# Study on highway bridge vehicle load standard value*

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**Abstract.** According to the data of 107 National Highway Luogang section of Guangdong vehicle load survey, By using theory of probability and statistics, the parameters such as gross vehicle weight, axle load, wheelbase, vehicle spacing and so on, are statistically analysed in this paper so as to confirm the probability distribution function of the category vehicle load and the representative values of related parameters, By using the extreme value distribution theory, We obtain 100 years design reference period of different vehicle load weight and axle load standard value, The standard value can provide basis calculation of abutment, retaining wall pressure and bridge local loading.

## Introduction

Vehicle load is an important part of the highway bridge live load, China's current "highway bridge design specification" specified load standard of vehicle is proposed based on series of engineering reliability studies in 99 years . After many years of development, vehicle and traffic situation has greatly changed, the vehicle load on the bridge structure is also developing continuously, so it is necessary to study the vehicle load standard value .

## China current standard vehicle load standard value

The vehicle load parameters and schematic diagram in Chinese current specification as shown in table 1 and figure 1.Compared with the 1989 and 2004 standard specification,the parameters did not change[1][2][3].

Because there are many types of cars in China and the traffic volume of different regions vary greatly,Only use one heavy vehicle load as the standard value for bridge local checking calculation is not appropriate.In this paper, through the analysis based on the measured data of 107 National Highway Luogang section in one week, We propose a vehicle load standard suitable for local traffic values.

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Table 1 The main technical indexes of vehicle load

| projects | unit | Technical indicators | projects | unit | Technical indicators |
|---|---|---|---|---|---|
| Vehicle standard gravity | kN | 550 | Wheel spacing | m | 1.8 |
| The front axle gravity standard | kN | 30 | The width and length of front wheel | m | 0.3×0.2 |
| The middle axle gravity standard | kN | 2×120 | The width and length of middle and rear wheel | m | 0.6×0.2 |
| The rear axle gravity standard | kN | 2×140 | Vehicle dimensions | m | 15×2.5 |
| wheelbase | m | 3+1.4+7+1.4 | | | |

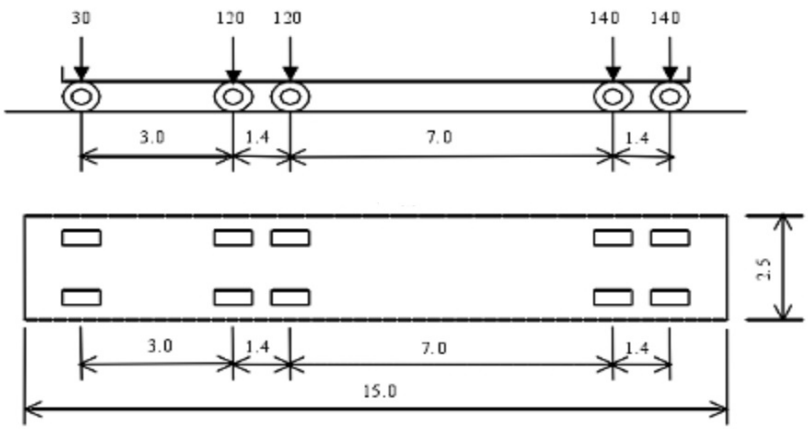


Fig.1 Schematic diagram of the vehicle load

## Traffic Composition Analysis

According to the measurement of the high speed dynamic weighing system, the vehicle load data was obtained from days in January 8th to 14, the average traffic volume was 33470/day, the maximum traffic volume was 35332. After removal of the error value, analysis the traffic composition, we can get the results are shown in table 2.

