Effect of Overloading of Vehicles In Pavement Design

Yalla Sai Avinash[1]
[1]PYDAH COLLEGE OF ENGINEERING

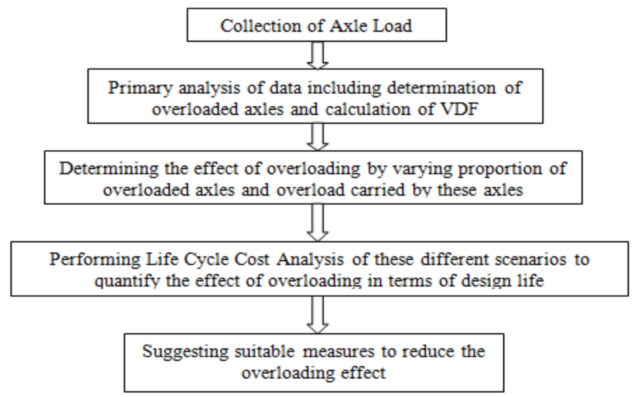
I. INTRODUCTION

India is one of the fastest growing nations in the world. India's economy has grown manifolds in the recent past and is likely to grow further as per the present trends. Traffic on a road pavement is characterized by a large number of different vehicle types, which 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 Government of India has specified the legal limit of axle load. Many trucks violate these load limits to reduce unit transportation cost. The damage by overloaded vehicles to pavements is exponential.

The analysis of the traffic characteristic and loading is carried out on the basis of data of axle load survey conducted on Hyderabad to Vijayawada National Highway 65 in A.P. The equivalent standard axle load (ESAL) of each vehicle is determined by using the fourth power law. The Vehicle Damage Factor (VDF) is a multiplier for converting the number of commercial vehicles of different axle loads and axle configurations to the number of standard axle-load repetitions. VDF is one of the parameter which incorporates the effect of loading of vehicles in pavement design. The objectives of this study are to determine the variation of vehicle damage factors with respect to change in the amount of overload on vehicle. Different proportions of percentage of overloaded axles as well as percentage of overload carried by these overloaded axles are considered simultaneously to study the effect incurred on vehicle damage factor. Also, the effect of overloading on the thickness of asphalt layer is studied to quantify the overloading effect.

Effect of overloading of vehicles is studied in various perspectives. The proportion of overloaded vehicles is identified and these are considered for the further analysis. An attempt is carried out to study effect of overloading of vehicles by increasing the proportion of overloaded vehicle to observe the variation in truck factors. Also, super pave mix design is considered in pavement design which incorporates a wide variety of characteristics related to pavement such as ageing of binder, weather characteristics so as to yield better and accurate results. And it is found that the truck factors are increasing substantially with overloading of vehicles

II. METHODOLOGY ADOPTED FOR THIS STUDY



In this present study, area considered for analysis is a road stretch on 4- lane national highway 65 between Keesara and Vijayawada section in Andhrapradesh. This highway stretch connects two important towns of Vijayawada and Hyderabad. As it runs between major cities, there will have good proportion of commercial vehicles for analysis.

