ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202106_4(6).0044

Safety Evaluation of Underground Parking Garag

-- Taking the Underground Parking Garage of A Residential Area as An Example

Yuanran Ren[1,*], Ke Ren[2]

[1]School of Chongqing Jiaotong University, Chongqing, 400074, China

[2]School of Chongqing University of Education University, Chongqing, 400065, China.

Abstract

In the high degree of mechanization of social development, the increasing number of motor vehicles, to solve the problem of urban parking more urgent, after the early roadside parking and open parking, people gradually focus on the underground parking, saving land and convenient management, so that underground parking becomes the best choice to solve the problem of urban parking. With the development of China's urbanization, with the planning and construction of urban commercial complex and its surrounding residential land, the number of underground parking lots will continue to increase, and the safety problems will also appear. This paper analyzes the safety factors of underground parking lot from four aspects of entrance and exit setting, garage road conditions, underground traffic system setting and safety facilities layout, and uses VISSIM to carry out experimental simulation, and discusses an actual residential underground parking lot, so as to provide systematic theoretical guidance for the planning and design of underground parking lot in the future.

Keywords

Urban parking; Underground parking; Safety; VISSIM simulation.

1. Introduction

The past 2020 was a severe year, COVID-19 was devastated by the rest of the world, and the world economy was devastated. However, under the impact of the epidemic situation, China's economy has become the main force. After the recession in the first half of the year, China's economy has picked up and developed rapidly in the second half of the year. In the context of China's economic recovery, many second - and third tier cities in order to enhance the vitality of the city, promote the development of urban regional economy, enrich the material and cultural life of citizens. In the planning and construction of the city's commercial complex. In order to rationalize the planning of economic benefits, the corresponding buildings will also be planned around the commercial complex. Whether it is a commercial complex or a residential area nearby, they all have their own underground parking lot, which is the main point of this paper.

2. Development of Underground Garage

As early as the 40 years ago, the parking problem of cities has been emerging in the process of high degree mechanization [1]. In view of the particularity of parking, the further discussion on parking is from urban planning [2]. Through understanding the management parking problem of American towns, Scully w J. puts forward that the influencing factors of parking in the central area of the city are parking supply and parking management. It is suggested that parking

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202106_4(6).0044

management should be paid more attention to the improvement of small and medium-sized cities [3]. From 40 last century to 2021, from roadside parking to underground parking, there are four main types of parking. At first, it was just a simple roadside parking, and then designed a certain scale of open-air parking lot. However, with the rapid growth of the number of vehicles, the open-air parking lot has some limitations in solving parking problems because of the excessive land occupation. The garage construction has to develop in three-dimensional direction, so there are many storeys of garage. However, in the face of the increasingly popular environment of cars, multi-storey garage is difficult to meet the rising parking demand; at the same time, the price of urban land is also rising, the urban prosperous areas are more land, and the cost of parking on the ground is too high. In this case, people have focused on the construction of parking facilities to mechanical three-dimensional parking and underground parking. Underground parking is the main parking mode nowadays, which can be divided into two types: single building type and auxiliary building type.

The single built underground garage is an underground garage without buildings on the ground. It is generally built under the city square, park green space and open space. Its main feature is that regardless of its size, it has no impact on the space and buildings on the ground. Except for a few entrances and vents, the top of the garage is still an open space in the city. The structural form and column network layout of single underground garage will not be restricted by the ground buildings. The planning and design of the garage according to the needs of vehicle driving and storage can comprehensively improve the utilization rate of garage area and the economy of construction. But the single underground garage also has some defects. In the process of its construction, it needs a certain excavation construction site, which will have a huge impact on the urban center area with a large flow of people and the road section with a large flow of traffic.

Because of the large demand for parking, the underground space of the attached underground garage is expanded to the square and green underground in the area to increase the capacity of the underground space. The attached underground garage is closely combined with the ground building, saving land resources, convenient to use and easy to manage, but the biggest difficulty of this type of underground garage is the restriction of the ground building structure column grid on the underground space layout [4, 5].

In short, compared with the single built underground garage, the attached underground garage is more common, the utilization rate is higher, and more problems need to be studied. This paper also discusses the safety factors of the built underground garage.

