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Research on Anti-Seepage Technology of Basement in Soft Soil Area by Drainage

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Research on Anti-Seepage Technology of Basement in Soft Soil Area by Drainage

Ning Wu [1], Liefeng Xu [1] and Longhui Xiao[2*]

[1] Guangzhou Environment Protection Investigation Co., Ltd., Guangzhou 510060, China;
[2] South China University of Technology, Guangzhou 510641, China
Email: 2824716967@qq.com

Abstract. In recent years, the modernization process of cities has been accelerated, and the scale of basement construction has been continuously expanded. The groundwater table in the southern soft soil areas is usually high, and the water pressure carried by the basement floor is often large, thus the accidents of leakage from the floor and exterior walls occur from time to time, which seriously affects the safety and use function of the basement. In this paper, based on a basement project in a soft soil area, a method of using drainage for anti-seepage treatment is proposed. By placing large diameter sand-free concrete relief wells at appropriate spacing in the basement, the seepage water in the basement is channeled into the relief wells through sand-free concrete to play the role of decompression and anti-seepage. The practice results show that the drainage system can effectively solve the leakage problem of basement floor with low cost.

Keywords. Anti-seepage,Drainage,Seepage Flow, Relief Wells

1. Introduction

With the rapid development of urban modernization, the development and utilization of underground space is becoming more and more extensive, and the scale of basement construction is getting bigger and bigger [1-2]. The basement is buried underground for a long time, and its bottom slab needs to bear the pressure of existing groundwater. In the actual construction and use process, if proper anti-seepage treatment is not carried out, it is easy to cause the leakage of the structural slab, which seriously affects the use function of the basement [3] .

In recent years, serious basement leakage accidents have occurred from time to time, causing great concern from all walks of life, especially in the soft soil areas of the south where groundwater is abundant and the groundwater seepage environment is complex. The external walls and floor slabs of basements are susceptible to the erosion of ground tides or groundwater, and the phenomenon of basement leakage has become one of the common problems of quality [4-5].Water leakage in a basement can have serious structural, durability and functional implications. The matter is worsened if leakage happens during the operational phase which could have serious financial and functional consequences [6]. In this context, it is of great practical significance to explore the problem of basement seepage prevention and propose feasible anti-seepage measures.

There are numerous reasons for water seepage and leakage in basements, mainly due to irregular basement construction, unreasonable design of impermeable structures, other construction problems, etc. After cracks appear in the external wall of the basement floor, the lack of structural waterproofing and impermeability leads to leakage [7-9]. At present, for possible water seepage problems, engineering often adopts the sealing method for seepage prevention treatment. Grouting is used to seal leaks at the point of seepage, using chemical grouting to inject slurry into the cracks in the concrete, causing it to spread and solidify, to achieve the purpose of plugging and waterproofing [10-12].

The conventional treatment of water seepage described above can only passively prevent leakage and cannot effectively reduce the water pressure acting on the bottom slab, which makes it difficult to ensure the reliability of the treatment. And the risk of cracking and seepage of the basement external walls and bottom slab remains high.Waterproof and leak-plugging methods often consume huge engineering resources, but still cannot guarantee the safety and comfort levels' long-term use of the structure [13].

This paper applies an active drainage seepage resistance method. The core of this method is to reduce the water table through drainage, reduce the water load on the structural subgrade, and improve the seepage resistance reliability of the underground structure. Based on a basement project example, this paper provides a new idea of basement impermeability treatment by setting up drainage depressurization shallow wells to reduce the bottom slab water pressure, which can effectively solve the seepage problem and greatly reduce the risk of water seepage.

2. Project Overview

A basement proposed site is located in Zhuhai City, the original landform of the project site belongs to the coastal shallow marine landform.

According to the geological survey report, the site stratigraphy from top to bottom can be mainly divided into 3 layers: artificial fill layer, sea-land intersection sediment layer,and Yanshan III granite weathering layer. Figure 1 shows one of the typical engineering geological profiles.

