Research on Optimal Design of Urban Underground Parking Space

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Abstract. In recent years, with the continuous acceleration of urbanization, underground parking lots have also sprung up and are moving towards intelligence. Due to the rapid development of underground parking lot construction, many problems have also been exposed, such as low space utilization due to unreasonable space design. Therefore, this article optimizes the design of the parking space in terms of the layout of the column network of the underground parking lot, the occupied area of the single parking space, the parking method of the vehicle, and the parking mode, so as to improve the utilization rate of the underground parking space resources.

1. Introduction
In recent years, with the continuous acceleration of urbanization, underground parking lots have also sprung up and are moving towards intelligence. Due to the rapid development of underground parking lot construction, many problems have also been exposed: on the one hand, the phenomenon of difficult parking can be seen everywhere, on the other hand, many existing parking facilities have a low utilization rate [1-3]. The cause of these problems can be summarized as the extensive parking space design, which is related to the extensive urban development in China in the past few decades. The continuous improvement of the level of urbanization makes the extensive development model unable to meet the new requirements. The efficient, intensive, multifunctional and composite land development model will become a new benchmark for urban land development [4].

Therefore, this article optimizes the underground parking space design from the aspects of column network layout, single parking space occupation area, vehicle parking mode, parking mode, etc., in order to improve the utilization of underground parking space resource [5-8].

2. Optimal Design of Column Network Layout in Underground Parking Lot
When designing the column grid of the parking lot, it is necessary to meet the technical requirements, optimal area index, and reasonable structural economy, including factors such as the size of the structural span should not be too large, the material consumption should be small, and the size of the structural members should be reasonable. It does not occupy too much indoor space, the column spacing is suitable for a certain structural form, and the types of column network units should not be too many.

According to the above analysis, the area of a single parking space for vertical parking in a city's common basement is: the size of a mini car parking space (width x length): 2.2m x 4.5m; the size of a small parking space (width x length) is 2.4m x 5.3 m, the size of the structural columns in the basement is generally considered as a 600mmx600mm square column.

Calculated value of the distance between two vehicle columns:
Mini and small car parking space combination: 2.4m + 2.2m + 0.3m + 0.3m = 5.2m
Two small car parking space combinations: $2.4m + 2.4m + 0.3m + 0.3m = 5.40m$
Calculated value of three-car column spacing:
Parking combination of three small cars: $2.4m + 2.4m + 2.4m + 0.3m + 0.3m = 7.8m$
Location combination of two small cars and one mini car: $2.4m + 2.4m + 2.2m + 0.3m + 0.3m = 7.6m$
Combination of three mini cars: $2.2m + 2.2m + 2.2m + 0.3m + 0.3m = 7.2m$

The economic span of a general reinforced concrete structure is about 8m, the width of each parking space of a mini car is about 2.2m, the width of each parking space of a small car is about 2.4m, and the size of three parking spaces is closest to 8m. The most economical mini car parking column clear distance is 7.2m (both: 3 cars x 2.2m / parking width + half column width x 2); the most economical small car parking column clear distance is 7.8m (both: 3 cars) x 2.4 m / parking width + half-column distance x 2). Considering that the length of the side of the column generally does not exceed 600, then: the column network of the parking area for mini cars generally uses a column distance of 7.2 m; the column network of the parking area for general mini cars uses a column distance of 7.8 m.

According to the analysis of the garage driveway: when a 5.6 m wide driveway is used, parking spaces can be arranged along the sides of the driveway to park backward, forward, and perpendicular to the driveway. The regulations stipulate that the length of parking spaces for mini cars is 4.5m, the length of parking spaces for small cars is 5.3m, and the width of the aisle is 5.5m. The most economical arrangement is a middle lane with two rows of parking spaces on both sides. Considering a little more margin, the general depth is to use the span of N * (4.5 + 5.6 + 4.5) and N * (5.3 + 5.6 + 5.3), but this span is not the most economical, so the width of the aisle is generally enlarged and the width of the parking space Reduced to form N * 7.3 and N * 8.1 spans.

Therefore, we obtained the reference dimensions of the city's common basement column network as follows: the most economical mini car parking area column network is 7.2m (face width) x 7.3m (depth); the most economical small car parking area column network is 7.8m (face area) Width) x 8.1m (depth). Partly due to other conditions, a dual-car column network can be used, that is, the mini-car area column network is 5.2m (face width) x 7.3m (depth); the small car area column network is 5.4m (face width) x 8.1m (depth) ). For the attached type, sometimes due to the small floor size of the upper building column net or shear wall, it may be reasonable to park a car between the two columns.