3. Safety Factors of Underground Garage

3.1. Entrance and Exit Settings

The entrance is the connecting passage between the underground garage and the road, and it is one of the important parts of the underground garage. The safety factors of entrances and exits are reflected in the following three points. The first is to build the number of entrances and exits. The number of entrances and exits should match the scale of the underground garage. If there are more vehicles in the underground garage but less imports and exports, and the efficiency of entering and leaving the site is low, it will cause serious congestion and security risks; on the contrary, if there are fewer vehicles in the underground garage but more imports and exports, it will cause excessive waste of resources. The second is the parameter setting of the entrance ramp. From the ground to the underground, the line of sight gradually becomes worse, and the entrance ramp is usually accompanied by turning, so the safety factors such as lighting, height limit, slope and turning radius are particularly important. Finally, the connection between the entrance of the ramp and the main underground passageway should be avoided as far as possible. When the vehicle enters the garage through the motor vehicle

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202106_4(6).0044

ramp, even the gentle ramp will have certain acceleration. In this case, it is not suitable to turn and other operations,it is safer to drive straight into the garage. This requires the three-dimensional structure of the underground garage, it is shown in Figure 1.

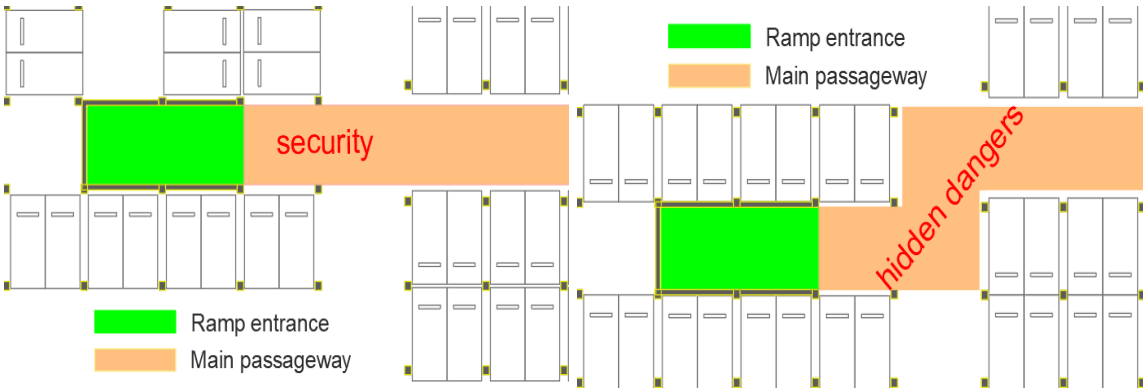

Figure 1. Connection safety between ramp and main passage

3.2. Road Conditions of Underground Garage

The road condition of underground garage is different from the ground road. Because the attached underground garage does not belong to the theme of the whole building, but the service space, the internal structure of underground garage is often restricted, and it is easy to have unusable space, resulting in waste of resources. Therefore, the disposable space of underground garage is limited. In order to ensure the fluency of underground traffic and facilitate the circulation of parking space, the underground traffic flow is designed to meet the internal circulation, which means that there must be two-way traffic in the underground traffic flow, which requires the road of underground garage to have higher conditions. However, with the existence of garage columns, the width of underground garage lane and turning radius space are often sacrificed to ensure the parking space of underground garage, which will become a serious traffic safety hazard.

3.3. Setting of Underground Traffic System

The setting of underground traffic system is an important part of underground parking garage. In this paper, the underground traffic system is divided into underground traffic flow, underground people flow and mixed flow of people and vehicles, which are analyzed in detail. Underground traffic flow is the main body of underground traffic system. In order to reduce the time and distance for vehicles to drive in unfamiliar environment when looking for parking space, and to prevent congestion, how to quickly and conveniently guide vehicles to park and enter the warehouse is the key. Nowadays, the commonly used traffic flow line is set as the inner circulation of underground flow line, and the guidance signs and prohibition signs of traffic vehicles are set up to ensure the safety of vehicles The driving direction is accurate to reduce the driving time of vehicles and avoid the safety hazards caused by congestion. Underground people flow is the inevitable product of underground parking garage, which is usually reflected in the back and forth people flow from each parking space to the passenger elevator, and it will inevitably overlap with underground vehicles, thus forming a mixed flow of people and vehicles. Compared with vehicles, pedestrians are weak entities. In the underground traffic system, it is necessary to ensure the personal safety of pedestrians. Pedestrian walking space with sufficient width should be set near each parking space and connected with each other. If it is a commercial underground parking lot, pedestrians are not familiar with the environment, and pedestrian signs should be set.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202106_4(6).0044

3.4. Layout of Safety Facilities

The safety facilities of underground garage mainly include deceleration belt, reflective spike, reflector, anti-collision bucket, corner protection, etc. reasonable layout of safety facilities can effectively guarantee the safety of underground parking. The location and function of each safety facility are as follows.

