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Adaptation of shallow foundations due to adverse effect of water table on base soils

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ABSTRACT
This paper shows the effect of water table on soil bearing capacity and settlement of footing. The effect of water table on base soil properties (shear strength, unit weight) described in this article. Due to lose of shear strength and unit weight of base soil, shear failure occurred and consequence the foundation will be settled. In this article calculation of bearing capacity of soil, types of settlements which may occurred and their calculation are stated. To perform satisfactorily, shallow foundations must have two main characteristics (I) They have to be safe against overall shear failure in the soil that supports them (II) They cannot undergo excessive displacement, or settlement. Settlement calculation is an important part for the designing of shallow foundations resting on granular are clays soils. Rise of ground water table is believed to increase the settlement significantly and had been a topic of research for many years. Since then, various researchers proposed correction factors to account for the additional settlement due to water table fluctuation. The correction factor due to water table for settlement and the used of reduction factors and methods for soil ultimate bearing capacity calculation are given in this paper.

KEYWORDS;- *Bearing capacity, effect of water table, settlement, adaptation due to water table.*

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I. INTRODUCTION

Shallow foundations considering less cost, easier construction and fewer environmental restrictions are fruitful, to pile foundations. However, in the conditions of weak soil seismic and environmental considerations may limit the use of shallow foundations and type of foundation selection. In general, the size and type of the footing, determined based on soil conditions, their properties and the applied load and type of super structure. Design of foundations required communication between the structural designer and geotechnical engineer throughout the design process.

Foundation have two design aspects, namely, soil design and structure design which every of them have a grate effects in the stability and durability of structures. The soil design includes:

- determination of foundation depth D_f, which depends to some practical criteria and soil strata;
- determination of allowable bearing pressure of soil at the level of D_f which depends on the properties of soil at and below that level;
- determination of plan dimensions of footing which depends on geometry of the structure, the loads on the column and allowable pressure of soil;
- determination of upward soil pressure on footing. In the structure design footing, includes the design of concrete and reinforcement [1].

The applied loads are calculated by the structural designer and for supporting the structures the soils resistance factors are calculated and reported by the geotechnical engineer. In foundation designing also consider site conditions and environmental factors to avoid from future failures.

The soils below the footings must support the building and resist all applied loads from building. When soils are strong, footings can be relatively small and foundation systems relatively easy and accumulate. When soils are weak the size of footings becomes large, complicated, difficult in construction and fully expensive.

The design of adequate footing size is related to the function of soil bearing capacity and structure loads which soil bearing capacity can be obtained from situ tests and laboratory tests. The value of soil bearing capacity effected through water content.

The aim throughout this paper is to learn and understand the effect of the water table that defect the soil properties (bearing capacity, fraction force between soil particles, unit weight etc.) excessed settlement of foundations which will be consequence crack appear in building in largely magnitude will damaged the building. By this understanding, hopefully be able to increase the knowledge of people about the effect of water and adverse effect of water table increasing which defect the base soil properties should be take consideration during construction and designing of building foundations.

II. CAUSES OF FOUNDATION DAMAGE

Many foundation failures are known to be assigning to inadequate protection to the base soils, absence of consideration in the designing soils characteristics under different stress and loading conditions, improper construction sequence and inadequacy of design against possible worst condition in long term.

The types of foundation failure commonly coincidence in the construction field can be classified into the following categories:

- Incompetent bearing stratum resulted in collapse or excessive deformation of foundation soil under the imposed loads;
- Inadequate protection resulted in weakening of foundation soil leading to instability and failure of foundations, like soil erosion caused by flowing water;
- Improper subsequence method of construction resulted in foundation failure caused by induced damaging effect;
- Pore construction quality affecting the performance of design and load to subsequence the failure foundation;
- Inadequate design not taking into account the most critical and worst combination of stress and force which may occur during its service period;
- Movement due to shrinkage or swelling of clay soils. Due to changes of ground water level, leakage of water supply and canalization pipes or any other causes that water to be contacted with base soils. This is the most common cause of foundation movement;
- Movement related with mining activities or ‘deglutition holes’ found in chalk;
- Buildings which made on ground surface [2, 3].
- Landslide occurrence. There is one major cause in the movement of soil that is the presences of water flow. Especially for the hill slope area, the probability of landslide occurrence is higher particularly while heavy downpour [4].

III. SIGNS OF DAMAGE IN BUILDING DUE TO FLOODING

Once certified that flooding has in fact occurred, here are the signs of damage in building due to flooding, so should review for foundation.

