Research on Highway Traffic Safety Measures in High Altitude Areas
—Based on Qinghai Province Gongyu Expressway

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Fundamental Research Funding for Central Universities, Number:310822171006

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ABSTRACT

In view of the traffic accidents caused by the uniqueness of natural environment in high altitude regions, the research object is traffic safety of expressways in the high altitude areas. With Gongyu expressway as an example, the research anchors on the practical investigation of expressways in high altitude areas, and thoroughly analyzed the distinguish features from 5 aspects: driver's physiological condition, road alignment, landscape, geological condition, and the transverse interference. The research goal is to provide protective methods to traffic safety problems of expressways in high altitude areas according to their traits.

Keywords: High altitude area, Expressway, traffic safety, protective methods

1. INTRODUCTION

The traffic safety problems of expressways in high altitude areas have been attracting experts’ attention. Urgent solutions are needed. Influenced by the high average altitudes, the special geographical environment, complex geological conditions, and varied climates as well as other special conditions, the traffic safety of highways in high altitude areas has unique needs. However, few researches, both home and abroad, are conducted from this perspective (Huang Yong, 2012). For a long time, the traditional technology has been employed while the environmental impacts on high altitude highway have been ignored. Considering above, the author believes that, to ensure the operation safety of highways under such a special environmental condition, the optimization of safety facilities and technological researches accordingly towards highways in high altitude areas are necessary.

There are three major factors involved in traffic safety system—human, vehicle and environment. About 94%~95% of traffic accidents are caused by human mistakes, among which about 81% is conducted by drivers’ personal faults (Zhang Enliang, Xiao Guiping, Nie Lei, 2006). The driver's behavior is the result of the comprehensive effect of human, vehicle and environmental factors. 26% of the drivers committing traffic accidents are raised by the mixed factors of human and environment (Zhao Zongli, 1996). Driver's traffic safety cognition process can be divided into 5 stages: feeling, understanding, decision-making, starting response,
and action (XIAO Run-mou, ZHAO Jin-long, CHEN Yin-san, et al., 2006). The driver at each stage is all affected by traffic environment (Xiao Runmou, Yun Wei, Xu Bing Tian, 2007). This influence is more distinct when he or she drives on expressways in high altitude areas with complicated environment.

Drivers are affected by various factors in high altitude environment. Anchored on the practical measured speed data of typical sections on Qinghai Tibet highway at different altitudes, Wang Shuangjie analyzed the running speed and its changes when drives in the Qinghai Tibet highway. The result showed that the vehicles in the flat straight sections could reach the desired speed when there is no roadside interference, while in the small radius curve section the running speed changed dramatically. The altitude of 4km is the critical point; in addition, the influence of longitudinal slope at this point on the vehicles’ uphill running speed is significantly greater than it in the low altitude area (WANG Shuangjie, FANG Jing, HAN Yan, 2010). Song Changping and his colleges at Qinghai Hospital of Prevention and Treatment for Occupational Disease have conducted neurobehavioral functional tests towards drivers under the circumstance of low carbon monoxide environment with altitudes at 2800m, 3650m, and 4600m. The results indicate that the neurobehavioral functions of the drivers varied significantly as the altitude increasing, while their attentions, sensitivity and accuracy decreased dramatically, and the reaction time was prolonged [SONG Chang ping, ZHANG Shijie, LI Jianguo, et al., 1993]. The research on the influence of road landscape on drivers began in 1930s. The American scholar Berlyne D E believes that although changing the complexity of visual stimuli can rouse driver’s attention, continuous complex visual stimuli could upset people even make them lose interests [Berlyne D E., 1973]. Li Xianghong of Inner Mongolia University believes that the landscape along the grassland highway can bring the driver the monotonous feeling and mental fatigue, so that unresponsiveness, distraction, the increasing of estimation errors of speed and distance, the psychological fatigue, and the decreasing of the ability to perceive and process information are generated, which seriously affects the driving safety (Li Xianghong, Zhu Shoulin, Qi Chunhua, 2010). When driving in high altitude area, due to the sudden change of running speed, especially the large speed drop, the driver will be caught unprepared and mishandled, leading to traffic accidents, and the discontinuity of the speed is generally due to the sudden change of road alignment (Wang, Zhang, Zhang Jianghong, 2009). According to statistics, when the current road speed difference is less than or equal to 10km/h, the probability of accident is 0.46 times / million vehicles kilometers; When it is less than or equal to 20km/h, and quick than 10km/h, the probability of accident will be expanded by 3.5 times, reaching 1.44 times / million vehicles kilometers; When the speed difference is greater than 20km/h, the probability of the accident will reach 2.76 times / million vehicles kilometers. This shows that the speed difference and road traffic accident have an important internal relationship (Han Zhongneng, Zhu Lu, Wang Wei, 2011; Gao Gang, 2011). Xiao Runmou and others rely on the G213 line Langmusi Chuanzhusi highway reconstruction project to carry out research on automobile driving safety. He put forward the main reason for the plateau long and
flat straight section to the traffic accidents (XIAO Runmou, YUN Weiguo, XU Tianbing, 2007). In the study of the influence of road lateral interference on drivers, American scholars Majid Khalilikhah and Kevin Heaslip put forward a preventive measure for traffic accidents caused by collisions between vehicles and animals on Expressways (Majid Khalilikhah, Kevin Heaslip, 2017).

