Research on the design rainstorm calculation for the watershed in northern area of Xiamen New Airport

Dejun Deng[1], Yanghua Huang[2], Shufeng You[3], Shengcai Li[1], Yanmin Liu[1*], Changjia Chi[4], Siqi Huang[1], and Sijia Liu[1]

[1]Xiamen Institute of Technology, Xiamen, China
[2] Chongqing Surveying and Design lnstitute Co., Ltd. of Water Resources,Electric Power and Architecture, Chongqing, China
[3] Xiamen University, Xiamen, China
[4] Xiamen Municipal Engineering Design Institute Co., Ltd, Xiamen, China

Abstract: Urban design rainstorm is the basis of urban hydraulic engineering design, which is related to the safety and economy of urban drainage engineering, and has an important impact on the design scale and investment of urban drainage engineering. Scientific design rainstorm is the basis for ensuring the construction of hydraulic engineering.To ensure the safety of the new airport, government restarts the hydraulic engineering in the northern area of Dadeng Airport. This paper takes the northern area of Xiamen New Airport as the research object, and provides an effective pursuant for hydraulic engineering design through scientific design rainstorm ,and also provides a reference for other similar construction projects.

1. Introduction

In recent years, urban flooding has caused heavy losses to economic and social development and the safety of people's lives and property, which has attracted extensive attention from the government, scholars, and all sectors of society[1]. In response to the problem of urban waterlogging, our government has put forward the concept of sponge city construction, which aims to achieve "natural accumulation, natural infiltration, and natural purification" goal, through "infiltration, detention, storage, purification, use, and discharge"six major measures comprehensively solve the urban water problem [2].Urban design rainstorm is the basis of urban hydraulic engineering design, which is related to the safety and economy of urban drainage engineering, through scientific design to ensure rainstorm design scale and investment of urban drainage engineering.Urban flood resilience is incorporated into urban planning, and different flood management strategies are used to reduce flood damage[3,4].

Xiamen New Airport, as a 4F-level international airport on the west Coast of the Strait, is an important gateway airport of Xiamen, also is an important support for the national implementation of the West Coast strategy and an important aviation port for the "Belt and Road" strategy.The water system improvement project in the northern area of Xiamen New Airport is an important project to ensure the safety of the new airport area, and its rainstorm design is the basis for ensuring the safety and economy of the water conservancy project. However, there are few researches on this aspect, only a few scholars such as Meixia Lin[5], Jiahong Liu [6], and Siqiang Ding [7]have conducted some researches on the hydrological hazards in Xiamen, but none of them have conducted a separate research on the new airport area, so this paper is an important research.

2.Meteorological feature

2.1 Rainfall feature

Dadeng Island is located in the southern subtropical oceanic monsoon climate zone, with a warm and humid climate throughout the year, abundant rainfall and sufficient heat.

According to the data recorded by the Xiamen Meteorological Observatory in 1956~2009 and the Wutong Temporary Wind Speed Observation Station, the meteorological characteristics of Dadeng Island are as follows:

The precipitation in Xiamen is concentrated in April ~ September, accounting for 76 percent of the annual precipitation. The average annual precipitation is 1188.4 mm, the average number of rainy days is 122.7 days, the maximum annual precipitation is 1998.6 mm (1990), and the annual minimum precipitation is 783.5 mm (1957).

The rainstorm in Xiamen is mainly concentrated in June ~ August. In 1952~1980, the daily precipitation ⩾ 50mm was 102d, with an average of 3.5d per year, the rainstorm days ⩾ 100mm was 23d, with an average of 0.8d per year, and the daily precipitation ⩾ 150mm rainstorm days was 6d, with an average of 0.2d per year. The heaviest rainfall was 23 April 1973, with 239.7 mm of rain and 88.1 mm in one hour.

