

Roadside safety evaluation by analyzing the roadside structures of Jingjintang expressway in China

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ABSTRACT

This paper discusses a common expressway roadside safety problem in China through a typical example, Jingjintang expressway and introduces some effective roadside structure by analyzing of the typical historical accident record during 2002~2004. The severity of the expressway problem has called great concern on the road safety. A high proportion of fatal crashes occurred on roadside in expressway during the past few years in China.

Some design components included horizontal alignment, vertical alignment, superelevation, hydraulic design and sight distance to name some of the most common freeway design elements. These elements have been revised and refined over the years through experience and research. However, Roadside safety design and maintenance still don't become a discussed aspect of highway design and maintenance until now. Meanwhile, problems like volume over load, too many crash accidents exist on almost all the expressways, especially the roadside accidents account for a large scale of the total accidents. The paper presents the practical crash investigative results about the roadside accidents.

Combining with the design criteria of other countries, the paper puts forgive concept, analyzes the expressway design factors which influence the roadside safety and evaluates the current Chinese design specification on slope, barrier, drainage, shoulder and curb. The purpose of this paper is to present the concept of roadside safety to the Chinese designer in such a way that the most traffic accident, types and roadside structure can be accomplished for each project.

Key Words: Traffic accident; Expressway Roadside; Roadside safety

BACKGROUND

The expressway has expanded quantitatively in China since the first freeway was constructed in 1988, and the mileage has reached more than 40,000 km by the end of year 2005, ranking the 2nd place in the world. Just in 2005, there were 6407 people died of traffic crashes, 6.5% proportion of these fatalities occurred in expressway. A high proportion of these fatalities occurred on roadside. Roadside safety has been paid attention by our research group.

Most of the highway design components were established in the late 1980s. These components included horizontal alignment, vertical alignment, superelevation, hydraulic design and sight distance to name some of the most common freeway design elements. These elements have been revised and refined over the years through experience and research. Roadside safety design and maintenance still don't become a discussed aspects of

highway design and maintenance until now, and it has been 18 years long for this type of roadside design was regularly incorporated into freeway projects except freeway shoulder from 2.00m to 2.50m in 2004, technical standard of highway engineering, JTG BOT-2003, was revised. But the traffic accident rates have increased continuously in recent years, especially the roadside accidents.

Facing to a worsening situation, unsafe factors have been exposed after a detailed analysis of Jingjintang expressway accidents statistics from 2002~2004 combined with roadside structures. Evaluation and improvements roadside is very necessary in china.

The Jingjintang expressway is located in North China, collecting Beijing, Tianjin municipalities and Hebei province. The AADT was only 6025 pcu/day when Jingjintang was opened to traffic in 1993 but the AADT has reached 26580 pcu/day in 2004, almost 4.5 times as much as in 1993. Jingjintang expressway has improved the highway network structure, enhanced the economic links and the investment environment, which attached great importance to the economic development, travel development, reform and opening. Jingjintang expressway is a typical 4-lane freeway and one of the busiest freeways in China.

ROADSIDE SAFETY STATUS OF JINGJINTANG EXPRESSWAY

The total number of accidents of Jingjintang Expressway is 2829 from 2002~2004, of which the number of property damage only(PDO) accidents, injury and fatal accidents are 1250, 1435 and 144, accounting for 44.2%, 50.7% and 5.1% of the total respectively. In these three years, the number of recorded people-injured accidents is 353, caused 779 people injured. All the crashes have caused 779 persons injured and 190 persons die. The number of fatalities and injuries in different segments is shown in Table1 and the number of crashes along the mileage is shown in Figure1.

