

Investigation on road damage due to vehicle overloading of high volume Ipoh state road

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Abstract. Traffic load was a major factor in thickness design due to the main function of pavement which was to resist traffic load. Although efforts to repair the road damage had been done continuously, the recovering effects were almost meaningless if the road was continuously receiving overloading from vehicles. Issues of road damage due to vehicle overloading had been addressed by most agencies in developing countries. However, there were no available study to address this issue on Perak state road. Therefore, this research aimed to determine the current traffic composition, the percentage of overloading vehicle, the Equivalence Factor (E.F.), the adequacy of existing pavement thickness and the reduction of pavement service life due to overloading of the road by referred to AASHTO and Arahan Teknik (Jalan) 5/85. The selected study area was at Jalan Tuanku Abdul Rahman, Ipoh (also known as Jalan Kuala Kangsar). Data were employed which acquired from traffic count survey, axle load survey, coring test and dynamic cone penetrometer test. Review on current traffic count data showed that vehicles with 2-axle contributes more than 60% of the overall daily traffic while percentage of overloading vehicle revealed that more than 50% of vehicles contributed from 4-axle, 5-axle and 6-axle exceeded the maximum permissible gross vehicle weight (PGVW). The analysis on the E.F. showed that primary and secondary directions gained E.F. value of 4 and 3 times higher than the 3.0 E.F. design value which were 12.4 and 9.2 respectively. This also denoted that additional overlay pavement thickness was required about 70mm and 50mm for primary and secondary direction respectively to ensure the target design life was achieved. This study also discovered the road pavement experienced 7 and 6 years of reduction of service life for both directions respectively.

1. Introduction

Pavements are engineering structure which economically designed to withstand traffic loading and climate action with minimal deterioration [1]. Pavements may encounter different mode of failures depending on its structural types which caused by specific factors [2]. For example, flexible pavement may experience fatigue failure, rutting, undulating, etc. while rigid pavement may experience faulting edge, cracking, etc. All these mode of failure are caused by several factors such as heavy traffic loading, climate effect, drainage effect, material properties and inadequate design thickness [1].

Among all these factors, heavy traffic loading has contributed significantly to pavement damage. The magnitude and configuration of vehicle loads in conjunction with environmental factor have imposed significant effect on the induced tensile stresses within flexible pavement [3].



Although heavy vehicle load is subjected to high stresses causing pavements damage, not all trucks have the same damaging effects. The damaging factor depend on speed, wheel loads, number and location of axles, load distributions, type of suspension, number of wheels, types of tire, inflation pressure and many other factors [4].

There are numerous studies have been conducted by previous researchers on the road damage due to vehicle overloading. The traffic load by surveyed data have far exceeded the designed bearing capacity of the designed road structure [5-12]. This has caused prevalent premature pavement damage. Those studies also addressed that the overload vehicles has imposed significant influence to the reduction of pavement service life. Although issues on road damage due to vehicle overloading have been addressed by most agencies in developing countries, there are no available study found to address this issue on Perak state road.

Ipoh has been known as the busiest town in Perak State. It is located at the heart of Perak under District of Kinta. Hence it has quite a numbers of inter-city road networks which connects Sungai Siput in the North of Perak, Simpang Pulai in the South, Batu Gajah in the West, Tambun in the North-West, Cameron Highland in the East and Jelapang in North-East. Other than that, crossing through Ipoh is the North-South Expressway with two (2) main exits i.e. in the South (Ipoh Selatan Interchange) and North (Ipoh Utara Interchange). In conjunction with this, obviously the road has been used by numbers of vehicles with various types and the pavement may have been imposed by high stresses from overloaded vehicle which causing road damage [13].

Based on records of previous maintenance works, it was found that several rehabilitation works has been carried out for the past three (3) years. In addition, Notice of Defect by maintenance concessionaire's company has also been issued to local authorities regarding the pavement damage and the necessity to conduct repairing work. This has been further proved by the records of pothole defect found on the road pavement. This phenomenon has indicated that the road may experience fatigue failure due to rapid overloading imposed on pavement surface. This also shows that the pavement could not last longer as per design life and the pavement service life has become shorter.

