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Research on impact of flooding on urban transportation safety

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Abstract. Extreme rainfall is one of the more serious disasters in recent years, and in recent years, many parts of the country have suffered from urban flooding generated under extreme rainfall, and the impact on transportation has been enormous. Researchers at home and abroad have found measures to cope with urban flooding in terms of transportation, but most of them are localized to explore the underground transportation or above ground transportation problems, and lack of a unified explanation. Therefore, the research theme of this paper is the measures of urban transportation to cope with urban flooding. The research method is as follows: this paper takes Zhengzhou City and several cities in Canada as examples and summarizes the impact of urban underground and above-ground transportation on extreme rainfall and the measures to cope with it in various places through the form of literature review. The study found that the improvement of drainage pipes for better drainage, as well as real-time monitoring of rainfall in the event of flooding, and the timely deployment of escape measures.

Keywords: Flooding, Transportation Safety, Zhengzhou, Underground Transportation.

1. Introduction

Flooding is a natural disaster of such magnitude that, according to statistics, there were an average of about 110 flood deaths per year in the United States of America between 1940 and 1999, most of which were automobile and flash floods; in China, 6,200 people died from freshwater floods in 1990 and 3,656 in 1998 [1]. Until this day, flood death rates remain high. in 2015, more than 27 people died when flooding occurred along the Mississippi River in the U.S. [2]. In 2023, July 22, 12 people dead in flash floods, 40 missing in Maidan Wardak province, Afghanistan [3]. July 2023 Beijing's persistent heavy rainfall caused flooding in many areas. There are many factors of flood formation. First, extreme rainfall is the main cause of flooding, which occurs when rainfall exceeds the carrying capacity of rivers, streams and creeks. And many climate changes contribute to extreme rainfall, such as El Niño events. Due to the development of convective activity in the equatorial east-central Pacific Ocean, the Middle East produces large amounts of rainfall [4], which results in flooding. Second, the construction of cities and the development of urbanization have led to the intensification of the heat island effect thus leading to increased water vapor convective movement inside high-rise buildings and the inability of air to flow, resulting in an increase in urban rainfall [5]. Third, in terms of coping with heavy rainfall, urban drainage systems are not yet adequate, with no effective planning for drainage pipes in the land planning process, and in some places, there is a problem of not adopting up-to-date urban drainage systems. Many cities have adopted a policy of diverting water from the city center to a distant pipe network, without forming a local drainage policy [6].

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Floods are usually very harmful. Firstly, floods can reduce biodiversity by increasing the spread of diseases among wildlife, for example, the 2012 floods in Kaziranga National Park in Assam, India, killed hundreds of animals. Secondly, floods cause huge damage to the country's economy and roads, such as collapsing houses, damaging crops, and destroying bridges and railroads. Thirdly, the floods have a direct impact on human beings as many people are displaced, infectious diseases spread and even many casualties are expected. Fourthly, floods also have a great impact on the environment, such as erosion of riverbanks and causing them to collapse, blocking river beds and streams. Fifthly, floods can bring pollution such as industrial chemicals, and sewage flows down the floodwaters into the oceans; in February 2019, the Great Barrier Reef off the coast of Queensland, Australia, was inundated with polluted floodwaters.

Underground stations of urban rail transit are an important part of urban transportation and a direct point of action for heavy rainfall. The generation of heavy rainfall will directly lead to the back-up of road surface water, which will flow into the underground rail system [7]. Underground track entrances and exits of the flood control system is an important factor in determining the degree of the underground track affected by rainstorms, entrances and exits are generally selected relatively low-lying areas or nearby roads have inclined slopes, the former can form a natural waterlogged area to reduce the risk of traffic being flooded, the latter can reduce the accumulation of water on the ground near the rainwater will be discharged into the drainage pipe to reduce the risk of rainwater backflow. The type of egress also affects the risk of underground transportation being affected by flooding. Enclosed egress reduces the area exposed to storm water but carries the risk of storm water backups, while open egress has more exposed area but better drainage capacity [8]. This paper examines the transportation management through case studies, in order to decrease the damage of the flooding on traffic.

