DEVELOPMENT OF DATABASE OF HEAVY TRUCK LOAD DATA IN PESHAWAR, PAKISTAN

Muhammad Usman Shafi*, Syed Muhammad Ali**, Syed Akhtar Ali Shah***, Kamran Ahmed****

ABSTRACT

The objective of this research project is to develop an indigenous solution that should be efficient and cost effective for determining truck loads passing from Peshawar. As heavy vehicles impacts road most, therefore small vehicles are put in one category and trucks are divided into two, three, four, five and six axles to give clear interpretation of each type of truck. To determine load data, a portable weighing station was designed keeping in view the size of each truck tire, the maximum deflection and economy. Weighing plates were made of steel which is easily available, cheaper as compare to the aluminum plates that are being employed in most of the weighing machines. Movable weighing station comprises of two rectangular steel plates of sizes 28" x 21" and thickness 1" considering the dimensions of loaded trucks tires and AASHTO specification. The thickness is taken as 1" as the deflection produced by the heaviest truck tire was less than 0.5". General purpose strain gages were installed on front and back side of each plate in full wheat stone bridge form and were connected to Data acquisition system (DAQ) to record deflection. Lab calibration was carried out to determine the value of strain for each load applied through Universal testing machine (UTM). Load verses strain graph was developed for each load cell which was used to interpret the value of load exerted by each pair of tire to produce strains. By adding the strains from each plate, axle load and similarly by adding axles, the load of the complete vehicle can be determined. Field calibration was carried out to check the precision of plates and was found in close agreement. Axle wise load of around 200 vehicles were taken randomly and were found that more than 80% of the vehicles of each category are overloaded. This sample survey of load can be implemented across the country as it is the representation of the loaded vehicles moving in the country.

Keywords: *Traffic load data, Heavy vehicles, design of load plate, Application of full Wheatstone bridge, Calibration*

INTRODUCTION

The major modes of transportation in Pakistan are land transport (road and railways), sea transport and civil aviation. However road is the dominant mode of inland traffic and carries 91% of passenger traffic and 96% of freight traffic. The road density of Pakistan is 0.32 Km per square Km[1,2].

With the increase in population there is increase in freight which is mainly moved by large trucks. The local and global trends indicate that truckers tend to overload to cut down on cost of hauling. The overloading is issue not only of developing countries but also seen in developed countries like USA[3].

Both passengers as well as freight have consistently been growing since 2005. An average annual growth rate of freight is 3.8% which is mainly moved by large trucks. This is especially true for urban infrastructure as people tend to migrate from remote villages to cities[4]. The Pavement Condition Survey in the year 2000 (National Highway Authority) indicates that 50% of the National Highway Authority's existing network is in need of major rehabilitation and reconstruction. The remaining 50% will be lost in the near future if timely and effective maintenance is not carried out[5]. In Europe study of heavy truck traffic was done through WAVE project in 1996 (worth 1.5 million Euros), which was done because of increase in overloaded trucks as they severely damage the road pavements and bridges[6]. In Pakistan Ministry of Industries and Production attempted for developing the implementation strategy for trucking policy[7].

The transport volume by road grew at 12% per year for freight in terms of ton-km[5]. The local and global trends indicate that truckers tend to overload in terms of weight and volume to cut down on cost of hauling[8]. As these trucks are above legal limits so they tend to damage the road pavements and bridges which result in poor transportation network[1].

Peshawar has seen tremendous increase in freight cargo in the last decade due to three reasons i.e. Corridor

* Research scholar, Department of Civil Engineering, UET Peshawar, Pakistan
** Professor, Department of Civil Engineering UET Peshawar, Pakistan
*** Chairman, Department of Urban and Regional Planning, University of Peshawar, Pakistan
**** Lecturer, Department of Civil Engineering, UET Peshawar, Pakistan

provided by Pakistan government for the logistic support to NATO forces, support in rebuilding Afghanistan which is to grow further over coming years, growth of trade within and outside Pakistan is putting more demand on the transportation infrastructure of Peshawar.

