ABSTRACT
Recently, highway safety issues are more increasingly concerned by people and government, because of the increasing accidents and developing highway traffic. Then the highway safety enhancement project is being launched in most provinces in China.

This paper introduces the ways of doing highway safety enhancement project in China. It arms to analysis some accidents happened on provincial highway S213 in Guizhou province in China, then the reasons of them will be given and the composite safety enhancement method will also be shown in this paper.

1 INTRODUCTION
Provincial highway S213 is a high-level automotive dedicated highway, which was built in 2003 from Guanling County to Xingren County. This section is 49 kilometres in Guanling County. It is maintained under local management by the Highway Authority of Anshun City in Guizhou Province, as the adjustment of the national secondary level highway charging policy.

In recent years, traffic accidents and incidents were in a growing trend. According to statistics (shown in the Figure 1) from Traffic Police Group of Guanling County, There were 176 traffic accidents happened in 2009, 223 cases in 2010, 367 cases in 2011, and 367 incidents happened during the period from January to April on this section of Highway S213. In addition, the number of accidents and casualties has increased sharply.
The increasing trend of accidents and casualties caused great concern of the Guizhou Provincial Government, and then the safety enhancement project on this section of S213 was launched to control the upward trend of traffic accidents, and to protect travelers’ safety.

2 INVESTIGATIONS AND OVERVIEW

2.1 Investigations
The investigations for HSEP (Highway Safety enhancement project) on the section of S213 were launched in July 2012 mainly including collecting geometric status, vehicles’ classification, and speed on straight and horizontal curve. The details of accidents were gained by discussing with local traffic policemen (FANG, 2001).

2.2 Overview of road status
According to the investigations, several information of overview can be found shown below:
- this section is a 12 metres wide two-lane road without central reserve;
- the design speed is 80 km/h;
- the AADT of the section is 7000.

2.3 Overview of vehicle status
Through analysis the investigations of the vehicles’ classification, the features are that:
- the vehicles’ classification are varied including car, coach, lorry, motorcycle, bicycle, tractor, etc;
- the car accounts for the most proportion;
- the proportion of motorcycle is almost 20%.
The classifications of the vehicles are shown in the Figure 2.
2.4 Overview of vehicle speed

Furthermore, to analyse data of the vehicle running speed, shown in Figure 3, it can be found that:
- the V85\textsuperscript{th} of the cars’ running speed is between 70 and 110 km/h, and it is more than 100 km/h on straight line;
- the V85\textsuperscript{th} of the lorries’ running speed is between 60 and 80 km/h;
- the V85\textsuperscript{th} of the motorcycles’ running speed is between 40 and 80 km/h;
- the vehicles have different type with much different running speeds;
- the running speeds on different curve are much different.

Figure 3: The V85\textsuperscript{th} of vehicles running speed with different vehicle types
Some researches point that the much different speed may relate to the pileup accidents, and more overtake behavior may be caused.

3 ACCIDENTS ANALYSIS

3.1 Accident forms analysis
There are 13 casualty accidents collected from police, and shown (in Figure 4) that:
- most casualty accident forms are head-on collision and side swipe accounting for 80 percent;
- the main reasons of these accidents are the centrifugal force on the horizontal curve and illegal driving behavior such as crossing central line to overtake;

![Casualty accident forms proportion](image)

3.2 Accidents analysis on road surface situation
By analysis the data of casualty accidents, the road surface situation can be known. It is found that almost 77% accidents happened on wet road, in the others only 23% happened on dry surface including some incidental cases, such as 2 cases in these are pedestrian rushing on the highway suddenly.

It means that the road surface situation can relate to the accidents apparently.

3.3 Accidents time and location analysis
By the same way, time and location can be focused, which will show the hazardous locations and time (QIN, 2009). The hazardous locations are concentrated in sections of the front end and the rear end, as shown in Figure 5.
These two sections have obvious features:
- slope and curve combined;
- continuous curve;
- (vehicles have much different speed on) straight line with horizontal curve;
- houses and restaurants next to the road (where pedestrian crossing frequently); (MENG, 2008)
- most occur during from 12 am to 8 pm (when most traveler on the road).