Table 2 All lanes of a week through all kinds of vehicle proportion summary table

| motorcycle type | lane | | |
|---|---|---|---|
| | Edge Lane(1,6lane) | Middle lane(2,5lane) | Inside lane(3,4lane) |
| The two axle truck | 28.70% | 28.45% | 19.39% |
| The three axle truck | 2.50% | 2.87% | 2.16% |
| The four axle truck | 1.45% | 1.81% | 0.90% |
| The five axle truck | 1.15% | 1.44% | 0.68% |
| The six axle truck | 1.16% | 1.40% | 0.82% |
| motor bus | 10.91% | 3.44% | 3.65% |
| passenger car | 54.14% | 60.58% | 72.41% |

**Statistical Analysis of Gross Vehicle Weight**

Through the analysis of the vehicles load data, drawing the passenger car, motor bus, two axle trucks, three axle trucks, four axle trucks, five axis trucks, six axle trucks gross weight histogram, Then we perform the probability distribution fitting and K-S test. Shows the passenger car, motor bus, two axle truck gross vehicle weight obey lognormal distribution, the three axle trucks, four axle trucks, five axle trucks, six axle trucks gross vehicle weight obey two humped normal distribution[4], as shown in Figure2 and Figure3(Take the passenger car and the six axle truck as an example). Parameters such as table 3 shows.

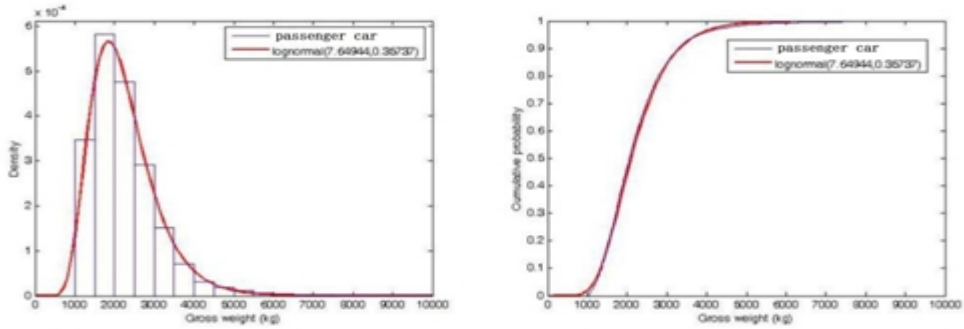


Fig. 2 Passenger car a total weight of probability density function distribution fitting and cumulative probability density function distribution fitting

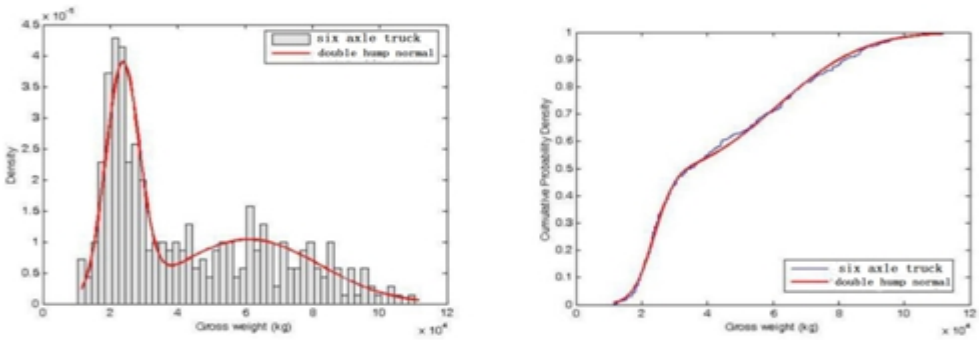


Fig. 3 Six axis vehicle total weight of probability density function distribution fitting and cumulative probability density function distribution fitting

Table 3 The different vehicle load probability distribution types and distribution parameters（In January 9th as an example）

| motorcycle type | sample capacity | The type of probability distribution | The probability distribution parameters[kg] | |
|---|---|---|---|---|
| | | | μ | σ |
| passenger car | 16606 | log-normal distribution | 7.70357 | 0.36098 |
| motor bus | 1434 | | 8.89355 | 0.67226 |
| The two axle truck | 7690 | | 9.60053 | 0.38295 |

| motorcycle type | sample capacity | The type of probability distribution | The probability distribution parameters[kg] | | | | |
|---|---|---|---|---|---|---|---|
| | | | p | μ1 | μ2 | σ1 | σ2 |
| The three axle truck | 792 | double hump normal distribution | 0.51712 | 17162 | 33991 | 5084.6 | 13756 |
| The four axle truck | 445 | | 0.67791 | 21977 | 54064 | 8817.3 | 12781 |
| The five axle truck | 350 | | 0.44541 | 25175 | 66534 | 6158.4 | 20673 |
| The six axle truck | 792 | | 0.56337 | 33155 | 84942 | 8959.5 | 26239 |