Literature Review

One of the most important factors in traffic data collection is truck weight data collection. Collecting truck weight data is the most difficult and costly but at the same time is important in many ways.[9]

Truck weight data are used for a wide variety of tasks. For example Pavement design, Pavement maintenance, Bridge design, Pavement and bridge loading restrictions, Determination of economic value of freight being moved on roadways and Determination of the need for geometric improvements related to vehicle size, weight, and speed.[9]

Only overloading is considered alone by assuming other factors constant for the life cycle of pavement structure, we can realize as an example: legal loaded truck is loaded with gross vehicle weight limit 40 tons, then if the truck is overloaded, the road pavement is deteriorating[10] as shown in Figure 1.

Strictly speaking, if design life of pavement is 15 years, then:

Overloaded 5% (42 tons) design life remains 15/1.22 = 12.30 years

Overloaded 10% (44 tons) design life remains 15/1.46 = 10.27 years

Overloaded 20% (48 tons) design life remains 15/2.07 = 7.25 years.

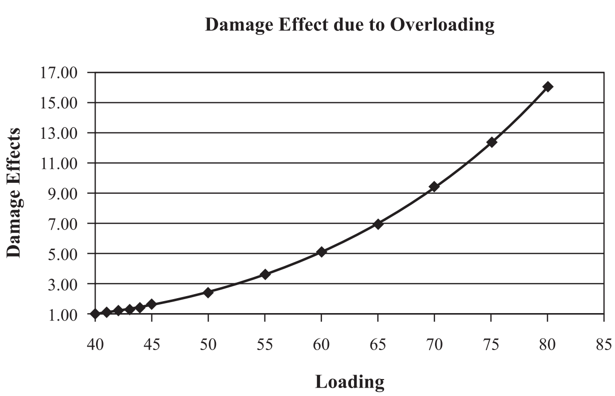

Figure 1: Damage effect due to overloading

Scope and Objectives

Development of database of prevailing heavy truck loads plying on roads along with details of configuration of such trucks. This would be helpful to researchers, policy/law makers, and owners of transportation system in Peshawar. The results will help in the management and assessment of traffic which will in turn reduces the annual maintenance cost of roads and bridges in Peshawar. The database would also further the research towards development of Live Load Model specific to Pakistan which in turn would help urban planners, road designers, bridge engineers and policy/law makers in their respective domains.

Objectives of the project are to:

Establish one digital weigh station on suitable location within Peshawar for random measurement of axle/gross weight of trucks along with configuration measurement, pictures and videos at all the main routes of Peshawar. This data would also be useful for researchers planning to update primitive Live Load Model of 1935 that is still prevailing in Pakistan.

Research Methodology

In order to achieve the objectives of this research work, portable load cells was design and fabricated. The design concept of design of load cells were taken from the lectures of Prof. Andrei M. Reinhorn[11].

After laboratory and field calibration, load of trucks on main route, carrying freight from Karachi to Torkham (N5) is determined. Research work mainly focuses on different categories of trucks including 2, 3, 4, 5 and 6 Axle trucks. Load of a total of 192 loaded vehicles were determined including 112 two axle, 33 three axle, 13 four axle, 6 five axle and 28 six axle trucks. Field load is obtained for 5 days from 0800 – 1400 hrs continuously and trucks were slow down consecutively as they passed by. Availability of Traffic police were made certain through special permission by higher officials of traffic police. Loads obtained were then compared with the NHA maximum permissible loads. Figure 2 shows the main activity of the research work

STRAIN-GAGE LOAD CELLS

Strain-gage load cells convert the load acting on them into electrical signals. The gauges themselves are bonded onto a beam or structural member that deforms when weight is applied. In most cases, four strain gages are used to obtain maximum sensitivity and temperature compensation. Two of the gauges are usually in tension, and two in compression, and are wired with compensation adjustments. When load is applied, the strain changes the electrical resistance of the gauges in proportion to the load. The advancement in technology and reducing unit cost of strain-gage load cell, its use in load data determination can be more reliable and cost effectiveness.