- Doors do not properly close and door frames have cracks;
- Windows no longer properly open or close and have cracks in the frame;
- New cracks have appeared in the ceiling, wall or floor board. Large tears in the wallpaper are also a sign of a wall crack;
- Foundation has moved outside (above, below, or further to one side) from the level of yard;
- Bricks have cracked in outdoor of foundation;
- Garage door no longer closes to the pavement;
- Appearance of floors sloping;
- Wall rotation has formed which can be seen through large, outlining cracks in wall panels;
- Gaps or separation between ceiling, walls and floor;
- Crown molding (wall frames) separation and crack [5].

IV. BEARING CAPACITY OF BASE SOIL

Bearing resistance is the capacity of soil to support applied loads on it and can be calculated using bearing capacity theory [6]. Bearing capacity is affected by various factors like change in water table, inclined loads, eccentric loads, dimensions of the footings, etc. The variation of moisture content stored in the ground and earth structures under varying environmental conditions is an important aspect which changing in the degree of saturation can cause significant changes in shear strength, volume and hydraulic properties, in reason bearing capacity. Eventually when the soil became submerged the bearing capacity will be reduced. In unsaturated case the ultimate bearing capacity for shallow foundation is analytically estimated by using any of the available bearing capacity equations.

Bearing capacity and the settlement are the two important parameters in the field of geotechnical engineering [7].

Bearing capacity of soils can be determined by the following methods:

1. by the theoretical analyses, such as Terzaghi’s, Meyerhof, Skempton and others analysis.
2. by the use of building codes method;
3. by the penetration test method;
4. by the plate load test method.

In the beginning of 20th century Bell [8] proposed an equation for ultimate bearing capacity of footing, based on classical earth pressure theory. Prandtl [9] presented their analysis based on plastic equilibrium theory.

Significant contributions to the subject of bearing capacity were later made by Terzaghi, Meyerhof, Brinch Hansen, Skempton and Balla [10-14]. In the following discussion Terzaghi's analysis and those following it as indicated in the above list are reviewed.

4. 1 Terzaghi's bearing capacity equations

Terzaghi derived equation for ultimate bearing capacity of strip footing as:

$$q_f = cN_c + \gamma D_f N_q + 0.5\gamma B N_\gamma, \quad (1)$$

Where N_c, N_q, N_γ - are bearing capacity factors;
C – Soil cohesion factor;
x – Soil shearing resistance angle;
q_f – ultimate bearing capacity of soil;
γ – unit weight of soil;
B - Width of footing.

These factors are dimensionless and depend only on angle of shearing resistance (x) of soil. It is to be noted that values of γ in the second and third terms of equation (2.1) depend on the position of water table [15]. The above equation is applicable for general shear failure.

Terzaghi has suggested following empirical reduction factor to actual c & x in case of local shear failure.

$$C_m = \frac{2}{3}C, \quad (2)$$

$$\emptyset_m = tan - 1\left(\frac{2}{3}tan\emptyset\right), \quad (3)$$

$$q_f = cm N'_c + \gamma D_f N'_q + 0.5\gamma B N'_\gamma \quad (4)$$

Where C_m- mobilized cohesion factor;
x_m - mobilized angle
N'_c, N'_q and N'_γ are bearing capacity factors in local shear failure.

Terzaghi's suggested following equations for ultimate bearing capacity in case of square, circular and rectangular footing based on the experimental results.

For circular footing; $q_f = 1{,}3CN_c + \gamma D_f N_q + 0{,}3\gamma B N_\gamma$, (5)
For square footing; $q_f = 1{,}3C N_c + \gamma D_f N_q + 0{,}4\gamma B N\gamma$, (6)
For rectangular footing; $q_f = \left(1 + 0{,}3\frac{B}{L}\right)CN_c + \gamma D_f N_q + \left(1 - 0{,}2\frac{B}{L}\right)0{,}5\gamma B N_\gamma$, (7)
where L & B - length and width of footing [16].