2. Impacts of flooding on transportation - the case of Zhengzhou

2.1. The cause of Zhengzhou flooding

In July 2021, there was continuous heavy rainfall in Zhengzhou, from July 18 to 22, the average precipitation in Zhengzhou was 537.4 mm, as shown in figure 1. 139 meteorological observatories generally experienced heavy precipitation (⩾20 mm/h), and heavy precipitation with an intensity of 100 mm/h or more was observed in the main urban area [9], and a once-in-a-century heavy precipitation was observed in Zhengzhou from July 20 to 21 (from 2:00 on July 20 to 21:00 on July 21), which caused water ingress into the subway and vehicles in a short period of time due to persistent heavy precipitation. July 20 to 21, Zhengzhou had a once-in-a-century heavy rainfall (622.7 mm of rainfall from 2:00 on the 20th to 2:00 on the 21st, with a maximum rainfall of 201.9 mm in 1 h) [10], and the sustained heavy rainfall within a short period of time resulted in the subway flooding in Zhengzhou and the vehicles were flooded.

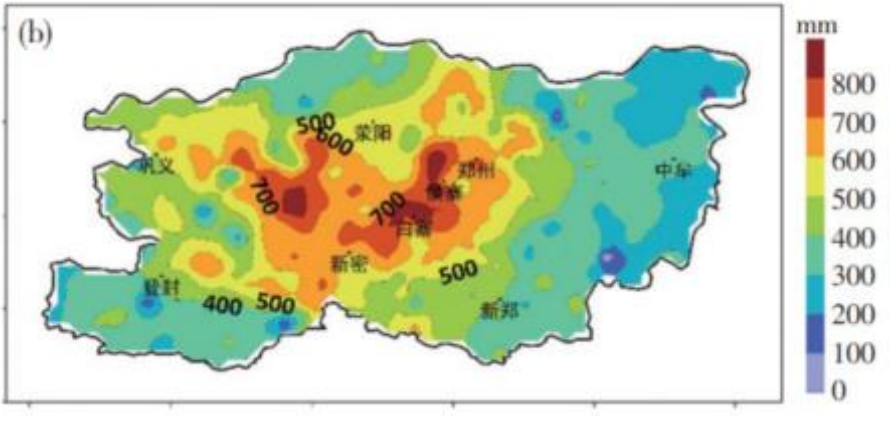

Figure 1. Cumulative Precipitation for Zhengzhou City, July 18, 2021, 08:00-22:00 [11].

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2.2. Zhengzhou City Drainage System

Zhengzhou drainage pipe using cast iron pipe, concrete pipe, steel pipe and plastic pipe, pipe network only 70%, and part of the pipe has not been improved and renovated, the diameter of only 20cm (normal pipe is usually 300-600cm) and the use of direct drainage mode. All these lead to poor drainage capacity in Zhengzhou and flooding whenever there is water. In addition to this, Zhengzhou's urban center is growing fast and chose to build a network of green facilities from within the city limits without a comprehensive risk assessment.

2.3. Zhengzhou "7.20" incident

In the case of continuous heavy rainfall, due to the Zhengzhou underground railroad tracks using the form of pit support, underground railroad tracks produce rainwater flooding phenomenon: 16 axes north of the ground 9 m, 20 axes south of the ground 6 m, 26 axle north of the ground 5.5 m, 25 axis south of the ground 6 m have appeared in the case of seepage, of which 25 axle of the amount of water more than 100/h, pit back to 7 m.

