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Use of Case Histories to Enhance Practical Geotechnical Engineering

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ABSTRACT

Mathematical models are constructed to describe the behavior of engineering systems in quantitative terms. During conceptualization stage of modelling several valid assumptions have to be made so as to make the model predict the behavior of the system as accurately as possible. Refinement of mathematical models need feed back from practice. Many practical cases are of interest in updating and enhancing quantitative judgment of geo-technical systems behavior.

This paper envisages to present a few interesting cases where the situation forced true synthesis of theory and practice for innovation and advancement of practical geo-technical engineering.

INTRODUCTION

From the days of thumb rules and qualitative judgments to the state of the art of quantification and designs geotechnical engineering has elevated itself to a serious combination of science and maths. Theory precedes practice though there are expectations where the theory has been fitted to explain how practice works.

For advancement, refinement and enhancement of the science of geotechnics, theory and practice have a lot to do in terms of give and take. This constitutes a self governing feed forward and feed back loop.

Technological advancement necessarily has three steps:

i) Creation
ii) Diffusion and
iii) Application

In these three stages the success of theory and practice are closely intertwined.

CASE 1. FOUNDATION SETTLEMENT

An RCC multistoried multi bay frame with 14 stories in all was built for a hotel complex. Later the utility was changed to that of a health care complex. The original structure neither had a ramp nor provisions for hospital lifts. It was therefore decided that an independent lift shaft be constructed adjoining the existing structure to accommodate high speed bed lifts.

Fig. 1. Add on high speed lift shaft after restoration

The add on (lift shaft) feature was designed and executed with a raft foundation. Within four months of completion and 3 days of incessant rains it was observed that the lift shaft had tilted away from the building suggesting foundation movement. Accurate measurements were made and the tilt was observed to be more than 1:800.The raft foundation for the lift shaft in question had been placed at the same level of footings of the building, assuming similar condition as that of the foundation for the building, to be available for the raft too. When soil investigations were conducted to ascertain conditions beneath the raft, to the dismay of all concerned, it was found that part of the raft was on loose compressible fill.

The raft was punctured to accommodate piles to be driven to hard strata bypassing the compressible fill. Piles were driven, connection between pile and raft were established by epoxy bonding. Steel trusses at intervals were introduced to connect the shaft to the building proper (see Fig. 1). Thus further settlements were arrested.

Reliance on records and placing confidence on precedence may not always be safe and when very important installations are to be founded investigations and sound engineering judgments are a must to avoid complications and hazards.

CASE 2. COST EFFECTIVE SOLUTIONS TO MODIFICATIONS MID WAY OF WORK

A small but very popular temple in pristine surroundings exists at Haldipur, near the coastal town of Karwar, Karnataka India. The temple authorities envisaged expansion of the temple complex by addition of a congregation hall. Rectangular single bay single storey RCC portal frames with isolated concentric footings for columns were designed (Fig.2)

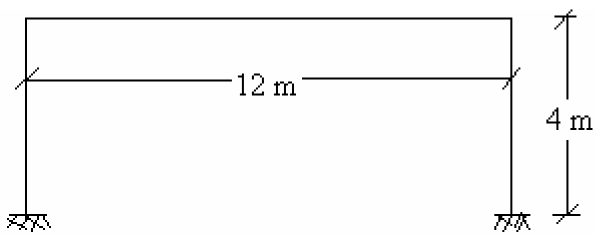

Fig.2. Original configuration of hall frame

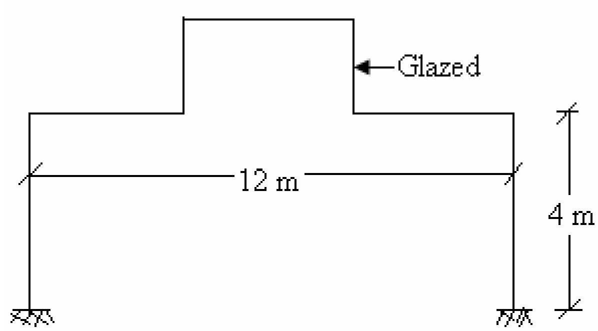

Fig. 3. Modified configuration envisaged

and execution of work began. Columns were cast upto the beam bottom. Before works on monolithic beam and slab elements for the roof could proceed, the authorities felt that the frame configuration needs to be changed for better light and ventilation. The envisaged revised configuration was as in Fig.3. It was now a problem to check whether the modifications contemplated would suit the foundation works that had been executed.