3.4.1. Crash Barrels

The anti-collision bucket is usually set up in the underground garage where the car and the fixed facilities in the road collide easily, such as the corner of the road, the sentry box in the road, the toll station and the entrance and exit of the basement, etc. It has the function of isolation. The anti-collision barrel is made of high elastic and high-strength modified plastic, and its surface is pasted with reflective film. If the car collides with the anti-collision barrel, it can effectively reduce the impact force, so as to greatly reduce the damage between the car and people.

3.4.2. Reflector

Generally, 800mm diameter convex reflective mirror is set at the bend, intersection of passageway, corner of wall and entrance and exit of parking garage. It can enlarge the driver's vision, help avoid the hidden danger caused by blind area of vision and find vehicles opposite the curve in time.

3.4.3. Angle Guard

The corner of the passage in the parking lot is often hit by vehicles, which not only damages the vehicles, but also brings hidden danger to the overall safety of the building. Therefore, a conspicuous rubber corner guard is added at the quarter corner of the column that may be impacted to avoid the damage caused by the collision between the vehicle and the wall.

3.4.4. Speed Bump

The speed bump is usually set at the entrance and exit of parking lot, intersection and the entrance and exit of basement ramp, while the deceleration strip is not set in the passage with general length of underground garage as far as possible. If the passage is more than 50m long, the speed bump is considered. It helps to reduce the driving speed in parking lot and avoid accidents caused by too fast speed.

3.4.5. Reflective Spike

Reflective studs are added on the ramp contour and central isolation line to highlight the marking contour to the greatest extent and prompt the driver to enter the road by rubbing the tire with it.

3.4.6. Outline Marker

At 800mm from the side wall of the garage ramp to the ground, a outline mark is installed every 4000mm in the straight section and every 2000mm in the curve section.The road contour of reflective luminous vehicle can be formed by continuously laying the outline mark, and the illumination of the outline mark can play a good guiding and warning role.

4. Case Analysis

The project case is an underground parking garage of a residential block near a large-scale commercial complex. The underground garage has only one floor and a total of 477 parking spaces. It serves nine residential blocks in the block and is a non-commercial underground parking garage. The structural plan of the garage on the lower floor is shown Figure 2. The structural plan has been simplified, only ramp entrance, residence, passageway and parking space are shown in the plan.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202106_4(6).0044