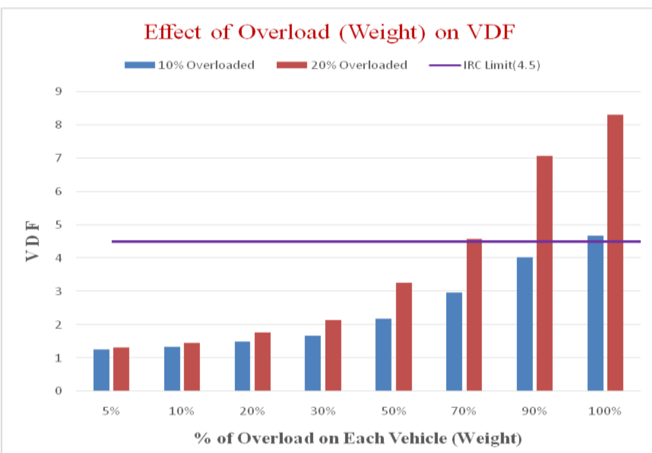
Sample of Axle Load Survey Data

Vehicle Reg. No	Vehicle Type	Axle Configuration	Front-1	Front-2	Rear-1	Rear-2	Rear-3
AP-05	5XL	1.1.122	4080	3730	3280	5690	5830
MH-01	5XL	1.2.222	3210	5080	1830	8750	6550
AP-05	5XL	1.2.222	1930	2410		2210	2125
MH-12	4XL	1.1.22	1870		1840	1835	
AP-05	5XL	1.2.222	2120	2690		2140	1485
TS-09	4XL	1.2.22	2080	7840	6230	4760	
MH-09	4XL	1.2.22	2150	4855	4480	5015	
MH-05	4XL	1.2.22	2050	7050	5230	5810	
AP-05	5XL	1.2.222	2355	4120		6380	6780
AP-05	5XL	1.2.222	3450	8140	5040	5230	6080
TS-09	5XL	1.2.222	2590	2580		2380	2355
MH-05	4XL	1.2.22	2230	5130	6480	5810	
AP-05	5XL	1.2.222	2590	2380		1750	2340
AP-05	5XL	1.2.222	2330	2590		2540	2270
MH-05	5XL	1.2.222	2920	6830	6340	6480	5230
AP-05	5XL	1.2.222	2380	7935	2730	6080	5230
TS-09	3XL	1.22	2230	5040	9850		
AP-05	5XL	1.2.222	3310	4305		6380	6230
AP-05	3XL	1.22	1980	4030	5140	4630	8030
TS-09	4XL	1.222	1830	5030		6830	6730
AP-05	5XL	1.2.222	3040	4030	5140	4630	8030
TS-09	5XL	1.2.222	2940	5030		6830	6730
MH-05	4XL	1.2.22	2930	6030	5540	8385	
TS-09	5XL	1.1.222	2530	7830	1785	6655	7250
AP-05	4XL	1.1.22	2130	3785	5260	6540	
MH-05	4XL	1.2.222	1810	2580		1575	2270
AP-05	5XL	1.2.222	1750	2430		1180	1510

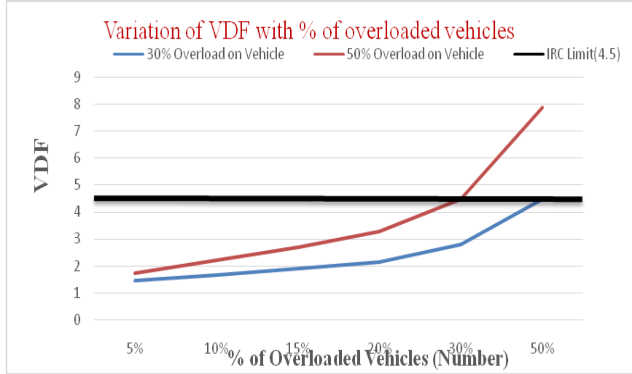
Vehicle Damage Factors for Different Overloading Combinations

Vehicle Damage Factors for Different Overloading								
	Percentage of Overload carried by selected set of axles (Weight)							
% Overloaded Axles	5%	10%	20%	30%	50%	70%	90%	100%
5%	1.24	1.27	1.34	1.46	1.72	2.07	2.38	2.91
10%	1.26	1.33	1.49	1.67	2.19	2.96	4.02	4.68
15%	1.29	1.39	1.63	1.91	2.68	3.83	5.79	6.53
20%	1.315	1.46	1.77	2.15	3.27	4.58	7.07	8.31
30%	1.47	1.63	2.16	2.81	4.47	6.86	11.21	14.86
50%	2.23	2.49	3.51	4.48	7.87	13.07	20.16	24.33

