INVESTIGATION OF OPERATION SPEED AND SUGGESTION OF SPEED LIMIT OF FREEWAYS IN CHINA

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ABSTRACT

Speed limit is an efficient measure to improve the safety of freeway. However, there are few studies on speed limit in China. 107 typical sections of fifteen freeways in China were investigated according to different terrain condition, traffic volume and geometric alignment. By analyzing observed data of 107 sections, speed distribution and the changing rule of speed in China are obtained. The power relation model between operation speed and radius and the linear relation model between operation speed and gradient are established respectively by means of regression analysis. According to the two models, it is suggested that speed limit should be set by different radius and gradient. Rational suggesting values of speed limit for freeways in China are put forward from the viewpoint of the safety.

KEY WORDS

FREEWAY; 85TH PERCENTILE SPEED; OPERATION SPEED; SPEED LIMIT

1 INTRODUCTION

It has been approved by many international studies (TRB,1984; Godwin, 1984; Garber and Gadiraju, 1989; Hale, 1990; CEC, 1991) that there is a clear relation between road accident rate and vehicles' speed variability, and that crashes at higher impact speeds have a greater probability of resulting in a fatality. It is also accepted that speeding increases the probability of accident occurrence (OECD, 1981; Mason, Seneca and Davinroy, 1992). Posted speed limit contributes to reducing the phenomena of speeding so as to improve road safety (Kanellaidis, Golias and Zarifopoulos, 1995). Now there is no gist of setting speed limit in China and few studies on it. Therefore, it is necessary to study on speed limit in China. The concept of operation speed must be introduced for the study. Operation speed is defined as 85th percentile speed on given highway length. 85th percentile speed is thought by many traffic engineers to reflect the safe speed for given road conditions and is always used to set speed limits. 85th percentile speed is in the speed range where the accident involvement rate is the lowest (Rietveld, 1996). Plentiful field observations were carried out from 1998 to 1999. Investigated highway sections covered fifteen freeways of fourteen provinces and cities. The investigation team selected 107 sections of fifteen freeways according to different terrain condition, traffic volume and geometric alignment characters in China. In the investigation, highway sections and spot location dispose were selected according to three alignments of straight-line, horizontal curve and vertical curve. So the investigating situation and speed limit question is discussed according to straight-line, horizontal curve and vertical

curve.

2 RELATION BETWEEN OPERATION SPEED AND DESIGN SPEED

One important aim of highway design is combining each design factor to consider synthetically so as to make design standard consistent. In order to realize above aim, two different methods are adopted internationally, namely, design speed method and operation speed method. Design speed is the highest safe speed promising certain running comfortable degree on geometry-constrained highway section under common conditions of road, traffic and climate. There are great difference between operation speed and design speed. However, design speed is always adopted in alignment design traditionally so that potential dangers are caused on some spot (Chen, 2000). Drivers always adjust the speed according to his intuition. If the highway is designed according to unitary design speed value, the dangerous sense of drivers to alignment will change so that the speed selected by them often exceeds design speed (Haglund, 2000). Therefore, highway design values which are fit to given design speed, for example sight distance, superelevation and so on, can't meet the actual request of speed selected by drivers.

Although design speed method is adopted in the Standard promulgated by American Association of State Highway and Transportation Officials in 1994, increasing Americans have realized the difference between design speed and operation speed so that operation speed method is considered and used by Australia, France, Germany and Switzerland and so on. Now operation speed has gained broad applications increasingly because its evident safety benefit by contrast with traditional design speed.

3 INVESTIGATION AND ANALYSIS OF OPERATION SPEED

Speed data were fitted and it indicted that most sections don't accord with normal distribution, but the speed distribution curves and accumulative frequency curves are very close to normal distribution curve. The break point of accumulative frequency curves near the percentile speed. The curve below the 15th percentile speed and above 85th percentile speed change relatively slowly but the curve between the 15th percentile speed and 85th percentile speed is comparatively steep and changes dramatically (seen fig.1).

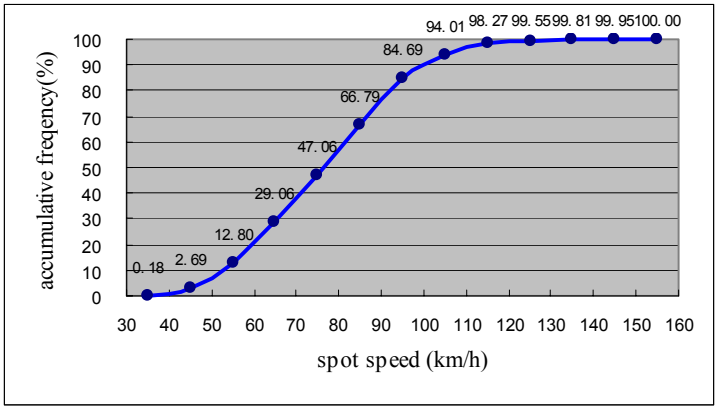

Figure 1 - Accumulative frequency curve of spot speed

Therefore, 85th percentile speed (operation speed) can be yet considered as the gist of the highest speed limit according to the principle of speed limit though the spot speed of sections don't accord with normal speed (Yan, 1994). Speed character will be analyzed respectively according to straight-line, horizontal curve and vertical curve.

