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Application of Full Length Adhesive Anti Floating Anchor Rod

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Abstract: With the increasing expansion of urban urbanization in China, the requirements of the project on the floor area are becoming higher and higher, so that the demand for the construction of basements is greatly increased when building large and high-rise buildings, such as houses. As a result, a series of concerns about the safety, reliability, durability, durability and construction convenience of basements have emerged one after another. At the same time, it should also ensure that the economy is at an appropriate level. However, due to the high groundwater level in southern China, different anti floating design problems of buildings are often encountered. Based on the application of anti floating anchor rod in a basement project in Xianning, this paper expounds in detail the construction process, process, quality control and inspection of the full-length bonded anti floating anchor rod in the construction process, so as to provide guidance for the subsequent application of other similar projects

1. Project summary

This project is the shanty town reconstruction project of Xianning High-tech Zone, which is located in Xianning High-tech Zone. The north side of the project is Jingui Avenue, and the plot is basically rectangular. The underground building area is 32751.34m ². This paper takes 1# underground garage as an example. Because Xianning belongs to subtropical monsoon climate, the frost-free period is 260 days, and the precipitation period is mainly spring and summer, with an average annual precipitation of 1580mm.

Xianning is located in wuhan, Hubei province, adjacent to the Yangtze River, and because of abundant precipitation all year round, the groundwater situation is more complex and changeable. According to geological survey report and regional hydrogeological data, the water in the site is mainly upper stagnant water and karst fissure water. During the investigation, the buried depth of the upper stagnant water is 1.70-4.20 meters, and the buried depth of the karst fissure water is 13.50-19.10 meters, which is slightly corrosive to the concrete structure.

Meanwhile, construction delay caused by COVID-19 and groundwater surge caused by heavy rainfall during construction should be considered in the anti-floating design of basement. Under the dynamic change of external objective conditions, the design requirements should meet the limit value, respect the objective conditions, improve construction technology and make corresponding

countermeasures.

The relative elevation of anti-floating water level in this project is -0.450m, and the overall anti-floating of no part of the structure is not satisfied, so anti-floating calculation is needed. After calculation, the basement adopts full-length bonded anti-floating anchor.

2. Introduction of full-length bonded anti-floating anchor bolt

2.1. Anti-floating anchor bolt selection is determined

Full-length bonded anti-floating anchor can be divided into equal diameter and enlarged head. When the anchor end is rock, the same diameter anchor rod is often used in construction. When the anchor end is strongly weathered rock or soil layer, the enlarged head anchor rod is often used in construction design. When a large number of experimental data show that the bolt stress along the anchoring length of the shear stress distribution is very uneven, appeared in the effective anchorage shear stress peak period of the front, as the load increases, the front slip, shear stress peak value increases and the peak position moves down, the shear stress distribution as the anchoring depth decreases until after certain depth is zero. The harder the surrounding rock mass is, the larger the shear stress peak value is and the shorter the shear stress distribution length is. The softer the surrounding rock mass is, the smaller the shear stress peak is and the longer the shear stress distribution length is. When the anchorage length exceeds a certain value, the uplift capacity of bolt is very limited, and the excessively long anchorage section will reduce the construction quality and adversely affect the anchorage effect and durability. Therefore, the appropriate length range of bolt anchoring section is stipulated in various bolt standards.

2.2. Bolt hole forming method

In the process of engineering construction, different construction methods of bolt hole formation and different disturbances around the hole affect the bond strength between grouting body and surrounding soil, and then affect the bearing capacity of bolt. The order of bolt bearing capacity of different hole forming methods is as follows: light drill pipe dry drilling once hole forming method - long screw dry drilling hole forming method - DTH hammer compaction hole forming method - light drill pipe water drilling hole forming method. Because the light drill pipe dry drilling method is used in the construction, the soil within the drilling range is stirred, the damage to the soil around the hole wall is minimal. The DTH hammer compaction method is the compaction method without soil discharge. When using this method, the soil within the drilling range is squeezed into the hole wall, affecting the permeability of the formation. When drilling holes with light drill pipe, mud skin is formed around the hole wall, which greatly affects the penetration of cement grout into the formation. Therefore, when designing bolt, attention should be paid to the requirements of hole forming method.

