International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 08 Aug. 2024, pp: 627-634 www.ijaem.net ISSN: 2395-5252

Research on speed limit standard of highway continuous bridge construction section based on vissim

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Date of Submission: 25-09-2024 Date of Acceptance: 05-09-2024

ABSTRACT: In order to ensure that the vehicles at the highway bridge construction section can pass through safely and efficiently, and to avoid the occurrence of traffic accidents at this section, this paper analyzes the process of the driver's driving behavior through the bridge construction section, and sets the relevant parameters of the driver in the driving process. If once the collision of vehicles occurs at the highway bridge construction, it will be very likely to cause damage to the pillars of the bridge, thus triggering the collapse of the bridge. Therefore, this paper is based on Vissim simulation software, to establish a highway bridge construction section and the entrance and exit of the traffic simulation model, and observe in different traffic flow and speed conditions, the operation of the vehicle state, so as to analyze the speed limit of the highway bridge construction section. On the basis of meeting the peak hour traffic flow of the road section, and determining the reasonable range of the speed of the road section under the condition of optimal traffic flow, the traffic flow of the road section is simulated by the traffic simulation model, which provides a basis for the design decision of the speed limit of the highway bridge construction road section.

KEYWORDS: Vissim Simulation; Highway; Bridge Construction; Speed Limit Standard

I. INTRODUCTION

With the ongoing development and improvement of our transport infrastructure, we have made great progress in terms of the mileage of motorways, which is now the highest in the world. Although the transport industry has been in the midst of booming development, certain sections of highways involve operational construction. In recent years, the safety of bridge construction on motorways has been a major concern, with frequent traffic accidents due to the high traffic flow and speed of the construction section, as well as the complexity and variability of the road conditions. In order to ensure that the bridge construction section can be safe and smooth through, it is necessary to carry out reasonable speed limit on the road. During the bridge construction period, drivers need to take the appropriate speed according to their own vehicle conditions through the construction section. Generally speaking, in the bridge construction section of the speed to be far lower than the normal driving speed, which thus formed a bottleneck section of the highway, to a greater extent, affecting the road capacity, resulting in traffic jams, and even cause major traffic accidents. In addition, it may also cause the collapse of the bridge, the construction section of the engineering work caused significant losses. Therefore, the study of speed control measures on the construction section of highway bridges is very critical to reduce the risk of traffic accidents, which has become a hot issue in current research. This paper uses Vissim simulation software to analyse the speed limit on the construction section of highway bridges, aiming to provide reference and basis for the actual engineering decision-making.

II. CURRENT STATUS OF RESEARCH AT HOME AND ABROAD

In contrast, the accident rate of the basic section of the general highway is lower than that of the bridge construction section, because the driving conditions of the section are more complex, and when the vehicle enters under the bridge and then crosses the bridge, the road vision will be dark, which is not conducive to the driver to judge the distance between the vehicle in front of him, if the driver makes a mistake in judgement and crashes into the bridge's columns and beams, it will produce a chain reaction and the entire project, which will cause losses of Bigger. According to the relevant data survey results show that speeding is the main factor triggering traffic accidents on the bridge construction section, and the entrances and exits of the bridge caverns are the black spots of traffic accidents. Some

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western developed countries on the vehicle speed limit research started earlier than our country, in general, countries use the road design of the maximum speed is 85% bit speed, 15% for limit low speed. At present, China's highway speed limit requirements are in accordance with the 'Road Traffic Safety Law Enforcement Regulations' to determine the regulations, the regulations provide that the maximum speed of the highway does not exceed 120 km per hour, the minimum speed is not less than 60 km per hour. There are also different regulations for the speed of each lane in a motorway. For example, the speed of the inner lane of a one-way two-lane carriageway should not be less than 100 km/h, the speed of the leftmost lane of a one-way three-lane carriageway should not be less than 110 km/h, and the speed of the middle lane should not be less than 90 km/h. If there are special regulations, the speed should be driven in accordance with the prescribed speed. The speed limit for motorways varies from country to country, for example, 88 km/h in the USA, 110 km/h in Russia and 100 km/h in Germany.

Through the relevant literature review, it can be found that at present the domestic for highway construction section speed limit research is less, for the construction section of the running speed of the lack of specific safety countermeasures theory, need to be combined with the construction section of the specific circumstances of the construction section of the highway bridge construction section of the speed limit theoretical research. Foreign research in this area earlier, has gradually accumulated a wealth of experience and research results, it is worthwhile for us to learn and reference.

