

Research on the Model of Sight Distance Triangle in Mountain Highway Intersections

Bai Bin*, Ou Zhilin**

*(Department of Road and Railway Engineering, Chongqing Jiaotong University, Chongqing 400074, China)

** (Department of Road and Railway Engineering, Chongqing Jiaotong University, Chongqing 400074, China)

ABSTRACT

Because of the complex terrain, the stopping sight distance of intersection is difficult to meet and intersections become accident-prone section in mountain highway. In response to this phenomenon, this study established sight distance triangle models for uncontrolled intersections and minor roads with a stop controlled based on driver's visual characteristics by analyzing the driver's visual features and driving characteristics of mountain highway intersection. It can provide a theoretical basis for the design of mountain highway intersection.

Key words-Mountain Highway Stopping Sight Distance Sight Distance Triangle Intersection

I. INTRODUCTION

Subjecting to great influence of topography, mountain highway intersections widely have a phenomenon that sight distance is poor. Complex transportation and traffic flow which are interfered in different directions has become a major hazard of mountain road traffic accident. In the road traffic system, People-Vehicle-Road is an essential factor to consider that influences the traffic safety of mountain highway intersection. And while driving, driver obtains information mainly through sight. Studies have shown that driver obtains 80% traffic information from the sight [1]. So, in order to ensure traffic safety when the driver passes the intersection, we must ensure that there is no obstacle in intersection sight distance triangle, driver can see vehicles in other crossings. Compared with the intersections in plain area, sight distance triangle in mountain highway intersection is affected by more factors (crossing angle, branch slope, etc.). Previous studies in intersection were basically on planar, and rarely combined flat with vertical sections [2-4]. In this paper, the study proposed stopping sight distance calculation model based on visual characteristics of driver and established sight distance triangle models for uncontrolled intersections and minor roads with a stop controlled by the analysis of the visual characteristics of the driver and the traffic characteristics of mountain highway intersection.

II. DRIVING CHARACTERISTICS OF MOUNTAIN HIGHWAY INTERSECTION

Mountain highway intersection has characteristics of small crossing angle, large access slope, small cross-area and sight distance is difficult to meet, etc. [5]

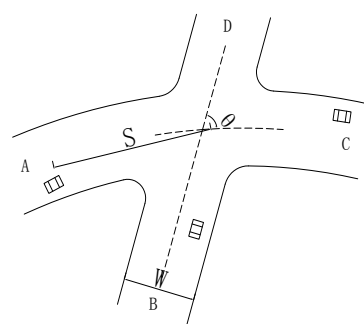


Figure 1 Schematic diagram of mountain highway intersection

As shown in Figure 1, A, B, C, D represent four different directions at intersection, θ is the crossing angle. Due to the small θ , when the driver travels from the direction of B, he is difficult to observe the transportation at other three directions. At this time, the driver will get traffic information about other intersecting sections by twisting the head or upper body, and decide operation behavior. The smaller θ is, the larger the rotating magnitude of the driver is, the larger distance of vehicle which straight through the intersection is. Because of the behavior of turning head, on the one hand, it will increase the driver's reaction time and observation time to cause traffic delays. On the other hand, it will lead to the change of driving direction to cause traffic accidents. At the same time, due to the small crossing angle, it will lead that apart of curbs' radius are smaller. Besides, the cross area of intersection is smaller, vehicle turning (especially large trucks and other vehicles with longer car body) becomes more difficultly.

Due to the limitations of terrain, the longitudinal

slope of mountain highway is big to reduce excavations and costs, and intersection branch access slope is large. When the vehicle is turning through the intersection, the angle of turning steering wheel is large and the driver needs to control the speed at the same time. Therefore, the driver's driving load has increased and it leads to driver's mental stress. Then, the risk of accidents is increasing.

III. CALCULATION FOR STOPPING SIGHT DISTANCE OF MOUNTAIN HIGHWAY INTERSECTION

The driver must observe the traffic situation and traffic control facilities from the intersection within a certain distance to ensure traffic safety. Thus, the driver is able to stop smoothly before conflicts and ensure traffic safety when there are conflict vehicles at intersection. So each branch of mountain highway intersections must meet requirements of the minimum safe stopping sight distance.

