Problems and Remedies for Basement Construction (In High Water Table Area)

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***Abstract*—As we know that India is the second largest country in population so day by more and more infrastructure facilities are going to develop. In other hand available lane for construction is becoming at the edge of shortness. So many underground constructions are going on each year for utilizing as car parking, shops in basement of building, basement in residential building, mass rapid transit stations, depressed roadways and civil defense shelters. Many cities are located in coastal areas where elevations are low with attendant high ground water table. So some problems are occurring during construction and after construction. This paper discusses the various methods of providing residence against those problems for construction of basement. For this works various literatures are referred. For this paper, case of Construction site at "AKSHAR PURUSHOTTAM CHHATRALAYA", V.V.NAGAR, and GUJARAT, INDIA is studied.**

***Keywords*—R.C.C retaining wall, hydrolic uplift pressure ,pile, basement, methodology**

I. Introduction

Soil is the most important factor for any type of construction work because whole structure rest on soil. Before starting the foundation of construction work on site, it must essential that various investigations are carried out regarding soil and surrounded water table condition. When underground structure i.e. basement is constructed at considerable depth below the ground level with high water level than it deals with some problems for it. When basement is subjected to low ground water table then it requires less precaution regarding construction works. But when there is high water table, it must require evaluating some major problems for construction of basement. Following are the main two problems which are influencing after the construction of basement.

A. Moisture and water seepage problems through peripheral retaining wall

B. Hydraulic uplift pressure

II. MOISTURE AND WATER SEEPAGE PROBLEMS THROUGH PERIPHERIAL RETAINING WALL

A. Intoduction to brick masonry retaining wall& RCC retaining wall

Brick masonry in contact with earth has a much more severe exposure than it does in walls above ground because the masonry is more apt to contain more salt when dry and water when frozen. Thus brick masonry in retaining walls, foundation walls, and planter boxes in a severe climate is less durable than the same masonry in a wall enclosing heated space.Similarly, brick masonry in the exterior wythe of an insulated wall has a more severe exposure than in an insulated solid wall. It is more apt to be frozen at the lower temperatures prevailing in the exterior wythe of the insulated cavity wall.Brick masonry in a nearly horizontal position has a much more severe exposure than in a vertical position1 because it is more apt to absorb more water. Brick masonry in pavements, copings and sills in a severe climate is less durable than the same masonry in a wall.

Brick masonry in walls exposed to weather on both sides has a much more severe exposure than in walls enclosing heated space because it is more apt to freeze more often. Brick masonry in parapets, chimneys, wing walls and fences in a severe climate is less durable than the same masonry in a wall enclosing heated space.Up to 2 m deep basement brick masonry retaining wall is suitable and depth more than 2m, R.C.C retaining wall is more preferred than brick masonry retaining wall.Choice of retaining wall structure depends on the depth of basement structure, its superstructure load condition and surrounded ground water table conditions.Though R.C.C retaining wall is more costlier than brick masonry retaining wall, now a days RCC retaining wall is more preferred because it gives more resistance against water seepage and moisture condition.

B. Problems due to brick masonry retaining wall

- It has less capacity to carry soil load.
- It has less poor workmanship.
- In brick masonry RW, There are many joints. So, there is possibility of water seepage through joints. Hence, brick masonry RW is not good barrier.
- It has less capacity to resist lateral load.
- Bricks are made of clay and sand. So, they have not good strength.

C. Prevention methods

Following are prevention method:

1) Tiles pitching

This is conventional method to prevent moisture and water seepage through peripheral retaining wall. In this method, inner face of retaining wall is covered by pitching tiles on its surface.

2) Application of bituminous layer & polythene sheet

This method involves following steps.

- Retaining wall is constructed
- 2 coat plasters (1st coat – 20 to 25 mm & 2nd cost – 5 to 6 mm) is applied to exterior face of wall.
- Now cement slurry is applied.
- After few days, bituminous layer is applied on the *exterior* face of wall.
- After application of bituminous layer, immediately a polythene HDPC sheet (1 mm thick) is applied.

This method is more effective than tiles pitching.