III. ANALYSIS OF TRAFFIC CHARACTERISTICS AND DRIVING PROCESSES IN BRIDGE CONSTRUCTION SECTIONS

2.1 . TRAFFIC CHARACTERISATION OF ROAD SECTIONS

In the investigation and analysis of the traffic characteristics of this road section, the traffic characteristics of passenger and goods vehicles were analysed separately. According to the data survey, the speed distribution of different models in each section of the construction roadway was obtained. Taking the construction section of a high-speed bridge in Zhaohua District as an example, the speed distribution of each operation area of the construction section was statistically obtained, as shown in Figures 1 to 3. From the figure, it can be seen that the speed distribution of each zone section of the construction operation area of the two-way six-lane highway is in line with the normal distribution.

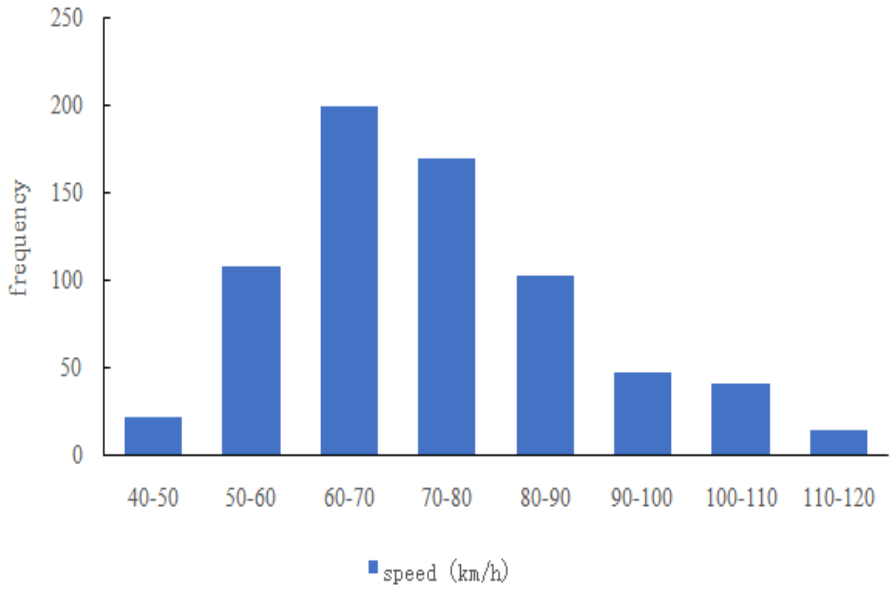

Fig 1Frequency distribution of vehicle speed in the upstream warning area

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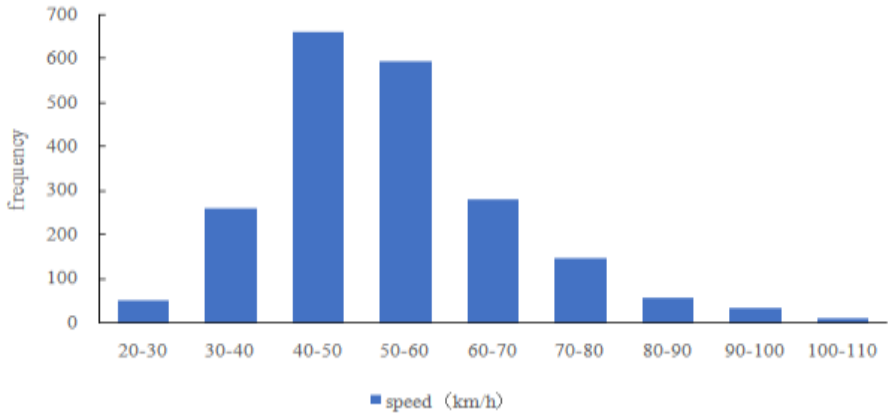