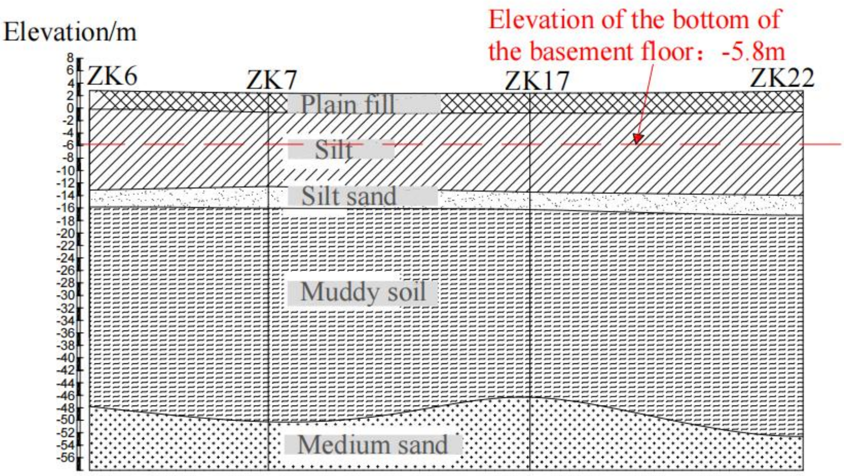

Figure 1. Typical engineering geological profile

The basement of the project is about 170m long, 160m wide, 652.3m in circumference, and the planned area is about 27216.4m^2 . The absolute elevation of ±0.000 of the site is 3.7m (1956 Yellow Sea elevation system), and the elevation of the bottom surface of the basement floor relative to ±0.000 is -5.8m.

The project was about to be completed when there was a more serious leakage problem, as shown in figure 2. the bottom plate of the negative second floor of the basement local column edge, bearing platform cracking damage, as many as more than 16, as well as the basement exterior wall cracking in many places, and cracking water seepage, seepage and cracking parts as shown in figure 3. In general, the basement bearing platform, exterior walls and other seepage parts are relatively discrete, and water seepage has a recurring nature.

Figure 2. Cracking and water seepage of basement exterior wall

Figure 3. Schematic diagram of water seepage areas and cracking areas

3. Analysis of Accident Treatment Plan

After analysis, the reasons that may lead to water seepage damage of the basement slab are as follows: due to the northwest side of the site near the waterway, and the upper layer of the blow-fill sand endowed with stagnant water, water-rich by the tidal flood and precipitation influence. In the rainy season, the groundwater level around the site rises, and then the groundwater infiltrates to the area where the basement slab is located, making the water pressure of the basement slab is greater than the maximum value that the basement slab can withstand, which leads to the local cracking and seepage of the basement slab, exterior walls, etc.

According to the characteristics of the surrounding strata, the site is mainly weakly permeable, the basement floor is in a thick silt layer, and the permeable powder sand layer is located 7 m below the floor. the foundation pit support program has adopted water stop curtain to effectively intercept the groundwater. Due to the discrete seepage parts, such as column edge, bearing platform and exterior wall, it is difficult to ensure the reliability of the conventional treatment of water seepage, and the risk of water seepage on exterior wall and bottom slab is still high. If we can effectively reduce the water pressure on the bottom slab, we can better solve the problem of water seepage in basement bottom slab and exterior wall.

According to the above characteristics, the solution of relief well is used to reduce the head value of the bottom surface of the basement floor, so that the water pressure on the basement floor can be reduced to solve the leakage problem caused by the increase of water pressure on the bottom surface of the basement floor due to strong precipitation and other working conditions, and to control the influence of drainage on the surrounding environment.

The relief well is located close to the existing water catchment well, and the water is pumped out by the water collection system after it enters the water collection system by itself, so that the water level under the bottom plate is constant. In summary, a "water stop curtain + relief well + self-flow into the water collection system" drainage pressure reduction system can be used, as shown in figure 4.