**Analysis of vehicle axle load weight ratio statistics**

Because of various vehicle types, vehicle weight and axle load different proportion of the complex relationship is difficult to unity. Therefore, the linear regression of automobile axle load and vehicle weight data using the least squares method, get the regression line between the axle load and the vehicle weight. Observed that the first axis of the intercepts of the linear intercept are larger, the rest axis of the intercepts of the regression lines are small, so the relationship between the rest of the axis except the first axle load and total weight can be approximated from slope of the regression line, and the relationship between the first axle load and total weight can be 1 minus the other axis ratio. The different models of the total load proportion, (the small car for example as shown in figure4), as shown in table 4.

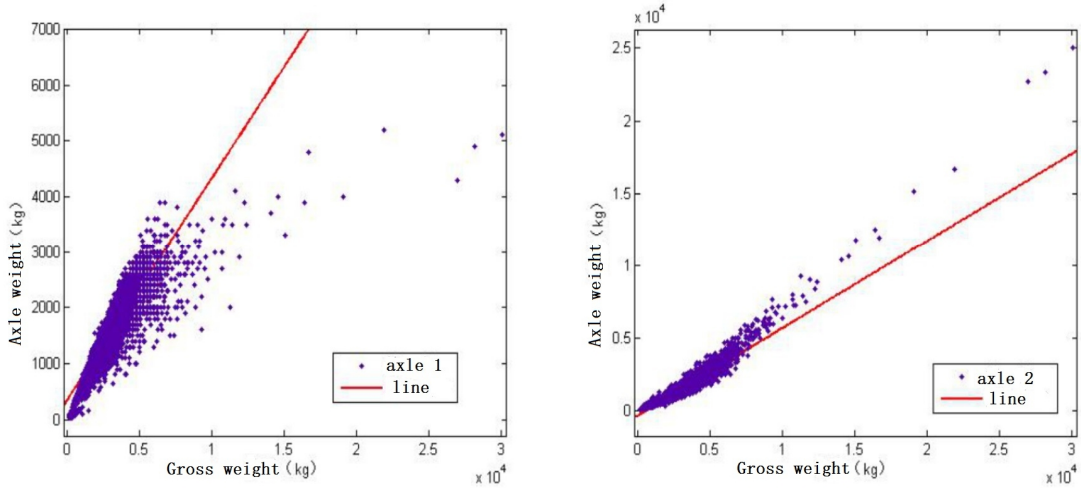


Fig. 4 Small passenger car the axle weight accounted for the total weight ratio of linear regression

Table 4 The different models of axle load of weight ratio

| motorcycle type | axle1 | axle 2 | axle 3 | axle 4 | axle 5 | axle 6 | sample capacity |
|---|---|---|---|---|---|---|---|
| passenger car | 0.39 | 0.61 | / | / | / | / | 121210 |
| motor bus | 0.26 | 0.74 | / | / | / | / | 9580 |
| The two axle truck | 0.28 | 0.72 | / | / | / | / | 51881 |
| The three axle truck | 0.17 | 0.38 | 0.45 | / | / | / | 5117 |
| The four axle truck | 0.13 | 0.22 | 0.32 | 0.33 | / | / | 2942 |
| The five axle truck | 0.06 | 0.24 | 0.25 | 0.23 | 0.22 | / | 2320 |
| The six axle truck | 0.04 | 0.18 | 0.18 | 0.20 | 0.20 | 0.20 | 2351 |

**Analysis of different vehicle wheelbase**

At present, China has a lot of automobile manufacturers, the wheelbase of same vehicle is various, so in this case can be combined with measured data from each vehicle maximum probability wheelbase as representative of the vehicle wheelbase value, from the 107 National Road a week of measured data, the various types of vehicles every day roughly stable, so use the measured wheelbase of January 8th day as the standard vehicle wheelbase representative value, as shown in table 5.

