SOIL STRUCTURE INTERACTION FOR HIGH RISE STRUCTURE

Pooja S Naik[1], Dr. Katti Anand Ramanath[2]
Department of Structural Engineering
[1] M E Student, B. R. Harne College of Engineering, Vangani. Mumbai University.
[2] Professor, Data Meghe College of Engineering, Navi-Mumbai Mumbai University.

Abstract- *One of the most important factors affecting the structures which are in the close vicinity of Mumbai metro line 3, is the geo static stresses due to the construction of this proposed underground metro construction. Therefore it is desired to evaluate the change in geostatic stresses due to the construction of this proposed underground metro construction. Closed form solutions for such analysis are not available in literature. Empirical and semi-empirical methods are available but may fail to take into account the complexities involved in terms of geometry or material properties. Therefore the finite element method is used for carrying out this analysis. The results can be evaluated, whether the amount of variations in forces and displacements are in the allowable ranges. The analysis work was carried out using the finite element code PLAXIS 3D:AE.01.*

I. INTRODUCTION

A. General

Mumbai Metro line is a metro line extending from Colaba passing through congested areas of Mumbai such as Cuffe Parade, fort, kalbadevi, Mahalaxmi, Dadar, Mahim, BKC, and finally terminating at Seepz. At Dadar, a 56 stories residential building is proposed under the redevelopment scheme. Due to the subsequent planning of Mumbai Metro line 3 which is found to be in the vicinity of 8 m, poses a challenge to the designers especially in terms of the stability of the structures.

The proposed building in subject is located at plot bearing C.T.S. No 179, 180, 189/1, 189/2, 189/4, 190 and 191 of TPS IV, Gokhale road, Dadar west, Mumbai, which is under redevelopment. The proposed new structure named Richa j class park marina is a shear wall framed structure consisting of G+56 stories. The area of the proposed structure admeasures 83 m x 35 m at its maximum extent. The superstructure consists of total 56 floors of which first 7 floors are parking floors and others are for residential purpose. There are total seven refuge floors and 42 residential floors. The Building is a shear-wall frame structure with piled foundation. The height of the structure is measured around 193m. the closest distance between the outer edge of the proposed structure and metro excavation which is about 8 m. The construction of the station is carried out by cut and cover method.

B. Geotechnical conditions

Ground conditions at the proposed site were investigated by rotary core drilling. The stratum contains different layers. Below the ground level, the top layer comprises of filling material with a depth varying from 1.3 m to 2.10 m. This was followed by brownish fined to medium grained sand layer up to depth varying from 6.60m to 7.5m below ground level. Followed by stiff grayish clay up to a depth varying from 7.95 m to 9.6 m. Brownish grey altered basalt was found from depth 7.95 m to 12.5 m below ground level. The rock was moderately weathered in upper stretch. The next layer noted was grayish basalt which is at various depths with varying thickness.

II. OBJECTIVE OF STUDY

The present work was focused on the evaluation of the stresses and the settlement generated in the soil beneath the structure due to the construction work for the underground metro station. By using finite element analysis i.e. PLAXIS 3D:AE.01software, the effect of underground excavation on the soil structure interaction is investigated. The main objectives of the present study are as follows:

1. To analyze the superstructure of G+56storey as per the architectural plans and loadings as proposed by Indian standard in its codes such as IS 875 and IS 1893, using ETABS 16.
2. To evaluate the loads at the base of the structure.
3. To design the soil domain and to define the boundaries and joints for the superstructure, substructure and metro excavation using PLAXIS 3D:AE.01 software.
4. To apply all the loads evaluated using ETABS analysis and used it as input parameters for each joint in PLAXIS 3D:AE.01software.

5. To evaluate the change in the geostatic stresses due to construction of this proposed underground metro using the finite element code PLAXIS 3D:AE.01.

