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Determination overloading permit fee/fine for Indian scenario

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Abstract

The influence of overloading on the operational life of flexible pavements is discussed for permit cost/fine formulation for overweight vehicles. To conduct this study, a theoretical study is carried out for flexible pavements for Indian Scenario. Using this analysis, permit cost/ fine fees for vehicle mode wise i.e., Light Goods Vehicle, Two Axle, Tandem Axle and Three axle vehicles are determined for medium, heavy and heavy traffic loading. The relationships between the passing loads and the number of allowable load cycles carrying legal loading condition are found out. These relationships form the basis by which the damage ratios of flexible pavements are assessed and vehicle fines are determined. Real case studies are presented to indicate the applicability and practicality of the proposed analysis for Indian Condition. Finally permit fees/ fine has been determined vehicle wise. Rs. 3.4, 22.4, 140 and 170 per km travelling road may be charged from Light Goods Vehicle, two axle, tandem axle and three axle trucks for Indian Scenario.

Keywords: Foundation, frame, piles, simplified models, soil-structure interaction, superstructure.

1. Introduction

One of the reasons for premature failures and unsatisfactory performance of roads in India is overloading of the commercial vehicles. Although there are legal axle load limits and gross vehicle weight limits of the vehicles plying on roads, they are violated wickedly by the transporters. By overloading, serious consequences are perpetrated on the life of the road, the truck and safety of all other road users. The damage caused by the overloaded vehicles is several times more than that induced by vehicles laden within the legal load limits / standard axle load limit. Overloading is among the most important causes of the deterioration of flexible pavements. This is especially critical in developing countries where the transportation of heavy freight on highways is increasing. Inspections indicate that this problem causes a great deal of damage to road networks and results in noticeable maintenance and repair costs. In order to overcome this problem, one has to develop other branches of transportation such as railroads, increase the bearing capacity of pavement for the heavier traffic loads, and improve the axle load distribution of overweight vehicles. Ticketing regulations/permit fees/fine fees for overweight vehicles can also be introduced so that the users either reduce their loads to the allowable limits or pay compensation fees or fines for the damage of road. Such regulation requires a method for calculating the fine.

The parameters included typical pavement compositions based on traffic survey, axle load survey and vehicle growth factor. The effect of these parameters on the behavior of pavement under various loading conditions was formulated. Mathematical correlations between the loading condition and the operational life of pavement were then developed. Pavement fatigue and rutting failure were the main criteria used in the development of these correlations. These were then used to develop overweight vehicle ticketing/permit fees. In order to show the applicability, numerical examples are presented in this paper.

The Central Motor Vehicles Rules stipulates that the maximum gross vehicle weight (GVW) shall not be more than the sum total of all the maximum safe axle weight put together and subject to restriction, if required, as indicated in Table 1 (IRC 1983). The permissible axle loads specified by the Government of India / competent authority is referred as "Legal Axle Load Limit". However, it is found that the actual loads carried by the transporters seldom follow these specified limits and tend to overload their commercial vehicles, which includes the new technology trucks, truck-trailer, tractor-trailer, etc. with high brake horse powers (BHP). This practice of carrying excess loads is coined as 'Overloading'.

Proportion of overloading is defined as = (Actual Load-Legal Load)/Legal Load (1)

2. Literature review

The rapid growth of freight traffic is now taxing a significant number of the U.S. national freight corridors. Additional demand accompanied by trucks over legal weight limits has been accelerating pavement at a faster rate than anticipated. States do not collect sufficient revenues to offset pavement damage caused by overweight trucks. As increase in overweight permit fee may affect different stakeholders positively and/or negatively, decision makers must develop policy options considering multiple conflicting objectives simultaneously. A multi-objective analysis approach was applied to address conflicting objectives associated with overweight freight truck mobility and to identify rational overweight truck damage cost recovery fee options by generating detailed tradeoffs between these options. Damage costs were estimated as fatigue damage using finite-element simulation models of pavement damage costs were estimated using a method based on equivalent single-axle load as per AASHTO standard. These costs were used to develop the mathematical relationship between the objectives and constraints in the multi-objective model. Tradeoff analysis framework and results of the tradeoff analysis depicted in the paper contributes to assessing infrastructure damage due to overweight trucks, and developing damage recovery fee policies considering multiple conflicting objectives (Dey et al. 2015).

