The analysis of strata and deformation in deep excavations

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Abstract: The Yangtze River is the third longest river in the world. City groups are concentrated along the two banks of the river. Because of the alterations of the hydrological condition of transporting debris deposit and the sediment environments such as flood plains, lakes and shores. Typical binary-layer structural sedimentation rhythms are formed on the first Yangtze River's terrace, which have an upper soft soil and lower sandy strata. Such geological structures make the geotechnical problems of deep excavation complicated in these regions. Firstly, because of the lower strength of the material powerful bracing foundation pit structures must be undertaken. Secondly, as high permeability sand, gravel and cobble layers are encountered such methods as high-pressure spinning and spraying, grouting with pressure, deep mixing to shape curtain for cutting off water along all sides of foundation pit are needed. Deep well dewatering methods are used to lower water and control underground water by decompression dewatering or depletion dewatering when there is confined water in a foundation pit. The deformation of a deep excavation within these areas are caused by the unloading and plastic deformation of soil mass, piping and seepage failure, dewatering. This causes lateral displacement, base heave and subsidence, even collapse and environmental impact.

Résumé: Yangtsé est la troisième plus longue rivière du monde, dans la première terrasse de son cours moyen-inférieur se concentrent des groupes de villes. Avec le changement de la condition de force hydraulique transportant les sédiments et détritus et de l'environemment sédimentaire par exemple les plaines d'inondation, les lacs et les rives, le rythme typique sédimentaire de bi-strate qui comprennent la strate molle supérieure et la strate sablonneuse inférieure s'est formé. Cette structure géologique rend le problème géotechnique de l'excavation profonde très complexe dans cette région: premièrement, pour la strate supérieure qui est composée de plain fill, miscellaneous fill, et la strate superficielle de l'état mou à l'état fluide, son intensité est faible, il faut des fortes mesures pour supporter et protéger en creusant l'excavation fondamentale; secondairement, pour la strate inférieure, comme la haute perméabilité de strate de sable, de gravier, de galet, comme le haut artesian head mais limité par le niveau de Yangtsé, il faut prendre des mesures d'anti-infiltration par exemple le tour et jaillissement de haute pression, le mélange profond, le grouting avec pression, pour prévenir et contrôler l'eau souterraine et le perched water. Quant à l'eau artésienne, il faut encore utiliser le puits profond pour baisser l'artesian head ou évacuer la couche aqueuse.

Keywords: alluvium, excavations, earth pressure, land subsidence, environmental impact, groundwater controls

GENERAL OVERVIEW

Accompanying with the construction of groundwork, subway, tunnel and basement of tall buildings, deep excavation has been the long existing problem for the foundation and underground constructions. Along with the continuous development and utilization of underground spaces, the depth of deep excavation becomes deeper and deeper and the area is larger and larger; simultaneously, since tall buildings, super tall buildings and subways are concentrated in the centre of city, structures, roads, underground pipelines etc., are crowded around the construction sites, the peripheral environmental conditions of deep excavation are growing severe. As a result, deep excavation remains a challenging geotechnical engineering problem with high risks and difficulties.

It is ultimately a problem of deformation and stability of deep excavation. A lot of construction practices prove that failure mechanism of deformation is different due to different engineering geological conditions of deep excavations (Xu 2001). Thus, the concept design for each deep excavation works is different. The so-called engineering geological conditions of foundation pit refer to mainly the distribution, burial and constitute characters and engineering properties of site strata.

Yangtse River is the third longest river in the world. The flood plain of the lower reaches of the river starts from Zhijiang City of Hubei Province, which shows an asymmetric distribution of banding or crescent moon shape. The area of the left bank is usually larger than that of the right bank with a ground elevation of 19m•22m, which is 2m•5m higher than the normal water level of Yangtse River. Many city groups are distributed in the first accumulation terrace of the river. It has strong practical significance to analyze the strata characteristics of first terrace in the middle and lower reaches of the Yangtse River and the failure and deformation mode of deep excavation, and then the relation between them in order to enhance the design level of deep excavation works of these cities.

