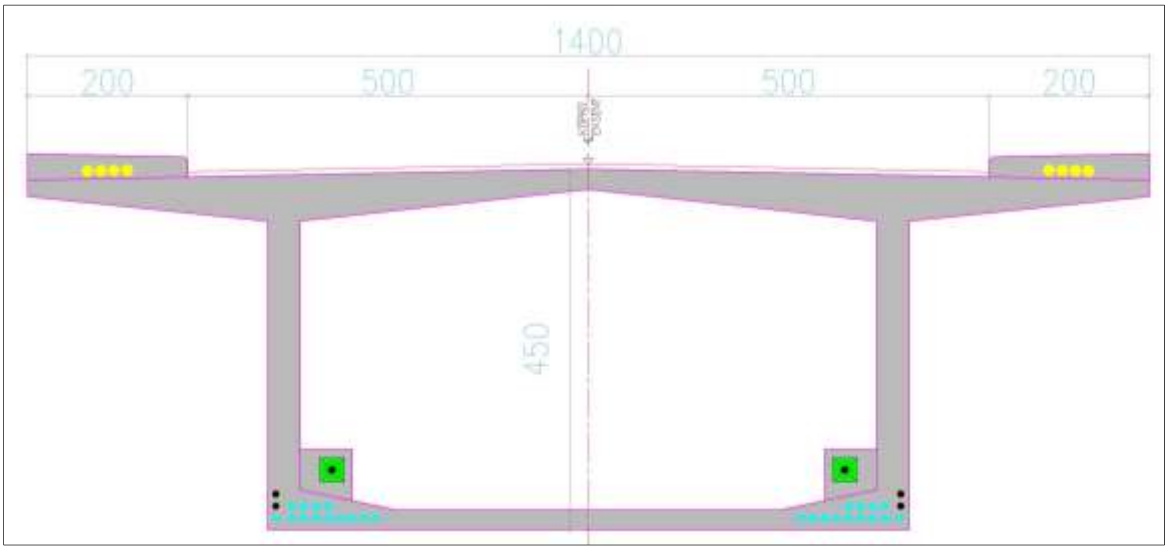


Fig. 8 - Pier Sections

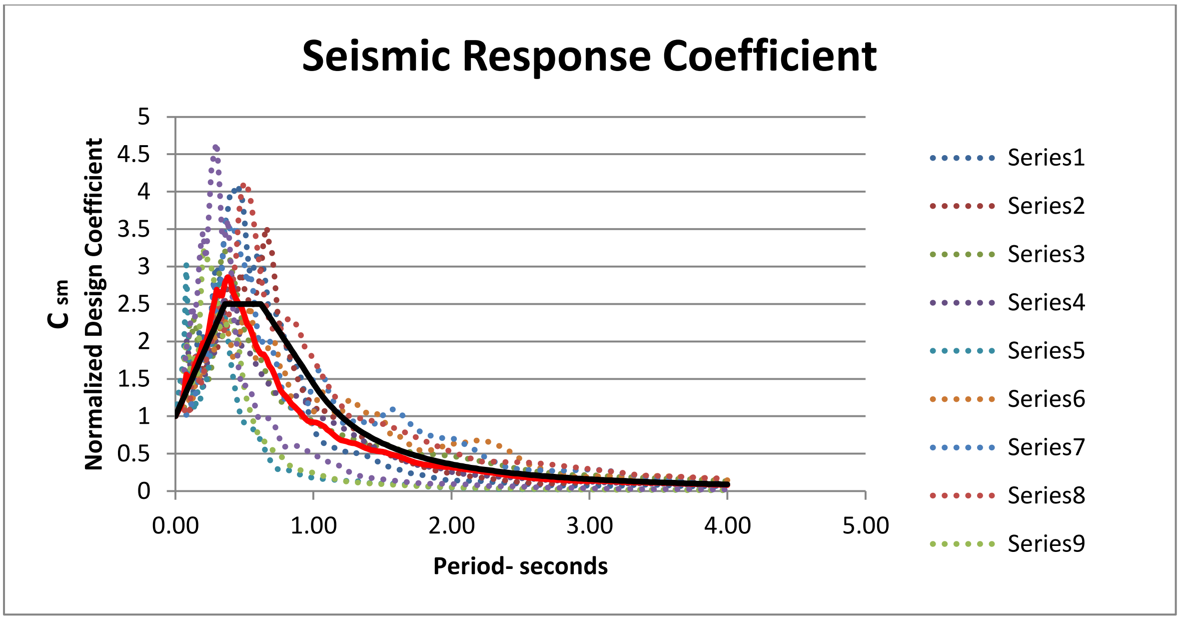
Fig. 9 - Thermal Effects

Design

Earthquake

Turkey can be classified as an earthquake country which has many active faults. Turkish specifications have four earthquake risk zones and zone1 being the most critical zone. Zone 4 has the lowest risk. Botan Bridge is determined to be in zone 1 and it is about 11 km away from the active fault line. The earthquake load analysis governs the design of most of the members besides the construction loads. The response spectrum curve has been generated based on the response spectrums of the past earthquakes in the vicinity of the bridge location within 100 km radius. The earthquake response spectrum curves are neutralized by dividing the seismic coefficients by the seismic coefficient of the peak ground acceleration (PGA). In determination of PGA, an earthquake with return period of 1000 years has been used at design