The above are the studies of traffic safety problems in a certain environment at present, which indicate that the research on the safety technology system of high altitude highway is still relatively insufficient. To provide technical support for traffic safety of high altitude highway, this paper, aiming at traffic accidents caused by the combination of the regional natural environment, special land characteristics (large, long road tunnels, etc.), and the unique weather conditions, taking Gongyu expressway as an example, analyzed the traffic safety characteristics in high altitude areas from 6 aspects, such as drivers’ physiological conditions, road alignment, climatic conditions, landscape features along the route, geological conditions and road lateral interference, and it also conducted a thorough research towards the main factors affecting the operational safety technology of the highway in high altitude areas. It provides experience and reference for traffic safety guarantee of high altitude highway in the future.

2. DATA SOURCE
2.1 Selection of research area

In order to carry on the thorough research to the highway traffic safety in the high altitude area, the research group has carried on a field survey in August 8, 2017. We chose to carry out research in Qinghai Province, because the average altitude of Qinghai province is more than 3000 meters, where the highest point is 6860m, and the lowest elevation is 1650m. The province is within the plateau range; it is famous for its complex topography and diverse landforms.

This study chooses Qinghai County of Hainan Tibetan Autonomous Prefecture to Yushu County of Yushu Tibetan Autonomous Prefecture (Gongyu Expressway). The expressway Gongyu was opened to traffic in August 1, 2017. It is the first “lifeline” highway crossing the Qinghai Tibet Plateau permafrost region and leading to the Yushu region. It is important sections of the main framework, three vertical and four horizontal, ten line (referred to as the "3410 road"), of the highway network of the Qinghai province. The highway passes through Elashan, Maduo County in the Yellow River along the town, Sanjiangyuan nature reserve, and Bayanhar. It connected with the town to Batang Airport highway. Full length of this highway is 630.316km, with the starting point as 2917 meters above sea level. The highest elevation is 4807 meters, and the end 3685 meters. The average altitude is more than 4100 meters, and the oxygen content is only half of the plain area. (see Figure 1)The location map of Gongyu Expressway
2.2 Experimental instrument

Due to the survey along the jade high-speed road, the instruments used in this experiment are the traveling crane recorder and the Garmin global positioning navigator (GPS). We surveyed the geological conditions, the influence of transverse interference on drivers, road alignment characteristics, landscape features along the route, the influence of high altitude on driver's reaction ability of the GYE by means of the traffic line method (Alexander & Water, 2000). Record the location of geological conditions, road alignment characteristics, landscape features along the route and take photos, GPS positioning.

3. CHARACTERISTICS OF TRAFFIC SAFETY OF EXPRESSWAY IN HIGH ALTITUDE AREA

Focusing on the jade highway, the paper analyzes road-operating characteristics in the cold and high elevation area from 6 aspects: the driver's physiological and climatic conditions, along the road alignment, landscape characteristics, geological conditions and road horizontal interference. Based on this, the key accident potential inducing factors such as road alignment index, long straight line and continuous downhill section are analyzed.

3.1 The influence of high altitude on driver's reaction ability

When exposed to high altitude hypoxia, driver’s intelligence, transient memory, short-term memory, digital order and operation function will be greatly affected (MA Yong, ZHANG Ro ng,1999). Drivers, especially in the plateau environment, tend to feel sluggish, headache and dyspnea. (see Figure 2) Elevation map along the Gongyu Expressway.
Related studies have shown that: with the increasing of the altitude, the oxygen content in the blood of the driver will gradually decrease, so that their reaction time is higher than the normal situation, which seriously affect the normal driving. Under such circumstance traffic accidents are easy to be triggered because of fatigue and delayed reaction time. Figure 1 is the survey data in the Xinjiang Tibet highway. The chart shows that with the increasing of altitude, the oxygen content of the driver reducing (see Figure3).

Therefore, when drivers of different physical conditions travel on the Sanjiangyuan expressway, they will have different degrees of altitude reaction, with physical fitness in an abnormal state. This factor, undoubtedly will bring about more traffic accidents.

