Research on Improving the Safety Margin of Rainwater System Design for Large Civil Airports

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Keywords: Large Civil Airports, Rainwater Systems, Flood Control and Drainage, Rainfall Recurrence Period, Safety Margin.

Abstract: Rainfall statistics obtained by using a self-recording rain gauge describe the natural law of atmospheric rainfall occurring, while the uncertainty of atmospheric rainfall makes human beings unable to calculate or forecast any climate event that is going to happen or the degree of its impact any more accurately. Although the calculation formula of urban rainstorm intensity deduced from the statistical perspective is included into relevant design specifications, and the proposed rainfall recurrence period standard is followed to instruct the rainwater system engineering design, the rainfall recurrence period standard has been determined after multidimensional consideration to such factors as technology, economy, management and coordination of the designated age, and also reflects the technical strength of that age, which is also the minimum "threshold" of design. This paper, combined with construction features and development issues of large civil airports, in view of rainwater system engineering schemes involved in flood control and drainage of airports, and by form of case study, puts forward the necessity to improve the safety margin of rainwater system design, and conducts multidimensional research on how to improve the safety margin of design schemes, enabling the equipment and facilities of rainwater systems to cope with sudden disastrous weather events, and to a certain extent, adapt to the upgrade of technical standards in the future.

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1 INTRODUCTION

As the global warming effect intensifies, looking at climate data from the statistical perspective, we find that many historical records have been constantly refreshed, occurrence intervals of low-probability climate events are getting closer, and the uncertainty in climate is becoming more serious. On July 21, 2012 and July 20, 2016, heavy rainfall never seen over the past 50 years occurred twice in Beijing, and some suburban areas even suffered heavy rainfall[1] even never seen over the past century. These twice of heavy rainfall not only caused massive waterlogging on main urban roads, and flooded several flyovers, but also endangered subway stations, while the operation of Beijing Capital Airport also faced challenges, and relied upon its emergency plan to tide over the difficulty. During the same period, the flood level of major river basin in China approached or exceeded the highest water level in history, some regions suffered a flood disaster, which caused significant property damage to those regions, and as the flood level rose up, the rainwater self-discharging system and pumping station drainage system of several civil airports adjacent to main drainage channels were also under much pressure. Disaster weather during the flood season threatens the safe operation of airports; although the emergency plan of airports can effectively reduce operational risks, we should consider how to improve the ability to cope with more complex climate risks? This requires in-depth research on a better construction scheme to avoid similar risks at the stage of airport planning & design, and meanwhile, establishing an efficient operation control system and an effective management coordination mechanism. The focus of this paper is to study how to improve the safety margin of rainproof systems of large civil airports from the perspective of planning, design and management coordination. It will involve technical standards, design schemes and multi-department management coordination.

[1] Refer to long diachronic, flood prevention design recurrence period standard series.

Zhao, Q.
Research on Improving the Safety Margin of Rainwater System Design for Large Civil Airports.
In *3rd International Conference on Electromechanical Control Technology and Transportation (ICECTT 2018)*, pages 67-71
ISBN: 978-989-758-312-4
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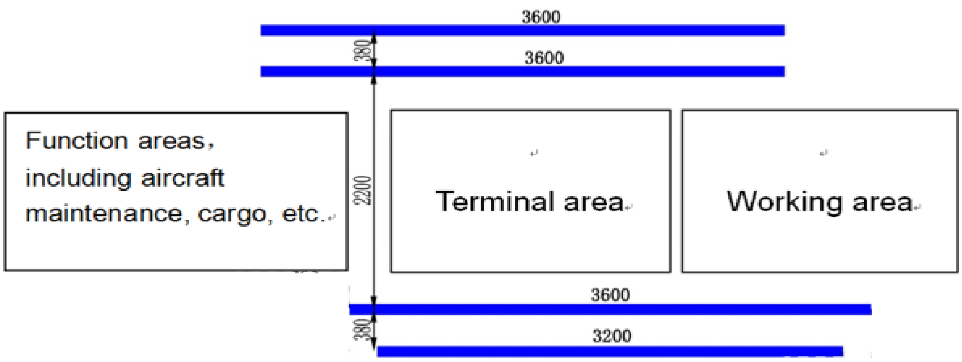