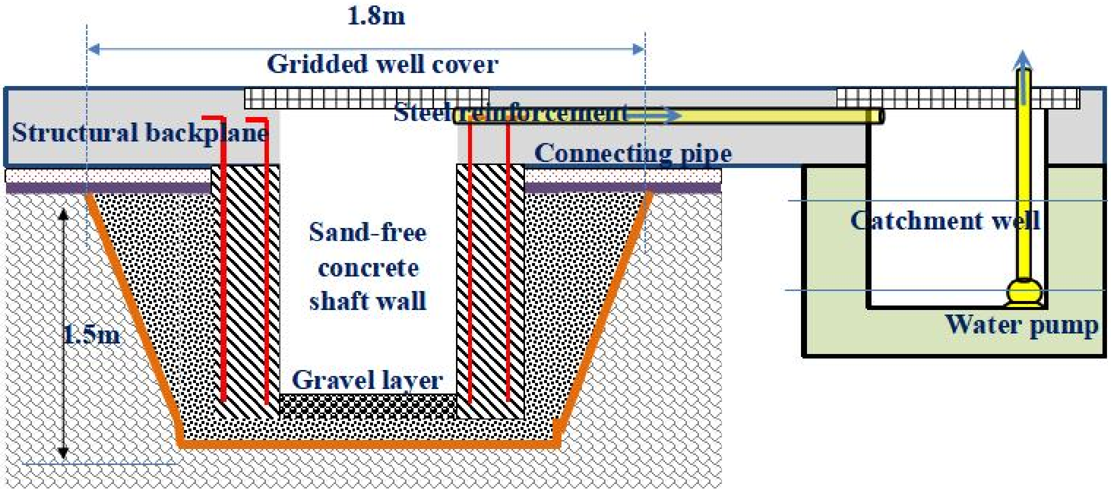

Figure 4. "Water stop curtain + relief well + self-flow into the water collection system"

Drainage depressurization system

4. Basement Floor Relief Well Arrangement Scheme

In order to ensure the long-term effectiveness of drainage measures, the drainage structure of this project adopts large diameter sand-free concrete relief wells [14]. Firstly, it is convenient to enter for maintenance; secondly, it increases its water crossing section, reduces hydraulic slope drop and prevents blockage from occurring. The relief well is close to the existing catchment wells, and the water from the relief well is discharged to the catchment wells by stainless steel pipes; the two adjacent catchment wells are connected to each other by stainless steel pipes to form a cluster of catchment wells, which work together. Two submersible pumps are set up in each collecting well to pump water outward. In order to check the decompression effect of the controlled area after setting the relief wells, a long-term water level monitoring system is set up inside the basement to monitor the working performance of the decompression system.

4.1. Plane Layout of Relief Wells.

A total of 24 relief wells were arranged near the cracked seepage area around the entire basement perimeter floor and part of the column side, set at the top of the second floor basement floor, with the wellhead elevation of -5.2m and the bottom elevation of -7.8m.

The shallow relief wells are evenly arranged, and in order to reduce the slotting on the floor, the relief wells are arranged close to the existing catchment wells, and the plane layout of the relief wells used is shown in figure 5.

4.2. Structure Setting of Relief wells.

The inner diameter of the relief well is 1200mm, outer diameter is 2400mm, the wall of the well is made of 300mm thick sand-free concrete material, and a 300mm coarse sand backfilter layer is set on the outside and the bottom, the position of the well opening is flush with the decoration layer, and a 800mm diameter opening is left to set the steel grille cover as the maintenance entrance. Since it is not convenient to open holes in the human defense area, so for 10 relief wells in the human defense area, after the construction of relief wells, a "back" shaped human defense partition wall is laid along the negative second floor of the basement to extend the opening of relief wells to the negative first floor of the basement, and stainless steel climbing ladders are installed on the human defense partition wall to facilitate maintenance personnel to go down the wells for maintenance.