3. Optimization of parking space in underground parking lots

3.1. Occupied area of single parking space

According to the "China's Auto Sales Rankings for the 2018 Market" published by China Business Information Network (see Tables 1 and 2 for details), it can be seen that the top 20 small and medium-sized cars account for more than 90% of the sales volume. At the same time, according to the statistics of the car home, the vehicle width is concentrated between 1.7 and 1.9m, and the width of some compact cars is about 1.6m. The width of some American vehicles even exceeds 2.0m.

It can be concluded that the class of vehicles with the largest number of vehicles in the society is small cars. Therefore, the design of our basement should also be based on small cars, and a combination of mini cars and small cars can be used. Generally, about 10% of micro parking spaces can be made.

| Model                  | Size (length / width / height)mm | Model                  | Size (length / width / height)mm |
|------------------------|----------------------------------|------------------------|----------------------------------|
| Changhe Big Dipper     | 3400×1575×1670                   | Chery QQ               | 3550×1495×1485                   |
| Changan Benben         | 3730×1650×1530                   | Suzuki Alto            | 3570×1600×1470                   |
| Geely Panda            | 3815×1648×1530                   | BYD F0                 | 3460×1618×1465                   |

From the above data, we know that the width of mini cars is mostly about 1.6m and the length is less than 4.0m. Considering the needs of parking and door opening and closing and combining with the provisions of Article 34.6.0.12 of the Code: when the vehicle length is ≤6m or the vehicle width is ≤1.8 m. At the time required for a car to leave and the distance between cars and cars is 0.5m. The width of
a parking space for a mini car can be 1.6m + 0.3m + 0.3m = 2.2m; the parking space for a mini car can be 4.0m + 0.5m (horizontal parking 2.2m) = 4.5m (horizontal parking 5.2m).

Therefore, the size of the parking space (width × length) when the mini-vehicle is parked vertically is: 2.2m × 4.5m; the parking space size (width × length) when the mini-car is parked horizontally: 2.2m × 5.2m.

Table 2: Common compact cars (Car size statistics table)

| Model                  | Size (length / width / height)mm | Model                  | Size (length / width / height)mm |
|------------------------|----------------------------------|------------------------|----------------------------------|
| Volkswagen Lavish      | 4605×1765×1460                   | Volkswagen Sagitar     | 4655×1780×1453                   |
| Nissan Xuanyi          | 4610×1760×1495                   | Volkswagen Jetta       | 4487×1706×1470                   |
| Buick Excelle          | 4515×1725×1445                   | Volkswagen Santana     | 4473×1706×1469                   |
| Chevrolet Cruze        | 4643×1797×1477                   | Hyundai Long Motion    | 4570×1775×1445                   |

From the above data, we know that the width of small cars is mostly about 1.8m and the length is less than 4.8m. Considering the need for parking and door opening and closing and combining with the provisions of Article 34.6.0.12 of the Code: when the car is 6-8m in length or 1.8 ～ 2.2m in width, the distance between the car and the car at a time of 0.7m is required. At the same time, considering the randomness of parking, it is impossible for all vehicles in the area to be fully filled at the same time and the width of the parked vehicles is greater than 1.8m. Small cars The width of parking spaces can be 1.8m + 0.3m + 0.3m = 2.4m; the length of small parking spaces can be 4.8m + 0.5m (horizontal parking 2.4m) = 5.3m (horizontal parking 6.0m).

Therefore, the size of the parking space (width × length) when the small car is vertically parked is: 2.4m × 5.3m; the size of the parking space (width × length) when the small car is parked horizontally is: 2.4m × 6.0m.

3.2. Vehicle parking and parking methods

(1) Vehicle parking mode

From the movement of the vehicle to stop in the parking space or drive out of the parking space, the following methods can be used: forward parking, backing out of the parking space, and backing out of the parking space.

According to Article 4.1.5 of the "Code for Design of Garage Building Design": The width of the traffic lane in the garage can be calculated according to the following formula, but it should be equal or greater than 3.0m[5].

1) Calculation formula for parking in forward and reverse: $W_d=R_e+Z-Sin[(r+b)\tan \alpha +e-L]$, ② $L=e+\sqrt{(R+S)^2-(r+b+c)^2}-(c+b)\tan \alpha$, ③ $R_e=\sqrt{(r+b)^2+e^2}$.

2) Calculation formula for parking in reverse and parking in forward: $W_d=R+Z-Sin[(r+b)\tan \alpha +a-e-L]$, ② $L=a-e-\sqrt{(r-s)^2-(r-c)^2}-(c+b)\tan \alpha$.