3.2 Landscape features along the route

The monotonous highway landscape will have an impact on the driver's psychology, while plateau terrain is generally flat, with frequent long straight-line segment. Especially in the area of Heka Mountain road alignment, the road alignment is long and straight, with more than 70 kilometers, traversing the prairie (see Figure 4).
When driving on the high altitude highway surrounding with the monotonous landscape, one will find difficulty in judging the distance and speed of the car accurately because of the insufficient stimulation to the eyeballs. The driver will have the illusion of stationary, and then lose the patience in order to drive away from this environment even speeding. Sometimes the driver is eager to speed up and overtake, making mistakes in judging the distance and leading to malignant traffic accidents. Especially in the large radius curve, the driver can be careless and drive speedy. The car will deviate from the direction of the road, wash down the roadbed, and cause to accident, because of the deficiency of cant and it cannot resist the centrifugal force, which laid a greater security risks for the safe operation of the traffic. We recorded the speed of the three drivers on the highway (see Figure 5).

It can be seen that the speed of the vehicle is higher than that of 90km/h on the expressway, but the speed limit is 80km/h in the corresponding section. The driver is speeding.

3.3 Road alignment characteristics

After a long running, the driver, surrounded by the comfortable environment on the wide and straight road, and has a good line of sight, will unconsciously drive in a speed faster than that of many designed (see Figure 6). According to the investigation of the fourth survey and Design Institute of railway
to drivers running on straight sections of long flat, most drivers who drive 5~6 min in the straight road would feel fatigue and have decreased heart rate; their reaction became slower and judgment towards speed reduced as well. The long and flat section is about 70km in the He Kashan of the Yu Jiang expressway. If calculated by the designed speed, it will need at least 30min to finish the journey. When the driver is in low alert in speeding, there will inevitably be traffic accidents.

The maximum longitudinal slope and slope length limits only give priority to the uphill performance of the vehicle, but lack of safety consideration for the continuous downhill. Putting on the break frequently on continuous longitudinal slope sections is inclined to heat the brake drum and decay the brake block, which followed by the disappearance of braking efficiency and trigger accident eventually(ZHENGKe, REN Fu-tian, 2003).

3.4 The influence of transverse interference on drivers

Most of the Sanjiangyuan expressway across the pasturing area and natural reserve. Large herds of cattle and sheep will cross the road in the morning, and other times there will also have a small amount of cattle, sheep and other wild animal abruptly across the road(see Figure 7). The drivers, if drive in a normal speed as designed ~80km/h (in fact the driver is often speeding), will distracted by the transverse animals and result in a collision.
3.5 Geological conditions

The observation indicates that the permafrost section of Gongyu Expressway has a slight deformation, among which some even became wavy, due to years changing of the permafrost and its subgrade temperature, which brings about security risks.

4. SAFETY PROTECTION MEASURES

In order to avoid the traffic safety problems, the author suggests that five aspects should be taken into great consideration. There are drivers, landscape of the roads, alignments, lateral interference, and the implementation of the emergency plan.

4.1 Drivers

Drivers’ response towards delay varies in accordance with altitudes. The higher the altitude is, the longer it takes the driver to respond. According to the influence of altitude on the driver's reaction time, the general driver’s reaction time is increased by 3~3.5s. During this period, the vehicle’s stopping distance is equal to the distance between the delay distance and the stopping distance of the vehicles on the plain. Considering the traffic safety and riding comfort, the parking sight distance in high altitude can be obtained (see Table 1), thus the highway alignment designed index based on drivers in high altitude area can be established (XIAO Run-mou, ZHAO Jin-long, CHEN Yin-san, 2006).

<table>
<thead>
<tr>
<th>Design speed (km/h)</th>
<th>120</th>
<th>100</th>
<th>80</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopping sight distance (m)</td>
<td>260</td>
<td>200</td>
<td>150</td>
<td>70</td>
</tr>
</tbody>
</table>

4.2 Road landscape

In order to improve the physiological and physiological effects of the singleness landscape of Gongyu Expressway on drivers, and integrate roads with nature so that they can be surrounded with comfortable environment, the author, with great consideration with the characteristics of highways in high altitude area, believes that facilitates as follows should be employed: 1) warning signs are suggested to be set at intervals; 2) different colors and heights of separation networks should be used on both sides of the roads; 3) fluorescent signs can be taken into consideration; 4) distance signs can be set in the middle of the long straight roads; 5) increase the public signs along the line, limit the speed repeatedly, and add small radius curve warning signs to strength the protection; in addition, constantly giving new information can prevent the driver from fatigue.