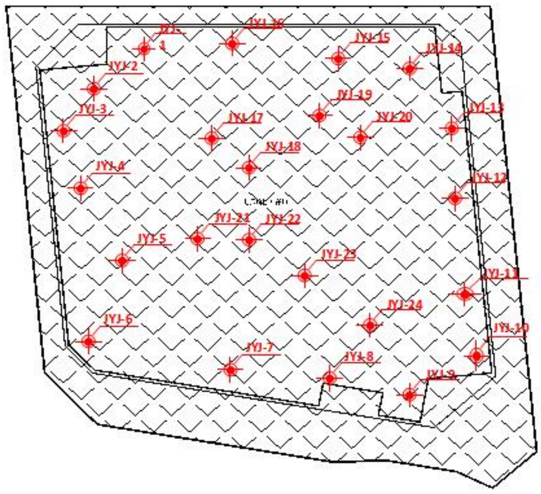

Figure 5. Plane layout of relief wells

The relief well wall can be divided into four prefabricated pieces, also according to the lifting situation can take a semi-circular ring or circular ring prefabricated. After the bottom plate is cut out and punched into the channel steel to form the support structure, the channel steel is lapped forward and backward, the bottom elevation of the channel steel is -9.00m, the channel steel is closed after excavating the silt layer to the elevation of -6.10m to set a support, after digging to -8.10m, laying 300mm after the gravel bedding as the bearing structure of the relief well. After the masonry of the sand-free concrete well wall was completed, an inverted filter layer consisting of medium-coarse sand and gravel was laid at the bottom of the well, and the gap between the well wall and the channel steel support was filled tightly with gravel, and the channel steel support was pulled out one by one after the above construction steps were completed. After the completion of the construction of the relief well, digging a slot to bury the stainless steel pipe connecting the relief well with the water catchment well, backfilling the pit with gravel, and the sand and gravel drainage layer into one.

5. Site Seepage Analysis

5.1. Calculation Method.

This calculation uses the horizontal two-way seepage finite element analysis method [15].

5.2. Computational Model.

The calculation area is considered according to the site where the project is located and the influence range of seepage field, and the model boundary is expanded by 2.5 times the project basement side length (400m), and the model boundary length is 970m and 880m respectively.

According to the basement surrounding environment, site geology and the construction of water stop curtain, the calculation model is divided into 3 areas, which are: total project outreach area (zone 1), project support pile borderline (zone 2), and project basement (zone 3), as shown in figure 6.

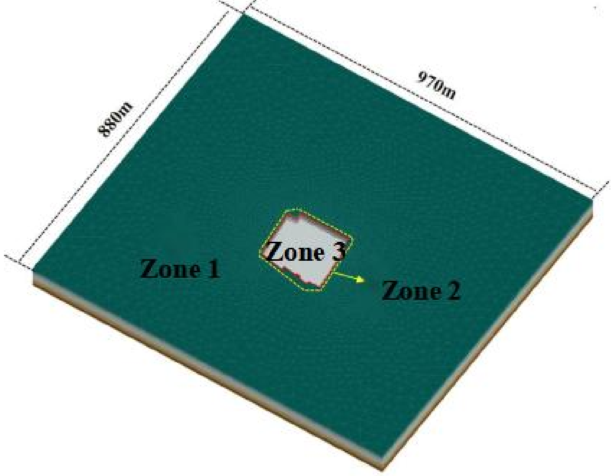

Figure 6. Calculation boundary and model partition

The soil layers in the site from top to bottom are plain fill layer, silt layer <2-1>, powdered sand layer <2-2>, silty soil layer <2-3>, medium sand layer <2-4>, powdered clay layer <2-5>, coarse sand layer <2-6>, and weathered sandstone layer <3>. Through the trial calculation of different soil layer models, it is found that the setting of muddy soil below the silt layer has little influence on the analysis results, that is, the lowest layer of the soil layer model is set after-17.2 at the bottom of the silt layer, and the increase of thickness has little effect on the analysis results. Therefore, the soil layer calculation model is divided into four layers, from top to bottom, which are the plain fill layer, the first silt layer <2-1①>, the second silt layer <2-1②>, and the powdered sand layer <2-2>, and the thickness of each soil layer was taken as the statistical average thickness of soil layers provided in the survey report.Among them, the setting of the first silt layer is mainly to facilitate the analysis of the water head change value of the soil layer where the basement floor is located.

5.3. Boundary Conditions and Parameter Selection.

The coefficient of permeability of the plain fill is 3.02×10-3 cm/s according to the recommendation of the survey report, and the coefficient of permeability of the second layer of silt layer and powdered sand layer is 4.0×10-7 cm/s and 1.0×10-3 cm/s according to the empirical value. At the same time, the permeability coefficient of the first layer of silt layer takes the value of the basement floor surge and pressure distribution is relatively large. Therefore, for the permeability coefficient of the first layer of silt layer, in order to ensure the reliability of the analysis, combined with the water out of the site catchment wells, the layer permeability coefficient inversion analysis, determine the permeability coefficient of the layer is 2.1×10-3cm/s~4.3×10-3 cm/s.