THE TYPICAL STRATA STRUCTURE AND ENGINEERING GEOLOGICAL CHARACTERISTICS OF THE FIRST TERRACE OF YANGTSE RIVER

The sediment grains of the middle and lower reaches of Yangtse River present the characters from coarse to small grains with depth due to the separation function of the river, and the floodplain has the typical phase change (Liu 2001). Along with the water transporting condition changes of detritus sediment of Yangtse River and the alternation among floodplains, lakes and pools along the river banks, it forms the river-lake deposit facies alluvium of Holocene Series of Quaternary System on the first terrace with a depth of 35m~55m, which presents a typical binary-layer structural sedimentation rhythms that have an upper soft soil and lower sandy strata. Table.1 shows the typical strata structure of first terrace in Hankou area.

Table 1. Typical strata structure of first terrace in Hankou area

Name of strata		Burial depth of super face (m)	Thickness of strata (m)	Formation cause type	Underground water type	Engineering geological evaluation
(1)	Miscellaneous fill	0~5	0~5	Artificial fill	Perched water and phreatic water	Uneven, loose material with and large compressibility
	Plain fill	0~5	0~3			
(2)	Cohesive soil	2~4	2~5	Floodplain phase		Relative overlying crust with plastic status, which can be as the natural foundation for multi-story buildings
(3)	Mucky soil, muck or soft cohesive soil	3~5	6~12			Soft~flow plastic status, soft soil
(4)	Silt, silty sand with silty clay (interbedding)	9~13	3~10	Transitional phase	Weak confined water	Relative soft soil with Soft~plastic status and sandy soil character
(5)	silty fine sand, medium coarse sand	12~18 25~30	30~35	Riverbed phase	Confined water	Density, grain and permeability increase along with the depth, which can be the bearing stratum for medium length piles.
(6)	gravel, cobble	43~45	3~6			It is comparatively dense, and can be the bearing stratum for medium and long piles.
(7)	dauk, mudstone	50~55				Medium and slight weathered layer can be as the bearing stratum of rock-socked pile.

Superficial artificial soil layer

It is mainly miscellaneous fill and plain fill produced due to human production and life with loose structure. For deep excavation, it is the bad strata that affect the slope stability, the seepage prevention and anchoring effects.

Cohesive soil layer of upper alluvial flat facies

It is formed by the sediments overflowed from the riverbed and is sorted by waters, its grains are small and even with horizontal bedding and organic matters. Since the sediment environment belongs to dead water status and formed newly, the soil mass has not been consolidated, which are under-consolidated soil with soft soil characters. According to the soil classification of engineering geology, it belongs to general cohesive soil and muddy soil or mud. Since its surface layer exposed periodically on the ground, the soil is dried and consolidated and formed relative overlying crust. Thus this layer can be divided into two sub-layers.

Surface crust

The underground water level in normal year is the bottom line of this stratum. With higher ground level in anterior margin area, it has a thick crust layer, while it disappears in lakes, swamps and depressions in trailing edges. The soil belongs to common cohesive soil with medium compressibility. Since it often exposes on the ground, its mineral matters can be sufficiently oxidized, the organic matters are discomposed gradually, and so its soil presents yellowish-brown or brown. This soil is the relative favourite layer to the slope stability of foundation pit in the first terrace.

Mud or muddy soil layer

Distributing under the solid crust, it is the main sediment of floodplain facies. According to its forming condition, the thickness of soil layer often presents increasing trends from anterior margin to the rear. Since the soil contains organic matters, it shows grey-brown colour and its soil usually is muck and mucky silty clay, muddy silty sand and etc., some have flaggy or lentoid loose silty sand and normal cohesive soil layer, which is the typical swamp of saturated soft soil sediment in dead water environment. It has the characters of large void ratio ($e \geq 1.0$), high natural water content ($\omega \geq \omega_L$), high compressibility ($a_{1-2} \geq 0.5MPa^{-1}$), low strength ($c_u \leq 30Kpa$) and high sensibility with flow plastic status, very strong thixotropy and rheological characteristics. With a maximum depth of more than 20m, it is the main bad strata to affect the stability of deep excavation in the first terrace and cause environmental hazards.

