EVALUATION OF VEHICLE DAMAGE FACTOR IN OVERLOADING FOR DIFFERENT TYPES OF LOADING

A Thesis Submitted

In partial fulfillment of the requirement

For the Degree of

Master of Technology

in

Transportation Engineering

By

YOGESHWAR KUMAR SINGH

(1170465004)

Under the guidance of

Prof D.S. RAY

PROFESSOR

In

Department Of Civil Engineering

BABU BANARSI DAS UNIVERSITY, LUCKNOW

June, 2019

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CERTIFICATE

This is to certify thesis entitled **"EVALUATION OF VEHICLE DAMAGE FACTOR IN OVERLOADING FOR DIFFERENT TYPES OF LOADING"** which has being carried out by Mr. Yogeshwar Kumar Singh (Roll No. 1170465004) for partial fulfillment of requirement for the award of Master of Technology degree in Transportation Civil Engineering of Babu Banaras Das University, Lucknow, is a record of his work carried out by him under the guidance and supervision. The result embodied in this thesis has not been submitted elsewhere for award of any other degree or diploma.

Prof. D.S. Ray
(Supervisor)
Department of Civil Engineering
BBD University, Lucknow

DECLARATION

I, hereby declare that the work which is being presented in the **M.Tech** Thesis Report entitled **"EVALUATION OF VEHICLE DAMAGE FACTOR IN OVERLOADING FOR DIFFERENT TYPES OF LOADING"** in fulfillment of the requirements for the award of the Master Of Technology in **Transportation Engineering (Civil Engineering)** and submitted to the Department of Civil Engineering of Babu Banarasi Das University, Lucknow (U.P.) is an authentic record of our own work carried out during the period from August 2017 to June 2019 under the guidelines of **Prof. D.S. Ray, Department Of Civil Engineering**. The matter presented in this thesis has not been submitted by me for the award of any other degree elsewhere.

Prof. D.S. Ray
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YOGESHWAR KUMAR SINGH
(Roll No. 1170465004)

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Finally, I want to express my deep gratitude to my friends and family who always loved, supported and encouraged me throughout this challenging process.

Thank You

YOGESHWAR KUMAR SINGH

(Roll No. 1170465004)

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

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. 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. 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. There are many factors which affect the design and maintenance of pavements. These factors include gross load, tyre pressure, type of load, number of wheels and type of wheel configuration, number of repetitions, subgrade properties, moisture content, environmental conditions, temperature, type of material used in pavement construction, etc. Commercial vehicles especially Trucks are the major consumers of the Road network, applying the heaviest loads to the pavement. Truck loads are transferred to the pavement through various combinations of axle configurations depending on the truck type. Tandem and Tridem axles have more wheels than do single axles and so they can carry a heavier load while introducing the same magnitude of stress on the pavement. Hence, knowledge of axle loadings and spectrum of axle loads of vehicles using a road system is necessary in the development and application of realistic pavement design and maintenance procedure

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.

It is observed from the study, that the percentage of overloading of commercial vehicles is very high, which result in greater extent of damage to the pavement, thus reducing the serviceable life of pavement. From analysis, it is observed that the rate of the growth of deterioration is less when enforcement is implied. It implies that there is necessary to strengthen the pavements much earlier with the present trend of overloading when compared with the enforcement situation, wherein the tandem axles / equivalent standard axle trucks are used to reduce the overloading effect. Hence, there is a need for an early maintenance in order to retain the structural integrity of the pavement which results in higher life cycle costs. The benefits in terms of lower maintenance cost are evident in case of overloading enforcement, with a lower Life Cycle Cost. It is recommended that the strict enforcement is necessary on axle load limit and introduction of multi-axle trucks, including tandem axle trucks to optimize the total transportation cost of the highway system.

1.2 PROBLEM STATEMENT

Most of the modern truck engines are capable of hauling much heavier loads than the legal upper limit. Therefore the truck owners and operators have a tendency to overload these trucks enabling them to get more returns for the same investment and manpower. One of the major factors affecting pavement life is the magnitude and frequency of the wheel load repetitions imposed on the pavement structure. In order to maintain the heavy gross vehicle weight and still stay within the legal axle load limits, the trucking industry has devised the multiple axle configurations, which include rear tandem axle trucks. 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. Structural damage to a road is caused almost exclusively by commercial vehicles expected to use it during its life. As observed i\n most of the developing countries, over loading of trucks in India also has assumed menacing proportions, endangering the pavement stability and road safety (MOT, Govt. of India 1992). Overloading is restored to by transport operators to economize in the cost of operations, resulting in axle-loads generally much higher than the standard prescribed limits. In the whole, the pavement of existing highways are grossly inadequate (structurally) to bear the rise in axle loads, keeping in view the fact that in some cases the damage caused to pavement by the heaviest 10% of the vehicles in the traffic stream by far greater than the total damage caused by the remaining 90% put together (MOST, Govt. of India, 1994).

1.3 IMPORTANT KEYWORDS

Here, we are discussing some of the major keywords used.

1.3.1 VEHICLE DAMAGE FACTOR

The Vehicle Damage Factor (VDF) is a multiplier to convert the number of commercial vehicles of different axle loads and axle configuration into the number of repetitions of standard axle load of magnitude 80 kN. It is defined as equivalent number of standard axles per commercial vehicle. The VDF varies with the vehicle axle configuration and axle loading. The objective is to evaluate vehicle damage factor from overloading. The guidelines use Vehicle Damage Factor (VDF) in estimation of cumulative million standard axle for thickness design of pavements. In case of cemented bases, cumulative damage principle is used for determining fatigue life of cementitious bases for heavy traffic and for that spectrum of axle loads is required. The following is the basic steps to evaluate vehicle damage factor:-

- To carry out the axle load or truck weight survey.
- To evaluate load equivalency factor and equivalent standard axle load by using axle load survey data.
- To evaluate vehicle damage factor by using above variables.

Every passage of a vehicle on a pavement will cause a certain amount of damage or distress in different forms. The degree of damage caused by a vehicle depends on its gross weight, number of axles as well as configuration of wheels. For example, if two vehicles have equal gross load, one with a single axle single wheel and the other with a tandem axle dual wheel assembly, the damage caused by the former vehicle will be greater. This is because the gross load is transferred onto the pavement surface over a wider area by more number of axles and wheels.

The damage caused by different vehicles is calculated using the vehicle damage factor which is used for performance modelling, design and maintenance of pavements. The vehicle damage factor (VDF) is a numerical value which represents the equivalent number of standard axles per truck (IRC: 37-2001). It is a multiplication factor used to convert different commercial vehicles with varying axle load repetitions to standard axle load repetitions.

From axle load survey data, VDF is calculated using the following equation. 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 pavement are not much different, for heavy duty pavements, the computed VDF values are assumed to be same for bituminous pavements with cemented and granular bases.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 pavement are not much different, for heavy duty pavements, the computed VDF values are assumed to be same for bituminous pavements with cemented and granular bases.

Single axle with single wheel on either side $= \left(\frac{\text{axle load in kN}}{65}\right)^4$

Single axle with dual wheels on either side $= \left(\frac{\text{axle load in kN}}{80}\right)^4$

Tandem axle with dual wheels on either side $= \left(\frac{\text{axle load in kN}}{148}\right)^4$

Tridem axles with dual wheels on either side $= \left(\frac{\text{axle load in kN}}{224}\right)^4$

1.3.1.1 VEHICLE DAMAGE FACTOR FORMULA

The vehicle damage factor is evaluated using the following formula:-

$$\text{VDF} = \frac{\sum_{i=1}^{N} [V_i \times \text{LEF}_i]}{N}$$

where, V_i = Traffic volume of the ith vehicle load-class

LEF_i = Load equivalency factor of ith vehicle load-class

N = Total number of vehicles weighed

1.3.1.2 FACTORS AFFECTING VEHICLE DAMAGE FACTOR

Factors affecting VDF numerous factors which are related to damage or distress caused to pavement affect VDF. The factors may be related to traffic composition at the time of survey, load on axles, possible occasional (or seasonal) overloading, number of axles, wheels configuration, terrain, type of pavement, region, pavement condition, temperature, rainfall etc. In pavement design, VDF obtained from axle load survey data should be used rather than an assumed value because the VDF value obtained from survey data represent a realistic value by considering actual traffic loading and other factors related to the region (or pavement' considered.

1.3.2 AXLE LOAD

The axle load of a wheeled vehicle is the total weight felt by the roadway for all wheels connected to a given axle. Viewed another way, it is the fraction of total vehicle weight resting on a given axle. Axle load is an important design consideration in the engineering of roadways and railways, as both are designed to tolerate a maximum weight-per-axle (axle load); exceeding the maximum rated axle load will cause damage to the roadway

The only effective way to compare the damaging effect of traffic on given roads is to measure the complete spectrum of axle loads and calculate the appropriate equivalence factors. The main purpose of the axle loads for trucks survey is to collect preliminary information regarding the range of heavy axle loads traversing the nation's main highways. With axle load calculation for trucks, road authorities can make better decisions on which stretch to repair and which part of the road or pavement to prioritize, in order to optimize traffic flow. The data helps reduce the effects of overloading and prevents accelerated damage to pavement.

With a comprehensive study of axle loads for trucks road planning departments can ensure that existing roads are appropriately maintained so that they provide appropriate level of service for road users across a longer duration. These surveys also assist to improve existing road conditions to meet the necessary standards in order to enable them to carry prevailing levels of traffic with the desired level of safety. The total weight of the vehicle is carried by its axles. The load on the axles is transferred to the wheels and this load is ultimately transferred on the surface of the pavement in the contact with tyres.

To keep wheel load induced stresses on pavement within allowable limit the total vehicle load is distributed onto wider areas of pavement by using more axles and wheels. This is the reason why more number of axles and wheels are fitted to heavy load carrying trucks. The VDF varies with the vehicle axle configuration and axle loading. There are following types of axles:-

- Single axle
- Tandem axle
- Tridem axle

When conducting an axle load survey the validity of the two following assumptions are made:

- The load on the wheels of an axle remains constant at all times, i.e. remains the same as it was when the vehicle was originally loaded
- The load exerted on the road by any wheel of any vehicle, whether at rest or in motion, is constant and determined by the initial load distribution of the vehicle.

To keep wheel load induced stresses on pavement within allowable limit the total vehicle load is distributed onto wider areas of pavement by using more axles and wheels. This is the reason why more number of axles and wheels are fitted to heavy load carrying trucks.

VDF should be arrived at carefully by carrying out specific axle load surveys on the existing roads. Minimum sample size for survey is given in Table 1.1. Axle load survey should be carried out without any bias for loaded or unloaded vehicles. On some sections, there may be significant difference in axle loading in two directions of traffic. In such situations, the VDF should be evaluated direction wise. Each direction can have different pavement thickness for divided highways depending upon the loading pattern.

Table 1.1 Sample size for axle load survey

Total number of commercial vehicle per day	Minimum percentage of commercial traffic to be surveyed
<3000	20 percent
3000<6000	15 percent
>6000	10 percent

1.3.2.1 AXLE LOAD SPECTRUM

The spectrum of axle load in terms of axle weights of single, tandem, tridem and multi-axle should be determined and compiled under various classes with class intervals of

10 kN, such as 10 kN, 20 kN and 30 kN for single, tandem and tridem axles respectively.

Where sufficient information on axle loads is not available and the small size of the project does not warrant an axle load survey, the default values of vehicle damage factor as given in Table 1.2. may be used.

Table 1.2 Indicative VDF values

Initial traffic volume in terms of commercial vehicles per day	Rolling/plain terrain	Hilly terrain
0 - 150	1.5	0.5
150 - 1500	3.5	1,5
More than 1500	4.5	2.5

1.3.2.2 MEASUREMENT OF AXLE LOAD

There are two methods to weigh truck or axle loads:-

1. Static weighing
2. Weighing In Motion (WIM)

In static weighing vehicles are stopped and weighed but WIM vehicles are weighed dynamically while in motion. In the static method, the axle load of a vehicle is weighed using portable weights or load-pads (Fig. 1.2) or a weighing platform.Only axle loads having more than or equal to 3 tonnes are taken into account for analysis since the damage caused by axles weighing less than 3 tonnes is negligible. For traffic analysis:-

Vehicles having axle weight = 3 tonnes or more are referred to as commercial vehicles

1.3.2.3 COMPARISON BETWEEN STATIC WEIGHING METHOD AND WEIGHT IN MOTION METHOD

Table 1.3

Sl. No.	Static weighing method	Weight in motion (WIM)
1	Vehicles are stopped and weighed	Vehicle are weighed automatically while in motion, without disturbing the driver.
2	Accurate weight measurement	Weight measurements may be influenced by parameters related to vehicle speed, suspension system of the vehicle, tyre pressure, acceleration and deceleration of the vehicle and dynamic forces produced due to pavement roughness, wind velocity etc.
3	Takes more time and interrupts free flow of; may pose problems related to safety	There is no such interruption to flow traffic; can weigh high volumes of traffic.
4	Other information such as body type of vehicles, loading type etc. can be physically ascertained.	Collection of other information is not possibly by automated WIM equipment.
5	Less number of vehicle can be measured; selected vehicles are weighed; need more personnel, time and space, to weigh all vehicles.	More number of vehicles can be measured; better coverage of all vehicle since its automatic.
6	Less installation and maintenance cost.	High installation and maintenance cost.
7	The weigh pads can be installed at any location.	WIM equipment can be installed at fixed location only.

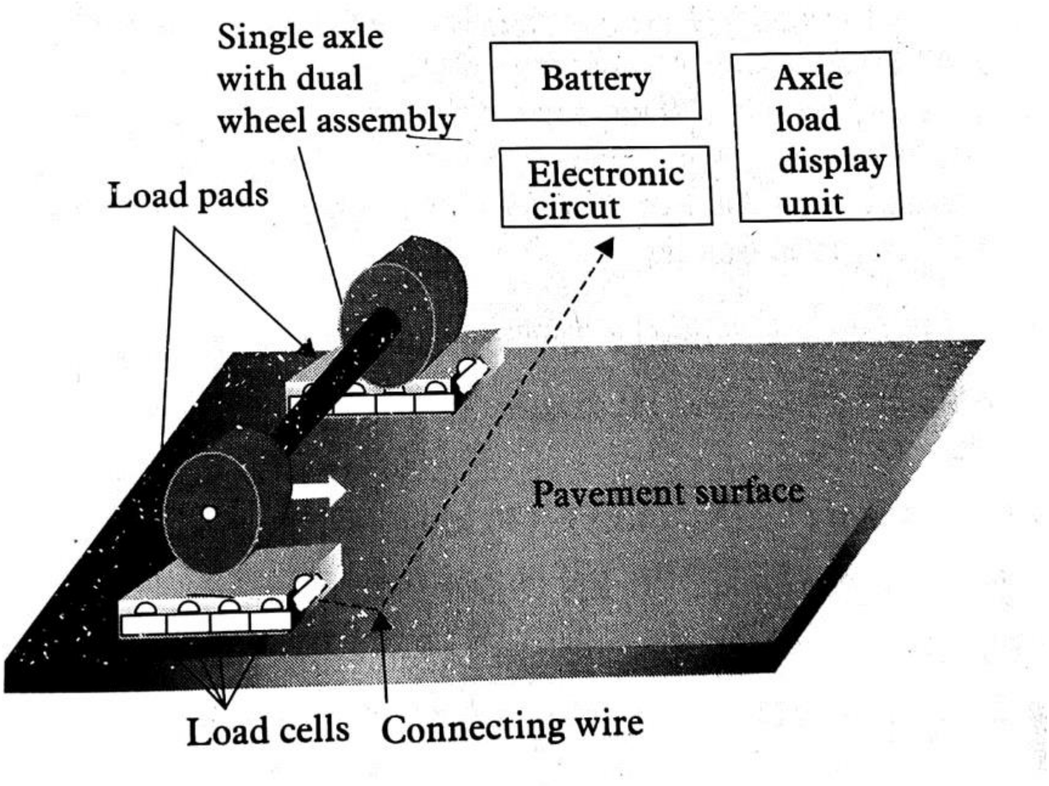


Figure 1.1 Static Axle load measurement

Figure 1.2 Weighing pads for weight in motion

Figure 1.3 Weighing pads for weight in motion with truck load

1.3.3 PERMISSIBLE AXLE LOAD LIMIT IN INDIA

The Ministry of Road Transport & Highways has issued a notification (18-July-2018) increasing permissible truck axle load. As per the amended rules, the maximum safe axle weight of each axle type in relation to the transport vehicles (other than motor cabs), with regard to the size, nature and number of tyres would be as follows :-

Table 1.4 Permissible axle load limit in India

Sl. no	Axle type	Maximum safe axle weight
1	**Single axle**	
1.1	Single axle with single tyre	3.0 tonnes
1.2	Single Axle with two Tyres	7.5 tonnes
1.3	Single Axle with four Tyres	11.5 tonnes*
2	**Tandem Axles (Two axles) (where the distance between two axles is less than 1.8 Mtr.)**	
2.1	Tandem axle for rigid vehicles, trailers and semi-trailers	21 tonnes*
2.2	Tandem axle for Puller tractors for hydraulic and pneumatic trailers	28.5 tonnes

3	**Tri–axles (Three axles) (where the distance between outer axles is less than 3 Mtr.)**	
3.1	Tri-axle for rigid vehicles, trailers and semi-trailers	27 tonnes*
4	**Axle Row (two axles with four tyres each) in Modular Hydraulic trailers** (9 tonnes load shall be permissible for single axle)	18 tonnes

* Note: If the vehicle is fitted with pneumatic suspension, 1 tonne extra load is permitted for each axle.