Table1. Terzaghi's bearing capacity factors for general and local shear failure

x	N_c	N_q	N_γ	x	N'_c	N'_q	N'_γ
0	5.70	1.00	0.00	26	27.09	14.21	9.84
1	6.00	1.10	0.01	27	29.24	15.90	11.60
2	6.30	1.22	0.04	28	31.61	17.81	13.70
3	6.62	1.35	0.06	29	34.24	19.98	16.18
4	6.97	1.49	0.10	30	37.16	22.46	19.13
5	7.34	1.64	0.14	31	40.41	25.28	22.65
6	7.73	1.81	0.20	32	44.04	28.52	26.87
7	8.15	2.00	0.27	33	48.09	32.23	31.94
8	8.60	2.21	0.35	34	52.64	36.50	38.04
9	9.09	2.44	0.44	35	57.75	41.44	45.41
10	9.61	2.69	0.56	36	63.53	47.16	54.36
11	10.16	2.98	0.69	37	70.01	53.80	65.27
12	10.76	3.29	0.85	38	77.50	61.55	78.61
13	11.41	3.63	1.04	39	85.97	70.61	95.03
14	12.11	4.02	1.26	40	95.66	81.27	115.31
15	12.86	4.45	1.52	41	106.81	93.85	140.51
16	13.68	4.92	1.82	42	119.67	108.75	171.99
17	14.60	5.45	2.18	43	134.58	126.50	211.56
18	15.12	6.04	2.59	44	151.95	147.74	261.60
19	16.56	6.70	3.07	45	172.28	173.28	325.34
20	17.69	7.44	3.64	46	196.22	204.19	407.11
21	18.92	8.26	4.31	47	224.55	241.80	512.84
22	20.27	9.19	5.09	48	258.28	287.85	650.67
23	21.75	10.23	6.00	49	298.71	344.63	831.99
24	23.36	11.40	7.08	50	347.50	415.14	1072.80

25	25.13	12.72	8.34				

From Kumbhojkar (1993) [17].

The above table which contents from the factors, use in the Terzaghi's equations for obtaining the bearing capacity of base soil [18].

V. EFFECT OF WATER TABLE ON BEARING CAPACITY

The basic components of soil are minerals, organic matter, air and water. So changing in moisture content of soil, occur affects in the properties of soil. Similarly, if soil gets submerged its ability reduced to support the load which coming on its unit area. When the water table is above the base of the footing, the submerged weight is used for the soil below the water table for computing the surcharge. Too much groundwater can be made a problem. In wet winters rising groundwater levels can flood into cellars and onto low - lying land. Because groundwater tends to react slowly, this type of flooding problem can be long lasting. Foundations of any construction require to be made on solid sub terrain. Water can erode man-made materials without providing any advanced warning of such erosion. High water content in ground causes the main foundation materials to become wet, and then they will become impregnated [19].

The estimations of safe bearing capacities determined by utilizing of safety factor of 3 by IS code technique [20] and Terzaghi's method for rectangular footing [16].

The soils unit weight used in the second and third term (the γ in N_q and N_γ terms) of the bearing capacity equation presented in the preceding sections are the effective unit weights. Of course, if dry subsoil becomes with a rising of the water table, the unit weight of submerged soil is reduced maybe to half the weight for that soil; obviously, we have to account for the floating effect of the water.

A reduction in the unit weight results in a decrease in the ultimate bearing capacity of the soil. Indeed, a rise in the water table may result in swelling of some fine grain soils, possible loss of evident cohesion, reduction of the internal friction angle and decrease in the shear strength of the soil [21].

There are three cases of water table. When the water table is above the base of footing, the submerged weight $\gamma^{/}$ should be used for the soil below the water table for computing the effective pressure or the surcharge. When water table is located somewhat below the base of the footing, the elastic wedge is partly of moist soil and partly of submerged soil, and a suitable reduction factor should be used with wedge term $0.5\gamma BN_\gamma$, since it uses effective unit weight. As a thumb role, this term may be reduced to half (since $\gamma^{/}=0.5\gamma_{sat}$) if the water table is just at the base of footing, no reduction factor to be used if the water table is at the depth equal to the width of footing below base of footing. For intermediate positions, liner interpolation of the reduction be made. For the calculation of ultimate bearing capacity of soil, generally following methods are used:

Method 1. For any position of the water table may use the reduction factors in the Terzaghi general equation [20],

$$q_f = cN_c + \gamma_1 DN_q Rw_1 + 0.5\,\gamma_2 BN_\gamma Rw_2 \qquad (8)$$

$$R_{w1} = 0{,}5\left(\frac{1+Z_{w1}}{D}\right),\ R_{w2} = 0{,}5\left(\frac{1+Z_{w2}}{B}\right) \qquad (9)$$

C – Cohesion factor

γ_1 – average unit weight of the surcharge soil situated above the water table.

γ_2 – average unit weight of the soil in the wedge zone, situated within a depth B below the base of the footing.

D – depth of footing

B – width of footing

N_c, N_q, N_γ - bearing capacity factors

Rw_1, Rw_2 – reduction factors for water table

When the water table just at the base of footing, $\gamma_2 = \gamma_{sat}$, when the water table is at the ground surface, both γ_1 and γ_2 are saturated weight.