phase. The PGA is computed to be 0.913g for final design. At construction stage, a lower return period earthquake with 0.279g has been used (100years).

Graph 1 - Neutralization of Response Spectra Curves



The seismic coefficient is based on the modified AASHTO equation.

$Csm = 1.2\ A\ S\ /T^{b}$

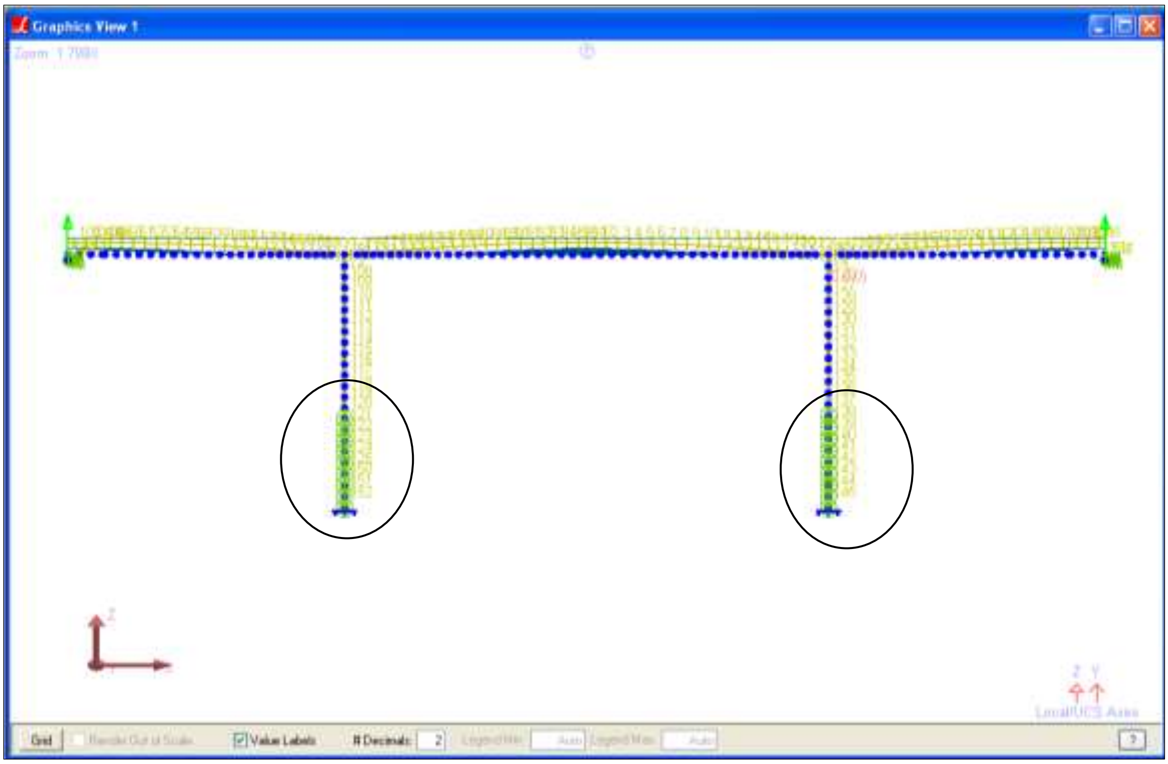
In the above equation, A is the peak ground acceleration, S is the soil site constants and T is the period and b is the period power constant. In AASHTO 2007, the period power coefficient has been suggested as 0.67 and in later version of AASHTO 2010 the equation has been modified and the power coefficient has been changed to 1.0. In the later version of the AASHTO 2010, the power coefficient for periods larger than three (3) a constant of 2.0 has been mentioned. In this study the power coefficient has been determined to be 1 for periods less than three, 2 for periods more than or equal to three based on the neutralization study.

