Analysis of Axle Loadings and Determination of Vehicle Damage Factor and Design of Overlay on Outer Ring Road in Bangalore, Karnataka

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Abstract— Over loading by commercial trucks in India is a serious problem. The over loaded trucks stress the road structure beyond safe bearing capacity. Traffic load is dominant function on pavement design because the main function of pavement is to resist traffic load. Efforts to repair of the road damages have been done, but almost meaningless since the overloading trucks keep in progress, even reached twofold from the normal load. In this work vehicle damage factors (VDF) is determined for single, dual, or multiaxle trucks. Average equivalent axle factors per vehicle. It can be seen that an average vehicle on the road adopted as case study, possesses an average equivalent factor of 3.0 which is about three times the standard axle weight for road pavements. This implies that an average truck on this road, used as case study causes the same pavement damage as three standard axles would cause. It shows that, there is high degree of overloading on the said road which is one of the major causes of pavement deterioration .The required overlay thickness has been calculated using WINFLEX 2000 software. The result analysis shows that the maximum axle loads were carried 3-axle trucks they carry the maximum average rear1axle load upto 10.45 tonnes and 10.16 tonnes on rear2 axle .So we need to prevent the trucks which were carrying wheel load more than 10 tonnes, otherwise they need an overlay thickness of 152mm. Overlay thickness for gross average loads of overall truck was 152 mm. From economical point of view providing 152mm thickness is not feasible, so as much as possible over loaded vehicles should be avoided on this road. From the results we have concluded that, enforced the 2-axle and 3-axle trucks which were carrying bulk manufactures, mining and quarrying.

Key words: Vehicle Damage factor, Axle Load Survey, Equivalence factor, Win flex, over loaded vehicles, Overlay

I. INTRODUCTION

Like most other developing countries, trucks in India carry loads much in excess of their rated capacity. The local truck body makers are producing wider and elevated truck bodies which enable the truck owners to reduce haulage costs. An axle load survey is carried out to determine the axle load distribution of the heavy vehicles using the road. These survey data are then used to calculate the mean number of equivalent standard axles for a typical vehicle in each vehicle class. These values are then combined with traffic flows and forecasts to determine the total predicted traffic loading that the road will carry over its design life in terms of millions of equivalent standard axles (MSA). If the flows of such vehicles are too high, a sample will need to be selected for weighing. However, not all types of vehicle need to be weighed. This is because almost all of the structural damage to a road pavement is caused by the heavy goods vehicles, medium goods vehicles, and large buses.

Thus it is not necessary to weigh vehicles of less than 1.5 tonnes weight, for example; motorcycles, cars, small buses or small trucks with single rear tyres. Large buses often have quite high axle loads and should be weighed in the survey. However, since many buses will pass the survey station repeatedly during the day with fairly similar payloads, to avoid unnecessary inconvenience it is often sufficient to weigh a smaller sample of buses than the sampling rate chosen for other vehicle types.

Overloaded vehicles causes serious damage to all roads, however, the problem may be even more serious in most of the country's first generation roads which are reaching the end of their design life. Furthermore, overloaded vehicles also become a traffic hazard, especially regarding the heavy vehicles braking system and additional braking distance involved.

The axle load weighing described in this project deals only with static weighing and does not deal with the weight of moving vehicles commonly termed Weigh-in-motion (WIM). Weigh-in-motion equipment has also become quite popular but it is less accurate and more expensive.

A. *Objective of the Present Case Study*

The objective of the present case study is to:

- To conducting axle load survey.
- To determine the equivalency factor.
- To determine the maximum overloaded vehicles.
- To determine the required overlay thickness

B. *Vehicle Classification*

The classification of vehicles into different types can vary according to the local conditions and the exact reason for the survey.

For some purposes, classifications are defined in such a way that vehicles can be assigned to them from a quick and purely visual inspection; in other words, irrespective of knowledge of a vehicle's unloaded weight or payload capacity.

The important point is that classifications can be flexible and those responsible for carrying out a survey should be aware of national practices

Heavy vehicle Category	Definitions
Buses	Seating capacity of 40 or more
Medium goods vehicle (MGV)	- 2 Axles incl. steering axle - 3 tonnes empty weight or more
Heavy goods vehicle (HGV)	- 3 Axles incl. steering axle - 3 tonnes empty weight or more

Very heavy goods vehicle (VHGV)	- 4 or more axles incl. steering axle - 3 tonnes empty weight or more

Table I: Heavy Vehicle Categories and definitions

II. PRESENT CASE STUDY

Outer ring road is the road that runs around most of the perimeter of Bangalore. This 62 km road was constructed by the Bangalore Development Authority and different sections were opened progressively between"2006-2012".

This road connects all major Highways around the city such as Tumkur road (NH-4), Bellary road (NH7), Old Madras road (NH-4), Hosur road (NH-7), Bannerghatta road, Kanakapura road(NH-209), Mysore road (SH-17), and Magadi road. It passes through major neighbourhoods and suburbs such as Hebbal (NH-7), K R Puram, Banashankari, Kengeri, Bangalore University, Nagarabhavi, Nandini Layout and Gokula.