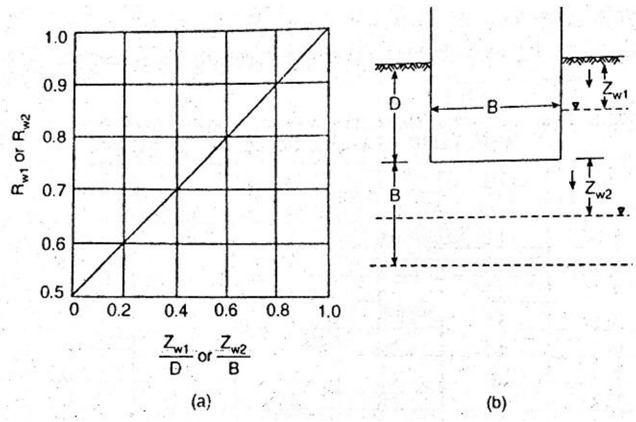

Figure1. Water reduction factors, BC Punmia, et al. [23]

Method 2: IS Code Method: Alternatively, q_f can be computed using only one reduction factor,

$$q_f = CN_c + \sigma'.N_q + 0.5\gamma BN_\gamma R_w \quad (10)$$

σ' = effective unite weight of soil situated above the base of footing,

$$R_w = R_{w2} = 0.5\left(1 + \frac{Z_{w2}}{B}\right) \quad (11)$$

This recommended by Indian Standard when the water table is situated at the depth D_1 below the ground level ($D_1 < D$) or D_2 above the base of the footing, such that $D_1 + D_2 = D$.

We have $\sigma' = (\gamma D_1 + \gamma_{sat} D) - \gamma_w$, $D_2 = \gamma D_1 + \gamma' D_2$,

Knowing σ' and R_w (= R_{w2}), q_f can be computed.

Method 3. In third method (Bowles, 1988), for the soil in wedge zone, effective unit weight (γ_e) is used [22].

Thus, $$q_f = cN_c + \sigma' N_q + 0.5\,\gamma_e BN_\gamma \quad (12)$$

σ' = effective overburden pressure

γ_e =effective unit weight of soil in the wedge zone.

The wedge zone has a depth, $H = 0.5B \times \tan(45^0 + \phi/2)$, (13)

hence when the water table is within this wedge zone, γ_e can be computed from the expression

$$\gamma_e = (2H - Z_{w2})\frac{Z_{w2}}{H^2}\gamma + \frac{\gamma'}{H^2}(H - Z_{w2})^2 \quad (14)$$

If, H = B the effective unit weight γ_e in wedge term can be computed as:

$$\gamma_e = \frac{\gamma.Z_{w2} + \gamma'(B - Z_{w2})}{B} = \gamma' + (\gamma - \gamma')\frac{Z_{w2}}{B}$$, when $Z_{w2} = 0$, $\gamma_e = \gamma'$

When $Z_{w2} = B$, $\gamma_e = \gamma$

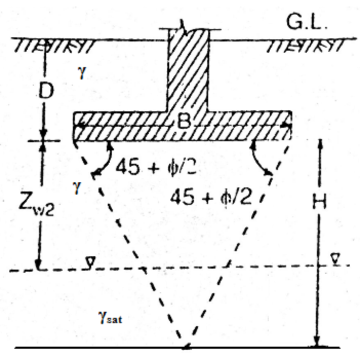

Figure2. Wedge zone depth, BC Punmia, et al. [23].

The depth of a foundation is dependent on the forest depth, type of building and type of the soil which the foundation stands. However, the ground surface is greatly influenced by the depth of the water table. In construction and design, water table shows the surface that separates between saturated and unsaturated groundwater zones. Relevant to the depth of bed rock, the water table may be low or high. In some areas, according the seasons of rain occur variations in the depth of water table.

When the rainfall is high, particularly during monsoon, water table rises near to the ground surface while on the other hand descending considerably to lower grounds during the summer. The depth of water table at any given time affects the modeling design, especially in the case of the shallow foundations. In all cases, the ultimate depth to which one can put utilization of underground space is dependent on the depth of the water table [19].

VI. LIQUEFACTION OF SOIL DUE TO WATER EFFECT

In liquefaction conditions, buildings can start to lean, overturn, or sink into the ground. Liquefaction occurs when sediments below the water table lose their strength provisionally and behave as viscous liquids rather than solids. Liquefaction occurs prevailing in newly deposited sands and silts with high ground water levels. When saturated, soils such as loose sands, during severe ground shaking lose their bearing capacity, and become fluid due to a sudden decrease in shear resistance caused by the temporary increase of the pore fluid pressure. High-density areas, built on lose ground material; can suffer destruction even from the effect of relatively small earthquakes. Usually after the earthquake, the grounds stabilize and the ground water recovers its deeper level.