Commercial Vehicle overloading on highways a menace; a bane to the exchequer having the onus of maintaining the road infrastructure - it not only increases his expenses but, is also one of the major causes of road accidents. Over 50 % of the commercial vehicles plying on our National / State Highways are overloaded. Although there are legal axle load limit and gross vehicle weight limit of the vehicles plying on roads, they are violated wickedly by the transporters. The damage by over-loaded vehicles to pavements is exponential. It is believed that the damage caused to a pavement by an axle load twice the standard axle is 16 times the damage incurred by the latter. There are standard legal axle load limit and gross vehicle weight limit but neither are followed by transporters nor enforced stringently by the enforcement authority. Overloading vehicles reduce the design pavement life. Controlling overloading not only prevents premature failure of the pavement but, also brings in monetary benefit to the Concessionaire. This paper presents the benefits in term of toll revenue for controlling overloading in a Build Operate and Transfer (BOT) Project with a real case study. From the case study, it is found that maximum revenue has been achieved by allowing vehicle to ply on the road carrying maximum permitted legal load. Controlling overloading reduces accidents, increases speed of vehicles, requires lesser pavement maintenance costs and operating cost. In the end, plausible ways of controlling overloading with strict enforcement are highlighted (Bagui et al. 2013).

Table 1
Legal Axle Load and GVW Limits

Axle category	Tire configuration	Legal Axle Load Limit (*T*)	Transport Vehicles Category	Maximum GVW (*T*)
Single Axle	Single tire – total 2 tires	6	Two-Axle truck (single in rear)	6+6 =12
	Dual tyre – total 4 tires	10.2	Two-Axle truck (dual in rear)	6+10.2=16.2
Tandem Axle	Two axles in a group with Dual Tires – total 8 tires	19	Three-Axle truck (tandem in rear)	6+19=25
			Three-Axle truck, three-axle trailer	6+19+10.2+19=54.2 (44 max. allowable)
Tri-dem Axle	Three axles in a group with Dual Tires – total 12 tires	24	Five-Axle Tractor-Trailer (dual in rear of tractor and tridem on trailer)	6+10.2+24=40.2

A process based on a mechanistic–empirical (ME) analysis was developed to estimate permit fees on the basis of truck-axle loading and configuration as well as the predicted pavement deterioration that they cause. The process was implemented in a software package, Integrated Pavement Damage Analyzer (IntPave). IntPave is a finite element–based program that calculates pavement responses, uses ME distress models to predict performance under any type of traffic load, is capable of comparing the level of distress caused by a heavy truck relative to a standard. Truck, and accordingly provides a permit fee. On the basis of a parametric study, it was found that, aside from the truck gross vehicle weight and axle configuration, pavement structure and the damage threshold to rehabilitation also heavily affect the permit fee (Tirado et al. 2010).

There are various methodologies that have been proposed worldwide for controlling overloading. But, in majority of the instances, these are theoretical and the practical implementation becomes difficult at site. Some of these methodologies are visited in this section. The Concessionaire of a project may control overloaded vehicle by measuring provision of weight of vehicle at roadside weigh bridge station. If overloading is controlled, number of vehicles are be increased assuming that same weight for different goods will be transported from one place to another place to fulfill the demand and supply of these particular goods.

If loading is controlled, the Vehicle Damage Factor (VDF) of each vehicle is reduced. For the purpose of the study, a total of five scenarios have been considered. The five scenarios are (1) actual case, (2) at legal load, (3) more than 10 % legal load, (4) more than 20 % legal load (5) more than 30 % legal load. Number of actual vehicles weighed during axle load survey and revised number considering different axle load controls and revised VDF values have been presented (Bagui et al. 2013).