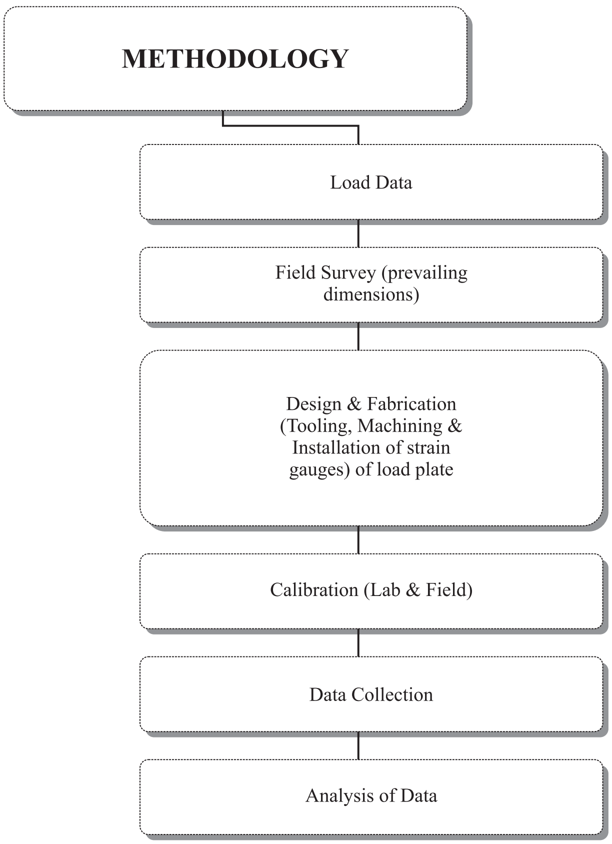

Figure 2: Flowchart of Experimental Program

Strain Gage Configuration

The Bending Beam

Because of its simplicity and low cost, bending beam sensor is one of the most popular load cell designs. It comprises of a straight beam attached to a base at one face and loaded at the other. It can be a "binocular" design, a "ring" design or a cantilever beam. At its top and bottom, strain gages are mounted to measure tension and compression forces. As strain gages are prone to damage, they are usually covered by rubber bellows. Often the beam itself is made of rugged alloy steel and is protected by nickel plating.

Wheatstone Bridge

A Wheatstone bridge is a divided bridge circuit used for the measurement of static or dynamic electrical resistance. The output voltage of the Wheatstone bridge is expressed in milli volts output per volt input. It is also well suited for temperature compensation. Keeping the advantage of full wheat stone bridge with regard to temperature compensation and high sensitivity, a full Wheatstone bridge is used.

LOAD PLATE DESIGN

Selection of Material

There were two options for selecting the type of weighing station, mobile and stationary. Keeping the advantages of mobile weigh station over stationary weigh station and keeping in view the versatility of the sites in this case study, mobile weigh station was preferred. It was decided to install a mobile weigh station on the service road of some heavy truck traffic region. Due to the simplicity of its design and construction, a bending beam sensor type of load cell was selected. For selecting materials, two options were discussed; one was to go for a concrete slab by placing load cells beneath it and find loads in terms of strains. This load weighing station would be fixed in one place. The second option was to use steel plates and cut them according to standard size of tires. Second option was adopted for the reason that steel plates can be easily moved from one place to another which only serves the need of this research. Thus, a mobile weigh station was designed by using steel plates of sizes and strength comparable with those of trucks passing over it. We checked the design by comparing it with some standards and found it convenient for heavy loads up to 30 tons per axle i.e. 15 tons per wheel.

