Prevention of Bridge Strike on Roadways for Safe Freight Transportation

Rezaur Rahman, Md. Anwar Hossain, Dr. Md. Shamsul Hoque

Abstract— Geometric design standard are mainly based on logically derived relationships and engineering judgments. The roadway environment has been identified as a prime cause of accidents, contributing to about 17 to 34 percent of the accident as the sole contributing factor for 2 to 3 percent of accidents. So geometric design standards or guidelines are important factors for safe roadway environment. This paper deals with one of the important features of roadway which are the vertical clearance of roadway superstructures, the adequacy of headroom provided and required headroom for roadway superstructures for safe traffic operation. Every year, bridges are hit by vehicles which are too high to pass underneath. The damage done to the bridges are not always obvious but can be serious. So there is a need in rechecking the adequate vertical clearance. According to RHD design manual to allow for adequate vertical clearance and the transport of abnormal loads 5.7m headroom should be provided when designing new roads and structures. This provision considered the typical height of the truck which is just over 4m high. But from the vehicle height survey, it was found that freight trucks have a total height of 5.8m in loaded condition including both freight and passenger traveled above freight. Considering design vehicle height as 5.8m the required headroom for roadway was found 6.3m.

Index Terms— Geometric design, roadway environment, accident, vertical clearance, superstructure, abnormal load, design vehicle.

1 Introduction

Many heavy vehicles have lower performance capability than cars in braking, acceleration, stability, dynamic handling and maneuverability. Therefore, they need additional road space to fit safely on a road and are likely to operate with a greater degree of safety if the roads and facilities they run on have been designed to take account of their particular operating characteristics. They are also more sensitive to road design features such as road curvature, camber, cross fall due to the high center of gravity of the loads they often carry and vertical clearance of the roadway superstructures which is the prime contributing factor to bridge hitting problem. Some other factors contributing to bridge hits include unavailability of penalties for over height violations, driver ignorance regarding vehicle/cargo height, lack of route planning by haulers, drivers not following authorized routes [1] and inadequate low clearance warning signs [2]. The damage done to the bridges are not always obvious but can be serious. So there is a need for rechecking the adequacy of vertical clearance provided.

Though most traffic accidents are products of several factors, the road environment has been identified as a prime cause of accidents, contributing to about 17 to 34 percent of the accident as the sole contributing factor for 2 to 3 percent of accidents [3]. Therefore, roadway features should be designed to ensure safer roadway environment. The objectives of this study are to check the adequacy of headroom of roadway superstructures provided and determine required headroom for roadway superstructures for safe traffic operation. It also deals with the safety measures to be incorporated to avoid bridge hitting.
2 Methodology

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2 Methodology

In total the vertical clearance of 11 footbridges was measured, all of which are located throughout Azimpur Bus Stop to Shyamoli Bus Stop corridor except Ramna footbridge which is located near Ramna park. Vertical clearance is considered as the vertical distance from roadway crown to the lowest fiber of the bridge [4]. In addition to these measurements, the vertical and the horizontal clearance of the Mayor Mohammad Hanif Flyover (MMHF) were also obtained. As it is located on a busy road (Dhaka-Chittagong Highway), it was difficult to use theodolite to measure the vertical clearance. Therefore, manual measurement was made for this case.

Truck height survey was conducted in the locations having a high concentration of HGV like Kawran bazar, Tejgoan truck terminal, Chankharpul etc. It includes vehicles such as freight truck, cover van, double decker bus etc. having height more than 3.0 m. In the case of freight trucks, measurement was made for both loaded and unloaded condition. All the measurements were done while vehicles were parked for loading or unloading to ensure no disruption caused by the moving traffic or any change in road user's behavior.

