Traffic intensity calculation criteria for freight vehicles

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Abstract. To choose the road pavement, it is necessary to determine the traffic intensity and composition of the traffic flow on highways. The existing methods are used depending on the number of axles or carrying capacity of trucks. The purpose of this study is to compare the methods for determining the traffic intensity of vehicles and analyze the values of the minimum total modulus of elasticity. The article presents the results of calculation of the modulus of elasticity based on the traffic flow, the number of axles and carrying capacity of the vehicle. As part of the analysis, tables were compiled, the total estimated number of applications of the design load to a surface point was determined, and the minimum total modulus of elasticity of the road structure was calculated. The result of the research is recommendations for choosing a method for recording traffic intensity depending on the road category and traffic flow composition.

Safety of highways depends on competent calculations and compliance with safety requirements for the design parameters, including the permissible weight and overall parameters of vehicles [1].

When designing highways, it is necessary to ensure the safe and uninterrupted movement of vehicles with set weight parameters at a permitted speed under predicted traffic intensity, taking into account the predicted traffic flow. It is necessary to ensure the strength and stability of structural elements of highways and road structures under the influence of established loads at all stages of their life cycle.

The main indicators of safe highways are pavement reliability and strength.

The reliability is an ability of the road structure to maintain performance characteristics (evenness, strength, roughness) during the life cycle.

The strength is an ability to resist to residual deformations and fractures under the influence of tangential and normal stresses arising in structural layers and caused by design loads (short-term, multiple or long-term single) applied to the pavement surface.

The pavement structure should provide a time-stable continuity, evenness and roughness under the influence of design transport loads [3].

When calculating pavements, the following characteristics reflecting the intensity of load are used:
- average daily number of passes of all wheels located on one side of the design vehicle within one lane of the carriageway reduced to the design load (traffic intensity reduced to the design load effect);
- total number of applications of the design load reduced to a point on the pavement surface.

The existing regulatory documents establish various methods of accounting for the traffic intensity and composition of the traffic flow [2, 6]. Methods for recording the intensity of traffic flows are designed to collect information on the total number of vehicles and composition of the traffic flow passing per unit of time through the cross-section of the road in each direction.
The freight vehicles are classified by two criteria - the number of axles and carrying capacity. The number of trucks is a decisive factor in determining the reduced traffic volume.

Currently, in the Russian Federation, two regulatory documents establish methods for calculating the intensity of traffic reduced to a truck when designing non-rigid road pavements: ODN 218.046-01 "Design of non-rigid road pavements" and PNST 265-2018 "Design of non-rigid pavements".

According to ODN 218.046-01, the method of accounting for vehicles depends on the carrying capacity of the vehicle. There are the following vehicles in the flow: light trucks with a carrying capacity of 1-2 tons, medium trucks with a carrying capacity of 2-5 tons, heavy trucks with a carrying capacity of 5-8 tons, very heavy trucks with a carrying capacity of more than 8 tons, buses, tractors with trailers [3, 16].

According to PNST 265-2018, vehicles are classified into B, C, D categories. C vehicles are classified by the number of axles: two-axle trucks, three-axle trucks, four-axle trucks, four-axle road trains (two-axle truck with a trailer), five-axle road trains (three-axle truck with a trailer), three-axle road trains (two-axle truck tractor with a semitrailer), four-axle truck-trains (two-axle truck tractor with a semi-trailer), five-axle truck-trains (two-axle truck tractor), five-axle truck (three-axle truck tractor with a semitrailer), six-axle truck trains, cars with seven or more axles, etc., buses [2, 4].

An analysis of the traffic intensity of motor transport was carried out on category 2 roads of Irkutsk region by two criteria: the number of axles and carrying capacity. The total length of roads was 64.045 km [5]. We identified 14 areas with different degrees of traffic intensity.

We have calculated the average annual daily traffic intensity, the traffic intensity reduced to the design load 115 kN and the total estimated number of applications of the design load to a point on the surface during the service life of pavement, and determined the minimum total modulus of elasticity of the road structure.

The calculation results are shown in Tables 1, 2 for highway R-258 "Baikal" Irkutsk – Ulan-Ude – Chita, 0-1 km section (near Irkutsk), and in Tables 3, 4 for highway Taishet – Chuna – Bratsk, 244+690 – 232+690 km section in the Bratsk district of the Irkutsk region.

