Behaviour of ‘segmental/meter panels’ for basements and subways

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ABSTRACT: Growing need of basements for vehicles storage and services in city of Mumbai is problematic. Proximity buildings, services, narrow lanes, traffic and crowds preclude open excavations or diaphragm walls. Building subways under crowded roads with utilities and closure is not possible, led to using segmental/meter panel construction. These are panels of small width designed as cantilever sheet piles adequately anchored in sub-stratum to develop necessary passive resistance and balancing couple. When constructed in succession, full length of the wall can be constructed. This is a fast, flexible and cheap engineering solution to the problems encountered in crowded localities. A number of such structures have been constructed. Some panels were instrumented for verification of in-situ behaviour. Points of interest concerning stress patterns and distribution were monitored. A comparative study of the observed readings of the instrumented meter panels and the results of theoretical analysis and design principles are presented.

1 METHODS OF ANALYSIS OF RETAINING STRUCTURE/SYSTEMS

1.1 Analytical methods

Usually, following methods for analysis of cantilever pile walls, all of which involve simplifications of net pressure distributions to allow calculations of critical retaining height are in use:

a. Factored Moment Method (FMM)

1.2 Empirical design methods

a. Strut Load: An important aspect in excavation support design is to estimate the strut load. Most of the methods are empirical and based on limit equilibrium of wedge (Terzaghi, 1941) and the apparent earth pressure diagrams (Terzaghi. 1943; Peck. 1969)
b. Base Stability: Another important aspect is the effect of base heave. (Bjerrum and Eide 1956) proposed the use of stability numbers against base heave.

1.3 Field measurements

Ground movement is a major concern in the design of excavation support systems. In built-up areas where the ground contains a soft layer, thorough investigation is required. The following observations are made for analysis:

a. Lateral wall deflections
b. Ground surface settlements
c. Stress state of soil near excavation

1.4 Finite element analysis

It is generally accepted that the Finite Element Analysis (FEM) is the major technique used in the numerical analysis of geo-technical problems. FEM in excavation related problems was first carried out between 1969 and 1971. Some fundamental techniques in excavation process simulation were developed in 1978.

1.5 Centrifuge model studies

Study of deep excavation using centrifuge model studies has several advantages over field instrumentation techniques. Model tests can be conducted repeatedly under controlled and well instrumented conditions and the behavior of the retaining wall and associated ground movements including pre-failure situation can be thoroughly examined. Excavation stability studies, collapse mechanisms and soil-wall deformation patterns of diaphragm walls constructed in clay were carried out between 1987 and 1991.
2 PRESENTED STUDY

The past concerns about the stability of excavation have now shifted emphasis on control of wall deflections and ground movements under working conditions especially in densely built-up areas. The numerical methods with appropriate consideration of relevant factors have the potential to give relatively accurate solution for both stability and ground movements for an excavation. However, a perfect model to predict the collapse of support system and evaluation of ground movements at some distance behind the retaining wall under working conditions is still not available.

3 INSTRUMENTATION SETUP

In and around the city of Mumbai, a number of basements/subways have been and are being instrumented and constructed. Normally, bending strains in wall are measured along its depth giving bending movement response. The evaluated geo-technical properties of soil and observed bending strains along with theoretical bending movements, shear force, deflection and earth pressure are presented and comparison made between theoretical and experimental values. The measurements have been taken using electrical resistance strain gauge. These adhesive type strain gauges were mounted on the panels, had the following specifications:

Type: BE 120 – 6AA (11)
Gauge resistance: $119.9 \pm 0.1 \Omega$
Gauge factor: $2.08 \pm 1.0\%$
Make: Tokyo Sokki Kenkyujo Company Limited

3.1 Strain gauge arrangement

Connections are made using red, black, yellow and green wires as indicated in Fig. 1.

3.2 Strain measuring instrument

A strain measuring device in the SYSCON product range was used. It accepts input from 10 numbers of strain gauge bridges simultaneously and signals are selected one by one through an electronic channel selector to a signal conditioner which consists of a high gain, stable, low noise, low drift, instrumentation type amplifier, GF setting control and bridge configuration select facility. The conditioned outputs provide 5V DC signal for an input of 20,000 micro strains. This output is connected to a micro-controller based 41/2 digit panel meter that can display strains up to 20,000 micro strains with one micro strain resolution. This voltage output is also made available to the user on the rear panel for purpose of monitoring or recording. (Strain indicator SI – 38 MS)

4 FIELD SETUP

As indicated in Fig. 2, the meter panel is instrumented before concreting and all lead wires are taken out at the top of the pile.
5 **CASE PRESENTED**

5.1 *Soil profile at Andheri site (Fig. 3)*

5.2 *Observed strains at each strain gauge station*

i) Location of site: New Link Road, Andheri

ii) Size of Meter panel: 1000 mm × 600 mm

iii) Total depth of Meter panel: 9.00 m from original ground level

iv) Total depth of excavation: 6.00 m

v) Total number of strain gauge installed: 5 on tension side and 5 on compression side

5.3 *Calculated bending movement from observed strain*

See table 2.

5.4 *Calculation of deflection, shear force and earth pressure*

Deflection is second integral of bending movement, shear force the first derivative of bending movement...
Table 3b.

<table>
<thead>
<tr>
<th>Location of strain gauge from top of the pile in m</th>
<th>Theoretical bending moment kN-m</th>
<th>Observed bending moment kN-m</th>
<th>Theoretical deflection mm</th>
<th>Observed deflection mm</th>
<th>Tensile stress in steel</th>
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</thead>
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</table>

Figure 5a.

Figure 5b.

6 COMPARISON OF THEORETICAL AND OBSERVED BEHAVIOR

Tabulated results are given in Tables 3a & 3b, and for graphical representation refer Fig. 5a, 5b, 5c & 5d.

7 CONCLUSIONS

On the basis of field measurements, the observed flexural behavior of cast-in-situ reinforced concrete cantilever segmental/meter panels leads to the following conclusions:

Theoretical and observed profiles of earth pressure, bending movements, shear force and deflection in the structure due to excavation are matching well.

Nature of variation in theoretical and observed values of force functions along the depth of the panel wall matches well with slight differences in magnitudes.

Differences in theoretical and observed values are due to variations in soil properties, inconsistent laboratory results of soil samples, changes in groundwater table, etc.

Magnitudes of observed values through instrumentation are less than the theoretical values. The difference occurred because the theoretical magnitude
of lateral earth pressures and consequently theoretical bending movements considered c value much less than actual.

Earth pressure diagram clearly shows that the actual passive earth pressure developed is greater than the assumed theoretical passive earth pressure in rock strata. This reflects a high factor of safety taken for design of panels and an underestimated c value of rock.

REFERENCES