Table 1
Permit Fee / Fine Fee for 30 MSA Traffic

Excess Load (KN)	CBR 5				CBR 10				CBR 15			
	3 Axle	Tandem Axle	Bus/Two Axle	LCV	3 Axle	Tandem Axle	Bus/Two Axle	LCV	3 Axle	Tandem Axle	Bus/Two Axle	LCV
0	0	0	0	0	0	0	0	0	0	0	0	0
10	2.7	0.4	1.0	*0.2*	2.4	0.4	0.9	0.1	2.2	0.4	0.8	0.1
20	3.4	0.5	2.3	*0.7*	3.0	0.8	2.0	0.6	2.8	0.8	1.9	0.6
30	4.1	1.6	4.0	*1.5*	3.6	1.4	3.5	1.3	3.5	1.3	3.4	1.3
40	4.9	*2.3*	6.1	2.6	4.4	2.0	5.4	2.3	4.2	1.9	5.1	2.2
50	5.9	*3.1*	8.7	4.1	5.2	2.7	7.7	3.6	4.9	2.6	7.3	3.4
60	6.9	*4.0*	11.9	6.0	6.1	3.5	10.5	5.3	5.8	3.3	10.0	5.1
70	8.0	*5.0*	15.7	8.6	7.1	4.4	13.9	7.6	6.7	4.2	13.3	7.2
80	9.2	*6.2*	20.3	11.7	8.1	5.5	18.0	10.4	7.7	5.2	17.1	9.9
90	10.5	*7.5*	25.8	15.7	9.3	6.6	22.8	13.9	8.9	6.3	21.7	13.2
100	11.9	*9.0*	32.1	20.5	10.6	7.9	28.4	18.2	10.1	7.6	27.1	17.3
110	13.5	*10.6*	39.5		11.9	9.4	35.0		11.4	8.9	33.3	
120	15.2	*12.4*	48.0		13.4	11.0	42.5		12.8	10.5	40.5	
130	17.0	*14.4*	57.8		15.0	12.8	51.1		14.3	12.2	48.7	
140	18.9	*16.7*			16.8	14.8			16.0	14.1		
150	21.0	*19.1*			18.6	16.9			17.7	16.1		
160	23.3	*21.8*			20.6	19.3			19.6	18.4		
170	25.7	*24.7*			22.8	21.9			21.7	20.8		
180	28.3	*27.9*			25.1	24.7			23.9	23.5		
190	*31.1*	31.4			27.5	27.8			26.2	26.4		
200	*34.0*	35.1			30.1	31.1			28.7	29.6		
210	*37.2*	39.2			32.9	34.7			31.4	33.1		
220	*40.5*	43.6			35.9	38.6			34.2	36.8		
230	*44.1*	48.4			39.0	42.8			37.2	40.8		
240	*47.9*				42.4				40.4			

The Government of India specified the limit of gross truck load. Many trucks violate the imposed load limits to reduce transportation unit cost. There is no upper limit to the excess load that a vehicle can carry after the imposition of fine; and unloading excess loaded at site is discretionary. Estimation of critical axle load that makes a boundary between penalized axle load limits and unallowable loads has been studied. KENPAVE, FPAVE and IIT PAVE software are used to determine critical axle load limits for single axle single tire, single axle dual tires, tandem axle dual tires and tridem axle dual tires. Critical axle load is found more than 28 – 33%, 29-33%, 25-28% and 22-23 % of permissible legal load for single axle single tire, single axle dual tires, and tandem axle dual tires and tridem axle dual tires respectively with variation of tire pressure from 0.56 MPa to 1.00 MPa (Bagui 2014).

A procedure was developed for quantifying the pavement cost of proposed changes in regulations governing truck weights and dimensions, particularly the marginal cost method used for pavement cost allocation. The procedure was part of a comprehensive study undertaken by the Ontario Ministry of Transportation in response to government and industry initiatives to harmonize Ontario's truck regulations with those in surrounding jurisdictions. The marginal pavement cost of truck damage was defined as a unit cost of providing pavement structure for one additional passage of a unit truckload (expressed as equivalent single axle load).

