# Management of hydrogeological risks in underground constructions

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**Abstract** - *In recent years, population growth has progressed, and large cities are growing rapidly as "compact cities" where space is a priority. This makes it particularly urgent to build the underground spaces of the future more cost-effectively and to increase the reliability of construction and operational performance. Considering the cost and performance of underground structures requires understanding and managing the hydrogeological risks that affect groundwater and Earth's geology. It deals with both the construction sector and the natural environment. Regarding underground structures, the risks and impacts caused by groundwater, soil and rock geology are unpredictable and there are many uncertainties. Therefore, proper investigation of groundwater assessment and geotechnical investigation of construction sites are very important aspects for underground structures. This study reports on the problems and challenges faced by groundwater and soil conditions during the construction phase of underground construction projects.*

***Key Words*: Groundwater challenges, dewatering methods, diaphragm wall construction, contiguous pile techniques, basement excavation, waterproofing.**

## 1. INTRODUCTION

Under the surface of the Earth, pore spaces in soil and fractures in rock formations contain groundwater. A fundamental property that influences the soil's strength and compressibility and its capacity to support structural loads is the flow of groundwater below the surface. Due to the relative incompressibility of water, the soil media takes on very specific physical characteristics when saturated. Groundwater has an impact on the project by influencing the facility's design, function, and cost whenever construction must take place below the water table or when soil is used to retain water. In construction projects, groundwater is a frequent source of disagreement between owners and contractors.

## 2. METHODOLOGY

The study's methodology includes a literature review of various ground water issues in construction. Investigations of contextual analyses confronting issues with cellar developments. Analyses of live case studies of buildings with basements that are at risk from hydrogeological hazards and comparisons between them based on a variety of criteria to make inferences and draw a conclusion.

## 3. IDENTIFICATION AND EVALUATION OF GROUNDWATERDURING PLANNING AND CONSTRUCTION

Reconnaissance: Utilizing symbolism understanding and site visits to recognize an outline of water table circumstances, yet frequently requires subsurface examinations. Investigation of the Subsurface: Test borings or potentially test pits to profundities underneath the expected exhuming will be expected to characterize the ground water profundity and conditions including static, roosted, and artesian circumstances. Cohesion-less soils, such as sands, gravels, and silt sands, allow water to flow more easily through them, so groundwater conditions can typically be observed visually. Conditions of groundwater in cohesive soils (clay and silt clay) cannot be observed visually for water flow and frequently require laboratory testing. Stream speeds in muds can be under 1 foot/year.

Because of the sluggish pace of stream in strong soils and wells, piezometers and other subsurface instruments might require days to months to record groundwater changes and tension. Ground water reading may require a "zero" volume change device, such as a diaphragm transducer, to read changes in groundwater head in real time when these changes are crucial to the design process. For their decisions to be effective, the engineering team in charge of all project phases—from initial planning and budgeting to final construction—must be aware of the potential impact of groundwater during design, construction, and after construction.

## 4. CASE STUDIES

### 4.1. GROUNDWATER CONTROL FOR CONSTRUCTION PURPOSES: A CASE STUDY FROM KUWAIT

Location- Kuwait

Purpose – foundation dewatering

Project - major sewage system renovation throughout Kuwait City

Groundwater occurs 4 m below the ground surface and construction specifications required lowering the groundwater table by 16 m to the foundation grade, 20 m below the ground surface .

This case study demonstrates that geological and climatic factors have a significant impact on the physical and hydrogeological properties of subsoils that control subsurface groundwater flow and are taken into account when designing drainage systems. It reinforces established geotechnical principles of necessity.

Detailed field conditions such as soil profile, soil provenance, petrological protocols, and soil/rock formation composition are important factors in designing a reliable and cost-effective groundwater drainage system. In addition, the geological conditions of the area are also very important.

Presence of consolidated sand layer in calcareous concrete. This may not be taken into account in particle size distribution analysis.