The following indicators were used:
- Design load group - A-11.5;
- Coating pressure - 0.8 MPa;
- The standard overhaul life of road pavements is 24 years;
- The estimated number of days that is dependent on the design area and corresponding to a certain state of deformability of the road structure is 150;
- The traffic intensity variation is 1.01.
- The traffic flow is composed of 77-87% of cars, 9.5-22% of trucks and 1-2.5% of buses.
- The total calculated number of applications of the calculated load to a point on the surface of the structure for the service life of the pavement differs for different methods of traffic intensity accounting by 6.23-8.43 times.

Table 1. Calculation of the minimum total modulus of elasticity by ODN 218.046-01.

| Types of vehicles                              | Actual traffic intensity $N_o$ | Average annual daily traffic intensity $N$, car/day | Conversion factor to design load A-11.5 | Reduced intensity $N_p$ | Total design number of load applications $\sum N_p$ | $E_{min}$, MPa |
|-----------------------------------------------|-------------------------------|-----------------------------------------------|----------------------------------------|------------------------|-------------------------------------------------|----------------|
| Cars                                          | 1674 86.6                     | 201859 0                                    | 0                                      | 0.000                  | 348                                             |                |
| Light trucks with a carrying capacity of 1-2 tons | 113 5.8                     | 1476 0.0026                                | 3.836                                  | 0.000                  | 1809111                                         |                |
| Medium trucks with a carrying capacity 2.1-5 t | 0 0.0                       | 0.1133 0.000                               | 0.000                                  | 348                    |                                                 |                |
Heavy duty trucks with a carrying capacity of 5.1-8 t   | 52  | 2.7 | 679 | 0.4 | 271.606  |  
Very heavy trucks with a carrying capacity of more than 8 t  | 10 | 0.5 | 131 | 0.715 | 93.365  |  
Tractor units with trailers with a carrying capacity of 20-30 t | 27 | 1.4 | 353 | 0.86 | 303.207  |  
Tractor units with trailers with a carrying capacity of more than 30 t | 8 | 0.4 | 104 | 0.86 | 89.839  |  
Buses  | 48 | 2.5 | 627 | 0.4 | 17.600  |  

**Total**  | 1932 | 100 | 25228 | - | 779.45  |

**Table 2.** Calculation of the minimum total modulus of elasticity by PNST 265-2018.

| Types of vehicles | Actual traffic intensity $N_i$ Car/h | Average annual daily traffic intensity $N$, car / day | Conversion factor to design load $A$-11.5 | Reduced intensity $N_p$ | Total design number of load applications $\sum N_p$ | $E_{min}$, MPa |
|-------------------|-------------------------------|---------------------------------|----------------------------------|----------------|-----------------|---------------|
| 1                 | 2                             | 3                              | 4                               | 5              | 6               | 7 8           |
| Motorcycles       | 0                             | 0.0                            | 0                               | 0              | 0               |  |
| Cars              | 1674                          | 86.6                           | 21859                           | 0.01           | 218.591         |  |
| Two-axle trucks  | 113                           | 5.8                            | 1476                            | 0.6            | 885.332         |  |
| Three-axle trucks| 52                            | 2.7                            | 679                             | 2.49           | 1690.750        |  |
| Four-axle trucks | 10                            | 0.5                            | 131                             | 3.62           | 472.700         |  |
| Four-axle road trains (two-axle truck with a trailer) | 3 | 0.2 | 39 | 1.81 | 70.905 |  |
| Five-axle road trains (two-axle truck with a trailer) | 0 | 0.0 | 0 | 2.15 | 0.000 |  |
| Three-axle semitrailer trains (two-axle semitrailer tractor) | 0 | 0.0 | 0 | 2.39 | 0.000 |  |
| Four-axle semitrailer trains (two-axle semitrailer tractor) | 0 | 0.0 | 0 | 4.13 | 0.000 |  |
| Five-axle semitrailer trains (two-axle semitrailer tractor) | 19 | 1.0 | 248 | 6.48 | 1607.701 |  |
| Five-axle semitrailer trains (three-axle semitrailer tractor) | 5 | 0.3 | 65 | 4.7 | 306.863 |  |
| Six-axle road trains | 5                             | 0.3                            | 65                              | 7.94           | 518.403         |  |
| Cars with seven or more axles, etc. | 3 | 0.2 | 39 | 8.47 | 331.804 |  |
| Buses             | 48                            | 2.5                            | 627                             | 0.75           | 470.088         |  |
| **Total**         | 1932                          | 100                            | 25228                           | -              | 6573.136        |  |

