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Design of Fire Systems in Nanjing Research Institute of Huawei's New Rent Engineering Office Building

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Abstract: *First, building fire research status at home and abroad are introduced, the main subject of the design of fire system in Nanjing research institute of Huawei's new rent engineering office building. The construction for the building is eight floors and the area of it is about 42537* m^2 *, the underground part is about 1713* m^2 *. Its height is about 30* m *. According to actual demand, with the fire regulations and specific engineering requirements, we ensure safety by comparing with regulations and drawing the conclusion. In the design, we check the pipeline strength of water. In the fire hydrant system, the pressure of the most unfavorable hydrant should be calculated and check.*
Keywords: *Building Fire; Automatic Sprinkler; Fire hydrant*

I. Introduction

With the rapid development of economy, the construction industry is also developing continuously, many new materials and new technologies have been used in the construction. But at the same time, the factors that cause the fire also increase. Building fire compared with other fire has the following characteristics the fire can spread quickly, the fight is difficult, the fire is easy to cause casualties and economic losses and so on.

High-rise buildings have many distinct characteristics, such as more complex architectural, dense personnel, difficult evacuation. Once fire accidents happen, our country can suffer a lot of material losses. Especially in high-rise buildings, we should pay attention to safety in order to reduce losses. Fire hydrant system and automatic sprinkler system are more used in water fire-extinguishing. Automatic sprinkler system has high sensitivity and probability of successful fire-extinguishing. The firefighting codes of developed countries indicate that this system will be used in all buildings which should be equipped with fire-extinguishing system. our country, the system is set only in the places where are crowded or difficult for rescue or public places where have high fire hazards.

This article mainly focuses on design of fire system in Nanjing research institute of Huawei's new rent engineering office building. The building has eight floors and one basement. Its total area of about 42537 m^2 and the underground part is 1713 m^2 . The height of the total building is about 30 m . Each floor in the building is 3.50 m and the height of the basement is as follows: the height of the garage is 6.50 m , every equipment room is 4.50 meters high. According to the national standard of fire hazard, fire hazard level is middle level I. In accordance with the national standard of the basement, the level is grade 2.

The paper introduces the design of fire-extinguishing system and related calculation, including automatic sprinkler system and fire hydrant system.

II. Automatic sprinkler system design

2.1 Parameter determination

Parameters designed in the system are required in accordance with the specification [, Parameters are as follows :

(1) The water jet strength of Automatic sprinkler system is 6 $(L \cdot min^{-1} \cdot m^{-2})$.

(2) Area of Action of the Automatic Sprinkler System is 160 m^2 , shown in Figure. 1.

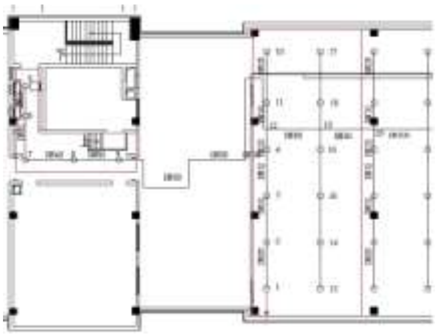

Fig. 1. Function area and spray nozzle layout

(3)）The fire hazard level is middle level I.

(4) The most unfavorable pressure is 98000 Pa .

(5) When water is supplied only by a water tank, pressure of the most unfavorable nozzle is 5×9800 Pa .

(6) Continuous injection time in automatic sprinkler system is 1 h .

2.2 Nozzle and pipe network layout

According to the request, water density is 6 $(L \cdot min^{-1} \cdot m^{-2})$. In the system, the spray nozzle is arranged in rectangle and the long side is 4 m .What's more, the maximum protection of each nozzle is 12.5 m^2 . The design whole building is as shown in Figure. 2.

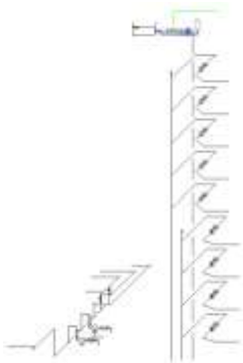

Fig. 2. Spray System Diagram

After calculation, requirements of design of fire system in Nanjing research institute of Huawei's new rent engineering office building are as follows :

1. The distance of the spray nozzles arranged is between 2.4 m and 4 m .
2. In this project, the distance between a nozzle and the wall is 1.8 m , and the distance between nozzles is about 3.6 m , and the other nozzles on the 8^{th} floor are arranged in Figure. 3.

