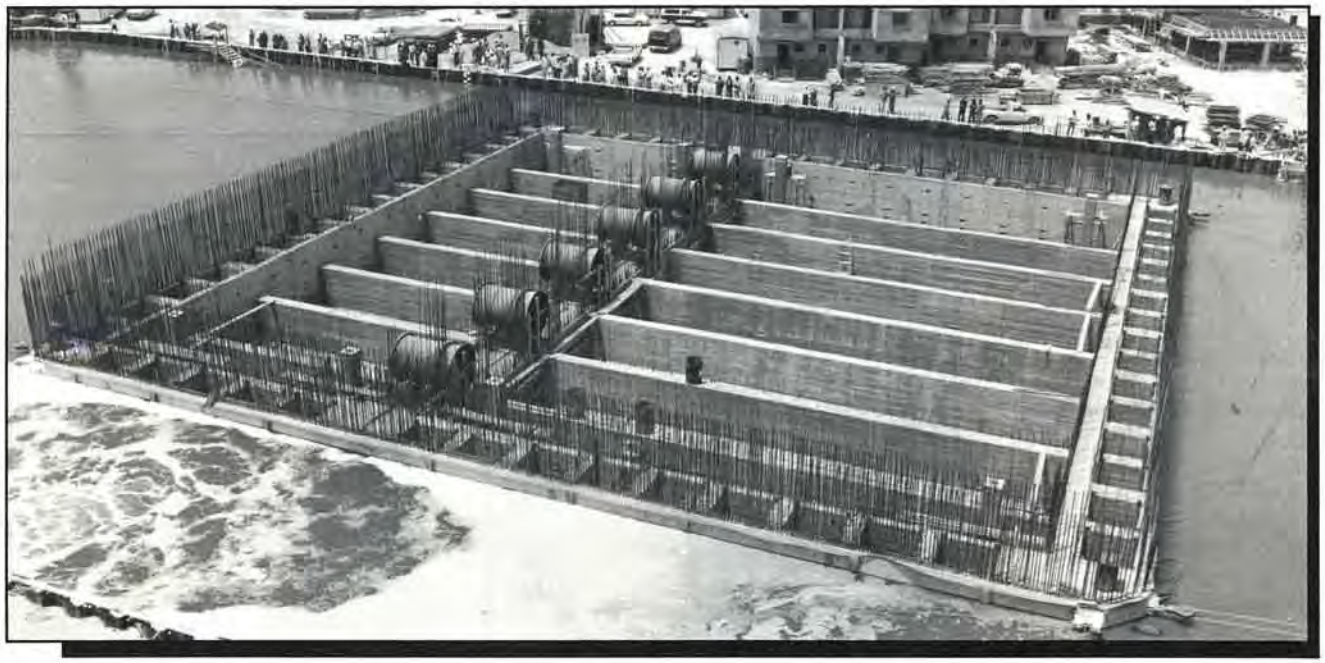
Severe Groundwater Problem Used To Advantage

by Granville White and Dr. Gerhard Giemscheid
Fru-Con Construction



In order to avoid threatening the stability of nearby buildings, a pump station was constructed as a floating concrete box.

When removal of groundwater from a 20 meter deep building pit for a large pump station would have threatened the stability of building within a one kilometer radius, engineers and constructors from Fru-Con Construction Corporation decided not to dewater the pit but make use of the high groundwater level and build the pump station as a floating concrete box.

Site Problem

Fru-Con is building a two vital wastewater treatment plants in Alexandria, Egypt to handle the untreated sewage of this 2,000,000 population city and help protect the Mediterranean Sea to the north and 40 kilometers by the 10 kilometers lake to the south. The lakeside site consists of several thick interconnected sand strates interspaced by layers of clay. The bottom of the influent pump station of one of the plants is to be 20 meters below the surface and in order to build from this depth, the original contract for dewatering within a tube shaped diaphragm wall 54 meters in diameter penetrating 34 meters down to the bottom sand layer.

Unfortunately, two principal factors prevented this procedure. After constructing the diaphragm wall by the slurry wall method, it was first found that the permeability factor of the sand of 4×10^{-4} m/sec was one thousand times greater than the amount predicted from preconstruction geotechnical data.

Because of this high permeability, water was being drawn from as far away as one kilometer. Therefore it became vital to change the construction method because within 200 meters of the site a densely populated residential area had been built. In this area scores of buildings, up to eight floors high on raft foundation, sit on the top alluvial clay. The distress of many of the buildings is readily visible. Many are leaning and all are steadily settling into the clay. Persuading the local authorities to evacuate the buildings has proved unsuccessful so far and the decision was made not to remove any water from underneath these buildings which caused a rethinking of the original construction plan.

