Impact Assessment of Hydro Geo-Technical Variation in Parts of Sector-8, HUDA Division, Ambala and Analysis of Foundation Design W.R.T. Water Logging Area.

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Abstract - *Houses in some parts of the City of Ambala are facing problems related to water seeping in and flooding of the ground floor area. This also leads to damping of walls and settling of foundation. As a result of settlement, structural members like beams and columns attain cracks. Thus this study has been undertaken to investigate the reason for the rise of water table and also its effect on the structural stability of the buildings. As Ambala is expected to see development in the next 10 years which includes multi stories this study thus become important to be carried out. This paper, after days of site study, list out the reasons and their remedies mainly in Sector 8, HUDA Division of Ambala.*

Key Words: **Seepage1, Settling of foundation2, Structural Analysis5, Crack stitching3, Ductile detailing4,**

1. INTRODUCTION

Ambala is one of the important cities of Haryana and is located at a proximity of both national capital Delhi and State capital Chandigarh. According to Master Plan for Delhi 2021 (MPD-2021) published by DDA "The rapid and almost uncontrolled growth of population has put basic facilities under severe pressure, and there are significant deficiencies. Even a cursory analysis of the present state of affairs, infrastructure problems could become a cause of crisis." Chandigarh also being immensely populated over the few decades, makes Ambala the next suitable place for development. As a result, lots of multi-story buildings and multiplexes are said to come up till next decade making Ambala a commercial and residential hub in future.

In lieu of providing the land for development to residential, and commercial sectors the nearby Nalas and other water courses that were acting as water shed for Yamuna river were filled up with garbage and local soil. This leads to water logging in and around the areas of the city which is responsible for reducing the bearing capacity of the soil. Due to rise in water table, bulking of sand occurs as the lithology of the area consist of 60cm of silty sand followed by fine sand upto 10m from the existing ground level.

Since the fine sand occurs at the top level, the bulking of sand in the area causes the formation of cavities and fissures below the ground which further weakens the foundation of the structure and becomes the main cause of settlement of the foundation of buildings in the underlined areas.

The study was further carried out for the analysis of development of the cracks viz a viz foundation type. Due to rising of water level the study area has become completely water logged as a result the soil is becoming saline with low permeability condition.

This study is going to be helpful for structure engineers, geotechnical engineers, architectures and planners and administrations to provide the remediation of safety of buildings in water logged areas using hydro geotechnical method which is a recent state of art with a combination of hydro geology, geotechnical studies along with design of structures with its impact analysis and safety measure.

2. AIMS AND OBJECTIVES

Following will be the Aims and Objectives-

1. Causes for water logging and low abstraction will be ascertained for Sector 8 HUDA Division, Ambala

2. Ascertaining the bearing capacity of the soil after and before the water table condition.

3. Analysis of foundation of the existing building and determining the cause of cracks near the plinth level of the existing structure.

4. Analysis of safe load bearing capacity of the soil in the presence and absence of water in the foundation of the structure.

5. Structural analysis of the building to ascertain the impact of settlement of the structural members like beams considering the building as a frame structure.

6. Finally, the remedial measures will be recommended to safeguard the structure against the differential settlement. Also, remedial measures will be suggested to reduce the settlement in and around the foundation of the pre-existing buildings using hydro geo-technical methods.

3. METHODOLOGY

1. Hydro geological survey was performed as per the norms of Central Ground Water Broad (CGWB) in the Ambala division of HUDA sector 8. Samples were taken from few hand pumps and submersible and salinity was established due to high TDS value.
2. Effect of groundwater on the bearing capacity if water is at the Influence zone with special reference to shallow foundations using Terzaghi's ultimate bearing capacity equation.
3. Analysis of the foundation of existing building where cracks and settlement is observed and possibility of cavity and fissures were established by using terra meter.
4. Comparative study of the past and existing situation i.e. in past the water was found at a depth of 15 m and at present water table has risen to 1.2m from the ground level, on the foundation of the structure considered.
5. A HUDA residential quarter of Ambala Division, Sector 8 which was effected and incurred cracks and settlement was analysed using the standard structural analysis software to understand the effect of settlement on the structural member such as beams.
6. The remedies that need to be incorporated to safeguard the structure in the present scenario was suggested. Also special attention was given to the pre-existing buildings, their retrofitting and future safety was also suggested.

