Cause Analysis of Traffic Accident and Its Migration on Long Steep Downgrade

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Abstract: Traffic accident occurring on long steep downgrade of highway is very frequent and severe in China. And there is the phenomenon of traffic accident migration on this type highway section, especially those that countermeasures have been carried out to improve traffic safety. Causes of traffic accident and its migration on long steep downgrade was analyzed based on the investigation of traffic accident data of 5 years period occurring on a expressway in South China and a brake temperature transformation model of trucks. Overload was given as a main cause of traffic accident on long steep downgrade. And some integrative cause correlating with overload was found resulting to the accident migration. The fact was helpful to understanding the cause of the accidents deeply.
Keywords: highway traffic accident, migration, downgrade

1 Introduction

Traffic accident occurring on long steep downgrade of highway is one of the most frequent and severe types of traffic accident in China. Official statistic shows death rate of traffic accident on sections of long and/or steep downgrade was about second to third more than flat sections[1]. The cause of traffic accident occurring on highway sections of long steep downgrade was considered from the aspects of highway design, vehicle function, overload and improper operations of drivers[2,3]. Obviously, there are various direct causes for a special accident. But it was still not answered that which cause is the most important to or the most widely existing in every accident in China.

At the same time, the traffic accident migration is a phenomenon which is found when traffic accident data was statistically analyzed along a highway. The phenomenon was found on the highway sections where intersections were converted to multiway stop control[4], where an additional non-standard mixed-flow lane was added[5], and where variable speed limits were applied[6]. And a possible traffic accident migration was found in an expressway section of long steep downgrade as well[7]. Two causes of the accident migration was researched which is the statistical analysis deviation[8] and the driver's risk compensation effect[9]. The former considered the traffic accident was a feint caused by statistical deviation. But the latter research proved the truth of the phenomenon and ascribed it to human's negligence resulting from safe condition changing from the dangerous. Although both of the reasons gave some kind of explanations of traffic accident migration after some special countermeasures being carried out, they are no helpful to explaining and solving the problem from the potential aspects of vehicles and highways.

So a typical expressway with long steep downgrades was selected to analyze the traffic accidents and their migration on it, in order to identifying the main accident cause on this type of highway section in China.

2 Facts about G4 Expressway and traffic accident occurring on it

2.1 Establishment condition of G4 Expressway

The G4 National Expressway is an important and busyness highway corridor from North China to South China. The section being discussed was about 109 km long in South China. There are many sharp turns, long steep downgrade sections, grand bridges and long tunnels in the section when it goes through the natural calamitous mountain area of South China, which caused the high risk of traffic accident, macroscopically.

Table 1. Design Guide Line of The Mountain Terrain Section of The G4 Freeway

Design Guide Lines	Unit	Value
Design Speed	km/h	80
Subgrade Width		
Entirety	m	23.0
Separate	m	2×11.75
Least Radius of Horizontal Curve	m	500
Maximal Longitudinal Gradient	%	5
Least Radius of Vertical Curve		
Protruding	m	8000
Concave	m	8000

The section is a bidirectional expressway with four lanes. The design guide lines of the section was shown as Table 1. The section was open to traffic in April, 2003. And two phases traffic safety improvement projects were implement in 2004 and 2005 because of severity situation of traffic accidents. There is a 13km long downgrade section with 2.9% average gradient (Called LSD 1) and a 25.54km long downgrade section with 2.6% average gradient (Called LSD 2), which are the typical long steep downgrade and one of the most dangerous highway sections in China.

2.2 Traffic accident occurring on the section

More than 2200 traffic accidents have occurred during the period from April, 2003 to December, 2007 in the section. And there are 557 severe traffic accidents everyone of which result in at least one death and/or three grievous bodily harm. And in the two long steep downgrade sections, 212 severe downgrade traffic accidents occurred during the 5 years period, on which the 38% severe accidents occurring on the 11% mileage section (two directions). Therein to, in LSD 1 (K39+180~K52+180, from north to south), 155 severe downgrade traffic accidents occurred and in LSD 2 (K39+180~K13+640, from south to north) 55 severe downgrade traffic accidents occurred.

