Influence of mountainous road alignment on traffic safety and reconstruction measures

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Abstract

This paper has roundly and systematically researched on the traffic crashes of certain westward mountainous road. Through the analyzing of crash general characters and auditing the influence to traffic safety of the road plain, profile and their combination, some hidden troubles of the road and relevant reconstructed measures would be found. The conclusion shows that the ill alignment (a lot of limit guidelines on design and continuous long downgrades) is the main reason of inducing traffic crashes on mountainous road, which let the hidden troubles especially high. Aim at the crashes reasons, this paper puts to setting up reducing temperature devices and escaping ramp to solve the downgrade crashes, which also can make up the defects on alignment design. What's more, other measures such as speed cortrol devices also can warn and restrict drivers to reduce the probability of crashes either.

Key words: Crash Characters, Alignment Auditing, Hidden Troubles, Reconstruction Measures

1. Introduction

Some overseas literatures point out, 70% traffic crashes result from road and environment. That is to say, person's main causation which were recorded by Public Security are only superficial phenomenon, in fact, about 30% traffic crashes caused by person's blame or vehicle, but the 70% remain all have close relationship with road and traffic system environment.

This paper aims at analyzing the alignment's effect on traffic safety of mountainous road. Accident data roots in certain mountainous secondary road for vehicles only, range from 2003 to 2005. The road designing on two lane criterion, design speed is 80 kilometer pre hour on plain and 40 kilometer pre hour on mountain. The following text would discuss the essence of crash frequent by analyzing the general characters and auditing the road alignments.

2. Crash general characters

2.1 Characteristic of mileage distribution

Figure 1 shows the crashes' mileage distribution of this road. It shows that the whole mileage appears unequal distribution, but some of areas occur more crashes. On the assumption that person is the main reason of crash, we could have the conclusion that the mileage distribution will equality because of the peccancy occurs at random. But in fact, centrality and scrambling show that there have some great relationship between crash and road problems.

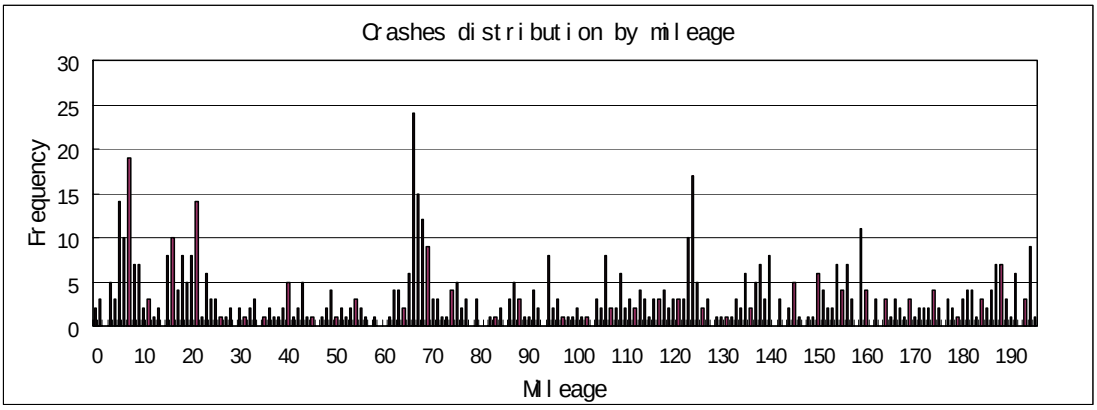

Figure 1. Crashes distribution by mileage

Due to the above figure, we find that the crashes centralized on few sections of this road, in order to further discuss the essence of more crashes, using the accident accumulation frequency method(AAFM)(ZhaoEnrong,1999)to obtain the sites where crash occurred frequently, which are called "black spots". The result shows that the abrupt point of AAFM is in 90% and the critical number of crashes is 7. For the need of typical research, 26 black spots on this section of road are found in Table 1.