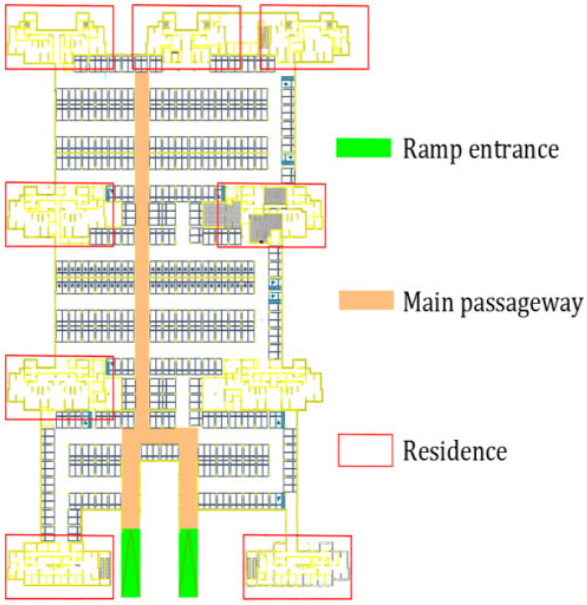

Figure 2. Plan structure of underground garage

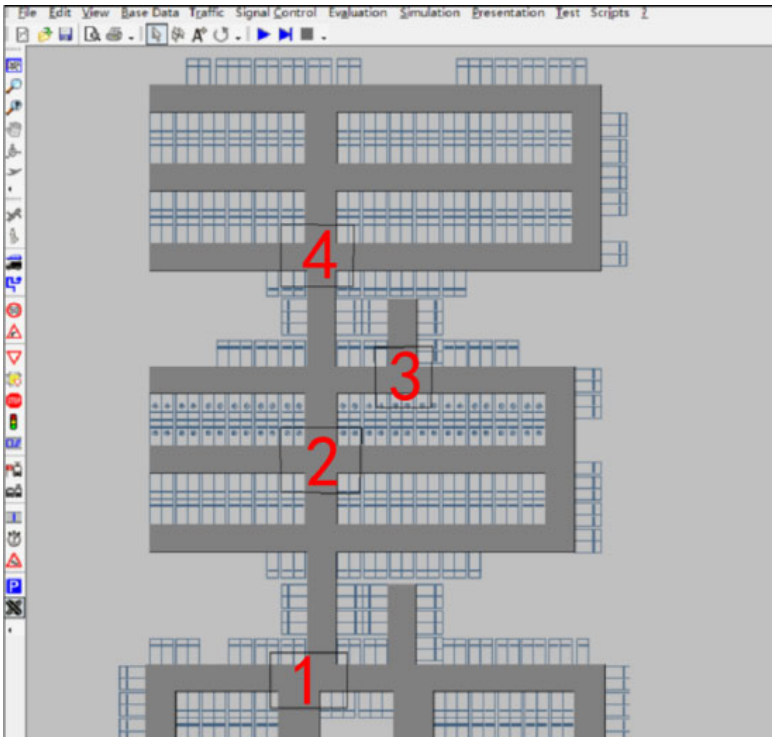

Figure 3. Simulation intersection number

According to the analysis and evaluation of the safety factors mentioned in the previous section, the first is the entrance ramp. Because it is a non-commercial small-scale underground garage with a parking capacity of 477, only two entrances and exits are set, and the structure of the entrances and exits is symmetrical and similar. The ramp is straight without turning, and the turning radius and other factors need not be considered. The clear width of the ramp is 7 meters, the clear height is 2.45 meters, and the slope is 15% The starting point of the ramp is not directly connected with the main underground passage, but there is a buffer distance of 25 meters behind the starting point to control the vehicle speed. Therefore, the ramp is ideal for non-commercial garages with only cars.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202106_4(6).0044

Secondly, the condition of underground road safety is analyzed. The author obtains the traffic flow line by hanging signs at the intersection of the underground garage, and finds out the shortest clear width of one-way traffic flow, two-way traffic flow and the minimum turning chamfer respectively. After measurement, the shortest clear width of one-way traffic flow channel is 5.5meters, which is far greater than the minimum required clear width of 4meters; The shortest clear width of the two-way traffic flow channel is 5.5meters, which meets the minimum requirement of 5.5meters. The minimum turning chamfer is 0.7meters, which meets the minimum requirement of 0.5meters [6].

The safety of underground intersections is analyzed and scored by VISSIM simulation. The plane structure of the underground garage is relatively regular and symmetrical, and there are intersections with similar structure, therefore, four intersections as shown in Figure 3 are selected for simulation evaluation. From bottom to top, they are intersection 1, 2, 3 and 4 respectively. The intersection flow, left turn traffic flow and delay data obtained are shown in the Table 1.

Table 1. VISSIM simulation data

Underground garage						
Intersections	Traffic volume	Left	Straight	Right	Proportion of left (%)	Delay (s)
1	124	11	101	12	8.9%	6.2
2	61	7	54	0	11.5%	3.7
3	19	0	13	6	0%	0.0
4	53	7	19	27	13.2%	0.8
Entrance and exit	136	-	-	-	-	-

The obtained data are standardized and analyzed with the marked data. For example, let Min a and Max a be the minimum and maximum traffic flow of an intersection respectively, and map an original value of a to a value in a certain interval through min max standardization. The interval value in this paper is [60,95], and the Formula 1 is as follows:

$$\alpha = 60 + 35 \times \frac{\mathrm{maxA-a}}{\mathrm{maxA-minA}} \tag{1}$$

The simulation intersection is divided into cross intersection and T-intersection. Here, the safety evaluation score of cross intersection is defined as 30, and the safety evaluation score of T-intersection is defined as 50. The other safety evaluation index data of intersection after standardization are shown in Table 2.

Table 2. Safety evaluation value of intersection

Intersections	Type	Traffic volume	Proportion of left	Delay
1	30	63.6	71.4	60.0
2	30	82.4	64.5	74.1
3	50	95.0	95.0	95.0
4	30	84.8	60.0	90.5

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202106_4(6).0044

According to the standardized data of intersection, a simple evaluation is carried out, and relevant experts and staff are organized to score the indicators to determine the weight. The final evaluation score is determined according to Formula 2:

$$P = \sum_{i=1}^{4} \beta_i \gamma_i \tag{2}$$

Where P is the final score, β_i is the weight of each index,γ_i is the index score based on the highest component of each index. The final score P is divided into four levels, 60 to 70 is poor, and 70 to 80 is general ,80 to 90 is good, 90 to 100 is excellent. See Table 3 for the safety assessment results of the four intersections.

Table 3. Safety evaluation grade of intersection

Intersections	Final score (P)	Evaluation grade
1	67.4	poor
2	75.4	general
3	100.0	excellent
4	80.6	good

It can be seen that the safety evaluation level of the underground garage intersection is relatively good, only intersection 1 has the lowest score, because it is closest to the entrance and exit, there are many traffic flows, and the traffic flow line here is complex, and there are many conflict points. There is only one-way traffic conflict between left and right, and there is no right turning point.