Safety improvement measures had been implemented on the expressway section for the severe traffic safety situations on it. A two phases traffic safety improvement projects were implement in 2004 and 2005. The amount of traffic accidents and fatalities were reduced obviously in the second half of 2005. But the two section of long steep downgrade are still black spots section of traffic accident on the basis of accident data in the period from 2006 to 2007 (See Fig. 1 and Fig. 2).

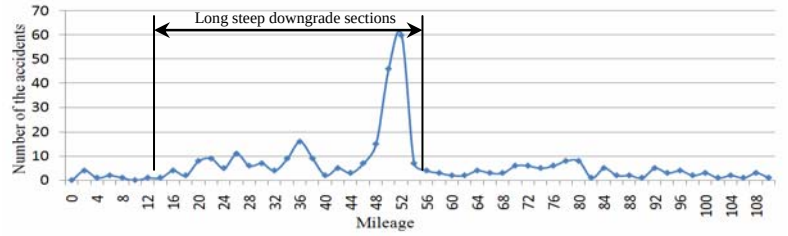

Figure 1. Traffic accidents distribution (2003-2004)

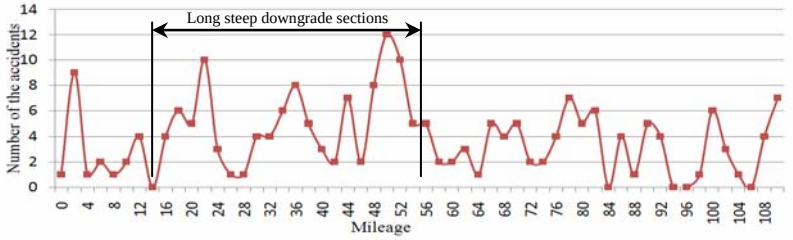

Figure 2. Traffic accidents distribution (2005-2007)

3 Analysis on traffic accident migration on the long steep downgrades

The accident spatial relationship charts[7] were drawn according to the data of accident occurring on the two sections (See Fig. 3 and Fig. 4). The chart labels the black spots with a coordinate of mileage (x axle) where the sits locates and year (y axle) when the sits are an accident spot. And the size of the points in the chart represents the amount of accident occurring in the site.

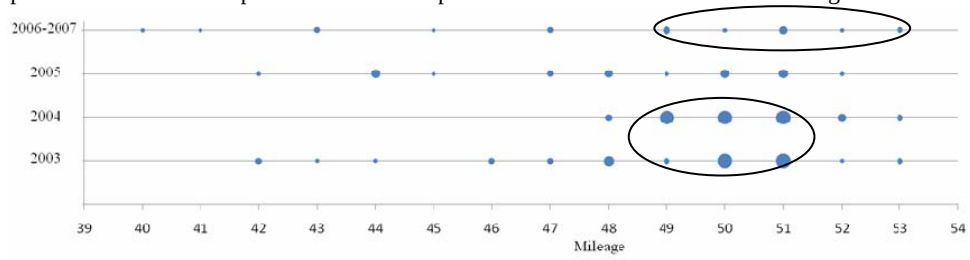

Figure 3. Spatial relationship of accidents spots of LSD 1

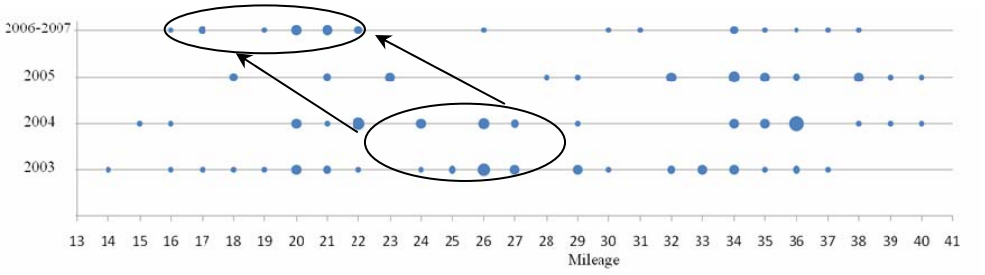

Figure 4. Spatial relationship of accidents spots of LSD 2

The accident migration was found on LSD 2 where high frequency spots of accidents moved from K28-K23 to K23-K16, describing in Fig. 4. And there was no obvious migration phenomenon on LSD 1. But accidents spots became more dispersive in 2005-2007 than that in 2003-2004. The amount of accidents occurring on the section of K52-K53 on LSD 1 seemed outstanding as well