The amendment lays down that the gross vehicle weight (GVW) will not exceed the total permissible safe axle weight as above and in no case shall exceed:-

- 49 tonnes in case of rigid vehicles
- 55 tonnes in case of semi-articulated trailers and truck-trailers except modular hydraulic trailers.

It further lays down that Modular hydraulic trailers can carry goods of indivisible nature of any load subject to the regulatory approvals as may be required.

Briefing correspondents about the following decision in New Delhi Shri Nitin Gadkari, Minister of Road Transport & Highways, Shipping, Water Resources, River Development and Ganga Rejuvenation said the decision to increase axle load was taken with a view to help in increasing the carrying capacity of goods transport vehicles and bring down logistics cost. He said the amendment will increase the carrying capacity of goods vehicles by about 20-25 % and lower logistics costs by about 2%. The Minister further said that while automobile technology and road construction quality have improved greatly over the years, the axle loads have remained the same since 1983 when they were last notified. There was a felt need to harmonize the axle load with international standards. Shri Gadkari also said that overloading rules will be implemented very strictly. State governments are also being requested to enforce the provisions against overloading very strictly and not allow vehicles to move till the excess load has been removed.

To safeguard pavements against overloading, different agencies (government or any competent authority) in different countries have prescribed maximum allowable limits of axle load depending on their method of compaction, materials used, considerations related to mix design as well as pavement crust thickness. The maximum allowable axle load limit is referred to as the legal axle load limit. This means that no axle of a vehicle should carry more than the legal axle load.

1.3.4 STANDARD AXLE LOAD

Generally, the load carried by any one truck is not the same as that carried by an axle. Each axle load will impart a certain amount of damage or distress on the pavement. The degree of distress caused by different loads of axle will increase as the magnitude of load and repetitions increase. Under mixed traffic conditions, repetitions of different axles having different loads, plying on a road will not indicate any meaningful value related to how much damage has been caused to the pavement due to their combined action. Different axle loads will cause different degrees of damage. Therefore, it is customary to convert repetitions of axles having different loads to an equivalent standard axle load. Configuration of the Indian standard single axle with dual wheel assembly is presented in Figure 1.4.

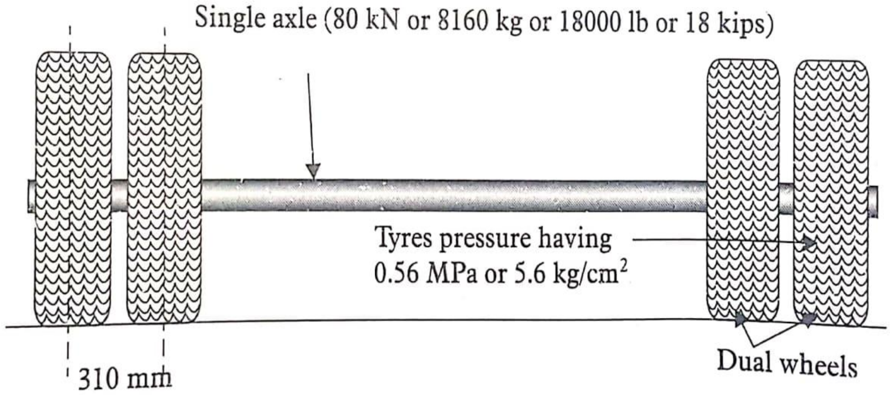


Figure 1.4 Details of Indian standard axle

Charts have been prepared for a specified number of repetitions of standard axle load on the pavement layers. The remaining life of in-service pavements is also incorporated in the charts and specified in terms of number of repetitions of the standard axle.

According to the Indian practice (IRC: 37-2001), standard axle load (W_{std}) is prescribed as 80 kN (8,160 kg) and 146.836 kN (14,968 kg) for single and tandem axles respectively. But according to AASHTO, the value of standard axle load (W_{std}) is taken as 64.7 kN (6600 kg), 80 kN (8160 kg) and 147.68 kN (15100 kg) for single axle single wheel, single axle dual wheel and tandem axle four wheels respectively (AASHTO 1993; Yoder and Witczak 1975).

Value of the standard axle load considered for designing flexible pavements by different agencies world-wide are given below.

- South African Mechanistic design method: 80 kN (Theyse et al. 1997)
- CARE and ASCON (Road and Hydraulic Engineering Institute, Delft): 100 kN (CROW report D06-06)
- French Design Manual (LCPC, Paris): 130 kN (CROW report D06-06)
- Shell Pavement Design Manual: 80 kN (Shell 1978)
- CROW design procedure for thin asphalt pavements: 100 kN (CROW report D06-06)
- Road Note 29, UK: 80 Kn

1.3.5 EQUIVALENT STANDARD AXLE LOAD

Although it is not too difficult to determine a wheel or an axle load for an individual vehicle, it becomes quite complicated to determine the number and types of wheel/axle loads that a particular pavement will be subject to over its design life. Furthermore, it is not the wheel load but rather the damage to the pavement caused by the wheel load that is of primary concern.

The most common historical approach is to convert damage from wheel loads of various magnitudes and repetitions (“mixed traffic”) to damage from an equivalent number of “standard” or “equivalent” loads. The most commonly used equivalent load is the 18,000 lb. (80 kN) equivalent single axle load (normally designated ESAL). At the time of its development it was much easier to use a single number to represent all traffic loading in the somewhat complicated empirical equations used for predicting pavement life.

Equivalent single axle load is calculated by using the load equivalency factors (LEF) from AASHTO Guide for Design Pavement and Structure and then multiplying it to the frequency of the vehicle class. It will give the Equivalent Single Axle load for desired Average axle load.

1.3.6 LOAD EQUIVALENCY FACTOR

Load equivalency factor (LEF) is a number which relates the amount of equivalent damage caused by a given load of axle to the standard axle load. Based on field test data, AASHTO has recommended specific load equivalency factors for single and tandem axles (Table 6.1). These LEFs were developed based on the effect of wheel load on serviceability of pavements. Equivalent standard axle loads (ESALs) may be calculated from the following relationship.

Repetitions of equivalent standard axle loads (ESALs) = Load equivalency factor (LEF)*No. axles observed.

1.3.7 FOURTH POWER DAMAGE RULE

'The following relationships equation (a) and (b)) developed from the AASHO road test data (AASHTO 1962) are widely used to determine equivalent standard axle load (ESAL) repetitions when axle load data of different axles is available. This relationship is popularly known as the fourth power damage rule.

$$\frac{N_1}{n_2} = \left(\frac{w_2}{W_1}\right)^4 \quad (1.1)$$

$$\text{Load equivalency factor (LEF)} = \left(\frac{W_m}{W_{std}}\right)^4 \quad (1.2)$$

Where,

- N_1 is a number representing repetitions of axle loads each having a weight equal to W_1
- n_2 is a number representing repetitions of axle loads each having a weight equal to w_2
- W_m = Measured axle load obtained from axle load (survey data)
- W_{std} = Standard axle load

Equation (1.1) may also be explained as the damage caused by N_1 number of repetitions of axle having weight W_1 is equal to the damage caused by n_2 number of repetitions of axle having weight W_2.

The exponent value in equations (1.1) and (1.2) is not a constant value of 4 because these are empirical relationships which were developed based on traffic characteristics, strength of pavement layers, in situ and environmental conditions.

As the thickness of the pavement decreases and temperature increases, the exponent value varies from 2.5 to 4.6. Higher exponent values are observed when the strength of the pavement is not enough to resist wheel loads.

The following equation was used by Caltrans of California (USA) to estimate the equivalent single axle loads (ESALs) of transit bus data (from Gibby et al. 1996).

$$\text{ESAL} = \sum N \left(\frac{W_m}{80.12} \right)^{4.2} \tag{1.3}$$

Where,

- W_m = axle load (kN)
- N = axle repetitions of a given load or axle number

The ESAL factors are also determined by comparing stress caused by a given vehicle to the stress caused by a standard vehicle. This relationship is referred to as the Vesic model and is given below (from Lin et al. 1996).

$$F_j = \left(\frac{\sigma_j}{\sigma_s}\right)^4 \qquad (1.4)$$

The ESAL factor may also be determined by (Yoder and Witczak 1975),

$$F_j = \frac{d_j}{d_s} = \frac{N_s}{N_j} \qquad (1.5)$$

Where,

- F_i = ESAL factor
- σ_j = stress caused by vehicle j
- σ_s = stress caused by standard vehicle s
- d_j = damage per pass of vehicle j
- d_s = damage per pass of vehicle s
- N_1 = number of passes until failure of pavement due to load of vehicle j
- N_2 = number of passes until failure of pavement due to load of standard vehicles

1.3.8 VEHICLE CLASSIFICATION

The classification of vehicle is done on the basis of the load carrying capacity of the vehicle. The heavy vehicle category is useful for our experiment and it is further categorized by number of axles and load carrying capacity.

The overloaded vehicle causes more damage to the pavement which directly affects the maintenance cost of the road. The vehicle classification for the heavy vehicle category of:-

- Articulated Commercial Vehicles and Rigid Chassis Commercial Vehicle

Table 1.5 Rigid Chassis Commercial Vehicle

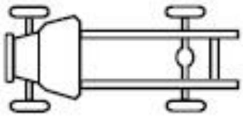
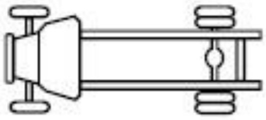
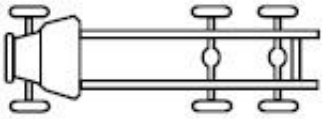
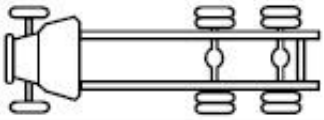
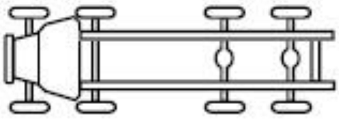
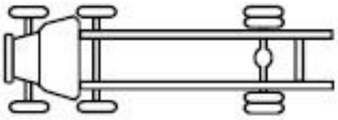
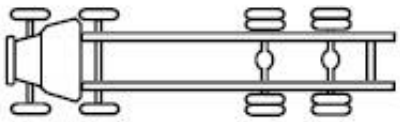
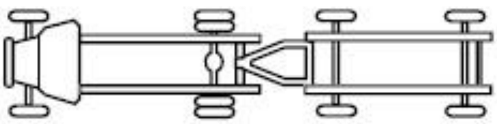
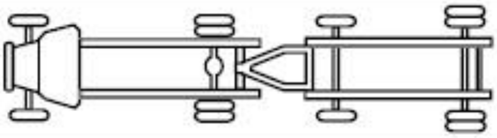
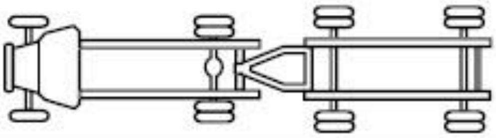
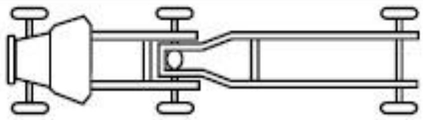
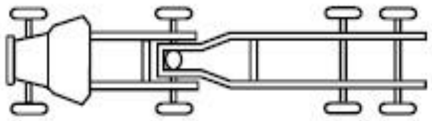
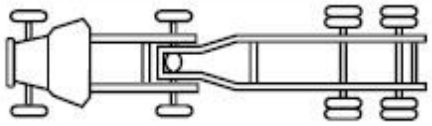
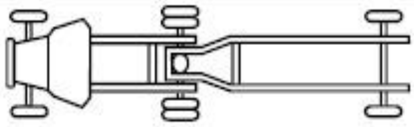
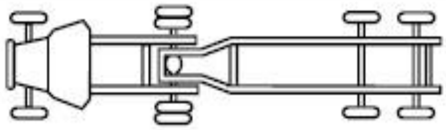
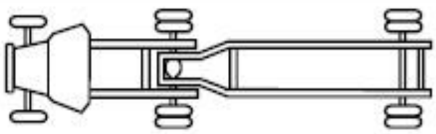
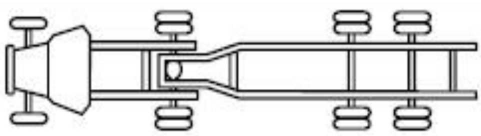
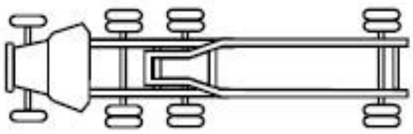
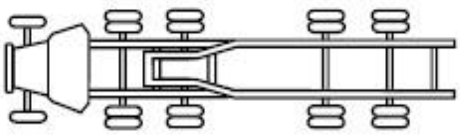
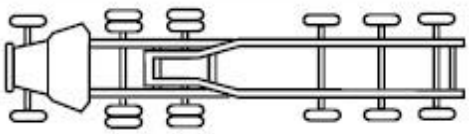
RIGID - CHASSIS COMMERCIAL VEHICLES		
	11	Single tyres on front and rear axles
	12	Single tyres on front axle Twin tyres on rear axle
	1.11	Single tyres on front axle Twin tyres on rear axles Two rear axles
	1.22	Single tyres on front axle Twin tyres on rear pair of axles Two rear axles
	11.11	Single tyres on front pair of axles Single tyres on rear pair of axles
	11.2	Single tyres on front pair of axles Twin tyres on rear axle
	11.22	Single tyres on front pair axles Twin tyres on rear pair of axles
	1.2 + 1.1	TRAILERS Single tyres on both axles
	1.2 + 1.2	Single tyres on front axle Twin tyres on rear axle
	1.2 + 2.2	Twin tyres on both axles

Table 1.6 Articulated Commercial Vehicles

ARTICULATED COMMERCIAL VEHICLES		
	1.1 - 1	Single tyres both axles of tractor Single tyres axle of trailer
	1.1 - 11	Single tyres on both axles of tractor Single tyres on both axles of trailer
	1.1 - 22	Single tyres on both axles of tractor Twin tyres on both axles of trailer
	1.2 - 1	Single tyres on front axle of tractor Twin tyres on rear axle of tractor Single tyres on axle of trailer
	1.2 - 11	Single tyres on front axle of tractor Twin tyres on rear axle of tractor Single tyres on both axleS of trailer
	1.2 - 2	Single tyres on front axle of tractor Twin tyres on rear axle of tractor Twin tyres on axle of trailer
	1.2 - 22	Single tyres on front axle of tractor Twin tyres on rear axle of tractor Twin tyres on both axle of trailer
	1.22 - 2	Single tyres on front axle of tractor Twin tyres on both rear axles of tractor Twin tyres on rear axleS of trailer
	1.22 - 22	Single tyres on front axle of tractor Twin tyres on both rear axles of tractor Twin tyres on both rear axles of trailer
	1.22 - 111 1.22 - 222	Single tyres on front axle of tractor Twin tyres on both rear axles of tractor Single/twin tyres on axles of tractor

1.4 OBJECTIVE OF STUDY

This study aims to analysis of the vehicle damage factor in overloading for different types of loading. 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 multi-axle trucks for different vehicle classification. The spectrum of axle load in terms of axle weights of single, tandem, tridem and multi-axle should be determined and compiled under various classes with class intervals of 10 kN, such as 10 kN, 20 kN and 30 kN for single, tandem and tridem axles respectively.

VDF should be evaluated carefully by carrying out specific axle load surveys on the existing roads. The idea is to use axle load survey data to evaluate Equivalent Single Axle Load (ESAL) and the Vehicle Damage Factor and then further analyse the pavement to determine the required overlay thickness.

To evaluate the vehicle damage factor the first step is to carry out the axle load survey. The axle load survey gives us the data to evaluate the equivalent single axle load and then further by using load equivalency factors, the vehicle damage factor is evaluated. Since the axle load survey is carried out only for the heavy vehicle category, the vehicle damage factor values increases.

When conducting an axle load survey the validity of the two following assumptions are made:

- The load on the wheels of an axle remains constant at all times, i.e. remains the same as it was when the vehicle was originally loaded.
- The load exerted on the road by any wheel of any vehicle, whether at rest or in motion, is constant and determined by the initial load distribution of the vehicle.

These assumptions disregard the fact that the load concentration on a wheel or an axle changes continuously when the vehicle is in motion. After the evaluation of the vehicle damage factor, its value is used in the determination of the million standard axle load which further used for the analysis of VDF (Vehicle Damage Factor), MSA (Million standard axles) and axle load survey data. The information obtained can be used in the final computation of pavement layers.

