Detection and analysis of concrete cracks in raft foundation and external wall of a basement

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ABSTRACT

Cracks and water seepage occurred in the raft foundation and basement exterior wall concrete of a commercial complex after construction. After demonstration by an expert group, in order to accurately analyze the causes of concrete cracks, the reinforced protective layer and concrete entity at the cracks were detected by steel bar scanning, core drilling sampling and impact echo method. After detection, some concrete cracks have been penetrated inside and outside, and there are many bubbles formed by insufficient vibration in concrete core samples at individual crack positions. The main reasons for concrete cracks are that the pouring interval is long during concrete construction, local positions are not vibrated tightly, and the concrete can not be cured after pouring. According to the above test results, after the construction unit treated the concrete cracks according to the high-pressure grouting scheme, no leakage was found after observation, which achieved good results and has been put into normal use.

Keywords: Concrete cracks in raft foundation, cracks in concrete wall of basement, concrete core sampling inspection, detection of reinforced protective layer, shock echo detection

1. INTRODUCTION

Cracks and water seepage occurred after the construction of the basement raft foundation and basement exterior wall concrete of a commercial complex project. The problem is how to deal with cracks. After core drilling sampling of the concrete at the crack and testing the impact echo method, the cause of concrete cracks was accurately analyzed, providing a reliable basis for later concrete crack treatment plans.

2. OVERVIEW OF THE PROJECT

2.1 Basic overview

The commercial complex project (hereinafter referred to as “the project”) is located in the city center of a certain city in Gansu Province, China. Its floor plan is shaped like the character “匚”, the east side of the central square with the ancient buildings adjacent to the north, west, south, respectively, adjacent to the city’s main roads; the project building length 206.400 m, width 104.400 m, two underground, three above ground, structural form for the frame structure, the foundation adopts raft + column pier foundation, raft bearing layer for the pebble layer, bearing capacity eigenvalue is not less than 420 KPa, the foundation concrete C35, foundation mat concrete strength grade C20, raft impermeable concrete, seepage resistance grade P8. raft thickness of 500 mm, through-length reinforcement of 500 mm, through-length reinforcement of 500 mm, through-length reinforcement of 500 mm, through-length reinforcement of 500 mm, through-length reinforcement of 500 mm, through-length reinforcement of 400 mm. The thickness of the raft slab is 500 mm, the through-length reinforcement is double-layer bidirectional C16@200, the thickness of the basement wall is 400 mm, the horizontal reinforcement is C14@150, the vertical reinforcement is C18@150, the anti-floating anchor under the foundation of the raft slab is set up, and the reinforcement of the anchor body is 2C25, 2C28, the length of the anchor is 6.5 m, 7.62 m respectively, and the spacing of the anchors is 2.2m, and the design value of the design value of the pull-out capacity of single anchor is 245 kN, 308 kN, 308 kN, and the length of the anchor is 6.5 m, 7.62 m respectively, and the spacing of anchor is 2.2 m. The design value of single anchor pull-out bearing capacity is 245 kN and 308 kN respectively[1].

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2.2 Stratigraphic lithology of the site

The construction site is located in the Heihe alluvial fine-soil plain area, and the strata exposed on the site mainly include Quaternary Holocene miscellaneous fill (Q4mL), Quaternary Holocene alluvial pebbles (Q4mL+pL) and Quaternary Holocene alluvial fine sand (Q4mL+pL). According to the exploration disclosure, the top-to-bottom distribution is as follows. (1) Miscellaneous fill (Q4mL): miscellaneous colour, thickness 2.0 m-3.8 m, dominated by artificial backfill of pebbles. (2) Pebbles (Q4mL+pL): greenish grey, with good gradation, locally sanded with thin layers of fine sand (Q4mL+pL) lenticular body, which is not disclosed by the survey; the groundwater of the site belongs to the pore diving of loose rock type of the fourth system, and the aquifer is mainly a layer of pebbles, and the elevation of groundwater level groundwater table is in the range of -2.8 m to -3.8 m[2].