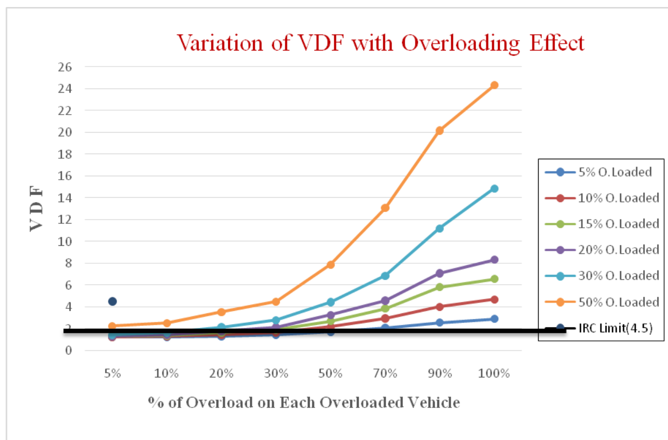
If the percentage of overload on overloaded axles is kept constant and percentage of overloaded axles is varied, VDF is in the increasing manner. But it is clearly seen in high amount of percentage of overloaded axles. In the initial increments such as 5%, 10% and 15%, it is bound to increase in a very less margin. But, after that it has clearly shown a substantial hike in VDF with each successive percentage of overloaded axles which is clearly seen from below figure



Also, when the percentage of overloaded vehicles is kept constant and percentage of overload on overloaded axles is varied, same result is noticed. Vehicle Damage Factor is increasing with percent of overload on axles. But it is nominal in initial stages of overload such as 5%, 10% for less number of overloaded vehicles. But it has shown a sudden hike with the percentage of overload for large proportion of overloaded axles which are depicted in figure below



From the results of VDF from, it is evident that the vehicle damage factor is substantially increasing with the increase of both percentage of overloaded axles and percent of overload carried by these axles which is shown in figure below. As discussed in previous sections, the variation of VDF is minimal i.e., in the range of 0.3-0.6 for lesser percentage combinations such as 5% overloaded axles with 5% overload. Whereas, this difference is very significant and in the range of 5-7 for high percentage combinations such as 50% overloaded axles with 70% or 90% overload(weight) on axles.



The horizontal line in black colour in the graph is the maximum value suggested by IRC: 37-2012 which is 4.5. But as discussed earlier, it has got exceeded right from the 10% overloaded axles onwards. As the proportion of overloaded axles increased more, the VDF is seen exceeding the IRC limit from earlier overload onwards. Also, it can be inferred from chart that the rise of VDF values is nearly exponential as it traces nearly an exponential curve at high percentage of overloaded axles. From this graph, one can infer that the effect of overload carried by axle on VDF is nominal in smaller percentages of overload, but it would be very high for higher percentage of overload. In this context, the difference between VDF values for 10% and 20% overloaded axles are highly noticeable for higher percentage of overloads.

III. CONSIDERING ALL VEHICLES CARRYING MAXIMUM LEGAL LOAD

Let us consider all axles are carrying their maximum axle legal load on them. It is not possible in practical situation, but it can be referred as an ideal case for analysis.

If all the axles are equally loaded to their legal limit, the VDF value must be equal to 1. Here, also the same procedure as followed earlier is followed to obtain VDF values and the values which exceeded maximum VDF given by IRC: 37-2012 are indicated with bold letters.

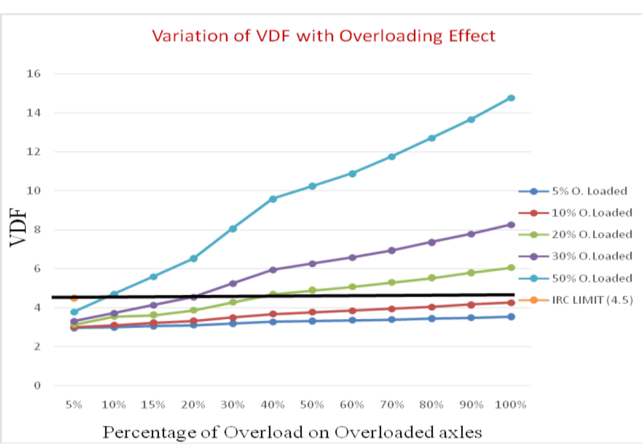
The results have been tabulated below:

Vehicle Damage Factors for Different Overloading Combinations for All-Maximum Load Limit Case

Vehicle Damage Factors for Different Overloading								
	Percentage of Overload carried by selected set of axles (Weight)							
% Overloaded Axles	5%	10%	20%	30%	50%	70%	90%	100%
5%	2.96	3.00	3.11	3.19	3.32	3.39	3.49	3.54
10%	3.02	3.12	3.33	3.51	3.78	3.93	4.16	4.27
20%	3.15	3.55	3.87	4.28	4.89	5.29	5.79	6.05
30%	3.32	3.73	4.55	5.25	6.28	6.94	7.79	8.26
50%	3.79	4.71	6.53	8.05	10.24	11.75	13.65	14.76

In this case, since all axles are taken as carrying their legal axle load, the VDF values are comparatively larger than the previous actual loading case. This is because all vehicles carrying maximum legal load will never happen in real condition on roads. But this can be taken as reference data to study the real overloading effect.

