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Research Article

Research on the Inspection Method of Chimney Appearance and Masonry Material Performance

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Abstract: As a high-rise structure, the safety of chimneys has always been a public concern. In this paper, the damage condition, tilting, and the strength of load-bearing materials of the chimney were inspected, and the inspection conclusions and maintenance suggestions were given based on the inspection results. The inspection method can provide relevant reference for the inspection of similar structures.

Key words: Chimney; Safety; Inspection items; Inspection conclusions

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This case project is a chimney built in the urban area for about 30 years. The residential area near the structure is crowded, and the safety inspection of the chimney is urgent. The inspection content in this case is the integrity of the chimney appearance, the tilting and the strength of the load-bearing material.

1 Project overview

The chimney under inspection is 40 meters high and has been built for about 30 years. The chimney foundation adopts a pile-cap foundation, and the format of the cap is a single-pile cap. The pile foundation is cast-in-place pile. The inner diameter at the top of the pipe is about 2.0 meters, and the diameter at the bottom is about 40 meters. The main load-bearing material is sintered ordinary clay solid brick. The design basis of the chimney structure is atlas 94G611 "Brick Chimney", some indicators in the atlas have been outdated far behind the current 04G211 "Brick Chimney" atlas in use.

2 Testing standards and basis

(1) "Load Code for the Design of Building Structures" (GB50009-2001) (2006 Edition) ;
(2) Engineering Construction Code "Standard of Structural Inspection and Assessment for Existing Buildings" (DG/TJ08-804-2005);
(3) "The Method of Evaluating the Fired Common Brick Strength Grading by Rebound Hammer" (JC/T796-1999);
(4) "Technical Specification for Testing Compressive Strength of Masonry Mortar by Penetration Resistance Method" (JGJ/T 136-2001);
(5) Engineering Construction Code "House Quality Inspection Regulations" (DG/TJ08-79-2008).

3 Surveying and mapping of chimney building structure drawings

The data collection content of the overall conditions of the chimney includes the height of the pipe body, the thickness of the pipe wall and the lining conditions. The height of the pipe was surveyed and mapped in full-section on the upper structure of the chimney with a Leica Total Station. The thickness of the pipe wall was determined by the method of drilling and coring, and the lining conditions were obtained by the method of filming inside the chimney. According to on-site measurement data: the height of the chimney pipe is 40m, the bottom of the pipe is 490mm thick, and the pipe is lined all the way up to the top. Based on the above data and in conjunction with the current atlas, the schematic diagram of the chimney section was drawn (Figure 1).

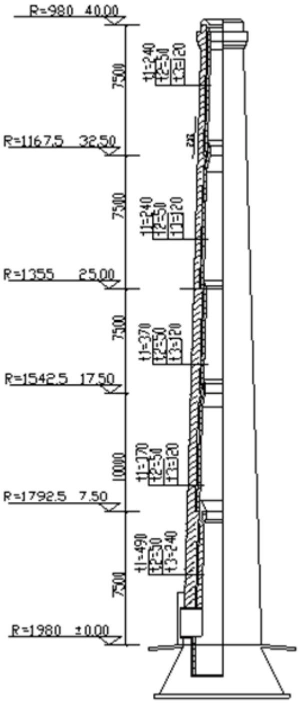

Figure 1. Schematic diagram of chimney section

4 Chimney damage condition inspection

4.1 The pipe

The overall conditions of the pipe are as follows: there are some small cracks on the top, while the rest is intact.

Leica TCR802 Total Station was used to survey and map the crack positions. The detailed conditions of crack surveying and mapping are shown in Table 1, and the schematic diagram of crack distribution is shown in Figure 2.

Table 1. Chimney cracks table

Crack Serial No.	B1	B2
Crack Length(m)	3	2

4.2 Lining

The chimney is lined to full height, it is in good condition and no significant cracks were seen.

