Multiple Geometric Factors Contributing to Mountainous Freeway Crashes

A Case Study of Changjin Freeway in Jiangxi, China

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Abstract—Many previous researches have analyzed the causes of freeway accidents, especially for those in the mountainous areas, but few of them have put deep insight into the geometric factors. Using 1,023 crash records during the period of 2006–2012 from Changjin Freeway in Jiangxi, China, this research evaluated the relation between contributory geometric factors and crash rate. Geometric factors were classified into three categories: vertical alignment, horizontal alignment, and cross section. Then detailed effects of geometric variables are separately discussed and quantified through the relation with crash rate (CR). It was found that the CR value is greater at minor radius and long-down grade sections. Additionally, segments of angle of deflection varying over 17-25^{o} and wider cross sections are much safer, compared with other locations.

Keywords- Mountainous freeway crash; Geometric factor; Vertical alignment; Horizontal alignment; Cross section

I. INTRODUCTION

During the past years, with the rapid development of economy and mechanization, the number of vehicles in China has experienced a dramatic increase [1]. Statistics released by the Ministry of Public Security found that there are more than 137 million vehicles in China in 2013 compared to around 2.4 million at the end of 2003. As a result, many traffic accidents appear in China especially on expressway. Expressway deaths increased by 10.2 times from 616 persons in 1995 to 6300 persons in 2010, and the average annual increase was 17.9 percent over the past 15 years [2]. What's more, the fatality rate of expressway is high whose deaths made up 13.54 percent of road traffic deaths but only 1.85 percent of road length. Overall, Chinese drivers in expressway still face a high risk of accident. It is estimated that accidents on freeways slightly decrease but the fatality rate is still high.

Freeway accidents are influenced by a large set of factors including human factors, vehicle factors, and environmental conditions, etc [3]. Actually, in the previous years while analyzing freeway traffic accidents these subject factors were given considerable attention but few studies focus on road factors including horizontal alignment (horizontal curve length, degree of horizontal curvature), vertical alignment (curve length, vertical grade), cross section (number of lanes, average shoulder width on each side and surface width), others (tunnel, ramp, etc) [4]. How to find the relationship between safety and road factors is an extremely complex problem.

China has a tremendous area of territory, which more than 70% was covered by mountain and hilly terrain, especially in South China. In 2012, the total mileage of mountainous freeways had reached 96,200 kilometers in 2012, but the safety situations are also very serious.

Despite of various efforts, however, many problem related to freeway accidents remain unsolved today. Facing continued population growth, automobile revolution, shrinking per capita infrastructure investment and tighter environmental constraints, however, it still has a long way to go. Upon the urgent requirement, this study focused on exploring the effects of variable alignments on crashes using a statistical analysis method. Changjin Freeway is used as a case to conduct this study using 1023 crash records. For a precise analysis, the count of crashes is viewed as a function of various geometric factors (e.g. radius of curvature and gradient). Several statistical models such as a linear-regression model are used [5].

II. DATA COLLECTION

In this study, 1,023 crash records from 2006 to 2012 were collected from Changjin Freeway (K905+000~K982+600), a section of Hukun Freeway in Jiangxi, China, including 182 common accidents and 841 simple accidents, respectively. Here the common accidents included those which caused serious injuries or casualties or more than 5,000 CHY losses and the simple accidents referred to other cases. The crash data was directly extracted from "Traffic Accident Database System" (TADS) under the permission of Department of Transport of Jiangxi Province. For further analysis, average crash rate (*CR*) of segment *i* can be then considered as the average count of crashes (*ACC*) per 100 million entering vehicles (100MEV), obtained as:

$$CR_i = \frac{ACC_i}{365AADT_i \cdot L_i} \times 10^8 \quad (1)$$

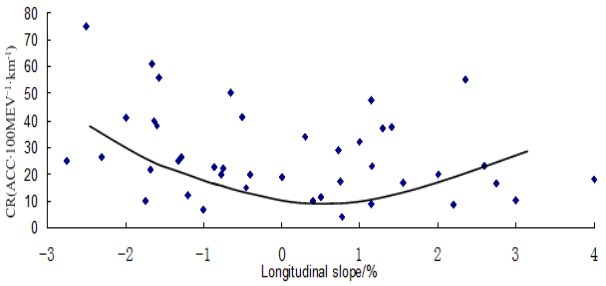
where, ACC_i = crash count of segment *i*; $AADT_i$ = average daily volume of segment *i*, pcu/day; L_i = length of segment *i*, km.

