The Analysis of Heavy Vehicle on Asphalt Pavement Service life based on Axle-mounted Traffic Volume Survey

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Abstract: Based on the surveyed data of the G202 Heihe to Dalian on the Beisanjia station in Fushun City, Liaoning Province, the traffic conditions of the observation section of the station are analyzed. The continuous data is compared with the axle-load survey data, and the service life of the asphalt pavement in the year of data is analyzed. In order to make full use of real-time axle load-traffic survey data and accurately predict the remaining service life of asphalt pavement in an accurate and real-time manner, it is of great value to develop targeted asphalt pavement maintenance and protection countermeasures.

1. Introduction
In recent years, China’s national economy and highway transportation have developed at a high speed. The national highway net has been basically completed, and the amount of highway traffic has increased year by year. The numbers of passengers and goods between cities and provinces has been increasing, and the phenomenon of heavy-duty overloaded transportation has become more and more serious. As a result, the impact on the service life of asphalt pavement is getting deeper and deeper. Therefore, it is especially important to grasp the load vehicle to predicting the service life of the road pavement.

This paper mainly analyzes the real-time monitoring data of heavy-duty overloaded vehicles on the road during the designed period, and based on this data, analyzes the service life of asphalt concrete pavement of G202 Heihe to Dalian Road.

2. Introduction of the Beisanjia axle-load survey sites and axle-load equipment in the Heihe to Dalian Road
The Beisanjia axle-mounted traffic survey site is located at K1171 (the territory of Qingyuan County, Fushun City) in Heihe to Dalian Road. The monitoring interval is from K1145+800 to K1202+471, with a monitored mileage of 56.671 km and a road width of 12 m, this section is locating in the hill area.

The site uses the equipment of axle-mounted survey, which is monitored 24 hours every day. Through the quartz sensor installed in the asphalt pavement, the dynamic signals generated by the reciprocating axes of the motor vehicles are converted into electronic digital signals, and the computer
system collects and analyzes the data. That is dynamic observation of vehicle models, flow, speed, number of axles, single axle weight, shaft type, total weight, overloaded vehicle license plates and others information. The system of axle load survey has a function of capturing image and a video monitoring function, which can monitor the data of the motor vehicle and license plates that travel through, and control the traffic load characteristics of the road section in real time.

Figure 1. Flow chart of the axle load survey

3. Traffic volume survey data introduction
This paper research the survey 2018’s data of the Beisanjia axle load traffic. The relevant data are introduced as follows.

Table 1. The site traffic volume by car natural counting situation in 2018
cars/day

| Station                      | Small goods | Medium goods | Large goods | Extra large goods | Container | Mini bus | bus | natural numbers |
|------------------------------|-------------|--------------|-------------|-------------------|-----------|----------|-----|-----------------|
| The Beisanjia axle-mounted station | 489         | 459          | 406         | 937               | 23        | 3333     | 201 | 5848            |

Table 2. The proportion of the site (equipment survey) model in 2018

| Station                      | Mini Bus | bus   | Two-axle goods | three-axle goods | four-axle goods | five-axle goods | Six-axle goods |
|------------------------------|----------|-------|-----------------|------------------|-----------------|-----------------|----------------|
| The Beisanjia axle-mounted station | 56.99%   | 3.44% | 12.92%          | 2.76%            | 4.54%           | 2.59%           | 16.76%         |

Table 3. The proportion of the station's lanes in 2018

| Station                      | up lane | down lane |
|------------------------------|---------|-----------|
| The Beisanjia axe-mounted station | 51.33%  | 48.67%    |

It can be seen from Table 2.3 that the number of vehicles in the up lane is similar to that of the down lane vehicles, which is basically the same.
Table 4. The daily equivalent axis in 2018

| Station                        | upward deflection | downward deflection | total deflection |
|--------------------------------|-------------------|---------------------|------------------|
| The Beisanjia axle-mounted station | 2645155           | 1689585             | 4335105          |

4. Comparative analysis of continuous-traffic volume survey data and real-time axle load traffic survey data

Among the equipment continuous traffic survey, the small car is a length of less than 6m with 2-axle. The medium car is a 2-axle vehicle. Medium goods have a loaded capacity between 2 and 7 tons. The bus is a 2-axle car with the seat of more than 19 seats. Large goods are between 7 and 20 tons with 3 or 4 axles. Extra-large goods are vehicles with more than 4 axles, and have a loaded capacity more than 20 tons.[1][2]