Table 2
Permit Fee / Fine Fee for 100 MSA Traffic

Excess Load	5 CBR				10 CBR				15 CBR			
	Three Axle	Tandem Axle	Single Axle	LCV	Three Axle	Tandem Axle	Single Axle	LCV	Three Axle	Tandem Axle	Single Axle	LCV
0	0	0	0	0	0	0	0	0	0	0	0	0
10	1.33	0.22	0.50	0.08	1.24	0.2	0.5	0.1	1.19	0.20	0.44	0.07
20	1.67	0.48	1.15	0.35	1.56	0.4	1.1	0.3	1.49	0.43	1.02	0.31
30	2.04	0.78	1.98	0.74	1.91	0.7	1.8	0.7	1.83	0.69	1.77	0.66
40	2.46	1.13	3.03	1.29	2.29	1.0	2.8	1.2	2.20	1.00	2.71	1.15
50	2.92	1.52	4.33	2.03	2.72	1.4	4.0	1.9	2.61	1.36	3.87	1.81
60	3.42	1.98	5.92	3.01	3.19	1.8	5.5	2.8	3.06	1.77	5.29	2.68
70	3.97	2.50	7.84	4.26	3.70	2.3	7.3	4.0	3.55	2.23	7.00	3.81
80	4.57	3.08	10.13	5.85	4.27	2.9	9.4	5.5	4.08	2.75	9.05	5.22
90	5.23	3.73	12.83	7.82	4.88	3.5	12.0	7.3	4.67	3.33	11.46	6.98
100	5.94	4.47	16.00	10.22	5.54	4.2	14.9	9.5	5.31	3.99	14.29	9.13
110	6.72	5.28	19.68		6.26	4.9	18.3		6.00	4.72	17.57	
120	7.55	6.19	23.92		7.04	5.8	22.3		6.74	5.53	21.36	
130	8.46	7.19	28.78		7.88	6.7	26.8		7.55	6.42	25.70	
140	9.43	8.30			8.79	7.7			8.42	7.41		
150	10.48	9.52			9.77	8.9			9.35	8.50		
160	11.60	10.85			10.82	10.1			10.36	9.69		
170	12.81	12.31			11.94	11.5			11.44	10.99		
180	14.10	13.90			13.15	13.0			12.59	12.41		
190	15.48	15.63			14.43	14.6			13.82	13.95		
200	16.95	17.50			15.81	16.3			15.14	15.63		
210	18.52	19.53			17.27	18.2			16.54	17.44		
220	20.19	21.73			18.83	20.3			18.03	19.40		
230	21.97	24.09			20.49	22.5			19.62	21.51		
240	23.86				22.25				21.30			

The results indicate that the highway type (or truck volumes associated with the highway type) has a major influence on marginal costs. For example, the annualized pavement life-cycle cost of the passage of one additional typical truck on 1 km of a highway in southern Ontario can range from about \$0.004 for a freeway to \$0.46 for a local road (Canadian dollars). The marginal cost method can be used to quantify pavement damage due to any axle load combination for both new and existing, in-service pavements.

The knowledge of marginal costs would enable highway agencies to quantify the impact of specific regulatory changes of truck axle weights on pavement costs; for example, to quantify the pavement costs associated with increasing allowable truck weights of logging trucks on a specific segment of the highway network (Jerry et al. 1998).

Summary of literature review

It is found from the past study that study on the determination overloading vehicle cost in India is very limited. Therefore, there is a need of such study to determine overloading cost to recover pavement damage cost from the transporter to maintain the road in usable condition. Based on this need, overloading cost in the form of permit fee/ fine has been presented in this present paper with case studies and determine single overloading cost vehicle mode wise.

