Design of Abutment and Pier Caissons of Lali Bridge

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**Abstract**: The design of abutment and pier caissons of Lali Bridge on Karoon river will be discussed. This is a bridge that will be the access between two abutments after the Gotvand Dam is constructed and the reservoir is impounded. The river is now at elevation of 104 and it will rise to elevation of 230 m after impoundment. The two piers are each on two caissons of 10 meter diameter and 20 meter deep which will be excavated in layered sloping of sandstone and siltstone. The design considers the basin stability and the effect of rising water level on slope stability. It considers the evaluation of pier and abutment stiffness to be used by the structural engineer and considers the settlement and bearing capacity of the caissons and abutments.

**Introduction**: The geotechnical report study of the Lali Bridge was assigned to this expert by Bolandpayeh Company. Two site visits were made and meetings with the owner and its experts and Bolandpayeh and its experts were attended by this expert. Full documents of the geotechnical, geological, and seismic reports were made available to this expert.

**Bridge location**: The owner had identified the strata A7 and its equivalent rock mass unit ASA3 as the proper location for the bridge foundation. The geotechnical borings and investigations of 8 borings were also carried out in this location. Figure 1 and 2 show the above units. Figure 3 shows this thick bedded sandstone taken during site visit.

![Figure 1: Rock Mass unit ASA3 foundation of rock socket for bridge](image-url)
Figure 2: Geological unit A7 with boring locations B1 to B8 for bridge foundation.

Figure 3: The thick bedded sandstone geological unit A7 and rock mass unit ASA3 for the rock socket bridge foundation.
The Rock mass properties: Based on the tender documents and the site visit appraisal the following are assigned to geological layers.

In the table, \( C \) is the cohesion of the layer in Mpa

\( \Phi \) is the internal friction angle of the saturated rock mass in degrees

\( E \) is the elastic modulus of rock mass in Mpa

\( \text{Sigc} \) is the Uniaxial strength of the rock mass in Mpa

\( \text{Sigcm} \) is the axial strength of the rock mass in Mpa

Table of Rock Mass Properties

<table>
<thead>
<tr>
<th>Layer No</th>
<th>Layer Designation</th>
<th>Description</th>
<th>C Mpa</th>
<th>( \Phi ) degrees</th>
<th>E Mpa</th>
<th>( \text{Sigc} ) Mpa</th>
<th>( \text{Sigcm} ) Mpa</th>
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<tr>
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</table>
**Heave of the bridge due to water impoundment:** Due to water impoundment the unit wait of the rock to be used in calculation changes to buoyant unit weight. Thus the rock basin will heave and the purpose of the analysis is to predict the heave. Two softwares are used to predict the heave of the rock basin. Plaxis 3D Foundation and Midas/GTS: These are state of the art softwares for geotechnical calculations and their three dimensional nature is suitable for such a large basin.

**Plaxis results:**

![Figure 4](image1.png)

**Figure 4:** The equivalent vertical gravity displacement before impoundment of water in the basin

![Figure 5](image2.png)

**Figure 5:** The equivalent vertical gravity displacement after impoundment of water in the basin
Midas/GTS: Analysis for the heave of the basin:

Figure 6: The displacement for equivalent gravity before water impoundment

Figure 7: The displacement for equivalent gravity after water impoundment

The final conclusion is that the heave of the bridge is about 200 millimeters and the differential is expected to be about 2/3 of the total heave due to basin water impoundment.

Factor of safety of rock mass in the basin after impoundment of water. The factor of safety was evaluated for the basin after impoundment by Plaxis and Midas.

Figure 8: Factor of safety vs. step number after water impoundment.

Figure 9: The lowest stable part is the M layer of the Mishan formation after water impoundment.
Figure 10: The factor of safety of the rock mass after water impoundment, the least stable part is the Mishan M layer.

The final conclusion is that the factor of safety of the rock mass show that the basin is stable before and after water impoundment and the least stable part is the Mishan M layer at the east bank of the river.

**Stiffness of the abutment and caisson:** The Midas was used to calculate the stiffness of the abutment and caisson.

![Abutment finite element mesh](image1)

![Vertical displacement](image2)

The Lali bridge abutment uses elastomers to transfer the load from the bridge to the abutment. Therefore the stiffness of the elastomers as indicated by the manufacture should be used for the bridge design.

**Stiffness of the caissons.** The Plaxis program was used to calculate the stiffness of the caissons
Therefore vertical stiffness becomes $K_v = 2.777 \times 10^7$ KN/M, horizontal stiffness along the bridge direction $K_x = 2.941 \times 10^7$ KN/m, horizontal stiffness along the river direction $K_y = 3.125 \times 10^7$ KN/m, and Tilt is negligible.

**Slip of the inclined layers:** The slip of the inclined layers was calculated using Midas.

The conclusion from slip analysis is that the amount of slip is very small amounting to 2 centimeters for the 20 meter caisson depth and the passive pressure thus will not be activated.

**Wedge stability for caisson excavation:** The unwedge program was used to calculate caisson wedge stability.
To stabilize and consolidate the unstable wedges, it is necessary to use rock bolts. The length of the bolts should be 6 meters and the arrangement of 2m by 2m is suitable. The diameter of the rock bolts should be more than 25 millimeters. The shotcrete of minimum of 4 centimeters on 2 centimeter base shotcrete with wire mesh of 6mm by 60mm by 60mm should be used.