### 4.2. EXPLORING CHANGES IN HYDROGEOLOGICAL RISK AWARENESS AND PREPAREDNESS OVER TIME: A CASE STUDY IN NORTHEASTERN ITALY

Due to climate and socio-economic changes, hydrogeological hazards are increasing in damage around the world. The purpose of this study is to investigate how risk perceptions and willingness to deal with hydrological hazards change over time. A cohort study was conducted in Romagnano and Vermiglio, two villages affected by debris flows in the northeastern Italian Alps.

Two study areas were chosen because both areas experienced extreme hydrogeological events in the early 2000s, followed by long periods of absence until the time of this study.

The questionnaire he divided into six main sections. (1) Community profile: (2) Risk awareness: (3) Hydrological Hazards: (4) Preparation: (5) Prevention: (6) Socio-demographics.

Cohort studies investigating changes in risk perceptions and risk appetite over time. First, we hypothesized that, in the absence of an event, perceptions of hydrogeological risk would decline over time (H1).

This assumption is supported by our data. The absence of hydrogeological events for long periods of time and inadequate risk communication strategies (if any) may account for such loss of awareness.

### 4.3. CASE STUDIES OF DEWATERING AND FOUNDATION DESIGN: RETAIL WAREHOUSES IN TAIWAN

The case study in this article describes three retail warehouse locations in Taiwan that share the same water table but have significantly different soil conditions. Two of the sites are in dense, permeable gravel and rock, and the third site is in intervening alluvial sand and clay. At the first site, shallow foundations and slab floors were placed on a permanent passive drainage system, requiring an accurate estimate of permeable gravel and cobble infiltration. This article presents a hydrogeological analysis of three sites and geotechnical design considerations for drainage and foundation systems and soil liquefaction control.

As illustrated in these three case studies, extensive Geotechnical and hydrogeological exploration and testing was performed at each site to characterize the Modeling hydraulic conductivity and groundwater response drainage. The actual amount of leachate reported is as follows. generally the same order of magnitude or less Estimates from modeling.

At locations A and B the foundation is very densely built Gravel and cobbles, use of permanent drainage systems Installed under floor slabs to lower the water table It is now possible to support buildings with cheaper shallow foundations and level floors. At Site B, additional structural panels were used to withstand this. hydrostatic pressure.

At Site C, where there was buried sand and clay Dominant soil type, more robust fertilizer (fortification). Concrete enclosure walls were required to define the lateral boundaries Movement during drilling and groundwater management Penetration for both structural and permanent conditions.

### 4.4. ENVIRONMENTALLY SUSTAINABLE GROUNDWATER CONTROL DURING DEWATERING WITH BARRIERS: A CASE STUDY IN SHANGHAI

Shanghai Metro Line 10 Liyang Road Station is located on Siping Road in Yangpu District. It is a transfer station with a length of 192 meters, built under Haerun Station.

There is a brick building on the west side of the station, and Hairun Road Station on the east side of it. The station excavation site is located on Siping Road. It is divided into four sections: Standard, North Shield Shaft, South Shield Shaft and Transition. The excavation depth is 16.3m for the standard part and 18.3m for the shield shaft part, and a continuous wall is installed as a support structure for the station foundation pit.

When calculating the deformation of the soil layer, we specified values for the model boundary and the bottom hydraulic height. Fixed limit settlement was set to zero. The soil surface provided a free boundary, allowing head and subsidence to vary depending on the drainage process.

In this study, the results of groundwater monitoring at Xiyang Road Station of Shanghai Metro Line 10 were analyzed. A three-dimensional numerical model was created to simulate a borehole. The effects of drainage processes on the adjacent environment, as well as the effects of soil subsidence and groundwater levels around drilling pits, were analyzed.

## 5. LIVE CASE STUDY

### 5.1 COMMERCIAL INNOVATION CAMPUS

#### 5.1.1 PROJECT DESCRIPTION

The Center is to make A level IT/ITES office space with elite elements and offices to draw in long haul occupants and to full fill by making adequate, practical, blended involved improvement in with neighborhood retail, public and semi-public conveniences, parks, open spaces and metropolitan roads. Roads, power, water, a storm water and sewer management system, a solid and sewage waste management system, high-tech optical fiber connectivity, and other infrastructure facilities are anticipated to be seamlessly incorporated into the construction. Phase I of the project has a built-up area of approximately 1.58 million square feet. Each tower has 12 office floors and three basements, as well as a ground floor. There will be two towers, each with a basement.

