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COMPARISON OF ACTUAL TRUCK TRAFFIC WITH LIVE LOAD MODELS USED FOR DESIGN OF BRIDGES IN PAKISTAN

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Abstract- Live load models representing truck traffic, primarily governs design of bridges in Pakistan. Bridge design is done using Pakistan Code of Practice for Highway Bridges 1967 (CPHB) and AASHTO LRFD Bridge Design Specifications (AASHTO Specifications). Legal limits are imposed by National Highway Authority (NHA) to prevent overstressing of bridges. . In order to meet heavy load carrying demands from various industries, the service-level truck traffic has changed significantly in axle configuration, axle weights, traffic volume and gross vehicle weights. In this study, characteristics of live loads (axle weights and Gross Vehicle Weight (GVW)) of actual truck traffic are compared with live load models NHA legal load specifications to elaborate the significance in change in code of practice. The samples truck traffic data recorded at Ayub Bridge Peshawar (411 trucks) have been used for Analysis. From the analysis it was found that all types of vehicles surpass the limitation by significant value. Approximately, 60% vehicle violates the GVW limit prescribed by NHA with nearly equal contribution by both light and heavy vehicles. Similarly, 84% vehicle violates the axle load limit that includes almost all 6-axles and 5-axles trucks. The live load models of NHA Specification projects much less load effects as compared to the effects caused by actual truck traffic and hence the bridges are stressed much greater than considered during design. Hence, existing live load model are not the true representations of actual truck traffic, and requires development of a new live load model in addition with strict enforcement of load limitations.

Keywords- Bridge design load, Axle load, Gross Vehicle Load, NHA legal limits.

1 Introduction

The Highway Bridges needs to be designed so that these can safely carry the anticipated loads that it will experience in its service or design life. Live load (Trucks) are the primary governing factor in bridge design and their lifelong structural performance depends significantly on the live loads to which bridges will be exposed during their lifetime [1]. Bridges may get damaged and deteriorated due to overloading [2] as well as due to aging and environmental effects.

There are number of design vehicle load used in different systems. It was highlighted during First World War (1914-1918) that some standard loading for bridge design should be there to cater heavy equipment, and other needs of Military. In 1922 Standard Loading Train was introduced for the first time in Britain [3]. Industrial progress along with technological advancement compelled Indian Road Congress (IRC) to develop some sort of standard loading for Highway Bridge Design which were adopted by PHB Code, 1967 later on. AASHTO in 1935 introduced the idea of a train of trucks. In 1944 idea of hypothetical trucks was introduced by AASHTO [4]. These trucks are called H (with two axles) and HS (with three axles) classes of trucks. These were used only for the purpose of design and have no resemblance with any truck on road. A truck train loading and 70-ton military tank is used for highway loading, according to PHB, 1967. HL-93, commonly represents AASHTO LRFD Live Loading [5]. It is hypothetical Live Load Model used to analyze bridges having a design period of 75 years at max [6]. This Live Load Model has a set of loads which produce extreme load effects approximately equal to that caused by exclusion vehicles.

TRUCK TYPE	Permissible Gross Vehicles Weight (In Tons)
2 AX SINGLE (Bedford)	17.5
2 AX SINGLE (Hino/Nissan)	17.5
3 AX TENDEM	27.5
3 AX SINGLE	29.5
4 AX SINGLE-TENDEM	39.5
4 AX TENDEM-SINGLE	39.5
4 AX SINGLE	41.5
5 AX SINGLE-TRIDEM	48.5
5 AX TENDEM-TENDEM	49.5
5 AX SINGLE-SINGLE-TENDEM	51.5
5 AX TENDEM-SINGLE-SINGLE	51.5
6 AX TENDEM-TRIDEM	58.5
6 AX TENDEM-SINGLE-TENDEM	61.5

Figure 1 NHA legal loading limitations for each type of Truck [7]

In Pakistan, bridges design is done using Pakistan Code of Practice for Highway Bridges 1967 (CPHB) and AASHTO LRFD Bridge Design Specifications [8] based on America traffic statistics. By installing weight stations on National highways, National Highway Authority (NHA) enforce limits on gross weights and axle weights. However, rising fuel prices, competition between transporters and development of powerful truck engines lead to illegal overweight. Thus, there is a need to characterize actual truck traffic and its load effects on the bridges and compare it with current live load models and NHA Legal Load Limits (Figure-1). Similarly, there is need to also consider the axle weight limitation [9]. The NHA axle Load limitations for these trucks are such that the weight of front, rear, tandems and tridems axles must not exceed 5.5, 12, 22 and 32 tons respectively.