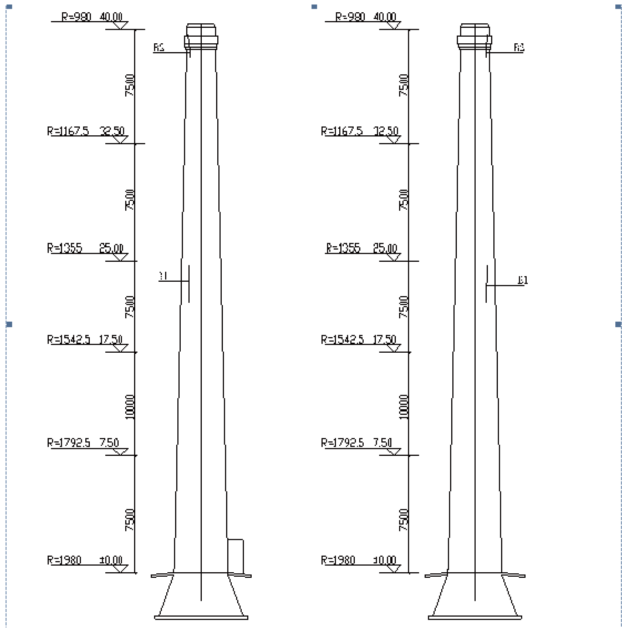

Figure 2. Illustration of chimney cracks

4.3 Auxiliary facilities

The external ladder and the rest platform of the chimney were all rusted. The top of the chimney was directly corroded and weathered by the flue gas, and the ladder and working platform at this part were particularly rusty.

5 Chimney tilting inspection

Multiple measuring points were set up at different heights of the chimney, where two Total Stations of the same model were used to measure the three-dimensional coordinates of the measuring points on site. The center at each height was calculated through the coordinates of the points, and then the centers at different heights were used to calculate the tilting of the chimney at different heights and the overall tilting separately, and the average of two measurements was taken as the final result. See Table 2 and Table 3 for local tilting and overall tilting.

Table 2. Measurement results of tilting at each measuring point

Measured Object	Measured Height Section(m)	Measured Height Section No.	K1 Station Site			K2 Station Site			Maximal Tilting(‰)
			△ h(m)	△ s(mm)	Tilting(‰)	△ h(m)	△ s(mm)	Tilting(‰)	
Chimney	0~22	1	20.656	63.8	3.1	20.654	43.3	2.1	4.2
	0~32	2	31.409	95.1	3.0	31.407	92.9	3.0	
	0~39	3	38.776	146.0	3.7	38.775	93.0	2.4	
			39.159	163.2	4.2	40.256	170.7	4.2	

△ h is the difference in height from the bottom to the measuring point; is the horizontal offset between the center of the section at each height and the center of the bottom

The calculation shows that the tilting of each measuring height section of the chimney is less than 6.0‰, which meets the requirements of the specification. "The Code for Design of High-rise Structures" (GB 50135-2006) stipulates that the maximum slope of the high-rise structure shall not be greater than 6.0‰.

Table 3. Overall tilting measurement results of the chimney

Measured Object	Difference in Displacement (mm)	Relative Difference in Height (m)	Tilting Direction	Tilting (‰)
Chimney	146	38.776	Northwest	3.8
	93	38.775	Northwest	2.4

The tilting direction of the chimney measured at two sites is northwest, and the average tilting is 3.1‰, which meets the requirements of the specification.

6 Inspection on the material performance of masonry structural components

According to "The Method of Evaluating the Fired Common Brick Strength Grading by Rebound Hammer[1]" (JC/T796-1999), a rebound tester was used to evaluate the strength of the blocks by testing the strength of the blocks in different measurement areas. According to the requirements of the specification, 12 and 7 test areas of the chimney had been tested respectively. The test results are shown in Table 4.