III. HYDROSTATIC UPLIFT PRESSURE

A. Hydraulic uplift pressure

When basement are constructed in high water table area, sounding problem occurring is the hydrostatic uplift pressure. Hydrostatic uplift pressure may be defined as the pressure exerted in upward direction by the ground water underneath of structure (basement floor slab). Hydraulic uplift pressure is caused when the water table is higher than the depth of basement floor slab. If the water table is at ground level and excavation work is carried out for certain depth of ground, in that portion water force will come up which is bailed out for construction purpose. But as it is continuous flow, it is required to check whether weight of structure on that portion is more than the water pressure or not. Since hydraulic uplift pressure acts in upward direction therefore it reduces the downward weight of the structure (basement floor slab) Hence, it acts against the stability of structure.

B. Damage due to the hydraulic uplift pressure

Generally basement having longer span in high water level area is mainly subjected to two main effects.

Hydraulicu uplift pressure exerted by ground water &

Heavy load coming from super structure.

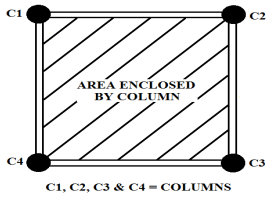

Fig. 1. floor slab

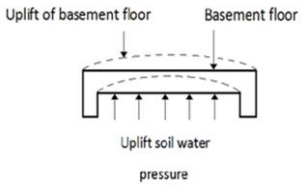

Fig. 2. Effect of soil water pressure

As per Fig. 1 load coming from the super structure at columns 1, 2, 3& 4 is greater than the hydraulic uplift pressure. Hence here is no effect of hydrostatic uplift pressure. But load of floor area enclosed by columns 1, 2, 3& 4 is less than the uplift soil water pressure, then due to this hydraulic uplift pressure, there is upward vertical movement of enclosed area of floor as shown in above fig. 2. Due to this effect, as time passes basement floor slab get to be cracked and finally it is totally damaged.

C. Methods for prevention of hydraulic uplift pressure

1) Toeing in of the base slab into the surrounding Ground

When a substructure is constructed inside a temporary cofferdam or open excavation, permanent resistance to uplift can be provided by extending the base slab beyond the perimeter wall. The weight of the backfill above the toed-in base slab adds to the weight of the structure in resisting uplift. This method is not feasible where a diaphragm or secant pile wall is used as a permanent retaining structure.

2) Increasing the dead weighs of the structure

The self-weight of the structure can be increased by thickening of its structural members and also by providing an extra thickness of concrete beneath the base slab tied into the structural base slab. Increasing the base slab thickness is not very economical because only the submerged weight of the concrete gives additional resistance to uplift. This is because the value of the weight of any additional thickness of concrete should take into account the increased volume of water displaced. In some projects, the dead weight of the low-rise podium in a high-rise complex is increased by incorporating a rooftop garden with a thick soil fill.

3) Ground anchors

Pre-stressed anchors can be used as a temporary measure to counteract uplift forces. In many jurisdictions, their application as a permanent measure to resist uplift is limited by concerns about their long-term performance with respect to corrosion.

4) Piling method

Pile is a slender structural member made of steel, concrete or wood. This is the most effective method to resist hydrostatic Uplift pressure

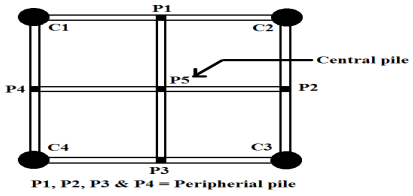

Fig. 3. Basement floor slab with pile

Fig.3 shows plan of basement floor slab. Now as previously said load coming from the super structure at columns 1, 2, 3& 4 is greater than the uplift soil water pressure. Hence here is no effect of uplift soil water pressure. But load of floor area enclosed by columns 1, 2, 3 & 4 is less than the uplift soil water pressure, due to this uplift soil water pressure, there is upward vertical movement of enclosed area of floor. To prevent this effect central pile P5 & peripheral piles P1, P2, P3, P4 are provided as shown in fig. To resist uplift soil pressure, various types of piles are provided according to soil condition and their necessity on site.

Example: End bearing pile, Friction pile, unreamed pile, Sheet pile Tension pile, Compaction pile. All of these are briefly discussed as following.

- *End bearing pile*

If a bedrock or rocklike material is present at a site within a reasonable depth, piles can be extended to the rock surface. In this case, the ultimate bearing capacity of the pile depends entirely on the underlying material; thus the piles are called end or point bearing piles. In most of these cases the necessary length of the pile can be fairly well established.

