

# Complications during Multi-Level Basement / Deep Foundation Construction Projects

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**Abstract:** *This paper chiefly confronts the major complications during multi-level basement / deep foundation construction projects in Delhi. Few of the problems are specifically discussed for Delhi, whereas others are ubiquitous. The major realm of concern are presented here: inadequate dewatering procedure, improper or inadequate soil nailing and shotcreting, poor workmanship in steel placing and binding, improper disposal of anchor slurry and muck, excessive water pressure. Lack of proper monitoring / leniency in monitoring of water table attributed to collapse of earth brim. Improper or inadequate soil nailing and shotcreting contributed to deposition of soil to foundation thereby adding to increase in deposition of muck. Inadequate PCC thickness led to collapse of PCC and creation of large pits thereby increasing inconvenience in muck clearing and causing poor workmanship in steel placement and binding. Failure to proper marking of steel bars in stacks after their cutting and bending can also be a major cause for poor workmanship in steel placement. In this paper, we present illustration of such complication during construction in Delhi and suggest preventive methods. Several of the deficiencies explained in each problem area could easily have been avoided by simply adopting stricter monitoring procedures, quality measures and by enforcing the specification infield practice. Prequalified foundation contractors should have adequate knowledge of soil conditions and behavior and water table and should be safety-conscious.*

**Keywords:** Dewatering complications, Multi-level foundation, cost risk, soil settlement, high-rise buildings, muck problems.

## 1. Introduction

In recent years Indian government has played an active role in promoting civil engineering works in order to improve the infrastructure in country and boost the growth of the industry. Despite the increasing inflation and highly volatile economy civil engineering projects have steadily increased in last few years. The major increase of infrastructure projects started before the commonwealth games and in the city of Delhi for its beautification.

But because of extremely high cost of land in Delhi's urban area and difficulties in land acquisition has caused owner's (i.e. government authorities) to push the governing building regulations to the limit by requesting the designers to achieve maximum use of underground space to fulfill the requirement for car parks and shopping marts, often at the risk of sacrificing the stability of the foundation and neighboring structures during and after construction. Keeping in mind the soil conditions and requirement of earth, Open-cut foundation excavation method are mostly used in these projects. This type of excavation is generally carried out in three stages. Making earth brim with slope of 1:10 after every 4-5 meters in case the foundation is very deep, for stabilization of these earth brims soil nailing technique is used.

Soil nailing technique is a technique in which soil slopes, excavations or retaining walls are positively reinforced by the insertion of relatively slender element-normally steel reinforced bars. Such structural element which provides load transfer to the ground in excavation reinforcement application is called nail. In the following sections, we illustrate some problems related to such foundation construction projects. More specifically, these examples cover topics related to inadequate dewatering of the excavated area, inadequate or improper soil nailing and

shotcreting, poor workmanship in steel placing and binding, and excessive water pressure. Illustrations of these complications in these cases are done for the purpose of altering the design and construction professionals against the potential for excavation failure.

## 2. Improper Dewatering Procedures

Inadequate dewatering procedure for deep foundation construction project cause many undesirable consequences which include settlement of existing buildings, cracks in walls and slabs of existing nearby buildings and improper working conditions, collapsing of soil from earth brims /shores. Particularly, if improper dewatering procedures are followed improper working conditions and collapsing of soil from earth brims are far most common problems in Delhi. These problems can be illustrated by the following case.

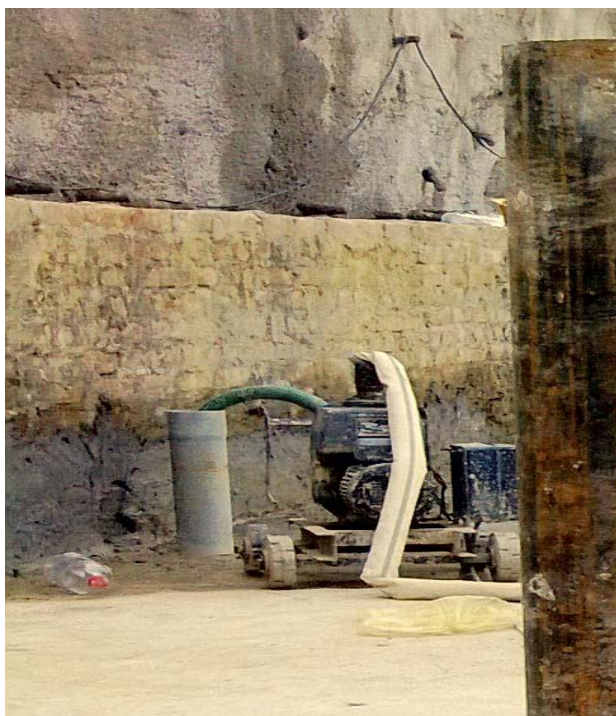
The average depth of ground water in Pragati Maidan and ITO area ranges from 1.8m to 4.7 m (Arun Kansal, 2006). In order to achieve workable and dry conditions, a dewatering system may be applied for the excavated area. There are two most widely used dewatering systems in Delhi: The gravity dewatering method and Deep well pump system.