Silt, silty sand and silty clay interbeds of medium transition facies

This layer is the transition layer between the cohesive soil of floodplain facies and sand soil of bed phase, mostly with a thickness of 3m~10m, some only have 1m or even no thickness, some reaches 16m, the individual layers are from scores of centimetre to 1m or so. It is mainly soft plastic and plastic silty clay layer, which accounts totally for about 55%~80%, silty sand is in the second place, which accounts for about 15%~30%, as well as some small amount of silty sand layer. The uneven soil quality reflects the instability of sediment environment. The soil compression modulus is low and saturated with strong penetrability, which is unfavourable to the slope seepage control of deep excavation.

Sand, gravel, cobble interbeds of lower riverbed facies

It consists of mainly fine sands often with silty sand. The medium sized fine sand, medium coarse sand and gravel and cobble layer is in the bottom. Comparatively speaking, it has a larger thickness, which usually is 30m~40m. Since it belongs to soil of bed facies, its grains become smaller gradually from the upper reaches to the medium and lower reaches in its size, shape, grade distribution and arrangement controlled by flow velocity, transporting distance and sediments; while the grain diameter in the geologic section grows gradually coarser from the upper to the lower part. Because of the local change of hydropower condition during the sediment process, cohesive soil lamella or lenticle appears in the sand layer. Under the overburden layer load, the soil layer changes gradually from slight density to medium density and thick density from above to below. This is the fine bearing stratum for tall buildings.

HYDROGEOLOGICAL FEATURES

Because of the composition features of typical binary structure strata of the first terrace of Yangtze River, basically, the permeability of water strata monotonically increases with depth. The occurrence underground water can be divided into three layers: ① Perched water and phreatic water in upper fill and cohesive soil. Perched water is mainly distributed in relatively small miscellaneous fill layer in old urban areas or other water bearing lenticle, phreatic water is mainly distributed in the Holocene saturated silt layer, silt along the river or relatively thick miscellaneous fill layer with fixed recharge source; ② Confined aquifer in intermediate transition layer of silty clay, silt and silty sand interbedding, in which the permeability coefficient of silt layer is generally 0.2 m/d ~1.0m/d, the permeability coefficient of silty sand is generally 0.5 m/d ~4.0m/d; ③ Confined aquifer in lower sand layer of mainly silty sand and fine sand, in which the permeability coefficient of silty sand is 7 m/d ~12m/d, the permeability coefficient of fine sand is 12 m/d ~30m/d, the permeability coefficients of medium coarse sand and cobble layers are even higher. Bedrock is the water-resisting base of the confined aquifer.

The confined water in the intermediate transition layer has hydraulic connection with the confined water in the lower layer. When pumping the confined water in the lower layer, there is “lag” and “potential difference” between the water level decrease of the lower layer and the water level decrease of the transition alternate layer. The value of “lag” time and the water level value of “potential difference” rely on the connection degree between two water-bearing strata as well as the thickness and permeable performance of the interbedding layer.

The confined water in Holocene sand layer of the first terrace of the Yangtze River has close hydraulic connection with the Yangtze River, in complementary relation of pressure transmission. The absolute elevation of confined water table is relatively higher. During the Yangtze River flood season, it is approximately 18m~20m, merely 1m~3m lower than the natural ground level. During the dry season, it is approximately 15m~16m, its annual natural change of absolute elevation is approximately 2m~4m.

DEFORMATION AND FAILURE MODES OF DEEP EXCAVATION SLOPE

The composition features of binary structure strata determine that deep excavations in the first terrace of the Yangtze River may cause geotechnical engineering problems, which can be generalized in three aspects:

- Deformation of slope and bracing structure, base heave or overall instability due to excavation hollow and unloading;
- The steep decrease of groundwater gradient resulted from excavation that underground water gushes from side walls to form gushing water and flowing soil, or puncture of upper impermeable layer of confined aquifer causes piping and sand pumping in the pit bottom;

- Deformation and damage of internal environment elements of foundation pits (such as engineering piles) and surrounding external environment elements (such as adjacent buildings, ground or underground pipeline network, roads and traffic facilities), caused by the two reasons mentioned above.

