Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 6, Issue 4; April-June, 2019, pp. 252-256

http://www.krishisanskriti.org/Publication.html

Influence of Wheel Load and Tire Pressure on Flexible Pavement

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Abstract—*Bituminous pavements constructed across the India may failed before their design life. There are many reasons for this earlier failure of pavements such as lack of dependable traffic, inappropriate selection of material, poor construction practice, environmental factors etc. As the axle load of the vehicle sare increased, the use of higher tire pressure became more popular in truck markets. In this paper, the influence of wheel loads and tire pressure on flexible pavement were studied. A location on SH-334B in Haryana state was chosen for study. IITPAVE software program is used to determine the critical design parameters of pavement such as horizontal tensile strain at the bottom of the bituminous layer ($\in_t$) and vertical compressive strain at top of subgrade ($\in_z$). The result shows that the influence of wheel load has more effects on both critical design parameters whereas the influence of tire pressure has more effects on horizontal tensile strain at bottom of the bituminous layer ($\in_t$) as compared to vertical compressive strain at top of subgrade ($\in_z$).The calculated strains are then used to estimate the number of load repetitions to pavement failure due to rutting and fatigue as per IRC: 37- 2012 rutting and fatigue models.*

Keywords: *Wheel Load, Tire Pressure, Tensile Strain, Compressive Strain, IITPAVE, Rutting, Fatigue.*

1. INTRODUCTION

Highway is vitally important to a nation's economic development. Construction of a high quality road network increased a nation's economy by reducingjourney time, vehicle operation cost (VOC) and easing the mobility of people and goods,make a region more attractive. There are various factors which affect the design and maintenance of pavement. These factors include the gross weight of vehicle, tire pressure, type of load, number of wheel load and tire type, type of load, number of repetitions, subgrade properties, moisture content, environmental condition, types of material used in construction etc. In the past, damage resulted in highway pavements due to load application primarily focused on application and frequency of axle load. In recent years, the influence of increasing tire pressure also became a subject of great concern. Effect of wheel load is more predominant in determining the total thickness of pavement(effects vertical strain at top of subgrade). whereas tire pressure influences the quality of the top pavement layer (effects the horizontal tensile strain at the bottom of bituminous layer)

2. OBJECTIVES AND SCOPE

The scope of this work is limited to a section of SH-334B from jhajjar to sampla in Haryana state for plain and rolling terrain. This mayalso apply to another pavement with similar conditions of traffic and environmental. The major objectives of work are:

- Carry out the axle load survey and tire pressure measurement on selected location of highway. The selection of highway is done in such a way that maximum number of commercial vehicle passed through this place.
- To analyze the effect of wheel load and tire pressure on critical design parameters of pavements that are the horizontal tensile strain at the bottom of the bituminous layer ($\in_t$) and vertical compressive strain at top of sub grade ($\in_z$).
- To find the number of load repetitions to pavement failure due to fatigue and rutting.

3. METHODOLOGY

3.1 Selection of study area

Major data requirements are wheel load and tire pressure of commercial vehicles. It is expected that a higher number of commercial vehicles passed through SH-334B (Jhajjar-Sampla road) in Haryana state. The traffic came from Maharashtra, Rajasthan, Gujrat, Utter Pradesh, Haridwar, Delhi, Punjab, Himachal Pradesh on the highway apart from Haryana in larger number. The location of study area is shown with the arrow mark in figure 1.

Fig. 1 Location of study area

3.2 Data collection

Data collection includes the primary data collection and secondary data collection.

3.2.1 Primary data collection

It includes, the axle load survey and tire pressure measurement. Direction wise data was collected on selected location of highway. In the axle load survey, axle load is checked and surveyed with the help of a portable axle weigh pad. Fig.2 and Fig.3shows the picture of axle weigh pad used for the survey of axle load. On an average approximate 3400 number of vehicles are used the highway. We carried out the axle load survey of 593 vehicles of both directions, which is 17.45 per cent of the total vehicles used the highway. This sample data is sufficient for study as per IRC: 37-2012. We also surveyed the 112 vehicles for tire pressure measurement. In this paper, we studied the effect of dual wheel on flexible pavement. Table 1 shows the field measurement of the weight of dual wheel on one side of axle with different weight range in KN. Under tire pressure measurement, tire pressure of vehicles are checked and surveyed with the help of digital gauge pressure shown in fig. 4. Only outer tire of one side (left side of road in the direction of vehicle movement) of each axle was taken into consideration. Table 2 shows the number of tires with different tire pressure range in KPa.