Table 3
Permit Fee / Fine Fee for 150 MSA Traffic

Excess Load (KN)	CBR 5				CBR 10				CBR 15			
	Three Axle	Tandem	2 Axle	LCV	Three Axle	Tandem	2 Axle	LCV	Three Axle	Tandem	2 Axle	LCV
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.93	0.15	0.34	0.06	0.85	0.14	0.32	0.05	0.83	0.14	0.31	0.05
20	1.16	0.33	0.80	0.24	1.07	0.31	0.73	0.22	1.04	0.30	0.71	0.22
30	1.43	0.54	1.38	0.51	1.31	0.50	1.27	0.47	1.27	0.49	1.23	0.46
40	1.71	0.78	2.11	0.90	1.58	0.72	1.94	0.82	1.53	0.70	1.89	0.80
50	2.03	1.06	3.02	1.41	1.87	0.98	2.77	1.30	1.82	0.95	2.70	1.26
60	2.38	1.38	4.13	2.10	2.19	1.27	3.79	1.93	2.13	1.23	3.69	1.87
70	2.77	1.74	5.46	2.97	2.54	1.60	5.02	2.73	2.48	1.56	4.89	2.66
80	3.19	2.15	7.06	4.08	2.93	1.97	6.49	3.75	2.85	1.92	6.31	3.65
90	3.64	2.60	8.94	5.45	3.35	2.39	8.22	5.01	3.26	2.33	8.00	4.87
100	4.14	3.11	11.15	7.13	3.81	2.86	10.25	6.55	3.70	2.78	9.97	6.37
110	4.68	3.68	13.71		4.30	3.38	12.60		4.19	3.29	12.27	
120	5.26	4.31	16.67		4.84	3.96	15.32		4.71	3.86	14.91	
130	5.89	5.01	20.06		5.41	4.61	18.43		5.27	4.48	17.94	
140	6.57	5.79			6.04	5.32			5.88	5.17		
150	7.30	6.63			6.71	6.09			6.53	5.93		
160	8.08	7.56			7.43	6.95			7.23	6.76		
170	8.93	8.58			8.20	7.88			7.98	7.67		
180	9.83	9.68			9.03	8.90			8.79	8.66		
190	10.79	10.89			9.91	10.01			9.65	9.74		
200	11.81	12.20			10.86	11.21			10.57	10.91		
210	12.91	13.61			11.86	12.51			11.55	12.17		
220	14.07	15.14			12.93	13.91			12.59	13.54		
230	15.31	16.79			14.07	15.43			13.70	15.02		
240	16.63				15.28				14.87			

3. Proposed methodology

Pavement design life is determined based on standard axle load as proposed below:
Legal axle load and gross weight of vehicle is mentioned in Table 1. Design life will be increased/ decreased depending on legal axle load and standard axle load i.e. vehicle damage factor. Total life of road will be determined from design life and distribution factor using following equations: Total repetition = Design life/distribution factor (2)

Distribution factor is equal to 0.5, 0.375 and 0.3 for two, four lanes and six lanes divided carriageway. It is found from field study that overloading of front axle (Steering) is minimal and not considered in the analysis and rear axle/axles are considered for analysis. Vehicle is allowed to operate at legal axle load limit and no fine is imposed. Fine / permit fee is imposed on the vehicle which is operating more than legal load. For the determination of fine, it is assumed that one type vehicle will ply on the road. Total number of repetition based on legal load and overloading will be determined and difference of repetition is responsible for damaging road and damaging cost will recover from the truck driver/owner.

Let N_S, N_L and N_O be design life in term of standard axle, legal axle and overloading axle respectively. Reduction in life per repetition of axle is $1/N_S$, $1/N_L$ and $1/N_O$ for standard axle, legal axle and overloading axle respectively.

Basic Excess damage for overloading vehicle for single repetition is given by (Sadeghi1 and Fathali 2007) has been used for damage analysis:

$$D_F=1/N_O - 1/N_L \tag{3}$$

Let C be cost per km of the road and D be distribution factor for used to determine design traffic. Therefore, damaging cost per axle repetition of overloading axle is given by:

$$\text{Damaging Cost}=D_F\times C\times D \tag{4}$$

Equation 4 is the general equation for determination of the damaging cost. This equation has been revised for different vehicle types namely, LCV (Rear axle single tire), two axle vehicle (Rear axle 4 tires), Tandem axle vehicle (Rear dual axles with 8 tires) and three axles' vehicle (3 axles with 12 tires). Legal axle load and gross weight are mentioned in Table 1.