The reason for selected the heavy vehicle category is that the major damage done to the pavement of highway is by this category only. Thus it is not necessary to weigh vehicles of less than 1.5 tones weight, for example; motorcycles, cars, small buses or small trucks with single rear tyres. Sometimes large buses have quite high axle loads and therefore should be weighed in the survey. The product of average axle load and the load equivalency factor gives the equivalent single axle load which further results in vehicle damage factor. The vehicle which is useful for our study is categorised in the table below.

Table 1.7 Commercial vehicles (heavy vehicle category)

Heavy vehicle category	Definitions
Buses	- Seating capacity of 40 or more
Medium goods vehicle (MGV)	- 2 axles including steering axle - 3 tonnes empty weight or more
Heavy goods vehicle (HGV)	- 3 axles including steering axle - 3 tonnes empty weight or more
Very heavy goods vehicle (VHGV)	- 4 or more axles including steering axle - 3 tonnes empty weight or more

CHAPTER 2

LITERATURE REVIEW

The following are the previous research review based on the analysis and evaluation of vehicle damage factor and it’s related important aspects

Shahul Hameed[1] (2018) conducted a study on impact of vehicle overloading on national highways in varying terrains. Pavement damage is mainly due to factors such as poor quality of materials used, poor construction practices, temperature variations, weather conditions, environmental changes, etc. One of the most important factors in the recent years is the pavement damage due to the overloaded trucks and the overloading effects caused by the increased truck traffic volume. Government of India has framed certain standards based on various research publications for the loads to be carried by the trucks with respect to their axle configuration. But the truck operators seldom follow these standards and regulations. This practice of overloading the trucks will have a direct impact on the pavements getting more damaged. It is expected that the impact of overload on roads in hilly terrain is more vulnerable than that in the plain terrain. This is mainly due to the change in gradient and thereby the load distribution in the vehicle. The impact caused by different classes of truck over the pavement is determined by the Vehicle Damage Factor (VDF). An attempt has been made in this study to determine the impact of vehicle damage factor caused by the overloaded vehicle on National Highways passing through varying terrain conditions. The major objectives of this work is to analyse the impact of overloaded trucks on flexible pavements and to study the variations in VDF in detail for various class of trucks with respect to varying loading and terrain condition. The scope of the work is limited to National Highway stretches NH-66 (Plain terrain) and NH744 (Hilly terrain) in Kanhangad and Kollam districts of Kerala. VDF was calculated considering two scenarios in both the terrain conditions. Scenario 1 implies the actual VDF values obtained and in scenario 2, the VDF value is determined by distributing the additional load from overloaded trucks to a new vehicle class. The result shows that the VDF values calculated shows a higher variation in both the scenarios in varying terrain conditions. As the VDF value increases, the pavement life will be reduced. Higher

VDF values necessitate thicker pavements and hence the pavement construction and maintenance costs will be increased. Pavement damages due to very high VDF value impose the need for frequent overlays before the design life period. This means that the design period of the pavement get attenuated before the actual design life and hence frequent strengthening measures such as overlay should be done in order to keep them in good condition. Therefore thickness and cost variation analysis is also performed as part of this study to estimate the varying cost.

Sunil Kumar. R[2] (2014) conducted a study on analysis of axle loadings and determination of vehicle damage factor and design of overlay on outer ring road in Bangalore, Karnataka. 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 multi-axle 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. The objective of this case study was to conducting axle load survey, to determine the equivalency factor, to determine the maximum overloaded vehicles and to determine the required overlay thickness

J. C. Pais [3] (2013) conducted a study on impact of traffic overload on road pavement performance. Traffic on a road pavement is characterized by a large number of different vehicle types, and these can be considered in pavement design by using truck factors to transform the damage they apply to the pavement to the damage that would be applied by a standard axle. The truck factors to convert trucks into standard axles or the load equivalent factors to convert axles into standard axles are defined by considering the average loads for each axle. This process includes the vehicles that travel with axle loads above the maximum legal limit. There are also a substantial number of overloaded vehicles in terms of total vehicle weight. These axles/vehicles cause significant damage to the pavements, increasing the pavement construction and rehabilitation cost. Thus, this paper investigates the impact of overloaded vehicles on road pavements by studying the truck factors for different vehicle cases applied to a set of pavements composed of five different asphalt layer thicknesses and five different subgrade stiffness moduli. The study revealed that the presence of overloaded vehicles can increase pavement costs by more than 100% compared to the cost of the same vehicles with legal loads.

Luis G. Fuentes[4] (2012) conducted a study on the evaluation of truck factors for pavement design in developing countries. The traffic represents a fundamental parameter used in the analysis and design of pavement structures. In order to simplify the characterization of the traffic variable for pavement structural analysis and design, the vehicle axles are converted to a number of 80 kN Equivalent Single Axle Loads (ESALs) through the Load Equivalency Factors (LEF). A Truck Factor represents the ESALs applications per commercial vehicle. This study determined the Truck Factors for commercial vehicles operating in Colombia. The high Truck Factor values found in this investigation could be used to explain the current critical condition of Colombian road infrastructure. The objective of the present research is to appropriately characterize the traffic condition of the Colombian´s highway network, creating a database with reliable and updated information for the purpose of pavement design.

The investigation presented the results of thirty-eight (38) mobile weigh stations that were positioned on different strategic points of the Colombian national road network to characterize the traffic condition of the country. This activity engaged seventeen out of thirty-two departments and four out of the six regions that make up the Colombian territory. The weight stations were monitored 24 hours for seven consecutive days, which allowed collection of data for 59,622 heavy commercial vehicles.

Sai Bruhaspathi [5] (2012) conducted a study on pavement design of nation highway, a case study on reducing pavement thickness. The National Highway, NH-6, from Kolkata in West Bengal to Hazira Port in Gujarat is a major connecting link between West Bengal, Orissa, Chhattisgarh, Maharashtra and Gujarat. The project road stretches from Saraipali-Pitora-Tumgaon-Arang of NH-6 in the districts of Mahasamund & Raipur in the state of Chhattisgarh. The Project in study starts at Chainage km 160 Manra Village and ends at Chainage km 180 Janpalli Village which is 92 km from Raipur, the Capital City of Chhattisgarh State. The project is located at approximately between N: 21° 19’ 20’’ E: 83° 30’ 46” and N: 21° 11’ 36’’ E: 81° 58’ 19” and passing through the Districts of Mahasamund and Raipur. Design for new pavement is worked out in accordance with prevalent practices in the country. The design of new flexible pavement is carried out as per IRC: 37-2001 [1]. The pavement design is done using Mechanistic Empirical principles with non-conventional materials i.e. laying cemented base/sub-base layer. This pavement design study will help, if non-conventional pavement design is adopted in the construction of pavement, there will be improved performance of the pavement thus increasing the life and leading to financial savings

P. Ram Mohan Rao[6] (2010) conducted study on the effect of commercial traffic overloading enforcement on pavement performance. There are many factors which affect the design and maintenance of pavements. These factors include gross load, tyre pressure, type of load, number of wheels and type of wheel configuration, number of repetitions, subgrade properties, moisture content, environmental conditions, temperature, type of material used in pavement construction, etc. Commercial vehicles especially Trucks are the major consumers of the Road network, applying the heaviest loads to the pavement. Truck loads are transferred to the pavement through various combinations of axle configurations depending on the truck type. Tandem and Tridem axles have more wheels than do single axles and so they can carry a heavier load while introducing the same magnitude of stress on the pavement. Hence, knowledge of axle loadings and spectrum of axle loads of vehicles using a road system is necessary in the development and application of realistic pavement design and maintenance procedure. It is observed from the study, that the percentage of overloading of commercial vehicles is very high, which result in greater extent of damage to the pavement, thus reducing the serviceable life of pavement. From analysis, it is observed that the rate of the growth of deterioration is less when enforcement is implied. It implies that there is necessary to strengthen the pavements much earlier with the present trend of overloading when compared with the enforcement situation, where in the tandem axles, equivalent standard axle trucks are used to reduce the overloading effect. Hence, there is a need for an early maintenance in order to retain the structural integrity of the pavement which results in higher life cycle costs. The benefits in terms of lower maintenance cost are evident in case of overloading enforcement, with a lower Life Cycle Cost. It is recommended that the strict enforcement is necessary on axle load limit and introduction of multi-axle trucks, including tandem axle trucks to optimize the total transportation cost of the highway system.

Shaifu [7] (2009) conducted a case study on vehicle damage factor analysis on freight transport vehicles. An accurate estimation of the current traffic load is essential for an appropriate pavement design, because pavement thickness and durability depend on the carrying loads. The accurate estimation of vehicle loads can only be obtained by an axle load survey. Overload on the traffic often considered as the main factor that shortens pavement life time. The information about axle loads is required so that accurate forecast can be made. A methodology is outlined using traffic volume, vehicle type and axle load data to estimate the VDF value. Data from a weight bridge have been collected and analyzed. The weight bridge unit, which comprises weigh pads and two unit digital weighing indicator, were available on Jl. Jogja-Prambanan sta 700. The data were collected continuously for 2 x 24 hours since 20th to 22nd October 2008 for each commercial vehicle and include axle loads, number of axle, tire configuration, vehicle type and vehicle direction. The weigh pads measure each axle loads and then digital weighing indicator shows axle loads value. Hourly traffic volumes were counted manually. Some preliminary data analysis including vehicle classification and direction were done on site by the surveyor. Further data analysis used Excel spreadsheet computer program to calculate equivalent single axle loads (ESALs), vehicle damage factor (VDF) and traffic analysis period. Beside real axle loads data which were obtained on the surveys, standard axle load limit and the default VDF were used as a comparison. The result of this study was the real VDF value for Jogja-Prambanan highway. Traffic composition was dominated by 95 percent of passenger cars and light buses. The composition of commercial vehicle was 5 percent from the total traffic volume. The differences of traffic analysis period resulted from real axle loads and the default VDF as 21.46 percent were also gained. This was caused by different assumptions on the vehicle types and axle load, especially on 60 passenger heavy buses. Overloading problem resulted in 11.65 percent differences in traffic analysis period. Those results may be used as a consideration to improve the default VDF, design and analysis of pavement structures as well as the law enforcement.

Hassan Salama[8] (2006) conducted a study on effect of heavy multiple axle trucks on flexible pavement damage using in-service pavement performance data. Truck axle configurations and weights have changed significantly since the AASHO road study was conducted in the late 1950s and early 1960s. Emerging concerns about the effects of new axle configurations on pavement damage, which is unaccounted for in the AASHTO procedure, have prompted several researchers to investigate the impacts of different axle and truck configurations on pavement performance. However, there is still a need to strengthen the mechanistic findings using field data. In this paper, actual in-service traffic and pavement performance data for flexible pavements in the state of Michigan are considered. Monitored truck traffic data for different truck configurations are used to identify their relative damaging effects on flexible pavements in terms of cracking, rutting, and roughness. The analysis included simple, multiple, and stepwise regression. The results indicated that trucks with multiple axles (tridem or more) appear to produce more rutting damage than those with only single and tandem axles. On the other hand, trucks with single and tandem axles tend to cause more cracking. Pavement roughness results did not show enough evidence to draw a firm conclusion.

E W H Currer[9] (2005) submitted a report on commercial traffic: its estimated damaging effect. The geometric design of a road is based on an estimate of the expected total flow of traffic, including cars, and on the changes likely to occur in that traffic during the life of the road. Structural damage to a road is caused almost exclusively by commercial vehicles and for the structural design of the road it is therefore necessary to characterise the cumulative damaging effect of commercial Vehicles expected to use it during its life. Similar information is required in order to estimate the remaining life of an existing road or to design strengthening measures for it. Heavier axles cause more damage than lighter ones; the damaging power is considered to be related to the fourth power of the axle load. Design procedures must therefore take into account the spectrum of axle loads in the commercial traffic. In the nineteen-fifties attempts were made by the Road Research Laboratory to sample the axle loads present in commercial traffic using portable weighing platforms and by the end of the decade the Laboratory had developed a weighbridge suitable for permanent installation in the running surface of the road and capable of recording automatically the weight of wheels passing over it. In succeeding years the effectiveness of the equipment has been further improved.

Morris De Beer[10] (1997) conducted a study on equivalent damage factor for multiple load and axle configuration. This paper describes the procedure developed for extending the existing HVS (Heavy Vehicle Simulator) based method. The method is then applied to the assessment of the effects of: wheel load, contact stress, single and dual wheels, and single, tandem and tridem axles. As a result, the procedure enables determination of EDFs for accurate estimation of equivalent traffic for design purposes and performance analysis. This, in principle, may facilitate the development of guidelines on permissible axle loads and tyre pressures for different axle configurations. Extensive research with the Heavy Vehicle Simulator (HVS) over the past 20 years has led to improved fundamental understanding of pavement response and performance and has permitted the development of effective EDFs for single-axle loads. A major limitation of this approach, however, is that it does not directly facilitate the calculation of EDFs for multiple axle configurations. Each pavement is associated with a particular distress mode governed by a specific pavement response (strain, stress or deflection). This response, in turn, controls the performance of the pavement. Thus, for example, if a load generates a specific amount of strain (or stress) at a specific position in the pavement which governs the pavement performance, that pavement is defined as having equal response only if the same strain (or stress) level is reached at the same position under a different load configuration. The Equivalent Damage Factor permit the prediction of the performance of pavement and materials under multiple wheel and axle load configurations. Pavement performance is expressed in relative terms by comparison of the performance of the pavement under a standard axle (SA) to its performance under the vehicle loading configuration being investigated. By using the SA, the EDF of a given heavy vehicle represents the equivalent number of 80 kN axles per such heavy vehicle (ESAs or E80s per heavy vehicle).

B.M. Sharma[11] (1995) conducted a study on effects of vehicle axle loads on pavement performance. The ever increasing vehicle population and heavy axle loads has caused substantial damage to Indian roads. Trucks carry loads much in excess of legal limits and are largely responsible for poor road conditions in addition to the inadequate structural capacity of pavements and diminishing allocation of funds year after year for maintenance and rehabilitation. Very huge capital investments are now needed to upgrade and rehabilitate the existing road network to make it capable to withstand high stresses and tyre pressures caused by heavy wheel loads. In view of very remote possibility of such large magnitude of funds ever becoming available in the near future, one of the best course to remedy the situation would be to strictly enforce the legal axle limits. Pavement performance data base generated and pavement deterioration models developed from the Pavement Performance Study, recently completed in the country, and has been used/applied for the present analyses. An attempt has been made in this paper to evaluate the effects of heavy axle loads on pavement performance in terms of increase in service life if overloading is restricted through strict enforcement. Further detailed analyses is planned to be done for obtaining reliable and accurate results.

John A. Deacon[12] (1969) conducted a study on equivalent axle loads for pavement design. One significant means for evaluating the relative destructive effects of repetitive vehicular loading on highway pavements is the equivalent axle load concept. To apply this concept to design situations, proper methods must be available for making valid predictions of equivalent axle loads for design that are based on data gleaned from traffic volume counts, vehicle classification studies, and loadometer surveys. This paper reports on the development and testing of such a predictive method for rural highways in Kentucky. The problem was treated as three separate but interrelated parts: (a) development of a proper methodology and identification of pertinent traffic parameters, (b) identification of relevant local conditions that serve as indicators of the composition and weights of the traffic stream, and (c) development of significant relationships between the traffic parameters and the local conditions. Percentages of the various vehicle types and the average equivalent axle loads per vehicle were selected as the most significant traffic parameters. These were empirically related by multiple regression and other techniques to the set of local conditions, which included road type, direction, availability and quality of alternate routes, type of service provided, traffic volume, maximum allowable gross weight, geographical area, and season. The resultant methodology was judged to be sufficiently accurate, simple, reasonable, and usable to satisfy the problem requirements. It is recommended for use, however, only when valid, long-term vehicle classification and weight data are unavailable for the route under investigation.

CHAPTER 3

METHODOLOGY

3.1. INTRODUCTION

To evaluate the vehicle damage factor the first step is to carry out the axle load survey. The axle load survey gives us the data to evaluate the equivalent single axle load and then further by using load equivalency factors, the vehicle damage factor is evaluated.

Since the axle load survey is carried out only for the heavy vehicle category, the vehicle damage factor values increases. The reason for selected the heavy vehicle category is that the major damage done to the pavement of highway is by this category only. Thus it is not necessary to weigh vehicles of less than 1.5 tones weight, for example; motorcycles, cars, small buses or small trucks with single rear tyres. Sometimes large buses have quite high axle loads and therefore should be weighed in the survey. The product of average axle load and the load equivalency factor gives the equivalent single axle load which further results in vehicle damage factor

3.2.AXLE LOAD SURVEY

The truck loads have a big impact on pavement conditions depending on the type of axles used (single or multi-axles). Our axle load surveys enable determining Vehicle Damage Factors (VDF).

Axle loads and gross vehicle weights can be measured by static or dynamic methods. In a static method, vehicles are stopped to measure their axle loads. In a dynamic method, axle loads are measured without stopping the vehicle or diverting it from other traffic; weigh-in-motion (WIM) technology has many advantages and several types of dynamic weighing equipment are now available worldwide.