Fig.2 Axle Weigh Pad

Fig. 3 Axle Load Survey

Fig. 4 Digital Pressure Gauge

Table 1 Weight of dual wheel on one side of axle

Sr. No.	Dual wheel weight(KN)	Numbers of Dual wheel	Percentage
1	0-10	6	0.55
2	10-20	240	22.16
3	20-30	160	14.78
4	30-40	103	9.42
5	40-50	115	10.62
6	50-60	124	11.45
7	60-70	136	12.56
8	70-80	88	8.13
9	80-90	42	3.87
10	90-110	32	2.94
11	110-140	37	3.58

Table 2 Number of tire with different tire pressure

Sr. No.	Tire Pressure(KPa)	Number of Tires	Percentage
1	690-830	44	11.2
2	830-965	76	19.33
3	965-1105	123	31.3
4	1105-1240	107	27.33
5	1240-1310	43	10.94

3.2.2 Secondary data collection

The secondary data required for the work is the modulus of elasticity, thickness and poison ratio (μ) of pavement layers shown in table 3. IRC -37 2102 provided the properties of material used in pavement layers.

Table 3 Properties of pavement layers required for pavement analysis

Sr. No.	Pavement Layers	Modulus of elasticity (MPa)	Thickness (mm)	Poison ratio(μ)
1	Bituminous layer	3000	175	0.35
2	Granular Base and sub-base	235	450	0.35
3	Subgrade	77	_	0.40

3.3 Determination of strains

The horizontal tensile strain at the bottom of the bituminous layer ($\in_t$) and vertical compressive strain ($\in_z$) at top of sub grade was determined with IITPAVE software for layered system analysis of flexible pavement and strains were calculated at critical location of pavement as shown in fig.5.

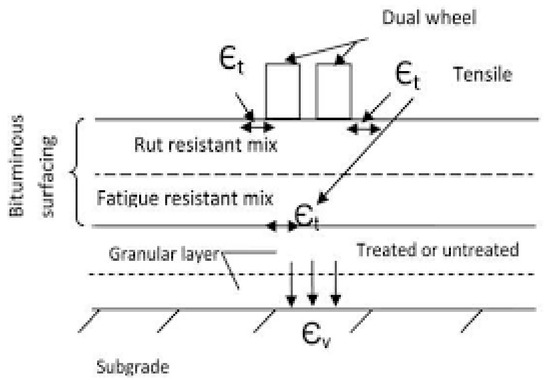

Fig. 5- Critical location of a fllexible pavement

3.4 Determination of number of load repetitions to failure

By using of the calculated strains we found out the number of load repetitions to fatigue and rutting as per IRC 37:2012 fatigue and rutting models.

N_f= o.711*$10^{-04} \times \left[\frac{1}{\mathcal{E}t}\right]^{3.89} * \left[\frac{1}{MR}\right]^{0.854}$ 1 (90 per cent reliability)

N_f = fatigue life in number of standard axles

$\mathcal{E}t$ = Maximum tensile strain at the bottom of the bituminous layer, and

M_R = Resilient modulus of the bituminous layer.

N_r= $1.41\times 10^{-08} \times \left[\frac{1}{\mathcal{E}v}\right]^{4.5337}$ 2 (90 per cent reliability)

N_r = Fatigue life in term of standard axle

$\in_v$ = Vertical compressive strain on top of subgrade

3.5 Results

3.5.1 Influence of wheel load and tire pressure on pavement responses

It can be seen from fig. 6 &7, the influence of the wheel load is more on both the horizontal tensile strain and vertical compressive strain whereas tire pressure has more effects on horizontal tensile strain but has fewer effects on vertical compressive strain.