III. RESULTS, FINDINGS AND ANALYSIS

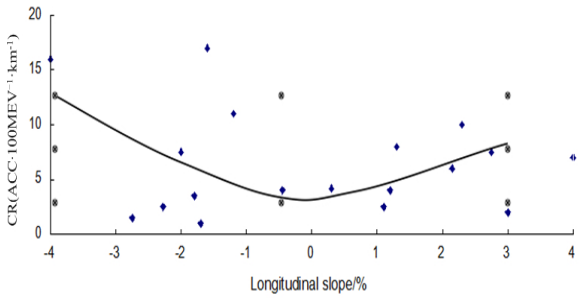
The contributing factors are classified into three components consisting of: vertical alignment, horizontal alignment, and cross sections.

A. *Vertical alignment*

In the past years, many accidents, especially truck involved record, have frequently occurred at segments with greater grades. When a vehicle brakes at down grade, it always takes longer distance than that of up-grade at the same speed. Thus, it is difficult for driver to keep safe distance with the front vehicle when a emergency brake occurred. At long-down grade sections, the situation seems much more serious, especially for trucks due to that the brake function will decrease when the brake block get hotter [6]. Generally, locations at down grade witnesses more crash occurrences. Figure 1 presents a comparison of CR values at locations of up and down grades.



a. simple accidents



b. common accidents

Figure1. Comparison of crash rates at locations of down and up-grades of Changjin Freeway

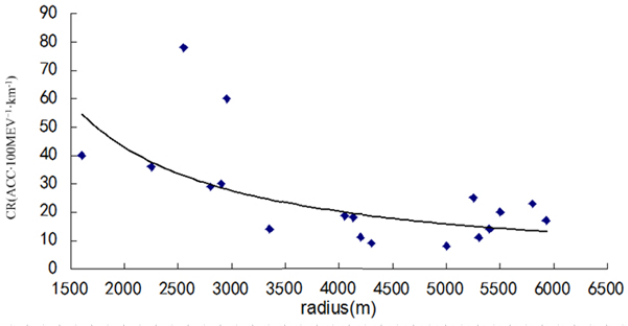
Reconsidering the above listed Figure 1, it is clear that both types of *CR* values come to a great increase with an increase grade. That's mainly due to less effective brake system performance and driver's incorrect operation, especially during the emergency conditions.

The vertical curve can be categorized into crest and concave. It's the necessary part to join two sections with different grades. However, it brings down the driver' sight distance and cause potential risk, particularly over crests. The radius of vertical curve determines the effect of transition between two different segments. The bigger, driver's sight distance gets better; the smaller, the worse. It should be pointed out that at the same vertical radius, crest curve generally witness bigger *CR* values than that of concave curve. By crash records of Changjin Freeway, 88 crashes occurred at crest sections while 53 at concave.

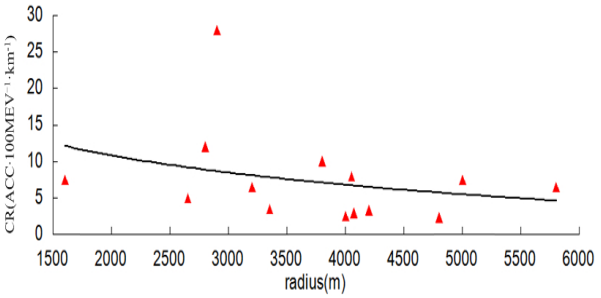
B. *Horizontal Alignment*

Safety performance has a close relation with the maximum value of horizontal curvature in mountainous freeway [4]. Figure 2 shows the relation between *CR* with the radius of horizontal curve of Changjin Freeway.