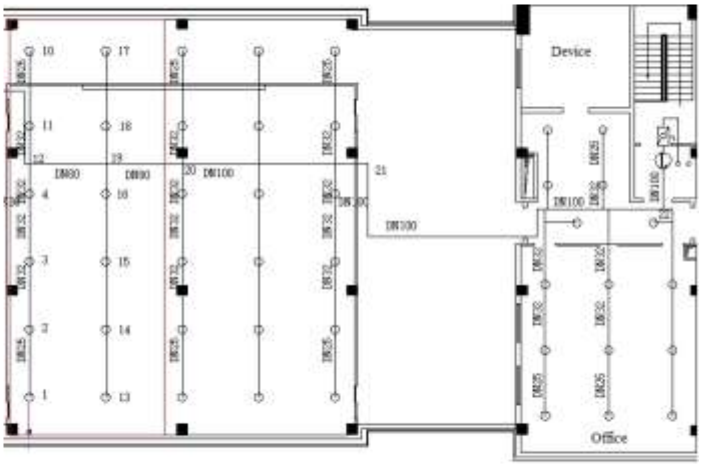

Figure. 3. Other Nozzles layout

III. Design and calculation of water fire-extinguishing system

3.1 Size of Area of Action determination

To the most unfavorable point in the plan and to define Area of Action in the system. In accordance with the norms, Area of Action is rectangular, the length is as follows :

$$L = 1.2\sqrt{F}$$

L is the long side of a rectangular Area of Action, F refers to the area.

F should be equal to 160 m^2 in the design. It is substituted into the formula, then we can conclude that L is equal to 15.18 m^2 .Actually F is taken 165.7 m^2 in this system.

The short side of a rectangular is calculated as follows :

$$B = F / L$$

B is the short side, F which equals 160 m^2 and L equal to 15.18 m are substituted into the formula, and B calculated will be valued as about 11 m^2 . Actual area of action in the system is 165.7 m^2 which is more than 160 m^2 , so we can draw the conclusion that the design meets requirements.

2.2 Hydraulic calculation of flow characteristic coefficient

According to all relevant formulas, the design of each system can be calculated, the detail is shown in Table 1. In the process, the working pressure of 1 is equal to 10 mH_2O , and there is $h = 1.2ALQ^2$.

Then pump head is :

$$H_b = (10 + 49.87 + 2 + 4 + 3.5 \times 7)\ mH_2O = 90.37 mH_2O$$

Assuming that the pump head is equal to 100 mH_2O . In Area of Action in the system, the average water jet strength is :

$$W_p = \frac{60 \times 29.76}{165.7} = 10.78\ L/（min \cdot m^2）$$

From the calculation, we can see that 10.78 $L/（min \cdot m^2）$ is more than 6 $L/（min \cdot m^2）$, so the design meets the demand.

In the system, we need check water spraying intensity. 1, 2, 3 and 4 are the most unfavorable nozzles in the Table. 2. What's more, they need to be compared with the normative intensity of the sprinkler. According to the risk level I, water intensity should be checked and chosen.

Table. 1. Hydraulic Calculation of Flow Characteristic Coefficient

		B	K	H/mH_2O	q (L/s)	Q (L/s)	Q^2 (L^2/s^2)	d mm	A/ (s^2/L^2)	L/m	h/mH_2O
1			0.42	10.00	1.33						
	1-2					1.33	1.78	25	0.4367	3.20	2.96
2			0.42	12.96	1.51						
	2-3					2.84	8.07	32	0.09386	3.20	2.91
3			0.42	15.87	1.67						
	3-4					4.51	20.37	32	0.09386	3.20	7.34
4			0.42	23.21	2.02						
	4-12					6.54	42.73	32	0.09386	1.60	6.74
12				29.94							
5			0.42	10.00	1.33						
	5-6					1.33	1.78	25	0.4367	2.10	1.94
6			0.42	11.94	1.45						
	6-7					2.78	7.73	32	0.09386	3.60	2.61
7			0.42	14.55	1.60						
	7-8					4.38	19.20	40	0.04453	3.20	3.28
8			0.42	17.83	1.77						
	8-9					6.16	37.89	50	0.01108	3.00	1.21
9			0.42	18.35	1.83						
	9-12a					8.00	64.04	80	0.001168	22.65	2.03
12a				21.38							
12a 修正		1.183									
	9-12a 修正					8.47					