TABLE 1 Fatal and Injury Accidents in Different Sections

Segments	Total Number	Mileage	Crashes/km	Fatal cashes	Fatalities/km
Beijing	1985	35	38.60	66	1.89
HeBei	96	7	13.71	5	0.71
Tianjin	748	100	7.48	119	1.19

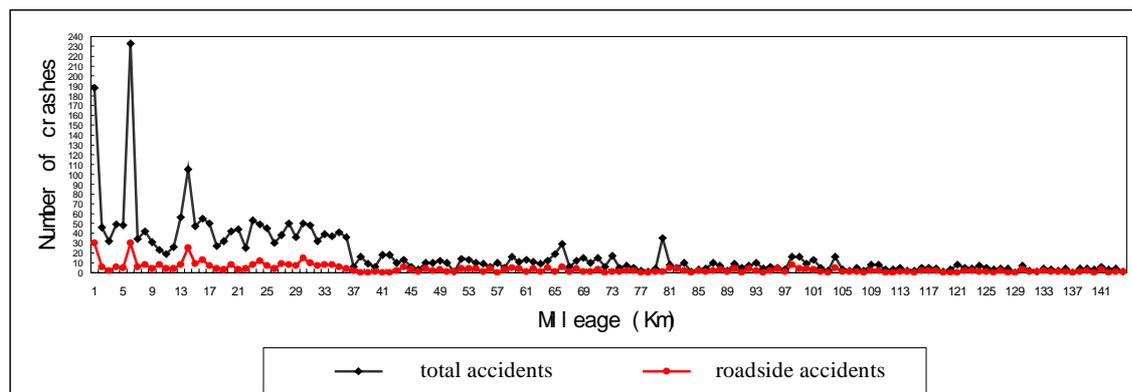


FIGURE 1 Total Accidents and Roadside Accidents Along the Freeway

The accident types distribution is shown in Figure 2, it can be seen that the most frequently occurred accident type are rear-end collision(1359, 53.55%), followed by roadside accidents(702, 24.8%) and side-swipe collision (348, 13.71%).