According to the latest specification of the People’s Republic of Chinese standard Highway-asphalt pavement design code (JTG D50-2017), the equivalent design axle load conversion factor $EALF_m = EALF_{ml} \times PER_{ml} + EALF_{mb} \times PER_{mb}$; [3]

$EALF_{ml}$--- Equivalent design axle load conversion factor ;$EALF_{ml}$--- Equivalent design axle load conversion factor for non-full load vehicles; $PER_{ml}$---Percentage of non-full-loaded vehicle;$EALF_{mb}$---Equivalent design axle load conversion factor for fully loaded vehicles; $PER_{mb}$---Percentage of fully loaded vehicles

The average annual equivalent axis of the design year of the initial year is:

\[
N_1 = AADTT \times DDF \times LDF \times \sum_{m=2}^{11} (VCDF_m \times EALF_m)
\]

Two-way annual average daily traffic of vehicles with

$AADTT$---2 axles with above 6 wheels (vehicles/d);$DDF$ --- direction coefficient;$LDF$ --- lane factor;$m$--- lane type number;$VCDF_m$ ---m type of vehicle type distribution coefficient;

Equivalent design axle load cumulative action

\[
N_e = \left[ \frac{(1 + r) - 1}{r} \right] \times 365 \times N_1
\]

$N_e$---the number of times the equivalent design load cumulative action on the design lane within the design life (times); $r$ --- the average annual growth rate of traffic within the design life; $t$ --- Design life (years); $N_1$--- Initial year design lane daily average equivalent axis (times / d).

Taking the bottom tensile stress of the asphalt mixture layer as the indicator[4], after calculating the equivalent design, the axle load conversion factor is calculated as shown in the following table.

Table 5. Equivalent design axle load conversion factor

| Type             | Mini Bus bus | Two-axe goods | Three-axe goods | Four-axe goods | Five-axe goods | Six-axe goods |
|------------------|--------------|---------------|-----------------|----------------|----------------|--------------|
| Equivalent Axis- Conversion Factor | 1            | 1.1           | 0.8             | 1.925          | 2.025          | 4.315        | 5.21         |

Table 6. Model ratio

| Station | method | Mini bus | Two-axe goods | Three-axe goods | Four-axe goods | Five-axe goods | Six-axe goods |
|---------|--------|----------|---------------|-----------------|----------------|----------------|--------------|
|         |        |         |               |                 |                |                |              |
Seen from the model weighting table 3.2, the proportion of equipment survey models are the proportion of vehicles that are monitored after 24 hours every day. The proportion of the manual survey models is based on the average of the two vehicle models in March and June 2018. In the manual survey of the specific gravity of the vehicles, there is a problem that the manual cannot be monitored for 24 hours every day. Calculating the proportion of the vehicle is surveyed by the equipment and the proportion of the vehicle is surveyed by manual. The calculated conversion factor of the shaft is shown in Table 3.3.

| Method       | Axis conversion factor | Equivalent design axle load annual cumulative action times | difference ratio |
|--------------|------------------------|--------------------------------------------------------|------------------|
| equipment    | 1.2712195              | 4107081.462                                            | 0                |
| Manual       | 0.991243               | 3509772.597                                            | 14.5%            |

It can be seen from the table that the ratio of the difference of the axis conversion factors are obtained by the two survey methods is 14.5%. The reason for this difference is that the manual cannot be monitored 24 hours every day, and the manual investigation causes errors in a certain period of time. With the development of the economy and the development of electronic equipment, the investigation of manual traffic volume will gradually turn into a full electronic equipment survey.