#### 5.1.2. SITE INSPECTIONS

Site inspections to assess topography, geology, hydrology and vegetation Drill 53 drill holes to characterize the soil and geology up to 16 meters deep below the depression Rock core drilling using NMLC method Construction of 5 measurement wells and installation of groundwater data loggers for constant monitoring of groundwater levels Laboratory testing of rock cores (axial and diametral strength) RQD and RMR Rating of Recovery Core Preparation of geotechnical reports to document geotechnical and hydrogeological conditions.

Providing geotechnical parameters for planning. Recommendations for groundwater management. Provision of construction supervision requirements Construction pit soil nails and temporary shoring design Inspections during construction to prove the condition of foundations and the stability of excavated pits.

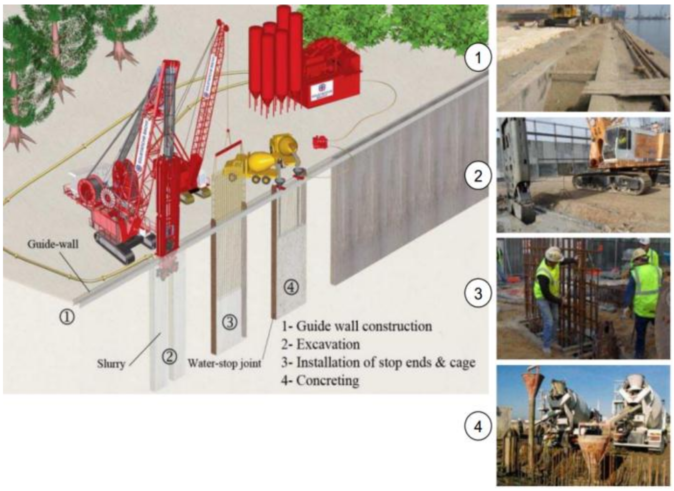
#### 5.1.3. DE-WATERING TECHNIQUES

In Well points, submersible pumps are installed in the well shaft and wells are drilled around the excavation area. These siphons are associated with a header pipe permitting the groundwater to be brought up by the siphons into the Well places and afterward released. One or more individual wells are drilled for deep wells, and submersible pumps are installed in each shaft. The Profound well strategy is the most ideal for profound unearthing where enormous water volumes should be released. Sump siphoning is the most well-known strategy for dewatering, since it fundamentally works by gravity. This strategy is likewise the most prudent. Boreholes with submersible pumps are used in the deep well point method, which lowers the groundwater level below the excavation level. Around the excavated area, where groundwater falls due to gravity, wells with diameters of 15 to 20 centimeters are drilled. This lowers the water table and depletes the groundwater in the excavated area.

*(Fig 1.Sump pumping and deep well points)*

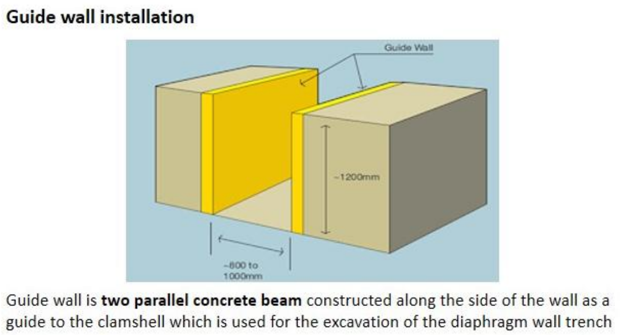
#### 5.1.4. DIAPHRAGM WALL

A structural concrete wall known as a diaphragm wall is built in a deep trench excavation using either components that are cast in situ or precast concrete. Diaphragm walls are frequently used on congested sites, close to existing structures, with limited headroom, or where the depth of the excavation necessitates the removal of much larger volumes of soil in order to create stable battered slopes. Diaphragm walls are reasonable for most sub soils and their establishment produces just a limited quantity of vibration and commotion, which builds their reasonableness for works completed near existing designs. Walls can also include recessed formwork and connections to the floor slab.