		B	K	H/mH_2O	q (L/s)	Q (L/s)	Q^2 (L^2/s^2)	d mm	A/ (s^2/L^2)	L/m	h/mH_2O
10			0.42	10.00	1.33						
	10-11					1.33	1.78	25	0.4367	3.30	3.24
11			0.42	13.24	1.53						
	11-12b					2.86	8.18	32	0.09386	1.80	1.65
12b				14.89							
12b 修正		1.418									
	11-12b 修正					4.05					
	12-19					18.86	355.82	80	0.001168	3.60	1.80
19				31.74							
	19-19a 修正	1.030				6.73					
	19-19b 修正	1.030				4.17					
	19-20					29.76	885.80	80	0.001168	3.60	4.47
20		—	—	36.21	—						
	20-21					29.76	885.80	100	0.0002674	8.70	2.47
21		—	—	38.68	—						
	21-22					29.76	885.80	100	0.0002674	17.30	4.92
						Σh=49.87					

$$W_p = \frac{60 \times（1.33 + 1.51 + 1.67 + 2.02）}{4 \times 3.6 \times 3.6} = 7.56 L/（min \cdot m^2）$$

From the calculation, we can see that 7.56 $L/（min \cdot m^2）$ is more than 6 $L/（min \cdot m^2）$, so the design meets requirements.

The flow rate of each pipe is checked in Table. 2.

Table. 2. Pipeline Flow Rate Verification

pipeline	1-2	2-3	3-4	4-12	12-19	19-20	19-22	Most flow is less than 5m/s
diameter/mm	25	32	32	32	80	100	100	
Flow/（L/S）	1.33	2.84	4.51	6.54	18.86	29.76	29.76	
Kc/(m/L)	1.883	1.054	1.054	0.796	0.201	0.115	0.115	
v /(m/s)	2.50	2.99	4.75	5.20	3.79	3.42	3.42	

The pump head in the system is selected as 100 mH_2O and the pump is selected $XBD3.7/28-100L$. And the volume of water tank is 18 m^3. Nozzles are adopted close-type sprinkler whose type includes ZSTZ and ZSTB and the water flow indicator is selected $SG-YL41-10$. The signal butterfly valve adopts $XD371$.

IV. Design of indoor fire hydrant system

The construction for the building is eight floors and the area of it is about 42537 m^2, the underground part is about 1713 m^2. Its height is about 30 m. In the design, fire demand need to be more than or equal to 20 L/s. But fire demand can be more than or equal to 15 L/s, each flow of ejection is at least 5 L/s. The full water column length of hydraulic monitor is at least 10 m and The diameter of the fire hydrant whose material is linen is selected 65 mm. If the diameter of the mouth of the hydraulic monitor is 19 mm, the pressure of fire hydrant mouth is :

$$H = H_q + h_d$$

In the formula, H is the pressure of the mouth of the fire hydrant and h_d is the loss of water flowing through fire hose.

Let H_m to be selected 12 m and the diameter of the mouth of hydraulic monitor to be 19 mm, according to Table. 3 and Table. 4. We can draw that φ is equal to 0.0097.

Table. 3. Coefficient α_f

H_m/mH_2O	6	8	10	12	16
α_f	1.19	1.19	1.20	1.21	1.24

Table. 4. Coefficient φ

d_f/mm	13	16	19
φ	0.0165	0.0124	0.0097

$$H_q = \frac{\alpha_f H_m}{1-\phi\alpha_f H_m} = \left(\frac{1.21\times12}{1-0.0097\times1.21\times12}\right) mH_2O = 16.9\text{m}H_2O$$

According to Table. 5, B is equal to 1.577, and then :

$$q_{xh} = \sqrt{BH_q} = \sqrt{1.577\times16.9} = 5.16L/s$$

From the calculation, we can see that 5.16 L/s is more than 5 L/s, calculation is effective.

In the formula, B is flow characteristic connected with the diameter of the mouth of hydraulic monitor and it is shown in Table. 5.

Table. 5. Characteristic Coefficient B

diameter /mm	13	16	19	22
B	0.346	0.793	1.577	2.836

The diameter of the fire hydrant whose material is linen is selected 65 mm, then A_z is equal to 0.00430 and q_{xh} is equal to 5 L/s, then h_d is :

$$h_d = A_z L_d q_{xh}^2 = 0.00430 \times 20 \times 5.16^2 mH_2O = 2.29 mH_2O$$

L_d is the fire hose and A_z is a resistance coefficient of fire hose, which is shown in Table. 6.