Fig 2 Frequency distribution of vehicle speed in the upstream transition zone

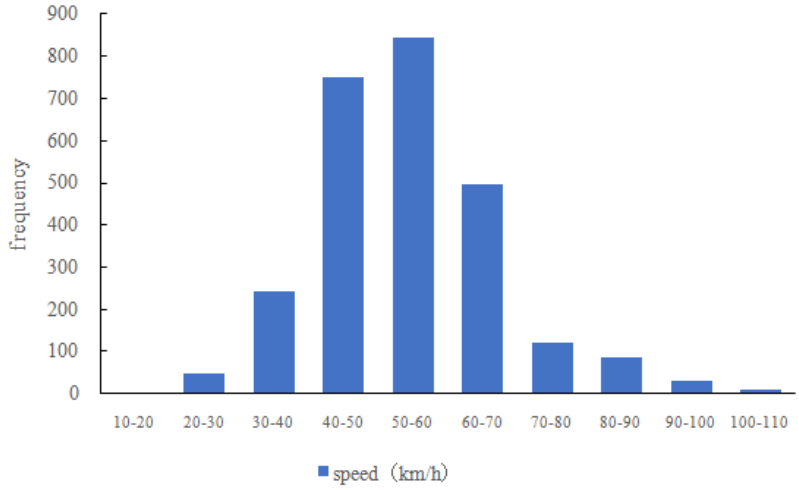

Fig 3Frequency distribution of vehicle speed in the construction work area

For the characteristics of vehicle operation in construction work zones, based on the principle of statistical distribution to determine the range of speed limits in construction w-ork zones, according to the following two formulas to determine the high speed limit val-ue and low speed limit value. The high speed limit value can be used in low-flow constr-uction work zones or low-density periods.

$$v_i^{high} = E_i + 0.5\sigma_i$$
$$v_i^{lower} = E_i - 0.5\sigma_i$$

Where: v_i^{high} ——the high speed limit value (km/h) of the speed limit of section i

v_i^{lower} ——Low speed limit value for zone i speed limit（km/h）

E_i——the average velocity of section i (km/h).

σ_i——Standard deviation (km/h) of the velocity distribution of section i

The determination of the speed limit value after considering the mixing of medium and large goods vehicles can be calculated by the following formula.

$$v_i = （1 - p）v_i^{small} + v_i^{large}$$

Where: v_i- section i considers the speed limit value (km/h) after the mixing of large and medium-sized trucks

v_i^{small} ——Speed limit values for small vehicles in zone i（km/h）

v_i^{large} ——The speed limit of large and medium-sized trucks in section I (km/h).

p—— Mixing rate of large vehicles (%).

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Table1 Calculated value for the speed of different vehicle models in each section

Segment type	Speed limit for small ca-rs(km/h) Lower Limit Upperlimit	Speed limits for large andm-edium goods vehicles (km/h)		Speed limits for large and medium goods vehicles (km/h)	
		Lower Limit	Upper limit	Lower Limit	Upper limit
Warning area	73 89	60	70	69	78
Transition Zone	51 66	44	52	50	60
Construction work area	52 71	45	56	50	60

2.2 .ANALYSIS OF THE MAIN DRIVING PROCESSES

Drivers crossing a motorway bridge construction section will experience sign recognition, acknowledgement, comprehension and response to take operational actions, and will also experience dark adaptation and light adaptation due to the darkening of vision as the vehicle crosses underneath the bridge horizontally.

2.2.1 . SETTING OF SIGHT DISTANCE FOR TRAFFIC SIGNS

According to the research, in the bridge construction section of the speed limit sign of the front distance of the setting and the road line and speed has a close relationship. The higher the speed, the narrower the driver's field of vision, the gaze time of the road ahead will become shorter, thus affecting the accuracy of the driver's judgement of the road conditions, so the construction section of the front distance of the sign should be increased appropriately. According to the national standard 'Highway Traffic Signs and Markings Setting Specification' in the setup of the visual recognition distance of the indication signs, as shown in Table 2.

Table2 The correspondence between the driver's field of view and the driving speed

Driving speed (km/h)	Distance from the front of the vehicle from the fixation point (m)	Field of view (°)
40	183	90-100
72	366	60-80
105	610	40

2.2.2 .LIGHT AND DARK ADAPTATION TIME AT THE ENTRANCE UNDER THE BRIDGE

When the vehicle crosses the road section below the bridge construction site, the driver will feel that the vision is darkened, and the driver's adaptation time is about 6 seconds, which is easy to cause the vehicle to drift due to improper operation, which may lead to a cut with other vehicles. On the contrary, when the vehicle is about to cross the road under the bridge, the driver's vision will gradually return to normal, and the driver's adaptation time is about 3 seconds. The process of vision going from light to dark is called dark adaptation; conversely, it is light adaptation. During this process, the vehicle must slow down appropriately, if the driver speeds, it is very likely that because of the dimming of the light leads to errors in judgement, thus crashing into the bridge below the columns and beams, ultimately resulting in major traffic accidents and huge losses in the engineering work.