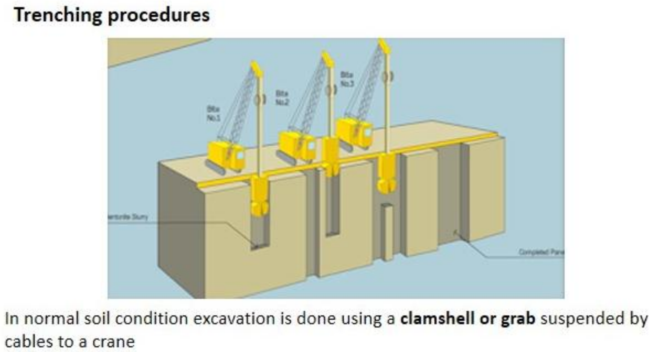



*(Fig 2.Diaphragm wall construction)*

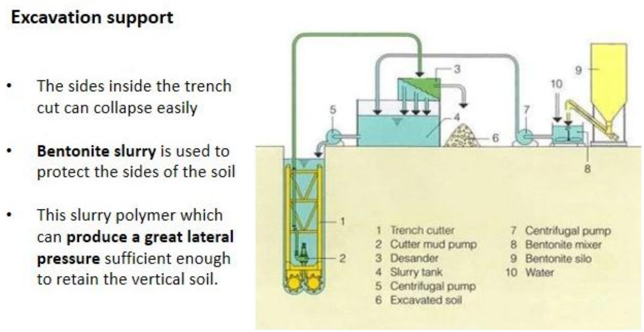
### 5.1.5. DIAPHRAGM WALL CONSTRUCTION



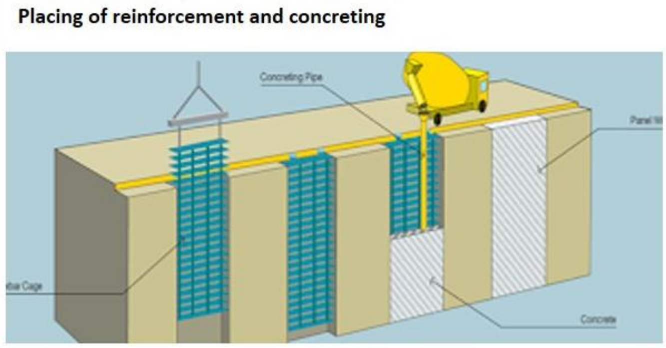

*(Fig 3.Guide wall installation)*




*(Fig 4.Trenching procedures)*




*(Fig 5.Excavation support)*




*(Fig 6.Placement of reinforcement and concreting)*

### 5.1.6. DIAPHRAGM WALL ANCHORING PROCESS

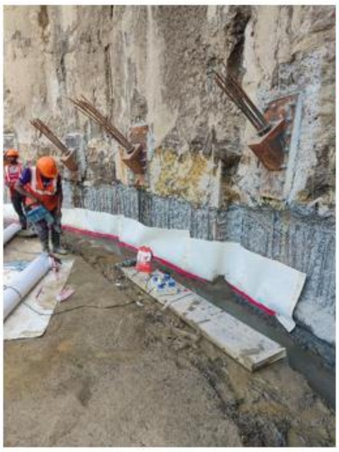
*(Fig 7.Diaphragm wall anchoring process)*

Ground anchor bolts are used to connect the D-wall's structural and non-structural components to the concrete during diaphragm wall construction. The most common way of projecting these anchors into the diaphragm wall is known as Securing. The Mooring action starts 7 days after the diaphragm wall boards are projected. In order to sustain force from the top, anchoring helps transfer the tension and shear forces between these structural elements and lateral support to the diaphragm wall. Boreholes of 150 to 180 mm are drilled using a drill rig at angles of 15 to 30 degrees until the hard strata is reached. After that, a casing pipe is used until the hard strata is reached, and the casing pipe is inserted into the hole in the middle. Endless supply of exhausting, the borehole is cleaned through compacted air. The anchor is grouted after a low relaxation pre stressed steel (LRPC) strand is inserted into the bore. After seven to ten days, the anchor head is jacked and pre-tensioned.