Table 4. Test results of the strength of common sintered bricks on the chimney

Serial No.	Testing Position	Average Rebound	Rebound Standard Value	Rebound Standard Deviation	Minimum Rebound	Deduced Strength Grade	Deduced Chimney Bricks Strength Grade
1	B1#	44.8	40.6	2.4	42.4	MU25	MU20
2	B2#	43.5	39.4	2.2	39.6	MU20	
3	B3#	46.0	43.0	1.7	43	MU25	
4	B4#	45.7	41.4	2.4	41.2	MU25	
5	B5#	44.4	41.8	1.4	41.8	MU25	
6	B6#	44.5	39.2	3.0	41.2	MU25	
7	B7#	44.9	40.0	2.9	40.6	MU25	

STY800B penetration mortar strength tester was adopted for the mortar strength test, the strength of blocks was evaluated by testing the strength of the blocks in different measurement areas according to "Technical Specification for Testing Compressive Strength of Masonry Mortar by Penetration Resistance Method[2]" (JGJ/T 136-2001). See Table 5 for specific test results.

Table 5. Test result of the compressive strength of chimney mortar

Serial No.	Testing Position	Average Penetration Depth (mm)	Converted Value of Mortar Compressive Strength(MPa)	Deduced Compressive Strength of the Chimney Mortar (MPa)
1	B1#	3.83	8.5	Average f_m=9.2Mpa Minimum f_{min}=7.8Mpa f_{min}/0.75=10.4Mpa
2	B2#	3.68	9.3	
3	B3#	4.00	7.8	
4	B4#	3.68	9.3	
5	B5#	3.53	10.2	
6	B6#	3.85	8.4	
7	B7#	3.22	12.5	
8	B8#	4.00	7.8	

According to the on-site inspection results, it was deduced that: the strength grade of the sintered clay brick is MU20, and the mortar strength is 9.2 MPa.

7 Inspection conclusion

(1) Appearance Inspection: There were two longitudinal cracks on the top of the chimney, the longest crack length was less than 3 meters, and the crack width was less than 2cm. The interior of the pipe was lined all the way to the top, and the condition was good, with no significant cracks or damage found. The external ladders of the chimney

were all corroded, and the working platform was corroded severely.

(2) Tilting Inspection: The tilting of the main body of the chimney (including construction error) is lower than the permissible deformation requirements of the "Code for Design of High-rising Structures" (GB 50135-2006), and the tilting inspection results are in compliance with the requirements.

(3) Material Strength Inspection: Chimney brick strength grade is MU20, mixed mortar strength is 9.2 MPa, and the strength grade is higher than the material strength requirements in the current "Brick Chimney" Atlas (04G211) (sintered ordinary clay brick strength: MU10; cement lime mixed mortar strength: M5). The results of material strength inspection are in compliance with the requirements.

8 Repair measures and suggestions

(1) The cracks at the top of the chimney have a small coverage and a small gap width, which do not have a major impact on the safety of the structure. If no reinforcement measures are taken, the cracks will continue to develop under the influences from the external environment. It is recommended to repair the cracks. The repair method is suggested as follows: ① Reinforce the cement mortar surface with a reinforced steel mesh of 8mm in diameter and spacing not more than 200mm (the thickness of the cement mortar surface is 50mm and the strength is M10), and grout the cracks with pressure grouting cement mortar. ② Along the length of the crack and within the range of 1m up and below, use a 60X5 flat iron to set up hoops along the pipe every 0.5m. Select hoops made of flat iron of the same model, and add fixed screws at both ends. The treatment method inside the crack is the same as step 1. The repair of the chimney should be entrusted to a qualified company. During the repair, climbing the bricks around the cracks at will is not allowed, and the repair personnel must take safety protection.

(2) It is recommended that the external steel ladder and the steel working platform be replaced.

(3) It is recommended that the horizontal section bearing capacity of the chimney and the reinforcement ring of the pipe be inspected.

References

[1] Hammer R. The method of evaluating the fired common brick strength grading. (JC/T796-1999).

[2] Technical specification for testing compressive strength of masonry mortar by penetration resistance method (JGJ/T 136-2001).