The graphical representation of all axles carrying their maximum legal load is shown in below figure.

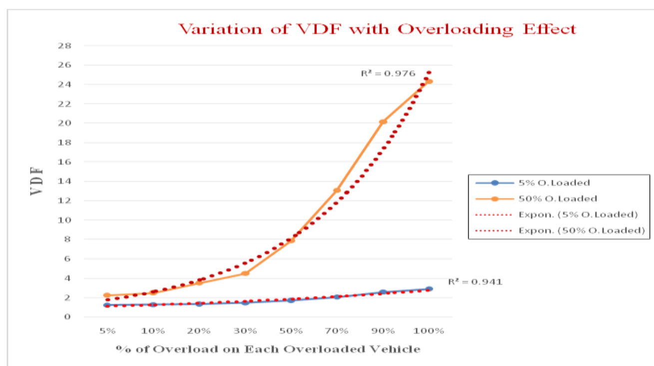


The variation of these values shown in above figure says that it is not increasing exponentially rather increasing nearly linearly because of the assumptions made for this case. Also, between 30% and 50% overloaded axles, at high overloads, the VDF values are nearly doubled. This shows how overloading will be a critical concern for higher overloads.

IV. CURVE FITTING FOR EFFECT OF OVERLOADING

Variation of VDF with overloading effect is given below keeping percentage of overloaded axles constant and percentage of excess load on each overloaded axle is varied. The trend lines for the considered two cases i.e., 5% and 50% overloaded axles are fit for different type of curves an R^2 value is calculated for each trend line.

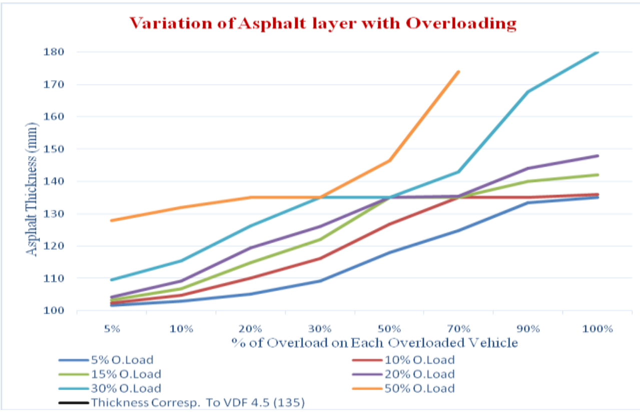
The trend lines are represented with dotted lines for 5% overloaded axles and 50% overloaded axles in the figure below.



Determination of Goodness of Fit for Overloading Effect

And it is observed that, the variation is perfectly fit for exponential curve with R^2 values greater than 0.9. Since, R^2 values are very high, it can be concluded that exponential curve is a good fit to explain overloading effect.

V. EFFECT OF OVERLOADING OF VEHICLES IN PAVEMENT DESIGN



So, it can be inferred that the thickness of asphalt layer is increasing in greater amount as the overload and proportion of overloaded axles increasing.

For IRC maximum VDF value of 4.5, cumulative msa is 50 and asphalt thickness required is 135mm which is indicated in figure by a thick black horizontal line. For the actual loading on this section whose VDF is nearly 4.7, the employed thickness can be 135 mm. But more than half of cases from 15% overloaded axles onwards, the value exceeded and rose up to around 180 mm. Providing an asphalt layer of thickness nearly 180 mm is very uneconomical.