2.3 Construction and cracks

This project raft slab foundation concrete design after pouring belt sub-district block construction, after pouring belt according to the design of construction practices set; basement wall according to the construction of each sub-district, vertical construction joints are set in the raft above 30 cm, construction joints at the water-stopping steel plate[3]. The construction of the basement began in October 2018, and water seepage of varying degrees was found to have occurred on the basement floor and walls on 24 October 2019 (at which time the underground portion of the construction had been basically completed), and the phenomenon of intermittent stopping of the descending water work occurred during the construction process, resulting in the rise of the groundwater level to a position of about 1.2 m above the elevation of the bottom of the raft slab.

3. ANALYZING ARGUMENTS

After the discovery of water seepage, the construction unit organised the design, supervision, construction unit relevant technical responsible personnel, and invited the province foundation and structural design experts, the cracks appeared the reason for the special argumentation, after verifying the raft and basement wall concrete entity test report, anti-floating anchor test report are in line with the design requirements, the expert group argumentation and analysis unanimously agreed that: The cracks in the external wall and raft slab are regular through cracks, perpendicular to the length direction, analysed in relation to various factors such as the cause of the concrete itself, the pouring process, temperature, etc.; it is recommended to carry out a comprehensive inspection of the concrete cracks, the depth and direction of the cracks, and to formulate a treatment plan based on the final inspection results. In accordance with the recommendations of the Expert Group, the construction unit commissioned a specialised unit to carry out a special test.

4. TESTING OF CONCRETE CRACKS AND REINFORCEMENT PROTECTION LAYER, ETC

4.1 Core drilling and sampling of concrete at cracks for testing

(1) Negative first floor 20~21×A~H axis position basement raft plate crack detection from the field test situation, negative first floor 20~21×A~H axis position basement raft plate stock cracking phenomenon, to the diagonal cracks are mainly (see Figure 1 for the specific location), as can be seen by the actual field observation: (a) From the morphology of the cracks, the cracks are large in the middle and small at both ends; (b) From the degree of crack distribution, the crack width is between 0.1mm and 0.2mm; (c) As can be judged from the water seepage at the location of the cracks at the test site, the cracks have penetrated up and down; (d) Core sampling was carried out at the crack location (see Figure 2 for sampling photos), and it can be seen from the core samples that the cracks within the depth range of the core samples drilled are through cracks, which continue to extend downwards, and the silt carried by the rising water table has already filled some of the cracks in the location[4].

(2) Crack detection of basement wall at 20-24×A axis location in the second negative floor: From the on-site inspection, the basement wall at the 20-24×A axis position of the negative first floor has different degrees of cracking, mainly vertical cracks, irregularly distributed, as can be seen from the actual on-site observation: (a) In terms of crack morphology, the cracks are large in the middle and small at both ends; (b) From the degree of crack distribution, the width of cracks is between 0.1mm and 0.3mm; (c) From the water seepage at the location of the cracks at the testing site, it can be judged that the cracks have penetrated both inside and outside; from the above, it can be seen that the cracks have also penetrated both inside and outside in some of the areas that have not been flooded by water; (d) Core sampling was carried out at the crack location (see Figure 3 for sampling photos). It can be seen from the core samples that the cracks within the depth

range of the core samples drilled are through cracks, and the cracks continue to extend in the depth direction, and the silt brought by the rising water table has already filled up some of the cracks in the location.