Table 1 Basic information statistics of black spots

Mileage	The time of crash	Road environment
K66	24	Long downgrade
K7	19	Continuum downgrade and blind bend
K124	17	Bridge
K67	15	Long downgrade
K5	14	Toll station
K21	14	Downgrade and blind bend
K68	12	Long downgrade
K159	11	Bridge
K6	10	Continuum downgrade
K16	10	Continuum swerve
K123	10	Tunnel
K69	9	Long downgrade
K194	9	Temporary toll station
K15	8	Continuum swerve
K18	8	Continuum downgrade and blind bend
K20	8	Downgrade and blind bend
K94	8	Basic road segment

Mileage	The time of crash	Road environment
K106	8	Basic road segment
K140	8	Basic road segment
K8	7	Continuum downgrade
K9	7	Continuum downgrade
K138	7	Basic road segment
K154	7	Basic road segment
K156	7	Basic road segment
K187	7	Toll station
K188	7	Crossroads

Table 1 shows that most black spots in the sections where road entironment are complicated in this road. Basic road segments only occupy 23.7% in all. So, road factors' influence on crashes is inevitable.

2.2 Crash type characters

According by accident data of three years, we find that the most crash type are rear-end collision, head-on collision, turn over collision and collision with obstacles, these four types of crashes account for 60.4% in all. The result shows in Figure 2.

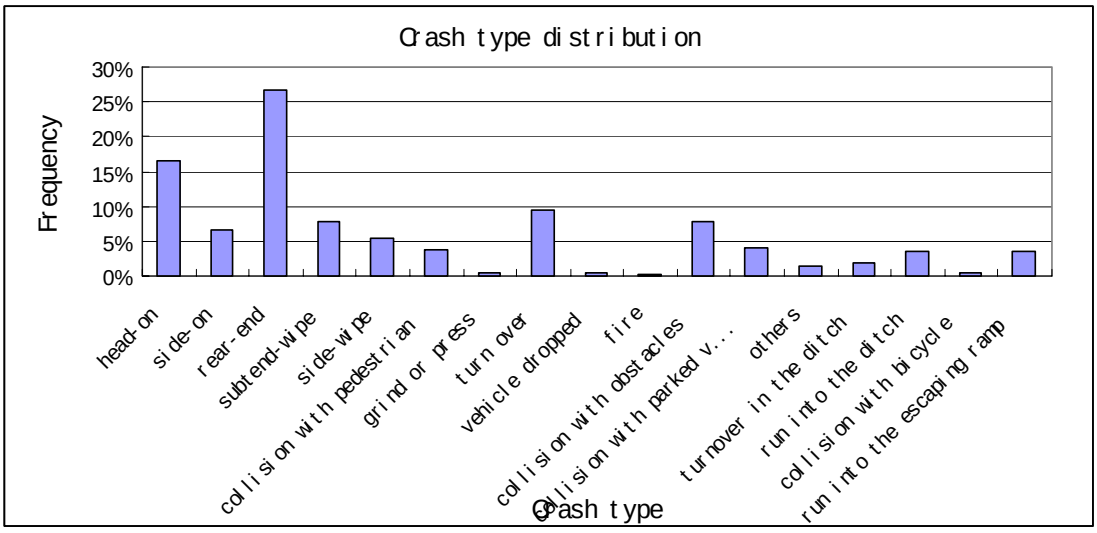

Figure 2. Crash type distribution

Rear-end collision and collision with obstacles are common types in most roads, but head-on and turn over collisiones are special characteristics in this type of mountainous road. With regard to head-on crashes occur frequently, the reason is that there has many long downgrades in this section of road and secondary road has no central divided belts, it may make vehicles bump against each other when they do overtake operation. What's more, big vehicles' overloading phenomenon pretty common not only in this road but in our whole country, it may lead to braking out of control and then turn over easily.

3. The influence of road alignment on traffic safety

Through the analyzing of crashes' general characteristics, more crash segments (76.3% non-basic sections)and frequent type(head-on and turning over accidents) both have direct relationships with road factors, hence, according to. Design Specification for Highway Alignment JTJ011-94(JTJ011-94,1994) to auditing this road alignment(ZhangYuhua, ZhuZhaohong,2005). The designing of this road on two lane criterion, design speed is 80 kilometre pre hour on plain, 40 kilometre pre hour on mountain. Road data comes from the database of Ministry of Communications.

3.1 Alignment of plain

By auditing road alignment, we find that the maximal radius of horizontal curve, limit minimum radius of horizontal curve and the least length of opposite direction curve could satisfy the demand of specification, but minimum length of horizontal curve, maximal length of linear and the least length of same direction curve all adopt lower guidelines because of the restrict of economy and terrain. The following text will do further analyse(LiuYinsheng, YangDongyuan, FangShouen, 1999). The results show in table 2.