Through the Figure 2, we could find that *CR* values decline with the increase of the radius. It should also be pointed out that driving on curves with different radius behaves more dangerous than that with same or similar radius. Particularly, it is much more dangerous when a small radius curve is inserted into long and straight line. That is partly due to the driver's unconsciousness of speed on the latter and may cause overturn or run off road crashes on the curve [7, 8].



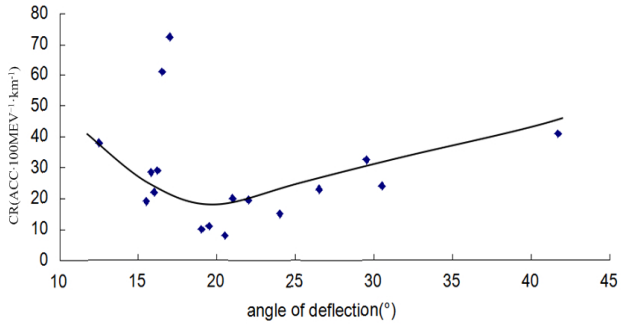
a. simple accidents



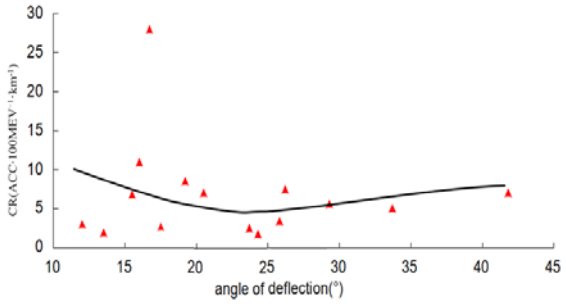
b. common accidents

Figure 2. Crash rates to radius of horizontal curve of Changjin Freeway

Angle of deflection has a direct influence on the driving safety. In the geometric database of Changjin Freeway, the maximum and minimum angles of deflection are 41°26′40″ and 12°12′14.4″, respectively. Crash rates vary with the angle of deflection, as shown in Figure 3.



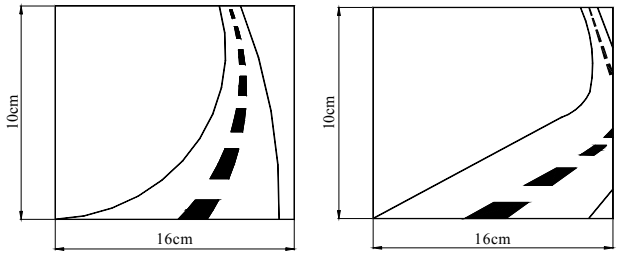
a. simple accidents



b. common accidents

Figure 3. Crash rates with angle of deflection

Reconsidering these two figures, we see the lower *CR* values, when the angle of deflection varies over 17-25° for Changjin Freeway. This is because drivers could have a better view sight, when the angle of deflection locates within this scope [9]. Otherwise, part of curve are beyond driver's sight and discontinuous pavement view is more prone to crashes, as shown in Figure 4.



a b

Figure 4. Schematic design of angle of deflection for roadway safety. a. angle of deflection is 20° or less; b. angle of deflection is more than 30°

C. Cross Section

Run off and rear end crashes are the most common type of crash on mountainous freeways. And cross section is closely connected with these crashes. The width of roadway is important to driving safety, which consist of travel line, hardship and grass verge. Generally speaking, driving in wider sections is safer than that in narrow ones. Particularly, the width of hardship is also important, for it can provide a "buffer region" for drivers when emergency cases occur. Additionally, turnover is another common type of crashes with a higher crash rate, which is mainly caused by high sub-grade design of roadway. Thus, it is better not to use high sub-grade and otherwise, enough traffic claim signs and other kind of safety facilities must be equipped together [10, 11]. Another factor worth investigating is the roadway number of lanes.