Service-level truck traffic has a significant deviation with respect to axle weights, axle configuration, gross vehicle weights and traffic volume in Pakistan as compared to United States and Canada [10]. No such literature or analysis were found that emphasis to update the current code of practice according to Pakistan traffic. Thus, PBH Code live load model based on 1961 AASHTO Specifications and current NHA Legal Load Limits may not truly represent service-level truck traffic of Pakistan. Therefore, current study aim is to determine live load characteristics (axle configuration, axle weights, and gross vehicle weights) and comparison of actual truck traffic load characteristics with NHA legal loads [1].

2 Research Methodology

Data is collected by using WIM technology that gives an excel sheet comprising axle weights, axles spacing, gross weight, velocity of approaching vehicle etc. Bugs and errors are removed from collected data by filtration. Ayub bridge in Peshawar is selected to analysis the traffic load trend in Pakistan. The Ayub bridge is comparatively highly exposed to heavy trucks.

2.1 Weight-in-Motion (WIM) Technology

WIM system acquires vehicle weights, axle loads, axle spacing, speed, and other vehicle information as vehicles drive over sensors. This data is used in the evaluation of bridges to repair or replace them. On the basis of the speed of the moving vehicle they are divided into two groups. Low speed vehicle is categized if its speed is less than 15 km/h while above are called as high speed. The most important component of WIM is Mass sensor and is positioned on or within the road system. They may be permanent, semi-permanent or temporary. Most WIM systems can classify and/or identify the vehicle to which the weighed axle belongs [11].

2.1.1 Load Cell

Typically load cell WIM system has a load cell. The load cell has two in-line scales, one axle sensor and at least one inductive loop. Likewise bending plate, load cell is positioned in travel lane at right angle to the direction of traffic movement. WIM load cell systems have a single load cell having two scales. These scales detect and weigh both sides, right and left, of axle simultaneously. A load cell has durable material such as steel with a strain gauge attached. The strain gauge has a wire for transmitting the electric current. When load is applied on cell, wire beneath strain gauge gets compressed and altered slightly. This change causes a change in resistance and hence follow of current changes. Weight is calculated with the help of this change. After summation of values from each scale axle weight is obtained.

2.1.2 WIM Data Acquisition Process

WIM electronics capture the digital signal outputs from sensor and the data from it are converted from binary strings to ASCII files and then further convert it to Excel files through a software i.e. Trafman 6.0 as shown in Figure 2. The Excel files contain data of lane codes, recording time, vehicle speeds, axle numbers, vehicle lengths, axles spacing, GVWs, and axle weights. The data is then further filtered out before an analysis to be carried out.

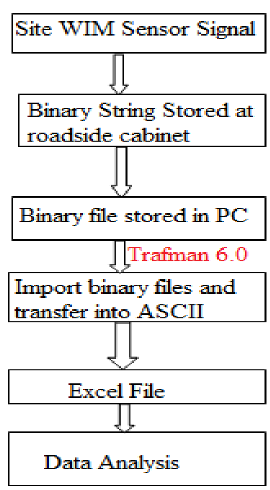

Figure 2 WIM Data Acquisition Process at Site

3 Results

Axle configuration and axle weights have been changed significantly over time but for design of bridges still CPHB 1967 and AASHTO specifications are used [7]. In order to check the adequacy of bridges, we did a case studies of simply supported RC-girder bridges i.e., at Ayub site, Peshawar.

3.1 Characterization of truck traffic

Axle weight, axles spacing and gross vehicle weight record from 411 trucks from Ayub Bridge gathered over a time span of 10 days was used to estimate loading trends of various truck types crossing bridge. The span of Ayub bridge is taken as 25 m. The random data was collected without classification as separate axle vehicles. To capable the data to compare with NHA provisions and limit, there is need to classify the data.