The boundary near West Qinhai Road is taken as the given head boundary in the calculation model, and the given head boundary is taken as 3.7 m.

All computational models were simulated using a given boundary water head plus surface infiltration conditions. In the model to invert the permeability coefficient of the silt layer in which the basement slab is located, the calculation conditions correspond to the rainfall conditions at the time of catchment well discharge collection, and the surface infiltration intensities are taken as 0 mm/d and 30 mm/d, respectively. In the further analysis of the drainage depressurization scenario, the calculation conditions are divided into rainstorm conditions and normal conditions. The rainstorm condition is used to analyze whether the basement floor meets the impermeability requirements under extreme conditions. For the rainstorm condition, the surface infiltration strength is 100 mm/d; for the normal condition, the surface infiltration strength is 0 mm/d.

5.4. Seepage Analysis.
Seepage analysis is conducted for the above scheme of arranging 24 relief wells in rainstorm conditions and normal conditions, respectively. In order to describe more intuitively the change of head in the basement floor of the main analysis area of the site, and to analyze the change of water head in the depth direction before and after the adoption of relief wells later on, two typical profiles are selected, as shown in figure 7. The longitudinal profile is oriented east-west and the transverse profile is oriented north-south.

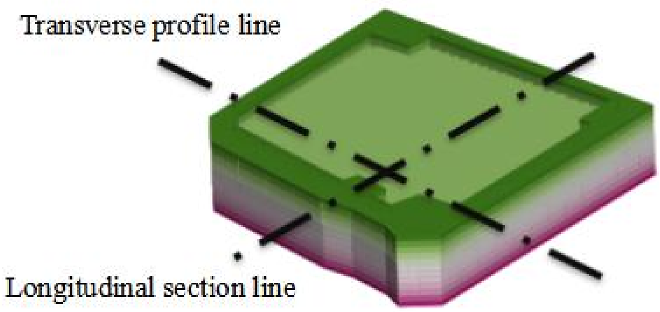

Figure 7. Schematic diagram of basement longitudinal and transverse direction section

Under rainstorm conditions, the water head around the site is 3.5 m. After 24 shallow wells are arranged in the basement, the water head contour diagrams of the basement profile are shown in figure 8 and figure 9, respectively, the head of the basement near the area of the relief wells is -5 m, and the maximum head reduction is up to 8.5 m. The water head of the local basement near the exterior wall is -3 m, which is 6.5 m lower than the water head around the site.

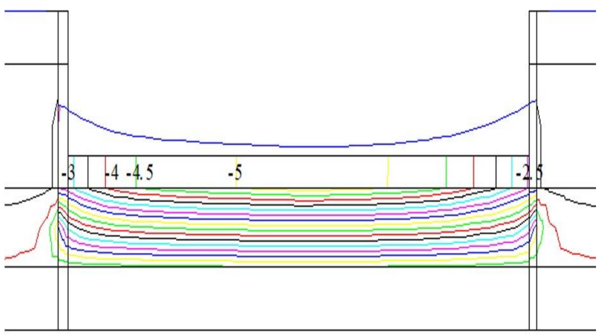

Figure8. Isoline map of water head in longitudinal profile
(under rainstorm conditions Unit: m)

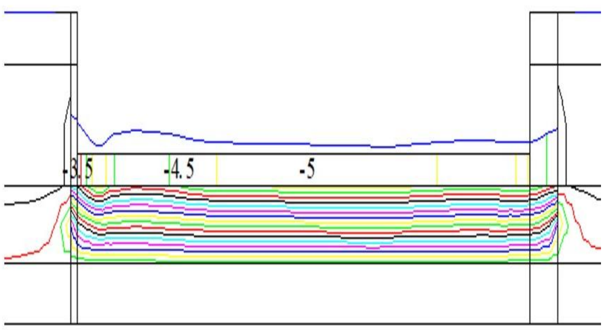

Figure 9. Isoline map of water head in transverse section
(under rainstorm conditions Unit: m)

