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Analysis of the Model Correction Coefficient Influence of Road Capacity after Earthquake

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Abstract. It is uncertain that the impact of earthquake on road capacity. There is a great significance to research the correction of road capacity model and study the evacuation and rescue of personnel after the earthquake. According to the existing road traffic capacity model, this paper combined with the damage of the road after the earthquake. This paper added the road buried length, signal control scheme, and the traffic flow as the correction coefficient of the capacity model. When the data are obtained by micro simulation, the coefficient of influence factors of traffic capacity will be corrected.

1. Introduction

Road capacity refers to the maximum number of traffic entities (pedestrians or vehicles) that may pass through a certain road on a road or in a unit time of a section[1]. The reduction of road capacity after the earthquake generally means that the normal road width is affected after the road is damaged, and the road can't run normally, which leads to the reduction of the overall road capacity. It will directly cause the evacuation work hindered after the earthquake, such as the great destruction of the earthquake, the cause of the road fracture, the post-earthquake traffic accident, the road surface buried and other uncertain factors, the reduction of road capacity. Therefore, the rationality of the road capacity after the earthquake is analysed, and the more accurate mathematical model is studied. It plays an important role in rapid evacuation and rescue work.

There are mainly two approaches to the study of road capacity after the earthquake. One is to establish the mathematical model by studying the relationship between the destruction of road, bridge structure and the earthquake grade, then calculate the damage of the earthquake[2-5]. These studies can provide a powerful theoretical basis for road traffic capacity when the researcher combined the probability theory and fuzzy mathematics, but it is also difficult to obtain data and analyse weight distribution of fuzzy theory. The second faction is to analysis the current situation and influencing factors of road traffic capacity through the theory of traffic flow theory, study the estimation and improvement methods of road capacity under abnormal conditions such as disasters and emergencies[6-10].

To sum up, there has been great progress in the study of road capacity after the earthquake, but there is a slight shortage in data acquisition and factor considerations. Therefore, combined with the existing capacity research method, the effect of road burial and traffic control strategy on traffic capacity on traffic capacity was added and analysed. And the statistical traffic data of road is obtained by microscopic traffic simulation, and then the capacity model is corrected to study the capacity of road traffic after the earthquake. It has practical guiding significance.

2. Modification of the model

2.1. Influence factors

The capacity of the post-earthquake network will be affected by many factors, such as the fracture of road, the buried Road, the collapse of the building, the spread of fire gas and so on. From the point of view of the traffic traveller, the traveller wants to choose the fastest, most convenient and non-congested route, but the complexity of the traffic network and the randomness of the traffic conditions will affect the choice of the traveller in the actual trip route, which is called the random factor[11]. Among the factors affecting the road capacity after the earthquake, there are the two most important factors: the length of the road and the strategy of traffic control. The length of the road buried objectivity reflects the destruction of the traffic facilities, and the traffic control strategy subjectively reflects the efficiency of the utilization of the limited road resources after the earthquake. Under the condition of buried length, according to the condition of traffic demand, what kind of traffic control strategy and scheme can be used to maximize the efficiency of post-earthquake traffic facilities. It is necessary to study the relationship between traffic demand, road burial length and traffic control strategy.

- The length of the buried Road.

It causes different lengths of damage to the road during to the collapse of buildings, gravel covered the road and other conditions caused by the earthquake, making roads buried or broken off. As shown in Figure 1, the length of the road buried is expressed using *l*.

- Traffic control strategy.

As the road buried, the road capacity is reduced. As shown in Figure 2, when a road is buried in a two-way of two lanes, a lane needs to be shared in two directions to ensure the smooth operation of the vehicle. It is necessary to organize traffic arrangements in an organized way to increase traffic control and control schemes. The signal cycle is expressed using *C*.

- Traffic flow demand.

Traffic flow (*Q*) refers to the number of traffic entities passing a selected time period. Judging from the size of the traffic flow, we can determine the traffic congestion condition and decide what kind of traffic management measures will be taken.

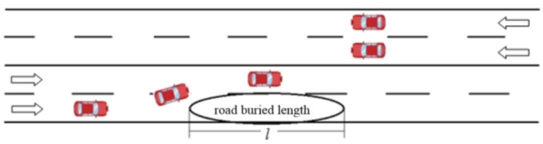

Figure 1. A sketch map for two-way four lanes buried

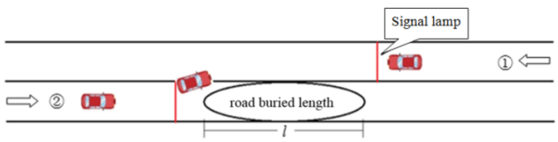

Figure 2. Installation of two-way two lanes traffic control scheme under burial

2.2. Establishment of correction model for road capacity after earthquake

The modified formula for designing traffic capacity is described:

$$C_D = C_B(v/C)_i f_s f_d f_w f_T f_L \tag{1}$$

According to the revised formula of the capacity, different factors will affect the road capacity. After studying the capacity model of the post-earthquake, the correction coefficient is added.

$$C_{EQ} = C_D f_l f_C f_Q \tag{2}$$

The above three correction coefficients are quantified by comparing the traffic capacity under ideal condition and the capacity under different burial lengths in microscopic simulation. Where major variables used in the paper are defined in Table 1.