4.3 Alignment

According to the highway condition investigation of the Gongyu, the author noticed hidden troubles on the flat straight sections of the road as follows: 1) the drivers will relax their vigilance and speed up unconsciously due to the great road
condition; 2) clear references are lacked and the road environment is monotonous; 3) the average altitude is above 4000 m, and the drivers have different altitude reaction; 4) the highway was built in the grazing area where cattle and sheep usually abruptly cross the road.

The above reasons lead to the traffic accidents on this road so that the traffic safety facilities should be rationally designed to improve the traffic safety.

4.3.1 Long straight line section

(1) Set up the rumble strip

According to statistics, the Rumble strip has been widely used in highway pavement in developed countries. The car accidents caused by bearing off the lane can be reduced to about 20% in such ways.

Total designed speed of Gongyu expressway is 80 km /h; however, the flat and straight road can be deceive that the actual velocity often exceeds the standard. Therefore, the installation of rumble strip on long and flat road will greatly reduce traffic accidents caused by driver's fatigue deviating from the lane.

(2) Set long straight line section notice

Set warning signs on the long straight sections, add public logos, and limit the speed repeatedly so as to strength the safety protection. Some of the warning signs and markings are suggested to be set at the starting point to fore notice the length of the line and the distance of vehicles. Warning signs should be set every 3~5 km, such as "speed limit x km /h", "grazing passage" and so on, so that drivers can have certain reference when driving.

(3) Setting thermoplastic vibration deceleration marks

This type of road deceleration belt has been applied in some western countries. Its general raised height is 5~6mm, which has the effect of reflecting light. When the vehicle passes the deceleration belt, the driver will feel different degrees of vibration. the higher the speed, the more obvious the vibration, so as to enhance the driver's sensitivity. On a long, flat and straight road section, a vibration deceleration belt is set every 5~6 km, which can effectively prompt the driver and control the speed of the vehicle actively.

4.3.2 Continuous downhill

On the continuous downhill road, the over heated brake drum temperature is likely to cause brake failure even traffic accidents. According to the characteristics of high altitude highway, some measures are put forward:

(1) Set up danger lane or emergency parking belt

The bay-type emergency parking zone should be installed upstream of the braking failure risk section. In order to reduce the risk degree of the brake failure, the dangerous lane can be set up under the condition of topography and landform matching for the key dangerous sections.

(2) Setting warning sign on continuous downhill

The form of warning sign should not be too simple, and the information of the length of longitudinal slope and the average slope should be given, so that the
warning function of continuous longitudinal slope sign can be easier to notice. Through the investigation of driving behavior on continuous downhill sections, we found it is function that adding long downhill signs at the slope section every 3~4 km, and set a long warning sign with information of the length of slope and limited speed every 10km. In 2~3 km of the gentle slope near the bottom, we’d better set the sign as “XX km left of the long downhill” to remind the driver that the vehicle is still on the way, and there is a distance to get exit to this section, suggesting the driver to be careful to control the speed.

4.4 Lateral interference of road

Barriers are suggested set both sides of Gongyu expressway to prevent the abruptly crossing cattle and sheep, for the highway is surrounded by pasture and through the Sanjiangyuan National Nature Reserve. Animal grazing channels and warning signs accordingly should be set to remind the drivers that what in front are the crossing channels and limited speed should be used based on the stopping sight distance. Anchored on the driver's visual researches (Huang Yong, Fang Jing, Zhang Yuancai, 2007), we found that: when the speed reached 80 km /h, the driver can only see the traffic signs 160 m ahead. According to the calculation of the energy equation of the vehicle running, the location of the warning sign of the grazing channel should be determined at 850 m ahead of the grazing passage.

4.5 Implementation of emergency plan

Emergency plans in high altitude areas are mainly to deal with disasters that are prone to raise serious threats to operational safety, which are in accordance with the geological and geographical conditions as well as the impact of climate. In order to prevent the adverse effects of disasters on the normal operation of the road, the following measures are suggested: 1) to strengthen the monitoring and prevention of early warning information of rainstorm and snowstorm areas; 2) to immediately investigate and verify the situation of the regions where endure rainstorm and snowstorm disaster, and timely report; to get ready to organize and rescue main material property in an appropriate time; 3) to strengthen the research and maintenance the roads of high altitude permafrost area.

5. CONCLUSION

This paper analyzes the traffic safety characteristics in high altitude area from 5 aspects: driver's physiology, road alignment, landscape features along the route, geological conditions and road lateral interference. This study is conducted from the practical investigation of Gongyu expressway, a typical example of highway in high altitude area. Anchored on that sample, the research put forward detailed technical measures for engineering prevention and safety measures in operation, which entail great practical value. Meanwhile, the study pointed out that high altitude areas should take specific measures to prevent and control traffic safety problems according to their own characteristics and local conditions. To have a better and comprehensive effect, the combination of the safety protection measures and many other management methods of highways are necessary.
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