3.1 Light Goods Vehicle (LCV)

As stated in Table 1, single axle with single tire is critical loading patterns for LCV. Gross weight is 12 t with rear axle legal load of 6 t.
Equation 3 will be modified as:

$$D_F=1/[N_{(12+dP-6)}] - 1/N_{[6]} \tag{5a}$$

Where, $_{dP}$ is the load in excess of legal load.
Similarly for two axles with rear 4 tires and three axles with 12 tires equation 3 will be reduced to:

$$D_F=1/[N_{(16.2+dP-6)}] - 1/N_{[6]} \tag{5b}$$
$$D_F=1/[N_{(25+dP-6)}] - 1/N_{[6]} \tag{5c}$$
$$D_F=1/[N_{(33+dP-6)}] - 1/N_{[27]} \tag{5d}$$

These are the basic equations which will be used for the determination of damaging cost of the different type of axles.

3.2 Existing model for pavement design

The resilient modulus of the subgrade is estimated from its respective CBR-value which is based on the following empirical relationship (IRC 37 2012):
The relation between resilient modulus and the CBR is given as:

$$E\ (\text{MPa}) = 10*\text{CBR for CBR} < 5 \text{ and } 17.6*(\text{CBR})^{0.64} \text{ for CBR} > 5 \tag{6}$$

E= Resilient modulus of subgrade soil in MPa.

Resilient Modulus (MR) of the untreated GSB above the subgrade of modulus, $MR_{subgrade}$ is given as:

$$MR_{gsb} = 0.2h^{0.45} * MR_{subgrade} \tag{7}$$

Where h=thickness of sub base layer in millimeter.

Fatigue life of a bituminous mixture for bottom up cracking at a reliability level of 80% and 90 % is given as (IRC 37 2012).

$N_f = 2.21 * 10^{-04} \text{ x } [1/\varepsilon_t]^{3.89} * [1/E]^{0.854}$ (8)
$N_f = 2.021 * 10^{-04} \text{ x } [1/\varepsilon_t]^{3.89} * [1/E]^{0.854}$ (9)

N_f = fatigue life, ε_t = Maximum Tensile strain at the bottom of the bituminous layer, E = Elastic modulus of the bituminous layer

3.3 *Subgrade rutting criteria*

The equation for rutting is given as (IRC 37 2012) for 80 and 90 % reliability.

$N= 4.1656 \text{ x } 10^{-08} [1/\varepsilon_v]^{4.5337}$ (10)
$N= 1.41 \text{ x } 10^{-08} [1/\varepsilon_v]^{4.5337}$ (11)

Where, ε_v = Subgrade strain at the top of subgrade. Design traffic up to 30 Million Standard Axle (MSA), a reliability level of 80 % has been considered and Viscosity Grade (VG) 30 bitumen is to be used with E value 1700 MPa for Bituminous Concrete (BC) and Dense Bituminous Concrete (DBM) for evaluation of pavement thickness. Design traffic above 30 MSA, a reliability level of 90% has been considered and VG 40 bitumen is to be used with E value 3000 MPa for BC and DBM for evaluation of pavement thickness. Average annual pavement temperature is considered 35^0 C for design.

3.4 *Determination of permit cost/fine for overloading vehicle*

Permit fees have been analyzed for LCV, BUS/ Two axle, tandem axle and three axle considering some case studies as mentioned below:

- California Bearing Ratio (CBR) taken 5, 10 and 15.
- Design traffic loading of 30,100 and 150 MSA.
- Two lane configurations are adopted for 30 MSA and four lane configuration adopted for 100 and 150 MSA traffic loading.
- Distribution factor 0.375 and 0.5 for four lane and two lane roads.

A typical calculation is presented below

Over Load = 10 KN		
Design Traffic =	100 MSA	
CBR=	5 %	
Pavement	Composition	
BC =	40	mm
DBM =	105	mm
WMM =	250	mm
GSB =	300	mm
Vehicle Type	Bus/ 2 axle	Overloaded
Rear Axle Single	axle with dual tires = 177 KN	
Standard Axle =	148	KN

VDF for rear axle = (T/148)^4
Design traffic in term of legal axle = 50 MSA
Rear Axle load = 187 KN
Axle repetition = 40 MSA
Operational Life reduction Factor = 4.88335E-09
Road Configuration = 4 Lanes

Length of Road = 40	km	
Cost Per km =	120000000	
Distribution Factor =	0.375	
Permit fee = Rs .79	for 40 km	Road

Permit fee has been determined for different cases and summarized results are presented in Tables 1, 2 and 3 and a typical graph is shown in Figure 1.