Table 1 Classification according to their number of axles

Number of axles	Number of vehicles	Percentage of total traffic (%)
2 axles vehicle	154	37.47
3 axles vehicle	66	16.06
4 axles vehicle	33	8.03
5 axles vehicle	3	0.73
6 axles vehicle	155	37.71
Total vehicles	411	

Table 1 shows the classification of traffic data according to their number of axles. Current studies concern about the heavy trucks with large number axles to deal with worst case. The data illustrates the significance of the site as quantity of six axle vehicle is comparable to small cars. The number 2 axles and 6 axles vehicles dominate the data by sharing approximately 37% each of total traffic. The 5-axle vehicles were found in least amount of only 3 (less than 1%).

Table 2 Vehicle weights description

Description	Weight (tons)
Minimum gross vehicle weight	6.88
Maximum gross vehicle weight	88.12
Mean gross vehicle weight	37.35
Minimum axle weight	2.72
Maximum axle weight	11.34
Mean axle weight	6.95

Table 2 describes the characteristics of gross and axle weights to make comparison with NHA weight limits. The weight varies between 6.88 ton to 88.12 ton with 37.35 ton as a mean, while axle weight changes between 2.72 ton to 11.34 ton with mean of 6.95 ton. Figure 3 illustrates the comparison of mean and maximum gross vehicle weights with the NHA limitations.

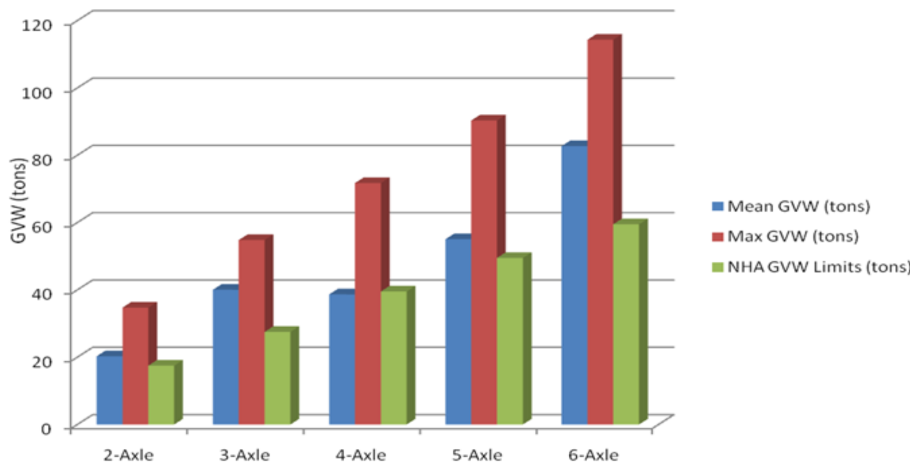

Figure 3 Comparison of mean, maximum and NHA gross vehicle weight limits

3.2 Comparison

Bridges are meant to bear the load of heavy traffic especially the trucks. In case if actually trucks load exceed the provision advised by authority might be very detrimental to lives and properties. Therefore, there is need to identify the violation and propose the appropriate action. Figure 4 explains the number of trucks in each axle category that violate the NHA prescribed limitations. The data clarity verify that all types of vehicles violate the limitations by significant amount. Smaller vehicles like 2-axles and 3-axles vehicles dramatically surpass the limit by 59% and 85% respectively. Similarly, heavy load traffic like 6-axles trucks considerably exceed the thresholds by 57%. Likewise, 21% of medium sized vehicle passes the NHA requirements. The number of 5-axle vehicle were insignificant therefore can't be consider but still 1 violates out of 3. Around 60% of total traffic violates the prescribed thresholds.