### 5.1.7. WATER PROOFING IN BASEMENTS

A layer of watertight material known as a waterproofing membrane is applied to a PCC surface to prevent water damage or leaks. Most waterproofing membranes are sheets that have been pre-formed or applied with liquid.

The layer is introduced around the establishments to forestall water entrance to safeguard building's cellar, waterproofing will assist with preventing water from penetrating in establishment and shield structure from water harm. The concrete is given a waterproofing membrane to help make it impossible for water to get through. A membrane HDPE film pressure-sensitive adhesive known as High Density Poly Ethylene makes it possible for poured concrete to fully bond with the membrane. It shields water and water vapour from harmful chemicals, hydrocarbons, and aggressive ground salts. It is a self-cement along one side of the roll to give fixed laps to improve on the application cycle.



*(Fig 8.HDPE - waterproofing membrane installation)*

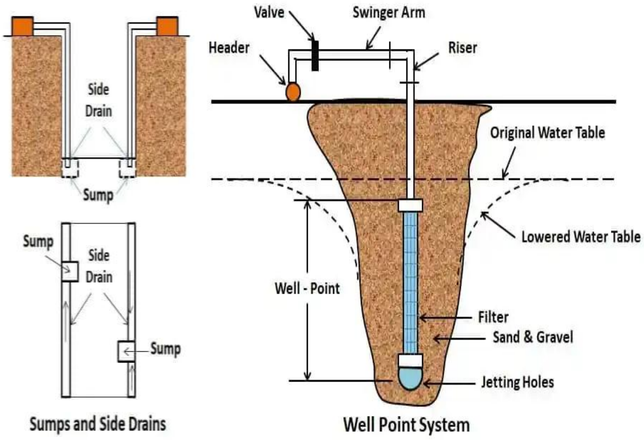
## 5.2. THE PEAK BAASHYAAM ASHOK NAGAR, CHENNAI

### 5.2.1. PROJECT DESCRIPTION

A high rise residential building consisting of 2 basements+stilt+20 floors, total 240 residential units within two towers, tower 1 and 2. 2 BHK-1346 sq.ft, 3BHK-1610 -1992 sq.ft, 4BHK-2715 sq.ft.

### 5.2.2. DE-WATERING TECHNIQUES

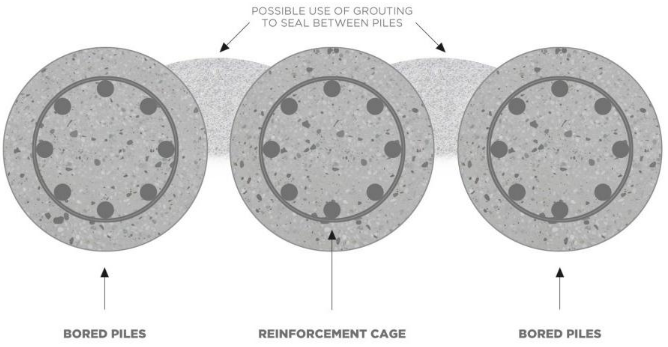
Sumps and ditches dewatering method is the most basic one employed in shallow excavations in coarse-grained soils. With this technique, sumps are small pits that are dug along the area's edge. Along the edge of the excavation, semicircular-shaped ditches or drains with a 20 cm diameter link these sumps. The water from the sides or slopes collects in sumps before being pushed away under gravity. The lowest portion of the slope may soften, ravel, or slough if there is sufficient seepage of water. Due to upward flow, there is also a chance of piping in the slump bottom. In these cases, the sump can be weighted down using an inverted filter made of layers of material that gets progressively coarser as it moves up from the bottom of the sump-pit.



