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# The influence of vehicles load on structural bearing capacity of underground parking garage

Liang Xijian<sup>1</sup>, Sun Qiuyan<sup>2</sup> and Huang Xingxing<sup>1</sup>

<sup>1</sup> Henan Provincial Communications Planning & Design Institute Co.,Ltd,  
Zhengzhou 450052, China

<sup>2</sup> Henan Technical College of Construction, Zhengzhou 450007, China  
275310524@qq.com

**Abstract:** For passing vehicles on underground parking garage, the difference between the codes for the bridge design and for the ordinary building structural design in design parameters of materials load combination etc is compared. Specification for Design of Municipal bridge has made the corresponding simplification computation to load function.

## 1. General situation

A planned road is an urban branch road, and the horizontal layout of the road is sidewalk(1.5m)+carriageway(9m)+sidewalk(1.5m). Because of the conditions, the planned road must pass above a certain lower garage. The underground garage is an underground three-storey frame structure, the column grid is 8.4m×8.4m. The maximum covering thickness of roof is 2.5m. Schematic diagram of underground garage structure is shown in Figure 1.

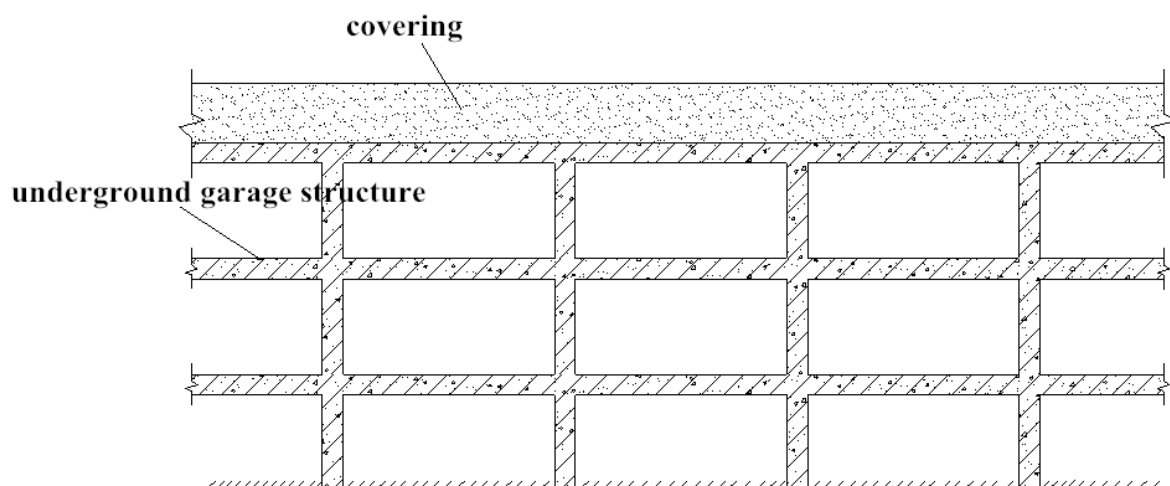


Figure 1. Schematic diagram of underground garage structure

## 2. Contrast the two codes

The underground garage structure belongs to the architectural structure, so it needs to meet the requirements of building structure related codes. Because of the vehicle load, it is necessary to meet the



requirements of bridge structure related codes. Therefore, the bearing capacity of the underground garage should meet the requirements of building structure and bridge structure.

### 2.1 Comparison of material design parameters

The design parameters of concrete and rebar are shown in table 1. From Table 1 we can see: for the same material design strength, the bridge structure code is smaller than the building structure code.

Table 1. The design parameters of concrete and rebar

material	category		building structure code	bridge structure code
concrete	beam	concrete grade	C30	C30
		design value of compressive strength (MPa)	14.3	13.8
	floor	concrete grade	C30	C30
		design value of compressive strength (MPa)	14.3	13.8
	column	concrete grade	C50	C50
		design value of compressive strength (MPa)	23.1	22.4
rebar	Steel grades		HRB400	HRB400
	Design value of tensile strength (MPa)		360	330

### 2.2 Comparison of load calculating parameters

Comparison of load calculating parameters are shown in table 2. According to the building structure code, the load combinations under the control of permanent load and variable load should be calculated respectively, and the most unfavorable combination should be calculated. According to the bridge structure code, the load combinations specified in the code should be calculated.

Table 2. Comparison of load calculating parameter

coefficient	category	building structure code	bridge structure code
component coefficient of permanent load	control of permanent load	1.35	1.2
	control of variable load	1.2	
component coefficient of variable load	control of permanent load	1.4	1.4
	control of variable load	1.4	
combination value coefficient of variable load	control of permanent load	0.7	/
	control of variable load	/	

### 2.3 Comparison of computational formulas

Computational formulas of bearing capacity are shown in table 3. The computational formulas of flexural bearing capacity and compressive bearing capacity are identical basically. Computational formulas of shear bearing capacity are different.