The gravity dewatering method requires number of wells (about 60cm dia.) to be dug out at the base of the excavated area, while the deep well pump system requires the use of submersible pumps to suck out the water in 15-cm dia. holes. Drilled to the desired water table. The latter is commonly employed for dewatering excavation projects. The employment / design of deep well pump dewatering system require good judgment and adequate knowledge for controlling the water table. Sometimes when one method alone cannot fulfill the dewatering requirement, then the combination of both methods can also be used.



**Figure 1:** Deep Well Pump Dewatering System Used For Dewatering Excavated Area

Fig. 1 and Fig. 2 illustrates a deep well pump dewatering system used for dewatering of excavated area and Gravity method dewatering system: centrifugal pump used to prevent rise in water table for foundation construction of a multi-tower high rise building project near Pragati Maidan area in Delhi. The depth of excavation is 15.25 meters i.e. around 50 ft below N.G.L for the 49331.18 sq mt. excavated area. Investigation revealed insufficient dewatering procedures for excavated area as 32 deep wells with 15-cm dia. pumps were used to draw down water-table. However, out of these 32 more than 10-12 pumps were found always out of order and no proper monitoring of water table was done because of which huge amount of water was stagnated in excavated area which was resulted in deposition of slurry and muck and unworkable conditions for labour. Problem is shown in fig. 3.



**Figure 2:** Gravity Method Dewatering System: Centrifugal Pump Used To Prevent Rise In Water Table.

### 3. Improper Soil Nailing and Shotcreting

Numerous complications during construction of deep foundations can be initiated by collapsing of soil from earth brim if its proper treatment i.e. nailing, shotcreting, shoring, etc is not done timely and properly. It may also result in life hazard of the workers working in excavated areas and there is a probability that the displacement of soil can also result in settlement of foundation of the nearby structures, On the other hand if soil displaces and falls in excavated area then it causes delay to the progress of project as that soil needs to be get removed from excavated area.

Fig.4 shows the earth retained on earth brims by means of nailing and shotcreting method. These nails are usually driven horizontally by mechanical driving method upto a depth of 7-8 meters spaced at 250 mm or more center to center depending upon the soil conditions.



**Figure 3:** Muck And Stagnated Water, Unworkable Conditions Due To Improper Dewatering.

Investigation revealed that because of slow working and incomplete shotcreting unacceptable performance of soil nail has been encountered in several projects. The following case reviews problem related to inadequate nailing performance. In one project, soil nails were driven and left as shotcreting was delayed. Because of delayed shotcrete the soil of earth brim started to erode and fall in excavated area. It also added to formation of muck in excavated area. This problem did not result in any catastrophe, and therefore was seldom publicized. However, their “near disaster” condition was obvious. The problem is shown in fig. 5.

### 4. Poor Workmanship in Steel Placement and Binding

Perhaps the most frequent problems in Delhi are related to poor workmanship. Steel in many structures such as retaining walls, columns, raft, etc are placed with poor workmanship. As, for any structure to gain strength, the reinforcing steel bars need to be placed with great precision, proper cover and avoiding contact with water, prior to concreting.