Hence, the objectives of this study were to determine the current traffic composition of the road, to assess the percentage of overloading vehicle according to different types of vehicle based on local Weight Restriction Order and the damaging factor from equivalency factor (EF), to calculate the adequacy of existing pavement thickness to withstand current overloading traffic and to estimate the reduction of pavement service life due to overloading.

2. Methodology

The study area was located at one of the major State Road in Ipoh, Jalan Tuanku Abdul Rahman (also known as Jalan Kuala Kangsar). It has about 5km length of flexible pavement road and consists of two (2) and three (3) carriageways at both directions. This location was chosen as the road links between Federal Road FT001, state administrative center of Perak and mixed development area (business and residential). Hence, the findings could represent the overall Ipoh state road conditions at city-town area.

This study was conducted based on data which obtained from concessionaire company for Perak State Road, Empayar Indera Sdn Bhd. All the field testing had been conducted by Ikram Paves Sdn Bhd on August 2015 which consists of traffic volume from traffic count survey, traffic load from axle load survey, soil strength in terms of California Bearing Ratio (CBR) from Coring and Dynamic Cone Penetrometer test and thickness of existing pavement layers. The methodologies used to achieve the objectives of this study were illustrated as shown in Figure 1.

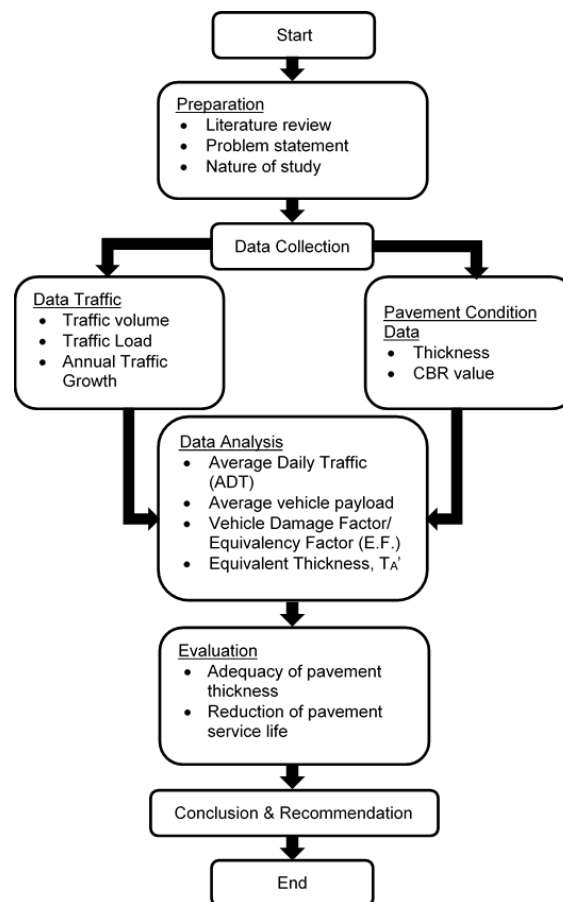


Figure 1. Flow chart of the study.

3. Results and Discussion

3.1 Traffic volume

Analysis on traffic data was performed in the means of calculating the average daily traffic (ADT) for survey period of 24-hours a day. In order to get survey period of 24-hours, raw data was converted by multiply with factor 1.2. Table 1 shows the ADT for primary and secondary directions. From Table 1, it was clearly shown that vehicle volume on primary direction was higher than secondary direction. It also showed that 2-axle class contributed more than 60% to overall daily traffic for both directions. Additionally, 5-axles class gave the least ADT for both directions as well. Based on the traffic data, the percentage of commercial vehicle, P_c was determined and gave about 39% of the total vehicle.

Table 1. Average Daily Traffic (ADT) for primary and secondary directions.

Direction	ADT of Each Vehicle Classes (16-hours)						Total ADT 24-hours
	2-axles	3-axles	4-axles	5-axles 5A	>6-axles 6A	Total	
Primary	1209	293	253	86	155	1996	2395
Secondary	969	208	211	48	124	1560	1872

3.2 Axle Load Data Analysis

Tables 2 and 3 show the average payload by axle configuration for primary and secondary directions. The axle load survey was conducted based on randomly selected heavy vehicles, on both directions for 16-hours survey period. For the weight of each axle, it were about 241 and 97 number of heavy vehicles were assessed and recorded for both primary and secondary directions respectively.