3.4 Accidents’ reason analysis

Given by the paper above, the vehicles’ type are various and have large proportion of cars on the accident increasing sections with different environments (ZHANG, 2008). Furthermore, the most accidents form is found as collision on wet road surface in some assemble locations. And the problem’s roots are that vehicles side-slipping frequently, illegal behavior, and lack of effective guide (TANG, 2007).

Force analysis can be used to study the reason of vehicles side-slipping shown as Figure 6.

\[ \text{Figure 6: Centrifugal force analysis on horizontal curve} \]

- N: Ground supporting force;
- G: Vehicle gravity;
- \( f \): Friction = G component \( \times \) friction coefficient
F: Centrifugal force $= \frac{mv^2}{r}$

m: Mass;  
v: Velocity;  
r: Radius.

It points that the problem of vehicle side-slipping is significantly related to surface friction coefficient, vehicle’s mass and vehicle’s velocity on a road section with certain radius of horizontal curve and certain superelevation. In addition, vehicle side-slipping could appear, when the friction coefficient is decreasing, when the vehicle’s mass is increasing, when the vehicle’s velocity is rising.

In further, the centrifugal force can also cause the illegal behavior – driving cross the central line. Furthermore, it can also be caused by overtaking, avoiding pedestrian crossing road. And some pileup accidents’ reason is another illegal behavior that vehicles rushing from rest area with a low speed are much different from the vehicles driving on straight section with high speed as usual, or is that vehicle rushing out from rest area located on a horizontal curve with limited stadia.

Another, the lack of effective guide includes lack of guidance signs which could result in rushing into curve with unexpected high speed, too wide lanes which may cause too small distance between two direction vehicles to result in crashes, and lack of warning signs before hazardous location which may cause accidents. (XIE, 2007)

4 TARGETED AND COMPOSITE SAFETY ENHANCEMENT METHOD

To solve this problem above, targeted enhancements and composite safety enhancement are needed.

4.1 Targeted safety enhancement method

To enhance the location where vehicles side-slip frequently, there are several ways. Firstly, micro-surfacing, which use certain materials to fix the road surface, can be used to increase the friction coefficient. Secondly, speed limit signs and speed-feedback facilities can be used which has great effect on other roads in HSEP. Another way is to use warning signs, illusion lines, vibration lines, etc. to warn drivers to decrease speed actively. (WANG, 2006) (WU, 2009)

To improve the section where traveler used to drive over the central line, the double central lines and fish-belly lines as the target safety enhancement, shown in Figure 7. These methods can increase the distance between two direction vehicles significantly, in order to avoid this form of accident.
And the hooting horn markings and convex mirror can be located on the section of horizontal curves which lack sight distance, such as Figure 8.

To target the behavior of rushing out of rest area and the section of houses and restaurants next to the road, the transverse speed reduction markings and warning signs should be located before entering the section, show as below. (ZHANG, 2007)

To deal with lack of effective guide, locating chevron alignment sign, using lines to decrease the width of lanes, and locating longitudinal alignment illusion lines could be the best way.
4.2 Composite safety enhancement method

These targeted methods above can solve most problems with significant effect, but composite safety enhancement should be expected where the section of the road has several hazardous elements. In fact, the section where the casualty accidents concentrated happened almost has more than 2 elements.

Therefore, the composite safety methods should be needed and an example given in Figure 10.

![Figure 10: Composite safety enhancement method](image)

This section where 2 casualty accidents happened is located from the highway S213 K20+400 to K21+400, which has a small radius of horizontal curve, two restaurants located next to the road. To improve it, the hooting horn markings and convex mirror is needed to increase the view distance at the corn, and the chevron alignment signs must be installed to warn travelers the curve as well. In addition, illusion lines, warning signs and transverse speed reduction markings should be located on two directions before entering the area of buildings and restaurant to warn driver to reduce the speed actively.

5 CONCLUSION

This paper introduces an example of HSEP on Highway S213 in Guizhou Province. 13 casualty accidents are analysis in this paper, and the main reason of them is given as high speed, low friction coefficient and drivers’ unsafe behaviors. After that the targeted and composite safety enhancement methods are given with several examples.

All of the methods involved in this paper have been used on the Highway S213, and accidents have decreased sharply without death. It indicates that these safety enhancement methods are effectively prevent crashes, and worthy recommending on other highway safety enhancement projects.
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