3 Comparison of Guidelines for Headroom

The minimum headroom depends on the maximum height of heavy goods vehicles (HGVs) and varies from country to country as shown in Table 1. In most European countries the maximum height of heavy good vehicles is 4.0 m; certain countries allow higher values (UK, USA). In the European Union the maximum height of heavy good vehicles is 4.00 m, although the Geneva conventions allow a maximum of 4.3 m. If a margin of 0.20 m is added to these maximum heights in order to absorb vertical movements of the HGV, the minimum vertical clearances required become 4.20m (4.50m) [5]. Above these minimum clearances, additional headroom is necessary for drivers of HGV's to feel comfortable. This comfort margin

is related to the object distance. The minimum height plus the comfort margin yields the maintained headroom. If a value of 0.30m is taken for the comfort margin, the maintained headroom becomes 4.50 m (Geneva Convention 4.80 m, UK 5.35 m, USA 4.90 m on freeways and 4.30 m on other highways (Table 2)). In the case of Bangladesh the minimum vertical clearance for the roadway is 5.7m and for the railway, it is 7.2m [6].

Table 1: Comparison among internationally maintained headroom

Country and name of guidelines or other source	Minimum Headroom above Carriageway (m)	Maintained Headroom above Carriageway (m)	Additional allowance as safety zone for signs, luminaries, fans etc. [m]	Allowance for signs, luminaries, fans etc. [m]	Allowances for later pavement construction [m]
Austria RVS 9.232		4.70	n.s.	min. 0.20	n.s.
Denmark (practice)	n.s.	4.60	0.20	n.s.	n.s.
France CETU	n.s.	4.50	0.10	n.s.	0.05 - 0.10
Germany RAS-Q1996/RABT 94	4.20	4.50	n.s.	n.s.	n.s.
Japan Road Structure Ordnance	n.s.	4.50	n.s.	n.s.	n.s.
the Netherlands ROA	4.20	4.50	0.20	0.30	n.s.
Norway Design Guide Road Tunnels	n.s.	4.60	0.10	n.s.	0.10
Spain Instruction 3.1	n.s.	5.00	n.s.	n.s.	n.s.
Sweden Tunnel 99		4.50	0.20	0.40	n.s.
Switzerland (rectangular tunnels)	n.s.	4.50	0.20	0.40	n.s.
Switzerland (oval tunnels)	n.s.	4.50	n.s.	n.s.	n.s.
UK TD27(DMRB 6.1.2)	5.10	5.35	0.25	0.40	n.s.

NS=Not Specified (Source: World Road Association, 2001)

Table 2: AASHTO guideline for ranges of minimum vertical clearance

Ranges for Minimum Vertical Clearance				
Type of Roadway	Rural		Urban	
	US (feet)	Metric (meters)	US (feet)	Metric (meters)
Freeway	14–16*	4.3–4.9*	14–16*	4.3–4.9*
Arterial	14–16	4.3–4.9	14–16	4.3–4.9
Collector	14	4.3	14	4.3
Local	14	4.3	14	4.3

*17 feet (5.1 m) for sign trusses and pedestrian overpasses.
(Source: Federal Highway Administration, 2004)

4 Overall Height of HGVs

During the survey, it was found that mainly four categories of trucks are commonly used in freight transport e.g. TATA, HINO, EICHER and ASHOK LEYLAND. Though most of the trucks have the same height in an unloaded condition (3m) but in the loaded condition, it varies considerably. Another important issue is that sometimes passengers are also carried with freight specially labors who carry instruments for loading and unloading the trucks. So additional increment (0.91m) in height is made for passengers traveled with freight. As shown in fig 1 measurement was made for 20 trucks and maximum height in loaded condition was found 4.9m, if passenger height is considered.