So, it can be said that, there is a need to reduce carrying of overloads on pavements so as to increase design life of pavement as well as to eliminate the provision for thicker layer of asphalt which in turn increases project costs to greater extent

VI. CONCLUSIONS

Different combinations of overloading by varying proportion of overloaded axles and percentage of overload on axles are analysed. The important conclusions are summarized below:

- Vehicle damage factors are observed to be exponentially increasing with the percentage of overloaded axles and overload carried by them as it is seen that R^2 value is above 0.9.
- Difference in VDF values is minimal i.e., in the range of 0.3-0.6 in case of 5%, 10% combinations, but the effect has been highly significant for high percentage of overloaded axles and high percentage of overloads as well, since the difference of VDF values is about 5 to 7.
- Vehicle damage factors are high for the all- axle maximum load case as these values are starting directly from 3 which is very high compared to actual loading scenario where values start from 1.4 itself. It is because all vehicles are carrying its maximum loads which are an imaginary condition.
- It can be concluded that effect of large number of axles carrying less overload (weight) is more than the less number of axles carrying more overload (weight).
- In most of the combinations, it is seen that asphalt layer thickness is exceeding the thickness of 135 mm which is obtained with IRC suggested maximum VDF value of 4.5.
- Since laying of asphalt layer throughout the road stretch is very expensive, thicknesses of the order of 170 and above which are obtained for 70% of overload (weight) on 50% overloaded axles are not feasible in practical conditions.
- The thickness of asphalt layers are substantially increasing with overloading effect which in turn incurs very high construction costs because of which it can be regarded as very uneconomical.
- So, in relation to practical conditions, the increase in asphalt layer thickness is not feasible due to economic considerations, there is a need to reduce this overloading effect on roads by employing social and legal measures.

VII. SCOPE OF PROJECT

- The scope of this study is particularly constrained to effect of overloading on VDF. Several other factors can also be considered which influence pavement design such as regional conditions, temperature for analysis.
- Since the loading on a vehicle is dynamic in nature, the effect of overloading can be mathematically modelled to obtain accurate effect of overloading in pavement design.

REFERENCES

[1] **Donia Savio, M.R. Nivitha, B.K Bindhu and J.M. Krishnan** (2016) Overloading Analysis of Bituminous Pavements in India using M-E PDG. *Transportation Research Procedia*, **17**, 607-616.

[2] **Pais, J. C., S. I. R. Amorim and M. J. C. Minhoto** (2013) Impact of Traffic Overload on Road Pavement Performance. *ASCE Journal of Transportation Engineering*, **139**, 873-879.

[3] **IRC: 37-2012** *Guidelines for the design of flexible pavements*, 3rd Edition, New Delhi: Indian Roads Congress, 2012.

[4] **Jeongho, O., Fernando, E.G. and Lytton, R.L.** (2007) Evaluation of Damage Potential for Pavements due to

Overweight Truck Traffic. *ASCE Journal of Transportation Engineering*, **133 (5),** 308-317.

[5] **Sadeghi, J. M. and M. Fathali** (2007) Deterioration analysis of flexible pavements under Overweight Vehicles. *ASCE Journal of Transportation Engineering*, **133(11),** 625-633.

[6] **Hassan, K. S., K. Chatti and Richard W. Lyles, P.E.** (2006) Effect of Heavy Multiple Axle Trucks on Flexible Pavement Damage Using In-Service Pavement Performance Data. *ASCE Journal of Transportation Engineering*, **132(10)**, 763-770.

[7] **Aloysius, T. and F. Chai** (2005) Determination of Equivalent Axle Load Factor of Trailer with Multiple Axles on Flexible Pavement Structures. *Journal of the Eastern Asia Society for Transportation Studies*, **6**, 1194 – 1206.

[8] **Chia Pei J. Chou** (1996) Effect of Overloaded Heavy Vehicles on Pavement and Bridge Design. *Journal of Transportation Research Board*, **1539,** 58-65.

[9] **Sharma, B.M., K. Sitaramanjaneyulu and P.K. Kanchan** (1995) Effect of Vehicle Axle Loads on Pavement Performance. *Road transport technology*, **4,** 263-272.

[10] **Mohammadi, J. and N. Shah** (1992) Statistical Evaluation of Truck Overloads. *ASCE Journal of Transportation Engineering*, **118(5),** 651-665.