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Multystory Constructions In The Unconsolidated Quaternary Deposit

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Abstract

The Quaternary stratigraphy of the western coastal belt provide soft sub-surface conditions for raft foundations. Within the City of Colombo such raft foundations have been successfully constructed at or below the ground water table, and typically were placed on dense sand beds and on soft sandstones.A well-balanced loading of a raft helps to prevent any tilt during long-term settlements in loose sands and cohesive clays. When the Profiles below the raft are unconsolidated sands, settlements will be mainly instantaneous, during construction loading of the raft. During excavations for a raft below the ground water table, shoring sheet piling and dewatering mechanisms will be necessary.

Keyword :

Introduction

The western coastal belt has a variable stratigraphy of Quaternary deposits based on palaeo-environment. A geotechnical drilling investigation can establish the different beds, their thicknesses and load bearing properties. In addition when cohesive clays are present their expected settlements are evaluated by the relevant laboratory tests on undisturbed samples.

It is from an overall engineering appreciation of the sub-surface profile that the depth of founding a raft is recommended. In addition deep rafts have been stable when placed on clayey sands and sandy clays. However placement of a raft on beds of peat is avoided due intense continuous settlements over long periods. Soft sandstone of the western coastal belt affords the best founding for deep rafts. Often loose and compressible clayey strata are excavated to reach a bed of sand and sandstone or clayey sand. Therefore the selection of the formative level of the raft is of utmost importance.

In unconsolidated formations above and below the groundwater table excavations for a deep raft require special engineering techniques. In the western coastal belt the water table is shallow seated, and bordering the coast in Colombo the ground water table is shallow seated, where it will range from 0.5m down to 5.0m depths. Therefore sheet pilling and dewatering was adopted during excavations for deep rafts at Hotel Galadari and Crescat of Hotel Oberoi in Colombo (Figure 1).

The dewatering surrounding the excavation need to be efficient in order to prevent "sand boiling" during the placement of the raft. For major projects as above, dewatering tube wells continuously operated

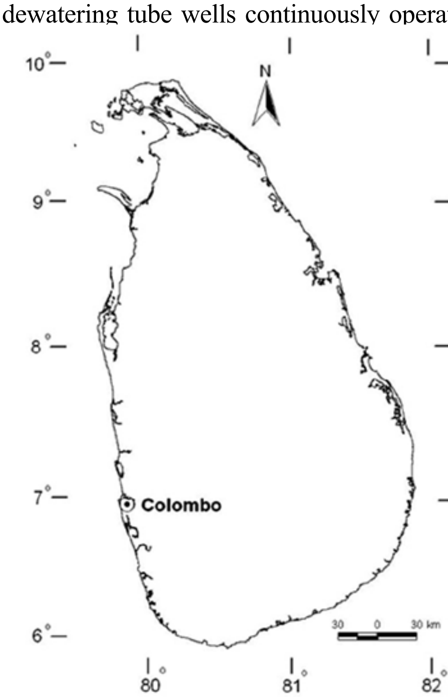


Figure 01: Location of Hotel Galadari and Crescat of Hotel Oberoi in Colombo

to lower the groundwater table during the raft emplacement.

Geological setting

The western coastal belt of Sri Lanka has Quaternary beds, which form as the basement for raft construction. These Quaternary deposits include marine, lagoonal and terrestrial deposits. Whereas areas of marine deposits constitute sands and sandstone, the lagoonal and terrestrial deposits have variety of sedimentary beds such as sandy clays, clayey sands, organic clays, peat, lean clays, plastic clays and sands (Cooray and Katupotha, 1992).

The sequence of the stratigraphy is essentially based on fluctuations of the mean sea level (MSL). These beds have been estimated up to Late Pleistocene, which is around 18,000 yr. B.P; called the Last Glacial Maximum. In this stratigraphic sequence the beds of peat in the area have been already dated at 5790+ 80 yr. BP, which is at a depth of around between 0.30cm to 0.50cm below MSL (Katupotha, 1988).