4. ANALYSIS AND DISCUSSION

1. The major observation was observed from the area near the Nala. It was observed that the water seeps out from the ground causing swelling of plaster and dampening of the structural member. It was also observed that water of considerable height was completely filled up in vacant plots of Sector 8, HUDA Division of Ambala district making the area flooded as shown in Figure 1.

Figure 1 Flooding in vacant plot

The field TDS meter was used and on spot TDS values were analysed along with pH and electrical conductivity in order to analyse the salinity condition in the area. The soil in that area was found as highly saline with the TDS value of 2800 mg/litre. The high level of salinity in the soil was established as the main reason for low abstraction of ground water.

2. As per Terzaghi's equation, the bearing capacity of soil when the foundation is closer to the water table i.e. water table is in influence zone to water table away from the influence zone has got 0.5:1 ratio which means the bearing capacity became half and affects the allowable load carrying capacity of the strata. It causes differential settlement of the structure which is the main cause for the development of cracks.

a) Shear consideration settlement

The analysis for net safe bearing capacity has been carried out against shear failure criteria. The values were computed for local shear failure. The foundation type was analyzed as square footing.

The following equation has been used for allowable ultimate bearing capacity.

For local shear failure-

q'd =2/3 CN'c icdcsc + q (N'q-1) iqdqsq + BrN'rSrdrir W' - (1)

Value of net safe bearing pressure is computed for shear failure in case of non-cohesive soil using above equation considering C=0 and keeping all other constants as per IS: 6403-1981.

Where,

q'd = Ultimate bearing pressure from local shear failure

Net safe bearing Pressure = 1/3.0x Ultimate bearing pressures.

Where 3.0 is taken as factor of safety.

C = Cohesion of soil obtained from Triaxial/Direct Shear Test

Angle of friction is ϕ' (for Local shear)

N'c, N'q, N'r are bearing capacity factors with respect to ϕ' respectively as per IS: 6403 – 1981

ic, iq, ir = Inclination factors and are taken normally 1

dc, dq, dr = Depth factors taken as one

Sc, Sq, Sr = Shape factor (For square footings Sc = 1.3, Sq = 1.2, Sr = 0.8)

B = width of footings

Df = Depth of footing at 1.5m

q = Overburden pressure = $\gamma . D_f$

w' = Water Correction factors.

Correction factor on account of water table is considered as 0.5 when the foundations are closer to sub surface water table. The values of safe bearing capacities determined by using factor of safety of 3 by IS code method and Terzaghi's method for square footing is underneath.

Allowable bearing capacity-

C	=	2.5t/m2	⍰	=	190	Ø '	=	12.990
N'c	=	7.8	N'q	=	2.2	N'γ	=	0.332
Dc	=	1.0	dq	=	1.0	dγ	=	1.0

Safety factor = 2.50

Width 1.2 x 1.2m
Depth: 1.5m

q'd	=	19.96 t/m	q safe	=	6.65 t/m2	Say	=	6 t/m2

Further, the initial design report of the existing building recommends the value of bearing capacity to be used as 8 tons per square meters and the water table was observed at a depth of 15 meters from the ground level. The bearing capacity of the soil at 15m water level came out to be 12 tons per square meters but for the safety and future consideration the design bearing capacity considered for the structure was taken as 8 tons per square meters. Over the period of time the water level of Ambala has seen a rising trend and at present the water table was observed at 1.2 meter from the ground level which reduced the load bearing capacity of the soil to nearly half the value.i.e. 6 tons per square meters. The area of Ambala has highly saline water which makes the abstraction of water very difficult and as a result the water table rises above the foundation level of the structure and causes settlement. The change in moisture content of the soil affects the properties of the soil. Similarly, if soil gets submerged its ability to support the load coming over its unit area is reduced when the water table is above the base of the footing.

The above calculation clearly shows that the bearing capacity of the soil is reduced to 6 tons per square meters from 12 tons per square meter. As the design bearing capacity was considered as 8 tons per square meters the reduction of bearing capacity to 6 tons per square meters resulted in settlements and cracks in the structural member.

3. The hydro geological analysis indicate that the water level has acquired the rising trend and at the time of construction of the building which was recorded 15 meter below the ground level. Due to construction activity the surrounding Nala was filled up with mud as a result the water ways were blocked. Due to restriction on ground water movement and the water started cumulating at the faster rate upto the condition that it has reached 1.2 meters below the ground level. As the depth of foundation of the structure is 1.5m, the water level has risen and reached the influence zone effecting the bearing capacity of the soil. This in turn effects the stability of the structure.