Table2. Auditing of plain alignment

Plain line feature content(m)	Practical value	Specification value
Maximal radius of horizontal curve	5000	10000
Limit minimum radius of horizontal curve	125	60
Minimum length of horizontal curve	45	70
Maximal length of linear	2693	1600
The least length of same direction curve	20	240
The least length of opposite direction curve	80	80

1. minimum length of horizontal curve

For vehicle appropriative secondary road, Design Specification for Highway Alignment prescribes that L=140 on plain and L=70 on mountain. Then we could audit the length of horizontal curve in Table 3.

Table 3. Length of horizontal curve

The number Of curve	Length>140m		70m<Length=<140m		Length =<70m	
	number	percent %	number	percent %	number	percent %
147	108	73.469	33	22.450	6	4.081

Table 3 shows that the proportion of the length of horizontal curve. There has 6 curves' length less than 70m, occupy 4.081% in all, which dissatisfy the demand. If the length of horizontal curve too short, it would make people feel unsuitable when driving.

2. maximal length of linear

If the linear too long, it will make drivers to feel fatigue and drive in high speed, which may lead to inappropriate operation and occurs crash easily. Design Specification for Highway Alignment prescribes that the maximal length of linear should less than 20V(design speed), design speed is 40 to 80 kilometre pre hour on this road, even if we according to 80 kilometre pre hour for calculating, the maximal length of linear should less than 1600m. Through analyzing, some of the linears' length exceed this value. But considering about the alignments varity a lot and the terrain in this mountainous road, longer linear's bad influence would smaller than plain road. However, these alignment should be avoided in designing process.

3. the least length of same direction curve

Design Specification for Highway Alignment prescribes that the length of same direction curve should more than 6V(design speed). Because if the length too short, it will form an ill alignment which usually called as "broken back curve". This type of alignment is lack of continuity so that it may make driver has some illusions to operate. The length of same direction curve should more than 240m if the design speed is 40 kilometre pre hour and 480m if 80 kilometre pre hour. The distribution of length shows in Table 4.

Table 4. The length of same direction curve

The number of same direction curve	Length>480m		240m<Length=<480m		Length=<240m	
	number	percent %	number	percent %	number	percent %
44	36	81.818	3	6.818	5	11.364

Table 4 shows that there have 5 curves' length less than 240m, occupy 11.364% in all, which will increase the difficulties in driving.

In addition, besides above specification's guidelines, the horizontal curve corner also should be set suitable, which reflects whether the curves smooth or not. We consider about that the smaller corner is good. However, if the corner less than 7 degree, it will make wrong impression to driver to slowdown in vain. So the curve corner which less than 7 degree belongs to small corner, it should be avoided either. Auditing results show in Table 5.

Table 5. Horizontal curve corner

The number of horizontal curve	Corner>7 degree		Corner=< 7 degree	
	number	percent %	number	percent %
147	141	95.918	6	4.082

Table 5 shows that there are 4.082% small corners in this road, where should set up longer horizontal curve to make up the deficiency.

3.2 Alignment of profile

In the auditing of profile alignments, the guidelines which minimum radius of vertical curve and minimum length of vertical curve could satisfy the demand of specification, but some of the maximal longitudinal gradient and minimum Length of grade beyond the criterion. The results show in Table 6.

Table 6. Auditing of profile alignment

Profile line feature content	Practical value	Specification value
Maximal longitudinal gradient (%)	8.3	7
Minimum Length of grade(m)	88	120
Minimum radius of vertical curve(m)	3000	450
Minimum length of vertical curve(m)	106	35

1.maximal longitudinal gradient

For vehicle appropriative secondary road, Design Specification for Highway Alignment prescribes that maximal longitudinal gradient should less than 5% on plain and less than 7% on mountain. In this section of road, there have 2 longitudinal gradients more than 7%, occupy 0.8% in all. The proportion of that shows in Table 7.

Table 7. Maximal longitudinal gradient

The number of longitudinal gradient	Longitudinal gradient >7%		5%<longitudinal gradient =<7%		Longitudinal gradient =<5%	
	number	percent %	number	percent %	number	percent %
250	2	0.800	15	6	233	93.200

2. minimum Length of grade

For the length of grade, Design Specification for Highway Alignment prescribes that the minimum length of grade should more than 200m on plain and 120m on mountain. In this section of road, there have 38 grade length less than 120m, occupy 13.67% in all, the alignments like this may have some hidden troubles on safety. The restrict of minimum length of grade mainly considering about driving's smooth or calm, if the grade length shorter, vehicles would change frequently, which may lead to uneasiness feeling. The distribution of the grade length shows in Table 8.