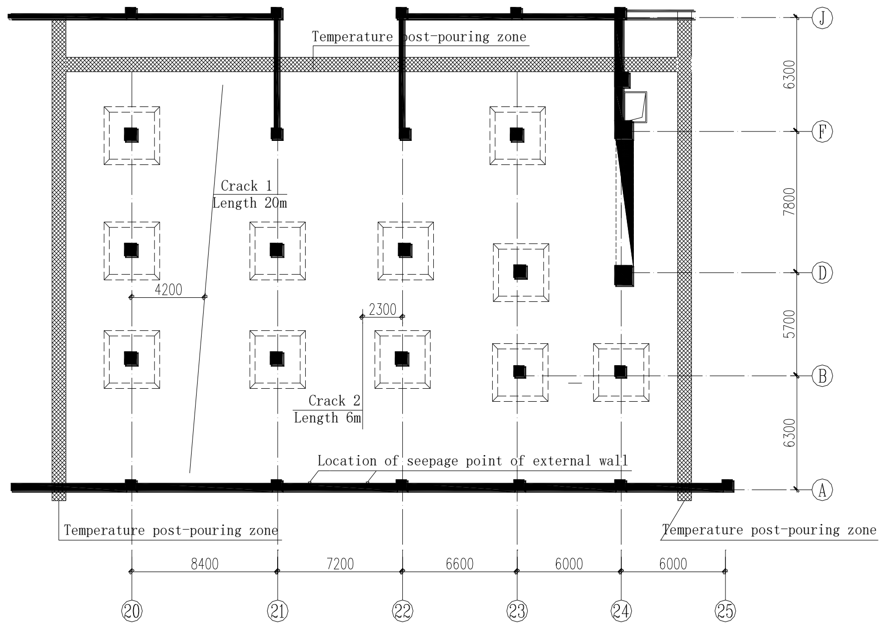

Figure 1. Schematic diagram of concrete crack position.

Figure 2. Sampling photo of raft concrete core.

Figure 3. Sampling photo of concrete core of basement wall.

4.2 Detection of protective layer thickness of reinforcement at crack location

(1) The thickness of the steel bar protective layer above the crack position of the basement raft slab at the 20~21×A~H axis position on the negative second floor of the project was scanned and tested. Judging from the test results, the thickness of the steel bar protective layer at individual positions of the basement raft on the negative second floor is too large and appears near the crack position[5]. The steel bar detection results are as follows (see Figures 4-7):

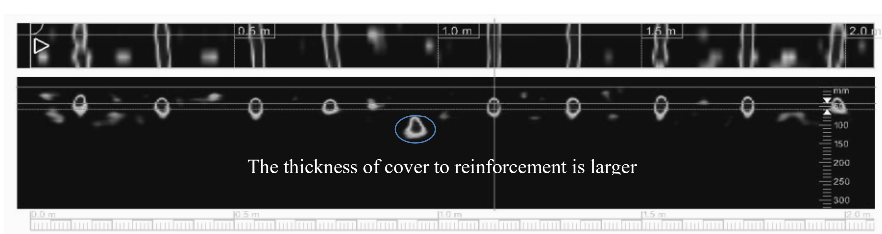

Figure 4. Detection results of reinforcement at points 1# and 2#.

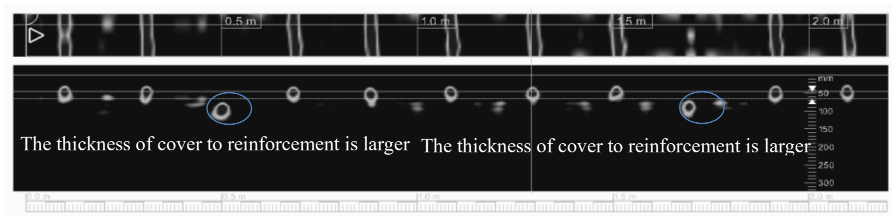

Figure 5. Detection results of reinforcement at point 3#.

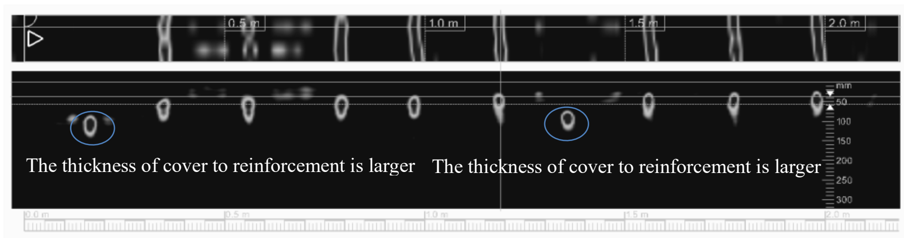

Figure 6. Detection results of rebar at point 4#.