It can be seen in Figure 2 and Figure 3 that the cracks are prominent and the water seeps through it. There are fewer cases in the residential buildings where the foundation seems to have heave inwards by 3 to 4 millimetre leaving the foot of wall exposed as seen in Figure 4.

Figure 2 Cracks at Plinth Level

Figure 3 Seeping of water at plinth level due to high water table

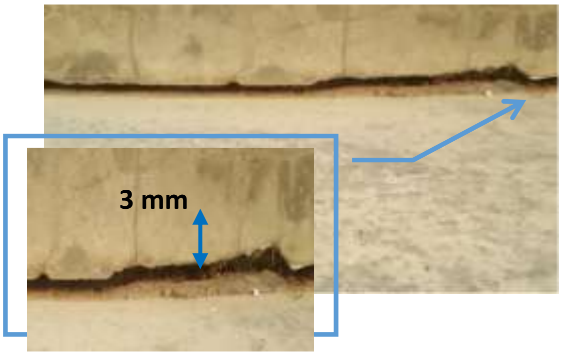


Figure 4 Settling of foundation

4. As earlier discussed the bearing capacity of the soil reduced to 6 tonnes per square meters from 12 tonnes per square meters when the water correction was applied to the Terzaghi's equation. This considerable decrease in values were seen as the main reason for the settlement of structure and in turn the cracking of the structural members.

Initially when the bearing capacity of the soil was 12 tonnes per meter the settlement was recorded as 50mm. With decrease in bearing capacity of the soil, the settlement was calculated using IS 2950: Part 1

Modulus of subgrade reaction, k = 10.8 kN/m (Clause 3.1 (f) of Appendix B, Table 2)

Average settlement of the raft, ∇ $= \dfrac{\text{Average contact pressure}}{\text{Average modulus of subgrade reaction}}$

$$= \frac{\textit{Bearing capacity x Area of footing}}{\text{Average modulus of subgrade reaction}}$$

$$= \frac{0.6 \times 1.2 \times 1.2}{10.8}\ \text{kN/m}$$

$$= 0.08\ \text{m or } 80\text{mm}$$

As the maximum permissible settlement in a stiff sand is taken as 60-65mm by the IS code, the settlement value to 80 mm is not acceptable. Due to settlement of structure the cracks are developed in the structural member which in turn effects the stability of the structure.

5. For the analysis of a structure a residential quarter of HUDA Division in Ambala was used which incurred cracks. The building is a framed type structure the plan of which is shown in Figure 2.

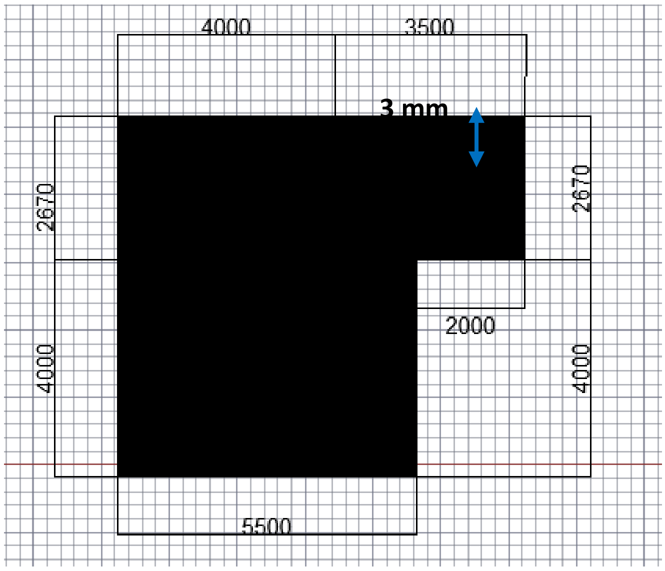


Figure 5 Plan of the residential building analyzed

The building was designed as G+3 with basic loads like dead load and live load taken from IS 875 (Part1).