However, as the soil consolidates after the earthquake, further damage to buildings can occur as a result of more settlement and 'sand boil' (figure 3) eruptions (water and sediment blow up from the pressure charged liquefied sand) [24].

The construction of building should be as to have liquefaction resistant and the foundation elements should be designed to resist against the effects of liquefaction. By improving the strength, density and drainage characteristics of the soil can be mitigate the liquefaction hazards [25].

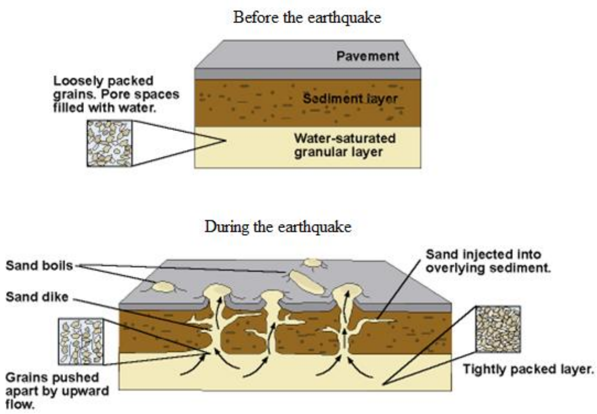

Figure 3. Soil liquefaction due to earthquake
Source: Theconstructor.org

VII. SETTLEMENT OF FOUNDATION

Settlement is movements are displacement of ground which followed by footings because of unreliable or weak ground by carrying loads of structure or by the cause of soil moisture changes. When the ground movement excesses the acceptable limit, it will result in foundation failure.

Foundation shall be so designed that the allowable bearing capacity is not exceeded, and the total and differential settlement are within permissible values.

Foundations may be settled in various causes and each of them may affect the performance of the structure [26].

More than 40 forecast methods for footings settlement on cohesion less soils are available in the literatures (Terzaghi and Peck, Schmertmann et al., Burbidge and Burland, Poulos and Mayne [27-30]. These methods recognized the major influencing factors, for shallow foundation settlements are the applied pressure, depth, soil stiffness, shape and width of foundation [31].

Cohesion less soil (sand and gravel) will generally compress during a relatively short time (8 - 16 hours). In fact, exactly most of the forecasted settlement of foundation resting on cohesion less soil has taken place during the construction phase of the structure. Furthermore, the compression by induced vibrational effects can be accomplished with much greater simplicity in such soils than with cohesive soil.

Contrasting cohesion less soils, a saturated cohesive soil mass (clay, fine, silt) with low permeability will compress quite slowly since the expulsion of the pore water from such soils occurs at a significantly slower rate than from cohesion less ones. In other words, because significantly longer time is required to exit water from the voids of a cohesive material, the total compression of a saturated clay stratum takes place during a longer period of time than for cohesion less soils, as illustrated by figure 4 [21].

Terzaghi [10] postulated that the submergence of the sand reduces the soil stiffness by half, which in turn doubles the settlement [27, 32]. This proposition was supported by a number of other researchers [33-35]. However by conducting laboratory model tests, Murtaza et al. [36] have observed that the settlement in submerged conditions can cause 8–12 times more settlement, depending on the relative densities of the sand. Morgan et al. [37] also have found that an increase in settlement in submerged conditions can be 3.2–5.3 times the settlement for the dry sand for very dense condition to very loose condition, respectively.

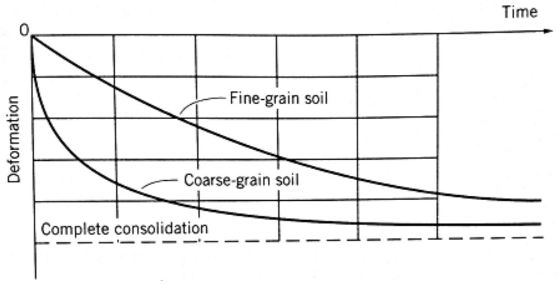

Figure 4. Time consolidation relation under constant load
John N. Cernica (1995)

Total settlement is the absolute vertical movement of the foundation from its as-constructed position to its loaded position. Total settlement of foundation due to net imposed load shall be estimated in accordance with established engineering principle.

In normal situation of organic and inorganic soil deposits the total settlement is ascribed due to the three types of settlements:

a) Elastic settlement;

b) Immediate settlement;

c) Consolidation settlements as mentioned below.

Elastic settlement of foundation soils is the results of lateral movements of soil without change in volume response to changes in effective vertical stress.