After detailed analytical investigation it was suggested to modify the configuration to the one shown in Fig. 4.

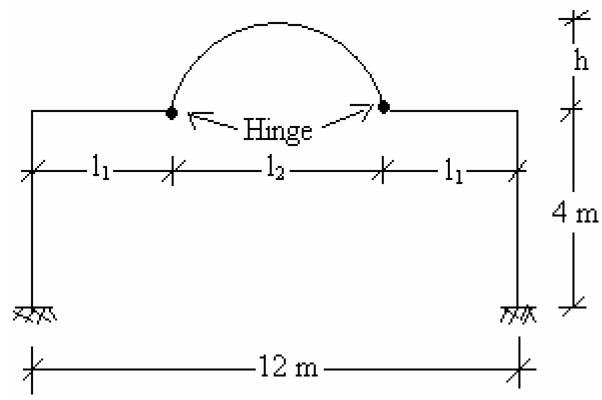

Fig. 4 Judicious final configuration

Careful consideration shows that part of frame without the two hinged arch behaves like a determinate structure (typical bus shelter) having tendency to trip inside necessitating an eccentric footing projecting inwards.

The two hinged arch has a tendency to spread out. Judiciously selected values for l_1, l_2 and h will lead to a situation were the loading on the existing concentric foundation can be rendered purely axial enabling it to absorb the changed conditions safely. This precisely was, what was done as the trouble shooting exercise.

Knowledge of behavioral aspect is a must in recognizing the implications of modifications, and also comes handy in suggesting cost effective solutions as has been explained here.

CASE 3. INNOVATION IN PRACTICE FOR SITE SPECIFIC SITUATION.

A multistoried building in difficult terrain had to be constructed wherein level difference of 15 m in footings had to be accommodated. The sizes and configuration for footings arrived would not permit this huge level difference. It was therefore decided to go for bored cast-in-situ piles. The site had medium dense laterite underlain by soft rock and hard rock.

Fig. 5 RCC framed building in difficult terrain

Fig.8 Close up view of chisel and bailer

Fig. 6 Floor configurations suiting terrain

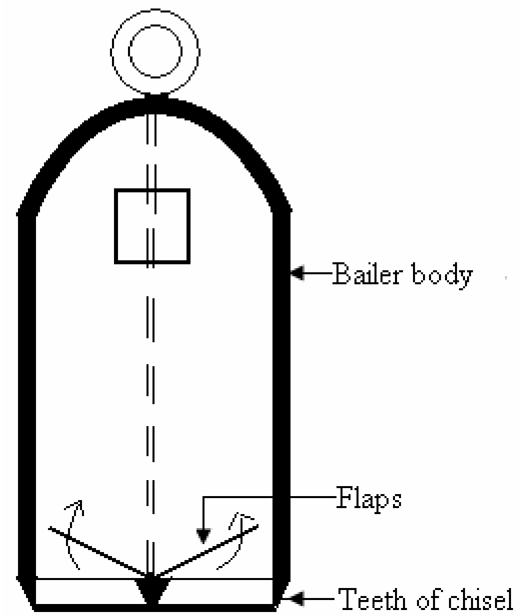

Fig. 9. Chisel cum Bailer

Fig. 7 Chisel and bailer for bored piles

Bored piles are done using bailer in soil, and chisel in hard strata. After chiseling in hard strata for clearance of muck bailer has to be employed. Since the site had hard strata at very near general ground level chiseling had to be resorted to right from the beginning. The frequent change over from chisel to bailer for drilling and muck clearance hampered the progress of work seriously.

This problem lead to the innovative idea of fabricating and employing a chisel cum bailer (Fig. 9) wherein the necessity for change over was eliminated and the speed of work was drastically improved in comparison to using regular method of chiseling and muck clearance by bailer.

