DEEP FOUNDATIONS FOR A BRIDGE IN BRAZIL

FONDATIONS PROFONDES POUR UN PONT BRESILIEN

ГЛУБОКИЕ ФУНДАМЕНТЫ МОСТА В БРАЗИЛИИ

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SYNOPSIS - The paper deals with the design and execution of the foundations of a highway and railway bridge on the Brazilian National Road BR-101. Caissons 1,5 m. diameter with lenghts up to 70 m. through sands and soft clays to weathered rock were used. Some peculiarities are mentioned as well as problems in execution and changes in design made necessary by special conditions of subsoil and equipment shortage.

1 - DESCRIPTION OF THE BRIDGE

It is a highway and railway bridge, with 832 m. in total lenght, over the S. Francisco River, northeast Brazil, between the cities - of Propriá and Colégio.

The bridge has one steel span, 90 meter long and the others in prestressed concrete 33,4m. long. The prestressed beams were precast ashore and transported along previously launched span.

FIGURE 1

The figure 1 shows a general view of the bridge during construction. A beam being transported can be seen.

The steel span has been designed taking in account the future necessity of navigation clearance.

2 - SOIL CONDITIONS

Borings were made in two different occasions: the first ones, previous to the bidding, were just preliminary borings to orient design.

After the bidding and during the final design the contractor ordered new borings to be made in the location of each column.

A typical boring shows fine and medium sands first loose then compact, with thin layers of soft clay to depths up to 20 meter.

Underlying the sand, very soft organic silty clay with fine sand, reaching 60 m. Below the soft clay, weathered rock, mostly sandstone or limestone, resistance growing with depth, until sound rock was reached at depths from 15 m. to 70 m.

In some borings a new layer of fine sand was located between the soft clay and the weathered rock.

Rotary drillings, AX in diameter were used normally in every boring, to test the - characteristics of the rock.

The river in that location, presents great variations in dry season and in rainy season. Because of that, the upper layer of fine compact sand had, according to specifications to be considered liable to erosion to a depth of 15 m.

3 - SOIL TEST

Soil test were performed on samples of the sandy layer, mainly regarding grain size and plasticity.

These data were important to define the choose of equipment to be used.

The tests indicated mostly (up to 94%) of fine sand.

As to the layer of soft clay, grain size was 40% clay, 35% silt and 25% fine sand.

Liquid limit of the clay was about 45% and plastic limit 20%.

In order to establish the bearing capacity of the rock, a compression test was performed upon a sample 4,2 cm. in diameter and 8,4 cm. height. Resistance obtained was 393,5 kg/cm2.

4 - PRELIMINARY DESIGN

Due to the characteristics of soil it was decided to design the foundation using steel cased caissons to sound rock.

Most columns were designed on four caisson. The columns for the steel span were to be supported by ten caissons each and two other columns, were the liable erosion could expose the rock, were designed on five caissons.

Each caisson has a 1,5m. diameter and distance between caissons is 4m. center to center.

Working maximum load of each caisson is 550 ton., corresponding to 35 kg/cm2 on the sound rock.

That value, obviously low when compared with the compression test, was adopted due to official specifications.

It was decided to use a vibratory hammer P.T.C. 2x60, to drive the casing through the sand and into the clayey layer, without an previous excavation.

Considering that, equipment casings where foreseen with a thickness of 1/4" whit a reinforcement in the lower 50 cm. to 1/2".

After introduction of the casing a Calweld 250B equipment with air-lift and a soil auger was to be used for excavation of the clay, to the top of weathered rock, below the bottom of casing.

Stability of the hole was assured by the use of bentonite slurry during all excavation procedure.

After reaching the weathered rock a special rock bit was to be used to drill to sound rock, control of the quality of rock being made measuring the drilling velocity (fig.2).

A new casing, aproximately 1,4 m. in diameter would then be lowered into the slurry to the top of weathered rock and, after introduction of the steel reinforcement, concrete poured through the bentonite using a tremie.

In two columns, where the sound rock was at less than 25 m. the caissons where to be excavated and concreted using the pneumatic caisson technique.

FIGURE 2

5 - PROBLEMS DURING CONSTRUCTION

Two kind of problems interfered with the real construction work:

a) - First and most important was the failure of the vibratory hammer to drive the casings to the required depth.

In spite of the soil boring results, the examination of sample of sand from different borings and the analysis of the grain size characteristics being previously made by the equipment experts the P.T.C. hammer, chosen to drive the casing through the sand and into the clay, was unable to drive more than 10m. into sand.

It is possible that the problem was caused by inadequate frequency of vibration, considering that the mentioned equipment is able of just little variations of frequency.

Considering the time schedule the contractor was forced to use the only available equipment, a Delmag D.22 diesel hammer.

Obviously the thickness of the casing having been designed to be used with the vibratory hammer, it was not thick enough to resist the driving with the Delmag.

Until problem was solved by reinforcing partially the casing (change of thickness was economically impossible) and driving to lesser depths, some casings were deformed to the point that it was impossible to use Calweld equipment and the earth auger.

Three different solutions were used:

a.1 - When the casings was deformed was or obstruction was at less than 30 m. depth, a pneumatic chamber - was adapted to the casing.

Working in compressed air, whit pressures up to 3,5 kg/cm2 the deformation was eliminated by jacking or even by removing the distorted section.

Obviously, working under such high pressures brought new problems due to necessary of specialized crews under strict medical assistance.