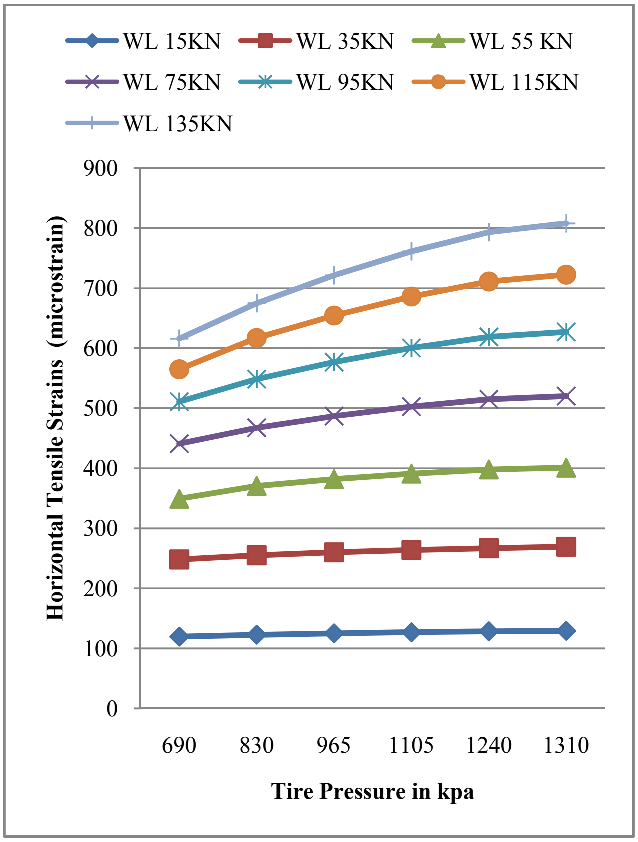

Fig. 6 Influence of wheel load and tire pressure on horizontal tensile strain at bottom of bituminous layer.

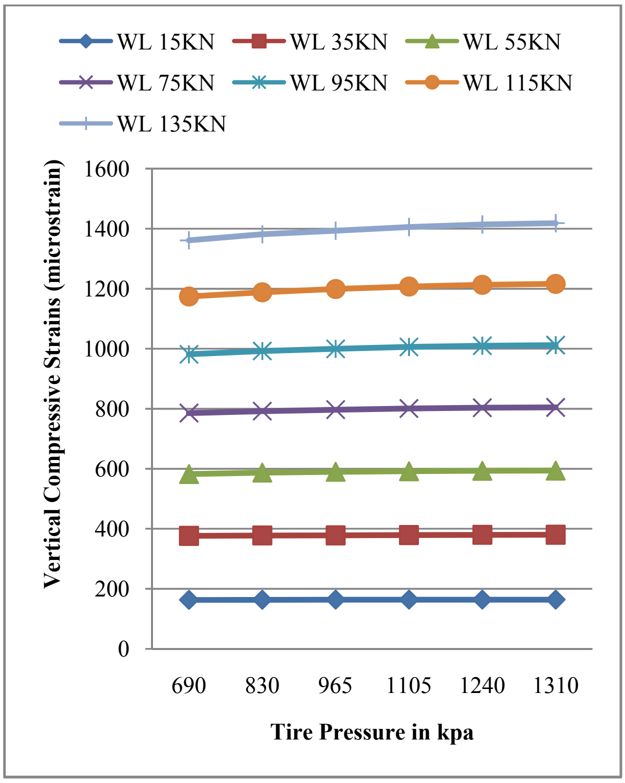

Fig. 7 Influence of wheel load and tire pressure on vertical compressive strain on top of subgrade.

3.5.2 Influence of wheel load and tire pressure on fatigue and rutting life of pavement

Results show that fatigue life of pavement decreased with both increased in tire pressure and wheel load whereas rutting life of pavement decreased more with increased in wheel load as compared to tire pressure show in fig. 8 and 9. It means that tire pressure affects the quality of surface course (determined the thickness of surface course)and wheel load effects the quality of subgrade(determined the total thickness of pavement).

It is also observed that pavement may fail first in fatigue than rutting failure because of load repetitions to fatigue failure are less than rutting failure but when the wheel load is increased more as more (wheel load more than 120KN) then the failure of the pavement turn to rutting failure because load repetitions to rutting failure are less than fatigue failure shown in fig. 8 and fig. 9.

