SOIL INVESTIGATION & FOUNDATION PROBLEMS AT PUNE - A CASE STUDY

Karra Raja Sekhar, Jt Director, HQ Chief Engineer Siliguri Zone, MES, Siliguri-734008, raja6667@rediffmail.com

ABSTRACT: Soil investigation is normally carried out on sampling basis based on the area of the building and its importance. An unusually large variation in the soil strata is not anticipated with in a distance of 50 m. However, in a project, due to varying strata of BC soil, water seepage, collapse of foundation trenches, increase in depth of foundation, additional grade beam etc, the increase in cost of the foundation exceeded the permissible 10 % deviation in sanctioned/contracted amount of the project and eventually time overrun.

INTRODUCTION
A work for Single Accommodation (Barracks) for 454 Other Ranks (OR) of Army at Pune was sanctioned in Mar 2006 for Rs. 6.67 Crs. The work comprised of Block A (Triple story) for 300 ORs, Block B (Triple story) for 154 OR, JCOs Single accommodation for 20 persons, dining halls & cookhouses, a OH water tank, pump house and other connected services like road, water supply, electric supply, sewage and furniture. The building work (except OH water tank and furniture) with services was contracted for Rs 6.03 Crs in Mar 2007.

SOIL INVESTIGATION
Block A and Block B of size 95 m x 47 m and 43 m x 59 m were located on different plots originally at distance of about 150 m (Fig1).

For Block A, soil investigation was carried out in 4 boreholes. The depth of BC soil found was 0.9 m & 1.0 m from ground level in 2 Nos of diagonal boreholes and 2.3 m & 2.4 m in other 2 Nos of diagonal boreholes and level of fractured rock varied at 3 m – 4 m depth with yellow clayey silty sand in between. For Block B, the depth of BC soil was 1.5 m from ground level and level of fractured rock was 4.5 m from ground level with yellow clayey silty sand in between. The depth of water table was found at 1.5 m – 2.0 m. BC soil deposit in the area had a Differential Free Swell Index in the range of 100% to 60 %. The soil was classified as highly expansive soil which can generate upward soil pressure in the range of 250-350 kN/m². Hence, Soil testing agency had recommended complete removal of BC soil under the footings, flooring and plinth protection.

Soil investigation report recommended SBC of 150 kN/m² at 1.5 m depth with footings resting in yellow clayey silty sand. Accordingly the foundation design was carried out and replacement of BC soil with moorum was proposed.

PROBLEMS DURING EXECUTION
Block B was resited next to Block A (Fig 2) by the clients for the following reasons:

a) The original location of this single accommodation block was very close to the Married accommodation blocks.

b) There was enough area available next to Block A for co-locating both the blocks as the plot required for both the blocks was approx 150 m x 50 m.

c) The soil investigation of the Block A was already available and soil strata at the new site of Block B was expected to be the same as that of the Block A in the nearby area up to 50 m.

Fig 1 Site Plan (Original siting)

Fig 2 Site Plan (after resiting)
During excavation, the water table was found to be as high as 0.6 m (Fig 3). Dewatering with 3-4 Nos of pumps was resorted to continuously to drain off the water (Fig 4). Even this could not drain off the water completely for the foundation trenches. This aspect was not anticipated as the soil report indicated water table at 1.5 m to 2.0 m below ground level.

This was primarily due to the fact that the excavation pits became the lowest place around the complete area and there was cross flow of water from the nearby Lake to the Mula river. This caused the caving of the foundation trenches. During excavation, the thickness of the top layer of BC soil varied from 0.9 m to 2.9 m, the thickness of clayey silty sand varied from 1.4 m to 2.9 m and depth of the rocky strata varied from 2.6 m to 4.1 m (Fig 5).

The foundation was originally planned to be kept on the yellow clayey silty sand strata, whose thickness varied from 1.4 m to 2.9 m. Due to high water level in the foundation trenches; during the excavation, BC soil strata collapsed and got mixed up with the underneath silty clayey strata (Fig 6).

