Construction of anchored caissons for a motorway viaduct

CONSTRUCTION OF ANCHORED CAISSONS FOR A MOTORWAY VIADUCT

Nader HALIMEH
Viaduct Engineer
Dar Al Handasah
Consultants
Adana, Turkey

Nader Halimeh, born 1955, achieved B.Sc. Honours in Civil Engineering from the University of Khartoum in 1979. He has supervised the construction of many bridges and viaducts in the Middle East, and is a member of the I.C.E. (United Kingdom), of the J.E.A. (Jordan) as well as of T.M.M.O.B. (Turkey).

SUMMARY

Caissons are a principal alternative to piles for bridge foundations, particularly where piles would have to be drilled or driven into ground containing large boulders or into rock of uncertain quality that might require further investigation during construction. A further advantage that caissons provide is more confidence, as the excavated surface can be closely inspected, and better quality concrete can be obtained, eliminating the need for integrity testing.

Caissons, some circular, others elliptical, provided the deep foundations for all piers and abutments of Viaduct V5, where the bed rock is overlain by several metres of slope debris. Step-by-step excavation was carried out by a hydraulic back-hoe excavator lowered down the caisson. Light wire mesh with shotcrete was used to support the sides of the circular caissons through slope debris, while reinforced-concrete ring beams supported by pre-stressed cable anchors were used in each excavation stage of the elliptical caissons. The anchors were installed using a drilling rig also lowered down the caisson. The design stressing force was generally achieved, except for the second stage of two of the caissons, despite the grouted bond length being increased. This problem was overcome by post-grouting the anchors, and accepting a lower force for the cable anchors of that stage. Proof tests on the pre-stresed cable anchors were performed at each stage of excavation. Inflows of water during the rainy season caused some problems, and interrupted construction of one of the deepest caissons. The caisson foundation was designed to be cast for the full cross-sectional area in vertical lifts, and the temperatures was monitored to assure quality. Heavy reinforcement was provided, to satisfy the minimum requirement of the AASHTO. The Paper gives some suggestions and recommendations based on experience gained.

1 INTRODUCTION

Viaduct V5 is one of the major viaducts presently under construction for a motorway in the Middle East. This section of the motorway is 258 km long with three lanes in each direction, and involves a number of large structures including fourteen viaducts.

Viaduct V5 is 500 m long, comprising nine spans, with a maximum span of 110 m in each carriageway, see Figure 1 below. The entire design and concept is governed by geological factors, as described below, which necessitated the use of caisson structures to form the deep foundations for all piers and abutments. Part of the viaduct super-structure is constructed of pre-cast beams, the remainder of structural steel box girders; accordingly, two different types of pier columns and foundations were required. Two types of caissons were designed, one circular, 6 m in diameter, and the other elliptical, 12 m by 8.5 m; the elliptical shape was chosen to reduce the obstructing effect that might occur in the event of a landslide. The caisson depth varies between 10 m and 31 m.

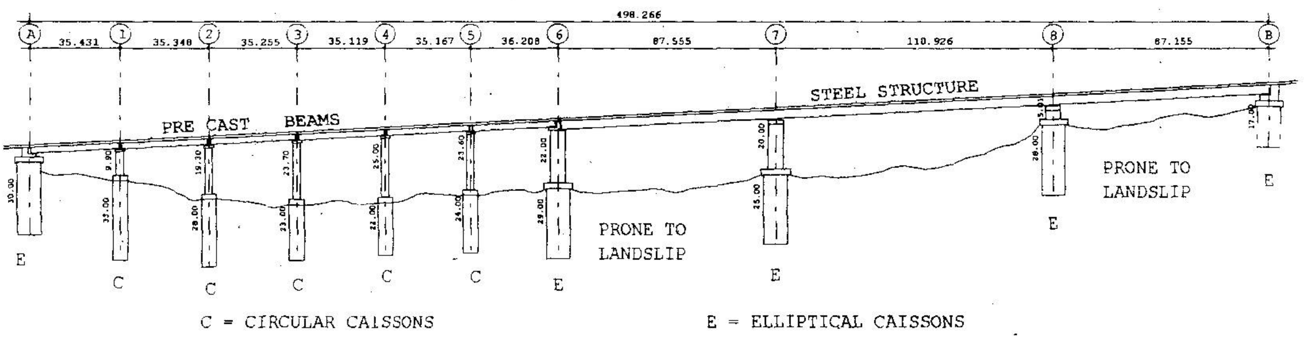


Figure 1: Longitudinal section of Viaduct V5.