Elastic settlements primarily occur when the load is confined to a small area, such as a structural foundation, or near the edges of large loaded area such as embankments. This type of settlement is nondependent to the time and similar to the Poisson's effect where an object is loaded in the vertical direction expands laterally [26].

Immediate settlements are those that occurred rather rapidly, maybe within hours or days after the load is applied. The consolidation settlement is a time dependent deformation that occurred in saturated or partially saturated silt or clays. These are soil that have low coefficients of permeability and are slow to dissipate the pore water.

The consolidation settlement is divided by two classes; primary consolidation and secondary consolidation that discuss below:

8.1 Primary consolidation settlement

The consolidation settlement is the process of water expulsion from the voids of saturated clay with time. The primary consolidation settlement is generally much larger also the primary consolidation is easiest to predict, occurs at faster rate than secondary consolidation [21]. But here, we want to calculate total primary consolidation settlement using the following three equations for three conditions:

8.1.1 Calculation for primary consolidation settlement

a) For normally consolidated clay:

$$\frac{\sigma'_c}{\sigma'_0} = 1$$

$$S_{c1} = \frac{C_c \times h}{1 + e_0} \times \log\left(\frac{\sigma'_0 + \Delta\sigma'}{\sigma'_0}\right) \quad (15)$$

Where S_{c1} - primary consolidation settlement;

C_c - compression index;

σ'_o - vertical effective stress;

σ_c' - present effective overburden pressure (at the middle of clay layer);

h - clay layer thickness;

e_o - initial void ratio;

$\Delta\sigma'$ - average effective stress increase for clay layer.

b) For over consolidated clay:

When the soil is over consolidated ($\sigma'_c/\sigma'_o > 1$) there are two cases and the S_{c1} have different valve:

Case 1 $\sigma'_c > \sigma'_0 + \Delta\sigma'$

$$S_{c1} = \frac{C_s \times h}{1+e_0} \times \log\left(\frac{\sigma'_c + \Delta\sigma'}{\sigma'_0}\right) \quad (16)$$

Case 2 $\sigma'_c < \sigma'_0 + \Delta\sigma'$

$$S_{c1} = \frac{C_s \times h}{1+e_0} \times \log\left(\frac{\sigma'_c}{\sigma'_0}\right) + \frac{C_c \times h}{1+e_0} \times \log\left(\frac{\acute{\sigma}_0 + \Delta\sigma'}{\sigma'_c}\right) \quad (17)$$

If the stress at the base of the foundation is decreased with depth, we can calculate the value of $\Delta\sigma'$ by Simpson's rule as following:

$$\Delta\sigma' = \Delta\sigma' t + 4\Delta\sigma m + \frac{\Delta\sigma' b}{6} \quad (18)$$

Where $\Delta\sigma'$ - effective stress at the top of clay layer;
$\Delta\sigma m$ - effective stress at the middle of clay layer;
$\Delta\sigma' b$ - effective stress at the bottom of clay layer;
C_s - swell index.

8.2 Secondary consolidation settlement

At the end of primary consolidation (after complete dissipation of pore water pressure), some settlement is observed that is due to the plastic adjustment of soil fabrics. This stage of consolidation is called secondary consolidation. Usually secondary consolidation is more important in highly organic soils.

$$S_{c2} = \frac{h \times c_a}{1 + e_p} \times \log\left(\frac{t_2}{t_1}\right) \quad (19)$$

Where S_{c2}- second consolidation settlement;
C_a - secondary compression;
e_p - void ratio at the end of primary consolidation stage;
t_1 - time at the end of primary consolidation settlement;
t_2 - any time after beginning secondary consolidation settlement.

The value of C_a is depending on the type of clay (normal consolidated clay, over consolidated clay or organic clay) and there are typical values for each of type [38].

8.3 Computation of Elastic Settlement in Saturated clay

In computing the elastic settlement, the Poisson's ratio (μ_s) and modulus of elasticity (*Es*) are the two key design parameters. The modulus of elasticity of soil is often determined from *in situ* tests. Poisson's ratio varies in the range of 0–0.5. For *all* saturated clays subjected to undrained loading, which implies no volume change, it can be shown from elastic analysis that $\mu_s = 0.50$. Janbu et al. [39] proposed an equation for evaluating the average settlement of flexible foundations on saturated clay soils (Poisson's ratio, $\mu_s = 0.5$) as fallowing.

$$S_e = A_1 A_2 \frac{q_0 B}{E_s} \quad (20)$$

Where
$A_1 = f(H/B, L/B)$
$A_2 = f(D_f/B)$
L = length of the foundation
B = width of the foundation
D_f = depth of the foundation
H = depth of the bottom of the foundation to a rigid layer
q_0 = net load per unit area of the foundation
Christian and Carrier [40] modified the values of A_1 and A_2 to some extent, and these are presented in following figure 5.