Evaluation of couple of trials of pier models indicated that the piers need to be flexible to attract less seismic force. In the first trial the selected 1.5 meter thick constant wall thickness along the height of the pier resulted in high seismic forces due to low period of the structure. To decrease the stiffness to achieve a shift in period to high period zone, the thickness of the wall has been decided to change along the height of the pier thru stepping down at 20 meters by 100 mm at each step. It shall be noted that the piers are 100 meter long. The period of the structure has been set to 3.97 seconds.

Hydraulic Effects

After the reservoir of the HPP will be filled with water, the 45 meter long height of the bridge piers will be under water. Since minimal amount of flow is expected around the piers, scouring and dynamic effects of flowing water is not taken into consideration. The seismic activities are believed to develop additional forces due to presence of water on the piers. The seismic mass of the acting water body on the piers are included in the analysis.

Fig. 10 - Water Mass Element Assignment



Section Design:

At service stage too much negative moment exists on piers, also during construction, and positive moment at middle of spans. For the construction stage without using any post tensioning, static analysis is done. According to the moment gathered from program a hand computation is done to calculate approximate number of strands (62*19strands for each cantilever).

Then by jacking different number of tendons at different stages we tried to keep negative moment at zero level at any sections. Also at the service stage when the bridge is completely constructed another analysis is done. By using the new force values we calculated the number of tendons to have zero moment at the middle of span at the bottom of deck (Fig. 4 and Fig. 5). The procedure is followed for 3 spans. For the residual moment reinforcement is used. Also upper tendons are used at the closure joint to satisfy continuity.