IV. ESTABLISH A TRAFFIC SIMULATION MODEL

2.3 . INTRODUCTION TO SIMULATION SOFTWARE

Vissim simulation software is a traffic simulation software developed by the German company PTV, which is mainly used for simulation modelling of urban roads, highways of all levels, road intersections, stations, pedestrians and vehicles, etc., and provides a basis for decision-making on the design of actual roads through the implementation of the simulation. Vissim model has the functions of graphic input, signal sensing, pedestrian and vehicle models, distribution of road traffic, and 3D scene reproduction. The Vissim model is equipped with graphic input, signal sensing, pedestrian and vehicle modelling, road traffic distribution and 3D scene reproduction. Vissim is a traffic simulation software based on time interval and driving behaviour. By setting various traffic parameters, such as speed, number of lanes, traffic volume, proportion of car

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models, lane width, radius of curves, signal timing, etc., Vissim performs virtual traffic simulation, so that it can analyse and evaluate the operating conditions of the urban traffic as well as other road traffic, and it is an effective tool for the layout and planning of the future traffic network. It is an effective tool for future traffic network layout and planning programmes.

2.4 .ESTABLISHMENT OF SIMULATION MODEL

Considering the actual road conditions to establish the simulation model of two-way two-lane bridge construction section, and according to the actual traffic conditions to collect the relevant data, mainly including the number of lanes, lane width, traffic volume and the radius of the entrance and exit curves. The length of this simulation section is 500 metres, with a single lane width of 3.5 metres and four lanes in both directions, and the simulated bridge road is eight lanes in both directions, with a width of 3.5 metres for each lane and a length of 400 metres. The ratio of small cars to large and medium-sized trucks in the construction section is 7:3. In the construction section of the bridge, the road may become narrower and overtaking is generally not allowed, so the impact of lane changing is not considered in this simulation. As the bridge is supported by columns, if the vehicle does not slow down when it passes, then the accident hitting the beams and columns is not an ordinary accident, and it is likely to trigger a chain reaction that affects the whole project, so the speed limit of the road should not be set too high. This simulation uses three combinations of speed limit values, and the specific programme combinations are shown in Table 3.

Table3A combination of speed schemes for different vehicle models

	Vehicle type	speed（km/h）	Vehicle type	Vehicle speed (km/h)
Scenario1	Small cars	40	Medium and large trucks	35
Scenario2	Small cars	45	Medium and large trucks	45

Based on the traffic statistics of the highway bridge construction section, the four traffic volumes of 2500veh/h, 2700veh/h, 2900veh/h and 3000veh/h were selected for simulation, and the time of each simulation process was 3600s, and the simulation of the traffic flow of the section is shown in Figure 4.

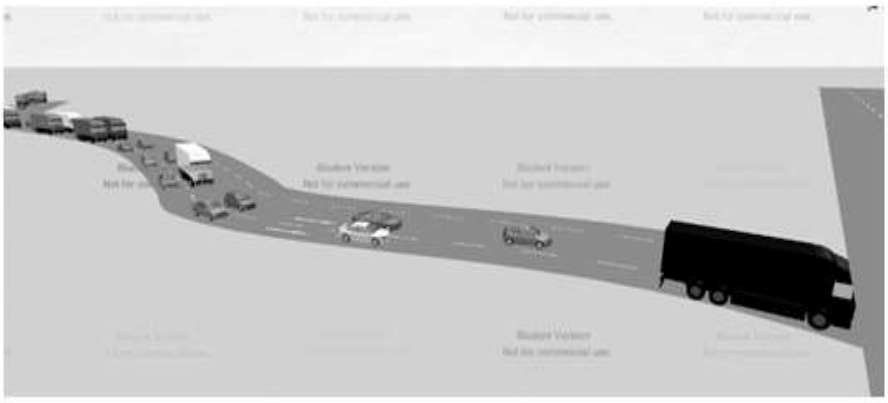

Fig4 Simulation model of speed limit in the construction section of a continuous highway bridge

V. EVALUATION OF TRAFFIC MODEL SIMULATION RESULTS

2.5 . STATISTICS AND ANALYSIS OF DATA

The results simulated by the traffic simulation modelling software are shown in Table 4 and Table 5. The simulation model carried out two simulations, due to the entrance of the road section has a curve and accompanied by a section of long downhill, the gradient is about 15 °, so the construction section of the speed limit signs should be set to 1000 m. The actual length of the bridge construction section is 300 m. Assuming that the small cars and medium and large vehicles are 40km / h, through the simulation we observed that the vehicle through the construction section time is about 40 s. Generally in the construction section will be stopped and congestion occurs, the design standard of traffic volume of four lanes in both directions of highway. The time of the construction section is

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about 40 s. Generally, there will be parking and congestion in the construction section, and the design standard of the traffic volume of four lanes in both directions of the highway is about 25,000 to 55,000 vehicles. According to the relevant investigation, the peak traffic volume of the road section is about 3000veh/h, and through the analysis of simulation simulation, it is more reasonable to adopt the traffic volume of 2400veh/h. At the same time, the average time for vehicles to pass through the road section during the peak period is 70s, at which time the phenomenon of following or even stopping will occur. The purpose of the speed limit on the construction section is to improve the safety of road traffic and reduce traffic accidents caused by excessive speed. In addition, while setting a reasonable speed, it is also necessary to consider the road capacity. According to relevant research, if the greater the dispersion of the speed, then the stability of the traffic flow is poorer, and the probability of traffic accidents is higher, so the dispersion of the speed can be used as a reference index after the safety speed limit.