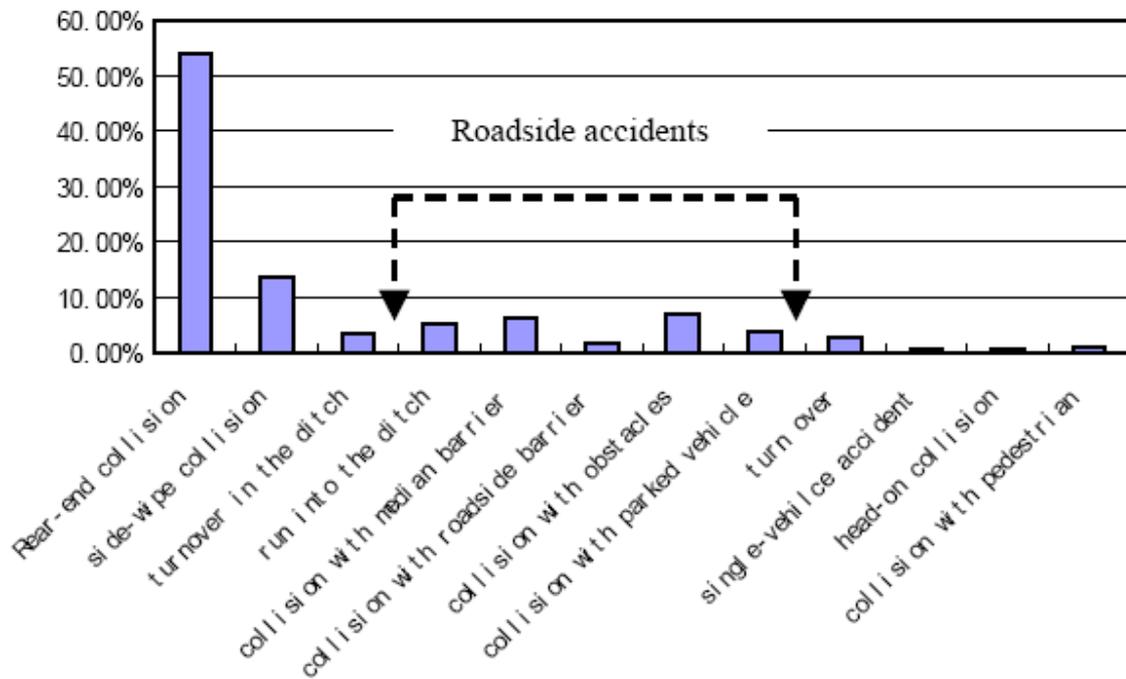


FIGURE 2 Accident Types

SEVERITY OF ROADSIDE ACCIDENTS

Roadside accidents include drainage ditch accidents, collision with roadside barriers, collision with fixed objects etc. It is shown in Figure 1 that the trend of roadside accidents is almost the same as the whole accidents. Of all the roadside accidents, there are 237 injury accidents and 30 fatal accidents result in 240 persons injured and 56 persons die, and the direct economic losses have reached 4780 thousand RMB involving roadside accidents, accounting for 24% of the total losses. The PDO includes accidents of roadside barriers, curb, signs, emergency telephone and drainage ditch. As to the severity of the roadside safety, we have to think over what is the reason for this, is there any problems with the roadside structure?

ROADSIDE STRUCTURE AND SAFETY ANALYSIS

The design speed of Jingjintang expressway is 120km/h, 2 lanes for each direction, with 2.5m hard shoulder, the typical cross section is shown in Fig.3. The roadside structure can be catalogued as roadside safety clear zone, embankment side slope, roadside barriers, hard shoulder, curb and drainage ditch.