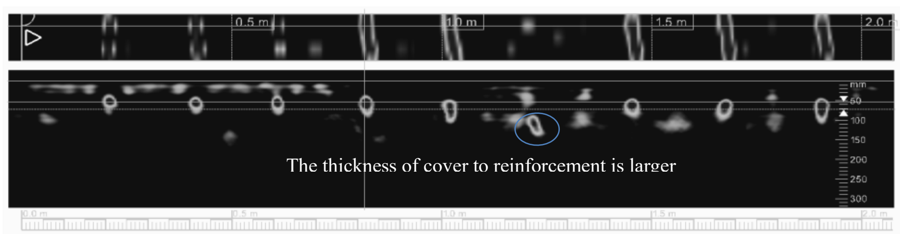

Figure 7. Detection results of reinforcement at point 5#.

From the above results of the analysis of the protective layer of reinforcement, it can be seen that the thickness of the protective layer of reinforcement in individual locations of the basement raft slab in the negative two floors was large and appeared in the vicinity of the location of the cracks.

(2) A rebar scanning test is conducted on the thickness of the protective layer of reinforcement in the basement exterior wall at the location of the axis of the project's negative first floor 20-24×A[6], and the specific test results are as follows (Figures 8-11):

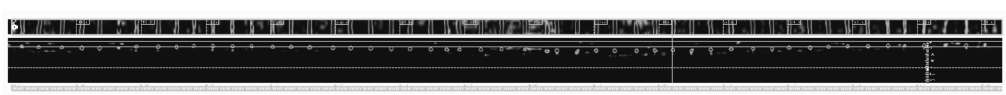

Figure 8. Detection results of 20~21× a steel bars in basement exterior wall.

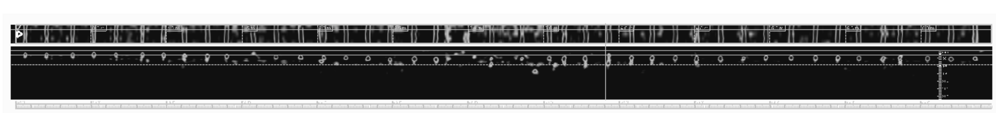

Figure 9. Detection results of 21~22× a steel bars in basement exterior wall.

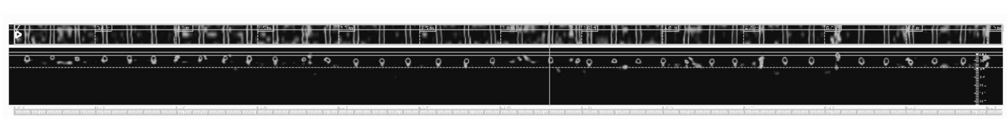

Figure 10. Detection results of 22~23× a steel bars in basement exterior wall.

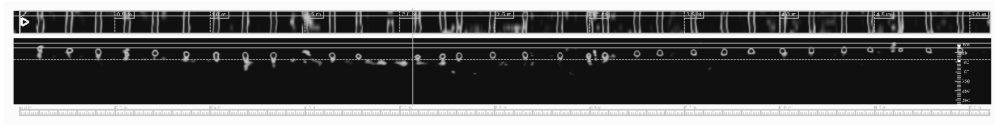

Figure 11. Detection results of 23~24× a steel bars in basement exterior wall.

From the above results of the analysis of the protective layer of reinforcing steel, it can be seen that the thickness of the protective layer of reinforcing steel of the exterior wall of the basement exterior wall of the negative two floors, 20 to 24×A, is large at individual positions of the exterior wall.

4.3 Radar detection

(1) Radar detection was carried out on the basement raft at the 20~21×A~H axis position on the negative second floor of the project. From the detection results, no abnormalities were found on the basement raft of the negative second floor of the project[7]. The specific detection results are as follows (Figure 12):