The superficial strata of the first terrace of the Yangtze River, which mainly consists of plain fill and miscellaneous fill in lakes, ponds and depressions as well as soft soil saturated, softened and plasticized into fluid plastic status, has lower strength. After excavation, the active earth pressure is large and the passive earth pressure is small, there is comparatively large deformation and a trend of displacement at the foundation pit bottom and its peripheral soil layer, shear slide surfaces tend to occur in soft layers or parts where shear stress is relatively concentrated in soil mass, which causes the slide of soil mass around the pit. At the same time, during excavation, unloading or excavation disturbance cause plastic flow and base heave in the soft soil of the working surface, the bracing structure generates horizontal displacement and follow-up deformation towards the pit under the action of the pressure difference between the two sides.

In macroscopic view, the deformation during and after the deep excavations of saturated soft soil includes:

- Subsidence and deformation of surrounding soil mass (Va);
- Lateral deformation of bracing structure or slope (Vb);
- Heave deformation of pit bottom (Vc).

Theoretically speaking, three kinds of deformation, such as land subsidence, lateral deformation of bracing structure and heave of pit bottom concur concomitantly, and their volumes have the relationship of $V_a=V_b+V_c$.

As soon as plastic flow and heave of soft soil layer of deep excavation slope or foundation pit bottom develop to the state of limit equilibrium, the soil mass will lose strength and the slope will completely loose stability and collapse. Its scope often exceeds the facture surface of active earth pressure and appears in arc slide. So, in unstable soft soil deep excavation projects, the common bracing structure itself is intact, but the bracing structure of the foundation pit has large-amplitude displacement towards the overall foundation pit inside. Of course, overall instability also includes malfunction or damage of bracing structure.

On the basis of the above analysis and engineering experience, the possible slope deformations and failure modes in case of deep excavations in the first terrace of the Yangtze River are generalized in the following conditions:

- Overall instability and slide of slope or bracing structure. See Figure 1 (a), (b);
- Bracing structure inclining towards the pit inside (often in cantilever structure) or "heeling outside" (often in internal bracing or anchoring wall). See Figure 1 (c), (d);
- Under earth load, the bracing structure itself reaches ultimate limit or large deformation to cause instability collapse. See Figure 1 (e), (f). The latter two kinds of conditions are always accompanied by obvious heave and deformation of pit bottom soil mass.

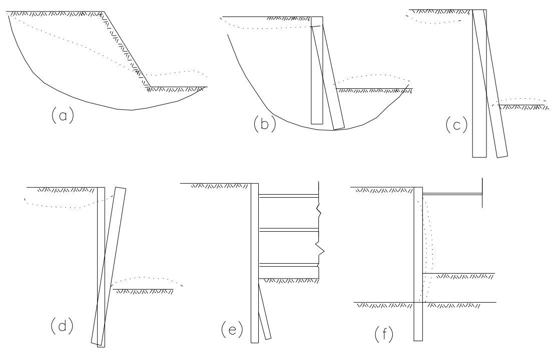

Figure 1. Deformation and failure modes of soft soil deep excavations

The coefficient of active earth pressure of saturated soft soil is very large, and the active earth pressure is directly proportional to the square of excavation depth. So, for deep excavations in thick saturated soft soil, it is very hard to control deformation only with cantilever pile bracing. Take the deep excavations of Xinyi Building in Hankou as an example. There is a depth of approximately 10m muddy soil beneath the pit bottom, and the length of cantilever bracing pile is 18m. When the excavation reaches 3m in depth, the accumulated displacement of pile top is 63.6mm; the maximum accumulated subsidence of adjacent factory building is 43.6mm. When the excavation reaches 4m in depth, displacement and subsidence reach 128.0mm and 85.2mm respectively, which seriously damages the adjacent factory building. Engineering experience indicates that whether bracing is set and the relative position of bracing settings greatly influence the displacement value of deep excavation slope in thick soft soil. Generally speaking, enhancing the position of the first bracing or adopting the excavation and bracing methods of "brace firstly, excavation secondly" can all help to reduce slope displacement of foundation pit. It actually reduces the cantilever height of bracing structure and the hollowing time of free face. Therefore, the horizontal displacement of the horizontal internal bracing structure is usually relatively small, for the horizontal internal bracing is usually set at the fore shaft beam on the pile top and can be pre-stressed. In the same way, the position of the first row of anchor rod is properly increased in deep excavation projects of anchored wall bracing structure in austere environment.