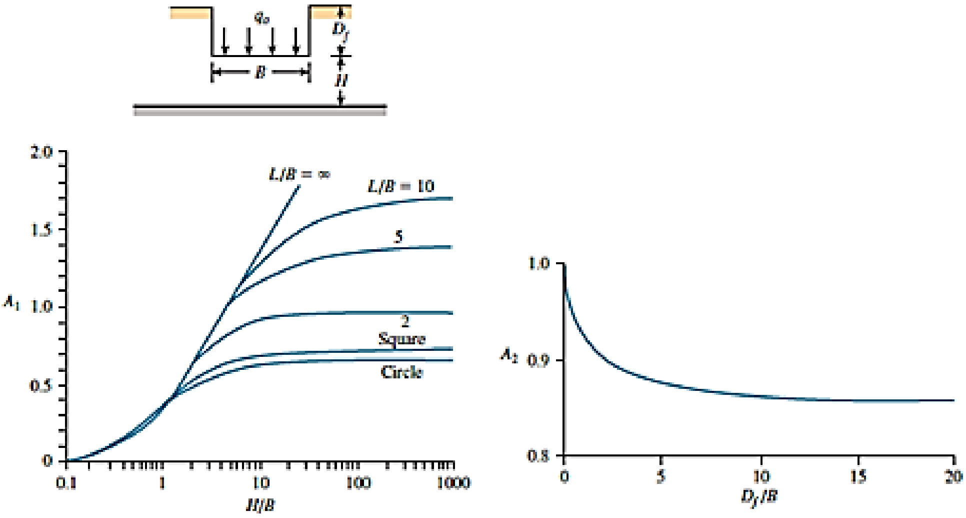

Figure 5 Values of A_1 and A_2 for elastic settlement calculation—Eq. (20) [40].

Table 2. Range of β for Clay[equation (21)]

	β				
Plasticity Index	OCR =1	OCR = 2	OCR = 3	OCR = 4	OCR = 5
<30	1500 -600	1380-500	1200-580	950-380	730-300
30 to 50	600-300	550-270	580-220	380-180	300-150
>50	300-150	270-120	220-100	180-90	150-75

Based on Duncan and Buchignani [41].

The modulus of elasticity (E_s) for calys can, in general be given as,

$$E_s = \beta C_u \qquad (21)$$

Where C_u = undrained shear strength of soil.

The parameter β is primarily a function of the plasticity index and over consolidation ration (OCR). Table 2 provides a general range for β based on that proposed by Duncan and Buchignani [41]. In any case, proper judgment should be used in selecting the magnitude of β [18].

Due to underground flooding, the soil moisture under the foundations can have an increase of 6- 8.9%, in volume which can lead to decrease in their ductility and an increase in their compressibility by 2 or more times [42].

VIII. CORRECTION FACTOR DUE TO RISE OF WATER TABLE

In (1943) Terzaghi provide an intuitive propose that when dry sand becomes saturated, the soil stiffness (Young's modulus) decreases by 50% approximately. He noted that, the effective vertical stress on soil below the water table decrease about to half; which reduces the effective stress by 50% [10].

This conducts to loss the half of stiffness the saturated soil than in the dry condition. As a result, in soil below the water table, settlement increase and occur twofold. When the water table raises to some depth below the footing, considering in the new location of water table the correction factor used for the designing of shallow foundations.

The value of settlement under dry conditions is multiplied by this factor fig (6 & 7), to give the expected settlement due to the rises of water table. The correction factor C_w is greater than or equal to ($C_w \geq 1$) and increases with rise of water table.

It is defined as:

$$C_w = \frac{settlement\ with\ water\ table\ below\ the\ footing\ level}{settlement\ in\ dry\ \ sand}, \qquad (22)$$

Several researchers (Terzaghi and Peck, Alpan, Teng, Peck, Bazaraa and Bowles [43 - 48]) also proposed correction factors to quantify the additional settlement due to the rise of water table below the footing. The depth below the footing where the water table has variation will not have any effect is not unanimously agreed upon. The depth of the footing also has effects on influence of water table in settlement, as the surcharge due to embedment increases the settlement in raised groundwater table. Figures 6 shows correction factors diagrams for different footing shapes in dense and loose condition. The figure shows that the additional settlement due to water table increasing is higher in loose sands, with C_w ranging from 4.9 to 7.6 times the settlement in dry condition. Footings on dense sand experienced less additional settlements than in loose sands, with C_w ranging from 2.9 to 4.4. These indicate significantly higher additional settlement due to rise in water table than what was suggested by Terzaghi [10].