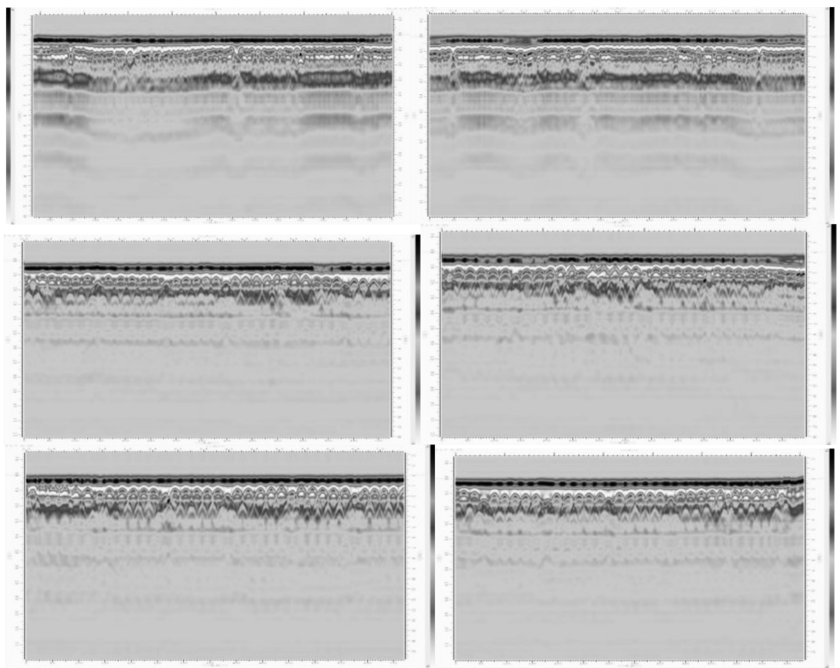

Figure 12. Radar detection results of basement raft concrete.

It can be seen that the horizontal direction of the basement raft slab at the axial position of 20~21×A~H in the negative first floor of the project has not found any abnormal site, and it can be determined that the horizontal direction of the raft slab at this position has not found any horizontal cracks with large length[8].

(2) Radar detection is carried out on the basement outer wall of the negative first floor 20~24×A axis position of the project, and no abnormality is found on the basement outer wall of the project from the detection results, which are as follows (Figure 13):

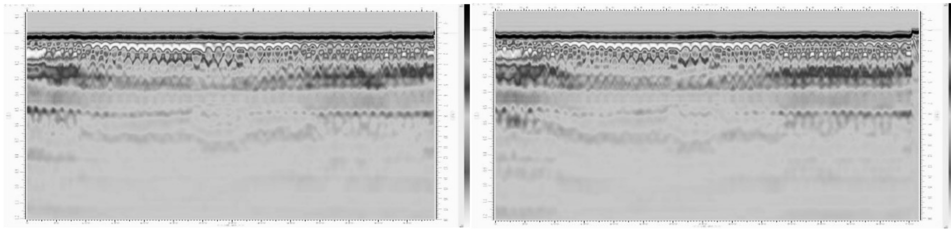

Figure 13. Radar detection results of basement exterior wall concrete.

From the radar analysis results, it can be seen that the project's negative first floor 20~24×A axis location basement wall testing location vertical direction did not find anomalies in the field, it can be determined that the location of the wall inside the wall parallel to the direction of the wall has not been found in the length of the vertical cracks.

4.4 Impact echo method results

The impact echo method was used to test the basement raft slab at the axial position of 20~21×A~H in the negative first floor and the basement cracks at the axial position of 20~24×A in the negative first floor locally. A total of 11 cracks were tested on site, 2 cracks in the basement slab and 9 cracks in the wall[9]. According to the testing conditions on site, the surface wave method was used to test the cracks in the basement raft slab of the negative first floor and the basement facade respectively, and the specific testing results are shown in Table 1:

Table 1. Test results of cracks in raft and basement exterior wall of negative second floor basement by surface wave method.