2.3. The influence of slurry materials

The commonly used materials are cement slurry, cement mortar and fine stone concrete. Although the compressive strength is generally used to represent the strength grade of the slurry, the tensile strength of the slurry is the main factor affecting the anchoring force of the bolt. Due to the existence of coarse and fine aggregate, the friction resistance between micro particles in the matrix is increased. Under the same conditions, the order of tensile strength of the above three slurry materials is fine stone concrete > cement mortar > cement slurry. The test shows that the bond state between concrete and bar body is better than that between mortar and bar body, and the balance between concrete and bar body can be realized with shorter force transmission path. When the bolt is under tension, the

force is transferred from the bolt to the grouting body and then to the surrounding soil body. The grouting body assumes the role of stress transfer between the bolt and the surrounding soil body, and the grouting strength is the main factor affecting the bearing capacity of the bolt.

2.4. Influence factors of bolt bearing capacity

Besides the length, the factors affecting the bearing capacity of the full-length bonded anti-floating bolt include the strength of the reinforcement, the strength of the grouting, the bond strength of the interface between the reinforcement and the grouting, and the bond strength of the interface between the grouting and the surrounding soil. The bond between grout and surrounding soil is composed of chemical adhesive force, friction force and mechanical bite. The surface shape and coating of the reinforcement, the infiltration degree of the grouting and the shear strength of the grouting determine the size of the interface adhesion. When the surface of the reinforcement is convex and rough, the bite effect between the reinforcement and the slurry is better. If the surface of the reinforcement is coated with anti-corrosion coating, the bond strength between the reinforcement and the slurry will be significantly reduced.

3. Application of full-length bonded anti-floating anchor bolt

3.1. Anti-floating bolt selection

The anti-floating bolts designed in this project are full-length adhesive bolts, with lengths of 10m, 12m and 14m and diameters of 180mm. The main bars of no.1 basement are 3 with diameters of 18mm. (as shown in the figure) There are 3 main bars of m1 bolt in no.2 bunker with diameter of 18mm, 3 main bars of M2 and M3 bolts with diameter of 20mm, and 3 main bars of civil air defense with diameter of 20mm. They are fixed with limit of 12 short bars with diameter of 1.5m along the whole length. The characteristic values of single anchor bearing capacity M1 and M2 of 1# basement are not less than 135KN; the characteristic values of single anchor bearing capacity M1, M2 and M3 of 2# basement are not less than 135KN, 190KN and 160KN; the characteristic values of single anchor bearing capacity of civil air defense part are not less than 100KN. Considering the micro-corrosivity of groundwater [1], bolts should be treated with anti-corrosion of II level.

Figure 1: Schematic diagram of main reinforcement of anti floating anchor rod

3.2. Anti-floating bolt arrangement

The anti-floating bolts of the project are set in the underground garage area between the main buildings, which are divided into 649 m1 bolts and 128 M2 bolts of the second phase garage, 1210 M1 bolts, 371 M2 bolts and 224 M3 bolts of the second phase garage, 1548 bolts of the civil air defense part, and the transverse spacing between bolts is 2 meters. The vertical spacing is 2.5 meters, and the total number of bolts is 4,130.

3.3. Construction technology of anti-floating anchor bolt

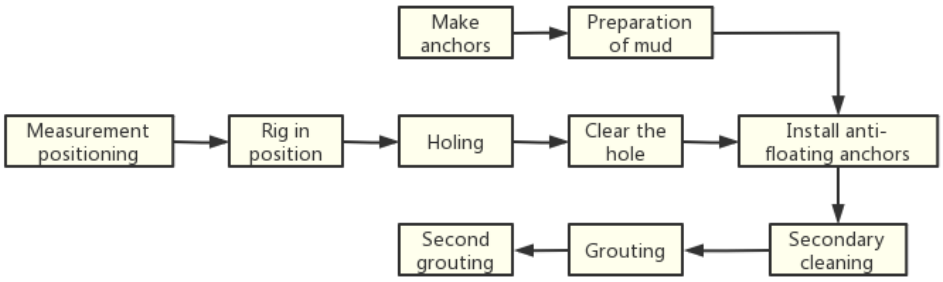

Figure 2: Construction flow chart of anti floating anchor rod

3.3.1. Measurement positioning

When the site is excavated to the upper 300mm of the design elevation, the hole position of the anti-floating bolt shall be measured and released with the total station instrument, and the steel bar shall be marked and numbered. The deviation of the bolt hole position shall be no more than 100mm. If affected by the building, according to the actual situation to negotiate positioning, grouting.