3.1 THE CALCULATION PRINCIPLES OF SAFE STOPPING SIGHT DISTANCE AT UNCONTROLLED INTERSECTION

At uncontrolled intersection, traffic flow in each direction is equally important and the road right of vehicles at each entrance is equal. All vehicles have the obligation of park brake to avoid before conflict points at intersection. So, each import-section can compute safe stopping sight distance according to the principle that the vehicle parking brake and avoid to other vehicles safely pass before conflict points. Safe stopping sight distance includes reaction distance, stopping distance and safety clearance. Because of the difference of vehicle's driving characteristics between the mountainous highway intersection and other intersections, the determination of safe stopping sight distance in mountain highway intersection is also different from other intersections.

Reaction distance is the distance traveled by car in the moment of finding, identifying obstacles and deciding to take braking measures after judging to the brake really comes into work. Because crossing angle at mountain highway intersection is small, the time of driver twisting the head or upper body is increasing, so the reaction time and reaction distance are increasing. As shown in equation (1):

$$s_1 = \frac{v}{3.6}t = \frac{v}{3.6}(t_1 + t_2) \quad (1)$$

Among them, s_1 is reaction distance, t is total reaction time, including the time of twisting the head or upper body t_1 and braking reaction time t_2 . Speed will be reduced when vehicle arrive at the intersection. The v in equation can be obtained in the following manner: the speed of vehicle needs to be depended on traveling direction [6]. In the imported lane the speed

of going straight vehicle generally takes the 0.7 times of design speed, and the speed of turning left or right vehicle generally takes the 0.5 times of design speed.

Branch slope of mountain highway intersection is big, so, the effect of slope on the braking distance can't be ignored. As shown in equation (2) [7]:

$$s_2 = \frac{v^2}{254(\varphi + f + i)} \quad (2)$$

Among them, φ is adhesion coefficient between the road surface and the tire, and is related to road wetness; f is dynamic resistance coefficient, and is related to pavement structure, tire construction and vehicle speed, etc. i is longitudinal road (uphill $i > 0$, downhill $i < 0$).

Safe stopping sight distance of mountain highway intersection is:

$$s = s_1 + s_2 = \frac{v}{3.6}(t_1 + t_2) + \frac{v^2}{254(\varphi + f + i)} + l_0 \quad (3)$$

Among them, l_0 is safe distance.

3.2 THE CALCULATION PRINCIPLES OF SAFE STOPPING SIGHT DISTANCE AT MINOR ROADS WITH A STOP CONTROLLED INTERSECTION

In the actual driving process, few vehicle initiatives parks to other vehicles pass while observing whether the vehicle at intersection or the distance from vehicles to the point of conflict after decelerating to the intersection. If there is no vehicle or the distance is far to safely pass, they would speed up and pass.

At minor roads with a stop controlled, vehicle through the main way has the priority. When there are straight traffics within the minor roads-driver's field of vision, there are two driving choices for left-turning vehicles to pass conflict points safely: the one is parking to wait; The driver immediately starts to accelerate speed through the intersection as soon as observing the gap that can pass. The process is uniformly accelerated procedure. The other one is that the vehicle directly through conflict point before straight traffics. This process is uniform deceleration and then accelerating speed through the intersection process. The driver can choose what kind of behavior by determining the gap that can cross. So, the critical time of the two acts is critical gap [8].

As shown in figure 3, when the vehicle in inlet B found the vehicle in AC direction, it will accelerate speed through the intersection. And its accelerations is affected by vehicle performance, the intersection

type and access angle, slope, etc. According to vehicle dynamics, accelerations calculation of vehicle starting is as follows:

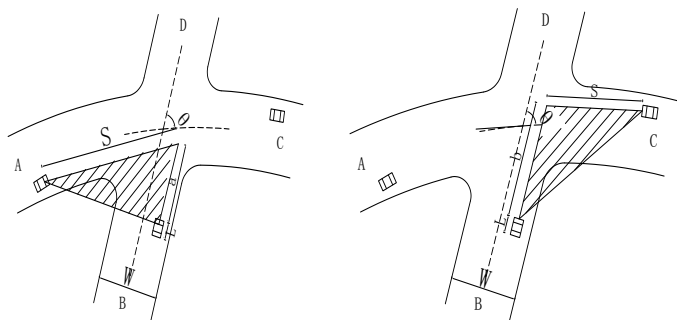


Figure 3 Schematic diagram of mountain highway intersection sight distance triangle

$$D = f + i + \frac{W}{g} a_c \quad (4)$$

So the critical gap is

$$t_c = \sqrt{2(d + L)/a_c} \quad (5)$$

Among them, D is power factor of vehicle; *i* is longitudinal road (uphill $i > 0$, downhill $i < 0$), W is car's rotating mass conversion factor; a_c is accelerations (m/s^2); t_c is critical gap (s); L is length of the vehicle (m).