**Figure 4:** Stabilization of Slopes By Soil Nailing And Shotcreting.



**Figure 5:** Soil Erosion From Earth Brim Due to Delay in Shotcrete.

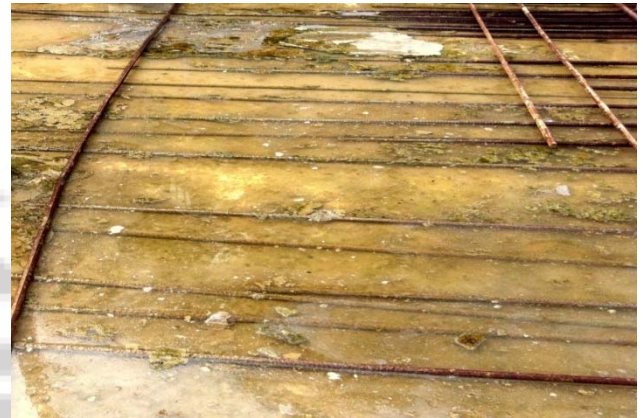
It was reviewed that poor workmanship in reinforcement placement is common in raft (foundation), and columns. Generally as there is no proper spacing maintained between rebars. Problem is evident when the de-shuttering reveals the bars exposed, without concrete cover. Clearly, such structures are less capable of accommodating proper strength and are susceptible to premature deterioration. In many cases the rebars get exposed to water, resulting in rusting. Such a problem is shown in Fig. 6.

### 5. Excessive Water Pressure

Very often water pressure triggers the failure of foundation. The failure of foundation occurs due to high uplift pressure by water. This force causes uneven settlement of foundation. This force during construction phase causes complication for

laying of foundation concrete in such a way that it raptures the PCC base of foundation over which steel has to be placed. The uplift pressure of water can cause seepage of water from ruptured PCC leading to creation of muck which makes conditions unworkable and also leads to formation of small ponds where soil has settled.

All the above discussed complications take place due to uncontrolled underground water table. Investigation revealed improper or less efficient dewatering system which leads to such complications and if not controlled all these factors have potential to cause catastrophe and delay the project to a large extent. Fig. 7 demonstrates such problems.



**Figure 6:** Rebars Placed Get Exposed to Water, Resulting in Rusting

### 6. Summary, Conclusion, and Recommendations

Increasing rate of economic progress and a race towards achieving the status of global city has led Delhi to the construction of numerous high-rise office and residential complexes in its urban areas. Most of these buildings designed normally have 3-storey deep or sometimes more than that underground foundation. The current investment market for these buildings has often emphasized maximum floor area at the expense of related performance and safety issues. During construction of such projects, problem such as settlement of foundation of neighboring buildings and collapse of earth retaining wall sometimes occurs. The most frequent problem concern dewatering, temporary earth retaining structures and workmanship; while excessive water pressure often triggers leakage of water from ruptured part of foundation base leading to base settlement and deposition muck.

When dewatering is performed without adequate water-table monitoring procedures, settlement of the soil surrounding the excavated area can occur. It is recommended that planning of a dewatering system should refer to the original design data, boring logs, and the instrument system data. Due to non-homogeneous and non-isotropic soil properties, monitoring and, if necessary, modifying construction operations before each stage of excavation should be performed. Survey and evaluation of the neighboring structures and facilities before, during, and after the excavation are extremely important. If observations of a neighboring structure or facility indicate an inadequate

foundation, underpinning, or grouting of the existing foundation should first be performed.



**Figure 7:** Deposition of Muck Due To Ruptured PCC

Whereas, the problem of soil erosion from earth brim is concerned, it can be prevented by carefully and properly monitoring soil nailing and shotcreting process. One thing should be taken care of that after the nails are driven into soil, after that they should be locked with the help of S.S mesh of desirable size and a bearing plate mostly of size ranging from 150 sq. m to 250 sq. m, followed by shotcreting. Iron nails should not be left exposed for a longer period of time. In most cases, the parties involved in the foundation construction were aware of these deficiencies; however, since safety measures have not been adequately adopted, no action was taken to improve the nailing performance. Clearly, many problems could be avoided and many collapses could be prevented if stricter quality control measures were adopted.

The common problem in the construction of deep foundation is the poor reinforcing steel placement. Such placement requires accuracy, particularly when the foundation is deep. Often the steel gets exposed to water in these kind of construction projects prior to concreting. The effect of exposure of steel can be diminished by coating steel with cement slurry coating. This will make a protective layer around rebars and will diminish rusting of rebars.

It is concluded from this paper that, thorough investigation of the soil characteristics prior to the excavation could reduce the risk of foundation failure. Furthermore, strict quality control measures should start early during the prequalification of the foundation contractors. This particularly is true for slurry and muck deposition problem leading to unworkable conditions. Qualified foundation contractors should have adequate knowledge about the soil conditions of the excavated area. The case presented here involved construction in Delhi. Some of the lessons, however, may be applicable to the construction of foundations in other urban locations.

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