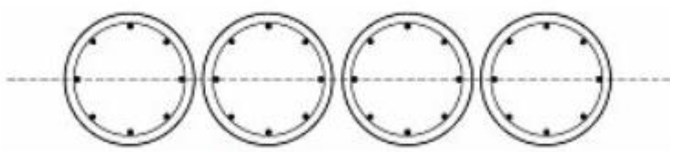

*(Fig 9.Sumps, ditches and well point system)*

### 5.2.3. CONTIGUOUS PILING TECHNIQUE

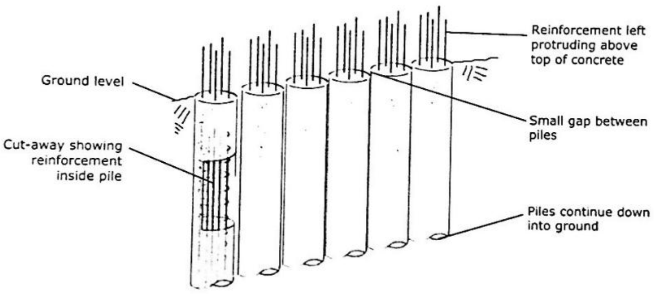
One of the most efficient and adaptable methods for building a solid foundation is piling, which is used for anything from supporting household buildings to anchoring large technical projects like bridges and oil rigs. Its application doesn't stop there, though. Contiguous piling is another effective and affordable method of building a retaining wall that may be done with piles. Contiguous piling is the process of installing a series of augured piles that are practically touching one another to build a retaining wall. The two most popular methods for inserting an augured pile are either drilling a hole with continuous steel sections that can later be removed and filled with concrete, or drilling a hole with a continuous steel flight that can later have grout injected into the hollow centre as it is removed. The spacing between the piles are normally between 50 and 150 mm. After filling up these spaces with grout, which has soil packed between them, a second wall may be built in front of the piles. The Tangent Pile shoring method, sometimes referred to as Contiguous Pile shoring, is a very practical shoring method. Tangent pile shoring is made up of closely spaced piles, and the term originates from the way the piles are positioned relative to one another.




*(Fig 10.Contiguous pile reinforcement details)*



*(Fig 11.Contiguous pile wall)*




*(Fig 12.Contiguous pile wall details)*

### 5.2.4. USES OF CONTIGUOUS PILING

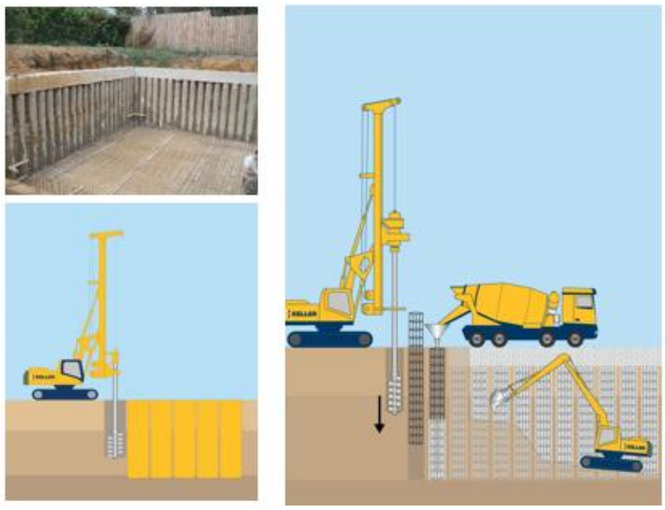
Contiguous piling is most commonly used to build basements or cellars, where the piles can be inserted and used as a retaining wall while the basement is being excavated. In the event that ideal, they can be taken out and supplant by a strong holding wall, however it's generally more powerful to leave them set up and, as depicted, add a second wall in front. Contiguous Pile Shoring is typically recommended for areas with clay soils, locations where water is not as important, or locations with very little water pressure. because it can aid in the retention of dry granular materials. However, this kind of shoring will allow water to seep through the pile gap in water-bearing granular soil. Water seepage can be prevented by grouting the pile's gaps to form a watertight wall. Additionally, without dewatering works, contiguous pile shoring is unsuitable for a high groundwater table.