The axle load survey is the first and the most important step in the evaluation of the vehicle damage factor. Light vehicles (gross weight less than 5.0 tonnes) cause minimal structural damage to road pavements, and therefore such vehicles are not included in axle load surveys and should therefore not be weighed.

Buses with seating capacity of more than 40 seats have, very often large axle loads and such capacity of more than 40 seats have, very often large axle loads and such buses must always be included in the survey.

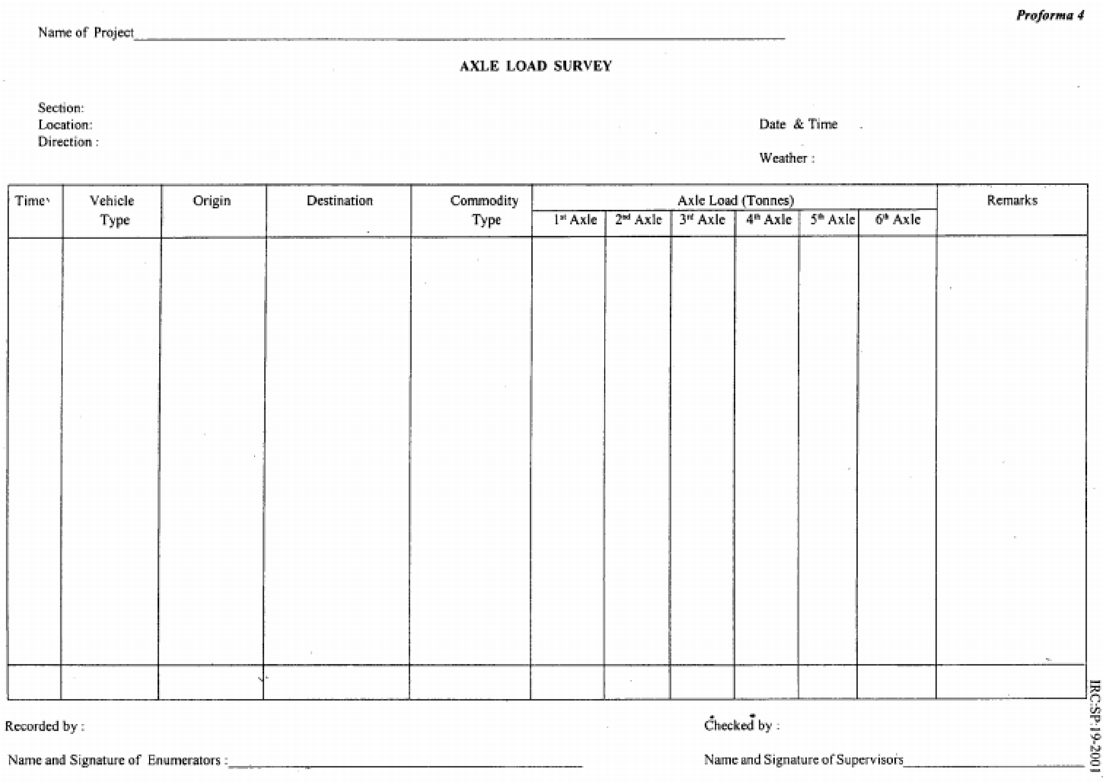
The axle load survey should consider the two traffic directions separately, as it is very rare that the traffic loading are similar for the two directions of traffic. Very often there is a significant difference in loading between the two directions of traffic. An axle load survey will among other things give the average vehicle equivalent factors (VEF) for a particular vehicle category and cumulative axle load distribution. It is, therefore, important to also include all the empty vehicles.

The axle load weighing described in this Guideline deals only with static weighing and does not deal with the weight of moving vehicles commonly termed Weigh - in - motion (WIM). Axle load survey is needed to generate data for pavement design. Portable weigh bridges are very useful for this purpose. This survey shall be carried out along with classified volume count survey.

Number of days of survey will depend on project location, the type of project and the intensity and expected variation in traffic. This survey duration may vary between 24 hours and 3 days, but should be carried out at least for one day at the traffic count stations on a random basis for commercial vehicles. Buses may be omitted as their weight can be easily calculated and they do not result in excessive overloads. The period of conducting the survey should also be judiciously selected keeping in view the movement of commodity/destination oriented dedicated type of commercial vehicles. While finalising the design Equivalent Standard Axle load, the following should be considered.

- Past axle load spectrum in the region as well as on the road to the extent available.
- Annual variation in commercial vehicles.
- Optimistic and pessimistic considerations of future generation of traffic.
- Generation of changing VDF factor during the project period

To input the value of the axle load survey, typical proforma 4 given in IRC-SP 19 2001was found to be very useful for this survey.



Proforma 4

Name of Project_______________

AXLE LOAD SURVEY

Section:
Location:
Direction :

Date & Time

Weather :

Time	Vehicle Type	Origin	Destination	Commodity Type	Axle Load (Tonnes)						Remarks
					1st Axle	2nd Axle	3rd Axle	4th Axle	5th Axle	6th Axle	

Recorded by :

Name and Signature of Enumerators :_______________

Checked by :

Name and Signature of Supervisors_______________

IRC:SP:19-2001

Figure 3.1 Axle load survey

Since the axle load were in the gross weight, to distribute them, the following method was used:-

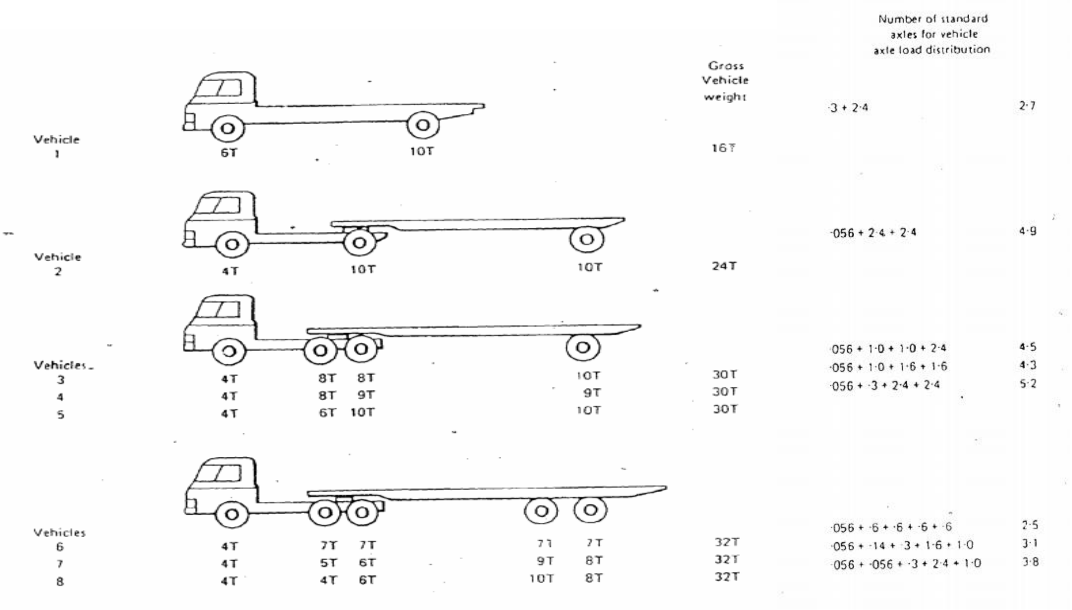


Figure 3.2 Axle load distribution

3.3.AXLE LOADING OF COMMERCIAL VEHICLE

The only effective way to compare the damaging effect of traffic on given roads is to measure the complete spectrum of axle loads and calculate the appropriate equivalence factors. Only those vehicles of unladen weight exceeding 1525 kg (30 CWT) are classified as commercial vehicles for pavement design purposes. A commercial vehicle may be fully loaded, unloaded or in an intermediate condition. The axle loads which it imposes on the road, and the structural damage which it will do depend on the degree of loading.

The term axle load is also applicable to trucks which is complicated by the fact that trucks may have more than two wheels per axle. In this case, the axle load remains the same, but the load borne by the individual wheels is reduced by having more contact area (more wheels, larger tires, lower tire pressure) to distribute the load

To assess the severity of a given traffic Row' in terms of the damage it may do to the pavement it is necessary to know the composition of the axle loads in terms of their weights. This is often termed the axle-load spectrum of the traffic.

To assess the potential damage which a particular vehicle will do to a pavement. The individual axle loads of that vehicle must be known. Further to quantify the damage which a particular class of vehicle will do, the average loading of the axles of that class of vehicle when in service is required. Some information on axle loading can be obtained by stopping a selection of vehicles and measuring the individual wheel loads on portable weighing platforms.

This procedure is tedious, and because of the comparatively small number of vehicles which can be sampled the information obtained tends to be unreliable. The transport and Road Research Laboratory developed in 1958 an automatic weigh bridge which could be permanently installed in the carriage way surface to give a continuous record of axle loading. The equipment is normally calibrated to record half axle-loads in increments of 910 kg (2000 lb), the top classification being 8160 kg (18000 lb) and above. Alternatively the Individual axles of particular vehicles can be weighed' and shown on a visual display which can be photographed together with the vehicle being recorded.

3.4. AXLE CONFIGURATION AND LOADS

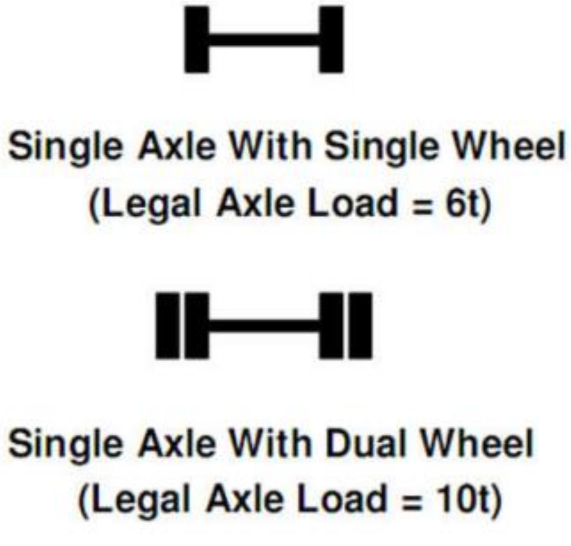


Figure 3.3 Single axle

The figure shows the single axle with single wheel whose legal axle load limit is 6 tonnes and the single axle dual with dual wheel whose legal axle load limit is 10 tonnes.

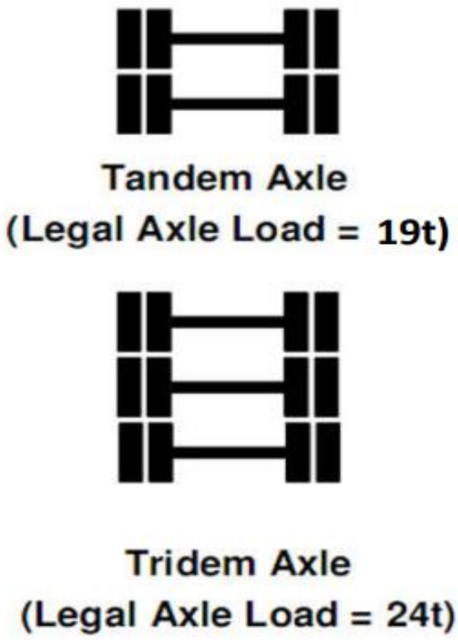


Figure 3.4 Tandem axle and tridem axle

The figure shows the dual axle with dual wheel whose legal axle load limit is 19 tonnes and the triple axle dual with dual wheel whose legal axle load limit is 24 tonnes.

2 Axle Truck – 16t …………………….

3 Axle Truck – 24t …………………….

4 Axle Semi Articulated – 34t …………

4 Axle Articulated – 34t………………..

5 Axle Truck – 40t………………………

LCV …………………………………….