- *Friction pile*

In these types of piles, the load on pile is resisted mainly by skin/friction resistance along the side of the pile (pile shaft). Pure friction piles tend to be quite long, since the load-carrying. Capacity is a function of the shaft area in contact with the soil. In cohesion less soils, such as sands of medium to low density, friction piles are often used to increase the density and thus the shear strength. When no layer of rock or rocklike material is present at a reasonable depth at a site, point/end bearing piles become very long and uneconomical. For this type of subsoil condition, piles ate driven through the softer material to specified depth.

- *Unreamed pile*

These piles are successfully developed by C.B.R.I., Roorkee (U.P.) for serving as foundations for black cotton soils, filled up ground and other types of soils having poor bearing capacity.

- *Sheet pile*

Sheet piles are thin piles, made of plates of concrete, timber or steel, driven into the ground for either separating members or for stopping seepage of water. They are not meant for carrying any vertical load. Therefore, sheet piles are also termed as non-load bearing Piles.

- *Tension pile*

These piles anchor down the structures subjected to uplift due to hydrostatic pressure or due to overturning moment. It is also called uplift pile.

- *Compaction pile*

When piles are driven in loose granular soil with the aim of increasing the bearing capacity of soil, the piles are termed as compaction piles. These piles themselves do not carry any load.

IV. CASE STUDY

A. *Site detail*

- *Site Location*: Akshar Purushottam Swamianrayan Chhatralaya AV Road, Anand – Vallabh Vidhyanagar Road, Ketivadi, Vallabh Vidhyanagar, Anand, Gujarat 388120
- *Client:* AKSHA PURUSHOTTAM CHHATRALAY
- *Site location (As per Google map)*

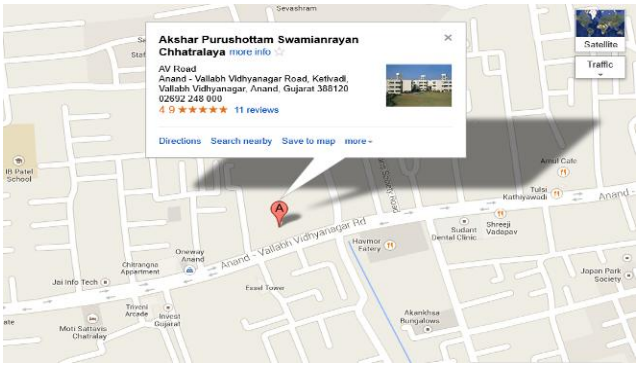

Fig. 4. Site location (As per Google map)

On site, construction of temple is running. It includes construction of main hall and admin block. In Main hall large basement having depth of 5 meters are provided for parking purpose. In Charotar region, where ground water table level is high, so it is required to take more precaution regarding seepage & moisture through peripherial r.c.c wall and hydraulic uplift pressure.

B. *Methods for prevention of moisture and water seepage through retaining wall*

- To prevent moisture and water seepage through peripheral wall, on site R.C.C wall having special feature is constructed.
- For the case study purpose we considered R.C.C wall segment having following dimensions :
  - Length =17.61 mt
  - Thickness=0.23 mt
  - Height=5.00 mt

C. *Methodology*

1) Excavation work is carried out
2) 150mm thick P.C.C is done.
3) Steel work is carried out to provide Raft and ground beam Raft of 20cm is provided. Between column to column ground beam is provided
4) Steel work is provided for wall segment.
5) Formwork is placed with cover of 25 mm and Concreting (M 20) is done.
6) Form work is removed after 1 day and then It is allow 7 days for curing purpose.
7) Exterior portion of wall is hatched for plastering and 1st coat of plaster (thickness of 20 to 25 mm) iappli
8) After 3 days 2nd coat of plaster (thickness of 5 to 6 mm) is applied
9) To prevent direct silent seepage through joints, vatta (75 mm * 75 mm) is provided at the base (bottom) of R.C.C wall.

10) After 4 days, bituminous layer is appliedon finished wall.

11) Next day polythene HDPC sheet (1 mm thick) is applied on this bituminous layer.

12) Surrounded dug soil is filled to the periphery of R.C.C retaining wall.

13) At last, for the compaction purpose & to check the leakage through R.C.C wall, a continuous water flow (by pipe) is applied in soil, until soil gets totally compacted.

- On site there was no any leakage problem through R.C.C wall.

Fig.5. Steps of methodology

Same above steps are carried out to construct other peripheral Wall segment.