3.1 Straight-line

Straight-line is the basic alignment of highway. Based on analysis of speed distribution characters of straight-line, 85th percentile speed on accumulative frequency curve will be considered as the highest speed limit value.

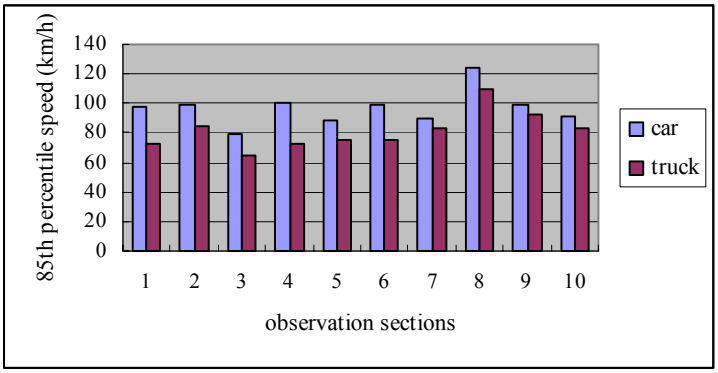

Figure 2 - 85th percentile speed on straight-line

Figure 2 is the statistic result of ten observation sections on straight-line. It can be seen from the figure that 85th percentile speed of car is the highest. The average value of 85th percentile speed of car is 96.79km/h, so we recommends the highest speed for straight-line is 100km/h from the viewpoint of safety.

3.2 Horizontal curve

Figure 3 is the statistic result of 85th percentile speed of twenty-five observation sections on horizontal curve. Analyzing the statistic results, it indicates that the speed of car is higher than that of truck on all sections. However, there is great difference among 85th percentile speeds of car on different sections. The minimum speed value is 55.62km/h (Guangfo freeway), but the maximum speed value is 114.28km/h (Chengyu freeway). Therefore, it isn't appropriate to consider the average value of 85th percentile speed as uniform speed limit value for horizontal curve. The relationship between curve radius and 85th percentile speed is studied so as to set the highest speed limit for horizontal curve according to different curve radius range.

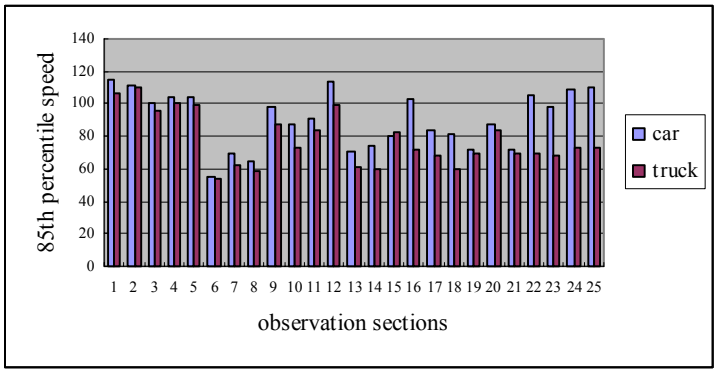

Figure 3 - 85th percentile speed on horizontal curve

3.3 Vertical curve

Figure 4 is the statistic result of 85th percentile speed of twelve observation sections on vertical curve. It can be seen by analyzing 85th percentile speed of all vehicular type on each observation section that 85th percentile speed of all vehicle type are low at large. It ascribes the effects of gradient. On the one hand, the power capability of truck is relatively worse so that it has to run at creep speed. On the other hand, it is impossible for car to has full overtaking opportunity on vertical curve as on straight-line so as to deduce speed to ensure safety.

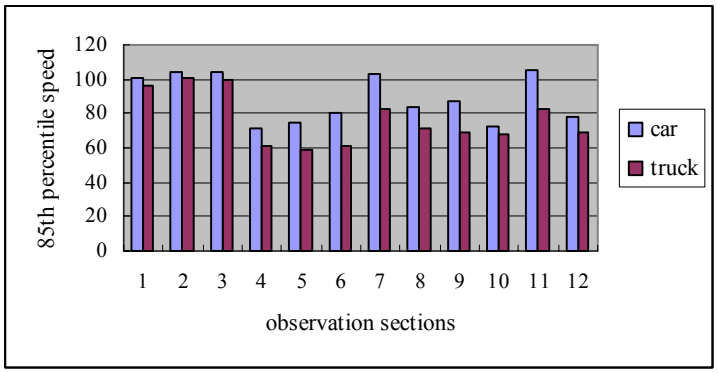

Figure 4 - 85th percentile speed on vertical curve

Considering the economy of operational management, it is necessary to study the relation between gradient and 85th percentile speed more in order to set the highest speed for vertical curve according to different gradient range.

4 SETTING OF SPEED LIMIT

The suggesting value of the highest speed limit for straight-line has been presented before. To set the highest speed limit for horizontal curve and vertical curve, it should be established that the relationship models between 85th percentile speed and curve radius and between 85th percentile speed and gradient firstly so as to find out their inherent relation so as to set the highest speed limit respectively according to different curve radius and gradient.