In the formula: Wd—the width of the traffic lane; S—the safe distance between the entrance and the entrance to the adjacent car may be 0.3m; Z—the safe distance between the traveling car and the car or wall may be 0.5 ～ 1.0m; Re—the distance from the car turning center to the rear outer corner of the car Horizontal distance; C—car-to-car distance; r—car inner circle radius; a—car length; b—car width; e—car rear overhang size; R—car outer circle radius; a—car parking angle.

According to the above formula, it is known that the minimum width of the traffic lane required for a mini car to stop forward is 7m, and the minimum width of the traffic lane required for a reverse car is 4.5m; the minimum width of the lane required for small cars and other vehicles to go forward is 9m. The minimum lane width required when parking is 5.5m.

To sum up: parking in urban ordinary underground garages should use backing parking, forward parking spaces, and parking perpendicular to the traffic lanes, which requires less space.

(2) Vehicle parking method

The parking method refers to the angle formed by the vehicle’s longitudinal axis and the center line of the driving line after the vehicle is parked in the parking space. Generally, there are 0 degrees (that
is, parallel parking), 30 degrees and 45 degrees, 60 degrees (that is, oblique parking), 90 degrees (ie vertical parking) and so on.

The advantages and disadvantages of the three parking methods are: parallel parking is more convenient and safe for vehicles to enter and exit the parking space, but each vehicle takes up a larger area due to the need to enter and exit; it is more convenient to enter and exit the vehicle when parking at an oblique angle. The turning radius is small, and the width of the corresponding aisle is small. However, entering and exiting vehicles can only follow a fixed direction, and a triangular area appears before and after the parking space, so each vehicle takes up a larger area; vertical parking can enter from both directions. It is more convenient to get out of the car and park it. It takes the smallest area in several parking modes, but requires a larger turning radius and a wider driving passage.

According to the advantages and disadvantages of the above parking methods, vertical parking should be adopted in large-area, multi-span underground garages in high-rise buildings. Parallel parking and oblique parking are suitable for areas where vertical distances cannot be achieved in certain spans with narrow column distances and corners of the basement.

3.3. Turning radius of car ring road and minimum turning radius of car

According to "Garage Building Design Code" [5], the minimum turning radius of the car is not less than 4.5m when the mini-car length is not more than 3.5m; the minimum turning radius of the car is not less than 6m when the small car length is 3.5-7m.

Generally, the length of a motor vehicle driving in a basement is less than 7m, and the turning radius of the motor vehicle needs to be at least 6m. (If it can pass, cars with a length less than 3.5m can also pass safely.) The minimum inner diameter of the car ring road in the garage is smaller than the turning radius of the motor vehicle. The general rough calculation can be approximated as: the radius of the arc on the inner edge of the road = turning radius - vehicle width - safety distance (vehicle width 1.8m, safety distance 0.25m). Therefore, it is safe to take the minimum inner diameter of the car ring road of the garage in the basement, which is less than 7m long, to take 3.95m, and generally take 3.9 to 4.2m.

4. Concluding remarks

This article discusses the underground parking space design from the aspects of column grid layout, single parking space occupation area, vehicle parking mode, parking mode, etc., and draws the following conclusions:

- To improve the utilization rate of underground parking space resources, an economic column grid span size of 7.8m and a parking rate of about 10% for mini cars can be used.
- Strictly control the indicators affecting the parking area of the unit, such as the occupied area of a single parking space of 2.4m x 5.3m when a small car is vertically parked; choose the parking mode mainly for vertical parking; The main vehicle parking mode; the minimum turning radius of a car with a turning radius of 3.9 to 4.2m is at least 6m

References

[1] Xiang Yang. Research on Intensive Design of Public Parking Spaces in Small and Medium Cities, Yangtze University, 2019.
[2] Zhan Biao. Research on Intensive Utilization of Urban Public Space, Shandong Jianzhu University, 2012.
[3] Bie M. Study on the prediction of parking demands and parking management strategy of Chongqing New Northern Zone (Master’s thesis) [D]. Chongqing: Chongqing Jiaotong University, 2011.
[4] Wen Q Y, Lu L Q. A Review of the present situation and development of stereo garage at home and abroad [J]. Logistics Engineer-ing and Management, 2016, 38(7): 159–161.
[5] JGJ 100-2015. Code for design of garage building [S].
[6] Shen L H. Stereoscopic parking planning—Discuss intensive land use mode of parking planning [J]. Traffic & Transportation, 2016(z2): 112–116.
[7] Guan H Z, Ren J, Yao S Y. The urban parking policy at the early and middle period of motorization in the developed countries [J]. City Planning Review, 2002, 26(10): 81–84.

[8] Yu S J, Yin B C, Liu Z P. Study on the development of static traffic at home and abroad [J]. City, 2011 (9): 89–91.