GEOTECHNICAL ENGINEERING PROBLEMS OF DEEP EXCAVATIONS CAUSED BY GROUNDWATER

The first terrace of the Yangtze River has the features of binary strata composition and three layers of aquifer, with rich ground water, high static water level and confined water head. Therefore in deep excavation engineering water proof and water-resisting measures must be taken.

Seepage of perched water and phreatic water cause abnormal ground subsidence and deformation around deep excavations

The perched water and phreatic water bleed of and seep from the miscellaneous fill or silt, mucky soil of wall or foot of the foundation pit, so that this part of soil mass (most are underconsolidated soil) will become dehydrated, consolidated and compressed, consequently cause ground subsidence.

At the same time, excavation will bring about hydraulic gradient to the phreatic water. When head pressure of the groundwater in the sidewall of the foundation pit surpasses the buoyant weight of the soil mass, the sand grains in the aqueous strata will float to the water surface. Once the phreatic water seeps from the silt or silty sand to the foundation pit, there will form drift sand under action of the dynamic flow pressure. Because of its abundant groundwater and large quantity of sand drifting in the silt or silty sand, if it is handled carelessly, the quick sand will hollow the slope foot of the foundation pit, making the surrounding ground differential settle, and even causing the slope to fail.

Quick sand makes great differences with piping in concept. The former is sand grains (mostly silty sand and fine sand grains) that suspend and flow over the ground under buoyancy of the groundwater, which happens mostly in the aqueous strata with poorly-graded soil. The later mostly happen in sand layer with well-graded soil (coefficient of uniformity C≥ 5), where when the groundwater flow velocity exceeds the critical velocity of sand of certain grain size in the sand layer, sand of smaller sizes will flow over the aqueous strata in shape of pipes, and sand of larger grain sizes remaining in the aqueous strata.

Piping and soil flow also occurs in deep excavations in the first terrace of Yangtze Rive. The former usually occurs in confined aquifer and phreatic aquifer with well-graded soil, while the later takes places in the soft soil strata with larger water capacity, especially in the thick silt strata which natural water content is more than 60%.

Water and sand gushing by the confined water pressure cause extensive land subsidence

As depth of deep excavations increases, the confined water in the confined aquifer will place increasingly higher pressure on the top confining bed, while the confining bed under the pit becomes thinner and pressure by weight of the soil mass decreases gradually. In case that confined sand bed under the pit is exposed in excavation or the top confining bed is insufficiently thick, or there are drilled wells left unfilled in investigation, and no waterproof and seepage prevention measures are taken, piping or extensive sudden surging will occur, which most likely causes instability of slope of the foundation pit and extensive subsidence of the soil strata around.

The following formula may be adopted to calculate the minimum thickness of the top confining bed under the pit needed to resist sudden-surging of the confined water (Figure 2):

$$D \geq \frac{\gamma_w}{\gamma} \cdot \gamma_{ty} \cdot H_w \qquad (1)$$

where γ_{ty} is the coefficient of sudden-surging resistance from 1.0~1.2, D is distance between the bottom of foundation pit to the top surface of confined aquifer in m, H_w is height of confined water head in m, γ_w is gravity of water(10kN m^3), γ is average natural gravity of soil within range of D in kN m^3.