Table 8. Minimum length of grade

The number Of Length of grade	Length of grade >200m		120m<Length of grade =<200m		Length of grade =<120m	
	number	percent %	number	percent %	number	percent %
278	200	71.943	40	14.388	38	13.669

In the process of designing, we should do our best to make longer distance between two change points in order to improve the smooth of alignments.

3.3 The combination of plain and profile alignment

The designing of alignment combination should satisfy two aspects of demands. First, driving safety must accord with mechanics request. Second, alignment should satisfy the demand of person's easiness and pleasure with vision and mentally. These two sides are indivisibility. With technique guidelines, mechanics requires least value(limit value), vision and mentally needs a value more bigger, which especially for mountainous road.

With auditing, the problems of combination show as follows:

1.Inserting sharp horizontal in the top or bottom of protruding or concave vertical curve. These alignment combination lead to crash easily because of bad sight distance, which needs to strike steering wheel rapidly by drivers.

2.Setting up broken back curve in the top(or bottom) of protruding(or concave) vertical curve. If broken back curve set in the top of protruding curve, the line of sight may have no inducement effect, drivers usually find the curve bend to opposite direction at the site of near the vertex, where may make them strain and worried; In the bottom of concave curve may result in drainage trouble.

3.In the same horizontal curve, vertical alignments changed frequently. This situation easily leads to crashes for the sunk alignment invisibility by drivers.

4.The combination of smaller corner horizontal curve and steep slope will increase the probability of crashes.

4. Reconstruction Measures

4.1 Setting up temperature reducing devices

From the above analysis, continuous long downgrade and big vehicles which usually overloaded are the main causations for crashes frequently occured in this road. When big vehicles driving on the long downgrade, arrester will brake for a long time and in great intension, which might lead to temperature go up fast. In that situation, even if overloading vehicles brake few times, it also may appear heat decline and lead to lose of control finally. At present, one of the valid measures is to cold the braking at the top of slope(HanFengchun, MaSheqiang,2005). So we suggest to set up temperature reducing devices could be settled some of the problems. Temperature reducing devices should consider about the factors of overweight. The effective depth of water can not be under 50cm, and the effective length of water can not less than 50m, we also should set up signs to inducement.

Due to the analysis above, we suggest to set up temperature reducing devices at the top of two long downgrades(K4—K18 and K63—K75)and record the crashes varieties at the same time.

4.2 Setting up escaping ramp

The location of escaping ramp needs to integrated consideration:

1. Black spots usually in the second half of continuous downgrade, if the distance of downgrade too long, exceed 10 kilometres for example, we should set up more than two escaping ramps.

2. The speed in the second half of continuous downgrade is usually high, where vehicle needs the largest deceleration. So in these locations, vehicle may lose of cortrol by invalid braking.

3. Considering about the influence of topography and terrain.

With the investigations and researches by crash frequent points(Table 1), we suggest to set up escaping ramp in K17 400M K63+400M and K65+780M.

.3 Setting up speed cortrol devices

After traffic sign reconstruction, the department of traffic police should feed back the crashes variety status, if the lose of cortrol crashes occurred all the same, we should set up speed cortrol devices in time.

We advise to set up speed cortrol devices on the two side of tunnels' downhill road, the form can be adopt decelerate cingulum or Belgium road surface. The speed cortrol devices can force vehicles to keep lower speed.

5. Conclusions

Through the analysis above, we have some conclusions as follows:

Most of the auditing guidelines satisfy the criterion, but some of them adopt limit or lower values(the proportion of each kind of guidelines have been listed in above paragraphs). Those values dissatisfy the demand of safety and induces crashes easily.

Long downgrade crashes occurred frequently is the main characteristic of this road(shows in Table 1). The designing of longitudinal gradient and length of grade can not be provided a safety driving circumstance for overloading vehicles. Using a lot of limit guidelines and most of overloading phenomenons may aggravate the effects of alignments on safety. Hence, there have some black spots which result from road factors.

So, ill alignments is the main causation on mountainous road, long downgrade is the typical segment of more crashes. This paper aims at enhance the important effect of designing, but not ascribe all the duties to person when crash happened. We should do our best to eliminate the hidden troubles in the designing process in order to improve our social safety levels.

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