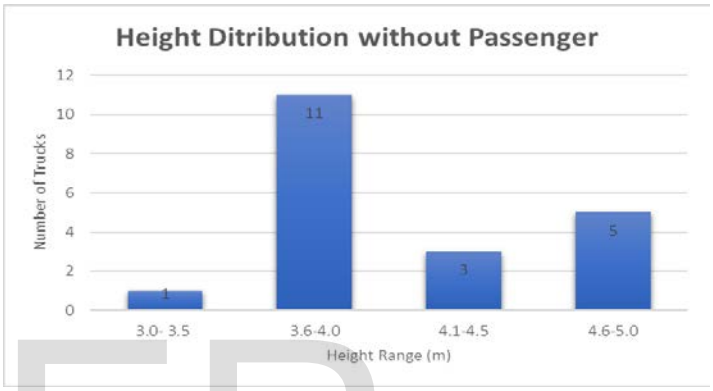

Fig 1: Height distribution of freight trucks without passenger

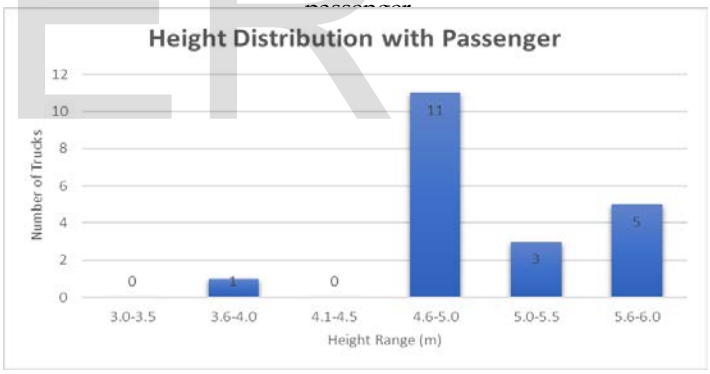

Fig 2: Height distribution of freight trucks without passenger

Three categories of Cover Vans were more common ASHOK LEYLAND, EICHER and TATA. The overall height of Cover Van depends on the container height it carries, which is uniform as fixed standard is maintained all over the country. The total height of a cover van so measured is 3.96m (13ft). Similarly, standard height of Double Decker Bus is 4.27m which is used as a standard vehicle for headroom provision in many countries. But in Bangladesh truck heights, in general, exceed this range.

4 Required Headroom for Roadway Superstructures

From the vehicle height survey, it is found that freight trucks have a larger height than Cover Vans or Double Decker

Buses. The largest height of truck so obtained considering passenger height is 5.8m. But in Geometric Design Standards for RHD typical height of the trucks was considered as 4m and based on this value allowance (5.7m) was made for vertical clearances for roadway Structures.

According to AASHTO Geometric Design Manual, a freeboard of 0.3m must be provided above maximum vehicle height for the drivers of HGV's to feel comfortable. In addition to this, allowances for future resurfacing must be considered and in the case of Bangladesh, this allowance must be higher as roads are more frequently exhausted and frequent resurfacing (thickness of resurfacing varies from 0.04 to 0.05 m) is required. For resurfacing 0.2m additional height is considered though the minimum guideline value is 0.1m. (Table 1).

Required Headroom = Maximum Height of HGV+ Freeboard (0.3m) + Resurfacing (0.2) (1)

From equation (1) the required headroom for roadway structures so obtained is 6.3m indicating a significant variation (0.6m) from recommended value (5.7m) of RHD Geometric Design Standards. Further consideration is required depending on the type of pier used, especially in the case of hammer head pier which causes a significant reduction in effective vertical clearance. Fig 3 depicted a significant reduction (0.61m) in effective vertical clearance due to hammer head pier. This type of pier is used in RCC and composite type bridges.

Fig 3: Reduced headroom due to hammer head pier (Science lab Footbridge, Field Survey, 2015)

5. HEADROOM ADEQUACY OF EXISTING STRUCTURES

From field survey, it is found that vertical clearance of the footbridges varies from 5 to 6m. Among which footbridges located at Sukrabad and Sobahanbag have the highest vertical clearance (6m). Though the allowance for headroom is 5.7m but most of the footbridges were found having vertical clearances less than the recommended value. Surprisingly Ramna footbridge located near Ramna Park having a vertical clearance of only 5.3m, due to low clearance it had recently been struck by a freight truck (Fig 4) according to the information obtained the from the secondary source. During the survey, several damaged portion of the bridge was found in an untreated condition which is clear evidence of bridge strike.

Table 3: Vertical Clearance and Overall Height of Footbridges

No	Location	Headroom	Additional height from bottom face of the slab to crown	Total Height including Shed
1	Balaka Cinema Hall	5.5m	3.96m	9.46m
2	New Market	5.5m	3.35m	8.85m
3	Science Lab	5.5m	–	–
4	Kalabagan	5.5m	3.96m	9.46m
5	Sukrabad	6m	3.96m	9.96m
6	Sobhanbag	6m	3.96m	9.96m
7	Dhanmodi 27	5.8m	–	–
8	Asad Gate	5.8m	–	–
9	College Gate	5.8m	–	–
10	Shyamoli	5.8m	3.81m	9.61m
11	Ramna	5.3m	–	–