4. Test results and discussion

Results have been presented in Table 1, 2 and 3 for 30 MSA, 100 MSA and 150 MSA traffic for CBR values of 5, 10 and 15. From Table 1, it is found that no fine /permit fee is imposed on vehicle operating at legal axle load limit. Fine is imposed when axle carries load more than legal load. Axle load data were collected from 70 locations in India for different roads namely national highways, state highways, major district roads and other district roads. Overloading identified for LCV, Bus/ two axle, truck with Tandem and three axle trucks.

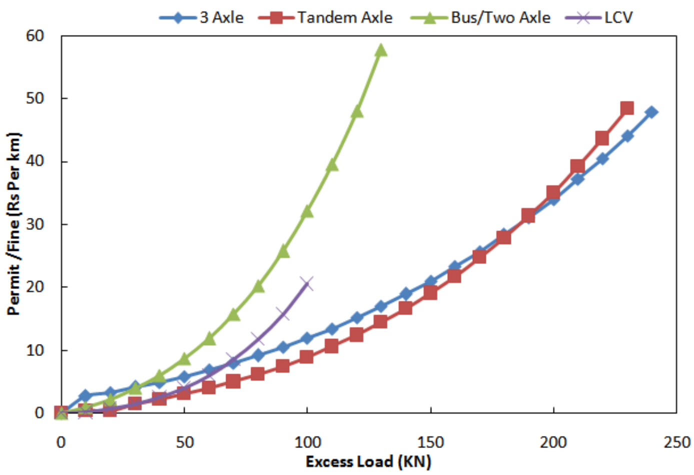

Fig. 1. Excess load vs. permit/fine per Km traveling of vehicle.

Finally excess load considered for 100 KN, 130 KN,230 and 240 KN for LCV, Bus/two axle, tandem axle and three axle vehicles respectively and fine has been determined accordingly. Fine per km has been presented in these tables (Table 1 to Table 3). From these tables, it is found that fine increases with increasing overloading weight. It is minimized at 0 excess load and maximum at highest overloading. For a given vehicle for a given over loading, fine increases with decreasing CBR of subgrade. This is due to increasing project cost for decreasing subgrade CBR value. Lower CBR demands higher bituminous thickness and sub base layer and higher project cost and higher fine cost. Therefore, higher subgrade is better choice for road for reducing damage cost. Therefore, strong subgrade strength is preferable option. Lane configuration is an important factor for damaging cost. Table 1 is presenting the damaging cost for two lanes road which requires more damaging cost. This is for the following reasons:

– Higher distribution factor for two lanes roads
– Lower design MSA but pavement life reduction factor for the case of two lanes road is more, although cost per km is less.

Even same lane configuration (4 lanes) for 100 MSA and 150 MSA are considered but fine is found more for traffic 100 MSA than that of 150 MSA traffic. This is due to higher pavement life reduction factor. For 30 MSA traffic and 5 CBR, beneficial overloading scheme is presented in Table 1 with color mark. From Table 1, it is found that overloading cost up to 30 KN is least for LCV, overloading in tandem axle vehicle is better option for over loading more than 30 KN and up to 170 KN. Overloading in three axle vehicle is better option for overloading more than 170 KN. Same is also shown in Figure 1. Figure 1 gives a guide line for beneficial for overloading for different vehicle types. For a known over loading which vehicle may be useful to minimize fine. Transporter may choice overloading accordingly. Average overloading cost has been determined and presented in Table 4. Average overloading weight for LCV, Bus/two Axle. Tandem axle and three axle vehicle are determined and presented in Table 5.