The water head distribution of the entire project area in the basement floor depth position (-5.8m) under the rainstorm conditions is shown in figure 10. After the deployment of relief wells, the water head of the basement slab position near the shallow relief wells under rainstorm conditions is obviously reduced, and the water head value of the basement slab of the whole project is evenly distributed, with the local minimum water head value of -5.5 m and the maximum water head value of -2.5 m. It can be seen that after the installation of relief wells in the basement slab, the head of the basement slab of the whole project is reduced by about 6.0~9.0 m compared with the water head of the surrounding area of the site, and the head of about 90% of the basement slab area is reduced by more than 7.0 m. The effect of pressure reduction is obvious and has an impact on the surrounding environment. The head reduction value of the basement floor is more than 7.0 m. The pressure reduction effect is obvious and has less impact on the surrounding environment. At the same time, the water pressure in the basement floor of the project was significantly reduced after adopting the relief well solution. The minimum water pressure of the basement slab near the relief wells is 5 kPa, and the maximum water pressure near the exterior wall of the basement is 35 kPa. Under heavy rainfall conditions, 24 relief wells discharged a total of 771.76 m3 /d. In summary, the arrangement of the basement relief wells greatly improves the reliability of the basement slab against seepage under extreme conditions such as heavy rainfall.

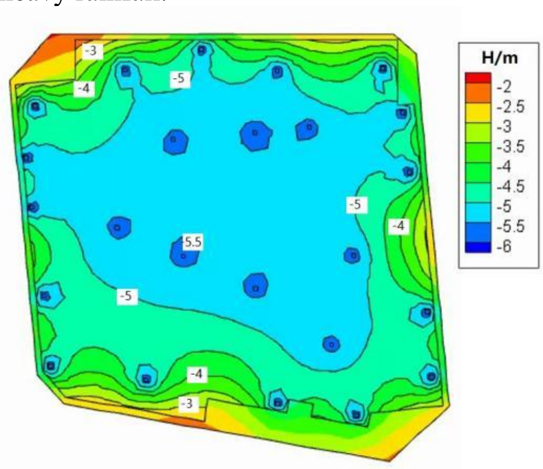

Figure 10. Isoline map of water head distribution of project area at floor depth (under rainstorm conditions)

Under normal conditions, the water head around the site is 0~1 m. After 24 shallow wells are arranged in the basement, the water head contour diagrams of the basement profile are shown in figure 11 and figure 12, respectively, after adopting the overall depressurization scheme, the water head value of the basement near the relief well area is -5.5 m, and the maximum water head reduction is 6.5 m. The local water head value of the basement near the exterior wall is -4.0 m, which is 5.0 m lower than that of the basement. The water head around the site is reduced by 5.0m.

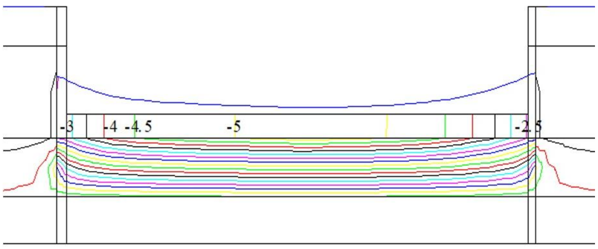

Figure 11. Isoline map of water head in longitudinal profile
(under rainstorm conditions Unit: m)

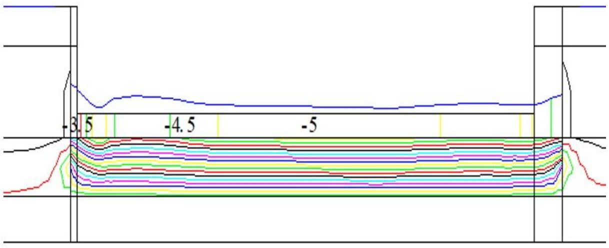

Figure 12. Isoline map of water head in transverse section
(under rainstorm conditions Unit: m

Under normal operating conditions, the head distribution of the entire project area in the basement floor depth position (-5.8m) is shown in figure 13. The head at the location of the baseboard near the shallow well for pressure reduction is obviously reduced, and the head value of the basement floor of the whole project is evenly distributed, with the local minimum head value of -5.5 m and the maximum head value of -4.0 m. It can be seen that after the installation of the relief well at the baseboard, the head of the basement floor of the whole project is reduced by about 4.0~6.5 m compared with the head around the site, and the head of the basement floor is reduced by more than 5.0 m in about 90% of the area, so the pressure reduction The effect is obvious, and the head outside the water stop curtain is basically not reduced, and the impact on the surrounding environment is small.