It is often affected and hit by tropical cyclones and typhoons in July ~ October every year. It is often

* Corresponding author: Yanmin LIU 2628165795@qq.com

affected and hit by tropical cyclones and typhoons in July ~ October every year. According to the statistics of 1949~2000, there were 344 tropical cyclones in 52 years, with an average of 6.7 tropical cyclones per year and a maximum of 14 per year (1961). The maximum wind speed ⩾ 24.5m/s occurred 212 times, with an average of 4.2 times per year. The instantaneous maximum wind speed can reach 60m/s (Typhoon No. 5903).

2.2 Watershed feature

Dadeng Island is a coastal hilly terrain, the terrain is high in the middle and low in the periphery. The drainage in the area is mainly discharged into the East China Sea through natural ditches.The new airport is based on the 10 km^2 land area reclamation in the eastern and southern seas, which will be expanded to 41.7 km^2. The current water system of Dadeng Island mainly includes the South Trunk Canal, the North Trunk Canal, the temporary water storage and two tidal and drainage gates station. According to Special planning for moisture prevention and drainage of Xiamen New Airport,11 new canals, 2 flood detention areas and 1 pump gate will be built in the northern area new airport. The airport area water discharges into the sea. Dadeng Island will form a drainage feature dominated by small watersheds.

3. Stormwater calculations

3.1 Analysis of rainstorm measurement data

Since there is no hydrological station and rainfall observation station in Dadeng Island, the rainfall data of the Maxiang station is used to design the rainstorm calculation, and the statistical parameters of rainstorm in the latest version of the "Rainstorm Contour Map of Fujian Province" is consulted for comparative analysis.

3.2 Design rainstorm calculation

According to the "Fujian Provincial Confluence Calculation Method", the total design flood volume is calculated with a 24-hour design without deduction.Maxiang Station has the maximum 3, 6, and 24-hour short-duration rainstorm records from 1968~2020, and the maximum 1-hour short-duration rainstorm records from 1981~2020. Through analyzing and interpolating the maximum 1-hour short-duration rainstorm data in 1968~1980, after that, Maxiang Station has the maximum 1-hour, 3-hour, 6-hour, and 24-hour short-duration rainstorm data in 1968~2020. By frequency calculation and analysis, the rainstorm data of short-duration design are detailed in Table 1.

Table 1. Maxiang station design rainstorm data

Diachronic (h)	Mean (mm)	Cv	Cs/Cv	Design rainfall (mm) 2%	10%	50%
1	44.4	0.36	3.5	86.7	65.8	41.1
3	70.0	0.37	3.5	139.1	104.7	64.6
6	92.2	0.44	3.5	203.9	146.1	82.3
24	141.5	0.45	3.5	317.9	226.2	125.8

Chart search the statistical parameters of rainfall in different rainfall periods in the latest version of the Rainstorm Contour Map of Fujian Province, the calculated results of the design rainstorm of Dadeng Island are shown in Table 2.

Table 2. Check the rainstorm contour map of Fujian Province to design the rainstorm data

Diachronic (h)	Mean (mm)	Cv	Cs/Cv	Design rainfall (mm) 2%	10%	50%
1	46	0.47	3.5	102	72	59
3	-	-	3.5	164	113	90
6	88	0.55	3.5	222	148	116
24	140	0.54	3.5	352	236	185

It can be seen from the above two design rainstorm calculation methods that the average rainfall is relatively close, but the Cv is quite different, and the maximum Cv of chart search method is larger 30.6% in 1 hour. The rainstorm observation data of Maxiang station has a long time and high accuracy, so the rainstorm data of Maxiang station is used to design the rainstorm calculation, and the rainfall data of the design rainstorm point is detailed in Table 3.

Table 3. Rainfall results of the design rainstorm point in the northern area of Xiamen New Airport.

Diachronic(h)	2%	10%	50%
1	86.7	65.8	41.1
3	139.1	104.7	64.6
6	203.9	146.1	82.3
24	317.9	226.2	125.8

The area of each river basin in the northern area of Xiamen New Airport is less than 10 km^2, so the point rainfall is the surface rainfall of the river basin.