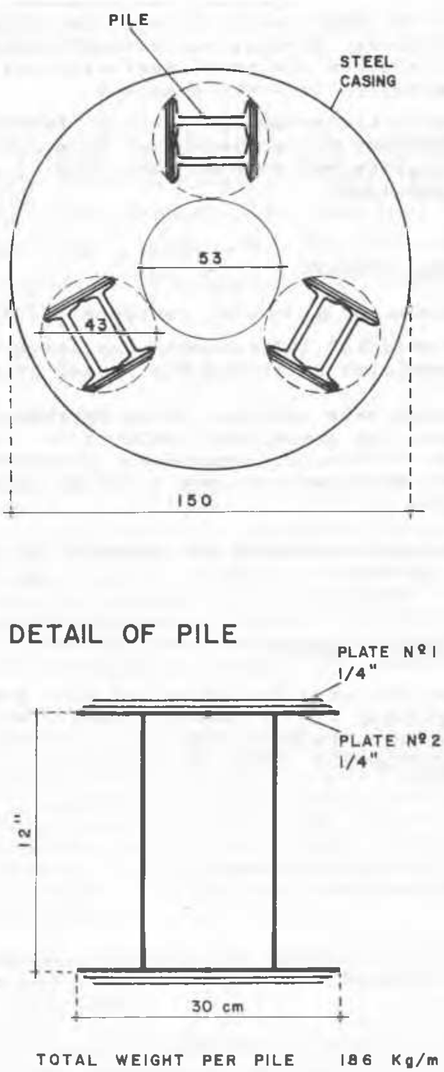


FIG. 3

a.2 - In other cases, even below 30 m. minor deformations were corrected using a specially designed steel mandrel adapted to the Calweld equipment.

a.3 - Finally when the deformations were too deep to be eliminated through compressed air and the mandrel was unable to solve the problem, the design was changed and steel piles driven through the casing to refusal in rock.

Special templates were arranged to guide the piles at different depths to guarantee verticality of the piles

Because Brazilian steel mills don't produce heavy profiles, the piles had to be specially made.

Three piles were driven in each caisson. Each pile was composed of two I profiles 12" x 5 1/4" with 66 kg/m. each, with additional reinforcement consisting of steel plates welded to the profiles in order to obtain a total weight of 186 kg/m.

Figure 3 shows a cross section of such a pile and the disposition of the pile in the caisson.

Top of piles was at elevation -25 m. in order to guarantee buckling resistance in case of erosion and a minimum penetration of 3 m. in the casing.

Some of the casings were redriven to achieve that specification.

Finally the casing was cleaned out and concrete normally poured through tremie.

FIGURE 4

Figure 4 shows the equipment in use. At the right hand caisson a steel pile is being put in position

b) - The second kindof problems resulted from the lack of experience in the techniques of using bentonite slurry and concrete pouring with tremie.

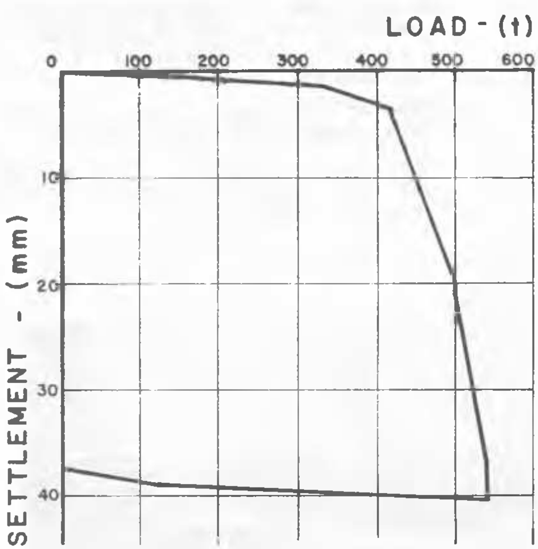
The problems with bentonite were solved with continuous testing in a complete field laboratory, studying the best density and viscosity to be used. After some time the technicians were perfectly able to specify correctly the vomposition of the bentonite slurry, the removal of sand grains, etc..

As for the use of tremie, only in two caissons, important problems were fbund.

In the first caisson to be finished with 61,55 m. long, during concrete pouring when concrete reached elevation -39,5 m. a reduction in the necessary effort to retrieve the tremie was verified.

Pouring was continued and, when finished the tremie retrieval, 16,7 meter of the total longht were missing, showing that a reasonable quantity of bentonite was mixed in the concrete, probably causing a complete interruption of the concrete column.

Even knowing that this caisson was not to be used a load test was performed (fig. 5).



DESIGNED WORKING LOAD	438 t.
MAXIMUM SETTLEMENT	40,36 mm.
RESIDUAL SETTLEMENT	37,32 mm.

FIG. 5

Up to aproximately 420 ton. total settlement was 3,5 mm but from that load on settlement increased rapidly to 40 mm with 535 ton.

In this load test reaction was provided by traction of two steel casings 1,5 m. in diameter and 27,0 m. longht driven 4,5 m. center to center from the tested caisson.

These two casings were afterwards used for two caissons to replace the faulty one.

After that accident a new tremie was provided and pouring was flawless. Only in one case due to a delay in supply of concrete, pouring was discontinued circa 20 minutes and some bentonite was entrapped into the concrete.

Using the pneumatic chamber because the accident was at less than 25 m. deep the concrete was removed and the caisson completed.

6 - FINAL RESULTS

The foundation is, by now, completely finished.

Of the original 105 caissons aproximately 80 were completed according the normal procedure

The others were modified using the steel piles In those, the casing was maintained with a minimum of 25 m. to guarantee protection against buckling of the piles in case of erosion.

Minimum penetration of the piles on the casing was of 3,0 m.

7 - ACKNOWLEDGEMENT

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