Fig 4: Over height Truck stuck with Ramna footbridge

More deviations in vertical clearance were found in case of flyovers among which vertical clearance of Moghbazar Mouchak (Combined) Flyover (MMF) varies from a minimum value of 5m to a maximum value of 9.3m (at level Crossing) while in case of Mayor Mohammad Hanif Flyover it varies from a 5.5m to 7.2m (at level crossing) (Fig 5 & 6). Though in both flyovers maintained headroom at level crossing is greater than the recommended value which is 7.2 m according to RHD Geometric Design Standards but headroom over the roadway is less than the recommended value (5.7m). This type

of design fault indicates a lack of foresight of implementing agencies regarding the problem that may arise from inadequate clearance.

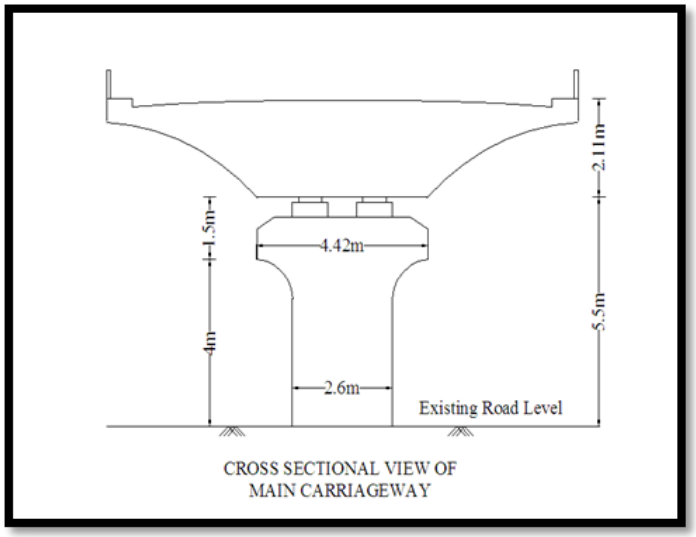

Fig 5: Vertical Clearance of Jatrabari Flyover (Main Carriageway)

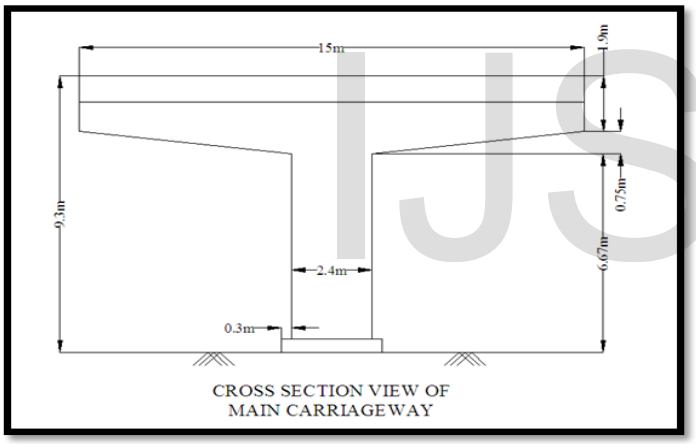

Fig 6: Vertical Clearance of Jatrabari Flyover (Main Carriageway)

6. PREVENTIVE MEASURES TO AVOID BRIDGE STRIKES

To design safer roads five design principles should be followed: designing for all road users, reducing conflicts, encouraging appropriate speeds and behavior by design, avoiding surprises and confusion, creating a forgiving road [6]. Therefore, it is necessary to reassign the recommended value of headroom (recommended value 5.7m) for future construction as it is found inadequate for heavy goods vehicle which requires a headroom of 6.3m. From an economic perspective, it is not a feasible solution to reconstruct all the bridges especially flyovers having lower headroom and also it will consume lots of time. Therefore, to ensure safe traffic operation following preventive measures must be taken to avoid bridge strikes. These will help the drivers of HGVs to feel more confident regarding their maneuverability. The preventive measures are based on limiting the travel routes of over height vehicles. Besides, all bridges should have advance warning sign mentioning the headroom available underneath the bridge.