3.3 Design Flood Calculations

Since there is no measured flow data in the basin, so the design flood is used to derived from the design rainstorm [8]. The design rainstorm of temporal pattern adopts the comprehensive rainfall pattern of Fujian Province, Taking the analysis results of Fujian Provincial Hydrological Station to check the correlation table between the intensity of net rain I and the stable infiltration fc. The design flood calculation includes surface runoff and subsurface runoff, which he same time flow is superimposed to form the design peak flow. The design flood calculation was based on the inference formula method and the East China extra-small watershed method, through comparing the two methodes calculation results determining the final calculation method.

(1) Reasoning formula method

Using reasoning to calculate the maximum peak flow method is:

$$Q_m = 0.278 \cdot \frac{R_\tau}{\tau} \cdot F \quad (1)$$

$$\tau = 0.278 \frac{L}{mJ^{1/3} Q_m^{1/4}} \quad (2)$$

Q_m —— design peak flow rate (m3/s)

J —— Average specific drop of slope and river channel along L (‰)

L - the longest distance from the outlet section along the main channel to the watershed (km) m—— confluence parameter

Rτ—— net rain depth in confluence time (mm)

τ——Catchment time of the maximum catchment area of the basin (hours)

F——Watershed area (km2)

According to the analysis data of Fujian Provincial Hydrological Station, coastal areas:

When $\theta \geq 1.5$, $m=0.053\theta^{0.809}$

When $\theta < 1.5$, $m=0.063\theta^{0.384}$

$$\theta = \frac{L}{J^{1/3}F^{1/4}}$$

After determining the confluence parameter m , the peak flow is calculated by equations (1) and (2).

(2)Extra small sized basin method of East China

According to the rainwater characteristics of the extra-small watershed, the East China extra-small watershed method uses the principle of reasoning formula to research and summarize the data, and researches on the characteristics rainwater and flood parameters in extra-small watersheds. According to the underlying surface type of the river basin in East China, the flood parameters of each basin were divided into five categories by adopting the underlying surface classification method. In the second category, it is divided into three types, and the calculation formulas of various types of flood parameters m are established respectively, which can be used for the design of water conservancy projects with a basin area of F<30Km2 (especially F<10Km2) in East China.

According to the underlying surface of the watershed, using $m=0.675\theta^{0.078}$ to calculate the design peak flow. $\theta=\frac{L}{J^{1/3}}$.

(3) calculation of design peak

According to the special plan for moisture and flood prevention in the northern area of Dadeng, the northern area of the new airport is divided into 9 zones(Figure1):

Zone 1: including 1-1 canals, the drainage area is $2.09km^2$;

Zone 2: including 2 canals, the drainage area is $0.29km^2$;

Zone 3: includes 3 canals, the drainage area is $1.45km^2$;

Zone 4: including 4 canals, the drainage area is $2.99km^2$;

Zone 5: including 5 canals, the drainage area is $0.52km^2$;

Zone 6: includes 6 canals, Hongbi and Dengqi flood detention area, the drainage area is $2.51km^2$;

the drainage area 7, 8 and 9 are directly discharged into the sea and not into the water system in the northern area.

Figure1:Zone map.

The features of watershed in the northern area of Xiamen New Airport are shown in Table 4.

Table 4. Characteristics of rivers in the northern area of Xiamen New Airport.

Zone number	Watershed area(km2)	River Chief(km)	Average grade(‰)
zone1	2.09	2.32	3.03
zone2	0.29	1.05	9.43
zone3	1.45	1.69	5.33
zone4	2.99	2.55	4.81
zone5	0.52	1.35	3.98
zone6	2.51	1.97	4.06

According to the reasoning formula method and the East China extra-small watershed method, the design peak flood flow was calculated once in 2 years, once in 10 years and once in 50 years. The design flood calculation includes surface runoff and underground runoff, which are superimposed to obtain the design peak flow. The design flood calculation results are shown in Table 5.

Table 5. Calculation results of each river watershed in the northern area of Xiamen New Airport.