Average payload by axle configuration for both directions were compared with the maximum permissible gross vehicle weight (PGVW) [15]. From the data, more than 50% of vehicle classes for 3-axles, 4-axles, 5-axles and 6-axles had exceeded the maximum PGVW while 2-axles vehicles only exceeded the PGVW about 9%. This also indicated that the vehicle overloading is mostly consist of vehicles from 3-axles and above.

Table 2. Average payload by axle configuration for primary direction [14].

Vehicle Classes	No. of Vehicles	Total Payload (ton)	Average Payload (ton)
2A	108	764	7
3A	47	943	20
4A	40	1228	31
5A	17	665	39
6A	29	1676	58
Total	241	5277	

Table 3. Average payload by axle configuration for secondary direction [14].

Vehicle Classes	No. of Vehicles	Total Payload (ton)	Average Payload (ton)
2A	55	354	6
3A	11	250	23
4A	17	494	29
5A	7	281	40
6A	7	298	43
Total	97	1677	

3.3 Determination of Equivalence Factor (E.F.)

Equivalency Factor (E.F.) of each heavy vehicle was determined using forth-power law relationship by AASHO Road Test [15]. Table 4 shows the average E.F. based on total vehicles for both directions. Based on the Pc value of 39%, the recommended value for designed E.F. is 3.0 [15]. The data showed both primary and secondary directions gave average E.F. about 4 times and 3 times higher than recommended value which were 12.4 and 9.2 respectively.

Table 4. Average Equivalency Factor (E.F.).

Direction	Total E.F. for Overall Vehicle	Total Vehicle	Average E.F.
Primary	2,650.788	214	12.4
Secondary	887.816	97	9.2

3.4 Analysis on the Equivalent Layer Thickness

The analysis on equivalent layer thickness was carried out to determine the adequacy of existing pavement thickness to withstand current traffic load. It was conducted by comparing the equivalent thickness between certain conditions as shown in Table 5. It reveals that the existing equivalent thickness, T_E was lower than thickness required by existing traffic condition, T_A' and design thickness based on recommended E.F., T_D' . It showed that, the increasing of E.F. will increase the thickness required to resist load.

Table 5. Summary of equivalent thickness for different conditions.

Condition	Equivalent Thickness (mm)
Existing thickness measured on site, T_E	255
Required thickness based on calculated E.F., T_A'	325 (primary direction) 305 (secondary direction)
Design thickness based on recommended EF, T_D'	260

Therefore, the minimum overlay thickness, to that needs to be carried out in order to achieve the required equivalent thickness were:

Primary direction:

$$T_o = 325 - 255 = \mathbf{70mm}$$

Secondary direction:

$$T_o = 305 - 255 = \mathbf{50mm}$$

3.5 Reduction of Pavement Service Life

The reduction of pavement life was determined by comparing the difference of road service life, n at the same magnitude of traffic load in basic year, w_{18} by using equation (1) and (2) as shown in Table 6. Based on the data shown, Figures 2 and 3 were plotted to analyze the relationship between traffic load and service life on standard and overloaded conditions.

$$W_{18} = w_{18} \times \frac{(1+r)^n - 1}{r} \tag{1}$$

Where

$$w_{18} = ADT \times 365 \times P_o \times E.F. \tag{2}$$

Table 6. Traffic load in basic year, w_{18} .

Cases	Axle Load Equivalency Factor (EF)	Traffic Load in Basic Year, w_{18} (ESAL)
Overload		
- Primary	9.2	2.4×10^6
- Secondary	12.4	4.2×10^6

Standard (design)	3.0	9.1 x 10 ⁵
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Figures 2 and 3 showed equation (1), (2) and (3) for overload condition at primary, secondary and standard design condition respectively based on the plotted curves.

$$y = 0.0986x^2 + 1.9978x + 0.7821 \tag{3}$$

$$y = 0.1708x^2 + 3.463x + 1.3556 \tag{4}$$

$$y = 0.0368x^2 + 0.7463x + 0.2922 \tag{5}$$

Based on both plotted data, the reduction of pavement service life were analyzed. The standard traffic load of design condition for both figures in 10 years was 11.460x10⁶ ESAL. However, primary condition at figure 2 shows that the load reached within 2.59 years under overload condition. This result revealed that the pavement condition service experienced about 7 years reduction of service life due to overloaded heavy vehicles.