in 2006-2007, although the section of K49-K51 was still a high frequency spots of accidents. The same phenomenon could be found on the section of K38-K30 on LSD 2.

4 Truck brake temperature evaluation and analysis

The traffic accidents records show almost all forms of the accidents are rear-end collisions and main cause of the accidents are the failure of truck braking system[10]. Continually applying to brake on a downgrade section will cause heat fade of the braking system of vehicles, especially that of trucks. And when the brake temperature is increased above 260℃, the efficiency of braking system will be reduced[11]. So truck brake temperature had to be considered as an important factor of traffic accident occurring on downgrade sections.

Table 2. Combination of truck types and loads

Serial number	Types of vehicle	Load (t)	Rate of overload (%)
2-20	Truck with 2 axles	20	0
2-30	Truck with 2 axles	30	50
2-40	Truck with 2 axles	40	100
3-30	Truck with 3 axles	30	0
3-45	Truck with 3 axles	45	50
3-60	Truck with 3 axles	60	100
5-50	Truck with 5 axles	50	0
5-65	Truck with 5 axles	65	30
5-75	Truck with 5 axles	75	50

PIARC (2003) has provided a tool to evaluate truck brake temperature on the downgrade sections, according to the principle of total energy of a vehicle arriving at the top of a downhill grade is equal to the sum of its kinetic and potential energy. The transformation of truck brake temperature was evaluated by using the tool (See Fig. 5 - Fig.). Three types of truck was evaluated combining with 9 types of loads (See Table 2).

Two types of situation, non-overload and overload, was considered when truck brake temperature was evaluated. The criterion of overload is that the load of a truck is over 10 times of the number of axles. The brake temperature was increased with the distance running along downgrade increased, and more heavy the load was, steeper the brake temperature profile. But no brake temperature of trucks in the non-overload group (Fig. 5) was found when they run along LSD 1, although. However, brake temperature of trucks in the overload group (Fig. 6) was increased above 260℃ from K46 to the end of LSD 1. Higher the rate of over load, higher the brake temperature at the end of the section. So it can be evaluated that the brake temperature profile would be more steep if the rate of overload was higher.

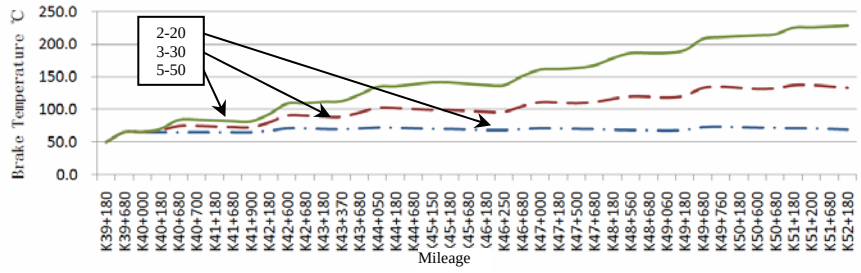

Figure 5. Truck brake temperature evaluation of LSD 1 (non-overload)

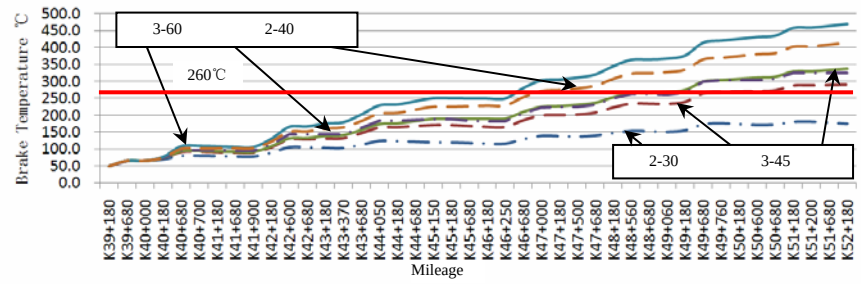

Figure 6. Truck brake temperature evaluation of LSD 1 (overload)