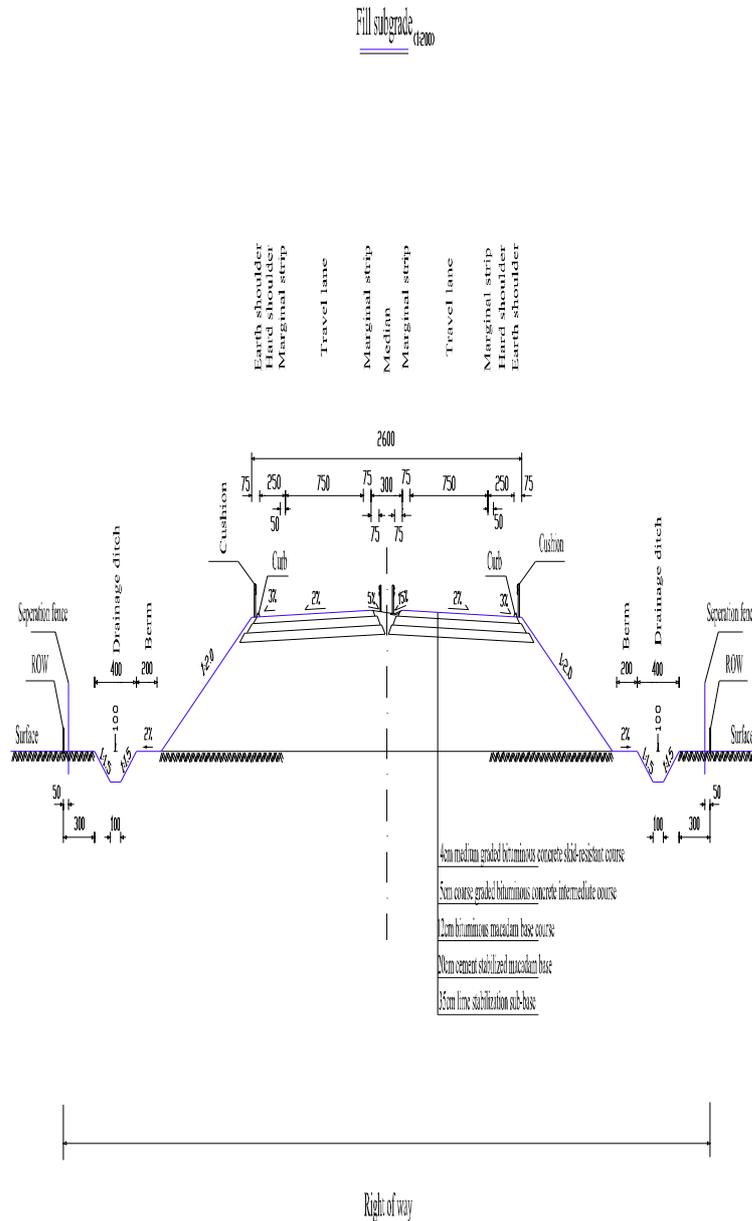


FIGURE 3 Typical Cross Section of Jingjintang Expressway

Roadside Safety Clear Zone

At present, the most efficient index to measure the roadside safety is clear zone. The definition of clear zone is a traversable, recoverable area that starts at the edge of the traffic lane, includes the shoulder, and extends laterally before encountering a hazard. Roadside clear zone is the most important design idea of "forgiving road". It may be fatal for the lose control vehicle if there is any hazard unprotected by the barriers in the clear zone.

In consideration of rapid increase of roadside accidents on expressways in China, "Guidelines for Safety Audit of Highway" (JTG B05-2004) (Guidelines) was launched in 2004 by Ministry of Communications in 2004. The concept of roadside safety clear zone is also transferred here. But the guidelines is not an imperative specifications of road design, and China has built more than 30,000 km expressway before this guidelines was issued, so this guidelines is used only as a reference book for design and safety audit.

The running speed of light vehicle is between 90km/h and 100km/h, the volume in Beijing section is 51519pcu/day, Hebei section is 47955 pcu/day and Tianjin section is 29454 pcu/day, and the average radius is greater than 1100 meters. According to the evaluation methods in this Guidelines (See Figure 4 and Figure 5), the width of clear zone is at least 9 meters, this is the same result as the research conducted by General Motors in the 1950s: 80% of the accidents occurs within 30 feet of roadside. So, roadside clear zone is very important to the traffic safety, shown in Figure 6.

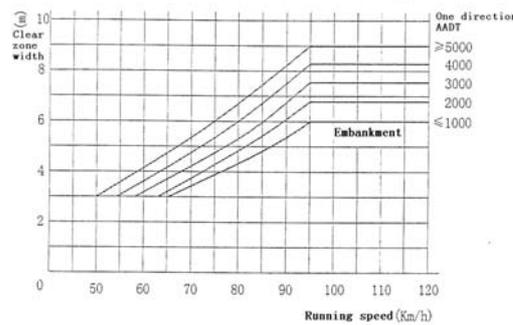


FIGURE4 Clear Zone Basic Width

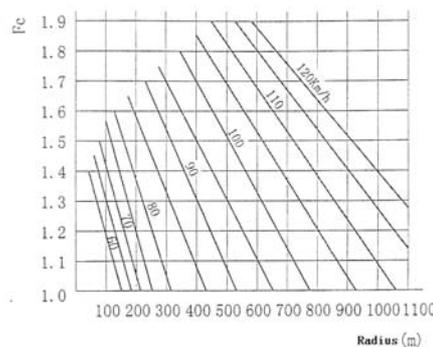


FIGURE5 Clear Zone Width Modification on Straight Section Coefficient on Curve

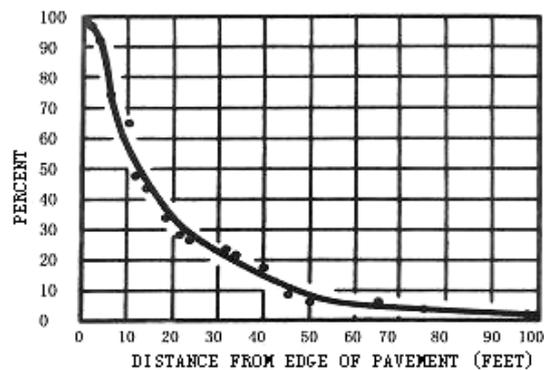


FIGURE 6 Effect of Clear Zone to Safety (Research by GM)

The slope grade of Jingjintang expressway is 1:2, and it is considered as dangerous slope in the Guidelines, so the slope is not the part of safety clear zone, in fact, the clear zone is only 3.25 meters (harden shoulder 2.5m plus earth shoulder 0.75m) of clear zone in Jingjintang expressway, far from the safe requirement. Therefore, barriers are needed installation along the freeway. However, not only barriers are not set along the embankment, there are many unsafe structures in the clear zone such as signs, curbs, shown in Figure 7. Furthermore, neither barriers nor breakaway structure is absent, which may cause damage to the lose control vehicle again.