3.3.2. Drilling emplacement

After the bolt hole location is determined, the drilling rig can be moved into place. The drilling rig should be leveled and stable to ensure that the drilling rig will not have large shaking during the drilling process and affect the drilling construction. The perpendicularity of the drill pipe should be adjusted with a hanging hammer, and the deviation of the perpendicularity of the drill pipe should not be more than 1%.

3.3.3. Drilling

Drilling began after the drilling rig was in place. The diameter of the hole was 180mm, the depth of the hole was 10m, 12m and 14m, and the vertical and horizontal deviation of the drilling position should not be more than 100mm. After hole forming, use wire hammer to check the depth of drilling, and the depth deviation is +100/-30mm. The site construction personnel should make a drilling record for each bolt. Due to uneven distribution of basement soil layer, the bolt length shall meet the following conditions: 1# basement a, the basement is located in layer 3-1, and the depth from the bedrock (layer 4-1 or 4-2) is large (more than 8m), the effective length of M1 bolt shall be no less than 12m, m2 bolt shall be no less than 10m, b. The base is located in layer 3-1, and the depth from the bedrock (layer 4-1 or 4-2) is small, the length of the bolt into the bedrock must not be less than 2m; 2# basement A. The basement is located at layer 3-1, and the depth from the bedrock (layer 4-1 or 4-2) is large (more than 8m). The effective length of M1 bolt must be no less than 10m, and m2 bolt must be no less than 12m. Due to the large layer 3-1 in some areas, The effective length of M3 bolt shall be no less than 14m in the basement with a large depth (greater than 12m) from the bedrock. B. The base is located in the 3-1 layer with a small depth from the bedrock (4-1 or 4-2 layer), and the length of bolt entering the bedrock shall be no less than 2m; For civil air defense part a, the base is located in the 3-1 layer and has a large depth (greater than 8m) from the bedrock (4-1 or 4-2 layer), the effective length of the bolt shall be no less than 10m; b, the base is located in the 3-1 layer and has a small depth from the bedrock (4-1 or 4-2 layer), the length of the bolt into the bedrock shall be no less than 1m. Bolt construction should closely cooperate with the investigation unit, and do a good job of construction records, rock gap, karst cave, etc., should be done by the geological investigation unit construction investigation, by the investigation unit to issue a specific treatment plan.

3.3.4. Hole cleaning

When the hole reaches the design depth, high pressure water is used to clear the hole before grouting and discharge the sediment in the hole until relatively clean water without a large amount of sediment is returned from the hole mouth. However, it should be noted that the cleaning time should not be too long to prevent hole collapse from affecting the quality of tube drawing and grouting.

3.3.5. Bolt placed

Before placing the bolt in the drilling hole, the rock powder and soil debris in the hole should be cleaned, and the steel bar should be straight, in addition to oil, rust removal. After the bolt is made, insert the grouting pipe (check whether it is cracked or blocked in advance) into the bolt body, and bind it with proper tightness, so that it is easier to pull out after grouting. The grouting pipe should be put into the hole together with the bolt. The distortion, bending and loosening of the bolt should be avoided when the anchor is lowered, and reinforcement measures should be taken to prevent the bolt body from deviation. In the process of anchoring, if the rod body cannot go down to the bottom of the hole or the grouting pipe obviously rises too long, the rod body should be pulled out and the drill should be used to sweep the hole again or the grouting pipe should be installed before anchoring [3].

3.3.6. Slurry preparation

The cement slurry used in this project is pure cement slurry with water cement ratio of 1.0. Sulphate-resistant cement should be preferred for slurry mixing, and its quality should comply with the provisions of the current national standard "Portland Cement, ordinary Portland Cement" GB175, and high aluminum cement should not be used. Cement strength grade is not less than 42.5, water cement ratio should be 0.45~0.50, mixing water should be drinking water; The content of chloride in cement slurry shall not exceed 0.1% by weight of cement. If adding admixture in slurry, admixture shall not affect the bonding performance of slurry and corrosion of steel, and shall be verified by the test before use. Cement slurry should be mixed evenly, used along with mixing, and used up before the initial setting. Prevent stones and sundries from mixing with grout.