From the curves in figure 6 obvious that the increase in correction factor is not linear with water table rise, instead, when the water table gets closer to the footing, the settlement increases at a faster rate. The stress level beneath the footing instantly is very high, which causes significant additional settlements [49].

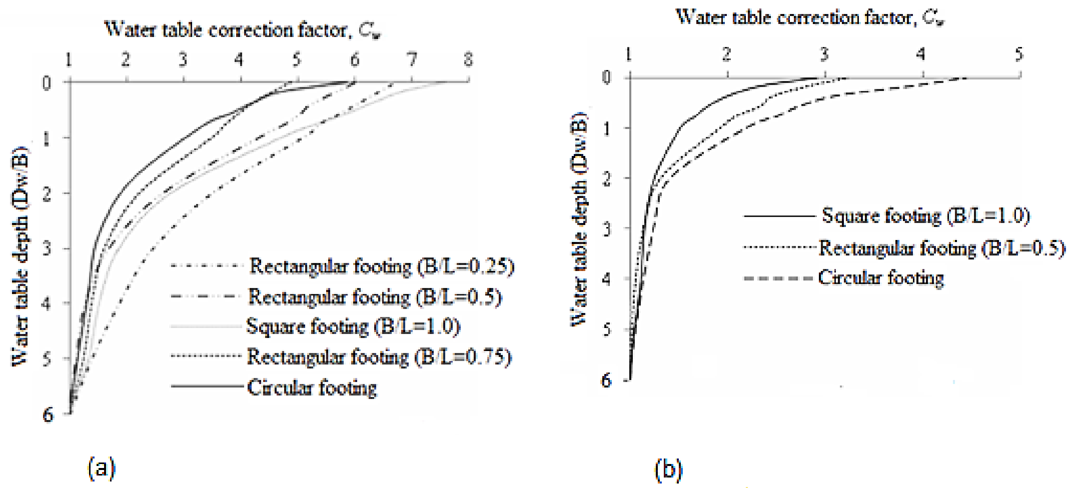

Fig 6 – (a) Water table correction factor diagrams for model of footings on loose sand
(b) Water table correction factor diagrams for model of footings on dense sand,
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IX. SOLUTION FOR FOUNDATION DUE TO AFFECTED BY WATER

When building constructed in the flooding risk area or ground water table arising during seasonal rain. However it is essential to avoid the foundation from the risks of the above condition, applied the following options which also indicated in figure 7:

- Use French channel and footer channel in and around the storm cellar or balance;
- Utilize a sump pump to pump the water table beneath the solid floor;
- Creation of edge channels;
- Consider utilizing the bentonite boards connected to new development, however want to use a bitumen (or adjusted bitumen) or adjusted elastic elastomeric covering and a dimpled film on both piece and installed solid dividers. These items will connect any splits that will in the long run show up; proceeding with the water sealing alongside the dimpled layer there should be safeguard water closed system, in the figure 8 shows the drain pipe which collect the water and drain away from the footing level [16].

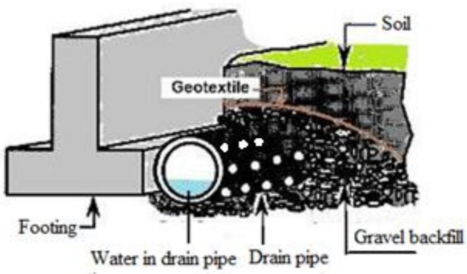

Figure 7 .drainage systems at the footing
Source- inspectapedia.com with modified

X. CONCLUSION

Naturally soil contents from mineral particles, air, water and organic matter. The amount of water contents in soil mass or ground water table have a grade effects on bearing capacity and movement of soil, when the water reached to soil mass in cause of flooding or seasonal water table changing the fraction between soil particles became weak. Before of construction building, it is required to perform surface and subsurface soil investigation. In the design and construction of foundation should be take consideration soil conditions. However bearing capacity of soils and the amount of total settlement of foundation are two important issues in foundation system, it is essential to tack consideration the influence factors in the designing of soil and foundation. To avoid from the adverse impacts of water, the foundation system should be safe from flooding (rain water, water supply or canalization network lockage, etc.) effect during construction.

As a result, we know, foundations are the part of structures which located under ground level, so when it damaged, it is difficult to find the source of occurred problem and their repair, therefore it is advisable to be careful in the designing and construction of them.

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