Table 1. Variable notation and definitions

Variable notations	Definition
C_D	The capacity of lane design under the level of service
C_B	The basic capacity, two-way two lanes condition
$(v/C)_i$	The ratio of secondary service traffic to basic capacity
f_s	Correction factor for capacity when design speed is less than 80km/h
f_d	Correction coefficient of traffic volume distribution to capacity
f_w	Correction factor for capacity of lane width and lateral net width less than ideal condition
f_T	The correction coefficient of traffic composition to traffic capacity when there are non-medium-sized trucks in traffic flow
f_L	Correction coefficient of lateral disturbance and traffic order when traffic conditions are not ideal
C_{EQ}	Design capacity of buried roads after earthquake
f_l	Correction coefficient of buried length to traffic capacity
f_C	Correction coefficient of traffic capacity by signal cycle
f_Q	The correction coefficient of traffic flow to traffic capacity

3. Microscopic simulation and determination of correction coefficient

3.1. Hypothetical condition

In the correction model of road traffic capacity after the earthquake, the following two conditions are selected: (1) Four lanes of two ways, one of which is buried in the direction of the road, the original pair of road will be changed into two-way traffic, as shown in Figure 1; (2) In a two-way two lanes road, one of the two lanes buried and changed into the two-way to current, and the traffic power is given two directions through the signal lamp, as shown in Figure 2.

3.2. Analysis of the capacity of two-way four lanes after the earthquake

3.2.1. Hypothetical conditions of simulation environment.

Using VISSIM simulation to determine the correction coefficient, it is necessary to set conditions in the simulation model to form a comparative simulation environment. Taking Tangshan City Xinhua Road as the basic map, a simulation model is established. The length of the section is 500m, the lane width is 3.5m, the gradient is 0% and the expected speed is 40km/h. This paper sets up the vehicle to the car because the vehicle will be converted into an equivalent car when the traffic capacity is calculated. The correction factor is set to: 10m, 20m, ..., 100m. The input traffic on the two sides of the same side is: 1000veh/h, 1200veh/h, ..., 4800veh/h.

3.2.2. Data analysis of correction coefficient.

In Table 2, this paper compares the capacity under unburied and road buried.

- With the increase of traffic flow, the traffic capacity increases linearly with the increase of traffic flow, and the capacity of road traffic is reached when the input flow is 4800veh/h.
- In the buried road, with the increase of the length in the road and the increase of traffic flow, the statistical flow of the road is basically stable.

There are shown in Table 2 and formula(3) that statistics of the capacity under different burial lengths.

$$f_l f_Q = \frac{C_{EQ}}{C_D} \tag{3}$$

The calculation results are shown in Table 2, it can determine that the road buried causes the capacity reduced, the degree of reduction is independent of the buried length and the input flow when the inaccuracy data is eliminated. Therefore, the correction coefficient is corrected f_l=0.19, f_Q=1.

Table 2. Statistics of traffic capacity under different burial length

l/m	Unburied length	10	20	30	40	50	60	70	80	90	100
C_{EQ}/(veh/h)	4407	824	848	808	843	823	806	830	848	831	841
C_{EQ}/C_D	1	0.19	0.19	0.18	0.19	0.19	0.19	0.19	0.19	0.19	0.19

3.3. Analysis of the capacity of the two-way two lanes after the earthquake

3.3.1 Conditional hypothesis.

When establishing the simulation model, the basic simulation condition of two-way two lanes is consistent with the two-way four lanes conditions, taking Tangshan City national Guofang road as the basic map. Adding signal control cycle sets: 60s, 70s, ..., 150s.

3.3.2. Data analyses of correction coefficient under

(1) Analysis of road capacity under different buried length

As shown in Table 3, statistics of road capacity under unburied conditions and different buried lengths were given. The change of traffic capacity of section ① and ② is basically same to Figure 2, so this paper selected the section ① to research. From Table 2, it is known that the capacity of single section is different due to the different buried length. With increasing of buried length, the capacity of section ① increases at first, then decreases to the stable value.