Such large variation in soil strata in a small area of just 150 m x 50 m plot is not normally encountered making this as an unusual case

The contract catered for the replacement of top 60 cm layer of BC soil with the moorum. Since the complete clayey silty sand strata had to be removed up to the rocky strata to rest the foundation. Part of the excavated clayey soil which got mixed with the BC soil was even unsuitable for the refilling.

The muddy and water logged conditions in the foundation trenches were even unsuitable for laying the PCC below the RCC footings. Plum concrete i.e. boulders mixed with lean dry concrete for a depth of 400-450 mm was filled in the trenches while simultaneously carrying out the dewatering (Fig 7).
It was noticed that the plum concrete also helped in reducing the water percolation in the trenches. Thus, the layout of the column footings and binding of the footing reinforcement could start over the plum concrete as the dewatering could only bring down the level of water just below the top of the plum concrete.

The foundation depth had to be increased up to the rocky strata at 3 - 4 m depth from the original depth catered in clayey silty sand strata at 1.5 m. Additional grid beams were provided for the columns of the increased depth of 4 m in Block B and in one wing of Block A (Fig 8). Since the foundation was rested on the rocky strata instead of clayey silty sand strata, the size of footings got reduced and nearly compensated for the increased length of the columns.

Thus, the reasons for the change in the foundation can be broadly classified into:
   a) Due to Site change of the Block B
   b) Due to unusual variation in soil strata
   c) Due to Structural requirements
      i) Removal of BC soil
      ii) Provn of grid beam for Block B
      iii) Increase in foundation dept up to the rocky strata
   d) Due to Constructional requirements
      i) Dewatering
      ii) Excavation of silty clay in muddy conditions
      iii) Plum concrete below the RCC footings

CONTRACTUAL IMPLICATIONS
After excavation of BC soil for both blocks, finding the water level as high as 0.6 m and unsuitable muddy conditions to start the footings even after continuous dewatering; the possibility of changing the site was also explored in consultation with the clients. Since these blocks were meant for single men; hence the same could not be relocated away as the other nearby area was of Married accommodation zone or of educational faculties/office accommodation area. Even if a suitable site was identified at a far away location, since the contractor had already carried out excavation of BC soil and disposed off the earth to far off location; the excavation & its disposal already carried out would have been infractuous expenditure to the Govt. Also it would have necessitated refilling the excavated plot and extra expenditure. Hence a conscious decision was taken to go ahead with the work at the present location itself.

The approximate additional expenditure due to change in foundation was initially calculated based on broad variations and was estimated to be within the allowable deviation limit of contract and sanction. The abnormal and uneven change in strata of all the 3 layers i.e. BC soil, silty clayey soil and rock, increased the cost of excavation and filling with moorum. The provision of plum concrete was a totally unforeseen provision and was unavoidable as already explained before. Even the thickness of plum concrete has varied at locations. Hence the cost of changes in the foundation exceeded the tolerance limits of both contract and sanction. This created a procedural problem of getting the sanction for the additional cost from the Govt before the work is further executed on site. However, there were no other substantial reasons to stop the work except the availability of funds to cater for the extra expenditure.

The possibility to stop the work was not feasible since the work had already got delayed initially due to change of site of Block B, accordingly shifting of Block A by few metres from its original location and as the excavation for foundation was also complete. Further the flooding of foundation trenches did not allow progressing the work as planned. The contractor wanted to make up the time lost initially. The delay was directly putting heavy burden on the contractor due to sharp escalation of material prices especially steel and cement during that period. The stopping of work would have also disturbed the labours and other T&P resources working at site and would have been difficult to re-mobilise them again. There was acute labour shortage faced in Maharrastra at that time due to migration of outside labourers to their natives as an effect of agitation started by the political party MNS. Therefore, the contractor did not want to stop the work as the contractor, an un-enlisted firm took up this contract in MES wanted to maintain its good reputation.

The work was thus continued and getting the additional sanction was expedited to regularise the procedural problems.

CONCLUSION
Soil investigation is normally carried out on sampling basis based on the area of the building and its importance. An exhaustive soil investigation covering the complete area is not practically possible as it would cost exorbitantly. Even if such exhaustive investigations are carried out, even then the provisions of foundations would have been similar to what has been provided at site and also its financial effect.

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