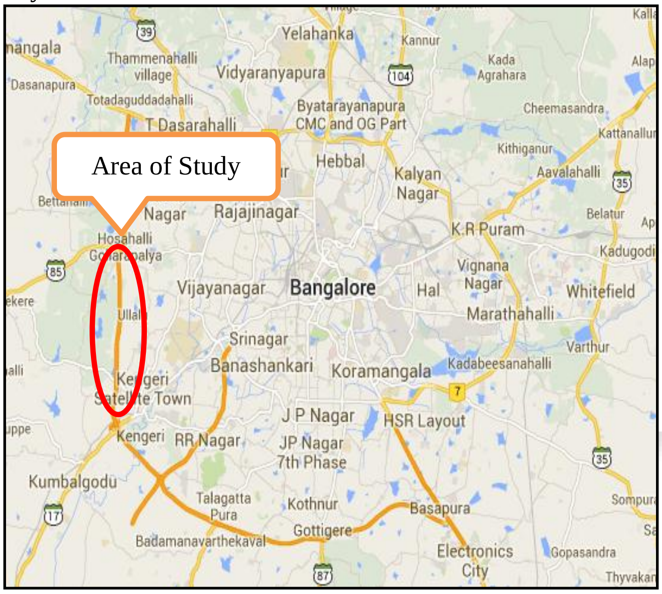

Fig. 1: Map showing the area of study

The axle load survey was conducted on the outer ring road, in between Nayandahalli to sumanahalli Junction and by the taking average of these and considering the seasonal variation of road temperature. By taking the loads of commercial vehicles, buses, truck etc, the vehicle damage factor and overlay thickness has been calculated

As per IRC:37-2012 the equations for computing equivalency factors for single, tandem and tridem axles given below should be used for converting different axle load repetitions into equivalent standard axle load repetitions. Since the VDF values in AASHO road test for flexible and rigid pavements are not much different, for heavy duty pavements, the computed values are assumed to be same for bituminous pavements with cemented and granular bases.

Single axle with single wheel on either side
$(\text{Axle load in kN}/65)^4$
Single axle with dual wheels on either side
$(\text{Axle load in kN}/80)^4$
Tandem axle with dual wheels on either side
$(\text{Axle load in kN}/148)^4$
Tridem axles with dual wheels on either side
$(\text{Axle load in kN}/224)^4$

III. DISTRIBUTION OF LOADED AND EMPTY VEHICLES BASED ON NUMBER OF AXLES AND MATERIALS CARRIED

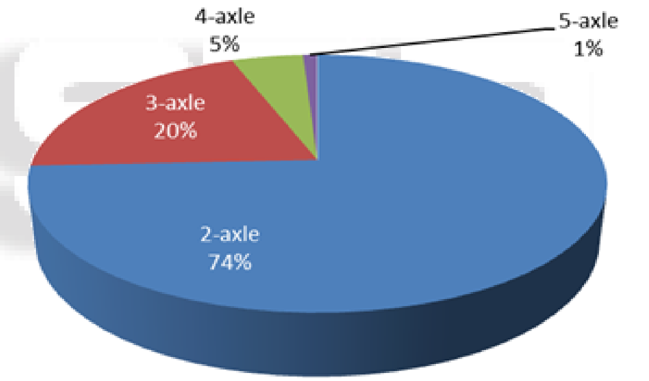

Fig. 2: Percentages of trucks and buses surveyed

Sl. No.	Vehicle Category	No. of Axles	Total No. of Vehicles (3 days)	Axle Load (Kg) single axle with single wheel	Axle Load (Kg) single axle with dual wheels on either side	Axle Load (Kg) Tandem axle	Axle Load (Kg) Tridem axle	Equivalent Factor (E.F) per Axle E.F (Axle load in kg/6500)^4	E.F (Axle load in kg/8000)^4	E.F (Axle load in kg/14800)^4	E.F (Axle load in kg/22400)^4	Total E.F	No of vehicles *EF	Average E.F (All Vehicles)
				1	2	3	4	1	2	3	4			
1	Buses	2	12	6080	6480	-	0	0.765	0.43	0	0	1.195	14.35	
2	Medium Truck	2	2879	5950	6250	-	0	0.702	0.37	0	0	1.07	3098	2.58 ≅ 3
3	Heavy Truck	3	619	7850	10450	20670	0	2.149	2.91	3.8	0	8.86	5488	
4	Very Heavy Truck	4/5	128	7370	7940	15580	0	2.149	0.97	1.22	0	4.35	556	
			3638										9152	A / B
			B										A	

Table: II Data analysis for Axle Load Survey As per IRC: 37 - 2012

A. Proportion of Overloaded Axles

With the standard axle of 80 kN resting on dual tyres on axle configuration, it can be assumed that the axle on single tyres is 6.5 kN. In line with above assumptions to the data of table no II, the respective overloaded axles are computed as:

3 – Axle 3 (619) + for 4 – axle 2(128) = 2113

Total number of buses and trucks axles = 2(12) + 2(2879) + 3(619) + 4(128). = 8151. Therefore, the proportion of overloaded axle for trucks = 2113/8151 =25% for entire traffic

From the axle weight conversion shown in table no II, it can be seen that an average vehicle on the road adopted as case study, possesses an average equivalent factor of 3 which is about 3 times the standard axle weight for road pavements.