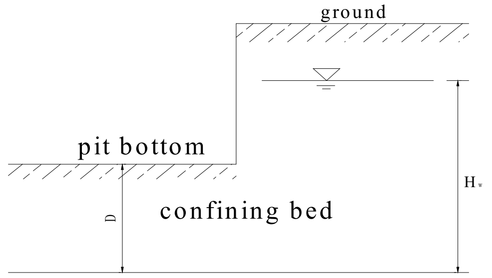

Figure 2. Figure for pit bottom sudden surge checking calculation

Displacement of the tangent piles caused by soil pressure will result in outside ground subsidence, and the area of influence will merely be within range of depth of the foundation pit and the ground subsidence quantity will be slightly smaller than quantity of displacement of the top of the tangent pile; while soil flow (plastic flow, piping, sudden-surging) or water gushing may bring about ground subsidence or displacement to a larger extent, sometimes results in disastrous deformation and devastating effects on the surrounding environment around the deep excavations.

Large-scope regularity land subsidence around the foundation pit caused by groundwater lowering

Since the groundwater lowering of foundation pit has changed seepage field of the groundwater, thus a groundwater depression-cone taking the excavation target depth of foundation pit as the basement is formed. Within the range of precipitation cone, an additional effective stress is formed correspondingly to the soil mass due to the decline of confined water. Between cone curve precipitation and standing level, the effective stress is strengthened with the degree of depth, the additional stress added in the soil layer under cone curve can be considered as the mass surcharge load (Figure 3), more close to the foundation pit on the plane, more the load of the additional stress (surcharge load) will be, and on the lateral section (that is along the vertical depth direction), the stress can be considered as the constant value.

Caused by the pumping and reducing of confined water in deep excavations for the first terrace of Yangtze River, the final peripheral land subsidence ΔS in mm is:

$$\Delta S=\Delta S_1+\Delta S_2+\Delta S_3 \qquad (2)$$

where ΔS_1 (in mm) is the drained-consolidation settlement of the upper overburden layer (top plate of confined aquifer) due to the geostatic stress increase as the uplift pressure is reduced while the confined water level is lowered. ΔS_2(in mm) is the drained-consolidation settlement of the interbedding aquifer as the groundwater is drained in this layer. ΔS_3(in mm) is the consolidation settlement of the underlying layer by increasing of the additional effective stress due to lowering overlying confined aquifer.

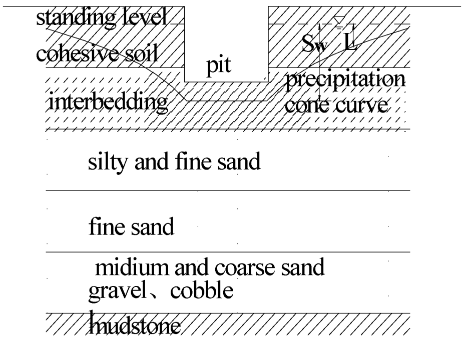

Figure 3. Figure of water level as lowering the confined water

Since these land subsidence is changed along with the descend value (S_w) of ground water level, and the ground water level is successive hydraulic head variation and regular. Theoretically speaking, during foundation pit dewatering, ground subsidence influence range resulted by pumping and reducing of confined water is the range of pumping level drawdown cone, nearer to the foundation pit, greater the descend value water level, greater the ground subsidence with obvious zoning features (see Table.2). Table 2 indicates that the potential ground absolute subsidence volume or differential subsidence ratio resulted by great influence zone is two times of those resulted by general influence zone and several times of weak influence zone. Moreover, the subsidence is in the same scope with foundation pit peripheral ground subsidence resulted by lateral shift of the bracing system of foundation pit, within the scope of 2~4 times of depth of excavation in peripheral foundation pit, thus special attention should be given to its additive effects.