2 GEOLOGICAL CONDITIONS

Situated in an area subject to earthquakes, the viaduct runs roughly from West to East sidelong across a steep slope which falls towards the viaduct from the South, and parts of the thick layer of unstable slope debris that makes up this slope have slid towards the viaduct in geologically very recent times; the viaduct spans over these landslide areas. The bed rock in the region is disturbed by faults, folding and dykes. The influence of fault- and dyke-related movements was minimised by shifting the alignment towards the North. However, the extension of the major faults which prompted the slide cross the viaduct alignment between Pier 6 and Pier 7 and between Pier 8 and Abutment B. These fault zones are associated with clayey fault gouges and completely decomposed dyke material. The slope debris comprises sand and gravel in an open matrix of clay . The caisson foundations went through this and down to sound strata consisting of alternate strata of thickly-bedded sandstone and thinly-bedded siltstone - sandstone. In general, this bed rock is slightly weathered and slightly to highly fractured.

3 EXCAVATION AND GROUND SUPPORT SYSTEM

3.1 Preparatory Excavation

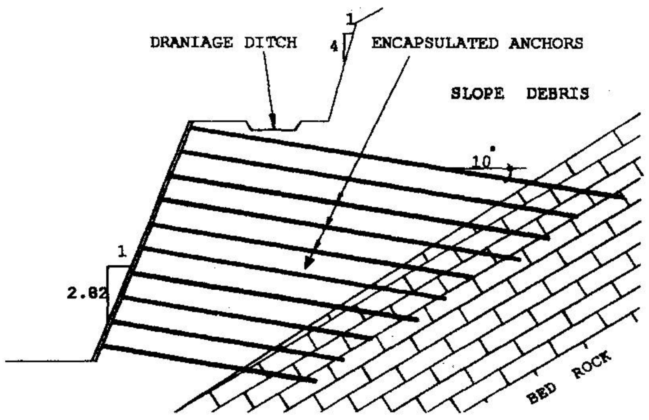


Figure 2: Slope formation.

Preparatory excavations were made in the slope debris in order to obtain a level working platform for construction of the caisson proper. These excavations were carried down step by step, each step being supported by shotcrete reinforced with wire mesh and retained by encapsulated (passive) anchors comprising 26.5 mm diameter bars of 835/1030 U.T.S. steel inserted into a 130 mm diameter hole. The anchors were embedded three metres into the bed rock, as shown in Figure 2. Two inclinometers were installed to monitor any movement during excavation.

3.2 Caisson Excavation

Excavation was carried out, using a hydraulic excavator, the use of explosives was rejected both from fear of precipitating further landslips, and to prevent loosening of anchors already installed for previous stages. The ground was removed down to the level of the next support stage; wire mesh was applied to the exposed ground that formed the wall of the excavation, and then shotcrete was applied as shown in Figure 3 on the next page. In the circular caissons, shotcrete 150 mm thick was sprayed onto the exposed ground, increased to 200 mm thick when more than 10 m below the top of the caisson. In the elliptical caissons, in addition to 200mm of shotcrete, a reinforced concrete ring beam was cast at the bottom of each excavation stage, through which pre-stressed cable anchors (active) were installed as described in Paragraph 3.3 below. These beams and anchors were only required through the slope debris; in rock, ring beams were formed in shotcrete. Drainage pipes , as shown in Figure 4, were installed through the shotcrete of alternate vertical panels, of each caisson, to prevent accumulation of ground water pressure behind the shotcrete.

The bigger the diameter of a caisson, the easier it is to excavate, but heavier support will be required. The deeper the caisson, the more difficult it is to construct - a heavy crane is required for lowering the excavator. A deeper caisson is also more likely to suffer more from water infiltration. A deep caisson of small diameter may also generate a ventilation problem, as well as suffering from congested working space.