2.6 . EVALUATION OF SIMULATION RESULTS

According to the speed distribution in each area of the bridge construction section, the lowest speeds are found at the connections within the construction section near the entrances underneath the bridge, because for the bridge construction section, these areas are the critical conditions that restrict the maximum service flow rate of the construction section in steady state. If the traffic flow in the construction section at the upstream is greater than the maximum service flow rate within the bridge construction section, then it will definitely cause congestion in the section and affect the traffic efficiency. In this simulation, the speed limit values of 40km/h and 45km/h are set in the upstream transition area. The upstream transition zone of this construction section is selected as the evaluation node, and the simulation evaluation is carried out according to the vehicle operation status.

Table4Simulation results of 40 km/h for small trucks and 45 km/h for medium and large trucks

	Traffic flow (veh/h)			
	2500	2700	2900	3000
60s		Start following slightly	Start following slightly	Started to follo-w the car obvi-ously
120s	Start following slightly			
180s			Started to follo-w the car obvi-ously	
240s		Started to follo-w the car obvi-ously		
300s				
360s				
420s	Started to follo-w the car obvi-ously		Congestion begins	Congestion begins
480s				

Table5The speed of small cars and medium and large trucks is 45 km/h

	Traffic flow (veh/h)			
	2500	2700	2900	3000
60s		Start following slightly	Start following slightly	Started to follo-w the car obvi-ously
120s	Start following slightly		Started to follo-w the car obvi-ously	
180s				
240s				Congestion

			begi-ns
300s		Started to follo-w the car obvi-ously	Congestion begi-ns
360s	Started to follo-w the car obvi-ously		
420s			
480s			

According to the evaluation of the simulation results, it can be found that setting the speed to 45km/h compared to the speed of 35km/h, the average delay of the vehicle is reduced, the average queue length of the vehicle is smaller, and all the other evaluation indexes have been improved, and at the same time, in the simulation operation, the vehicle can pass through the transition zone smoothly and smoothly when the speed is set to 45km/h. If the speed limit is set to 50km/h, although the passing efficiency is improved, it will increase the risk of accidents, and when an emergency occurs, the system distance will increase. When the speed limit is 45km/h for both small cars and large and medium-sized trucks, the average value of the speed is basically the same as the initial speed, which does not have a large impact on transport efficiency. The standard deviation of the speeds is also lower, the traffic operation is more stable, and the road service satisfaction of most drivers is better. Therefore, the speed limit value of the final transition zone should be determined as 45km/h is more appropriate. According to the calculation results, and combined with simulation software simulation analysis, the final determination of the warning area, transition area, construction work area speed recommended value of 60km / h, 45km / h, 40km / h respectively.

VI. CONCLUSION

In this study, we conducted an in-depth research on the speed limit standard for the construction section of a continuous bridge on a motorway based on Vissim software. By simulating the traffic flow under different speed limits, we considered the characteristics of the construction area, safety distance and traffic efficiency, as well as the construction progress and the speed of construction vehicles, and finally determined the most appropriate speed limit standard. Reasonable speed limit standard can effectively ensure the safety of vehicles and workers during the construction period, while minimising the impact on traffic, providing an important reference for the traffic management of the construction section of the continuous bridge on the highway, and having a certain guiding significance for the relevant departments to formulate the traffic management policy during the construction period. Through the simulation of this traffic simulation, and according to the actual start of the highway construction section, reference to the road traffic related laws and regulations and the research results of other scholars, the construction section of the traffic parameter values are extracted, and the study of the traffic characteristics of the section. The bridge construction section is simulated and analysed by Vissim simulation software, because the construction section is different from other construction sections in that the driver's vision in the construction section will change from light to dark and from dark to light, so considering the transport efficiency and traffic safety of the road section, the speed limit reference values for the warning zone, the transition zone and the construction zone are finally derived, and the analysis can provide a reference for the setting of speed limits in other similar road construction zones. This analysis can provide a reference basis and standard for the setting of speed limits in other similar road construction zones. However, there are some limitations in this study, such as the simulation results may be affected by the actual situation, and further field verification is needed. Future research can combine more actual data and field observations to further improve the study of speed limit standards for continuous bridge construction sections on highways.

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