Table 4
Average Single Overloading Cost Considering Different Scenario

Excess Load (KN)	Average 30 MSA Traffic				Average 100 MSA Traffic				Average150 MSA Traffic				Average			
	3 Axle	Tandem Axle	Bus/ Two Axle	LCV	3 Axle	Tandem Axle	Bus/ Two Axle	LCV	3 Axle	Tandem Axle	Bus/ Two Axle	LCV	3 Axle	Tandem Axle	Bus/ Two Axle	LCV
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0
10	2.4	0.4	0.9	0.1	1.3	0.2	0.5	0.1	0.9	0.1	0.3	0.1	1.5	0.3	0.6	0.1
20	3.0	0.7	2.1	0.6	1.6	0.4	1.1	0.3	1.1	0.3	0.7	0.2	1.9	0.5	1.3	0.4
30	3.7	1.4	3.6	1.3	1.9	0.7	1.9	0.7	1.3	0.5	1.3	0.5	2.3	0.9	2.3	0.8
40	4.5	2.1	5.5	2.3	2.3	1.1	2.9	1.2	1.6	0.7	2.0	0.8	2.8	1.3	3.5	1.5
50	5.3	2.8	7.9	3.7	2.7	1.4	4.1	1.9	1.9	1.0	2.8	1.3	3.3	1.7	4.9	2.3
60	6.2	3.6	10.8	5.5	3.2	1.9	5.6	2.8	2.2	1.3	3.9	2.0	3.9	2.3	6.8	3.4
70	7.3	4.6	14.3	7.8	3.7	2.4	7.4	4.0	2.6	1.6	5.1	2.8	4.5	2.8	8.9	4.9
80	8.4	5.6	18.5	10.7	4.3	2.9	9.5	5.5	3.0	2.0	6.6	3.8	5.2	3.5	11.6	6.7
90	9.5	6.8	23.4	14.3	4.9	3.5	12.1	7.4	3.4	2.4	8.4	5.1	6.0	4.3	14.6	8.9
100	10.9	8.2	29.2	18.7	5.6	4.2	15.1	9.6	3.9	2.9	10.5	6.7	6.8	5.1	18.2	11.7
110	12.3	9.6	35.9		6.3	5.0	18.5		4.4	3.5	12.9		7.7	6.0	22.4	
120	13.8	11.3	43.7		7.1	5.8	22.5		4.9	4.0	15.6		8.6	7.1	27.3	
130	15.4	13.1	52.5		8.0	6.8	27.1		5.5	4.7	18.8		9.6	8.2	32.8	
140	17.2	15.2			8.9	7.8			6.2	5.4	0.0		10.8	9.5		
150	19.1	17.4			9.9	9.0			6.8	6.2	0.0		11.9	10.9		
160	21.2	19.8			10.9	10.2			7.6	7.1	0.0		13.2	12.4		
170	23.4	22.5			12.1	11.6			8.4	8.0			14.6	14.0		
180	25.7	25.4			13.3	13.1			9.2	9.1			16.1	15.8		
190	28.3	28.5			14.6	14.7			10.1	10.2			17.7	17.8		
200	31.0	32.0			16.0	16.5			11.1	11.4			19.3	20.0		
210	33.8	35.7			17.4	18.4			12.1	12.8			21.1	22.3		
220	36.9	39.7			19.0	20.5			13.2	14.2			23.0	24.8		
230	40.1	44.0			20.7	22.7			14.4	15.7			25.1	27.5		
240	43.6				22.5				15.6	0.0			27.2			

Table 5
Permit/Fine in Rupee per km in Indian Scenario

Overloading(KN)	3 Axle	Tandem Axle	Bus/Two Axle	LCV
	170	140	110	60
Fine(Rs. Per km)	14.6	9.5	22.4	3.4

5. Conclusion

This paper presents the behavior of flexible pavements under overloaded vehicles and the determination of overloading permit fees/fine under different scenario for Indian condition. Typical case studies have been considered for different traffic loadings and different subgrade strengths. Mathematical correlations between the allowable number of load cycles and the magnitude of axle loads were determined, incorporating the main factors influencing the pavements behavior and taking into account the load conditions. Using these correlations, the operational life reduction factors due to the excess loads for the different overloaded vehicles were obtained fine costs. Several numerical examples were presented. The results may be used to collect fines by the road authorities for pavements damages compensation as predicted by analysis as shown in this present paper. Similar study may be carried out for a particular road and damaging cost may be determined which may be imposed for overloading vehicle to recover damaging pavement.

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