FIGURE 7 Unsafe Structures Along the Roadside

Embankment Slope

Embankment slope is an important part of clear zone, and comprising a large proportion of it. So the clear zone, to great extent, is dependent on the slope design. And the 1:2 slope meets the "Specifications for design of highway subgrades" JTG D30-2004 on the good geologic condition, the slope height should be no more than 20 meters, the foreslope should not steeper than 1:1.5, and the other part should not be steeper than 1:1.75.

Gradual slope is good for traffic safety, the more gradual slope is, the easier it is for maintenance and the easier it is to meet the safety requirement. In "ROADSIDE DESIGN GUIDE 2002 (RDG 2002)" the side slope is classified to 3 kinds: Recoverable, traversable and critical. The recoverable is the one whose grade is 1:4 or more flatter, the grade of traversable is between 1:4~1:3, and if the slope is steeper than 1:3, most of the vehicles cannot park or run back to the lane, i.e. the critical is not traversable, and it may cause the vehicle to turn over.

Compared with the RDG 2002, Guidelines in China has the similar items: steeper than 1:3.5 is critical, 1:3.5~1:5.5 for traversable and flatter than 1:6, it is recoverable and can be used as clear zone. Therefore, the side slope of Jingjintang expressway is critical either in US or China. The main roadside index of US and China are compared in details in Table 2.

TABLE 2 Main Roadside Index of US and China

Compare	Recoverable	Traversable (Non-recoverable)	Critical (Non traversable)
Guidelines for Safety Audit of Highway (China)	<1 6	1 3.5~1 6	>1 3.5
RDG 2002 (US)	<1 4	1 3~1 4	>1 3
Jingjintang expressway			1 2

Due to the limitation of the earth, gradual slope cannot be easily realized in China except in western plain areas. So, more attention should be paid to safety of the lose control vehicle.

Barriers

Of accidents involving collision with barriers, the number of collision with median barriers is more frequent than collision roadside barriers, but the latter is more severe. The number of median barrier accidents is 161, accounting for 6.34% of the total roadside accidents, averagely 0.16 people died per accident; While only 55 roadside barrier accidents occurred, but 0.22 people died per accident. Roadside accidents mainly occur near the entrances, exits and toll gates, this is most likely because of lapse or following too close to the lead vehicle. The time distribution is also in agreement with that of the rear-end collision, and mainly occurred at the peak hour in the morning.

The main reason for the severity of barrier accidents is related with the placement of the barriers, the following is the barriers placement

- A. The sections where the embankment is higher than 4 meters
- B. Bridge approaches:
 - a. long span bridge: 32m each side
 - b. middle span bridge: 32m each side
 - c. short span bridge: 32m each side
- C. Passage: 20m each side
- D. Portal framed sign supports, 8m on each side
- E. service area: 80m each side
- F. Emergency telephone
- G. There is always breaks in the barriers average every 100 meters along Jingjintang expressway, and the one which protects the emergency telephone is much more shorter, are shown in Figure 8 and Figure 9.



FIGURE 8 Barriers Protecting Telephone



FIGURE 9 Short Barriers of Jingjintang

H. There is no flare design at the terminal of the barriers, nor is any end treatment, which is evident from Figure 10.



FIGURE 10 Terminal of the Barriers

The basic functions of barriers are to protect a vehicle from leaving the traveled way, redirect the impacting vehicle and absorb energy. When there are obstacles which cannot be removed, or breakaway design cannot be applied, barriers are needed. The barriers can protect the vehicles from the traveled way and collision with the obstacles on either side. When the vehicles hit the barriers, the barriers should endure the impact force. Meanwhile the barriers should guide the vehicle to run back to the traveled way. But attention: the barriers is also a kinds of hazards, barriers must be less than a hazard. So the basic principle of barriers is it can reduce the severity of collision.