**Table 3.** Calculation of the minimum total modulus of elasticity by ODN 218.046-01.

| Types of vehicles | Actual traffic intensity $N_i$ Car/h | Average annual daily traffic intensity $N$, car / day | Conversion factor to design load $A$-11.5 | Reduced intensity $N_p$ | Total design number of load applications $\sum N_p$ | $E_{min}$, MPa |
|-------------------|-------------------------------|---------------------------------|----------------------------------|----------------|-----------------|---------------|
| 1                 | 2                             | 3                              | 4                               | 5              | 6               | 7 8           |
| Types of vehicles                                      | Actual traffic intensity \( N_i \), Car/h | Average annual daily traffic intensity \( N \), car / day | Conversion factor to design load \( A \)-11.5 | Reduced intensity \( N_p \) | Total design number of load applications \( \sum N_p \) | \( E_{\text{min}} \), MPa |
|-------------------------------------------------------|------------------------------------------|----------------------------------------------------------|-----------------------------------------------|-----------------------------|-----------------------------------------------|----------------------|
| Motorcycles                                           | 0                                        | 0.0                                                      | 0                                             | 0                           | 0                                             | 0                    |
| Cars                                                  | 188                                      | 77.0                                                    | 2754                                          | 0.01                        | 27.539                                        | 27.539               |
| Two-axle trucks                                      | 16                                       | 6.6                                                     | 234                                           | 0.6                         | 140.627                                       | 140.627              |
| Three-axle trucks                                    | 13                                       | 5.3                                                     | 190                                           | 2.49                        | 474.177                                       | 474.177              |
| Four-axle trucks                                     | 1                                        | 0.4                                                     | 15                                            | 3.62                        | 53.028                                        | 53.028               |
| Four-axle road trains (two-axle truck with a trailer) | 0                                        | 0.0                                                     | 0                                             | 1.81                        | 0.000                                         | 0.000                |
| Five-axle road trains (two-axle truck with a trailer) | 2                                        | 0.8                                                     | 29                                            | 2.15                        | 62.989                                        | 62.989               |
| Three-axle semitrailer trains (two-axle semitrailer tractor) | 0                                        | 0.0                                                     | 0                                             | 2.39                        | 0.000                                         | 0.000                |
| Four-axle semitrailer trains (two-axle semitrailer tractor) | 0                                        | 0.0                                                     | 0                                             | 4.13                        | 0.000                                         | 0.000                |
| Five-axle semitrailer trains (two-axle semitrailer tractor) | 2                                        | 0.8                                                     | 29                                            | 6.48                        | 189.847                                       | 189.847              |
| Five-axle semitrailer trains (three-axle semitrailer tractor) | 10                                       | 4.1                                                     | 146                                           | 4.7                         | 688.487                                       | 688.487              |
| Six-axle road trains                                  | 7                                        | 2.9                                                     | 103                                           | 7.94                        | 814.173                                       | 814.173              |
| Cars with seven or more axles, etc.                   | 2                                        | 0.8                                                     | 29                                            | 8.47                        | 248.148                                       | 248.148              |
| Buses                                                 | 3                                        | 1.2                                                     | 44                                            | 0.75                        | 32.960                                        | 32.960               |
| Total                                                 | 244                                      | 100                                                     | 3574                                          | -                           | 2731.977                                      | 2731.977             |
The minimum general modulus of elasticity of the pavement structure on category 2 roads was:
- depending on the number of vehicle axles – 410-454 MPa;
- depending on the carrying capacity – 320-348 MPa.

It can be concluded that the results of calculating the pavement based on the traffic intensity dependent on the number of vehicle axles (PNST 265-2018) and carrying capacity (ODN 218.046-01) are different from each other.

When calculating by PNST, the minimum total modulus of elasticity of the road structure was 1.28-1.3 times higher than when calculating by ODN.

Difficulties and contradictions arising are due to the collection of information on the quantitative characteristics of traffic flows, and the method of traffic intensity calculation. In addition, the calculation procedures and points for recording the traffic intensity [7, 8, 9] are also important.

When calculating the non-rigid road pavement taking into account the traffic intensity depending on the number of vehicle axles, the minimum total modulus of elasticity is of greater importance and, therefore, the road structure is thicker, which increases the service life of the road structure [10, 11]. This approach can be applied to high-class motor roads and roads with a number of trucks exceeding 9.5%.

The choice of the method for calculating the traffic intensity to obtain reliable values of the minimum total modulus of elasticity of the road structure is a key task in solving practical engineering problems.

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