The next is the setting of underground transportation system. The underground traffic flow and hanging signs are shown in the Figure 4. The ban signs are also included in the hanging signs. The internal traffic flow is smooth, the accessibility of vehicles is high, and it can reach any parking space. A total of 27 hanging signs are set up in the underground garage, which are distributed at each key intersection to guide vehicles to drive and complete parking reasonably. Because this is an underground garage for residential use, the driver knows the environment of the garage very well, so there is no need to set signs related to pedestrian guidance, but it still needs pedestrian space to realize the separation of people and vehicles. The underground garage in this case is very simple There is a pedestrian space with a width of 0.2m, and each parking space is connected with the passenger elevator.

Finally, the layout of safety facilities. Through on-site investigation, the safety facilities of the garage are recorded, and the overall and detailed layout of safety facilities are shown in the Figure 5. It can be found that the safety facilities of the garage are relatively perfect, but the anti-collision bucket is set less, which is only set at the entrance and exit of the underground garage, but not at the corner of the underground garage which is prone to collision There are anti-collision buckets, but there are some deficiencies.

To sum up, as an underground garage serving residential residents, from the above four perspectives, the safety situation of the garage is relatively good.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202106_4(6).0044

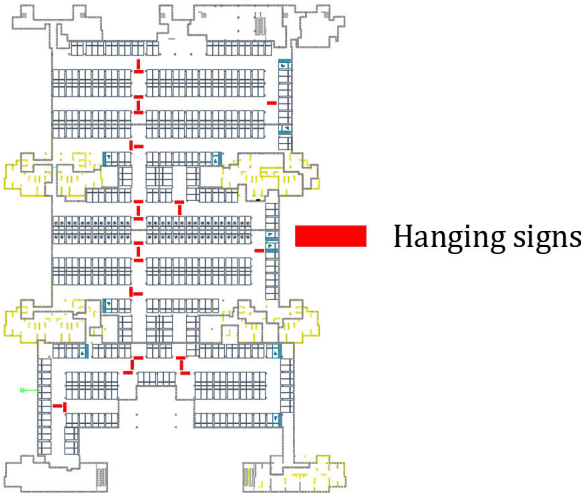

Figure 4. Schematic diagram of hanging signs

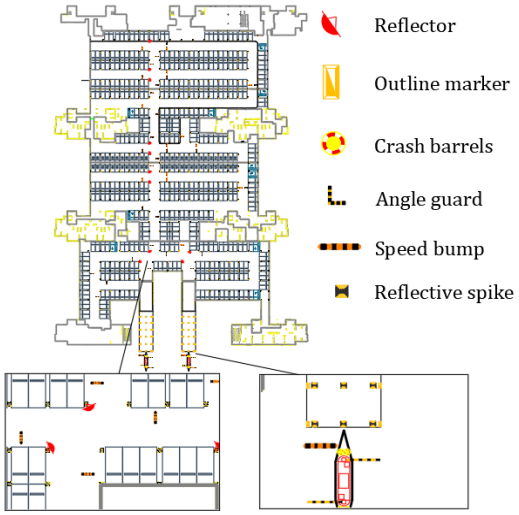

Figure 5. Schematic diagram of safety facilities

5. Conclusion

There is no doubt that, as the second largest economy in the world, in the process of further urbanization, there will be more and more commercial complexes, and the surrounding residential plots will follow suit. In the future, there will be more and more underground garages planned and built. Therefore, the safety of underground garages needs our attention. Now, in the intelligent era of emphasizing the combination of traditional transportation and computer network, I believe that more intelligent modern underground parking will appear in front of us.

References

[1] Tobergte D and Curtis S: Shared parking in the Portland metropolitan area, Journal of Chemical Information and Modeling,Vol. 53(2013)No. 9,p.1689-1699.

[2] Liu Ying: Discussion on the parking problem of Nanjing City, Jiangsu Urban Planning, (2006) No.11,p.2 1-23.

[3] Scully W J: Parking management in a small community : back to basics, Ite Journal, Vol. 58(1988) No.11,p.32-35.

[4] Hu J:Research on urban underground garage design,(MS., Zhengzhou University, China 2012), p.83.

[5] Chain National Standardization Management Committee. Code for design of garage buildings (China Standardization Press, China 2015).

[6] Li C, Chen K and Xiang X: An integrated framework for effective safety management evaluation: Application of an improved grey clustering measurement, Expert Systems with Applications, Vol.42 (2015) No. 13,p.5531-5553.