Along LSD 2, most of the brake temperature of trucks in the non-overload group (Fig. 7) was under 260℃ as well. And in the overload group, the brake temperature of trucks was increased above 260℃ from K34 to the end of the section. To some combination of

truck and load, the brake temperature fluctuated around 260℃, because the average gradient of LSD 2 was less from K34 to K27. But all kinds of overload truck with more than 3 axles had their brake temperature increased above 260℃.

So the overload was found to be the main cause of brake system heat fade of trucks on LSD 1 and LSD 2. In fact, the proportion of overload trucks is more than 80% in 2003-2004, and that is still near 60% in 2007, after forcefully treated[10]. The overload seemed to be the important cause of traffic accident on the sections.

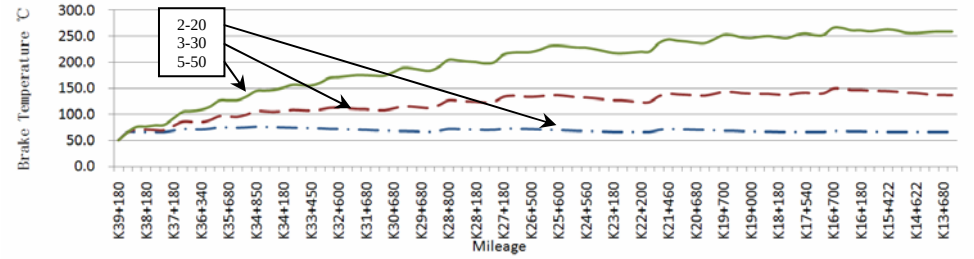

Figure 7. Truck brake temperature evaluation of LSD 2 (non-overload)

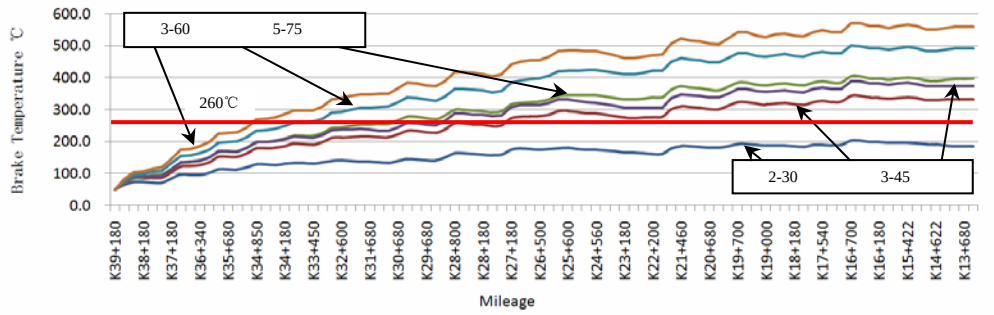

Figure 8. Truck brake temperature evaluation of LSD 2 (overload)

5 Conclusion

The main black spots sections of K48-K51, K35-K33, K25-K20 had superposition of brake heat fade. And considering the failure of truck braking system is the main cause of accidents in the record, it could be confirmed that main cause of traffic accidents occurring on LSD 1 and LSD 2 was the truck brake heat fade caused by the overload.

The overload was the cause of traffic accidents on LSD 2 as well. Traffic safety countermeasures and the treatment aiming at the overload reduced the possibility of brake system failure in the upper reaches of long steep downgrade sections, but in the lower reaches of the sections, continual using caused brake heat fade and new black spot of accident was formed.

So brake temperature evaluation is an effective tools to cause analysis on traffic accident and its migration on long steep downgrade.

Acknowledgement

This work is sponsored by the Scientific Innovation and Personnel Developing Projects of Research Institute of Highway, MoT, China.

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