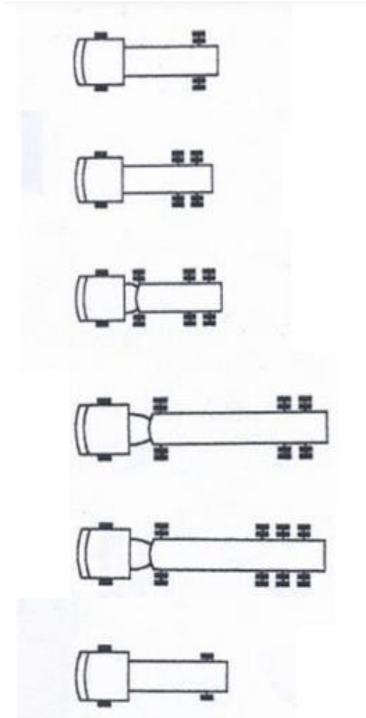


Figure 3.5 Tandem axle and tridem axle trucks

Figure 3.6 Different types of commercial vehicles

Figure 3.7 Tridem axle trucks in India

Figure 3.8 Single axle with dual wheels trucks

Figure 3.9 Tridem axle trucks open view without trailer

Figure 3.10 Tridem axle with tandem axle trucks, open view without trailer

Figure 3.11 Tandem axle truck with convertible to tridem axle

Figure 3.12 Tandem axle Tata tipper

Figure 3.13 Steerable front dual axle

Figure 3.14 Tandem axle dual wheel

Figure 3.15 Tandem axle + tandem axle tipper

Figure 3.16 Single axle vehicle

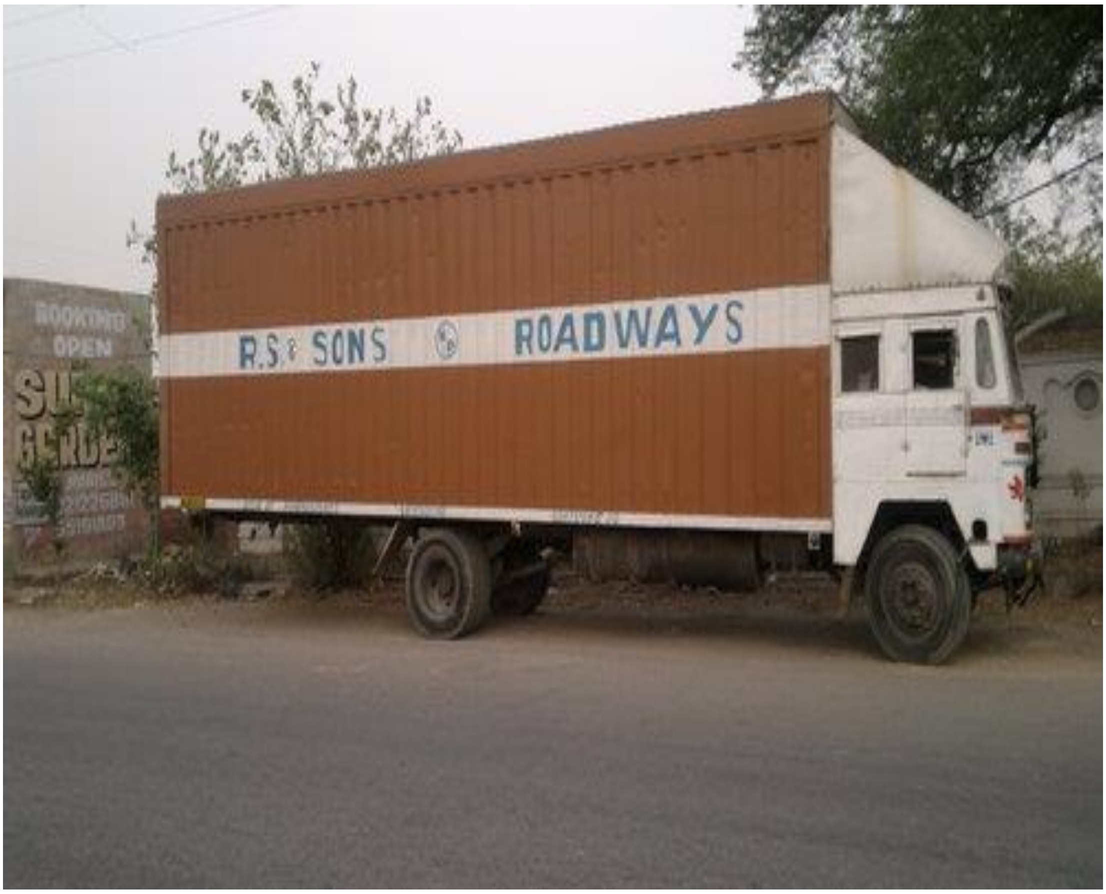


Figure 3.17 Single axle truck with large closed trailer

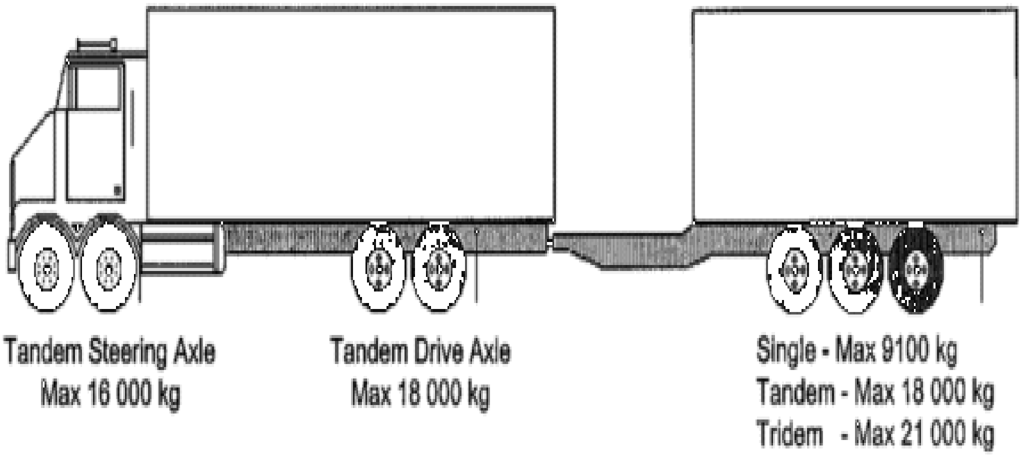


Figure 3.18 Distribution of load on different axle

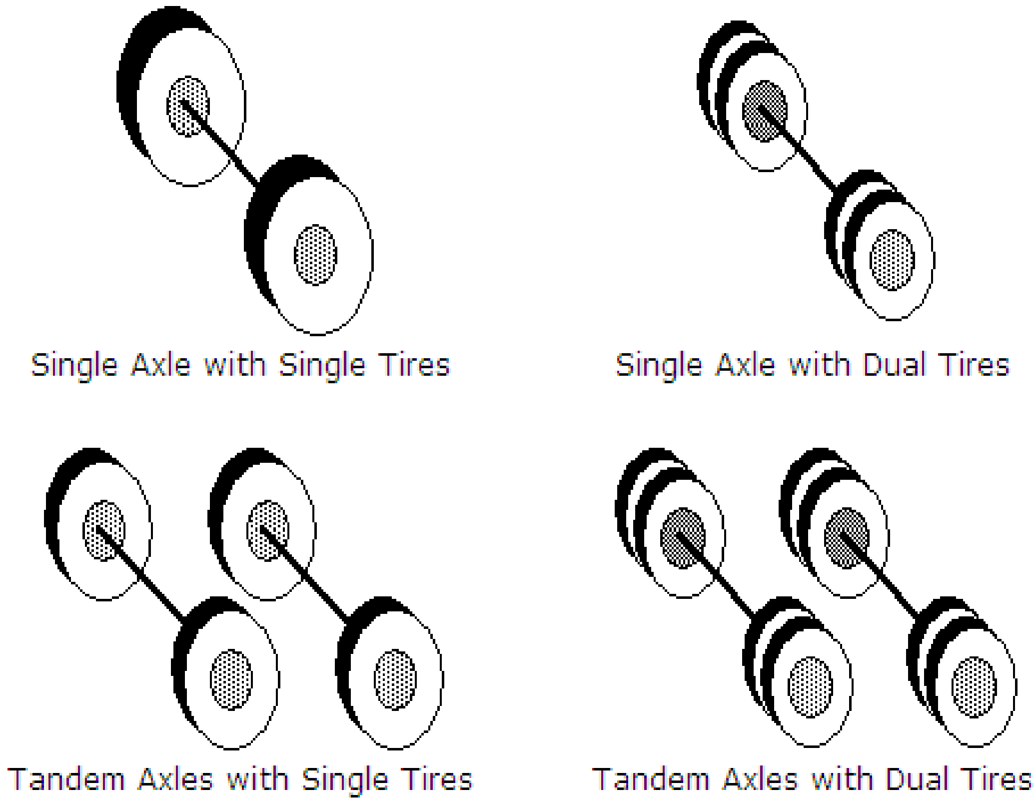


Figure 3.19 Different types of axles with single and dual wheels

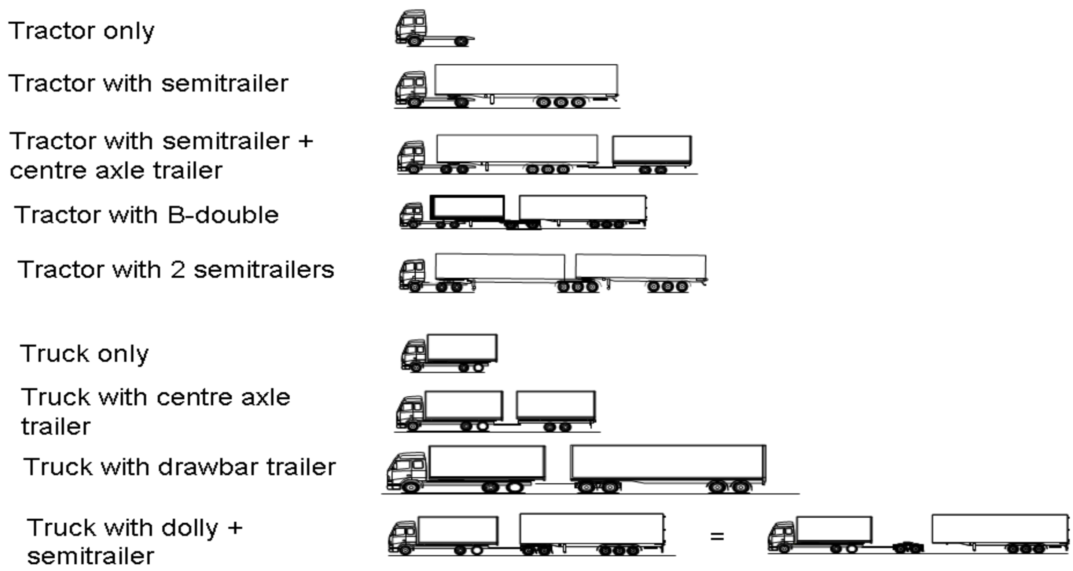


Figure 3.20 Different types of axles with trailers

Figure 3.21 Tandem axle truck with semi-trailer

Figure 3.22 Tandem axle bus

Figure 3.23 Tandem axle bus side view

Figure 3.24 Common trucks in India

Figure 3.25 Multiple axle truck in India

3.5.EFFECT OF WHEEL CONFIGURATION

The effect of axles 1, 2 and 3 on stresses and strains within pavement layers are considered independently. Within a group of axles, each axle is not considered as independent.

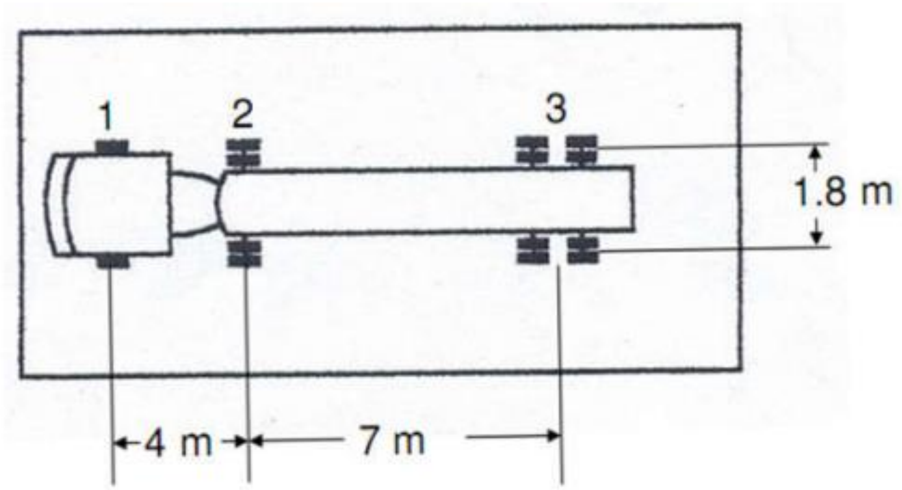


Figure 3.26 Effect of axle on 1, 2, 3 axle

In flexible pavement design by layer theory, only the wheels on one side are considered for the calculation purpose and in rigid pavement design by plate theory, the wheels on both sides are usually considered (even when distance > 1.8 m) for the calculation

3.6. EQUIVALENT SINGLE WHEEL LOAD (ESWL)

To carry maximum load with in the specified limit and to carry greater load, dual wheel, or dual tandem assembly is often used. Equivalent single wheel load (ESWL) is the single wheel load having the same contact pressure, which produces same value of maximum stress, deflection, tensile stress or contact pressure at the desired depth. The procedure of finding the ESWL for equal stress criteria is provided below. This is a semi-rational method, known as Boyd and Foster method, based on the following assumptions:

- equalancy concept is based on equal stress;
- contact area is circular;

- influence angle is 45°; and
- Soil medium is elastic, homogeneous, and isotropic half space.

The ESWL is given by:

$$\log_{10} ESWL = \log_{10} P + \frac{0.301 \log_{10}\left(\frac{z}{d/2}\right)}{\log_{10}\left(\frac{2S}{d/2}\right)} \tag{3.1}$$

where P is the wheel load, S is the centre to centre distance between the two wheels, d is the clear distance between two wheels, and z is the desired depth.

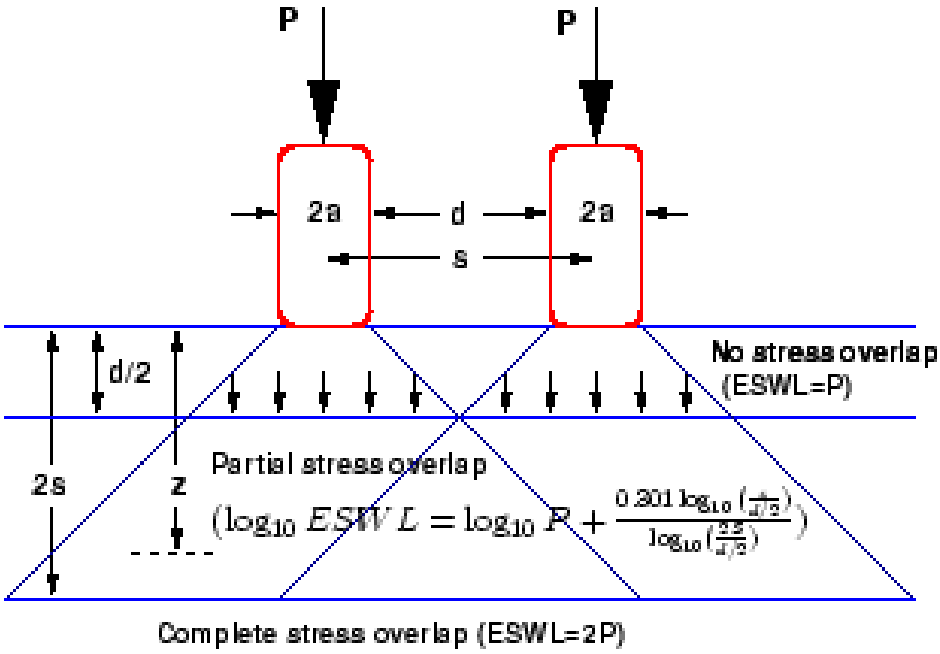


Figure 3.27 Representation of wheel stress on the pavement

3.7.EQUIVALENT SINGLE AXLE LOAD (ESAL)

It is the equivalent repetitions of Standard Axle during the design life of pavement IRC terms this ESAL as Cumulative number of standard axles during the design life The number of repetitions of different types of axles are converted into equivalent repetitions of standard axle by using Equivalent Axle Load Factors (EALF). It defines the damage per pass to a pavement by an axle relative to the damage per pass of a standard axle. The exact EALF can be worked out only by using distress models and the approximate EALF can be worked out using the fourth power rule.

3.7.1 FOURTH POWER DAMAGE RULE

If the AASHTO factors are not available the load equivalency factors are calculated based on the standard axle load by using fourth power damage rule.

(N1/n2) = (w2/W1) ^4 (3.2)

N1=number representing repetition of axle load each having weight equal to W1

n2 =number representing repetition of axle load each having weight equal to w2

EALF = (Wm/Wstd) (3.3)

Wm = measured axle load obtained from axle load data

Wstd = Standard axle load

CalTrans of California (USA)

ESAL= ΣN (Wm/80.12) ^ (4.2) (3.4)

3.8. EQUIVALENT AXLE LOAD FACTOR (EALF)

It defines the damage per pass to a pavement by an axle relative to the damage per pass of a standard axle and exact EALF can be worked out only by using distress models. Approximate EALF can be worked out using the fourth power rule which is discussed as above and the formula for the EALF is given as followed:-

EALF = (Axle load/ Standard axle load) ^ 4 (3.5)

Note: Standard axle load is given as followed:-

- Single axle – 8160 kg
- Tandem axle – 14968 kg

3.9. EVALUATION OF VEHICLE DAMAGE FACTOR

Instead of converting each axle pass into equivalent standard axle passes, it will be convenient to convert one truck pass into equivalent standard axle passes.

$$VDF = \frac{V_1\left(\frac{W_1}{W_s}\right)^4 + V_2\left(\frac{W_2}{W_s}\right)^4 + V_3\left(\frac{W_3}{W_s}\right)^4 + \ldots\ldots}{V_1 + V_2 + V_3 + \ldots\ldots} \quad (3.6)$$

$$VDF = \frac{V_1 EALF_1 + V_2 EALF_2 + V_3 EALF_3 \ldots\ldots}{V_1 + V_2 + V_3 + \ldots\ldots} \quad (3.7)$$

Determination of vehicle damage factor

- For all important projects, the vehicle damage factor need to be worked out from axle load survey. Equation (3.7)
- In axle load survey the axles of a sample of about 10% of randomly chosen trucks are weighed using axle load pads.
- Different configurations of trucks should be proportionately represented in the sample.
- A stratified sample would be ideal for this purpose.
- Annual Daily Traffic (ADT) of trucks need to be obtained for the road from the recent volume surveys or if not available should be estimated by conducting traffic volume survey.
- Formula for the evaluation vehicle damage factor is as followed :-

$$\text{VDF} = \frac{\sum_{i=1}^{N} [V_i \times \text{LEF}_i]}{N}$$

where, V_i = **Traffic volume of the ith vehicle load-class**
LEF_i = **Load equivalency factor of ith vehicle load-class**
N = **Total number of vehicles weighed**

3.10. COST ANALYSIS

The cost analysis is done by evaluating the vehicle damage factor and then using it to evaluate the Million Standard Axle. The MSA will decide the thickness of the dense graded bituminous macadam and then it will be compared with the default values of the vehicle damage factors (which will be used according to IRC: 37 2001).

The 1 km road with the width of 7.5m will be used for the cost comparison. The rate per cubic metre will also decide the difference we will be getting due to the overloading.

3.11. COMPUTATION OF DESIGN TRAFFIC

The design traffic is considered in terms of the cumulative number of standard axles (in the lane carrying maximum traffic) to be carried during the design lift of the road. This can be computed using the following equation:

$$N = \frac{365x[(1+r)^n-1]}{r} x\ A\ x\ D\ x\ F \tag{3.8}$$

where,

N = The cumulative number of standard axles to be catered for in the design in terms of msa. A = Initial traffic in the year of completion of construction in terms of the number of commercial vehicles per day.

D =Lane distribution factor

F = Vehicle damage factor

n = Design life in years

r = Annual growth rate of commercial vehicles (for 7.5 per cent annual growth rate, r = 0.075)

The traffic in the year of completion is estimated using the following formula:

$$A = P(1 + r)^x \tag{3.9}$$

where,

P = number of commercial vehicles per last count.

x = number of years between the last count and the year of completion of construction.

After the evaluation of the Million Standard Axle, the CBR value is chosen. The pavement design catalogues is then further decided using the following figure from the IRC: 37 2001.

The pavement thickness charts decides the thickness of the pavement.