Table 2. Zoning table for peripheral environmental influence due to deep excavations precipitation in the first terrace of Yangtze River

Zoning name	Distribution range (Since the edge of foundation pit)	Land subsidence volume (mm)	Average hydraulic gradient	Remarks
Great influence zone	$0\sim3S_w$	$0.73\Delta S\sim\Delta S$	0.16	This table takes foundation pit area $2000m^2$, and water level decline S_w =10m as example
General influence zone	$3S_w\sim10S_w$	$0.45\Delta S\sim0.73\Delta S$	0.09	
Weak influence zone	$10S_w\sim30S_w$	$0.12\Delta S\sim0.45\Delta S$	0.04	

In the soft soil section of first terrace, due to the reduction of ground water level, regular land subsidence of different degree usually appears in relatively large peripheral range of foundation pit. General speaking, as for the foundation pit with depth in 12m, the differential settlement ratio resulted by lowering confined water in peripheral 30m areas is 0.6‰~2‰, and less than 0.6‰ outside 30m. However, if thick mucky soil or transitional confined aquifer (above 5m) exists in the 1-2 times of water level drawdown range, the amount of deformation of soil mass is great after groundwater oozes because the compressibility modulus of soil mass is low and the water degree is great. Therefore, relatively great differential subsidence is easily generated in the section of which great various soft ground thickness distributions occur. It is easy to do harm to building which is sensitive to ground subsidence,

Varied depth of foundation pit excavation will have harm with different extent and nature resulted from the groundwater. Generally, for shallow foundation pits (e.g. an 6m- deep basement), the main problem is that bleed of the phreatic water or perched groundwater may cause ground subsidence of areas around the foundation pit if the fill strata of the superficial part is dewatered and consolidated or piping occurs to the muddy soil aquifer, thereby endangering the above (constructions) buildings. While in medium depth foundation pits (generally 8m-10m), piping (often from the side wall) of muddy soil or silty sand caused because the pit penetrates or approaches the transition layer will probably cause ground subsidence around the pit or even the side slope instability accident. In foundation pits over 10m deep, there often occurs abrupt gush of the confined water in the sand strata under. If no reliable waterproof, decompression and drainage measures are taken, it certainly will cause extensive abrupt gush of the bottom of foundation pit, resulting in extensive ground subsidence around the pit, sometimes extending to 50m outside the foundation pit.

As for seal of the perched water or phreatic water, sideway water seal curtain is mainly adopted in engineering practice, which mainly forms by means of high-stress spinning and spraying, cement powder spraying piles, static pressure grouting etc. Perched water and underground water distribute in the upper part of the foundation pit, so that the side water pressure is comparatively low. Therefore in waterseal curtain design, primary attention should be paid to the lap between piles with its thickness at 300mm~500mm generally. As for the foundation pit whose confining bed has not been excavated through, the side waterseal curtain should penetrate the fill strata or silt seam, reaching the bottom cohesive soil 2.0m under. If the excavation depth is relatively large and its bed has already entered into the transition layer or aquifer, the side waterseal curtain should reach the soil strata of the foundation pit bottom 4m under, which will on one hand, prevent the flow of lateral soil mass of the foundation pit, and on the other hand, effectively prevent sand flow and sand boil at the foot of slope of the foundation pit. As for confined water, medium deep well dewatering is mainly adopted in Wuhan, etc. to lower the water head value of the pressure aquifer. When the foundation pit exposes the bottom sand body, the medium deep well dewatering can also be useful to drain part of the aquifer.

CONCLUSION

Unique geological historical depositional environment determines the typical binary-layer strata configuration and the hydrogeological feature of the first terrace in middle and lower reach of the Yangtze River. And such engineering geologic conditions to a great extent determine the deformation and failure mode of deep excavations. Unlike in ordinary structural engineering and foundation engineering, rock, soil and aqueous medium in deep excavation engineering are not only objects of construction operation and those that bears load but also subjects generating load and deformation. Due to the uncertainty and distinctive regional feature of the rock and soil material, the engineering geology analogy method based on the Empirical Rule and the Expert System is the major approach in deep excavation engineering concept design. Correct engineering judgment, sieve and optimization of deep excavation engineering plans can only be made by focusing on problems and the environmental characteristics of specific deep excavation engineering plans. This is also the quintessence of geotechnical engineering concept design.

What should be made much of is that in deep excavation in the first terrace of the Yangtze River, the vertical or horizontal seepage prevention curtain, relief and dewatering wells to prevent groundwater inundation are very important engineering measures as important as the bracing structure.

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