IV. CONCLUSIONS

Aiming at identifying contributory geometric factors which contributing to higher crash rate and sever injuries or deaths in mountainous area, a series of statistics investigation research has been performed. The considered or discussed geometric factors that affect or relate to safety and operational quality of mountainous freeway include: vertical alignment, horizontal alignment and cross section. By this research, we made a deeper understanding of the mechanism of crash occurrence and its relation with different roadway alignment. Surely, crashes may be affected by many factors (human, environment, vehicle, roadway etc.). Therefore, we should still make more quantitative researches to overcome this difficult issue [12].

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REFERENCES

[1] F.M. Council, "Safety Benefits of Spiral Transitions on Horizontal Curves on Two-lane Rural Roads", Transportation Research Record, No. 1635, 1998, pp. 10-17, doi: 10.3141/1635-02

[2] A. Polus, M.A. Pollatschek, C. Mattar-Habib and J. Jarroush, "An Enhanced Integrated Design-consistency Model for Both Mountainous Highways and Its Relationship to Safety", Road and Transport Research, Vol.14, No.4, 2005, pp. 13-26.

[3] M.D. Fontaine, "Effect of Truck Lane Restrictions on Four-Lane Freeways in Mountainous Areas", Transportation Research Record, No.2078, 2008, pp. 135-142, doi: 10.3141/2078-18

[4] Y.G. Wang, L.C. Li, L. Feng and H. Peng, "Professional Drivers' Views on Risky Driving Behaviors and Accident Liability: A Questionnaire Survey in Xining, China", Transportation Letters: The International Journal of Transportation Research, Vol.6, No.3, 2014, pp. 126-135, doi: 10.1179/1942787514Y.0000000019

[5] J. Zhao and W. Deng, "Traffic Accidents on Expressways: New Threat to China", Traffic Injury Prevention, Vol.13, No.3, 2012, pp. 230-238, doi: 10.1080/15389588.2011.645959

[6] A. Gregoriades and K.C. Mouskos, "Black Spots Identification Through a Bayesian Networks Quantification of Accident Risk Index", Transportation Research Part C: Emerging Technologies, Vol.28, 2013, pp. 28-43, doi: 10.1016/j.trc.2012.12.008

[7] Y.G. Wang, K.M. Chen, L.W. Hu and Y.L. Pei, "Voluntary Killer: Multivariate Highway Geometric Factors Contributing to Crashes and Collisions in China's Mountainous Regions", Technics Technologies Education Management - TTEM, Vol.5, No.3, 2010, pp. 531-543

[8] P. Kopelias, F. Papadimitriou, K. Papandreou and P. Prevedouros, "Urban Freeway Crash Analysis: Geometric, Operational, and Weather Effects on Crash Number and Severity", No. 2015, 2007, pp. 123-131, doi: 10.3141/2015-14

[9] S.M. Easa and Y. Hassan, "Development of Transitioned Vertical Curve II Sight Distance", Transportation Research Part A: Policy and Practice, Vol.34, No.7, 2000, pp. 565-584, doi: 10.1016/S0965-8564(99)00037-3

[10] R. Fu, Y.Guo Y, W. Yuan, H. Feng and Y. Ma, "The Correlation Between Gradients of Descending Roads and Accident Rates", Safety Science, Vol.49, No.3, 2011, pp. 416-423, doi: 10.1016/j.ssci.2010.10.006

[11] J. Milton and F. Mannering, "The Relationship Among Highway Geometrics, Traffic-related Elements and Motor-vehicle Accident Frequencies", Transportation, Vol.25, No.4, 1998, pp.395-413, doi: 10.1023/A:1005095725001

[12] M. Sultana, X. Qin, M. Chitturi and D. Noyce, "Analysis of safety effects of traffic, geometric, and access parameters on truck arterial corridors", Transportation Research Record, Vol.2404, 2014, pp. 68-76, doi: 10.3141/2404-08