5. The comparative analysis of the service life of asphalt pavement

| Field of investigation | Design period | Accumulated standard axis (10^6) | Cumulative equivalent axis by Axle-load equipment (10^6) | Cumulative-equivalent axis by Continuous-survey equipment (10^6) (model-scale by equipment) | Cumulative equivalent axis by cumulative equivalent axis (10^6) (model-scale by manual) |
|------------------------|---------------|----------------------------------|--------------------------------------------------------|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| K1145+800-K1202+602    | 12 years      | 36                               | 4.34                                                   | 4.11                                                                            | 3.51                                                                            |

From table 4.1, the data of vehicle specific gravity has a greater impact on the annual cumulative equivalent axis, and the axle load equipment is monitored by 24 hours every day. The continuous survey equipment can not investigate the axle type of the truck. The proportion of the vehicle model is referenced to the axle load equipment. The ratio of the annual cumulative equivalent axis calculation difference is 5.3%; The continuous survey equipment model weight equipment survey and manual survey method. The ratio of the cumulative equivalent axis calculation difference is 14.6%; The ratio of the cumulative equivalent axis of the axle load equipment survey to the annual cumulative equivalent axle of the continuous survey equipment (the vehicle weight is the manual survey) is 19.1%. It can be seen that the calculation method of the equivalent design axis in the new specification is very close to the data obtained from the equivalent design axis survey of the on-board survey equipment. In the section where the axle load survey equipment is not available, the accuracy of the vehicle weight
survey determines the accuracy of the cumulative design equivalent axis.

In 2018, the annual service life reduction period calculated by the cumulative equivalent axis calculation of the axle load equipment survey is data 1; the annual service life reduction calculated by the continuous survey equipment annual cumulative equivalent axis which model weight by the equipment, calculated annual service life reduction period is data 2; The continuous survey equipment annual cumulative equivalent axis which model weight by the manual, calculated annual service life reduction period is data 3, the results of calculation are shown in Table 4.2

Table 9. Lifetime reduction comparison analysis

| Survey interval     | Design life | Service life (data 1) reduced period | Service life (data 2) reduced period | Service life (data 3) reduced period |
|---------------------|-------------|--------------------------------------|--------------------------------------|--------------------------------------|
| K1145+800--K1202+602| 12 years    | 1.45 years                           | 1.37 years                           | 1.17 years                           |

Table 10. Service life reduction ratio

| Survey interval     | Design life | data 1 | data 2 | data 3 |
|---------------------|-------------|--------|--------|--------|
| K1145+800--K1202+602| 12 years    | 12.1%  | 11.4%  | 9.8%   |

As shown in Table 4.2 and Table 4.3, heavy vehicles have a large impact on the service life of asphalt pavements. Accurately grasping the data such as traffic volume and vehicle weight of each model of heavy-duty vehicles is particularly important.

Within the design period, the traffic volume varies in different years, the traffic volume and vehicle weight of each model changed. From the 2018 annual load traffic data analysis, the service life reduction of the asphalt road in the current year can be seen that the service life of the actual heavy-duty vehicle is reduced by 1.45 years. Compared with the other two survey methods, the service life consumption of the axle load equipment survey is the most consistent with the actual one. The service life reduction period by the continuous investigation equipment (model weight by the equipment) is 1.37 years, which is close to the actual situation. The reduction period obtained by continuous investigation equipment (manual investigation of the proportion of vehicle models) is 1.17 years, which is far from the actual situation.

6. Conclusion

- Using the survey data of axle-mounted equipment, it can monitor the traffic volume, the proportion of each vehicle, the overload condition and the transportation volume in real time 24 hours every day, and realize the visualization, information and real-time dynamic traffic volume monitoring.
- The accuracy of the vehicle's specific gravity directly affects the data of the annual cumulative equivalent axis.
- Heavy and overloaded vehicles seriously affect the service life of asphalt pavement. Mastering the operation status of heavy vehicles and overloaded vehicles in monitoring road sections is of great value to master the service life of asphalt pavements.
- In the 2017 of the “Standard for Design of Highway Asphalt Pavements”, new calculation is made for the calculation to the equivalent design axis. The comparison between the cumulative equivalent axis monitoring data of the axle load equipment and the cumulative equivalent axis
calculation results in the new specification is found. The two columns of data are very closed. Mutual verification of the accuracy of the data.

- Traffic data is surveyed by axle-mounted equipment mainly including data such as traffic volume, axle-data, overload, traffic volume, and vehicle weight proportion, all of which are raw data of traffic conditions. It is necessary to further seamlessly integrate with specific work such as designing the pavement structure, projecting the highway road net, overloading road administration department, and analyzing highway traffic condition, so as to give full play to the important functions of traffic digitization.

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