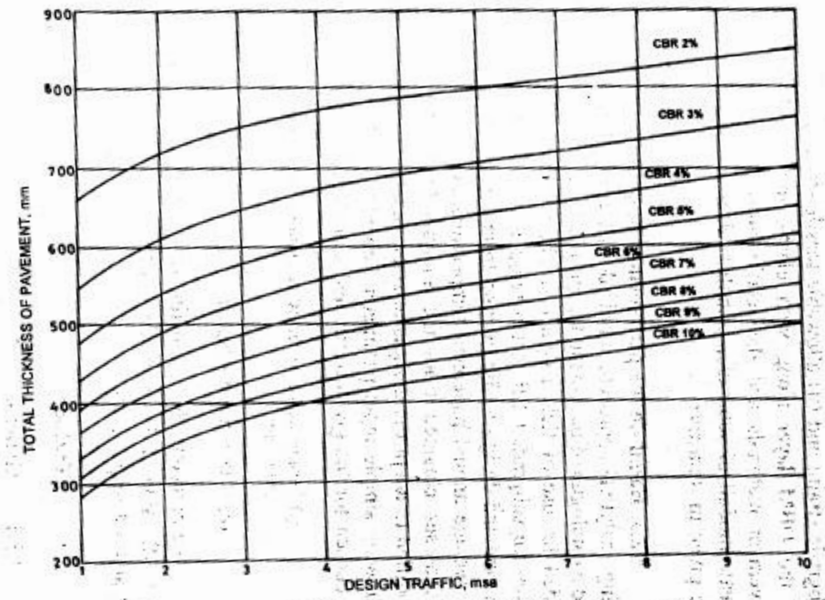


Fig. 1. Pavement Thickness Design Chart for Traffic 1-10 msa

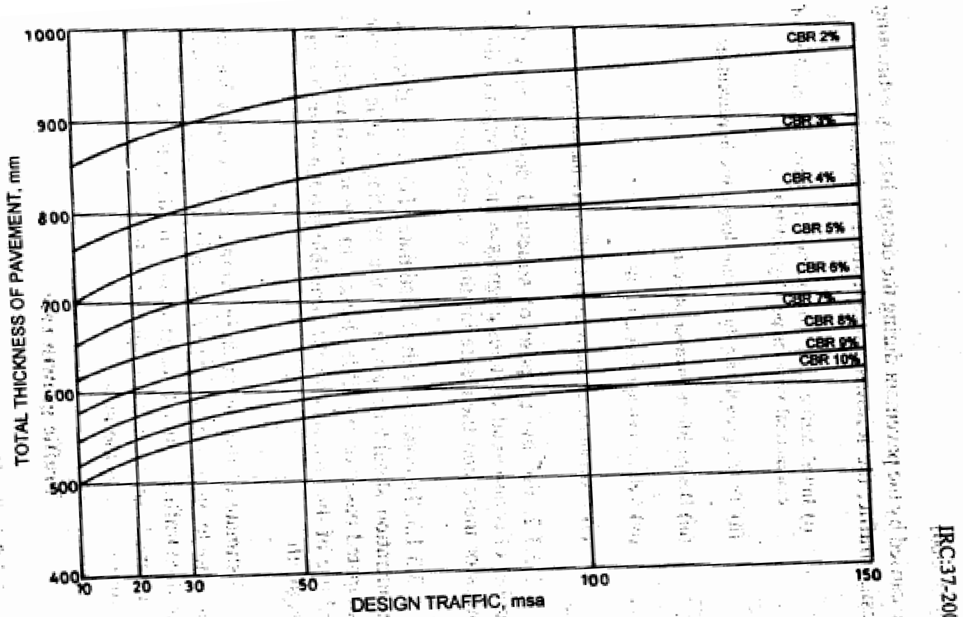


Fig. 2. Pavement Thickness Design Chart for Traffic 10-150 msa

Figure 3.28 Pavement Thickness Charts

The after the evaluation the thickness of the pavement, the cost is evaluated and compared by the default values of the vehicle damage factors and actual value of vehicle damage factor. The comparison shows the pavement damage cost and further conclusion and solution is formed from it.

CHAPTER 4

EVALUATION

4.1. AXLE LOAD SURVEY DATA

Here the number of axle is computed by doing the axle load survey and the Equivalent Axle Load Factor is calculated by using this formula:-

EALF = (Axle load/ Standard axle load) ^ 4

Since the standard axle load of the single axle is taken as 8160 kg, therefore the formula changes becomes:-

EALF = (Axle load/ 8160 kg) ^ 4

And the number of the standard axle is calculated by using this formula:-

Number of Standard Axle = Number of Axle * EALF

Table 4.1 Calculation of number of standard axle of single axle

Axle Load (in Tonne)	No. of Axles	EALF	No. of standard Axle
2	0	0.004	0.00
4	3	0.058	0.17
6	109	0.292	31.86
8	1279	0.924	1181.59
10	78	2.255	175.92
12	68	4.677	318.03
14	23	8.665	199.28
16	14	14.782	206.94
18	5	23.877	118.38
TOTAL			2232.17

The number of axle is computed by doing the axle load survey and the Equivalent Axle Load Factor is calculated by using this formula:-

EALF = (Axle load/ Standard axle load) ^ 4

Since the standard axle load of the tandem axle is taken as 14968 kg, therefore the formula changes becomes:-

EALF = (Axle load/ 14968 kg) ^ 4

And the number of the standard axle is calculated by using this formula:-

Number of Standard Axle = Number of Axle * EALF

Table 4.2 Calculation of number of standard axle of tandem axle

Axle Load (in Tonne)	No. of Axles	EALF	No. of standard Axle
4	0	0.005	0.00
8	104	0.082	8.486
12	55	0.413	22.72
16	503	1.306	656.73
20	157	3.188	500.45
24	98	6.610	647.76
28	67	12.246	820.44
TOTAL			2656.59

4.2. COMPUTATION OF VEHICLE DAMAGE FACTOR

The total number of the standard axles of trucks = 2232.17 + 2656.59

= 4888.76

Number of trucks sampled = 400

Vehicle damage factor = (The total number of the standard axles of trucks / Number of trucks sampled)

= 4888.76 / 400

= 12.2219

4.3. OVERLOADED AXLES

Generally, the load carried by one truck is not the same as that carried by an axle. Each axle load will impart a certain amount of damage or distress on the pavement. The degree of distress caused by different loads of axle will increase as the magnitude of load and repetitions increase. Under mixed traffic conditions, repetitions of different axles having different loads, plying on a road will not indicate any meaningful value related to how much damage has been caused to the pavement due to their combined action. Different axle loads will cause different degree of damages. .

Figure 4.1 Overloaded vehicles

Figure 4.2 Overloaded trucks

Figure 4.3 Overloaded truck with single axle

Figure 4.4 Various overloaded truck with tandem axle

Figure 4.5 Overloaded bus

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 3, the respective overloaded axles are computed as:

3 – Axle 3 (1605) + for 4 – axle 2(156) = 5127

Total number of buses and trucks axles = 2(165) + 2(6050) + 3(1605) + 4(156). = 17869. Therefore, the proportion of overloaded axle for trucks = 5127/17869 =28.69% for entire commercial vehicle. The axle weight conversion shown in table number 3 shows an average equivalent factor of 3 which is about 3 times the standard axle weight for road pavements.

Table 4.3 Data Analysis for Axle Load Survey

Serial number	Vehicle Category	Number of Axles	Total number of vehicles (5 days)	Single axle with single wheel	Single axle with dual wheel	Tandem Axle	Tridem Axle	(Axle load in kg/6500)^4	(Axle load in kg/8000)^4	(Axle load in kg/14800)^4	(Axle load in kg/22400)^4	Total Load Equivalency factor (E.F)	Number of vehicles* E.F	Average Equivalent Factor
				1	2	3	4	1	2	3	4			
1	Buses	2	165	6095	6750	-	0	0.773	0.506	0	0	1.279	211.035	2.8 ~ 3
2	Medium Trucks	2	6050	6240	6480	-	0	0.849	0.430	0	0	1.279	7737.95	
3	Heavy Trucks	3	1605	7850	10500	20650	0	2.127	2.967	3.789	0	8.595	13794.97	
4	Very Heavy Trucks	4/5	156	7540	8050	15550	0	1.810	1.025	1.21	0	4.045	631.02	
			7976										22374.97	A/B
			B										A	

CHAPTER 5

OBSERVATION

5.1. DISCUSSION

From the present study it can be observed that the overloading of commercial vehicles on highway network is very high. It is known that increase in axle loads cause considerable damage to the pavement. It can be observed from the analysis and results that the damage caused by the vehicles with overloaded axles is very high when compared to the damage caused by the vehicles with allowable axle loads. It implies that the pavement is needed to be strengthened much earlier during the design life, if the same trend of axle loads and type continues. This increases the life cycle cost as the number of overlays to be provided is more. By enforcing the limitations on overloading of vehicles i.e. either by restricting the axle load limit for all vehicles or by introducing more no. of multi axle commercial trucks for higher loading capacity, the strengthening measures can be delayed / extended so that the number of overlays and thus the life cycle cost will reduce.

Overloading accelerates the pavement damage and reduces the pavement life to a great extent. This causes wastage of huge amount of funds invested in road projects. Overloading of pavements only benefits a small percent of population while the others also have to suffer its impacts. Numerical calculations were done to express the loss in economy due to the overloading effect.

Truck manufacturer’s technical specifications and highway agencies general concept is that the loading of trucks should be distributed in a ratio so that the all the axle of trucks will have equal load distribution. If the surface area of load distribution increases the pavement will sustain for a longer life. For a two axle truck, the loading ratio of 1:2 on front and rear axles seem to be a safe loading pattern and for a four axle truck it is 1:2:2:2. Truck operators should follow this loading pattern which will provide mutual benefits. Overloaded trucks violate this load distribution. Even if the gross weight of a truck is within the legal load limit, if the load distribution pattern is varying, say, for a two axle truck if the load distribution pattern of 1:2 is varied the heavier loaded axle will cause much impact on the road surface than which it is meant to withstand.

As VDF is the measurable parameter of the damage caused by vehicle on pavement, the change in loading pattern will gradually increase the VDF. This can be well studied by considering a 2 Axle truck, in which the loads were assumed to be distributed in the ratio 1:2, 1:3, 1:4 and 1:5 . The data resulted from axle load study and the analysis show that both single axles as well as tandem axles exceed their legal limits by considerable amount.

This results in multiplying damage to the pavement to a greater extent. The results of axle load data shows that the vehicle damage factors for trucks are varying from 3.4 to 12.7 which is much higher than VDF that are normally adopted in the design of pavements. The indicative VDF factors suggested by IRC vary from 1.5 to 4.5 depending on the terrain and number of commercial vehicles. Therefore, there is a need to modify the VDF values in the design of pavements for highway network, if the present extent of loading and axle type continues.

The analysis shows that by converting overloaded axles in to additional vehicles with allowable axle loading, the extent of damage can be reduced significantly. The damage to the pavement can be reduced by strict enforcement on legal axle load limits. The multi axle (tandem and tridem) trucks with heavy loads are effective in lower life cycle costs as the number of maintenance interventions required during life cycle of a pavement are less. This is likely to result in significant increase in benefits.

The time has come to modify the policies regarding axle load limits as well as axle configurations of commercial trucks, to safeguard a pavement system as well as the total transport cost of highway system.

5.2. COST ANALYSIS

As we evaluated the vehicle damage factor, we observe that Dense Graded Bituminous Macadam which is below the Bituminous concrete can be compared and analysed because we see changes only in the DBM layer while all the layer remains the same i.e. base course and sub-base course.

Table 5.1 Analysis of Rate

S. No.	Reference to MORT&H Specifications	Description	Unit	Quantity	Rate Rs.	Amount
1	**2**	**3**	**4**	**5**	**6**	**7**
5.6	**507**	**Dense Graded Bituminous Macadam**				
					KM	**1**
		Providing and laying dense graded bituminous macadam with 100-120 TPH batch type HMP producing an average output of 75 tonne per hour using crushed aggregates of specified grading, premixed with bituminous binder as per job mix , transporting the hot mix as per Technical Specification Clause 507 Unit = Cum Taking Output = 195 cum (450 tonnes)				
	(a)	**Labour**				
		Mate	day	0.84	235.00	197.40
		Mazdoor working with HMP, mechanical broom, paver, roller, asphalt cutter and assistance for setting out lines, levels and layout of construction	day	14.00	222.00	3108.00
		Skilled mazdoor for checking line & levels	day	5.00	227.00	1135.00
	(b)	**Machinery**	85%			
		Batch mix HMP @100 tonne per hour actual output	hour	6.00	21266.57	127599.40
		Paver finisher mechanical 100 tonne per hour actual output	hour	6.00	1197.88	7187.25
		Generator 250 KVA	hour	6.00	856.99	5141.91
		Front end loader 1cum bucket capacity	hour	6.00	990.29	5941.76

		Tipper 10 tonne capacity	t.km	450 x 40	3.30	59469.88
		Add 10per cent of cost of carriage to cover cost of loading and unloading			0.00	5946.99
		Smooth wheeled roller 8-10 tonne for initial break down rolling	hour	6.00 x 0.65*	565.61	2205.88
		Vibratory roller 8 tonne for intermediate rolling	hour	6.00 x 0.65*	1892.99	7382.64
		Finish rolling with 6-8 tonne smooth wheeled tandem roller	hour	6.00 x 0.65*	1405.46	5481.28
	(c)	**Material**				
	(c)	**i) Bitumen VG_30 @ 4.5 percent of mix** Weight of mix = 205 x 2.2 = 450 tonne **ii) Aggregate** Total weight of mix = 450 tones Weight of bitumen =20.25 tonnes Weight of aggregate = 450-20.25 = 429.75 tonnes (Volume of aggregate = 286.5 cum)	tonne	20.25	28722.72	581635.08
		Grading I (40 mm nominal size)				
		37.5 - 25 mm 22 per cent	cum	0	2488.30	0.00
		25 - 10 mm 30 per cent	cum	85.95	2738.30	235356.89
		10 - 4.75 mm 28 per cent	cum	80.22	1798.20	144251.60
		4.75 mm and below 40 per cent	cum	114.6	1540.20	176506.92
		Filler @ 2 per cent of weight of aggregates	tonne	5.73	2196.30	12584.80
	(d)	**Add Over Head @ 10%**			1381132.68	**138113.27**
	(e)	**Contractor's profit @ 10%**			1519245.95	**151924.60**

		Rate per cum = (a+b+c+d+e)/ 195 (For Grading II) Although the rollers are required only for 3 hours as per norms of output, but the same have to be available at site for six hours as the hot mix plant and paver will take six hours for mixing and paving the out put of 450 tonne considered in this analysis Quantity of Bitumin has been taken for analysis purpose. The actual quantity will depend upon job mix formula. Labour for traffic control, watch and ward and other miscellaneous duties at site including sundries have been included in administrative overheads of the contractor. In case DBM is laid over freshly laid tack coat, provision of mechanical broom and 2 mazdoors shall be deleted as the same has been included in the cost of tack coat.				**1671170.55**
				Rate Per Cum		**8570.11**

Say Rs. 8570.10

The rate per cubic metre is Rs. 8570.11 for the Dense Graded Bituminous Macadam.

Using the default values of vehicle damage factor

Now the design of the pavement according to the suitable data.

Data that we have: –

Initial Traffic = 1550 CVD

Traffic growth per annum = 7.5

Design life = 15 years

Default Vehicle Damage Factor = 4.5

Actual evaluated Vehicle damage factor using axle load survey = 12.22

Design CBR = 8%

Distribution factor = 0.75

Cumulative number of standard axle for default value of vehicle damage factor

$$N = \frac{365x[(1+r)^{n}-1]}{r} x\ A\ x\ D\ x\ F$$

where,

A = Initial traffic = 1550

D =Lane distribution factor = 0.75

F = Vehicle damage factor = 4.5

n = Design life in years =15 years

r = Annual growth rate of commercial vehicles (for 7.5 per cent annual growth rate, r = 0.075)

N = [365 *{(1 + 0.075)^{15} - 1} * 1550 * 0.75 * 4.5] / 0.075

N = 49.870568.81

N = 49.87 msa ~ 50 msa

At CBR 8 %

Using the interpolation rule in pavement thickness design graph, the pavement design is 610mm for this evaluation. For further evaluation, the pavement design catalogue is used to determine the dense bituminous macadam.