CASE 4. LIMITING POSSIBILITIES FROM THEORETICAL COMPUTATIONS

Masonry gravity retaining walls are very popular for low heights and are extensively used as the skill and paraphernalia required for there construction is limited.

It is interesting to know before hand what can be the limiting possibility from simple and elegant calculations that can be performed with basic knowledge of soil and structural mechanics as has been illustrated here.

Fig. 10. Gravity masonry retaining wall

Consider a case of masonry retaining wall of height h as shown in Fig. 11.

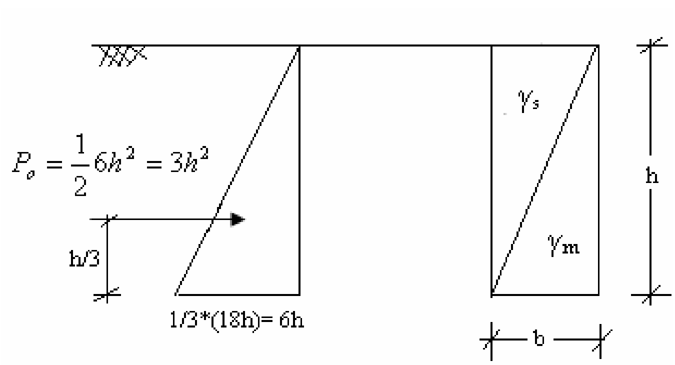

Fig. 11 Driving forces on gravity walls

Most usual values encountered in practice have been assumed for illustration as under:

Angle of internal friction $\varphi = 30°$; Unit weight of soil $\gamma_s = 18$ kN/m^3; Unit weight of masonry $\gamma_m = 20$ kN/m^3 ; W = 20*(bh)

$$k_a = \frac{1-\sin\varphi}{1+\sin\varphi} = \frac{1-0.5}{1+0.5} = \frac{1}{3}$$ and $\mu = \tan\varphi = 0.577$

<u>For no sliding</u>

Restoring force which can be mobilized by friction should be greater than driving force.

Driving force = $P_o = 3h^2$

Restoring force = μW

$\mu W \geq FS \times P_o$ where FS – Factor of safety.

Let FS = 1.5

Therefore $0.577 * (20\ b\ h) \geq 1.5 \times 3h^2$ and hence $b \geq 0.3899h$

<u>For no overturning</u>

Restoring moment should be greater than overturning moment

$M_R \geq FS \times M_o$ where M_R – Restoring moment
Mo – Overturning moment
FS – Factor of safety

Let FS = 2

Since $M_R = (20\ bh) * (b/2)$
$Mo = 2\ h^3$ we get for no overturning
$(20\ bh) * (b/2) \geq 2\ h^3$
or $b^2 \geq 0.2\ h^2$ and hence $b \geq 0.4472\ h$

For no tension at base $e \leq (b/6)$ and also maximum pressure should not exceed SBC

$e = (M/W) \leq (b/6)$

$(h^3/20bh) \leq b/6$

$h^2 \leq (20/6)b^2$ or $b \geq \sqrt{\frac{6}{20}}h$

Therefore for no tension at base
$b \geq 0.5477\ h$

and for maximum pressure not exceeding SBC

$$\frac{2\gamma_m bh}{b} \leq SBC$$

$$h \leq \frac{SBC}{2\gamma_m}$$

for $\gamma_m = 20$ kN/m^3 and SBC = 200 kN/m^2

$$h \leq \frac{200}{(20*2)} = 5m$$

Therefore knowing SBC and unit weight of masonry it can be pre decided as to what is the theoretical maximum height of retention. Any thing beyond this should not be ventured. Many failures are due to non recognition of existence of such theoretical limits.

CONCLUSIONS

A state of the art of the geotechnical engineering has reached the current levels and much is being done to advance and enhance its capabilities. Analytical tools come handy in solving field problems. They feed back from practice is of immense help to update theories that describe behavior of geotechnical engineering systems. Few interesting cases demonstrating the close association of theory and practice in advancement of the science have been presented to highlight the necessity of feed forward (theory) and feed back (practice) loop for refinement of both analytical and practical tools.

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