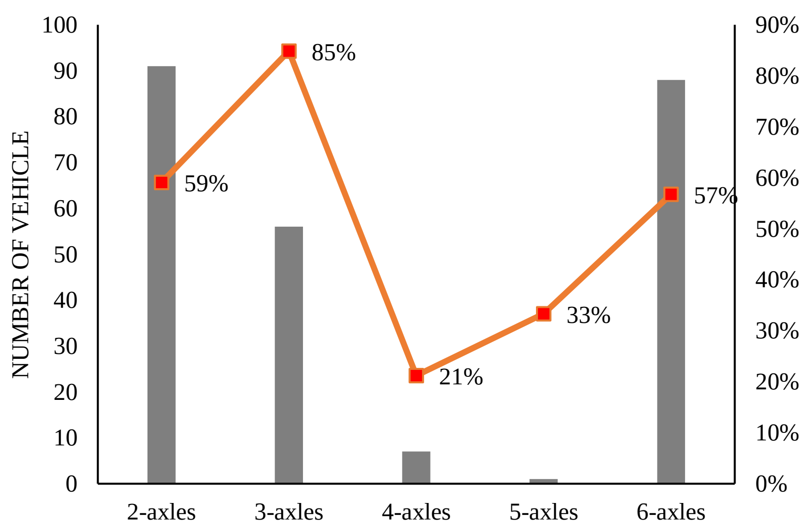

Figure 4 Vehicles that violates the NHA gross weight limitations

Similarly, Figure 5 illustrates the quantity of automotive that outstrip the axle load limits to point out the danger of point load on bridge. If any of axle surpass the required value is classify as a violated vehicle. Figures of axle load violation is more alarming than gross weight violation. All category of trucks passes the value by considerable amount. More than 73% and 95% of 2-axle and 3-axle exceed the obligation. Almost all heavy trucks violate the permissible limit while only

3% of 6-axle vehicle are traveling within allowable limit. In addition, 4-axles vehicles show comparatively moderate rise of 42%. Overall, 87% of trucks crosses the NHA limitation that is serious threat to existing bridges designed for lower design load.

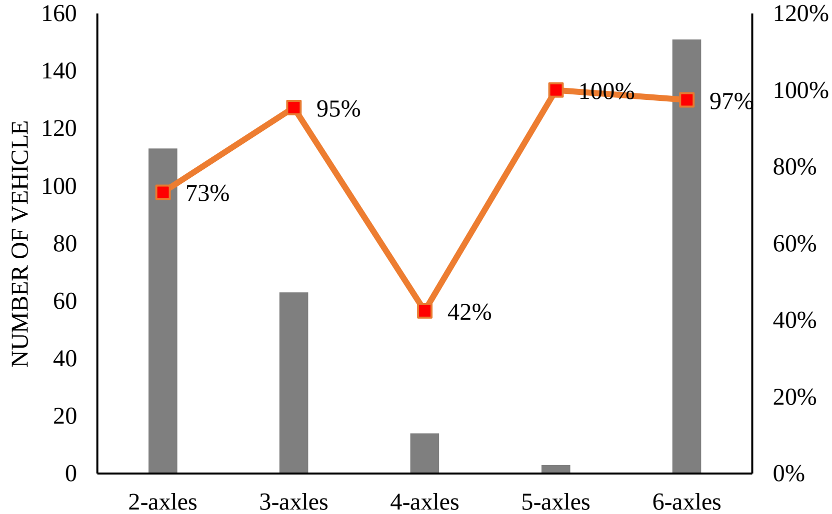

Figure 5 Vehicles that violates the NHA axle weight limitations

There is need to enhance the current research on other bridges also and formulate new code of practice that in actual illustrates the current traffic situation of Pakistan. Current research proposes the methodology and analysis parameters to lay a predefined path for other engineers and researcher.

4 Conclusion

Results of the case study indicate that bridges in Pakistan are potentially subjected to more extreme effects than they were actually design for, owing to prevailing traffic trends. From the study it is concluded that actual truck traffic of Pakistan is significantly different in axle weights and gross vehicle weights than the values specified NHA Legal Load limits. The load effects because of real truck traffic is much higher as compared to the indication by live load models of AASHTO Specification, PHB Code, and legal load limits of NHA. Thus, bridges may be considerably overstressed than that being assumed in bridge design. Hence, existing live load model of NHA legal limits are not the true representations of actual truck traffic of Pakistan, thus, there is requirement of developing a new live load model and also to ensure strict enforcement of load limitations.

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