BC = 40 mm

DBM = 120 mm

Base = 250 mm

Sub Base = 200mm

Cumulative number of standard axle for actual value of vehicle damage factor

$$N = \frac{365x[(1+r)^n-1]}{r} x\ A\ x\ D\ x\ F$$

where,

A = Initial traffic = 1550

D =Lane distribution factor = 0.75

F = Vehicle damage factor = 12.22

n = Design life in years = 15 years

r = Annual growth rate of commercial vehicles (for 7.5 per cent annual growth rate, r = 0.075)

$N = [365 *\{(1 + 0.075)^{15} - 1\} * 1550 * 0.75 * 12.22] / 0.075$

N = 135426300.2

N = 135.42 msa

At CBR 8 %

CBR 8%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	**PAVEMENT COMPOSITION**		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	550	40	60	Base = 250 Sub-base=200
20	575	40	85	
30	590	40	100	
50	610	40	120	
100	640	50	140	
150	660	50	160	

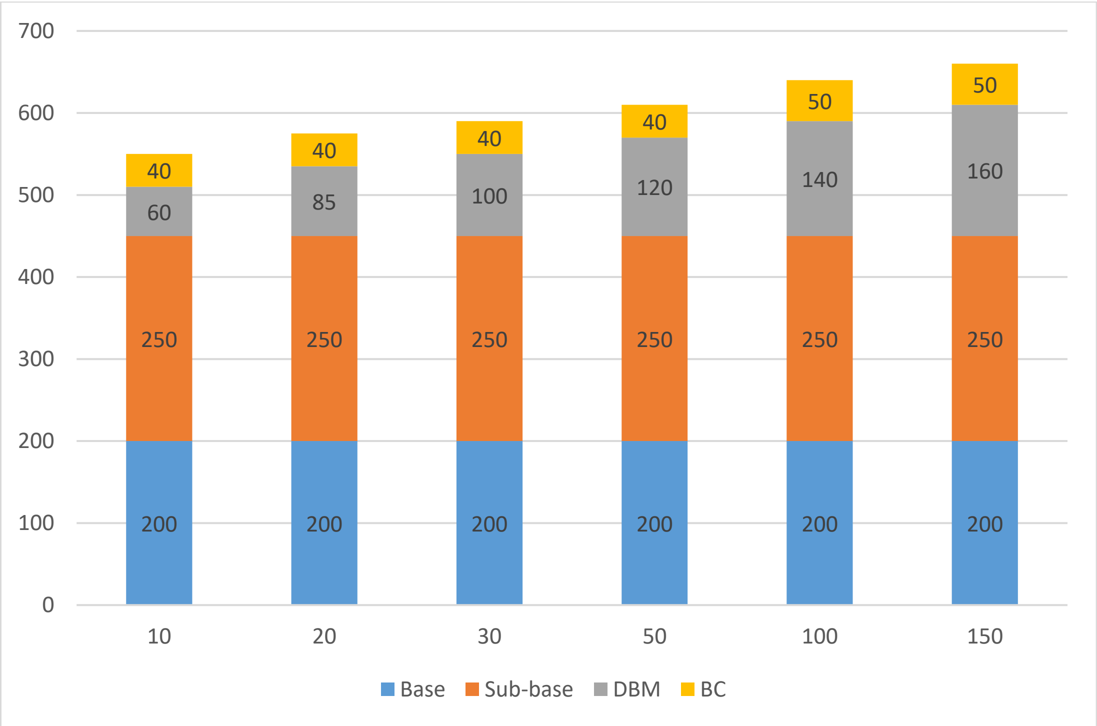


Figure 5.1 Pavement design catalogue

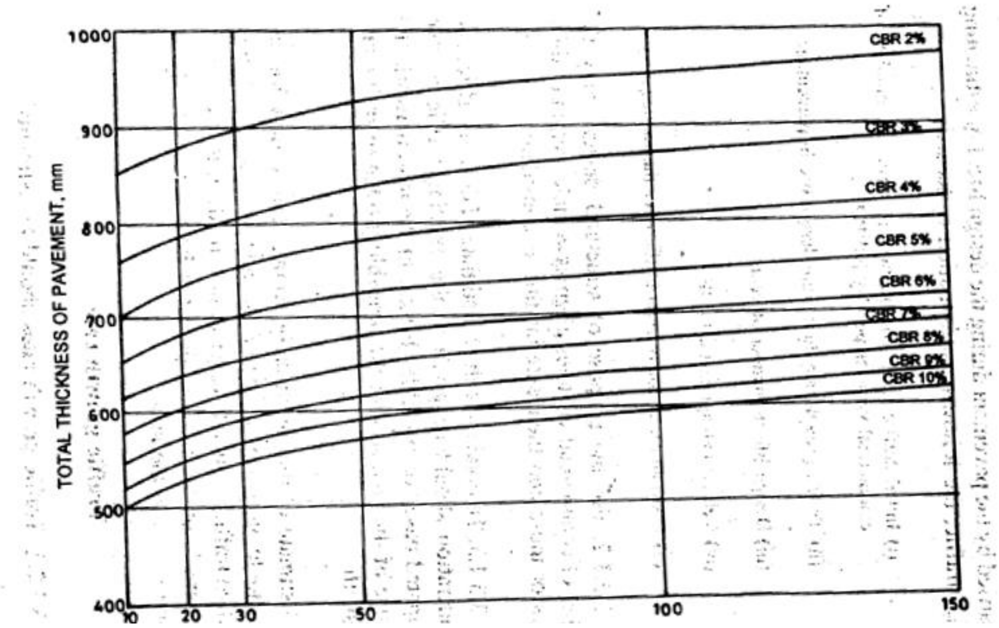


Figure 5.2 Pavement thickness

Using the interpolation method in pavement thickness design graph, the pavement design is 654 mm for this evaluation. For further evaluation, the pavement design catalogue is used to determine the dense bituminous macadam.

BC = 50 mm

DBM = 154 mm

Base = 250 mm

Sub Base = 200mm

5.3 ANALYSIS OF RESULT

Now estimating the cost for 1km of road

Taking the length of the road = 1 km

Width of the road = 7.5 m

Therefore, for default Vehicle Damage Factor is

= 1000 * 7.5 * (120*0.001)

= 900 cum

Rate per cum = Rs 8570.11

For 900 cum = 8570.11*900

= Rs 77,13,099

Therefore, for actual Vehicle Damage Factor is

= 1000 * 7.5 * (154*0.001)

= 1155 cum

Rate per cum = Rs 8570.11

For 1155 cum = 8570.11*1155

= Rs 98,98,477

Difference is = Rs 98,98,477 - Rs 77,13,099

= Rs 2185378

Due to overloading , pavement deteriorates at faster rate and the loss value due to overloading is estimated to be Rs 2185378 for our current surveyed site which is 28.33 percent of the road cost. Hence the overloading should be restricted to avoid further road damage and to provide more serviceability.

CHAPTER 6

CONCLUSION AND SUMMARY

Following recommendations seen to be helpful to control the overloading.

- As overloading is increasing, it has to be controlled by rules and regulations.
- Intensity of weight enforcement and the level of penalty only cannot control overloading activities. So fines must be associated with intensified enforcement when considered in further strategy. Enforcement has higher efficiency at the initial stage. However efficiency decreases rapidly when enforcement levels increase gradually. Thus, the balance between level of enforcement and efficiency of enforcement must be considered. Effective means of managing truck overloading is not unitary. It must combine monitoring, inspection, enforcement and punishment as a complete. Regular monitoring, inspection and enforcement are the effective ways to control overloading.
- Use of technology (Automatic overloading information system) may be the effective way to control the overloading and Design should be done as per the actual traffic loading condition.
- To construct or improve road built quality to withstand heavier loads.
- To impose axle load limit and 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.
- The deterioration rate of the pavement and the loss value due to overloading is estimated to be Rs 2185378 for our current surveyed site which is 28.33 percent of the road cost of DBM layer. Therefore, overloading should be restricted to avoid further road damage and to provide more serviceability

- There are many factors which results in overloading and heavier axle loads on the road, one of the reason is that the new introduction of the more spacious trucks which eventually alter the axle load distribution on the road. In order to compete and keep themselves in the market by keeping the haulage cost at minimum, the truck owner generally overload their vehicle much beyond their rated capacity. To carry extra load, the vehicle owner strengthens the vehicle body and adds extra suspension springs to increase the height of the vehicle's body.

FUTURE SCOPE OF THE STUDY

Based on the present observation, it is felt that further work should be pursued in the following area:

- The axle load limit should be strictly followed and the penalty for the overloading should be increased.
- Damage may occur in base course (bituminous). Evaluation should be carried out considering base course damage.
- Further investigation should be carried out in different region and different area.

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Research Article Volume 9 Issue No.3

Evaluation of Vehicle Damage Factor in Overloading for Different Types of Loading

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Abstract:
This paper aims to study the analysis of the vehicle damage factor in overloading for different types of loading. 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 multi-axle trucks for different vehicle classification. The spectrum of axle load in terms of axle weights of single, tandem, tridem and multi-axle should be determined and compiled under various classes with class intervals of 10 kN, such as 10 kN, 20 kN and 30 kN for single, tandem and tridem axles respectively. VDF should be evaluated carefully by carrying out specific axle load surveys on the existing roads. The idea is to use axle load survey data to evaluate Equivalent Single Axle Load (ESAL) and the Vehicle Damage Factor and then further analyze the pavement to determine the required overlay thickness.

Keywords: Axle load survey, ESAL, vehicle classification

I. INTRODUCTION

The Vehicle Damage Factor (VDF) is a multiplier to convert the number of commercial vehicles of different axle loads and axle configuration into the number of repetitions of standard axle load of magnitude 80 kN. It is defined as equivalent number of standard axles per commercial vehicle. The VDF varies with the vehicle axle configuration and axle loading. The objective is to evaluate vehicle damage factor from overloading. The guidelines use Vehicle Damage Factor (VDF) in estimation of cumulative msa for thickness design of pavements.

- To carry out the axle load or truck weight survey.
- To evaluate load equivalency factor and equivalent standard axle load by using axle load survey data.
- To evaluate vehicle damage factor by using above variables.

Axle load survey should be carried out without any bias for loaded or unloaded vehicles. On some sections, there may be significant difference in axle loading in two directions of traffic. In such situations, the VDF should be evaluated direction wise. Each direction can have different pavement thickness for divided highways depending upon the loading pattern. The AASHO axle load equivalence, factors may be used for converting the axle load spectrum to an equivalent number of standard axles. For designing a strengthening layer on an existing road pavement, the vehicle damage factor should be arrived at carefully by using the relevant available data or carrying out specific axle load surveys

II.KEYWORDS OF THE PROPOSED EXPERIMENT

A. Axle load survey

The only effective way to compare the damaging effect of traffic on given roads is to measure the complete spectrum of axle loads and calculate the appropriate equivalence factors. The main purpose of the axle loads for trucks survey is to collect preliminary information regarding the range of heavy axle loads traversing the nation's main highways. With axle load calculation for trucks, road authorities can make better decisions on which stretch to repair and which part of the road or pavement to prioritize, in order to optimize traffic flow. The data helps reduce the effects of overloading and prevents accelerated damage to pavement. With a comprehensive study of axle loads for trucks road planning departments can ensure that existing roads are appropriately maintained so that they provide appropriate level of service for road users across a longer duration. These surveys also assist to improve existing road conditions to meet the necessary standards in order to enable them to carry prevailing levels of traffic with the desired level of safety.The total weight of the vehicle is carried by its axles. The load on the axles is transferred to the wheels and this load is ultimately transferred on the surface of the pavement in the contact with tyres. To keep wheel load induced stresses on pavement within allowable limit the total vehicle load is distributed onto wider areas of pavement by using more axles and wheels. This is the reason why more number of axles and wheels are fitted to heavy load carrying trucks. The VDF varies with the vehicle axle configuration and axle loading. There are following types of axles:-

- Single axle
- Tandem axle
- Tridem axle

When conducting an axle load survey the validity of the two following assumptions are made:

- The load on the wheels of an axle remains constant at all times, ie.remains the same as it was when the vehicle was originally loaded

– The load exerted on the road by any wheel of any vehicle, whether at rest or in motion, is constant and determined by the initial load distribution of the vehicle.

These assumptions disregard the fact that the load concentration on a wheel or an axle changes continuously when the vehicle is in motion.

Table.1. Heavy Vehicle Categories and definitions

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

B. Equivalent Single Axle Load

Although it is not too difficult to determine a wheel or an axle load for an individual vehicle, it becomes quite complicated to determine the number and types of wheel/axle loads that a particular pavement will be subject to over its design life. Furthermore, it is not the wheel load but rather the damage to the pavement caused by the wheel load that is of primary concern.

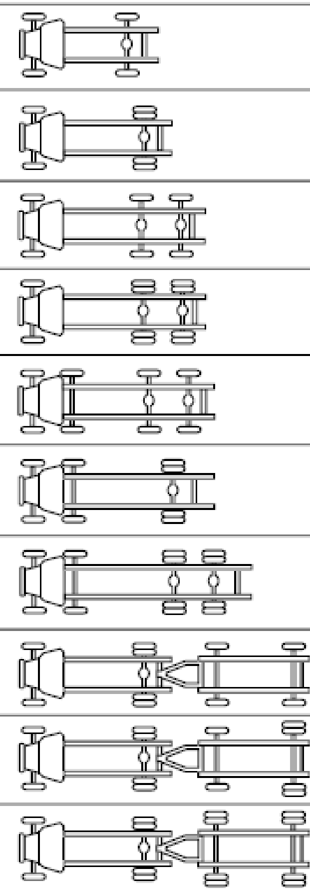
The most common historical approach is to convert damage from wheel loads of various magnitudes and repetitions ("mixed traffic") to damage from an equivalent number of "standard" or "equivalent" loads. The most commonly used equivalent load. is the 18,000 lb (80 kN) equivalent single axle load (normally designated ESAL). At the time of its development it was much easier to use a single number to represent all traffic loading in the somewhat complicated empirical equations used for predicting pavement life.

Equivalent single axle load is calculated by using the load equivalency factors (LEF) from AASHTO Guide for Design Pavement and Structure and then multiplying it to the frequency of the vehicle class. It will give the Equivalent Single Axle load for desired Average axle load.

C. Vehicle Classification

The classification of vehicle is done on the basis of the load carrying capacity of the vehicle. The heavy vehicle category is useful for our experiment and it is further categorized by number of axles and load carrying capacity. The overloaded vehicle causes more damage to the pavement which directly affects the maintenance cost of the road. The vehicle classification for the heavy vehicle category:-

Table.2. Rigid chassis commercial vehicles



RIGID - CHASSIS COMMERCIAL VEHICLES		
	11	Single tyres on front and rear axles
	12	Single tyres on front axle Twin tyres on rear axle
	1.11	Single tyres on front axle Twin tyres on rear axles Two rear axles
	1.22	Single tyres on front axle Twin tyres on rear pair of axles Two rear axles
	11.11	Single tyres on front pair of axles Single tyres on rear pair of axles
	11.2	Single tyres on front pair of axles Twin tyres on rear axle
	11.22	Single tyres on front pair axles Twin tyres on rear pair of axles
	1.2 + 1.1	TRAILERS Single tyres on both axles
	1.2 + 1.2	Single tyres on front axle Twin tyres on rear axle
	1.2 + 2.2	Twin tyres on both axles

III. METHODOLOGY

A. Evaluation of the vehicle damage factor

To evaluate the vehicle damage factor the first step is to carry out the axle load survey. The axle load survey gives us the data to evaluate the equivalent single axle load and then further by using load equivalency factors, the vehicle damage factor is evaluated. Since the axle load survey is carried out only for the heavy vehicle category, the vehicle damage factor values increases. The reason for selected the heavy vehicle category is that the major damage done to the pavement of highway is by this category only. Thus it is not necessary to weigh vehicles of less than 1.5 tones weight, for example; motorcycles, cars, small buses or small trucks with single rear tyres. Sometimes large buses have quite high axle loads and therefore should be weighed in the survey. The product of average axle load and the load equivalency factor gives the equivalent single axle load which further results in vehicle damage factor

$$\mathrm{VDF} = \frac{\sum_{i=1}^{N} [V_i \times \mathrm{LEF}_i]}{N}$$

where, V_i = Traffic volume of the ith vehicle load-class
LEF_i = Load equivalency factor of ith vehicle load-class
N = Total number of vehicles weighed

B. Permissible Axle Loads in India

The policy at National level for the road system in India with regard to the Registered Laden Weight (RLM) limit (Govt. of India 1992) was as follows:

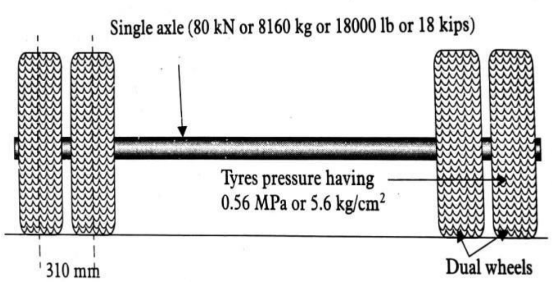
– Maximum Single Axle Load (with 2 Tyres) – 60 KN (6.0 T)
– Maximum Single Axle Load (with 2 Tyres) – 60 KN (6.0 T)
– Maximum Tandem Axle Load (with 8 Tyres) – 180 KN (18.0 T)

Table.3. Data Analysis for Axle Load Survey

Serial number	Vehicle Category	Number of Axles	Total number of vehicles (5 days)	Single axle with single wheel	Single axle with dual wheel	Tandem Axle	Tridem Axle	(Axle load in kg/6500)^4	(Axle load in kg/8000)^4	(Axle load in kg/14800)^4	(Axle load in	Total Load Equivalency factor (E.F)	Number of vehicles* E.F	Average Equivalent Factor
				1	2	3	4	1	2	3	4			
1	Buses	2	165	6095	6750	-	0	0.773	0.506	0	0	1.279	211.035	
2	Medium Trucks	2	6050	6240	6480	-	0	0.849	0.430	0	0	1.279	7737.95	
3	Heavy Trucks	3	1605	7850	10500	20650	0	2.127	2.967	3.789	0	8.595	13794.97	2.80 ~ 3
4	Very Heavy Trucks	4/5	156	7540	8050	15550	0	1.810	1.025	1.21	0	4.045	631.02	
			7976										22374.97	A/B
			B										A	

C. Overloaded Axles

Generally, the load carried by one truck is not the same as that carried by an axle. Each axle load will impart a certain amount of damage or distress on the pavement. The degree of distress caused by different loads of axle will increase as the magnitude of load and repetitions increase. Under mixed traffic conditions, repetitions of different axles having different loads, plying on a road will not indicate any meaningful value related to how much damage has been caused to the pavement due to their combined action. Different axle loads will cause different degree of damages.