Figure1 diagram of the floor plan of the airport

2 DESIGN STANDARD EVOLUTION

The drainage design of movement areas in China's civil airports 30 years ago applied the rainstorm intensity formula, with its designed recurrence period of 1 year[2] (i.e. P=1 year), lower than the design standard proposed by International Civil Aviation Organization. At the end of 1980s, the domestic civil airport engineering design kept in line with the proposed standard of International Civil Aviation Organization, and raised such design standard to 5 years (i.e. P=5 years), and meanwhile, gradually unified the rainwater system design standard of the terminal area and working area with the movement area, and the rainwater system design standard of underpasses already reached 30 years (i.e. P=30 years). Rainwater system design schemes within airports have become increasingly reasonable. In recent 20 years, based on several decades of design experiences, we have successively prepared the industry standards and technical specifications in line with the construction features of China's civil airports.

3 LAYOUT CHARACTERISTICS AND PROBLEMS OF LARGE CIVIL AIRPORTS

Large civil airports refer to airports with multi-runway systems, with a basic structure of two long-distance runways enclosing the terminal area, and for future development, new runways will be constructed successively, which, as far as runway locations are concerned, will be defined as short-distance runways, medium-distance runways or long-distance runways relative to existing runways.

Near runway locations at airside, there are navigation facilities and airfield lighting facilities. Airport planning includes the cargo area, aircraft maintenance area, and working area. In the working area, there are various energy stations/rooms, such as switch station and substation of the power supply system, boiler room and refrigeration station of the heating & cooling system, pump station of the water supply and drainage system, regulator station of the gas system, etc. (fig. 1)

During the airport construction peak in 1990s, all of new provincial airports in China were planned with multi-runway systems, and phase one projects mostly first construct a runway and the relevant terminal area and supporting facilities. Due to insufficient experience in planning and construction at that time, rainwater systems lacked systematic planning, with inadequate consideration given to subsequent expansion in the medium and long term.

As the airport construction scale expands, especially when constructing the second runway, we would find some problems, such as the connection between existing facilities and subsequent expansion facilities is not smooth, particularly in respect of topographic connection, which caused an over-high price for subsequent earthwork projects due to lack of more thoughtful considration in the previous phase; since in-site and off-site rainwater system schemes were not smooth in connection, lots of rewiring and crossing problems arose, leading to an increase of project costs.

[2] Refer to short diachronic of rainfall, subject to urban rainwater system design storm recurrence standard series.

Besides, the earlier planning and design lacked systematic research on airport waterlogging issues. For example, when the runoff amount generated by rainfall within the scope of airports exceeds the planned capacity of off-site flood systems, how should airports resolve waterlogging issues on the premise of ensuring their own safety? Also, targeted research has been conducted on the “Sponge Airport” proposed recently.

4 NECESSITY TO IMPROVE THE SAFETY MARGIN OF RAINWATER SYSTEM DESIGN FOR AIRPORTS

4.1 Large civil airport project cases

The author was lucky to have the opportunity to take part in the design of Shanghai Pudong Airport construction project in 1990s, and experienced the process from project initiation to planning, design and construction site service. The Pudong Airport project is near the mouth of the Yangtze river, with long-term planning of land for at least two runways to be provided by subsequent land reclamation by filling the sea in the long run. Due to lack of soil source at the location near sea and in site per se, airports must solve the problem of flood prevention in-site and off-site. Through multiple rounds of scheme argumentation, and with overall consideration to all adverse factors at that time, the scheme design reserved a certain safety margin, and from completion to present, for 18 years, the rainwater system operation of Shanghai Pudong Airport remains safe and sound. The project has used a combination of multiple schemes to have addressed the rainwater system and damp/flood prevention issues within airports.

The new Guangzhou Baiyun Airport is China’s first project that has constructed two long-distance runways simultaneously. The flood prevention standards outside the airport are far lower than the airport construction standards. Through systematic analysis, and considering by the project team the planned conditions of off-site water systems, in areas restricted by in-site topography, the project uses forced drainage to raise the water level of the in-site drainage system, while for off-site open drainage channels, uses an inverted siphon drain culvert to cross low-standard watercourse for connection to flood control and drainage channels with planned conditions satisfying the requirements of civil airports. At the time of rainwater system design, when raising the design standards up to a higher grade for recalculation, we found the original design scheme could still realize smooth drainage. By comparing design calculation results, we find the cost for improving the safety margin of rainwater systems is limited, while the reduced degree of heavy rainfall risks faced by airports is significant (Table 1).