Selection of Size of Plates

The size and thickness of plates was determined using finite element analysis software i.e., SAP2000 and results confirmed with manual analysis. The contact area of the tire is 20” x 10” according to AASHTO specifications[12,13]. The load of 16tons on the above mentioned area was applied and behaviour of the plates was analyzed. Next was the assessment of most critical scenario, i.e. reducing the contact area up to 50% of the actual area. The contact area came out to be 14 inch x 7 inch. From Standard Loads of HL-93 truck, applied load on each plate was 16 tons/plate for design purpose. First step was to select size of plate. By preliminary survey of different load cells and standard dimensions of tires, sizes for plates under consideration were rectangular place of dimension 30 inch x 24 inch, 28 inch x 24 inch, and 28 inch x 20 inch. Steel plates of sizes 28 inch x 20 inch were found to be best size for weigh station. Reason for selecting 28 inch x 20 inch was that from AASHTO specifications as the contact area, i.e. 20 inch x 10 inch and keeping some factor of safety for placing tire on weigh plate. By checking thickness range from .5 inch to 1 inch, using a live load of 16 tons per wheel, it was decided to select 1 inch thick plate as it fully accomplished the deflection, strains and serviceability issues. The deflection diagram of plates in SAP for loading area of 20 inch x 10 inch and 14 inch x 7 inch and strains producing from the uniform load of 16tons is shown Figure 3.

Load Plate Size
Length = 28in, Width = 20in, Thickness = 1in

Fabrication of Load Plates

Two steel plates of thickness 1 inch and dimensions 28 inch x 20 inch were cut from a single plate, so that they had same material properties throughout. After cutting steel plates according to selected dimensions, these were tooled and buffed. For placing the strain gages, grooves of 1/8 inch depth, 1 inch width, and 2 inch length were made. These grooves were 2 in number for each plate and are 7 inch from the centre for both the grooves. The surfaces of the tooled portion of plates were leveled and buffed with sand paper to have smooth surface for placing of strain gauges. Two holes of 1/8 inch diameter were made in the tooled places for passing the gauge connections. The edges of the plates were also smoothened to avoid any incidence.

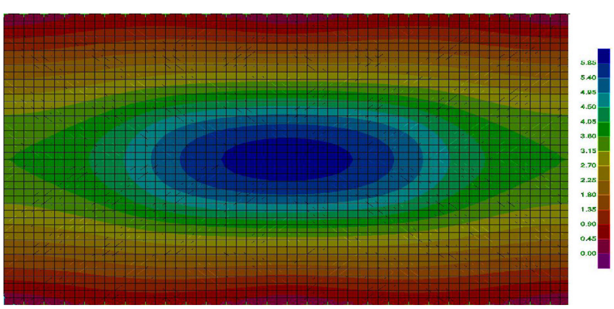

Figure 3: SAP model showing moments due to loading on 20 incg x10 incg

As per calculations, the deflection was not more than 0.5 inch therefore supports of 1 inch square and 28 inch long rod were provided on both the sides of each plate. Supports were also provided at 20 inch edges of plates to handle them with convenience (Figure 4).

Installation of Strain Gauges

The defections in plates were determined with the help of strain gauges. A bonded Strain gage C2A-XX (06)-125LW-350 resistance was used for its sensitivity and reliability. Following were the specifications of the gage used. (Figure 5)

Figure 4: Load Cell showing groves for installation of strain gauges

Four strain gauges were placed at both sides of the plate. A full wheat stone bridge was selected for the circuit as it was twice as sensitive and covered temperature compensation. Two strain gages were placed on the top face and two on the bottom face. The connections were fixed to steel plates by using tapes and glue etc. It was then allowed to settle for 24 hours.