According to "Specification for design and construction of expressway safety appurtenances" JTJ074-94 barriers are essential at high embankment, portal framed signs, emergency telephone and pier. The minimum length should be at least 70meters, but no specifications were found on terminal treatment. Research of RDG 2002 has indicated that the length of barriers is decided mainly by the distance between the hazard and the pavement edge, the runout length (depending on the design speed and volume), angle of departure and place as far as possible. If the pavement is flat, the vehicle will run along the tangent direction when the vehicle runs off road. So the length of need can be determined by the line which is tangent with the edge of the travel lane and the obstacle, are shown in Figure 11 and Figure 12. Furthermore, if there is less than 200 feet between successive runs of barrier and no obvious reason for the break, the barrier is made continuous. The function of a terminal is to develop tension and safely accept an impact. If hit, minimize the damage to the vehicle and its occupants. Untreated barrier terminal is like a spear, it will be fatal to the drivers when the vehicle is running at high speed, so it is always more dangerous than the hazards. Therefore, more attention should be paid to improve the barrier design to ensure safety.

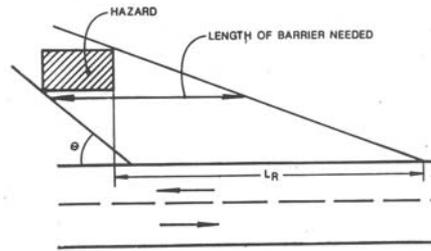


FIGURE 11 Decision of Length of Barriers

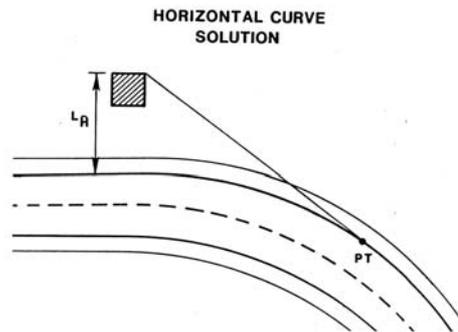


FIGURE 12 Length of Barriers at Curve

Drainage Facilities

Among the 541 roadside accidents along the expressway, 129 were related with drainage ditches, accounting for 24% of the total roadside accidents, 15 people injured and economic losses have reached 1035 thousand RMB. Among the accidents, 102 vehicles ran into and turned over in the drainage ditch, others accidents were the secondary accidents which ran off or turned over in the drainage ditch after rear-end collision or collision with barriers or parked vehicle. The description of such accidents is inexplicit in the archives, some is "run into the ditch", while others is "overturned in the drainage ditch", but in fact, they are all significantly correlated with ditch, so they are classified into the same category: drainage ditch accident.

The V-type drainage ditches whose slope grade between 1:2~1:1 are adopted on this expressway, almost all such police-reported accidents have the same result: the run out vehicles cannot traverse the ditch and have to stop at the bottom, some of them turned over and caused injuries.

Drainage ditches collect and disperse the water from the roadway pavement and the run off from the uphill side of the carriageway. These are designed to accommodate the expected rainfall, but can often be hazardous to vehicles that run off the road. Adequate attention must be given to the safety consideration in the future. To reduce right of way (ROW) V-type or U-type drainage ditches are commonly used in China, and constructed by stone. It has the advantage of aesthetic and easy to clean, but it may lock the wheel when the vehicles run into, result in increasing danger to vehicles which accidentally run off the road. The detailed structure is shown in Figure 15. Traversable ditch design is recommended in RDG 2002. V type ditch is suitable to round ditch bottom width less than 2.4 meters and trapezoidal ditch bottom width less than 1.2 meters, shown in Figure 13, if not, Figure 14 is more suitable.