4.2 Necessity to improve the safety margin of design

Inspirations from the above two cases: the design standards are rigid and fixed, and multi-dimensional research schemes can be used to improve the safety margin of design. With the improvement of overall strength of engineering construction projects in China, considering that civil airport projects are a long-range program, the upgrade of technical standards is inevitable in the future. Therefore, it’s necessary and feasible to improve the safety margin of rainwater system design of large civil airports. The rainwater system design of airports follows the specified standards, which can be moderately raised up to a higher grade at recalculation, and can be optimized in combination with specific design conditions.

Table 1: Comparison of Calculation Results on Different Designed Rainfall Recurrence Periods

Designed Rainfall Recurrence Periods	P=5 years	P=10 years	P=20 years	P=50 years	Remarks
Runoff Growth Calculation	-	< 16%	< 32%	< 41%	Relative to P=5 years
Project Cost Growth	-	< 6%	< 15%	About 20%	

Notes: Take the calculation results of rainwater system design of a regional airport for example.

5 NEW TECHNOLOGY APPLICATION AND GRASPING KEY POINTS OF SAFETY MARGIN

At present, the newly developed flood control and drainage simulation software is introduced into new airport projects in Beijing and Qingdao. The flood control and drainage simulation software validates the safety of design schemes, and simulates the degree of waterlogging within airports under super-standard rainfall conditions. This points out a direction for further optimization of in-site rainwater system planning and design schemes, and also provides effective support for the operation department to make contingency plans for the future.

All the new airport projects launched recently are multi-runway projects. Also, reclaimed land is used to build artificial islands for construction of multi-runway civil airport projects, similar to Kansai International Airport in Japan. With regard to flood prevention of airports constructed on reclaimed land, consideration shall be given to the year-by-year rise of sea levels caused by climate changes.

In the age of information explosion and rapid technology progress, the rate of technology upgrade goes far beyond our imagination. Relevant mandatory specifications and technical standards promulgated by the state at different time frames are the minimum "threshold" under social, economic and technical conditions at that time, so the safety margin of design proposed herein is based on all-round thinking and research, and adaptable to the upgrade of technical standards in the future.

According to research and experience accumulation on design schemes of more than 20 large civil airport projects, factors that should be considered for improving the safety margin of rainwater system design for airports are summarized as follows:

5.1 Planning

1) Apply the same standard to off-site existing flood systems or planned drainage watercourse;

2) Transfer in-site rainwater system risks to off-site water systems to the greatest extent, which is good for actual operation and operation cost control of airports;

3) On the premise of observing the design standards and specifications, make sure to reserve a safety margin of design;

4) Use the "Sponge Airport" concept to reduce the pressure of flood systems, but in-site rainwater system design standards shall not be lowered.

5.2 Details of design schemes

1) Favorable for connection between current construction and future expansion, ensuring airports can realize reasonable and effective connection at different construction sequences;

2) The airport topography design and rainwater systems shall give consideration to connection with future construction schemes, and the selection of rainwater system as self-drainage or forced drainage shall control the volume of earth works within a degree acceptable to projects;

3) Various energy and water resource facility stations, depots, venues and underground entrances shall reserve a safety margin higher than the design specifications, all of which shall be designed to prevent rainwater from flowing backward.

4) To the extent allowed by designed conditions and controllable investments, the design of rainwater system pipelines, open channels and box culvert cross sections shall reserve a certain margin.

5.3 Operation management

1) According to the principle of administration by region and segment, in-site rainwater systems are controlled by the airport operation department, while off-site segments are controlled by the local watercourse administration;

2) Outlets with self-drainage functions are subject to dual-brake control as per internal and external division of labor, wherein, the outer gate is in a normally open state and controlled by the watercourse administration, while the inner gate is controlled by the airport operation department to prevent from backflow;

3) Build smooth in-site and off-site information communication channels to exchange data and information in a timely manner for use of emergency plans;

4) Clear rainwater system pipelines, channels and culverts every year, and regularly maintain and update equipment, facilities and key parts of rainwater pumping stations.

6 CONCLUSION

With the rapid development of civil aviation transportation, we should make a forward-looking master plan for large civil airports to lead each specific planning, and only those airport construction schemes of multi-system coordinated development would be scientific and reasonable. Facing climate challenges, we shall not stop at bearing, but cope with the upgrade of technical standards, and employ new technologies and new philosophies to reduce risks brought about by climate environments to airport operation.

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