4.1 Horizontal curve

Figure 5 is relation curve between 85th percentile speed and curve radius. When fitting the data of curve radius and 85th percentile speed of horizontal curve, data of some sections weren't used because they were affected by other factors. For example, the speeds of three observations sections on Guangfo freeway are low evidently (85th percentile speeds are 57.23km/h, 69.65km/h and 66.23km/h respectively) because the traffic volume of this freeway has been close to saturation so that vehicles can’t run normally. In addition, considering the geometric characters of long-radius curve are hardly different from that of straight-line, the data of one section on Hujia freeway whose radius is 12587.83m and two sections on Xibao freeway whose radiuses are 10000m aren’t adopted also.

It can be seen from figure 5 that the best fitting result is binomial function and power function in three types of curve. The relativity of the two types of curve are very high and hardly differentiate. However the power model is relatively easy to research, so we recommend power model:

$$V_{85\%} = 30.5742R^{0.1404} \quad (1)$$

This model reflects the inherent relationship between 85th percentile speed and curve radius that 85th percentile speed increases with the increase of radius but its increase rate becomes slow gradually.

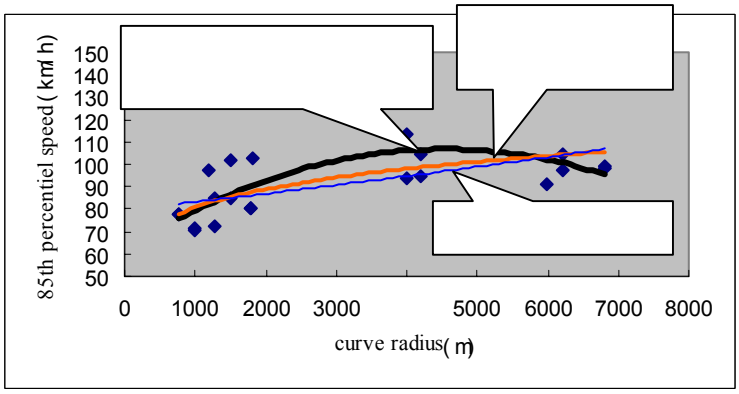

Figure 5 - Relation curve between curve radius and 85th percentile speed

It can be gained by this model that 85th percentile speed equal to 80.64km/h, 88.88km/h, 101.09km/h and 111.42km/h respectively when radius equal to 1000m, 2000m, 5000m and 10000m. Considering the safety of freeway, we suggest that the highest speed limit for horizontal curve of freeway as following in table 1.

Table 1 - Suggestion value of the highest speed limit on horizontal curve

curve radius(m)	R≤1000	1000□R≤2000	2000□R≤5000	R□5000
The highest speed limit (km/h)	80	90	100	110

4.2 Vertical curve

It accords with fact that car is regarded as the study object because both its speed and proportion are higher than truck. Figure 6 is the relation curve between 85th percentile speed and gradient value.

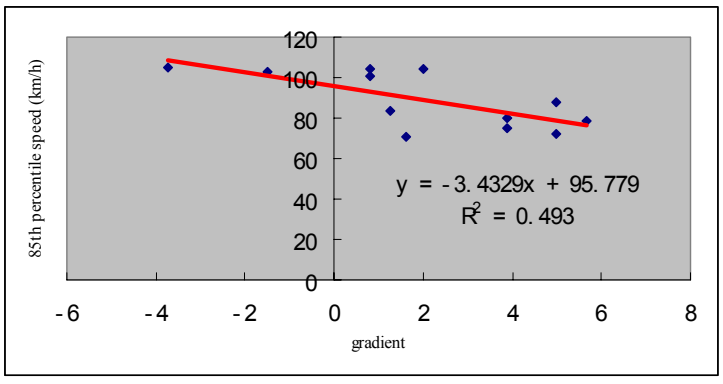

Figure 6 - Relation curve between gradient and 85th percentile speed

It can be seen from figure 6 that 85th percentile speed of vertical curve range from 60km/h to 110km/h and the speed takes on the trend of fall. The relationship between two things is linear degressive relation. The relation model is:

$$V_{85\%} = -3.4329i + 95.779 \quad (2)$$

It can be obtained by this model that 85th percentile speed equal to 95.78km/h, 92.35km/h, 88.9km/h, 85.48km/h, 82.05km/h and 78.6km/h respectively when gradient equal to 0, 1 percent, 2 percent, 3 percent, 4 percent and 5 percent. We recommend the highest speed limit for vertical curve of freeway as following in table 2.

Table 2 - Suggestion value of the highest speed limit on vertical curve

gradient	i≤1%	1%<i≤2%	2%<i≤3%	3%<i≤4%	4%<i≤5%
the highest speed limit (km/h)	100	95	90	85	80

5 CONCLUSIONS

Combining actual situation of freeway in China, the relationship models are established between 85th percentile speed and control technical indexes of plane and longitudinal alignment, curve radius and gradient on the basis of referring and contrasting international methods, so as to present rational suggesting value of speed limit corresponding to different indexes from viewpoint of safety. It has important theoretical and practical significance to speed limit for freeways in China.

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