6. To compare the results for stresses and settlement with the allowable values.

7. To check the safety of the structure.

III. METHODOLOGY

A. Modelling of Structure:

ETABS version 16.2.0 is an engineering software product that caters to multi-story building analysis and design. Modeling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class of structure. Several analysis methods, both elastic and inelastic, are available to predict the seismic behavior of the structures. A Response Spectrum Analysis (RSA) will be carried out using software ETABS version 16.2.0. Software ETABS version 16.2.0 is a fully integrated program that allows model creation, modification, execution of analysis, design optimization, and results review from within a single interface. Software ETABS version 16.2.0 is a standalone finite element based structural program for the analysis of civil structures

1. Floor plan:

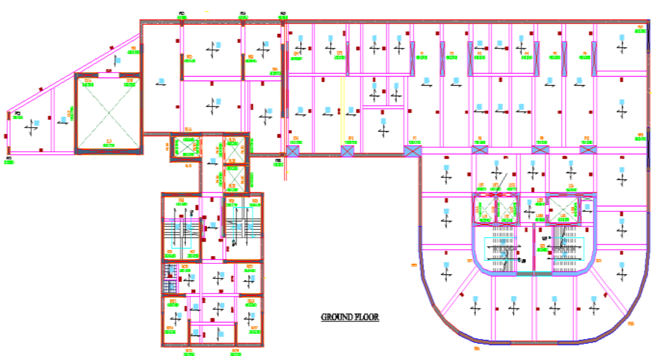

Figure 3.1: Ground Floor Layout

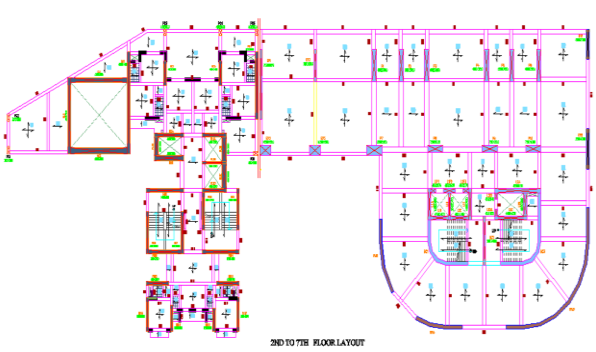

Figure 3.2: Second to Seventh Floor Layout

B. Geostatic Stresses:

The soil is a multi-layer homogeneous material and homogeneous material property may or may not change with depth. It would be inappropriate to consider soil as a homogenous material and the analysis was carried out using the finite element software PLAXIS 3D:AE.01.For evaluation of the geostatic stresses PLAXIS 3D:AE.01software was used as a tool.

The plastic behavior of soil and rock is non-linear and unique for each material depending on its mineral composition, stress history, weathering etc. It is with this rationale that the Mohr-Coulomb model was chosen for defining the behavior of the soil and rock encountered at the present site. In case of rock, equivalent Mohr-Coulomb parameters were obtained using Hoek-Brown (2002) criteria.

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1. Analysis steps

After completing the geometry input and arriving at the optimum mesh size the final analyses were performed. These analyses were run in four stages:
Stage 1corresponds to the initial conditions i.e. development of geostatic stresses.

Stage 2 corresponds to the condition when the excavation for the building has been completed and retaining wall and raft are in place.
Stage 3 corresponds to the conditions when all the foundation members and full building load acts on the ground.
Stage 4 corresponds to the condition when 25.00 m deep excavation is carried out close to the structure.

IV. TECHNICAL CONSIDERATION

A. Modelling of Structure:

1. Sectional properties:

i Beam

Sectional dimensions(mm)	**Grade of concrete(MPa)**
230 X 600	M40
300 X 600	M40
300 X 1200	M40
450 X 600	M40
450 X750	M40
450 X 1200	M40
600 X 600	M40
600 X750	M40

ii Slab

Thickness (mm)	**Type**	**Grade of concrete(MPa)**
125	Oneway	M40
150	Oneway	M40
150	Twoway	M40
200	Oneway	M40
200	Twoway	M40
250	Twoway	M40
300	Twoway	M40

iii Shearwall

Thickness (mm)	**Grade of concrete(MPa)**
230	M70
300	M70
1050	M70

2. Load considered

Functional area	Intensity (KN/m2)
Living rooms	2.0
Rooms with storage	3.0
Toilet and Bathroom	2.0
Staircase, common passages	4.0
Stilt, Car parking and Corridors, Stationary stores	4.0
Balconies and Flower Bed	3.0

3. Earthquake load

Earthquake loads are automatically calculated as per IS 1893:2002 by program Etabs version 16.2.0 itself and distributed along the height of structure, as per provisions of IS 1893:2002 (clause no. 7.4.1 and table no.8). 25% of imposed load is considered in seismic weight calculation for live load up to 2 KN/m^2 and above it up to 5 KN/m^2 50% is considered. The factors used are as follows-

i Zone factor – 0.16 (Mumbai under zone III)

ii Importance factor – 1.0

iii Response reduction factor, R - 4

iv Soil type – I

v Time period = $\frac{0.09H}{\sqrt{D}}$

vi Time period in X Direction = 2.63sec.

vii Time period in Y Direction = 3.19sec.