In order to determine the correction coefficient of the capacity of the buried length to the capacity, the regression analysis method is used to fit the simulation data in the SPSS software. The fitting results are shown in Figure 3. The results of the three squares fitting curves was better, R^2=0.721, *sig*=0.042<0.05, which shows that the buried length can predict the dependent variable effectively, and it has a certain fitting. The fitting relationship between buried length and statistical traffic is:

$$Q_T = 0.0001l^3 - 0.046l^2 + 2.198l + 952.167 \tag{4}$$

In the model: the statistical flow of the road segment in the simulation is Q_T. At this time, if the influence of input traffic and signal cycle is ignored, that is, f_C=1, f_Q=1. It is carried out to obtain the correction coefficient of buried length for a comparison of the capacity under different buried lengths and the capacity under no buried length. As shown in Table 3, the value f_l is 0.43-0.45.

$$f_l = \frac{C_{EQ}}{C_D} = \frac{Q_T}{2187} \tag{5}$$

(2) Road traffic capacity under different signal control cycles

As shown in Table 4 and Figure 4, the statistical flow of the section increases at first and then decreases with the increase of buried length in the same period of signal. The smaller the cycle, the faster the trend of the capacity declines. When the signal cycle is 150s, the capacity of the whole section is reached. In order to show the effect of signal control on the capacity of traffic, the regression analysis method is used in the SPSS to compare the multiple regression curves in order to get the best curve of the fitting degree.

As shown in Figure 5, it can be seen from the figure that the degree of the three squares fitting is the best, R^2=0.856, *sig*=0.001<0.05. Its coefficient of determination and the regression coefficient test show that the buried length can effectively predict the dependent variables and have better fitting. Therefore, the fitting relationship between the signal cycle and the statistical traffic is:

$$Q_T = 9.627\times10^{-5}C^3 - 0.015C^2 + 0.0001C + 995.293 \tag{6}$$

Because there is no influence of input traffic on traffic capacity at that time, that is, f_Q =1. It can be seen that:

$$f_C = \frac{C_{EQ}/C_D}{f_l} = \frac{Q_T/2187}{f_l} \tag{8}$$

When the period is 150s, f_C=1. When the signal period is 60s and the buried length is 100m, the minimum value can be obtained. At this time, the capacity is 697veh/h, and the computation is available. Therefore, the correction coefficient range of the signal control scheme f_C is 0.71-1.

Table 3. Simulation data of single lane under different buried length

l/m	Unburied length	10	20	30	40	50	60	70	80	90	100
C_{EQ}/(veh/h)	2187	973	971	987	988	980	969	965	967	968	967
C_{EQ}/C_D	1	0.44	0.44	0.45	0.45	0.45	0.44	0.44	0.44	0.44	0.44

Table 4. Simulation data of capacity under different signal control periods

C/s	60	70	80	90	100	110	120	130	140	150
C_{EQ}/(veh/h)	955	961	949	948	948	941	947	944	970	988

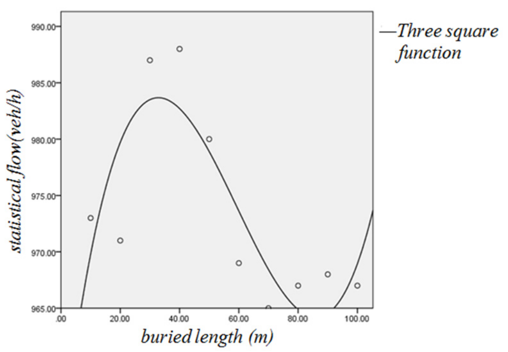

Figure 3. The fitting curve of the influence of the buried length on the statistical flow

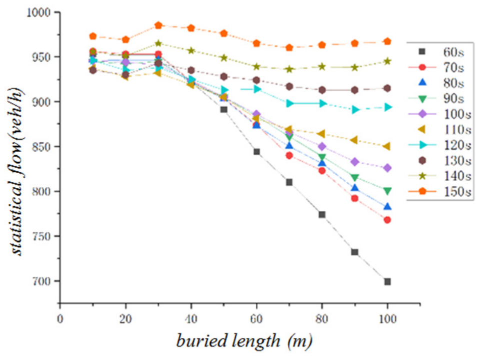

Figure 4. The influence of signal period and burial length on traffic capacity

(3) Road capacity under different input traffic flow.

Table 5. Simulation data of traffic capacity under different input flow

Q/(veh/h)	500	600	700	800	900	1000	1100	1200	1300	1400
C_{EQ}/(veh/h)	548	661	776	876	946	976	984	985	988	984
Q/(veh/h)	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
C_{EQ}/(veh/h)	985	985	984	987	986	985	985	985	983	985