Test location	Crack number	Wavelength	Amplitude ratio x	Surface wave velocity (m/s)	Test results of crack depth for 3 times (cm)	Average crack depth (cm)	Note
Negative second floor basement raft	1-1	32.8	32.8	32.8	32.8	32.8	
		0.35	0.35	0.35	0.35		
		0.31	0.31	0.31	0.31		
	1-2	0.32	0.19	2254	0.401	40	
		0.36	0.23	2254	0.409		
		0.32	0.20	2254	0.389		
	1-3	0.32	0.13	2250	0.483	47.9	
		0.32	0.14	2250	0.468		
		0.27	0.09	2250	0.486		
	2-1	0.27	0.10	2238	0.463	46.5	
		0.27	0.11	2238	0.457		
		0.36	0.17	2238	0.476		
	2-2	0.31	0.14	2205	0.461	44.4	
		0.26	0.12	2205	0.422		
		0.35	0.19	2205	0.450		
	2-3	0.27	0.26	2282	0.278	28.0	
		0.27	0.24	2282	0.294		
		0.32	0.33	2282	0.267		
Basement exterior wall	1-1	0.36	0.48	2256	0.204	20.8	
		0.27	0.37	2256	0.205		
		0.27	0.35	2256	0.215		
	1-2	0.37	0.46	2296	0.219	21.1	
		0.32	0.44	2296	0.203		
		0.37	0.47	2296	0.213		

Test location	Crack number	Wavelength	Amplitude ratio x	Surface wave velocity (m/s)	Test results of crack depth for 3 times (cm)	Average crack depth (cm)	Note
	2-1	0.27	0.16	2232	0.372	36.7	
		0.36	0.26	2232	0.366		
		0.31	0.22	2232	0.362		
	2-2	0.27	0.15	2240	0.388	38.2	
		0.36	0.24	2240	0.394		
		0.36	0.26	2240	0.366		
	3-1	0.32	0.44	2294	0.202	19.8	
		0.32	0.46	2294	0.190		
		0.28	0.38	2294	0.203		
	3-2	0.32	0.24	2252	0.346	35.4	
		0.36	0.26	2252	0.374		
		0.32	0.24	2252	0.344		
	4-1	0.27	0.20	2262	0.332	34.3	
		0.32	0.24	2262	0.348		
		0.36	0.28	2262	0.351		
	4-2	0.36	0.34	2224	0.291	29.7	
		0.27	0.23	2224	0.299		
		0.36	0.33	2224	0.301		
	5-1	0.32	0.27	2272	0.319	31.2	
		0.27	0.21	2272	0.320		
		0.27	0.24	2272	0.298		
	5-2	0.32	0.27	2272	0.319	31.2	
		0.27	0.21	2272	0.320		
		0.27	0.24	2272	0.298		
	6-1	0.31	0.25	2216	0.326	32.7	
		0.31	0.26	2216	0.321		
		0.31	0.24	2216	0.335		
	6-2	0.27	0.23	2221	0.297	29.6	
		0.27	0.23	2221	0.301		
		0.27	0.24	2221	0.292		

(1) From the above table, it can be seen that the depth of cracks at the test location of the basement raft slab at the axial position of the negative first floor 20~21×A~H of the project is in the range of 28.0 cm to 44.4 cm; (2) From the above table, it can be seen that the depth of cracks at the test location of the basement facade at the axial position of the negative

first floor 20-24×A of the project ranges from 19.7 cm to 40.5 cm. As the testing of the impact echo method is strongly influenced by the fill (sediment carried by the rising water table) within the cracks, it is clear, however, that longer horizontal cracks were not detected[10].

5. ANALYSIS OF THE CAUSES OF CRACKS AT THE TEST LOCATIONS

According to the on-site investigation, the construction of the basement was carried out in October 2018, and the main body of Axis 36-19/(2/R)-A and the first floor of Axis 1-19/AA-A are now completed, and water seepage of varying degrees was found to have occurred on the basement floor and wall on 24 October 2019. On 24 October 2019, water seepage on the basement floor and walls was found to varying degrees. There were intermittent stoppages of precipitation work on site, which caused the groundwater level to rise to about 1.2 m above the bottom elevation of the raft slab.