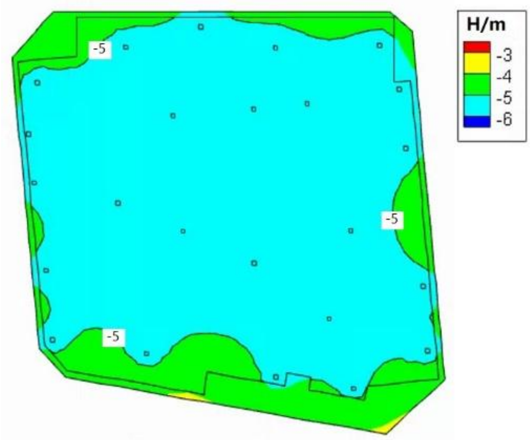

Figure 13. Isoline map of water head distribution of project area at floor depth (under normal working conditions)

6. Water Volume and Water Head Observation

Since the construction was completed in May 2021, the drainage depressurization system system has been operating stably, during which the flow rate of each catchment well and relief well was observed and recorded, and the total pumping volume of the catchment well and weather conditions are shown in figure 14, while the total flow rate of the relief well has been relatively stable in general, indicating that the drainage depressurization system system of "water stop curtain + relief well + self-flow into the catchment system" is working well. The system works well and effectively intercepts a large amount of groundwater at the periphery.

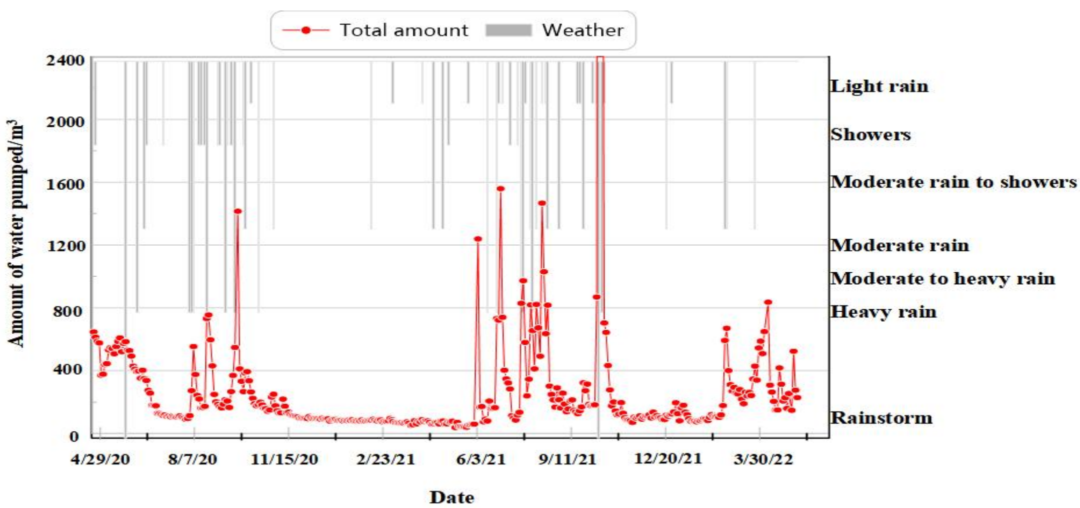

Figure 14. Total water pumped from catchment wells and weather conditions

The water output of the catchment wells is closely related to the rainfall, and the water output of the catchment wells increases with the increase of rainfall intensity, and there is a "hysteresis" phenomenon, that is, the water output gradually increases within two days after the rainfall. It is worth noting that in October 21, due to the sudden heavy rainfall, the total volume of water pumped from the catchment wells increased suddenly and water surges occurred in 4#, 15# and 16# relief wells. In order to increase the drainage capacity, for the occurrence of gushing water 4 #, 15 # and 16 # relief well, increase the flow rate of 200m3 /h centrifugal pump. In the other relief wells, a submersible pump with a flow rate of 25m3 /h and a pipe diameter of 65mm was added. After increasing the drainage capacity, the flow rate of each relief well was restored to be stable.