Table 5 The different vehicle wheelbase representative value

| motorcycle type | wheel base [cm] | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| passenger car | 260 | / | / | / | / |
| motor bus | 520 | / | / | / | / |
| The two axle truck | 450 | / | / | / | / |
| The three axle truck | 180 | 550 | / | / | / |
| The four axle truck | 180 | 430 | 130 | / | / |
| The five axle truck | 330 | 680 | 130 | 130 | / |
| The six axle truck | 315 | 135 | 620 | 130 | 130 |

**The different models of vehicle load standard value analysis**

According to the provisions on variable action (load) standard values of "engineering structure reliability design uniform standards" : when the variable is a random variable, the statistical parameters and probability distribution type should be to observational data as the basis, using parameter estimation and probability distribution test method determine, the level of significance test is 0.05.

"General specification for design of highway bridges and culverts" specified in the design reference period of bridge structures for 100 years.

According to the research results of the reference[5,6], it is assumed that the probability distribution(F(x))of the vehicle load in the design reference period does not change, that is, the maximum effect of the observation period is independent identically distributed. For example, the value($X_1$,$X_2$,...,$X_n$)of the effect is the maximum value of all the observation periods. Then the maximum distribution($F_T(x)$)of the design reference period effects can be derived, such as the Eq. 1.

$$F_T(x)=P(M_n\leq x)=P(X_1\leq x,...,X_n\leq x)=F^n(x) \quad (1)$$

Assuming that the vehicle load effect is independent and identically distributed random variables. According to distribution analysis of vehicle load effect. We can use the above method to calculate the standard value of vehicle load effect in the design reference period. assuming that the vehicle load effect is independent and identically distributed every day. The section distribution period is one day. That is, the maximum effect distribution($F_T(x)$) in the design reference period can be calculated by the section distribution(F(x)) , as the Eq. 2.

$$F_T(x)=[F(x)]^{36500}$$

(2)

By using the above method,we obtain 107 state road vehicle load 100 years design standard value,as shown in table 6.

Table 6 107 State Road vehicle load standard value

| motorcycle type | gross weight (kg) | |
|---|---|---|
| | standard value | sample maximum |
| passenger car | 7566 | 3450 |
| motor bus | 53916 | 40600 |
| The two axle truck | 70704 | 43200 |
| The three axle truck | 97520 | 70800 |
| The four axle truck | 114040 | 87400 |
| The five axle truck | 157710 | 114000 |

According to the standard value of vehicle load and vehicle weight and the ratio between the axle load and total weight. We obtain the standard axle load vehicle load design reference period value, as shown in table7.

Table 7 107 State Road vehicle load of 100 years design reference period divided axle load standard value

| motorcycle type | gross weight (kg) | axle load (kg) | | | | | |
|---|---|---|---|---|---|---|---|
| | standard value | 1 | 2 | 3 | 4 | 5 | 6 |
| passenger car | 7600 | 3000 | 4600 | / | / | / | / |
| motor bus | 55000 | 15000 | 40000 | / | / | / | / |
| The two axle truck | 71000 | 20000 | 51000 | / | / | / | / |
| The three axle truck | 98000 | 16000 | 37000 | 45000 | / | / | / |
| The four axle truck | 116000 | 15000 | 25000 | 38000 | 38000 | / | / |
| The five axle truck | 160000 | 10000 | 40000 | 40000 | 35000 | 35000 | / |
| The six axle truck | 208000 | 8000 | 37000 | 37000 | 42000 | 42000 | 42000 |

## Conclusions

- Based on the statistical data of 107 national highway vehicle load test analysis, we obtained the distribution and parameters of different types of weight. The analysis shows that knowledge: the total weight of the passenger car, motor bus, two axle truck distribution is lognormal distribution; and the total weight of three axle trucks, four axle trucks, five axle trucks and six

axle trucks distribution is two humped normal distribution.

- The distribution of car weight classification obtained and statistical analysis on the measured data, the various models of the design reference period weight standard value and axle load, the representative value parameter can provide basis calculation of abutment,retaining wall pressure and bridge local loading.

**Acknowledgements**

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