C. Methods for prevention of hydraulic uplift pressure

- To prevent hydraulic uplift pressure on site pilling method is applied. On site total 65 piles are provided beneath the basement floor slab. On this site good soil (Alluvial soil) is available, so friction pile is provided.

D. Methodology for pile

1) On site for pile(P1), hole of 230 mm dia. is dug out by equipment. To check either pile digging going to vertically or inclined, plumbob method is adopted.
2) Steel is placed in this pile hole and Concreting (M20) is done for pile.
3) 150mm P.C.C is done.
4) Between columns (G6) to columns (G6) & between mid-span of column to G column(G6),Ground beam is provided.
5) P.C.C (thickness of 125mm) is done and then compacted.
6) P.V.C HDPC sheet is placed on this P.C.C.

- Why P.V.C sheet is provided?
- Prevent moisture effect conning from ground water.
- Prevent the erosion of steel in R.C.C.
- Hence durability of concrete increase & tensile & compression force are resisted.

7) Steel work for R.C.C floor slab (125mm) is placed. Now steel of this R.C.C floor slab is bounded with pile (P5) & G.B(G.B5) at junction.

8) For R.C.C floor (125mm thick), concreting (M20) is done.

Fig .6 steps of methodology

Methodology shown in step-6,7,8 is remaining on site so for that steps images are not available

E. Phenomenon of resistance provided by pile to hydraulic uplift soil pressure:

- Condition: 1

"If piles are not provided."

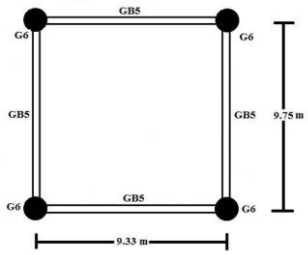

Fig. 7. Basement floor slab without pile

An area enclosed by columns (G6) and ground beam (GB5) is having long span say 9.33m * 9.75m (enclosed area=90.97m2).As time pass uplift pressure exerted by soil water, floor slab is uplifted & floor segment

In this condition,

Hydraulic uplift pressure (↑) >self-weight of floor slab (↓)

- Condition: 2

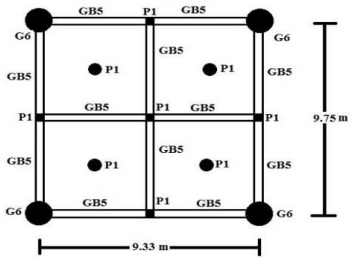

Fig. 8. Basement floor slab with pile

"After providing pile"

Here the main reason for uplift of floor slab is that total upward load (hydraulicuplift pressure) is greater than the total vertical downward load (self-weight of basement floor slab).so it is required that total downward pressure must greater than the total upward pressure. Let here assume

X= Total vertical upward pressure (hydraulic uplift pressure) (assumed)
Y= Total vertical downward pressure (self-weight of basement floor slab)
On site X > Y. So it must require to provide piles.
To resist uplift soil water pressure, required condition is X<Y.
Therefore minimum downward weight required=X-Y
Let X-Y=Z (assumed). Now this excess weight (Z) is provided in form of piles.
From this excess weight (Z), total number of pile are found and these pile are provided according to most favourable design condition by structure engineer. Here the value of X,Y & Z are not provided because structural data of site is very confidential. As shown in above fig, piles (P1) & ground beam (GB5) are provided. Here ground beam provide connectivity to piles (P1) according to structural criteria.

After providing piles, we can see than in fig. 5, now whole area (90.97m2)is divided in four equal segment having area 22.74m2. These piles provide download force to various floor segments. Hence, hydraulic uplift pressure is resisted & its effect is prevented.

In this condition
{Self-weight of floor slab (including ground beams)+self-weight of piles}(↓)
=total weight (↓) > hydraulic uplift pressure (↑)

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CONCLUSION

Now a days due to haphazard development of city, to facilitate various services more and more basement(having large area) are constructed and particularly those basement which are in high water table area are being affected by uplift soil water pressure & water seepage & moisture problem through peripherial retaing wall and after construction of it as time passes basements are damaged. So it demands continuous maintenances of these basement and it lead to high cost and its time consuming. To prevent this problems, provision of piles (under the execution of skilled person) and application HDPC sheet with bituminous are most effective method to encounter the hydraulic uplift pressure and moisture problem through peripheral retaing wall respectively.

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