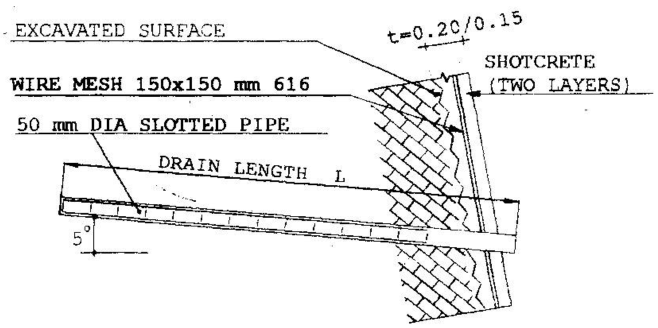
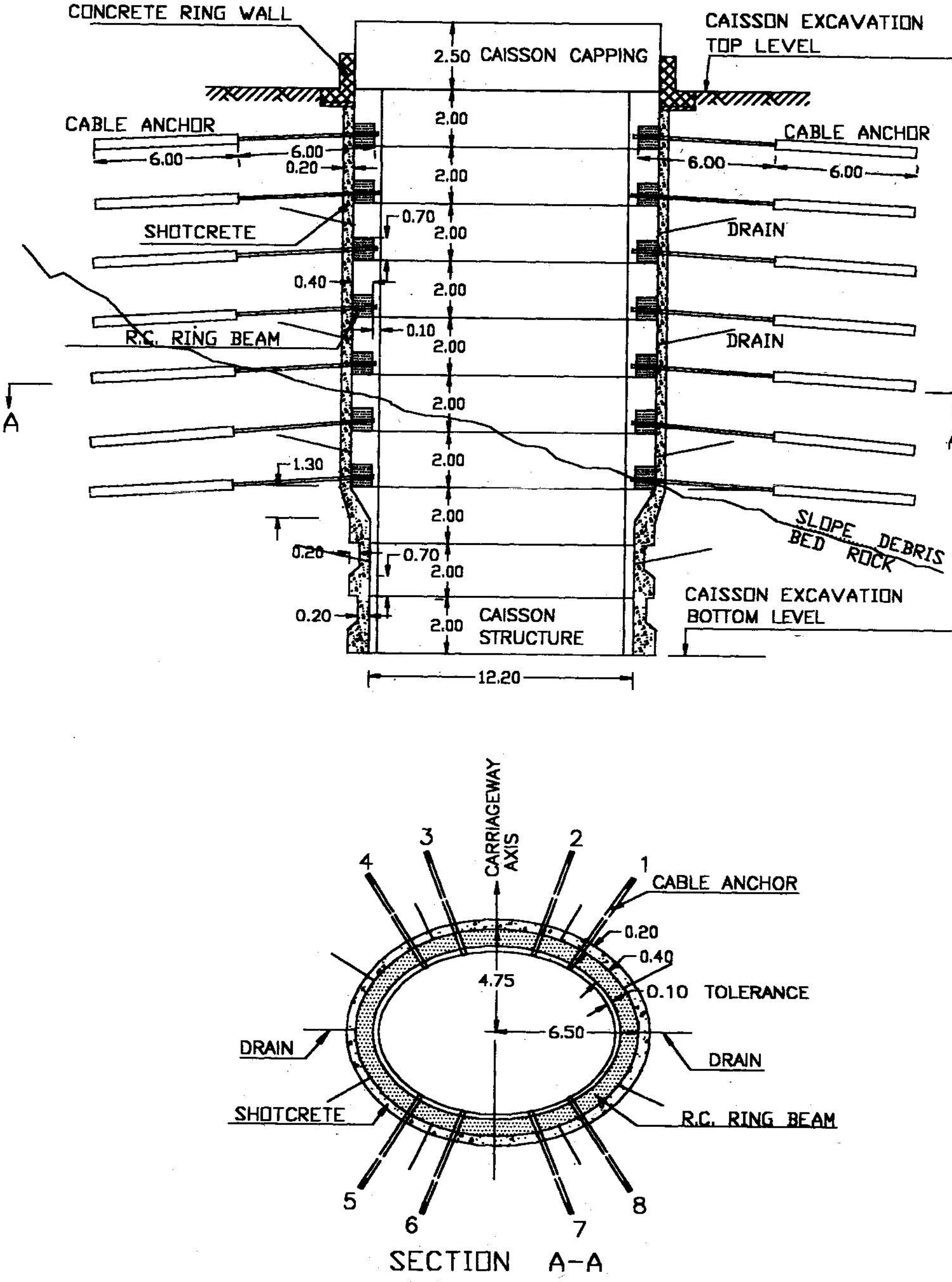


Figure 4: Drainage behind shotcrete lining.

The accumulation of ground water draining into the excavation was a cause of delay in construction of the deepest caissons; a system of four well-points outside and on the axes each caisson had been intended at the design stage, using 150 - 200 mm diameter pipes with submersible pumps, but this could not be adopted, because such pumps were not available. Although the Contractor used a sump at each level of the excavation, this proved to be



NOTE : ALL DIMENSIONS ARE IN METRES

Fig. 3. Plan and section of an elliptical caisson showing excavation stages and the peripheral supporting system.