At the same time, during the operation of the system, real-time observation of the water head of the pressure tube has been carried out, figure 15 indicates the average value of the water head of the pressure tube for each month, as well as the average value of the water head of the pressure tube in heavy rain and the average value of the water head of the pressure tube in normal weather. The monitoring data show that the head of the pressure tube varies slightly, but is relatively stable overall, with the water head of the pressure tube below 220 mm most of the time, while the water head of GC2 and GC11 pipes increased significantly in June 21, August 21, and especially in October 21, probably due to the significant increase in flow caused by rainstorm. During the typhoon rain, the water level rises to the surface and a large amount of water may pass directly through the fill layer, overturn the water stop curtain and enter the fertilizer trough. Under normal working conditions, the overall water head of each pressure measurement pipe is relatively stable.

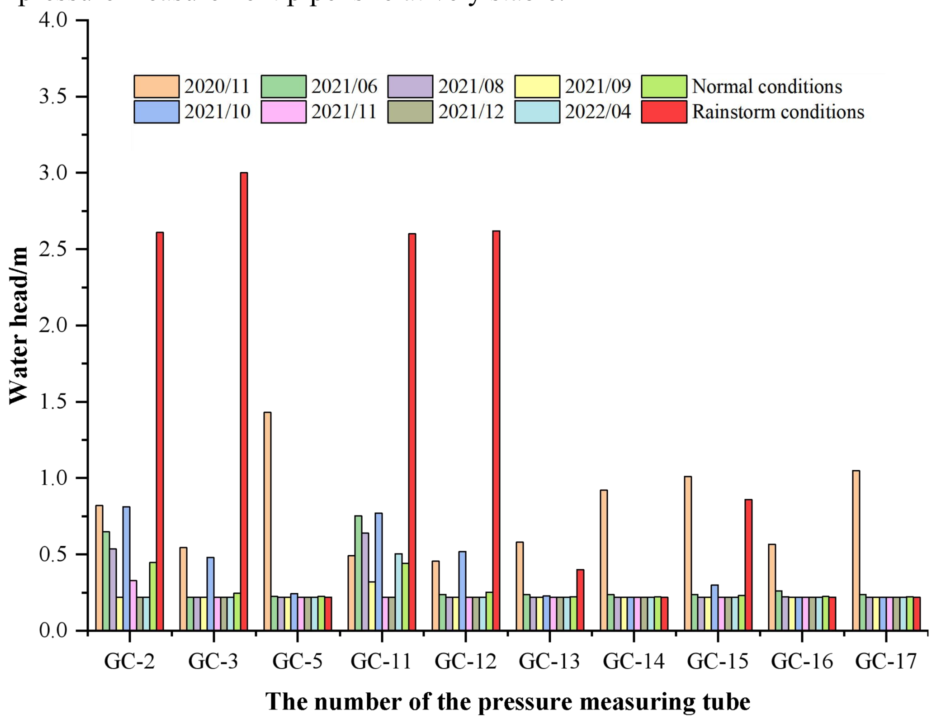

Figure 15. Water head of pressure measuring tube

Overall, the head of each pressure measuring tube was significantly reduced, and the effect of using the system for drainage was obvious.

7. Summary

Since the operation of this drainage and pressure reducing system, there is no obvious water seepage in the basement floor and exterior wall, and the flow of relief wells is stable in general. It proves that the disposal of water seepage accident in basement in soft soil area by using this system is successful, from which the following experiences can be obtained.

(1)When the stratum conditions permit, the use of drainage depressurization system to deal with the basement floor and exterior wall leakage accident project has very obvious advantages.

(2) After the application of the system, the pressure reduction effect is obvious, and the water pressure in the bottom slab is relatively stable, which better solves the problem of water seepage in the basement, and at the same time greatly reduces the risk of water seepage in the bottom slab and exterior wall.

(3) The setting of shallow wells for drainage pressure reduction has almost no effect on the head of water in the area outside the basement water stop curtain, and has very limited impact on the surrounding environment.

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