Data Collection and Comparison

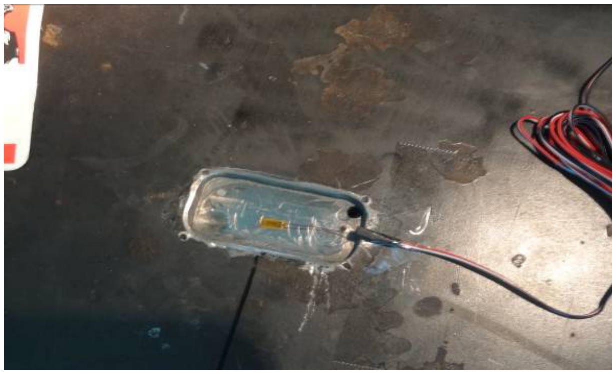

Figure 5: Strain gauge after installation on front side of Plate

To differentiate between the plates, they were given specific numbers i.e. 1 and 2. Calibration of weigh plates was carried out in Concrete laboratory. 2 plain and 2 inch thick loading pads of 12 inch in length and 6 inch in width were placed on plate for the purpose of uniform loading. The weigh plate was placed in Universal testing Machine (UTM) and repeated load up to 13 tons was repeatedly applied 4 times. After some repeated cycles of loading and unloading, the Weigh plates were loaded up to 8 tons with increment of about 50 kg and then unloaded in the same manner as of loading. The strain on 8 tons came out to be 1366μξ for weigh plate 1 and 1380μξ for weigh plate 2. 2-cycles on each plate were performed.

After manual calculations, the maximum strains were determined as 2343 for both plates (i.e. the yield point)

For the calibration based on strains, the weigh plates were loaded up to 2200μξ with 100μξ increment and load was noted. For the increased strains of up to 2238μξ and 2278μξ for load cell 1 and 2 respectively, the load of 13 tons was produced.

In order to determine that by changing the position of the load i.e., to the left or right of the center, what will be the effect on strains. For this purpose the weigh plate was loaded by moving the load towards the right side by at least 4 inch from the centre. The results came out to be very much closed to the results obtained by placing the loading pads on the centre. We plotted these results on a graph by plotting Load versus Strains curve. An equation was developed by using strains and load combination.

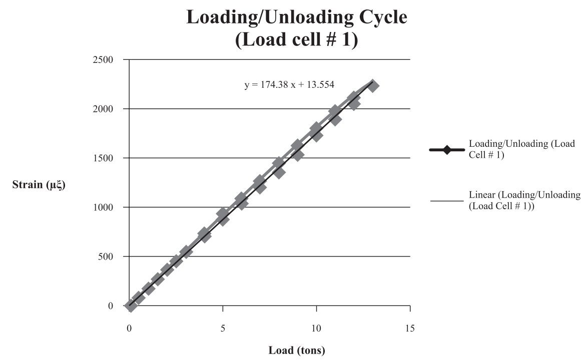

Figure 6: Loading and Unloading Graph of load Vs Strain (Load Cell # 1)

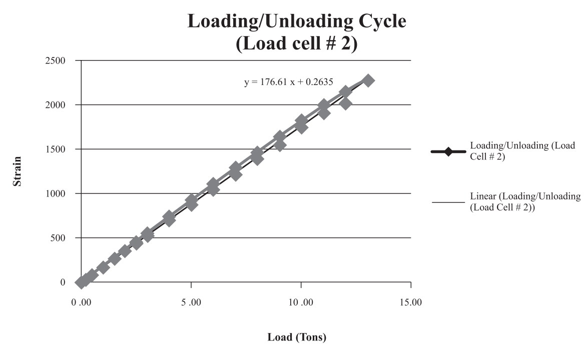

Figure 7: Loading and Unloading Graph of load Vs Strain (Load Cell # 2)

Developing Approach Ramps for Weigh Plates

As the dimensions of the weigh plate as decided were 28 inch x 20 inch, but it was 2 inch high (one inch of plate and one inch support) from ground i.e. it was uneasy for the tires to come on weigh plate without disturbing (imparting some lateral force to it) and moving it in horizontal direction. And it would disturb the alignment as well as position of weigh plates, thus making the data inconvenient.

For this purpose, it was decided to have approaches before and after weigh plates i.e. approach slope and recede slope. The slope provided was 6% i.e. the length of approach ramp was 33 inches, 2 inch high, and a stay i.e. flat portion of 6 inches was also there for the smooth passage of vehicle over weigh plate. The stay was increased to about 2 ft by adding additional wooden pieces.