4. Wind Load

Wind loads are calculated as per IS 875(part III):1987. The factors used for calculating Wind load are as follows-

i Basic wind speed Vb in m/s – 44 (Mumbai Region)

ii Terrain category – 3

iii Structural class – C

iv Risk Coefficient (k1) – 1.0

v Terrain, height and structure size factor (K_2) – Varies as per height taken as per Table 33

vi Topography factor (k_3) - 1

vii Design wind speed, $VZ = Vb \times K_1 \times K_2 \times K_3$

$= 44 \times 1 \times K_2 \times 1$

$= 44 K_2$ m/s

viii Design pressure, pz $= 0.6 \times (44 K_2)^2$

$= 1161.6 K_2^2$ N/m^2

The above all factors are taken as per building location and description from IS 875(part III):1987

5. Material properties

i Steel

a) Unit Weight – 78.5 KN/m^3

b) Grade of steel – Fe 500 / Fe 415 MPa confirming to IS 1786:1985 and Fe 250 confirming IS 432:1982.

c) Modulus of elasticity – 2.1X10^{5}Mpa.

B. Geological properties:

1. Material properties:

Only the backfilled material was modeled as a linear elastic material since no structural loads are imposed on it table below shows the material as well as their properties

Properties	γ_{unsat}	γ_{sat}	**E**	**ν**	**c**	**ϕ**
Material Name	*kN/m^3*	*kN/m^3*	*kN/m^2*	-	*kN/m^2*	°
Filling	18.00	19.00	6300	0.30	-	-
Brownish Sand	18.00	19.00	22.14x10^3	0.30	10.00	30
Greyish Clay	20.00	21.00	25.00x10^3	0.30	50.00	5
Basalt	24.00	25.00	1200x10^3	0.30	2562	49.7

V. RESULT AND DISCUSSION

For the analysis and design of the foundation which is the objective of this particular thesis, it is essential to evaluate the stresses which are going to be coming from top to bottom in turn transmitted to the foundation and this particular data which is evaluated using the analysis software Etabs will be used as the input parameter for carrying out the foundation analysis.
Based on the input parameters which were picked up from the results obtained from the Etabs foundation analysis was carried out using PLAXIS and based on the execution of the programming PLAXIS the outcome of the result are presented and discuss here.

1. Study of settlement in Z direction

Sequence	Minimum settlement (mm)	Maximum settlement (mm)
End of building excavation	-1.3	1.3
Building loads applied	-9.8	0.3
Metro excavation completed	-9.8	2.6

2. Study of stresses in Z direction

Sequence	Minimum stress (kN/m2)	Minimum working stress (kN/m2)	Maximum stress (kN/m2)	Maximum working stress (kN/m2)
End of building excavation	-981	-654	90	60
Building loads applied	-3641	-2427	949	633
Metro excavation completed	-3616	-2410	966	644

VI. CONCLUSION

These results are compared to the limiting values and from the study it is concluded that:

- From the settlement study, it is observed that the minimum settlement and maximum settlement are -9.8 mm and 2.6 mm as compared to the values for end of building excavation and when building loads are applied.
- From the study stresses in z direction, it is observed that the values of minimum and maximum stress are -2427 kN/m^2 and 633 kN/m^2 as compared to the values for end of building excavation and when Metro excavation completed.
- According to the settlement study, it is seen that the minimum and maximum settlement values are under the limiting value which is 15 mm for the rocky soil.
- According to the stress values, it is seen that the minimum and maximum stress values are under the limiting value of stress which is UCS value of rock strata which is 3041.04 kN/m^2.
- It is concluded that the values of settlements and stresses are within the safe limits. Hence there are no changes required in the design of the superstructure or substructure.

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