Table. 6. Resistance Coefficient Az

material	diameter		
	50	65	80
linen	0.01501	0.00430	0.00150
rubber lining	0.00677	0.00172	0.00075

Then the pressure of the fire hydrant is :

$$H = H_q + h_d = (16.9 + 2.29) mH_2O = 19.19 mH_2O$$

The construct of fire hydrant water supply system is shown in Figure. 7.

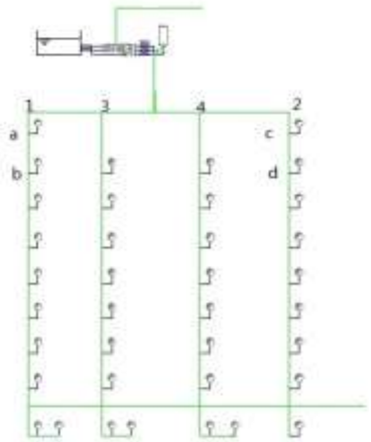

Figure. 7. Fire Hydrant Water Supply

According to the specification, when fire happens, four hydraulic monitors need to work at the same time, and two hydraulic monitors which are in one pipeline need to work at the same time. From figure. 7, 1 which is on the 8th floor and 2 which is on the 7th floor are the most unfavorable points.

The full water column length of hydraulic monitor at the point a which is in the 1st pipeline is 12 m and then :

$$H_q = \frac{\alpha_f H_m}{1 - \phi \alpha_f H_m} = \left(\frac{1.21 \times 12}{1 - 0.0097 \times 1.21 \times 12} \right) mH_2O = 16.9 mH_2O$$

The flow of ejection is :

$$q_{xh} = \sqrt{BH_q} = \sqrt{1.577 \times 16.9} = 5.16 L/s$$

From the calculation, 5.16 L/s is more than 5 L/s . So we can see that the design meets the requirements.

$$H_q = \frac{q_{xh}^2}{B} = \frac{5.16^2}{1.577} = 16.88 L/s$$

In fact, the full length of the water column is as follows :

$$S_k = \frac{H_q}{\alpha_f \left(1+\phi H_q\right)} = \frac{16.9}{1.21\left(1+0.0097\times16.9\right)} = 11.99 mH_2O$$

The pressure of the fire hydrant on the 8th floor is :

$$H_a = H_q + A_d L_d q^2 = 16.9 + 0.0043\times20\times5.16^2 = 19.19\text{m}$$

$$H_{g(b-a)} = 1.1 h_y = 1.1\times0.00749\times3.5 = 0.029\text{m}$$

$$H_b = 19.19 + 3.5 + 0.029 = 22.72 m$$

The water of fire hydrant on the 7th floor is :

$$H_b = A_d L_d q^2 + \frac{q^2}{B}$$

$$q = \sqrt{\frac{H_b}{A_d L_d + \frac{1}{B}}} = \sqrt{\frac{22.72}{0.0043\times20+\frac{1}{1.577}}} L/s = 5.62 L/s$$

Similarly, the pressure of the fire hydrant on the 1st floor is:

$$H = 22.70 + 3.5\times6 + 1.1\times3.5\times0.00749\times6 = 43.87 m$$

The pressure of the 2nd pipeline is as same as the 1st pipeline, so q is as follows :

$$q = \sqrt{\frac{H_c}{A_d L_d + \frac{1}{B}}} = \sqrt{\frac{23.13}{0.0043\times20+\frac{1}{1.577}}} L/s = 5.67 L/s$$

The total flow of the pipeline is :

$$Q = 12 + 5.61 + 5.67 = 23.28 L/s$$

From the calculation, the lift of the water pump is :

$$H_b = 3.5\times7 + 10 + 19.17 = 53.67 mH_2O$$

In the design, the pump is selected $XBD4.4/28-100L$, its lift can meet the demand.

The condition of the fire hydrant from the 1st floor to the 8th floor is the same, and the pressure of the fire hydrant in the pipeline 3 is :

$$H = 19.19 + 3.5\times6 + 1.1\times3.5\times0.00749\times6 = 40.36 m$$

From all the calculations, we can know that the pressure of all the four pipelines is less than 50 m , so reducing orifice is not necessary.

V. Conclusion

The system designed according to the requirements of the use of wet sprinkler system has high reliability. Then we select the automatic sprinkler system, calculate and check safety of each system.

In the fire hydrant system, in addition to calculation of the most unfavorable hydrant mouth pressure and check, the pump needs to be selected and the project budget should be considered fully. The national standard is the main guarantee for the engineering design and the check of each system is also vital in the whole design.

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