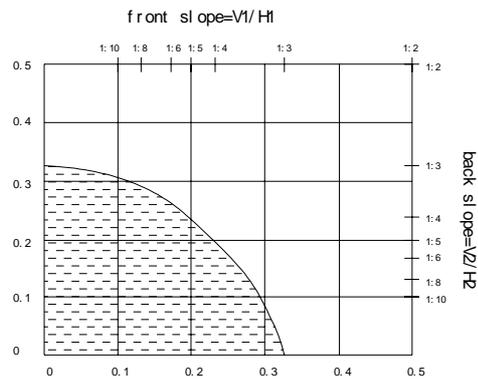


FIGURE 13 V Type Side Slope

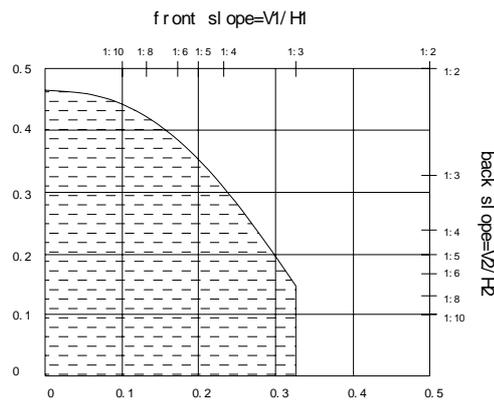


FIGURE 14 Round or Trapezoidal Side Slope



FIGURE 15 Drainage Ditch of Jingjintang

The frequency of ditch accident is rather high, and always brought fatal accidents. The main reason that the vehicles run into ditch is driving errors. According to the accidents archives, some vehicle cannot be aware of the parking vehicle on the shoulder and hit it into the ditch, some accidents are caused by aggressively merge, when the following car tried to avoid rear-end collision or side-wipe collision and run out into the ditch, others fell into the ditch after a collision with barriers.

So, in order to avoid such accidents, measures should be taken by combining the slope grade, type of drainage ditch and roadside barriers, trigonal type or plate type ditch is recommended when possible.

Signs

Some fatal accidents have occurred when vehicles hit the sign posts, passengers and drivers died but the signs did not be destroyed. What is the reason? Let us look at the design of sign posts. Post signs are placed at the roadside, only 25 cm away from the pavement edge. Since the sign supports have to endure the sign's weight and the shear force when windy. Steel pipes are commonly adopted on China's expressway, and the thickness and diameter will correspondingly increase with the area of the sign, The maximum steel pipe's thickness on Jingjintang expressway is 14mm, and the diameter is 325mm for single cantilever sign, The more stiffer the support is, the more dangerous it is to the roadside safety, shown in Figure 16. But there is not any protecting device along the roadside, thus in recent 3 years, the accidents involving sign collision have reached 52, including 38 injuries and the direct economics losses is 332 thousand RMB. Research in developed countries have indicated that breakaway design can efficiently reduce these kinds of collision accidents.



FIGURE16 Roadside Signs on Jingjintang



FIGURE17 Breakaway Foundation Stub

Curbs

Curbs are placed on Jingjintang expressway to collect rain. The basic type is: 49.5cm×15cm×30(25)cm, length×width×height it called semi-mountable curb.

In RDG 2002, curbs are not recommended on the freeway of design speed is greater than 80km/h, If must, the height should be limited within 4 inches(about 10.16cm). The compare of curb size used in US and China is shown in Figure 18.