In founding of a raft, a bed of sand is normally preferred. In the western coastal belt these sand beds can be of marine of fluvial in origin. In order to achieve a good compaction of such sand the particle size distribution is critical. Sand beds of fluvial origin, which are well sorted normally, have a good particle size distribution and makes such beds well compact. Conversely the marine sand beds are less dense. However when marine sands have been consolidated to sandstone these beds make an excellent formative basement for rafts, especially when such sandstone is followed by in-situ weathered rock. All these overburden Quaternary formations lie unconformably on the Precambrian metamorphic crystalline gneiss. This unconformity leaves a hiatus of at least 600 million years in the geologic history of Sri Lanka.

The in-situ basement rocks are identified as the Vanni Series of Granitic gneisses (Cooray, 1984). These granitic gneisses mainly include granites, biotite gneisses, biotite hornblende gneisses and charnockitic gneissess. These gneisses are crystalline rocks of high uniaxial compressive strength, which makes them ideal for load bearing, especially for pile foundations.

Case studies

Within the City of Colombo, along the western coastal belt, two major raft constructions were for the Hotel Galadhari and Crescat for Hotel Oberoi (Dias and Gunasekera, 1983; Dias and Tennakoon, 1993; Dias, 1995). Both these rafts have been placed on dense sands and semi-consolidated sandstones (Figures 2 and 3).

For the Hotel Galadhari the loose and soft strata were excavated within a sheet piled area to reach the depth of firm sands of ‘N’=10 to 15 at a depth of about 08 meters. Geothchnical investigations revealed an adequate thickness for the dense sands, and therefore the pressure bulb of the loaded raft did not reach any soft beds below the sands.