2.4. Countermeasures for flooding in Zhengzhou

First, Zhengzhou needs to improve its drainage pipes and use large-diameter pipes, such as the 2.8-meter-diameter rainwater irrigation used in the Zhengzhou Zhongzhou Avenue and North Ring Intersection renovation project [12]. It should also popularize the drainage pipes, expand the network and try to use the rainwater and sewage diversion system. Second, the use of durable materials to build pipelines, reduce the risk of pipe aging, and replace traditional concrete pipelines with UPVC pipelines to increase the durability, strength, and drainage efficiency. Thirdly, increasing the permeability of the ground can better help rainwater infiltrate during heavy rainfall, reducing the risk of urban flooding [13]. Similarly, it is possible to increase the green area, build green areas along the river and use the wetland model to build part of the green area. Fourth, improve the design standard of drainage pipe network and drainage efficiency in underground space, and add vertical escape routes such as drainage wells in the underground railroad tracks to help people escape better when flooding occurs [14]. Fifth, real-time detection of pit leakage, in small leakage occurs in time for drainage treatment [15]. Sixth, the government should also increase financial support, activities to advocate, mobilize people to build green roofs or cisterns on their own roofs to better collect rainwater to reduce the possibility of flooding [16].

3. Impacts of flooding on transportation - the case of Canada

3.1. Occurrence of rainstorm in Canada

As Canada is located next to streams, flooding is one of the most enormous problems. Similarly, hurricanes, flooding and other problems that arise during heavy rainfall also have a huge impact on transportation. Halifax, for example, has urban flooding that affects its transportation network in that area. In Halifax, most commuters use two bridges to connect the twin cities of Halifax and Dartmouth, which are vulnerable to extreme weather events [17].

In Montreal, for example, heavy rainfall is the biggest cause of traffic accidents: due to high speeds, heavy rainfall affects can range and traffic accidents are frequent. Speed limits on Montreal highways are still high (70-100km/h), which leads to frequent traffic accidents on highways. The SAAQ in Montreal counts the number of accidents per day, and the results show that the frequency of accidents is higher in winter, as shown in figure 2, and one of the reasons is flooding in Canada in winter due to ice jams: when ice debris builds up, the flow of rivers is restricted, which triggers flooding [18].

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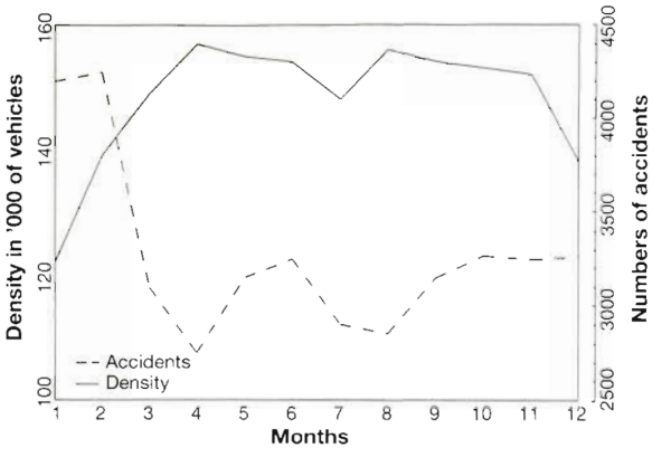

Figure 2. The accidents during a year [19].

3.2. Flood prevention measures

First, in improving the ground. In Ontario, for example, periodic heavy rainfall has a significant impact on ground concrete, which may create a risk of urban flooding if not drained in a timely manner. Therefore, experts have suggested that stabilized base materials can be used in JPCP concrete floors in Ontario, which can help to promote drainage in places where frequent flooding occurs, prevent urban flooding due to water buildup, and strengthen the base support of JPCP slabs [19]. Secondly, improving transportation evacuation measures in response to flooding. Taking Halifax as an example, the amount of water accumulated at each exit was analyzed, as shown in Figure 3, and the best shelter for people at each time period was analyzed and studied to disperse a large number of people to different exits as well as shelters to avoid population casualties caused by traffic congestion .

Figure 3. The exists in Halifax [20].

4. Conclusion

Based on the two case studies, this paper finds that in situations where urban flooding occurs frequently, it is essential to improve urban drainage and expand the transportation network, build and improve drainage systems in underground transportation areas, and find the best way to evacuate people based on the topography of the terrain. Similarly, it is important to keep an eye on traffic accidents due to urban flooding and revise policies to reduce the probability of traffic accidents. This paper also has some drawbacks: it is based on only two case studies, which has the limitation of not being able to take into account all urban flooding occurrences in a comprehensive way.

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