Zone number	Reasoning formula method(m^3/s)			East China Extra-small Watershed Law(m^3/s)		
	2%	10%	50%	2%	10%	50%
zone1	26.1	18.2	9.97	29.1	20.3	11.4
zone2	4.75	3.22	1.83	6.35	4.46	2.52
zone3	20.6	14.5	8.42	26.3	18.7	10.3
zone4	38.7	27.4	15.4	45.5	31.4	18.1
zone5	7.09	5.07	2.92	8.59	5.77	3.30
zone6	34.4	24.4	14.0	43.6	30.1	16.4

According to the data of the two calculation methods, it can be seen that the calculation data of the East China extra-small watershed method is too high, and the calculation data of the East China extra-small watershed method is used according to the design principle that is more unfavorable to the project. According to the design principle that is unfavorable to the project, the East China extra-small watershed method is adopted.

3.4 Flood process line

According to the rainstorm flood process line of Fujian Provincial Hydrological Station calculates the surface flood process line the underground flood process. The underground flood process is according to the isosceles triangle distribution under the underground flood volume W, which the bottom width is twice the bottom width of the surface flood process line. The finally design flood process is obtained the same time superimposing the surface and underground flood process lines. The design flood process lines for 50 years of each drainage area are shown in Table 6.

Table 6. The northern area of Xiamen New Airport 50-year design flood process line

Diachronic(h)	zone1	zone 2	zone 3	zone4	zone5	zone 6	inbound
0	0	0	0	0	0	0	0
1	0.13	0.03	0.11	0.20	0.40	0.18	0.69
2	0.25	0.05	0.22	0.39	0.07	0.37	1.35
3	0.38	0.08	0.33	0.59	0.11	0.55	2.04
4	0.6	0.13	0.53	0.94	0.17	0.88	3.25
5	0.82	0.17	0.73	1.28	0.23	1.21	4.44
6	1.05	0.22	0.93	1.63	0.3	1.54	5.67
7	1.33	0.28	1.17	2.06	0.39	1.95	7.19
8	1.61	0.34	1.42	2.50	0.47	2.37	8.71
9	1.92	0.41	1.70	2.98	0.56	2.83	10.4
10	2.26	0.48	2.00	3.50	0.66	3.33	12.2
11	2.66	0.56	2.36	4.12	0.77	3.91	14.4
12	3.14	0.67	2.79	4.87	0.91	4.63	17.0
13	3.82	0.81	3.41	5.94	1.12	5.56	20.7
14	5.63	1.21	5.04	8.76	1.65	8.36	30.6
15	9.60	2.07	8.63	15.0	2.82	14.3	52.4
15.5	16.2	3.52	14.6	25.3	4.77	24.2	88.6
16	29.1	6.35	26.3	45.5	8.59	43.6	159
16.5	20.8	4.52	18.8	32.4	6.12	31.1	114
17	15.4	3.34	13.9	24.0	4.53	23.0	84.2
18	9.09	1.96	8.15	14.1	2.66	13.5	49.5
19	6.34	1.37	5.74	9.99	1.88	9.52	34.9
20	4.98	1.06	4.42	7.73	1.45	7.34	27.0
21	4.14	0.87	3.66	6.41	1.20	6.07	22.3
22	3.56	0.74	3.12	5.49	1.03	5.19	19.1
23	3.12	0.64	2.72	4.81	0.90	4.53	16.7
24	2.71	0.55	1.01	4.16	0.77	3.91	13.1

4. Conclusion

By analysis of the rainfall runoff and flood feature of Dadeng Island, take the rainfall data of the Maxiang rainfall gauge station as the bases to calculate design rainstorm point rainfall data of the northern area of Xiamen New Airport. After comparing the calculation data of reasoning formula method and East China extra-small watershed method, the East China extra-small watershed method is adopted to calculate the flood process line, which according to the design principle of the calculation project.This paper provides data reference for the design scale and investment of water engineering in the northern area of Xiamen New Airport.

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