### 5.2.5. ADVANTAGES AND DISADVANTAGES OF CONTIGUOUS PILING

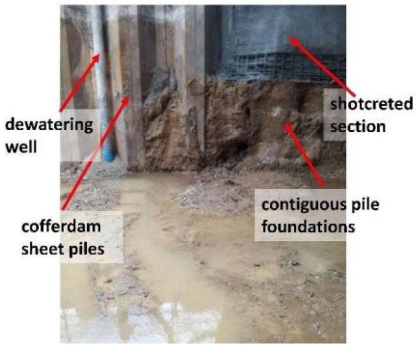
The fact that insertion of contiguous piling causes very little vibration is the most significant advantage. This method is ideal for use in built-up areas or close to other structures because noise and shaking are kept to a minimum because the piles are bored rather than driven. Moreover, contrasted and alternate approaches to placing in underground holding walls, adjacent heaping requires practically no additional uncovering. This makes it ideal for use in bound spaces or, once more, close to different designs. Contiguous piling has few real drawbacks, but as with any construction method, there are times when it is not the best choice. It works best in dry, firm soil, so it shouldn't be used in soil with a lot of water in it.

### 5.2.6. CONTIGUOUS PILE WALL

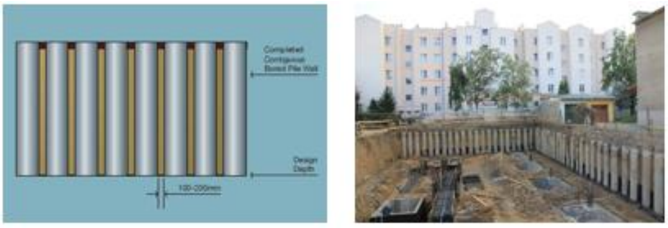
The execution of a contiguous pile wall requires a space between the piles. Such heap wall is essentially applied in cognizant (fine-grained) materials where there is no chance of material breakdown between the heaps. The short crete layer can be applied to the pile wall to stabilize the material if necessary. Benefits to performance: Speed construction, less expensive and less difficult execution contrasted with different sorts of contiguous wall, versatility in execution stage.



*(Fig 13.Contiguous pile wall construction technique)*




*(Fig 14.Detailing of contiguous pile foundations)*



*(Fig 15.Contiguous pile wall in basement constructions)*

### 5.3. COMPARITIVE ANALYSIS OF CASE STUDIES

| TOPIC | COMMERCIAL INNOVATION CAMPUS | THE PEAK BAASHYAAM |
|---|---|---|
| PROJECT AREA | 1,90,000 sq ft approx | 40,000 sq ft approx |
| SITE AREA | 40 acres | 1.37 acre |
| BUILDING HEIGHT | 3 basements+stilt+12 floors | 2 basements+stilt+20 floors |
| TYPE OF EXCAVATION | Diaphragm wall one three sides and retaining wall on one side. | Contiguous pile shoring one three sides and retaining wall on one side. |
| SOIL TYPE | Clayey soil,fine sand mixed soil strata , layered. | Clayey soil, mixed layer soil strata |
| GROUND WATER LEVEL | The average ground water level is present at 13.5 mts approx. | The ground water level is very low and it is dewatered through shallow groundwater removal techniques. |
| DEWATERING TECHNIQUES USED | Deep wells and bore wells. Deep excavation pits. 53 bores were created at the site.<br>Dewatered waste water is sent through the corporation drains.approx.80 crore litres of ground water is dewatered in three months of excavation | Sumps and ditches for collection of ground water .because of low ground water table .shallow dewatering techniques have been used.<br>Dewatered waste water is sent through the corporation drains. |