According to the vehicle's driving characteristics, the model of safe driving distance at intersection can be calculated as follows [9]:

$$S = 0.278Vt_c \quad (6)$$

IV. THE CALCULATION MODEL OF INTERSECTION SIGHT DISTANCE TRIANGLE

The geometric design at intersection has a great influence on the horizon, and adverse horizon is an important factor leading to traffic accidents. Only to ensure there are no obstructions in sight distance triangle, and to ensure observe the whole picture of intersection, the driver could have sufficient distance to predict and take action to avoid potential conflicts, and pass the intersection safely. At uncontrolled intersection or minor roads with a stop controlled intersection, the driver needs to consciously determine the conflict situations of intersection and take steps to avoid conflicts. So, it is particular important that sight distance triangle needs to be met the requirements at mountain highway intersections.

4.1 THE CALCULATION MODEL OF UNCONTROLLED INTERSECTION

At uncontrolled intersection, traffic flow in each direction is equally important, the two cross-sections of sight distance triangle are got by security stopping

sight distance model, as shown in formula 7:

$$S = \frac{1}{2} S_1 \times S_2 \times \sin \theta$$

$$= \frac{1}{2} \left[\frac{1}{3.6} (t_1 + t_2) + \frac{v^2}{254(\phi + f + i)} \right]^2 \times \sin \theta \quad (7)$$

4.2 THE CALCULATION MODEL OF MINOR ROADS WITH A STOP CONTROLLED INTERSECTION

At minor roads with a stop controlled intersection, when secondary-road vehicle is waiting to turn left or right at the gap of main-road vehicle, there are no obstacles in sight distance triangle of secondary-road vehicle turning left or right for guaranteeing vehicle to pass safely. According to the geometric formula, the model of sight distance triangle as follows:

$$S_{\text{左}} = \frac{1}{2} X_{\text{左}} \times (L + a) \sin \theta = \frac{1}{2} 0.278Vt_c (L + a) \sin \theta$$

$$S_{\text{右}} = \frac{1}{2} X_{\text{右}} \times (L + b) \sin \theta = \frac{1}{2} 0.278Vt_c (L + b) \sin \theta \quad (8)$$

Among them, L is length of the vehicle (m), the value of *a* and *b* is influenced by the number of main-road lane, lane width, crosswalk width, and the safe distance from car-head to crosswalk.

V. CONCLUSION

Complex geometry features of mountain highway intersections lead that intersection sight distance is difficult to meet and cause traffic accident risks. This study established safe stopping sight distance model at mountain highway intersection and sight distance triangle models by analyzing the driver's visual features and driving characteristics at mountain highway intersection. It can be used as a basis for mountain highway intersection. Due to the limit of conditions, paper mainly used crossing angle and slip slope as objects of study that affect driver's vision, and ignored the influence of other factors. It needs for more in-depth study and research.

References

- [1] LI Yong-fang, Test Study on Car Driver's Dynamic Visual Characters Tractor & Farm Transporter, 2010(6):1618+20
- [2] ZHANG Jian-guo, LI Guo-wen. Study on Safe Driving Sight Distance at Deformity Intersection[J]. Highway, 2011(6):45-48.
- [3] WEN Yuan, ZHOU Yang, HAN Ru-bi, etc. An Auxiliary Control Method to Overcome Inappropriate Sight Span[J]. Journal of Highway and Transportation Research and

- Development,2012(s1):44-49.
- [4] CHEN Yan, HU Jiang-bi, LIU Xiao-ming
Experimental Study on Reasonable Information
Volume of Highway Crossing Guide Signs[J].
Communications Standardization,2009(1):25-
29.
 - [5] SU Pei, TANG Bo-Ming,Liu Tang-Zhi.etc.
Analysis and Countermeasures of traffic safety
at Mountain rural road intersection[J].
Highway,2009(7):50-54.
 - [6] YANG Xiao-Guang,etl. Urban Traffic Design
Guide[M]. China Communication Press,2003.
 - [7] PEI Yu-Long, MA Yi. Road Conditions Cause
Analysis and Preventive Measures for Road
accidents[J]. China Journal of Highway and
Transport,2003,16(4):77-82.
 - [8] GAO Hai-long, WANG Wei, CHANG Yu-
lin,etc. Amathematical model for critical gap of
unsignalized intersections[J]. China Journal of
Highway and Transport,2011(2):80-82.
 - [9] Fhwa.Intersection Diagnostic Review
Engineer'S Sub-manual, Version
2. 07a[R].2003.