Fig 11 - Maximum Compression Stresses during Service Stage

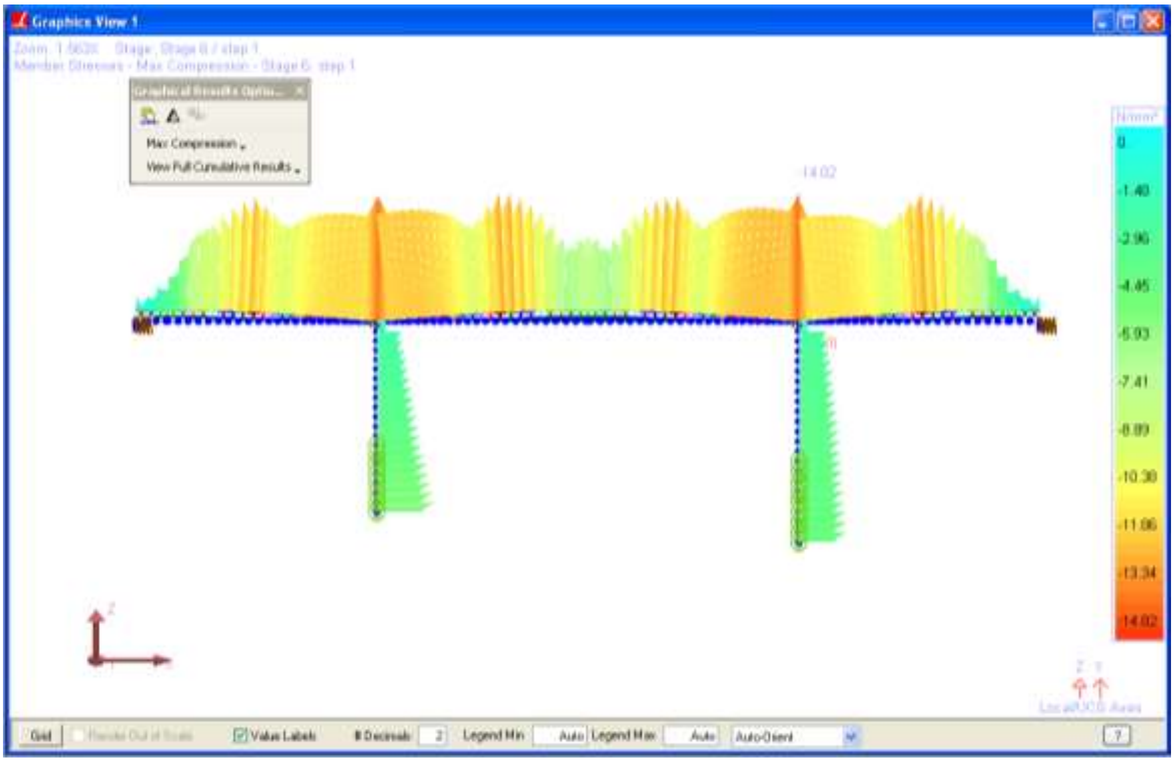
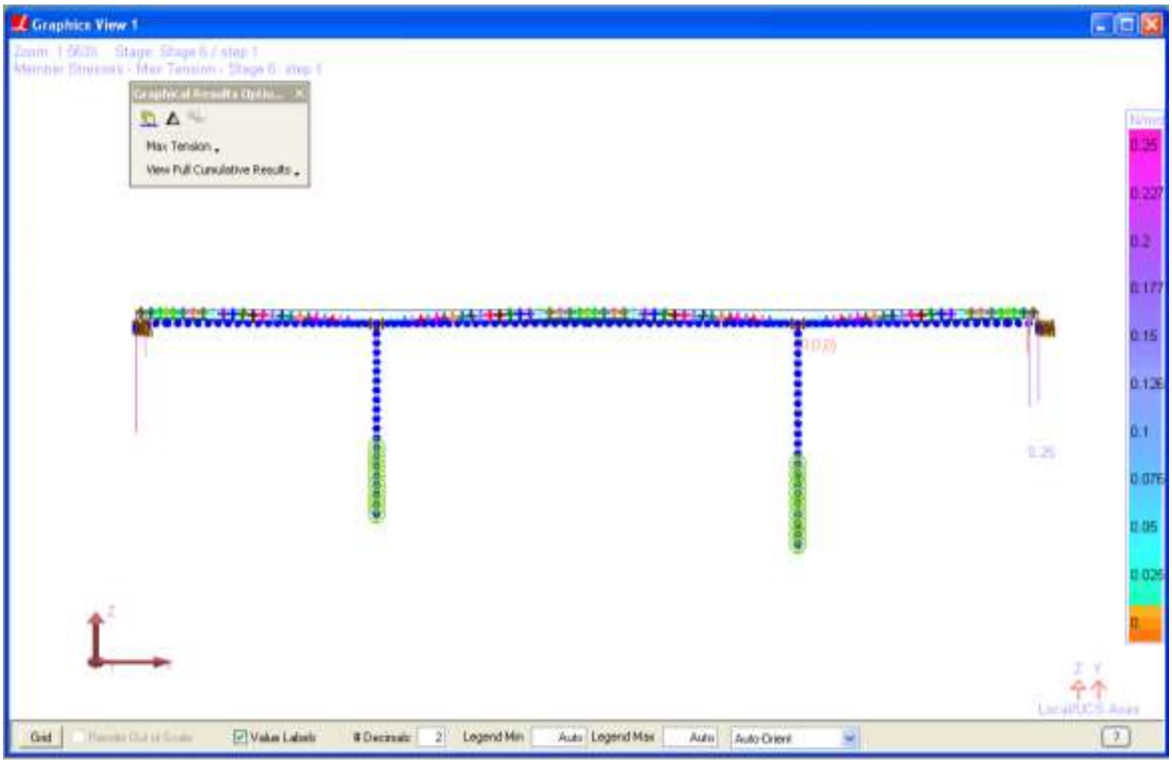