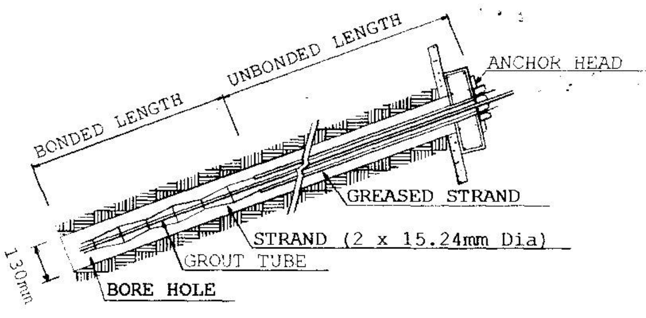


Figure 5: Pre-stressed cable anchor details.

insufficient to prevent work from being stopped during the rainy season.

3.3 Pre-stressed Cable Anchors

Eight cable anchors were used at each stage of excavation of the elliptical caissons, as shown in Figure 3, each anchor had two strands 15.24 mm in diameter as shown in Figure 5. The drilling of the 130 mm diameter holes was performed by a SoilMech SM 305 drilling rig, lowered down to the current floor of the excavation. The cable anchors were assembled on site, and inserted into the holes, after which grout was pumped in to form an anchorage, from a grouting plant located on the surface nearby. After the ring beam had gained sufficient strength, the anchors were stressed. The imposed stressing force was 150 kN for the top row, and 250 kN for the remainder; however, for some anchors at the second level this could not be achieved, even after the bond length was increased from six to ten metres, probably due to excessive ground water. This was overcome by accepting 150 kN for these anchors as well, and post-grouting them. One anchor at each level was tested in accordance with the relevant AASHTO specification.

4 CONCRETE

The entire cross-section of the caisson was filled with 22.5 N/mm² concrete, i.e. no internal shutter was used. The Contractor originally proposed to cast each caisson in one continuous operation, but this was rejected, and the concrete was cast in lifts of 2.05 metres in order to prevent a build-up of heat. The controlling factor was to ensure that the temperature differential between successive lifts did not exceed 20°C; however, this proved to be very slow, and as limestone aggregate was being used, the differential was increased to 40°C, as recommended by Neville & Brooks. Five rows of 32mm diameter bars were used as the main vertical reinforcement for the full height of the caisson, tied to 16 mm diameter spiral reinforcement.

5 DISCUSSION

"Because of the very great complexity of all ground problems, it is very dangerous to carry out a design prior to construction and never modify it" (Hanna, 1982). The designed depths of four of the caissons of Viaduct No. 5 were modified following close examination of the rock surface exposed as the excavation progressed. This was also the case with other viaducts in the Contract, and in some cases it was found necessary to carry out further site investigation, including the drilling of extra boreholes, for foundations where these were to rest on bored piles.

In general, tie-back walls are constructed in soft ground such as clay, sand, gravel and shales. The caissons for the piers adjacent to Abutment A of Viaduct No. 5 were six metre diameter circular caissons, as shown in Figure 1. When the Contractor came to create Abutment A itself, for each carriageway it have been logical to have two similar caissons, but he elected instead to have one larger 12 x 8.5m elliptical caisson with anchor-supported walls because the excavation of the smaller circular caissons at the adjacent piers had proved to be slow. Hanna points out that for any specific problem, and the above is a good example, a large number of possible solutions is often available, and selection is usually controlled by factors other than technical.

6 SUGGESTIONS AND RECOMMENDATIONS

1. The force obtainable in the anchors in the top four metres of an anchor-supported caisson will be less than for anchors further down.
2. For cable anchors in wet slope debris, it may be necessary to take extra measures to obtain the required loading, in which case a post-grouting system will give better results than increasing the bonded length.
3. Since the estimation of bond magnitude is uncertain, field anchor tests should always be carried out in order to confirm the bond values used in the design.
4. For caissons constructed by similar methods, eight metres is considered to be the smallest diameter that will avoid construction problems caused by limited working space and poor ventilation.
5. The shape of the elliptical caissons and the use of pre-stressed anchors for this viaduct were enforced by the existence of landslides; otherwise. the use of controlled blasting and soil nails would have been more economical.

7 ACKNOWLEDGEMENT

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