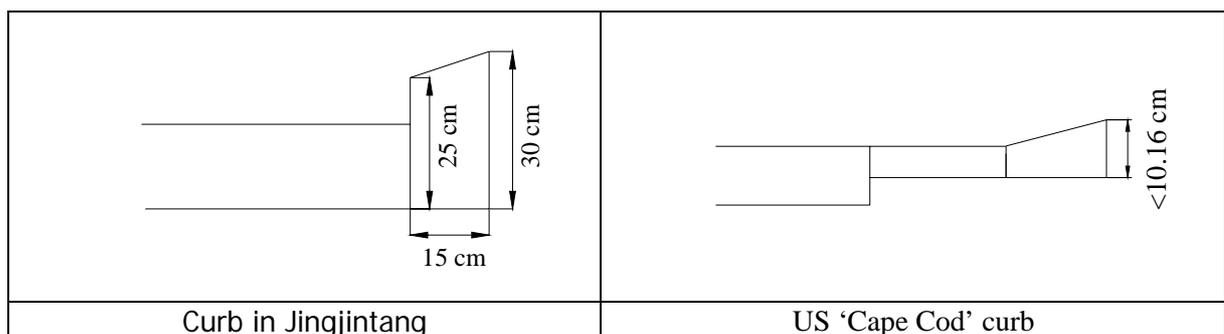


FIGURE18 Curb Size Used in US and China

When running at high speed on the expressway, if the vehicle run off the travel lane and towards the higher curbs, which will increase the possibility of turning over and severity. So, in order to keep off such kind of accident, curbs should be removed; When needed, lower curbs is more reasonable(no higher than 12cm over the ground)

Width of Shoulder

There are 97 accidents of collision with the parking vehicles on the shoulder, accounting for 3.4 % of the total, 25 persons died and the direct economic losses has reached 1710 thousand RMB. Most of these accidents occurred between K40~K70 section. No service area was set in this long section, so if the vehicle has any mechanical failure, it have to be parked on the shoulder, this increases the probability of collision with the parking vehicles. In general, the parking vehicles are mostly trunks, since such trunks are in big size, so the travel lane is partly occupied by them. Furthermore, the warning signs behind the parking trunks are not significant or the drivers do not place any signs, it is unavoidable when the following vehicles are running at high speed especially the sight is poor at night or in the early morning, unclear day.

Narrow shoulder is strongly related with these accidents, the width of Jingjintang expressway is only 2.5 meters which meet the specifications highway design in China in 1988(first edition). However, this standard is rather low and proved to be unreasonable. In 1997, new edition of at least 3 meters wide shoulder was issued to replace the old one, but the freeways built between 1988 and 1997 are all in 2.5 meter-wide shoulder. It is really not enough for the trunks.

Research has indicated that accidents are significantly correlated with the shoulder less than 3-meter-wide, it is proved to be helpful to emergency medical service, emergency parking and rescue. Therefore, the shoulder should be broadened.

SUMMARY

Much unsafe troubles are discovered in the roadside of China's expressways by analyzing a typical four ways expressway, the Jingjintang expressway, roadside structures:

Inadequate clear zone will increase the severity of accidents, but due to the limitation of the boundary mark, enough clear zone cannot be reached in China except in western plain areas.

The embankment in China is rather steeper slope and cannot be used as clear zone, and may cause damage to the lose control vehicle again.

The V-type drainage ditch may lock the wheel when ran off vehicle trapped.

Meanwhile, the sign poles exiting in clear zone do not adopt any breakaway design or barrier protecting, so barriers should be placed all along this freeway. However, the every 100 meter-breaks in barriers result in insufficiency tension, lack of end treatment will increase the severity when hitting the end. But lots of money is needed to reconstruct roadside, so it is difficult to solve this problem in a short period.

Narrow shoulder and high curbs will also increase the severity of the accidents.

CONCLUSION

This paper discusses a common expressway roadside safety problem in China through a case study of Jingjintang expressway and introduces some effective roadside structures by analyzing of the typical historical accident record during 2002~2004. As China moves quickly forward to motorization, so do the expressway roadside fatalities. Improving roadside safety has become a top priority on the government and expressway agencies and agenda. To propose an effective countermeasure, it is important to know why and how crash happened. The problem proposed in this paper presents an initial step in combating freeway roadside safety problem. The research team at the Beijing University of Technology is currently undertaking two projects by trails to further find out which kind of roadside structure is suitable for Chinese drivers.

More attention should be paid to the field of traffic safety on expressway, and more considerations involving safety should be added to the freeway roadside design and construction, thus, reasonable strategy can be established to enhance the roadside safety.

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