Fig. 12 - Maximum Tension Stresses during Service Stage

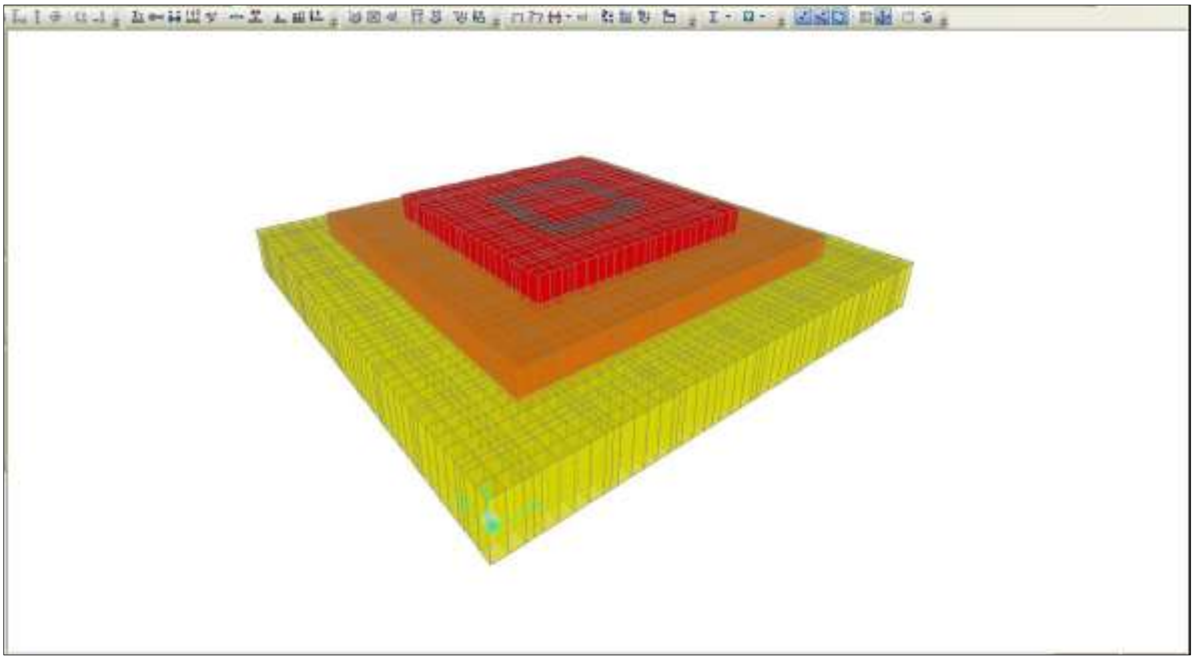


The calculations mentioned above are for the tendon calculations at the top and the bottom of the deck. But during earthquake we have high lateral displacements at the middle of the span and moments at webs of deck at same location. Post tensioning at the webs or using metal plates are the alternatives but they will be hard for the workers to construct. To achieve design limits we used more reinforcement at the middle portions of the spans at the side walls of the deck.

Foundation Design:

Foundations of the piers will lay on the hard rock, so high settlements are not expected. But we might expect sliding and the overturn. To overcome these problems we designed a section of 40m*40m*6~8 foundation and 10m*10m*3m shear key. Section forces at the foundation section at the connection line of the foundation and the pier are very high. To satisfy the moment it is possible to use too much reinforcement or post tensioning. As an alternative we design a foundation with thickness 4-6-8 meters. (Graph 6).

Graph 6 – Foundation And Pier



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