6.1 Traffic Sign Regulations

During the survey, no Traffic Sign Regulations were found showing headroom or allowable height of vehicles those are allowed to pass underneath the bridge except at Kalabagan footbridge which unfortunately faded away due to lack of maintenance. To prevent bridge strikes, it is important that the drivers know the height of their vehicle as well as understand and obey the traffic signs. To assist them the Traffic Signs Regulations that shows the maximum headroom in imperial and metric units should be adopted.

Fig 7: Traffic signs used at bridges to show the maximum permitted vehicle height

As shown in figure 6 red circle indicates prohibition and a Red triangle indicates warning which is used when the head room is non-uniform and the vehicle have to use a specific section. At arch bridges, white lines on the road and 'goal posts' on the bridge may be provided to indicate the extent of the signed limit on vehicle height, normally over a 3-metre width [2]. Signing must be installed in advance at the last feasible turning point before the bridge to enable drivers to reroute without having to reverse.

6.2 Vehicle Height Check

The maximum height of the vehicle, its load or its equipment must be checked before commencing a journey and the height must be shown on the headboard to be rechecked by law enforcing agencies to provide a permit to use the certain route. Maximum height must be rechecked again after every loading, unloading or reloading to ascertain whether the trailer suspension characteristics have changed the height of the vehicle. The maximum height of any vehicle, its load or equipment can be checked using a simple hand held devices or fixed depot installations. This process is cheaper than Over Height Vehicle Detection Systems (OHVDS) or Laser Ranging over Height Vehicle Detection System (LARA-OHVDs) installed at the bridges, therefore more suitable for Bangladesh.

6.3 Road Map with Vertical Clearance of Roadway Structures

A survey conducted by U.K. department of transport in 2011 indicated that 11 % of the drivers believed poor information about low bridges is the prime cause of bridge strike [8]. Therefore, the drivers must be provided with proper information regarding low height bridges. Based on this information travel routes must be planned in advance and selected in such a way to eliminate the risk of bridge strike, avoiding routes having low height bridges. To do so a route map must be developed showing the vertical clearances of roadway structures on a particular route to assist the drivers of HGVs to trace their routes before commencing a journey. This must be available to all transportation agencies and freight transport industry.

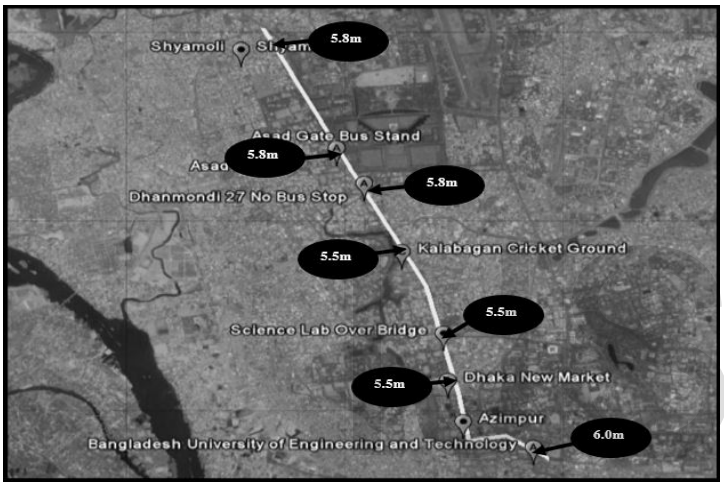

Fig.8: Route map with vertical clearance from Azimpur bus stop to Shyamoli bus stop

4 Conclusion

Rather than relying on enforcement which is more uncertain, it is better to design forgiving roads to ensure safe traffic operation. Therefore, the recommended value of vertical clearance of the roadway bridges must be reassigned to 6.3m considering the complex nature of maneuverability of HGVs. In addition to this several safety measures like providing proper traffic signs, enforcing over height limit and information system to assist route choice must be taken to ensure freedom in maneuverability for the drivers of heavy vehicles. To ensure uniformity in headroom over the roadway steel footbridges with flat headed pier should be given priority rather than RCC or Composite ones with hammer head or flower head pier.

This study is useful for transportation planners to ensure roadway safety for all road users as well as freight industries to ensure safe operation of freight vehicles. The results obtained from the study are based on limited data due to time and resource constraints, further study should be carried out using a more data especially large sample of HGVs to obtain the more precise value of required headroom.

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