The compressive strength of cement slurry should not be less than 30MPa, and the compressive strength test should be carried out. At least one group of test blocks should be made for every 30 bolts, and there should be no less than 6 test blocks for each group.

3.3.7. Grouting

The hole should be cleared again after the anchor is placed, and grouting can be started after completion. The outlet of the grouting pipe should be inserted 300 places away from the bottom of the hole, and the slurry should be continuously poured from bottom to top, and smooth drainage and exhaust from the hole should be ensured. The grouting equipment should have sufficient grout production capacity and the required rated pressure, and the grouting pipe adopted should be able to complete the continuous grouting of a single bolt within 1h. The rotary jet pressure of the grouting pipe is 25-30mpa, the slurry volume is 75L/min, and the rotary jet lifting speed is 10-20cm /min. When the cement slurry is seen to overflow from the orifice, the grouting can be stopped and the grouting pipe is gradually pulled out until the orifice is pulled out. It is required to ensure that the cement slurry in the orifice is full. After grouting, the bolt head should be temporarily supported to ensure the bolt in the central position of the hole mouth. After grouting, it is not allowed to hit the rod body at will, nor to hang heavy objects on the rod body.

In the process of grouting, if it is found that the amount of grouting is greatly reduced or the

grouting pipe bursts, the rod body and the grouting pipe should be pulled out, and the bolt body should be lowered after the grouting pipe is replaced. If the delay in the middle is too long and exceeds the initial grout setting time, the hole should be re-cleared, anchor, grouting. Construction personnel should make detailed and complete construction records during grouting.

3.3.8. Anti-floating bolt connection

The detailed drawing of the joint between anti-floating bolt and foundation raft in this project is as follows:

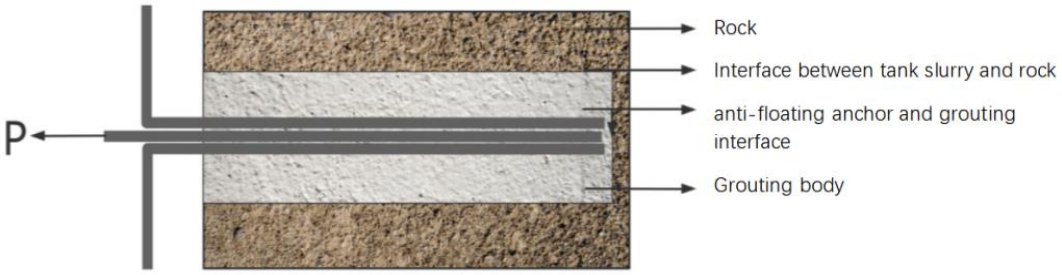

Figure 3: Connection diagram of anti floating anchor rod and foundation

4. Anti-corrosion durability of bolt

4.1. Durability design of bolt

The anchor bolt is under tension for a long time, and there are a lot of corrosive media, such as sulfate ions and chloride ions, in rock and ground water. On the one hand, the crack of grout under long-term tensile stress will accelerate the invasion of corrosive medium with the development of cracks. On the other hand, when the corrosive medium enters the interior of the slurry, chemical reaction takes place and ettringite and other expansion crystals are generated, which leads to the decrease of the slurry strength. When the corrosive medium reaches the surface of the reinforcement, the rust expansion of the reinforcement will accelerate the cracking of the slurry. The design service life of ordinary house construction is generally 50 years. How to ensure the durability of bolt to meet the requirements of service life of 50 years or permanent durability is a problem that should be paid attention to in the future [1].

4.2. Bolt reinforcement is corrosion resistant

4.2.1. Steel bar corrosion prevention

General thread steel is usually used in the full-length bond anti-floating anchor bar, and prestressed thread high strength steel is used when the anchor bar has a large bearing capacity. The corrosion of reinforcement is the coupling action of stress corrosion and electrochemical corrosion. Although the strong alkali environment generated in the early cement hydration process generated a layer of dense oxide passivation film on the surface of steel bars to prevent rust [2], in the weak position of the grip layer, corrosive media such as weak acidic groundwater and chloride ions spread from cracks to the surface of steel bars, and the passivation film is easy to be destroyed, leading to corrosion of steel bars. As the steel bar rusts and expands, the annular tensile stress of the slurry is greater than the tensile strength of the slurry under the combined action of rust expansion force and surrounding rock constraints, and the slurry cracks, reducing the bond between the bar and the slurry. The reinforcement corrosion destroys the effective transfer path from bolt to mortar, resulting in the decrease of ultimate tensile force of bolt and the increase of slip at anchor end. Under the action of tensile force, the axial