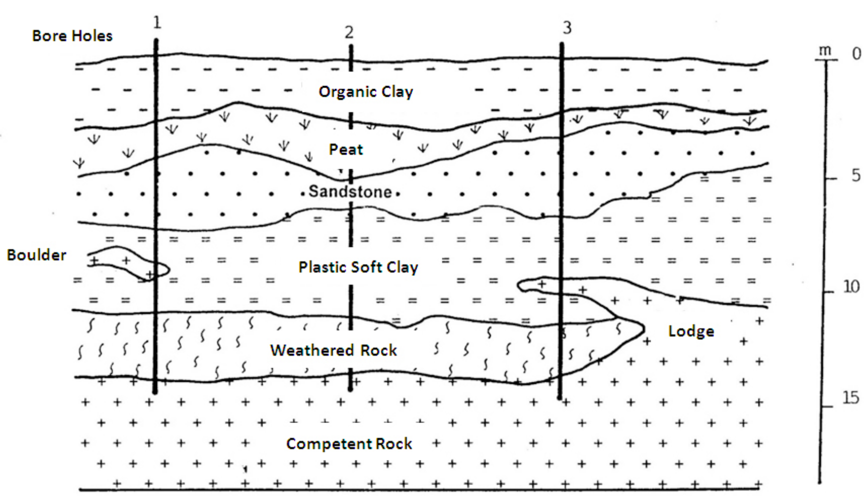


Figure 02: Typical Quaternary Profile

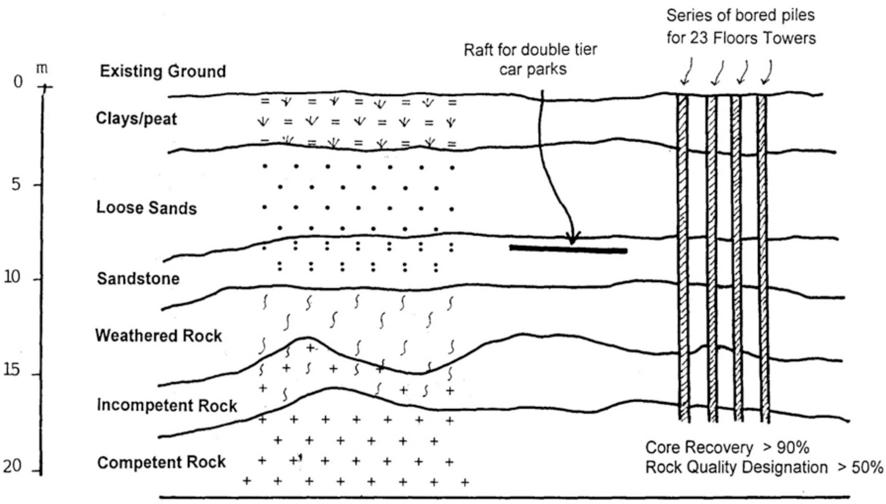


Figure 03: Foundation for Hotel Oberoi

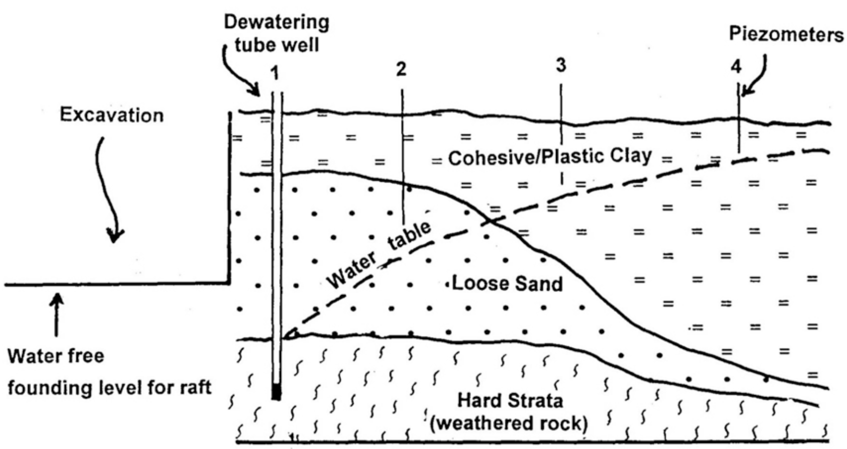


Figure 04: Dewatering for Raft Foundations

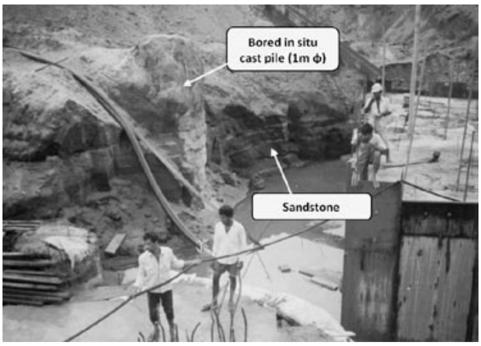
A series of shallow tube wells drilled down to about 15.00m, were placed strategically surrounding the sheet pile area, which ensured dry excavation down to a depth of about 12.00m and ensured a water free surface without "sand boiling" for the raft construction.

Similarly for the Crescent Development of the Hotel Oberoi an extensive double tier underground car park is on a deep raft, where the formative level is on friable sandstone at a depth of around 10.00 m (Dias and Tennakoon, 1993). It is interesting to note that for this project whilst a deep raft is suitable for the double tier car park, heavy loads of the 23 floor tower is placed on end bearing bored piles (Figure 3), where the pile base is rock socketed into fresh rock. For the placement of this raft on the sandstone sheet piling and dewatering was adopted for satisfactory construction.

For the construction of such deep rafts, sheet piling and an intensive dewatering programme is undertaken (Figure 4). Interlocking sheet piles are driven to firm strata at least 3-5m below formative level of the raft. Mechanical excavation is terminated well above the bottom depth of the sheet piles, so that there will be no collapse of sheet piles into the excavation by lateral soil pressures.

Prior to the dewatering programmes

the behavior of the soil types and quantum of groundwater that requires pumping out should be evaluated. This is normally done by dewatering a test-tube well on a step up pumping basis. By monitoring a series of spaced out piezometers, the drawdown curves of the water table can be plotted for different rates of pumping (Figure 4). From the above investigation the spacing and depth of dewatering wells surrounding the sheet piled excavation is designed, along with the required quantum of pumping. The pumped out water is diverted to a long distance, in order to avoid seepage back, to replenish the groundwater table.