Data Collection and Comparison

After laboratory calibration, it was desired to check the Weigh plates with actual weighs taken from weighing stations. For this purpose, arrangements were made to calibrate it in Hayatabad (Industrial zone) in front of an already built weigh station. The data was taken axle by axle of loaded trucks, by loading the plate. Both the weight of truck and the rare axle weight were also taken from the already built weigh station. The strains from the weigh plates were used in the equations developed in lab and results obtained in the form of loads. The variation in the data ranges between ± 20% which is well within the limits.

Figure 8: Axle wise weight of 4-axle truck while total weight being obtained at the same time from commercial weighing station

Figure 9: View of heavy vehicles in queue for Axle load

For field data collection, the specified locality is selected due to the availability of space for truckers to move on and off the weighing plates with convenience. The plates are placed parallel at the distance of 20.52″ from center. (Figure 8)

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

On the basis of this research work, the following conclusions were drawn

1. The results of the proposed weighing system were not very different than of existing system. However, this new system was found more flexible, easy to use, movable and cost effective.

2. Trucks in this study were found to carry 25% to 40% more load than permitted by NHA. This over-loading can reduce the design life of the pavement from 15 years to 6.14 and 4.20 years respectively. Thus effective life of the road pavement is reduced from 41% to 28%

3. The volume of 6-Axle truck only comprises of 9% of the total truck traffic and its average weight is 78.3 tons which is 27% above NHA permissible limits. The design of the road is bound to the weight of maximum load passing on the road.

Recommendation

1. The data of truck weights and volume collected in this research and previous work of the authors[14] can be used for developing live load model used for design of bridges in Pakistan.

2. It is of utmost importance to closely monitor over-loading menace .and robustly enforce load control mechanism for the effective, efficient and economic functioning of roads and allied infrastructure

3. All roads and particularly the intercity national highway networks should be designed keeping in view the modern truck weights and volume.

4. Robust statutory tools and well equipped enforcement intuitions supplemented with awareness of general public can effectively control overloading problem of commercial vehicles.

5. Weigh-in-motion (WIM) system should be installed on bridges in Pakistan which will eliminate the need for stopping the trucks.

REFERENCES

1. *A joint report of JICA and NTRC,2006."Pakistan Transport Plan study in the Islamic republic of Pakistan (PTPS)".*

2. *World Bank Website "web.worldbank.org"*

3. *Transportation Research Board, 1998, NCHRP Web Doc 13 Developing Measures of Effectiveness for Truck Weight Enforcement Activities: Final Report, The National Academies Press, Washington D.C., USA.*

4. *PIDE, 2010, Shahnaz Hamid, Rural to Urban Migration in Pakistan, Working Paper 2010:56, Pakistan Institute of Development Economics (PIDE), Islamabad.*

5. *"National Highway Authority" Ministry of Communication Government of Pakistan*

6. *WAVE, 1996, Weigh-In-Motion Axle and Vehicles for Europe, 4th Framework Program Transport, European RTD Project, RO-96-SC, 403*

7. *MOIP, 2009, Developing the Implementation Strategy for the Trucking Policy and Help Initiating the Implementation Process, Ministry of Industries & Production, Government of Pakistan, Islamabad.*

8. *Reuters, 2009 U.S. Senate Vote Imminent on Deadly and Destructive Overweight Truck Exemption, http://www.reuters.com/article/pressRelease/idUS111985+11-Sep-2009+PRN20090911.*

9. *Traffic monitoring Guide of US department of transportation (Federal Highway Authority)*

10. *Chhoeuy Roeun, Mom Mony, 2007, "Damage Effects of Road Pavements due to Overloading" https://www.academia.edu/1375429/Damage_Effects_of_Road_Pavements_due_to_Overloading_in_Cambodia*

11. *Multi Axis Load Cell (Design and Construction) by Andrei M. Reinhorn P.E PhD, Professor of Structural Engineering "University at Buffalo"*

12. *AASHTO, 1992 Guidelines for Traffic data Programs.*

13. *Richard M.Barker and Jay A. Puckett, 2007, "Design of Highway Bridges"*

14. *Syed Muhammad Ali, 2011, Structural Evaluation Report, "Report on feasibility study for Structural Evaluation of Bridges at Hayatabad, Peshawar"*