Table 3. Computational formulas of bearing capacity

category of bearing capacity	category of code	formulas
flexural bearing capacity	building structure code	$M \leq \alpha_1 f_c b x \left( h_o - \frac{x}{2} \right) + f'_{ys} A'_s (h_o - a'_s) - (\sigma'_{po} - f'_{py}) A'_p (h_o - a'_p)$
	bridge structure code	$\gamma_o M_d \leq f_{cd} b x \left( h_o - \frac{x}{2} \right) + f'_{sd} A'_s (h_o - a'_s) + (f'_{pd} - \sigma'_{po}) A'_p (h_o - a'_p)$

shear bearing capacity	building structure code	$V \leq \alpha_{cv} f_t b h_o + f_{yv} \frac{A_{sv}}{S} h_o$
	bridge structure code	$V \leq \alpha_1 \alpha_2 \alpha_3 0.45 \times 10^{-3} b h_o \sqrt{(2+0.6P)} \sqrt{f_{cu}} \rho_{sv} f_{sv}$
compressive bearing capacity	building structure code	$N \leq 0.9 \varphi (f_c A + f'_y A'_s)$
	bridge structure code	$\gamma_0 N_d \leq 0.90 \varphi (f_{cd} A + f'_{sd} A'_s)$

### 3. Analysis of equivalent load

According to the relevant codes[1], class of loading of city branch is city-B class. The number of lanes is two. The building structure is checked by vehicle load[2]. The layout of vehicle load for city-B class is shown in Figure 2.

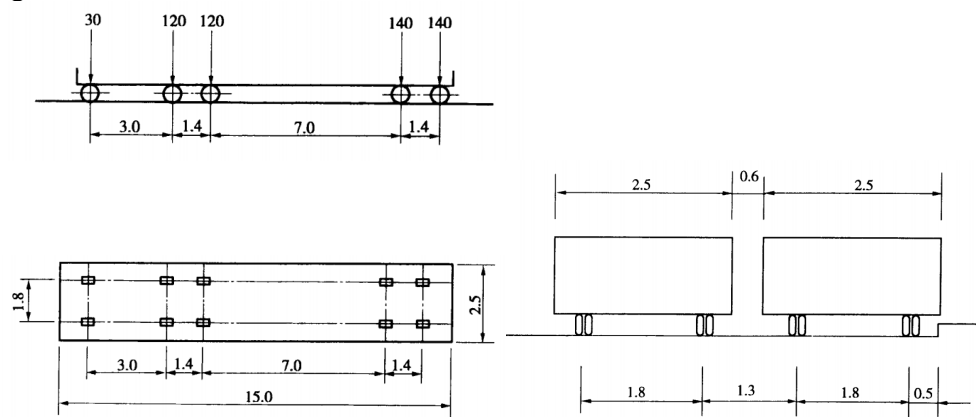


Figure 2. Layout of vehicle load for city-B class

Vehicle load diffuse downward for  $30^\circ$  by covering soil of 2.4m[3]. Transverse two vehicle load diffuse on floor of ground floor, the schematic is shown in Figure 3.

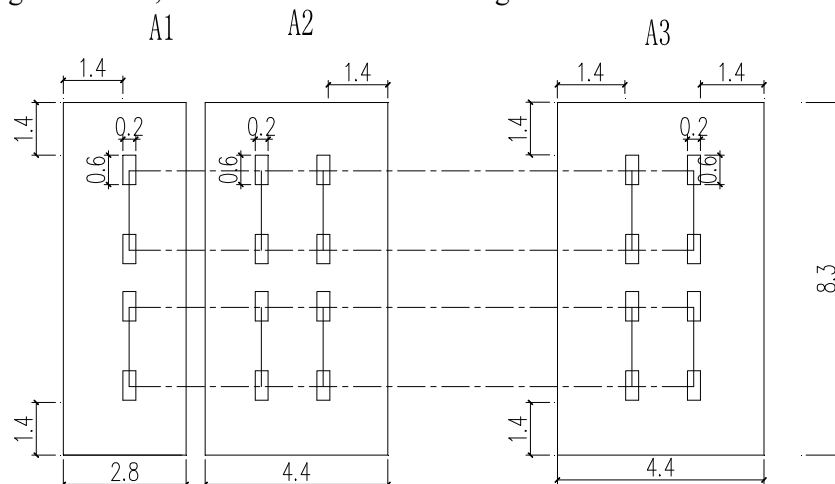


Figure 3. The schematic of diffusion for vehicle load

#### 3.1 Simplify load of city-B class to even load[4]

The even load of A1:  $\frac{30 \times 2}{8.3 \times 2.8} = 2.6 \text{ kN/m}^2$ , The even load of A2:  $\frac{(120+120) \times 2}{8.3 \times 4.4} = 13.1 \text{ kN/m}^2$

The even load of A3:  $\frac{(140+140) \times 2}{8.3 \times 4.4} = 15.3 \text{ kN} / \text{m}^2$

Impact coefficient is 1.3, so the maximal even load is  $15.3 \times 1.3 = 19.9 \text{ kN} / \text{m}^2$ .