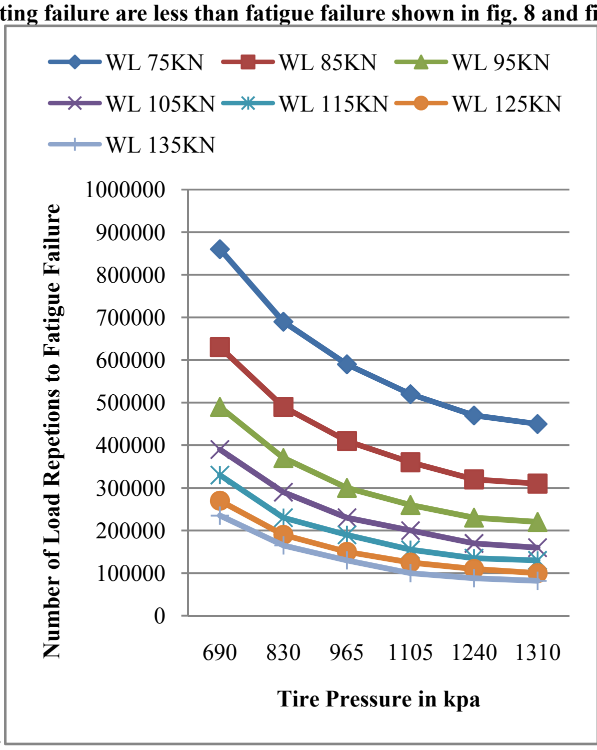

Fig. 8 Influence of wheel load and tire pressure on fatigue life of pavement.

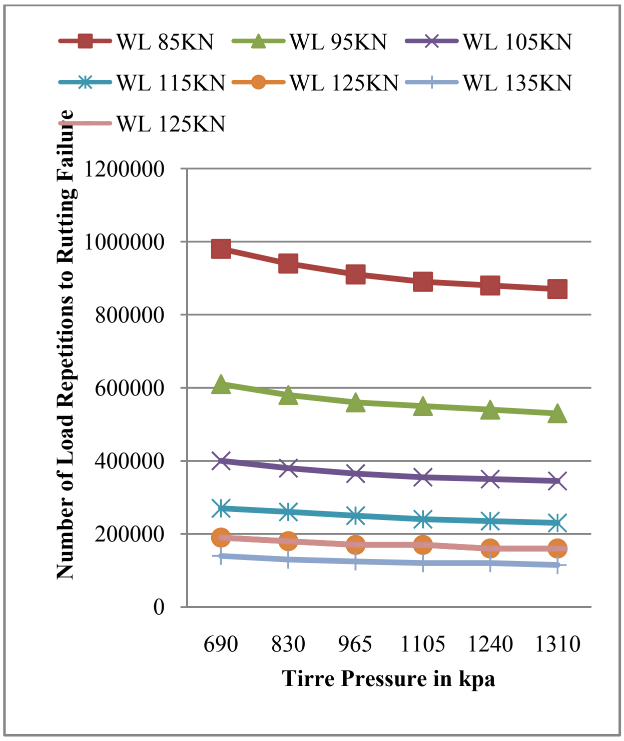

Fig. 9: Influence of wheel load and tire pressure on rutting life of pavement.

4. CONCLUSIONS

1. Horizontal tensile strain ($\in_t$) at bottom of the bituminous layer is affected more by increased in both wheel load and tire pressure and vertical compressive strain ($\in_z$)at top of subgrade is affected more by wheel load as compared to tire pressure.
2. IRC used the 40KN dual wheel load and 0.56MPa (or 560KPa) tire pressure for the analysis of flexible pavement. This data is called standard for the analysis of pavement. When we compared the standard data results with field data results, we find that on an increasing the standard dual wheel load of 25%, 50%, 100%, 150% and 200%, the pavement life is decreased by 47%, 68%, 84%, 905 and 97% respectively whereas an increasing the tire pressure of 25%, 50%,100%, 120% and 130%, the pavement life is decreased by 16%, 36%, 36%, 39% and 40% respectively.
3. It is observed that pavement may fail first in fatigue than rutting failure because of load repetitions to fatigue failure are less than rutting failure but when the wheel load is increased more as more (wheel load more than 120KN) then the failure of the pavement turn to rutting failure because load repetitions to rutting failure are less than fatigue failure
4. Wheel load has significant effects on both rutting and fatigue life of pavement and tirepressure has more significant effects on fatigue life as compared to rutting life.

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