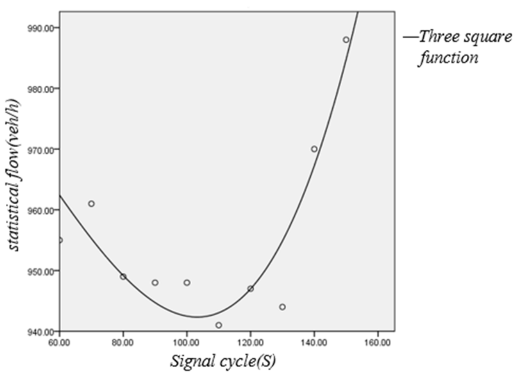

Figure 5. The influence of input flow on traffic capacity

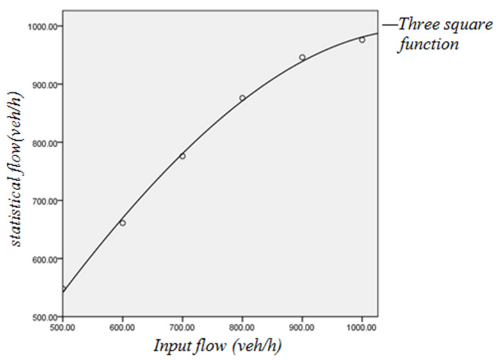

Figure 6. The fitting curve of the influence of the input flow on the statistical flow

As shown in Table 5 and Figure 6. When $Q \leq 1100$, there are three relations between the capacity and the input flow when the input flow is used.

$$Q_T = -5.048\times10^{-7}Q^3 + 0.0001Q^2 + 0.1.757Q - 275.166 \quad (9)$$

Due to R^2=0.999, *sig*=0.0001<0.05, the fitting determination coefficient and regression coefficient test of the function show that buried length can effectively predict dependent variables and has good fitting property.

At 150s, the statistical traffic under the input traffic reaches the capacity, so f_C =1. According to the formula (7), When the input flow is more than 1100 vehicles, the traffic flow does not vary with the input traffic, and the road traffic is saturated. When the capacity is 988veh/h, the correction factor is f_Q=1. Therefore, the correction coefficient of road input flow to traffic capacity can be expressed as:

$$f_Q = \begin{cases} Q_T/(2187 f_l) & Q \le 1100 \\ 1 & Q > 1100 \end{cases} \quad (10)$$

4. Conclusion

Through the study of the relationship between road capacity and road burial length, signal control scheme and traffic flow, it is found that in the analysis of two-way two lanes, road burial leads to reduced road traffic capacity. When the road vehicles are not saturated, the statistical flow of roads increases with the input flow of the road section until the traffic is reached. After the capacity, the statistical flow has nothing to do with the input flow of the road; the length of the road is affected by the signal cycle, so the appropriate timing scheme is helpful to guide the traffic of road vehicles and reduce traffic congestion. In the study of two-way four lanes capacity, burial leads to lower traffic capacity, which has nothing to do with the length of burial and the input volume of the road section.

Acknowledgments

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References

[1] Li J. (2002) *Traffic Engineering*. China Communications Press, Beijing, China.
[2] Hosseinpour F, Abdelnaby A.E. (2017) Effect of different aspects of multiple earthquakes on the nonlinear behavior of RC structures. J. Soil Dynamics and Earthquake Engineering. 92:706-725.
[3] Torbol M, Shinozuka M. (2014) The directionality effect in the seismic risk assessment of highway networks. J. Structure & Infrastructure Engineering, 10:175-188.
[4] Flavio B, Eugenio G. (2011) A network-based analysis of the impact of structural damage on urban accessibility following a disaster: the case of the seismically damaged Port Au Prince and Carrefour urban road networks. J. Journal of Transport Geography. 19:1443-1455.
[5] Li Z J, Wang J Y Dong F. (2010) Randomness Analysis on Traffic Capacity of Road after Earthquake. J. Transport Standardization, 12: 131-133.
[6] Kong X J, Xua Z Z, Shen B, et.al. (2016) Urban traffic congestion estimation and prediction based on floating car trajectory data. J. Future Generation Computer Systems, 61:97-107.
[7] Juan E. Muriel-Villegas, Karla C. Alvarez-Uribe, Carmen E. Patiño-Rodríguez, et.al. (2016) Villegas Analysis of transportation networks subject to natural hazards – Insights from a Colombian case. J. Reliability Engineering & System Safety, 152:151-165.
[8] Xia Y, Ban X G, John M. (2018) Modeling multimodal transportation network emergency evacuation considering evacuees' cooperative behaviour. J. Transportation Research Part A: Policy and Practice.
[9] JIA G B. (2015) Research on Road Capacity Resulting from Pavement Distress.Beijing Jiaotong University.
[10] Al-Kaisy A, Hall F. (2003) Guidelines for Estimating Capacity at Freeway Reconstruction Zones. J. Journal of Transportation Engineering, 129:572-577.

[11] Faturechi R, Miller-Hooks E. (2015) Measuring the Performance of Transportation Infrastructure Systems in Disasters: A Comprehensive Review. J. Journal of Infrastructure Systems,21:401-402.