The sidewalk width is  $w_p = 3.5 \text{ m}$ , the crowd load is

$$w = 1.5 \times (20 - w_p) / 20 = 1.5 \times (20 - 3.5) / 20 = 3.71 \text{ kN} / \text{m}^2$$

The crowd load is diffused by  $30^\circ$ , the crowd load after diffusion is:

$$3.71 \times 3.5 / (3.5 + 1.4 \times 2) = 2.1 \text{ kN} / \text{m}^2 < 2.4 \text{ kN} / \text{m}^2$$

The total variable load is:  $19.9 + 2.4 = 22.3 \text{ kN} / \text{m}^2$

### 3.2 The even load of GB50009-2012

$$b_{cy} = b_{ty} + t = 3.8 + 0.2 = 4.0 \text{ m}, b = 0.6b_{cy} + 0.94l = 0.6 \times 4.0 + 0.94 \times 3.8 = 5.97 \text{ m}$$

$$q = 19.9 \times 3.8 = 75.6 \text{ kN} / \text{m}^2, M_{\max} = \frac{ql^2}{8} = \frac{75.6 \times 3.8^2}{8} = 136.5 \text{ kN} \cdot \text{m}$$

$$q_e = \frac{8M_{\max}}{bl^2} = \frac{8 \times 136.5}{5.97 \times 3.8^2} = 12.7 \text{ kN} / \text{m}^2$$

The crowd load is  $2.4 \text{ kN} / \text{m}^2$ , so the total variable load is:  $12.7 + 2.4 = 15.1 \text{ kN} / \text{m}^2$

### 3.3 Comparison of two load computational methods

Comparison of even load for city-B class and even load for building structure code are shown in table 4[5]. We can see from the table that the structure is safe according to the even load for city-B class.

Table 4. Computational formulas of bearing capacity

area	even load(kN/m <sup>2</sup> )	
	even load for city-B class	building structure code
A1	5.8	15.1
A2	19.4	
A3	22.4	
computational load	22.4	

## 4. Partial computational results of bearing capacity

Partial computational results of bearing capacity are shown from table 5 to table 7. We can see that flexural bearing capacity, compressive bearing capacity and shear bearing capacity meet the requirement of building structure code and bridge structure code. So the underground garage structure can meet the requirement of safe passage for vehicle load of city-B class.

Table 5. The computational result of flexural bearing capacity for partial component

component	the type of bending moment	the value of bending moment(kN·m)	flexural bearing capacity(kN·m)		whether meet the requirement
			building structure code	bridge structure code	
beam 1	maximal positive bending moment	4123	5123	4863	yes
	maximal negative bending moment	2381	3190	2745	yes
beam 2	maximal positive bending moment	2386	2972	2744	yes
	maximal negative bending moment	2070	2989	2738	yes

Table 6.The computational result of flexural bearing capacity for partial component

component	the type of shear	the value of shear(kN)	shear bearing capacity(kN)		whether meet the requirement
			building structure code	bridge structure code	
beam 1	maximal shear	1856	2629	2502	yes
beam 2		1719	2217	1919	yes

Table 7.The computational result of flexural bearing capacity for partial component

component	the type of axial force	the value of axial force(kN)	compressive bearing capacity (kN)		whether meet the requirement
			building structure code	bridge structure code	
column 1	maximal axial force	8559	10235	9832	yes
column 2		9486	11278	11021	yes

## 5. Conclusion

(1) When the car travel on the building structure,the value of simplified even load is greater than the value of GB50009-2012.Therefore, the building structure is more secure according to simplified even load.

(2)After calculation, the underground garage structure can meets the requirement of safe passage for vehicle load of city-B class.The computing method of this text can provides reference for similar works.

## References

- [1] CJJ 11-2011. 2011 *S. Code for design of the municipal bridge*.(Beijing:China Building Industry Press)
- [2] JTG D60-2015. 2015 *S.General specifications for design of highway bridges and culverts*. (Beijing:China Communications Press)
- [3] JTG/T D65-04-2007. 2007 *S. Guidelines for design of highway culvert*.(Beijing:China Communications Press)
- [4] Xi Liang. 2013 *J.Analysis of road reinforcement for roof construction of underground garage in huting community.City building*, 2 p 60-67
- [5] GB50009-2012. 2012 *S.Load code for the design of building structures*.(Beijing:China Building Industry Press)