For secondary condition at figure 3 shows the same manner. The pavement condition service experienced about 6 years reduction of service life due to overloaded heavy vehicles because of the load was reached within 4.39 years under overload condition.

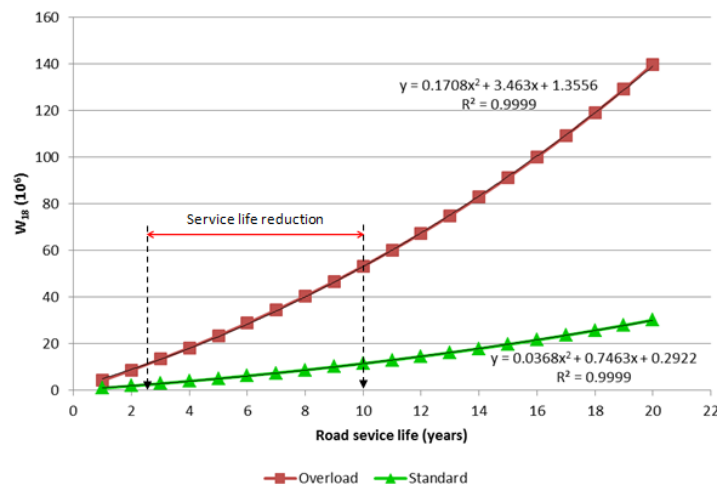


Figure 2. Relationship between traffic load and service life on standard and overloaded conditions (primary direction)

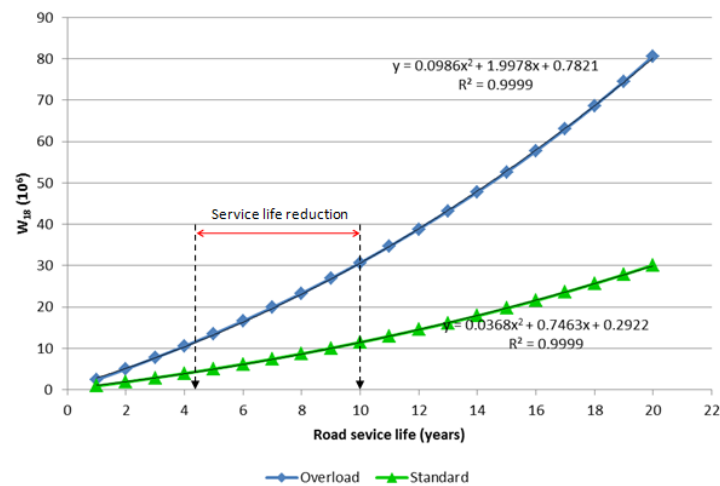


Figure 3. Relationship between traffic load and service life on standard and overloaded conditions (secondary direction)

4. Conclusions

Based on the results, it can be concluded that the existing traffic composition of the road revealed that numbers of vehicle travelled on primary direction was higher as compared to secondary direction for all vehicle classes, and 2-axle class has contributed more than 60% of the overall daily traffic compared to 3-axle class and above. However, more than 50% vehicles from 4-axle, 5-axle and 6-axle vehicles exceeded the PGVW compared to 2-axle vehicle was only exceed the PGVW about 9%. This also indicated that the vehicle overloading is mostly consist of vehicles from 4-axle and above.

By comparing with recommended design value for E.F. which is 3.0, the primary direction gained E.F. value of 4 times higher than the E.F. design value with 12.4 while secondary direction gained E.F. value of 3 times higher than the E.F. design value with 9.2. It can be concluded that the current road traffic load was higher than road traffic load for designed existing road. Furthermore, based on the results, primary direction need to be overlaid with at least 70mm additional thickness while secondary direction need to be overlaid by at least another 50m thick in order to resist current traffic load. Thus, road damage can be prevented.

Lastly, both primary and secondary conditions experienced 6 and 7 years of reduction of service life respectively due to overloaded heavy vehicles. This also denoted that both primary and secondary directions met maximum service life within about 2.59 and 4.39 years under overload condition.

For more reliable results, data collection for traffic count shall be conducted based on recommended 24-hours survey period, and by taking optimum results from data which collected through the whole week.

5. References

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