Several different options were considered, including recharge systems, sealing the bottom of the cofferdam with an anchored tremie concrete plug and also sinking a closed bottom pneumatic caisson, but none were favored because of reasons of safety or economy. Further investigations showed that by modifying the construction sequence of the pump station, sufficient buoyancy could be built into the two-meter-thick walls so that the structure could be made to float. This discovery meant that by excavating the pit within the completed circular slurry wall without removing water, the floating pump station walls could be built up to their full 22 meter height while their increasing mass would settle the bottom of the pump station closer and closer to the final design depth. This floating caisson solution was accepted by the owner as being the one which best combined cost economy, safety during construction and protection to the third parties outside the site boundaries.

Design Considerations

Several parameters guided the design. Each construction state had to be considered for floating stability and also for structural stability. Additionally, the resistance to leakage, especially through concrete shrinkage cracks, also had to be considered. Finally, the finished structure had to conform with

the original design.

It was decided to build the walls of the pump station in lifts of three meters. Buoyancy chambers would be introduced into the walls by building only the outer and inner skins (thickness 38 cm and 28 cm respectively) and joining these skins by webs to form 1.5 x 1.34 meter buoyance tubes. The bottom slab is 2.5 meters thick and this was redesigned to be built in three structural stages, the first, for the floating stage, is 35 centimeter thick with seven 50 centimeter wide 2.15 meter high stiffening ribs above it. These ribs stiffen the slab until the pump station has a draft of 6.80 meters. Two subsequent construction stages strengthen the slab's 2.5 meter thickness to resist the increasing waterhead. As construction of the outer wall and bottom slab proceed, the internal wall, elevated slab columns and beams are being built in normal sequence to give stability to the still floating structure.

Altogether, 14 floating stages were considered in the calculations. For each stage, the gravity and buoyancy forces were calculated not only to provide statical floating stability but also to ensure that there is always freeboard below the final formwork of a particular pouring level and to guard against flooding.

The statistical analysis considered ultimate strength and serviceability design using an overall finite-element grid system. A compute model was built to consider geometrical symmetry in one direction and asymmetry in the other direction under the uniform loading of each construction stage. The floating box was designed as a series of grid systems framed by a skeleton of very rigid horizontal beams hidden within the outer walls and connected to the rigid vertical columns at the corners where the walls meet. The three dimensional analysis considered the grid system of the multicell was to be modeled horizontally as Vierendeel beams while vertically the walls were considered as joined T beams forming the buoyancy chamber.

Pour sizes of the walls were determined by consideration of probable crack widths arising from shrinkage. The calculations were done with a software program which ran as an additional module to the finite element program and this deterministic approach used the strain/stress reaction and bond behavior in any section with several cracks. The investigation gives a certainty that 95 percent of all cracks will be less than he characteristic crack width of 0.2 millimeters.

With the problems resulting from floating conditions and loading resolved, attention was then turned to ensuring that the structure in its finished form conformed to the original design as if it had been built in a dry pit. The primary consideration for ensuring this was to prove structural continuity throughout the full two meter width of the walls and not through the webs around the buoyancy chambers. This condition was satisfied by making the walls of the buoyancy chambers corrugated so that the corrugations were able to transmit all possible shear forces. After the pump station is placed on its foundation, these chambers are filled with non-shrink concrete.

Construction

The first floating stage, which is an open-topped box — 37 meters square and three meters high, was built at ground level at the side of the circular diaphragm wall. At the same time, the inside of the pit was excavated from the perimeter of the diaphragm and from floating pontoons with the groundwater remaining at its natural level. Divers graded the foundations for the pump station and the whole works were surrounded by a sheet pile wall to form a dry dock 3 1/2 meters above ground level. When all was ready, the dry dock was flooded using 17,000 cubic meters of lake water and the concrete box caisson floated for the first time. In May it was towed the short distance to the diaphragm wall and the water was immediately removed from the dry dock. The box caisson was thus lowered within the top of the circular diaphragm wall, where it floated 20 meters above its final design position, and the subsequent construction stages commenced.

Summary

Groundwater is often a major problem in the construction of deep foundations. However, like most problems, if they are big enough, the contractor simply has to accept them as fact and find ways to avoid doing constant battle with them.

By finding a way to use the high groundwater, Fru-Con guaranteed that its construction activities will not affect the surrounding properties while at the same time ensuring an orderly construction sequence.❑

Granville White, vice president, Fru-Con Construction Corporation, is responsible for the management of operations and support services for all Fru-Con overseas assignments. He is a Civil Engineer with degrees received from New York State University and Loughborough University in England.

Gerhard Giemscheid, is a senior project manager at Fru-Con and serves as on-site design manager for the East & West Wasterwater Treatment Plant projects in Alexandria, Egypt. He possesses a Doctorate of Engineering from the University of Darmstadt, Germany and has provided management leadership for the Alexandria project for the past three years.