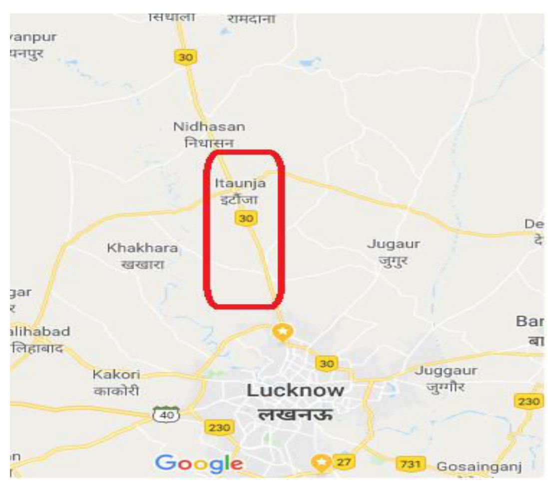


The above picture shows the details of the Indian standard axle. With the standard axle of 80 kN resting on dual tyres on axle configuration, it can be assumed that the axle on single tyres is 6.5 kN. In line with above assumptions to the data of table no 3, the respective overloaded axles are computed as:

3 – Axle 3 (1605) + for 4 – axle 2(156) = 5127

Total number of buses and trucks axles = 2(165) + 2(6050) + 3(1605) + 4(156). = 17869. Therefore, the proportion of overloaded axle for trucks = 5127/17869 =28.69% for entire commercial vehicle. The axle weight conversion shown in table number 3 shows an average equivalent factor of 3 which is about 3 times the standard axle weight for road pavements.

D. Location of the study



The location of the study is near Itaunja toll plaza connecting Lucknow to Delhi via Sitapur.

IV. CONCLUSIONS

From the analysis of vehicle damage factor using axle load survey data, the following conclusions can be drawn:-

- The axle weight conversion shown in table 3 shows that the vehicle damage factor is about 3 times more than the average vehicle damage factor used for the Heavy Commercial Vehicles (HCV), due to this amount of overloading, the pavement deterioration is 3 times faster than the normal.
- The strength of the pavement structure is decreases by overloading of single axle truck. The more overloading results in more decrease of the strength of pavement structure.
- Almost 30% of overloaded vehicle were moving on the pavement.
- The individual load equivalency factor of 3 axle vehicles is more as compared to the remaining commercial vehicles which is 26.94%
- Since the haulage cost is reduced by overloading and it results in the economic benefit but it causes the earlier failure of the road pavements. The premature failure of the pavement causes loss of billions of rupees invested in road infrastructure.
- There are many factors which results in overloading and heavier axle loads on the road ,one of the reason is that the new introduction of the more spacious trucks which eventually alter the axle load distribution on the road. In order to compete and keep themselves in the market by keeping the haulage cost at minimum, the truck owner generally overload their vehicle much beyond the their rated capacity. To carry extra load, the vehicle owner strengthens the vehicle body and adds extra suspension springs to increase the height of the vehicle's body

To solve the current situation here are the following suggestions

- To construct or improve road built quality to withstand heavier loads.
- To Impose axle load limit and 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.

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Research Article Volume 9 Issue No. 5

Analysis of Vehicle Damage Factor in Overloading for Different Types of Loading

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Abstract:
This paper aims to study the analysis of the vehicle damage factor in overloading for different types of loading. Overloading has been a problem because of permissible axle load limit is not followed. The idea is to use axle load survey data to evaluate Equivalent Single Axle Load (ESAL) and the Vehicle Damage Factor and then further analyze the pavement to determine the required overlay thickness. The axle load survey is carried put very carefully in order to get the correct vehicle damage factor value. There are many constraints regarding the steps to evaluate the vehicle damage factor, therefore it is carried out very carefully to avoid any wrong data. After the evaluation of the vehicle damage factor cost analysis is done for the dense bituminous layer of the flexible pavement. Overall this study can be used for the analysis of VDF (Vehicle Damage Factor), MSA (Million standard axles) and axle load survey data. The information obtained can be used in the final computation of pavement layers.

Key words: Axle load survey, permissible axle load limit.

I. INTRODUCTION

Vehicle damage factor is evaluated by using following formula:-

$$\text{VDF} = \frac{\sum_{i=1}^{N} [V_i \times \text{LEF}_i]}{N}$$

where, V_i = Traffic volume of the ith vehicle load-class
LEF_i = Load equivalency factor of ith vehicle load-class
N = Total number of vehicles weighed

Every passage of a vehicle on a pavement will cause a certain amount of damage or distress in different forms. The degree of damage caused by a vehicle depends on its gross weight, number of axles as well as configuration of wheels. For example, if two vehicles have equal gross load, one with a single axle single wheel and the other with a tandem axle dual wheel assembly, the damage caused by the former vehicle will be greater. This is because the gross load is transferred onto the pavement surface over a wider area by more number of axles and wheels.

The damage caused by different vehicles is calculated using the vehicle damage factor which is used for performance modelling, design and maintenance of pavements.

The vehicle damage factor (VDF) is a numerical value which represents the equivalent number of standard axles per truck (IRC: 37-2001). It is a multiplication factor used to convert different commercial vehicles with varying axle load repetitions to standard axle load repetitions. From axle load survey data, VDF is calculated using the following equation.

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 pavement are not much different, for heavy duty pavements, the computed VDF values are assumed to be same for bituminous pavements with cemented and granular bases. Factors affecting VDF numerous factors which are related to damage or distress caused to pavement affect VDF.

The factors may be related to traffic composition at the time of survey, load on axles, possible occasional (or seasonal) overloading, number of axles, wheels configuration, terrain, type of pavement, region, pavement condition, temperature, rainfall etc.

In pavement design, VDF obtained from axle load surveydata should be used rather than an assumed value because the VDF value obtained from survey data represent a realistic value by considering actual traffic loading and other factors related to the region (or pavement considered.

II. KEYWORDS OF THE PROPOSED EXPERIMENT

A. *Axle load survey*

There are two methods to weigh truck or axle loads:-

- Static weighing
- Weighing In Motion (WIM)

In static weighing vehicles are stopped and weighed but WIM vehicles are weighed dynamically while in motion.

In the static method, the axle load of a vehicle is weighed using portable weights or load-pads (Figure 6.6) or a weighing platform.

Only axle loads having more than or equal to 3 tonnes are taken into account for analysis since the damage caused by axles weighing less than 3 tonnes is negligible. For traffic analysis, vehicles having axle weight = 3 tonnes are referred to as commercial vehicles.

Table.1.Comparison between Static weighing and Weighing in Motion (WIM)

Sl. No.	Static weighing method	Weight in motion (WIM)
1	Vehicles are stopped and weighed	Vehicle is weighed automatically while in motion, without disturbing the driver.
2	Accurate weight measurement	Weight measurements may be influenced by parameters related to vehicle speed, suspension system of the vehicle, tyre pressure, acceleration and deceleration of the vehicle and dynamic forces produced due to pavement roughness, wind velocity etc.
3	Takes more time and interrupts free flow of; may pose problems related to safety	There is no such interruption to flow traffic; can weigh high volumes of traffic.
4	Other information such as body type of vehicles, loading type etc. can be physically ascertained.	Collection of other information is not possibly by automated WIM equipment.
5	Less number of vehicles can be measured; selected vehicles are weighed; need more personnel, time and space, to weigh all vehicles.	More number of vehicles can be measured; better coverage of all vehicle since its automatic.
6	Less installation and maintenance cost.	High installation and maintenance cost.
7	The weigh pads can be installed at any location.	WIM equipment can be installed at fixed location only.

B. Permissible axle load limit

The Ministry of Road Transport & Highways has issued a notification (18-July-2018) increasing permissible truck axle load. As per the amended rules, the maximum safe axle weight of each axle type in relation to the transport vehicles (other than motor cabs), with regard to the size, nature and number of tyres would be as follows :-

Table.2. Permissible axle load limit in India

Sl. no	Axle type	Maximum safe axle weight
1	**Single axle**	
1.1	Single axle with single tyre	3.0 tonnes
1.2	Single Axle with two Tyres	7.5 tonnes
1.3	Single Axle with four Tyres	11.5 tonnes*
2	**Tandem Axles (Two axles) (where the distance between two axles is less than 1.8 Mtr.)**	
2.1	Tandem axle for rigid vehicles, trailers and semi-trailers	21 tonnes*
2.2	Tandem axle for Puller tractors for hydraulic and pneumatic trailers	28.5 tonnes
3	**Tri–axles (Three axles) (where the distance between outer axles is less than 3 Mtr.)**	
3.1	Tri-axle for rigid vehicles, trailers and semi-trailers	27 tonnes*
4	**Axle Row (two axles with four tyres each) in Modular Hydraulic trailers** (9 tonnes load shall be permissible for single axle)	18 tonnes

*** Note:** If the vehicle is fitted with pneumatic suspension, 1 tonne extra load is permitted for each axle. The amendment lays down that the gross vehicle weight (GVW) will not exceed the total permissible safe axle weight as above and in no case shall exceed:-

- 49 tonnes in case of rigid vehicles
- 55 tonnes in case of semi-articulated trailers and truck-trailers except modular hydraulic trailers.

Number of days of survey will depend on project location, the type of project and theintensity and expected variation in traffic. This survey duration may vary between 24hours and 3 days, but should be carried out at least for one day at the traffic countstations on a random basis for commercial vehicles. Buses may be omitted as their weight can be easily calculated and they do not result in excessive overloads. The period of conducting the survey should also be judiciously selected keeping in view the movement of commodity /destination oriented dedicated type of commercial vehicles. While finalising the design Equivalent Standard Axle load, the following should be considered.

- Past axle load spectrum in the region as well as on the road to the extent available.
- Annual variation in commercial vehicles.
- Optimistic and pessimistic considerations of future generation of traffic.
- Generation of changing VDF factor during the project period

III. COST ANALYSIS

A. *Introduction*

From the present study it can be observed that the overloading of commercial vehicles on highway network is very high. It is known that increase in axle loads cause considerable damage to the pavement. It can be observed from the analysis and results that the damage caused by the vehicles with overloaded axles is very high when compared to the damage caused by the vehicles with allowable axle loads. It implies that the pavement is needed to be strengthened much earlier during the design life, if the same trend of axle loads and type continues. This increases the life cycle cost as the number of overlays to be provided is more. By enforcing the limitations on overloading of vehicles i.e. either by restricting the axle load limit for all vehicles or by introducing more no. of multi axle commercial trucks for higher loading capacity, the strengthening measures can be delayed / extended so that the number of overlays and thus the life cycle cost will reduce.

As we evaluated the vehicle damage factor, we observe that Dense Graded Bituminous Macadam which is below the Bituminous concrete can be compared and analysed because we see changes only in the DBM layer while all the layer remains the same i.e. base course and sub-base course.

The rate per cubic metre is Rs. 8570.11 for the Dense Graded Bituminous Macadam. Using the default values of vehicle damage factor Now the design of the pavement according to the suitable data.Data that we have: –

Initial Traffic = 1550 CVD
Traffic growth per annum = 7.5
Design life = 15 years
Default Vehicle Damage Factor = 4.5
Actual evaluated Vehicle damage factor using axle load survey = 12.22
Design CBR = 8%
Distribution factor = 0.75
Cumulative number of standard axle for default value of vehicle damage factor

$$N = \frac{365x[(1+r)^n-1]}{r} x\ A\ x\ D\ x\ F$$

where,
A = Initial traffic = 1550
D =Lane distribution factor = 0.75
F = Vehicle damage factor = 4.5
n = Design life in years =15 years
r = Annual growth rate of commercial vehicles (for 7.5 per cent annual growth rate, r = 0.075)
$N = [365 *\{(1 + 0.075)^{15} - 1\} * 1550 * 0.75 * 4.5] / 0.075$
N = 49.870568.81
N = 49.87 msa ~ 50 msa
At CBR 8 %
Using the interpolation rule in pavement thickness design graph, the pavement design is 610mm for this evaluation. For further evaluation, the pavement

Table.3. Pavement thickness CBR value

CBR 8%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	550	40	60	
20	575	40	85	
30	590	40	100	Base = 250
50	610	40	120	
100	640	50	140	Sub-base=200
150	660	50	160	

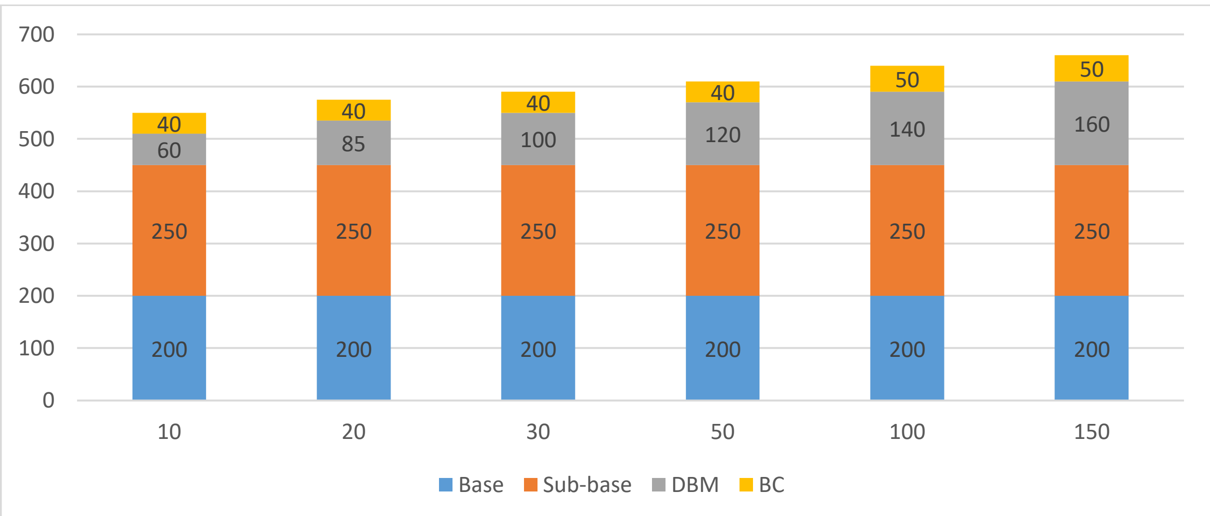

Table.4. Pavement thickness catalogue design catalogue is used to determine the dense bituminous macadam.

BC = 40 mm
DBM = 120 mm
Base = 250 mm
Sub Base = 200mm
Cumulative number of standard axle for actual value of vehicle damage factor
A = Initial traffic = 1550
D =Lane distribution factor = 0.75
F = Vehicle damage factor = 12.22
n = Design life in years = 15 years
r = Annual growth rate of commercial vehicles (for 7.5 per cent annual growth rate, r = 0.075)
$N = [365 *\{(1 + 0.075)^{15} - 1\} * 1550 * 0.75 * 12.22] / 0.075$
N = 135426300.2
N = 135.42 msa
At CBR 8 %
Using the interpolation method in pavement thickness design graph, the pavement design is 654 mm for this evaluation. For further evaluation, the pavement design catalogue is used to determine the dense bituminous macadam.
BC = 50 mm
DBM = 154 mm
Base = 250 mm
Sub Base = 200mm

IV. ANALYSIS OF RESULT

Now estimating the cost for 1km of road
Taking the length of the road = 1 km
Width of the road = 7.5 m
Therefore, for default Vehicle Damage Factor is
= 1000 * 7.5 * (120*0.001)
= 900 cum
Rate per cum = Rs 8570.11
For 900 cum = 8570.11*900
= Rs 77,13,099
Therefore, for actual Vehicle Damage Factor is
= 1000 * 7.5 * (154*0.001)
= 1155 cum
Rate per cum = Rs 8570.11
For 1155 cum = 8570.11*1155
= Rs 98,98,477
Difference is = Rs 98,98,477 - Rs 77,13,099
= Rs 2185378

V. CONCLUSIONS

Due to overloading, pavement deteriorates at faster rate and the loss value due to overloading is estimated to be Rs 2185378 for our current surveyed site which is 28.33 percent of the road cost for DBM layer. Hence the overloading should be restricted to avoid further road damage and to provide more serviceability.

- As overloading is increasing, it has to be controlled by rules and regulations.
- Intensity of weight enforcement and the level of penalty only cannot control overloading activities. So fines must be associated with intensified enforcement when considered in further strategy. Enforcement has higher efficiency at the initial stage. However efficiency decreases rapidly when enforcement levels increase gradually. Thus, the balance between level of enforcement and efficiency of enforcement must be considered. Effective means of managing truck overloading is not unitary. It must combine monitoring, inspection, enforcement and punishment as a complete. Regular monitoring, inspection and enforcement are the effective ways to control overloading.
- Use of technology (Automatic overloading information system) may be the effective way to control the overloading and Design should be done as per the actual traffic loading condition.
- To construct or improve road built quality to withstand heavier loads.
- To impose axle load limit and 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.
- The deterioration rate of the pavement and the loss value due to overloading is estimated to be Rs 2185378 for our current surveyed site which is 28.33 percent of the road cost of DBM layer. Therefore, overloading should be restricted to avoid further road damage and to provide more serviceability
- There are many factors which results in overloading and heavier axle loads on the road, one of the reason is that the new introduction of the more spacious trucks which eventually alter the axle load distribution on the road. In order to compete and keep themselves in the market by keeping the haulage cost at minimum, the truck owner generally overload their vehicle much beyond their rated capacity. To carry extra load, the vehicle owner strengthens the vehicle body and adds extra suspension springs to increase the height of the vehicle's body.

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