5.1 Cracks in raft slabs

(1) From the point of view of the rising water level, the buoyancy force generated by the water was not sufficient to cause the 500 mm thick raft slab to crack in the upper arch; (2) From the concrete core samples obtained from the on-site drilling, there were more air bubbles formed by insufficient vibration in the concrete core samples at individual crack locations; (3) From the location, direction and extension of the cracks in the concrete raft slab, the two cracks are basically parallel, and water seepage and leakage phenomena of different degrees have occurred, and the cracks extend downward diagonally in the interior; (4) From the crack pattern, the cracks are large in the middle and small at both ends. In summary, the main reason for cracks in the raft slab is that during the concrete construction process, the concrete slump is large, the interval between concrete pours is long, the local position is not vibrated densely, and the heat preservation and moisturising maintenance is not in place and the temperature difference is large after the concrete is poured, which leads to cracks in the concrete of the raft slab[11,12].

5.2 Cracks in the external walls of basements

(1) From the location of the cracks on the basement wall, the cracks mainly appeared at the root of the wall, extending upwards, some cracks appeared in the middle of the wall, the cracks appeared along the wall at a certain distance from each other, and the location of the cracks was not regular; (2) From the degree of cracking, some cracks have penetrated inside and outside, and some cracks appeared on the surface of the concrete and did not penetrate; (3) From the crack morphology, the cracks are large in the middle and small at both ends. In summary, the main reason for cracks in the basement wall is that during the concrete construction process, the concrete slump is large, the two concrete pouring rubbing position is not in place, thus causing the root of the concrete shear wall to produce varying degrees of cracking, the concrete pouring is completed after the thermal insulation and moisture maintenance is not in place and the temperature difference is large, which leads to the central position of the concrete wall to produce cracks, cracks to the upper and lower extensions.

6. DETECTION FINDINGS

Based on the results and contents of the above tests, the project's conclusions on the testing of cracks in the basement raft slabs at the 20 to 21×A to H axial locations and the basement exterior walls at the 20 to 24×A axial locations are as follows:

6.1 Cracks in basement raft slabs

(1) 20~21×A~H axis location of the basement raft slab cracks in the middle of the big two small, the width of 0.1 mm~0.2 mm between the cracks have been up and down through, and the groundwater level rises with the sediment has been part of the location of the cracks filled. (2) The main reason for cracks in the raft slab is that in the process of concrete construction, the concrete slump is large, the interval between concrete pours is long, the local position is not vibrated densely, and the heat preservation and moisturising maintenance is not in place and the temperature difference is large after the concrete is poured, which leads to cracks in the concrete of the raft slab.

6.2 Cracks in the external walls of basements

(1) 20~24×A axis location of the basement wall cracks to vertical cracks, along the wall towards the cracks were irregularly distributed, the middle of the two ends of the small width of 0.1 mm-0.3 mm between, part of the cracks inside and outside of the through, and the groundwater level rises with the sediment has been part of the position of the cracks to fill. (2) The main reason for cracks in the exterior wall of the basement is that during the concrete construction process, the slump of concrete is large, and the location of the two concrete pours is not dealt with in place, which results in varying degrees of

cracking at the root of the concrete shear wall, and the heat preservation and moisturising maintenance is not in place and the temperature difference is large after the concrete is poured, which leads to cracks in the middle of the concrete wall, and the cracks extend to the upper and lower parts of the concrete wall.

7. CRACK TREATMENT AND EFFECTS

According to the above test results and content, the construction unit has developed a high-pressure grouting treatment programme, the main contents of which are: (1) Raft foundation cracks, each along the cracks on both sides of the 5 cm pick open the surface concrete depth of 2cm, cracks using high-pressure grouting (grout mixed with polymer water-stopping materials) to deal with the surface of the groove with plugging materials; (2) Cracks at the basement wall are treated with high-pressure grouting (grout mixed with polymer water-stopping materials). After treatment according to the above programme, no more leakage was observed, and better results were achieved, and it is now normally put into use.

8. CONCLUSION

There are many reasons for concrete cracks, how to scientifically analyse the causes of concrete cracks is the key to deal with concrete cracks, the project after a comprehensive testing of concrete cracks, accurate analysis of the causes of concrete cracks, for the later concrete crack treatment programme provides a reliable basis for the concrete crack treatment, concrete crack treatment also achieved better results, but also for the region to carry out similar projects to deal with the accumulated experience of certain reference. It also accumulates certain experience for similar projects in the region.

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