| TOPIC | COMMERCIAL INNOVATION CAMPUS | THE PEAK BAASHYAAM |
|---|---|---|
| TYPE OF WATER PROOFING MEMBRANES USED AT THE SITE | HDPE MEMBRANE<br>High Density Poly Ethylene is a membrane HDPE film pressure sensitive adhesive which allows poured concrete to bond fully with the membrane. | Layers of water proofing membranes are used at the side shoring walls and the ground slab water proofing is done using high density poly ethylene membrane sheets. |
| MAJOR RISKS INVOLVED IN THE UNDERGROUND CONSTRUCTIONS | • Existing pile foundation wastes<br>• Mixed soil strata<br>• Diaphragm wall – cracks, leakages of ground water into the excavations.<br>• Rocks and rock bottoms present in the ground. | • Contiguous pile shoring systems – is used due to low water table.<br>• Excavated soil wastes, unwanted soil stratas. |
| RISK MITIGATION MEASURES | Continous inspection and perfect handling of equipments and procedures of construction.<br>Removed water and soil stratas can be used effectively . Thus reducing cost of underground constructions. | Proper usage of men,material and labour must be implemented so as effective work is done without reworks and proper work progresses without any disturbances.thus selection of construction technologies are also an important factor for cost reduction. |

*(Fig 16.comparative analysis of live case studies)*

## 6. INFERENCES

Reduced costs and risks ,Risk avoidance, New technologies and methods, Improved background characteristics, Better water management, Risk recognition, assessment and management, Risk communication and willingness to accept and share risks. Development of geological spatial variability framework models for predictive management of geological risks in sub soils. Increased costs are often due to increased risk. Risk = Probability x Consequence (or Impact). For impact assessment, a framework is needed to assess mitigation strategies and assign responsibilities during construction and operation, along with improved quantitative assessment of risks, impacts and their likelihood of occurrence. Subterranean geological conditions should be managed primarily through the concept of subterranean zoning. This enables spatial thinking and integrated planning for the placement of surface and underground facilities in an optimized geological environment. New technologies must not only be implemented, but their short-term and long-term performance must be evaluated. Spatial and temporal variability of subsurface materials and conditions continue to pose risks, and the integration of geophysical and remote sensing methods should be reconsidered. Engineers must also consider the materials and methods used.

A good GBR (Geological Engineering Baseline Report) is carefully written to present a geological analysis of the expected conditions and/or frequency of "geological events" (temporal and spatial) expected during the project .Collected project data provides planners and contractors with information about the behavior and properties of geological materials. However, it is difficult to statistically assess the likelihood and consequences of large-scale geotechnical disruption to underground drilling, yet such phenomena are a major source of major drilling problems in underground engineering projects. We need to systematically access all surface and subsurface exposures of geological materials to obtain three-dimensional and temporal information about the spatial distribution of material properties in various formations and stress history regions. This includes field work related to road cuts and natural exposures, as well as exposures such as underground excavations and pits.

## 7. CONCLUSIONS

Engineers will have to work with geologists, architects and planners on new designs for the city's underground spaces, but they will be more than just tunnels and stations.

These experts work together to develop a city that society will demand in terms of excavated shape and depth, human occupation (social acceptance of underground space, spatial reference, emergency preparedness, population aging). Be prepared for creative use of underground space. These professionals must support the development and introduction of new technologies to meet the flexibility and quality needs of facilities in limited urban spatial resources. Although the focus here is on geological uncertainties and impacts, engineers are encouraged to develop and apply advanced methods for subsurface characterization, expand the use of soil amendment methods, and more. It needs to be radically rethought. Frameworks for understanding the risks and spatial variability of geological conditions and understanding of in situ stress assessment and redistribution should be improved. Improved drilling methods are also needed, including drilling/blasting, lasers and other innovative technological methods.

Engineers need professional homework. Data must be collected to support rational and long-term sustainable design and his LCE, including time dependence. Furthermore, the true value of subsurface space must be determined by creating a market that can determine the value of, for example, cubic meters of subsurface space in specific soil and rock conditions. More effective management of underground and geological conditions can help foster a new understanding and public acceptance of urban underground design.

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