Figuer 05: Deep bored pile founded and rock socketted in bedrock for 23 storey structure.

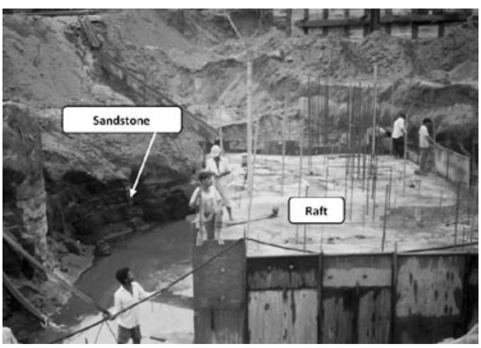


Figure 06: Exposed sandstone upon which raft is founded.

Problems and issues

In sheet piling unconsolidated formations with a shallow water table, pile verticality, proper interlocking, and sometimes bracing will be important criteria in construction. When verticality is not maintained buckling of sheet piles can occur resulting in the collapse of the excavation. In the absence of proper interlocking, saturated clays and peat will flow into the excavation terminating disturbing all excavation operations. To hold the sheet piles together as a rigid "box structure" proper bracing is essential.

The depth of the sheet piles should be well below the depth of excavation, which is normally 3m to 5m depending on the unconsolidated formation at depth. In dense granular formations 3m can be sufficient, while is soft clayey sandy strata at least 05m will be preferred.

During excavation within the sheet piled area below the water table, efficient dewatering is necessary. Dewatering is normally from tube wells located just outside the sheet piled perimeter. On reaching the formative level of the raft, the surface need to be unsaturated and undisturbed. The water table has to be to be drawn below this surface. On a sandy basement "sand boiling" due to hydrostatic pressure will occur if the water table is not properly drawn down. After laying of the raft, if the normal water table is above the raft structure, continuous dewatering will be necessary for the construction of the basement of the structure.

In the coastal sand belt of the west coast excessive long duration dewatering should be avoided, to prevent adverse environmental impacts. Two major impacts are drying up of shallow dug wells in the vicinity, and salt water intrusion. Long duration excessive pumping in sands bordering the coast causes the inland migration of the saline water wedge, whereby the perched fresh water lens is depleted. The other environmental impact is the potential threat for the subsidence of adjoining foundations by the reduction of hydrostatic pressure due to dewatering.

A significant environmental impact in dewatering for the Galadhari Hotel raft was salinity intrusion (Dias and Gunasekera, 1983). Here the delays in construction of the raft entailed a long period of fresh water dewatering. Thereby shallow dug wells in the vicinity (Colombo Fort and the Galle Face) were rendered saline for a period of about 2 years.

Conclusion

Dense sand formations and sandstone horizons of the western coastal belt afford a suitable basement for the construction of deep raft foundations. Therefore it is essential that a geotechnical-drilling programme be conducted to identify the different beds of strata for their safe load bearing capacities. Thereafter a suitable bed for founding can be identified for load distribution.

For foundations supporting heavy loads per unit area to the underlying soil a deep raft can be suitable for load distribution over the entire area. One must ensure soft beds at depth receive minimal loads, and thereby settlements are limited. Most instantaneous settlements occur during the construction loading. For minimal long-term settlements the R.C. concrete raft acts as a whole unit in accommodating settlements. Therefore structural failures are avoided, including any tilt of the raft. Any tilt of a raft can occur due to non-horizontality of stratigraphy due to dilation or pinching out of soft compressible beds.

For construction projects, which involve heavy loads over an extensive area, raft foundations on unconsolidated formations are more economical than end-bearing piles, especially when the bedrock is deep seated. However for high concentrated loads such as multistory towers (Figure 3) bored piles end bearing on bedrock can be the only option.

To obtain an undisturbed water free surface for a deep raft, shuttering and dewatering can be essential. In built-up urban surroundings dewatering requires caution. Excessive lowering of the groundwater table can cause subsidence of adjoining shallow foundations, and the drying up of dug wells. In areas bordering the coast excessive dewatering often causes salinity intrusion, which can be an environmental hazard for the raft construction.

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