IV. WINFLEX 2000

Winflex is a mechanistic-based overlay design system for flexible pavement. This program was developed at the Centre for Transportation Infrastructure (CTI), which is part of the National Institute for Advanced Transportation Technology (NIATT) at the University of Idaho (UI). The program was developed under a series of contracts with the Idaho Transportation Department (ITD). The original program (FLEXOLAY, 1996) is a DOS-based program; it was upgraded to a Windows-based program (WINFLEX) in 1997.

The 2000 version of the program is an update of the 1997 version, and includes many modifications.

Fig. 3: Output Screen of Results

Overlay (mm)	Fatigue damage on Overlay	Fatigue Damage on old AC	Fatigue on BTB	Rutting Damage	Fatigue Damage Due to past traffic
152.65	0.00001	0.9446	0	0	0

Table III Results Obtained in WINFLEX 2000

V. CONCLUSIONS

From the analysis of vehicle damage factor (VDF) calculation results, the conclusions can be drawn as follows.

- From the axle weight conversion shown in table II, it can be seen that an average vehicle on the road adopted as case study, possesses an average equivalent factor of 3, which is about 3 times the standard axle weight for road pavements. This implies that an average truck on this road, used as case study causes the same pavement damage as three times standard axles of would cause. It shows that, there is high degree of overloading on the said road which is one of the major causes of pavement deterioration.
- About 25% of overloaded trucks which were moving on this stretch.
- The detrimental effect of 3-axle trucks is high compared to other axle trucks which carrying about 17% of overall traffic. The average gross load is 27.28 tonnes, while that on the front axle, it was the 6.67 tonnes, 10.45 tonnes on rear1 axle and on the rear2 axle, it was 10.16tonnes. Trucks carrying bulking, quarrying and mining materials which have high detrimental effect to the pavements From the Winflex software, 152mm is maximum required overlay thickness for average overloaded vehicles.
- Relative strength of pavement structure decreased by overloading of single axle truck
- The higher the overloading, the higher decreasing of relative strength of pavement structure.
- India like most developing countries is facing with the dilemma of vehicle over loading. The vehicle loads flying on the roads are much heavier than the strength of the infrastructure of the country. Most of the road infrastructure was built 30-40 years ago, when there was no anticipation of the heavier loads of today, as the economic activity was low and transportation by trucks was small as compared to railways. But today, the situation has entirely changed and goods transportation by railways has been mostly shifted to road.
- The reason for the heavier axle loads on our roads is not only that fleet of new and more capacious trucks have been introduced which has radically altered the axle road distribution on the road, but also mainly attributed to the overloading tendency of the trucks. In order to compete and keep themselves in the market by keeping the haulage cost at minimum, the truck owners have the tendency of vehicle loading to the extent much beyond their rated capacity. To carry the extra payloads, the truck owners strengthen the body of the trucks by adding extra springs, making the body strong and increasing the height of the truck body
- Though the haulage cost is reduced by overloading, which results in the economic benefit to the country, but it causes the premature failure of the road pavements. This result in the loss of billions of rupees invested in road infrastructure.
- The question now arises is that what options we have been left with to resolve this dilemma. In most of the developed countries, the problem has been solved by imposing axle load limit in the country and having strict enforcement. But unfortunately in most of the developing countries,

either there doesn't exist any legislation or in case even if it exists, it is not followed.

- In Bangalore outer ring road, the situation is not different from other developing countries. In the absence of legal axle load limit in the country, the commercial vehicles are loaded by truck owners to the extent that a truck normally carries over twice its rated payload.

To resolve the situation we are left with two options:

- Build / improve our road infrastructure to withstand heavier loads.
- Impose axle load limit and exercise strict enforcement. This seems to be the only viable solution for saving our road infrastructure from the deterioration due to overloading and bringing it at par with international standards. Most of the highway engineers believe that unless a limit of axle load is imposed, no matter how strong pavements are built, would fail under the prevailing heavy loaded vehicles. The vehicle overloading is seriously handicapping the improvement of road network in many developing countries.

Overlay thickness for gross average load of all trucks was152 mm. From economical point of view providing 152 mm thickness is not feasible, so as much as possible over loaded vehicles should be avoided on the road. So we have concludes that, enforced the 2-axle and 3-axle trucks which were carrying bulk manufactures, mining and quarrying commodity.

VI. SCOPE FOR FUTURE STUDIES

These studies can be used in future for the purpose of designing roads,

- Axle load survey should be conducted in various seasons for knowing the seasonal variations that occur in traffic,
- This studies can be used for development of highways in future,
- This studies can used for finding the efficiency & serviceability of roads,
- Necessity of electronic traffic counting instruments are required in high traffic volume counts,
- Overloading trucks can be avoided for increasing life span of pavements or thickness of pavements should be increased for better life span.

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