force of full-length bonded anti-floating bolt is the largest at the orifice, where the slurry is the most easy to crack. Researchers at home and abroad have proposed a series of corrosion prevention methods for reinforcement, such as surface coating of reinforcement, improving the density and impermeability of slurry, adding rust inhibitor and so on. The corrosion of reinforcement usually starts from the pitting of the weak protected parts such as the cracks of the slurry and the positioner of the bar body, and the corrosion position is not uniform and the dispersion is large. First consider the reinforcement surface anti-corrosion measures, can choose epoxy coating reinforcement or coated in the reinforcement surface epoxy asphalt and other anti-corrosion materials. Because the anti-corrosion coating affects the bond strength of the reinforcement and slurry, it should be noted that the anti-corrosion coating should not be used in the anchoring section and the scope of anchoring main structure, and the length with anti-corrosion coating should not be included in the calculation of bond bearing capacity and anchorage length. When the distance between anchor bolt and bottom plate is long, it can be divided into free segment and anchorage segment, and anti-corrosion measures should be taken in sections. In the free section of bolt, the anti-corrosion of the reinforcement should be strengthened, and the influence of the anti-corrosion on the bond strength should be paid attention to when taking anti-corrosion measures for the anchoring section of bolt.

4.2.2. Nonmetal corrosion protection

In order to solve the problem of reinforcement corrosion, some scholars have introduced new bolt material, such as glass fiber reinforced polymer, which has the advantages of small mass, high tensile strength and strong corrosion resistance, and is favored by engineering circles. There are many surface forms of GFRP [3] reinforcement, among which the screw type increases the occlusion between the reinforcement and the slurry due to its surface protrusion, and the bond strength is the largest. GFRP bolt with the same diameter has larger anchorage force than steel bolt, but the anchor head displacement is larger. The shear stress peak of GFRP bolt appears at 0.9m below the ground of the anchorage section, and cracks and fiber spalling appear at the GFRP bolt body under the ultimate load, which is analyzed as low elastic modulus and shear strength of GFRP [4]. In addition, due to its high brittleness, it is not suitable for bending, so connectors and anchors need special development and design. Therefore, only when the bearing capacity of bolt is not large, the displacement requirement is not high, and the length is not more than 12m, GFRP and other non-metallic reinforcement bolt can be used to solve the problem of reinforcement corrosion.

Bolt corrosion protection level and measures, should be based on the design of the bolt use fixed number of year and formation with and without corrosion, corrosion environment of permanent anchor should adopt I double anti-corrosion protection structure, corrosion environment of temporary permanent anchor bolt and non corrosive environment should adopt II simple anti-corrosion protection structure, the design level is II [4], Class II anticorrosion protection structure should conform to the following table:

Table 1: Protection table of anchor rod and anchorage

Anti-corrosion protection grade	Bolt type	Protection requirements for bolts and anchors		
		The anchor head	Free period	The anchorage segment
II	Tension type, tension dispersion type	Use transition tube, anchor with steel cover protection or coated with antiseptic grease	Use grease - injected sheath or unbonded strand	grouting

In addition to the above, the lap length of cement slurry and free section protection pipe shall not be less than 0.3m, and the thickness of cement slurry protection layer shall not be less than 20mm.

5. Summary

Based on geographical conditions, economic needs and humanistic requirements, this paper simply expounds the use principle, practical application, construction requirements and matters needing attention of full-length bonded anti-floating anchor bolt, and clearly shows the importance of full-length bonded anti-floating anchor bolt to underground construction in areas with high groundwater level. As a result, the pressure of land occupation in urbanization has been alleviated to a certain extent, and the "green" construction has also been developed accordingly. Therefore, the benefits of the full-length bonded anti-floating bolt technology are greater than the disadvantages.

At the same time, with the continuous development of anti-floating bolt technology, the content of this paper still needs to be improved, if there is any mistake, please also criticize and correct.

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