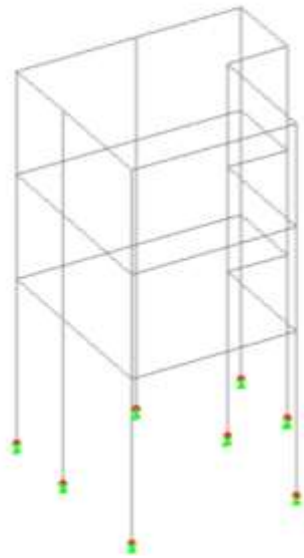


Figure 6 Building analysed in a standard structural analysis software

DESCRIPTION	IS 456 – 2000	
	CLAUSE	Contents
Loading combination	36.4.1	a) 1.5 DL + 1.5 LL b) 1.5 DL + 1.5 WL c) 1.2 DL + 1.2 LL + 1.2 WL

Figure 7 Load Combination table as per IS 456

** Wind and earthquake loads were not considered for the design of structure.*

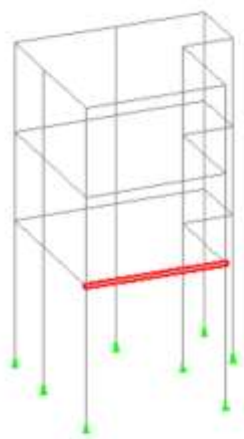
6. Results of Structural analysis

Estimation of structural element such as beam are designed and checks were done with the help of moment criteria.

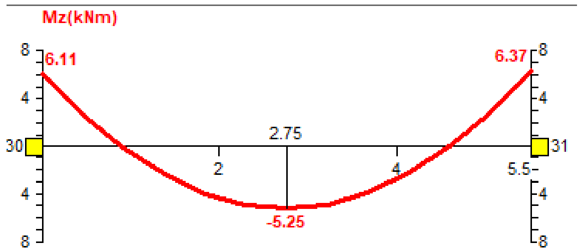
Concrete Grade	=	M25
Steel Grade	=	Fe415
Live load on slab	=	4 KN/m2
Live load on roof	=	1.5 KN/m2
RCC Specific Weight	=	25KN/m3
Bearing Capacity of Soil	=	6 T/m2

4.1 Floor wise variation in Bending Moment

For First Floor



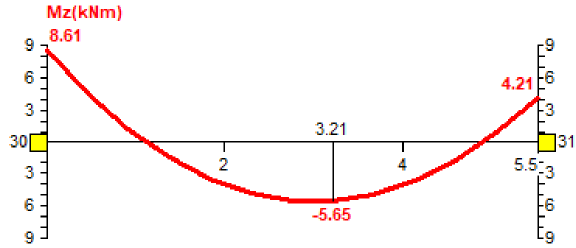
– **Bearing capacity 8 T/m2**



Hogging Moment = 5.25 kNm

Sagging Moment = 6.37 kNm

– **Bearing capacity 6 T/m2**

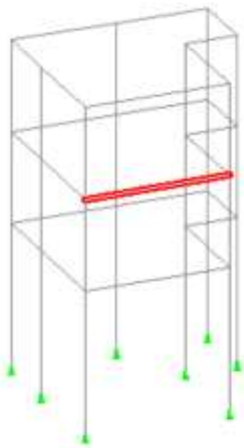


(IS 875-1964 Table II)

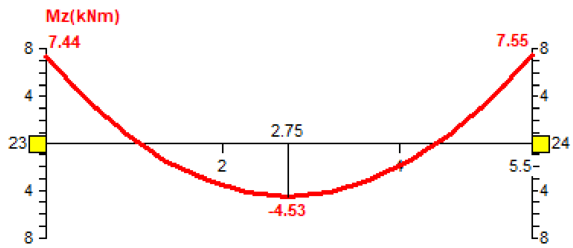
Hogging Moment = 5.65 kNm

Sagging Moment = 8.61 kNm

For Second Floor



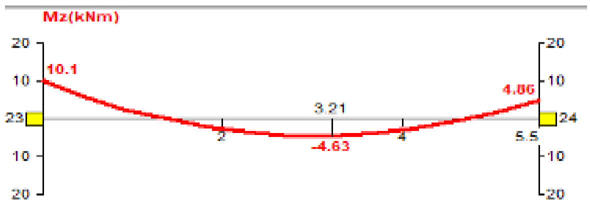
– **Bearing capacity 8 T/m2**



Hogging Moment = 7.55 kNm

Sagging Moment = 4.53 kNm

Bearing capacity 6 T/m2



Hogging Moment = 10.1 kNm

Sagging Moment = 4.63 kNm

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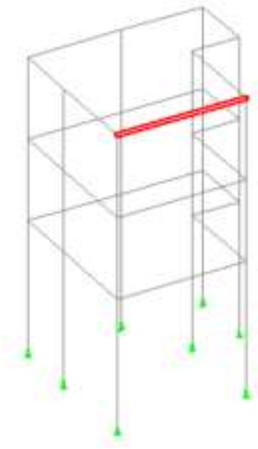
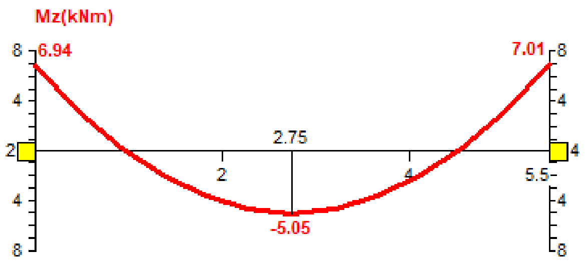
For Roof Level



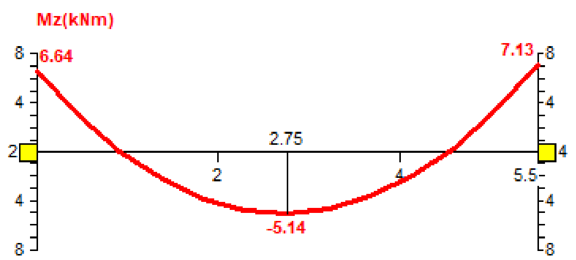
– **Bearing capacity 8 T/m2**



Hogging Moment = 7.01 kNm

Sagging Moment = 5.05 kNm

– **Bearing capacity 6 T/m2**



Hogging Moment = 7.13 kNm

Sagging Moment = 5.14 kNm

Figure 8 The Bending moments in the beam

The structure was analyzed using a basic structural software and the effect of settlement of foundation on structural members like beams are established.

5. CONCLUSION AND RECOMMENDATION

1. By analysing the structure with different stiffness values and after varying differential settlements of foundation we have seen that in some elements there is a development of additional moment of almost 7% in comparison with the bending moment values obtained by usual analysis with 8 tonnes per square meter of bearing capacity as shown in the table below.

Table 1: Floor wise graph of Sagging moment for 6t/m^2 and 8t/m^2 of bearing capacity

Floor level	Bearing capacity of soil		Percentage Variation %
	8T/m^2	**6T/m^2**	
First	5.25	5.65	7.07
Second	4.53	4.63	2.15
Roof	5.05	5.14	1.75

2. It should be mentioned that the magnitude of this ratio will decrease in the upper floors of the building. In the other word, the maximum additional redistribution of moments will occur in the first and second floor above the ground floor, by moving to the top of the structure the ratio will be nearly zero.

3. The HUDA sector in Ambala area has developed the cracks in the residential buildings of Sector 8 due to rising water table condition from 15m at the time of construction to 1.2m as per recent measurement. This has occurred due to blockage of water ways and thereby hydro geotechnical characteristics of the sub surface strata and change in foundation type are difficult remedial measures. However, there is a possibility of strengthening of sub surface structure and ground improvement. Structural remedies can also be employed to make the structure serviceable till its design life.

4. Strengthening of sub surface structure can be done either by Underpinning the structure or by anchoring the structure to the adjoining soil strata.

5. Grouting can also be done to fill up any cavity or fissure developed around the foundation or in the surrounding soil that is making the structure unstable.

6. Abstraction wells can be put up in the area to reduce the water table which in turn will increase the bearing capacity of soil.

7. If the foundation encounter differential settlement i.e. certain part of the structure continue to settle in comparison to those which are prevented from further downward movement, the tear will appear in the concrete as it is forced into tension. The cracks thus develop are at regular spacing and reflect the reinforcement layout.

8. For the existing building demolishing and re-construction to strengthen the building or to came it ductile is taxing and in many cases not feasible. Thus, fibre-reinforced polymers

(FRP) can easily strengthen the structure as well as came it ductile which in turn prevent the structural cracking. Crack stitching can also be a procedure to restore tensile strength across major cracks. The stitching procedure consist of drilling holes on both sides of the crack and grouting in U-shaped metal units with short legs called stitching dogs that span the crack.

9. Also to control the sagging moment caused due to settlement as seen in Section 4.1 intermittent supports can be installed to reduce the span of the structure and in turn reducing the additional moment.

10. For the proposed structure, it should be made ductile to cater additional moment caused due to differential settlement of the foundation. The joints of the structure should be deigned and carefully detailed to prevent any structural damage to the structure under adverse loads and combinations of load during its design life.

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BIOGRAPHIES

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