Standard Axle Loads in the Design of Motorway Pavements

A Korochkin\textsuperscript{1,*}

\textsuperscript{1}MADI, Leningradskii prospekt, 64, Moscow, 125319, Russian Federation

E-mail: andrey_korochkin@mail.ru

Abstract. The paper considers issues of standard axle load, which is among the main design parameters when designing motorway pavements. Changing standard axle loads over time due to changes in the traffic flow composition is shown. Standard axial loads recommended for the design by the currently valid regulatory documents are given. Also, axle loads are given for trucks most widespread on domestic highways. Attention is drawn to the axle loads of modern vehicles, significantly exceeding the standard values. Also, the paper provides research data showing that more than 75\% off freight vehicles are overloaded, which also increases axle loads. These two factors: axle loads exceeding the standard values and overloaded vehicles lead to additional loads on the motorway pavement, for which it has not been designed. This, in turn, leads to the premature destruction of road pavements, the loss of their service quality, and additional costs for repairs. The paper justifies the need to increase the standard axle load when designing the motorway pavements since the use of the currently adopted value of 115 kN in the pavement design leads to insufficient strength of the pavement designed and its inability to withstand the existing loads. It is proposed to use an axial load of 150 kN as a design parameter when designing the motorway pavements.

1. Introduction

According to modern techniques for designing road pavements, one of the basic design parameters is the design axle load of a truck, i.e., the load transmitted from the truck by its wheels and axles to the pavement. This is one of the basic design parameters directly affecting the strength, service qualities, and life of the pavement designed \cite{1}. For public highways, the standard axle load prescribed by regulatory documents is used as the design value.

This parameter is primarily associated with the design vehicle weight and the mass load distribution between its axles. Since the truck carrying capacity has changed over time, the standard load has also changed thereupon. For a long time, N-13 has been the standard axle load \cite{2} recommended by the Head Highway Department back in 1938 to design road pavements. Further, N-13 was included as a standard load in VSN 46-60, Guidelines for Establishing Non-Rigid Pavement Structures, and then VSN 46-72, Guidelines for Designing Non-Rigid Pavement Structures. The N-13 load corresponded to an axle load of 9.1 t (91 kN) per axle. Therewith, the main cargo vehicles on public roads were GAZ-51, GAZ-93, ZIL-585, ZIL-150, ZIL-154, MAZ-205, and other trucks with a carrying capacity of 4-8 tons and a maximum axle load 3.75-8.7 t (37.5-87 kN).

But already in VSN 46-83, Guidelines for Designing Non-Rigid Pavement Structures, the standard axle load has been increased. For I-III category roads, it was 100 and 110 kN per axle of trucks (group A cars) and buses, respectively. For IV and V category roads, it was 60 and 70 kN per axle of trucks (group B cars) and buses, respectively. This was logical since trucks with a carrying capacity and an
axle load within 8-14.5 tons and 80-130 kN, respectively, such as ZIL-133G1, Ural-377N, KrAZ-257B, MAZ-516B, MAZ-500A, KAMAZ-5320, etc. appeared on the country roads. ODN 218.046-01, Designing Non-Rigid Pavements, which replaced VSN 46-83 in 2001, proposed to design road pavements for three groups of loads: A1 – 100 kN per axle, A2 – 110 kN per axle, and A3 – 130 kN per axle. The A3 load was adopted mainly to design pavements of industrial highways (quarry, haulage, etc.) intended for the passage of special machinery. Road pavements of highways and primary roads were designed for the A-2 load (110 kN per axle), which corresponded to the traffic flow on these roads, consisting mainly of domestic-made vehicles with a carrying capacity of 10-15 tons such as KAMAZ-6520, KAMAZ-5410, MAZ-5336, MAZ-54329, etc. with an axial load of 8.2-11.5 t (82-115 kN).

2. Current standard axle load
Currently, the standard loads for highways are determined by the whole range of documents. First, these are SP 34.13330.2012, Highways, GOST R 52748-2007, Automobile Roads of the General Use. Standard Loads, Loading Systems and Clearance Approaches, and GOST 32960-2014, Automobile Roads of the General Use. Traffic Load Models, Application of the Load Models. According to these documents, for designing heavy-duty pavements, the standard axle load should be 115 kN (11.5 t) for roads with heavy-duty pavements and 100 kN (10 t) for roads with intermediate ones. I.e., for highways, the standard axle load is 115 kN. The primary road pavement should be designed just for such a load.

But here, two critical points should be considered.

Firstly, neither the existing regulatory documents in force nor those outdated segregate the design of motorway pavements into a separate group. As before, both highways and ordinary roads are currently designed for the same axle load [3]. According to the latest regulatory documents SP 34.13330.2012 and GOST 32960-2014, all heavy-duty pavements are designed for a standard load of 115 kN, regardless of the road’s technical category. This does not consider the fact that highways and ordinary roads of IV-III categories operate in completely different conditions and experience completely different loads from road transport [4].

According to the data of the Federal State Statistics Service for 2018, 5,544 (67 %) of 8,268 mln. t of cargo transported by all vehicles in the Russian Federation was carried by road [5]. All this cargo traffic falls on highways since they are the main traffic arteries of the country. Only a small share of traffic flow comes on local and regional roads, which, as a rule, reaches them from the primary highway system. Actually, this is the main function of highways, formulated by V.F. Babkov back in 1966 [6]: long-distance passenger and freight transportation at high speeds without the interference of oncoming vehicles and local transport. Thus, highways perceive traffic loads many times exceeding those of the local transport network, but thereat, the pavements of both highways and regional category IV roads are designed for the same standard load [7].

Secondly, as mentioned above, the standard axle loads have always been calculated based on the traffic flows of highways and focused on the types of vehicles forming the bulk of freight traffic. But if at the end of the last century, it has not been complicated to link the axle load with a specific (design) vehicle since the truck fleet consisted of mainly domestic-made vehicles, now it is much more difficult because, in recent years, the number of domestic-made cars on our roads has significantly decreased, giving way to foreign trucks of increased carrying capacity. Moreover, according to the study of some highways performed by the author in 2003–2019 [8], from year to year, the percentage of such heavy vehicles in the traffic flows is steadily growing, which means that the load on highways is also growing. Thereat, we repeat, the standard axial load remains unchanged, i.e., 115 kN.

The extent to which this load corresponds to the actual values is considered below.

3. Actual axial load
As already noted, the axle load of a car depends on two basic parameters: the car weight and the number of axles. Only 20-30 years ago, the predominant part of the cargo was transported on Russian
roads by domestic-made vehicles (KAMAZ, MAZ, ZIL, etc.) with a carrying capacity of 6-12 tons. As a rule, at that time, the axle load of these vehicles did not exceed the standard values. However, now the situation on the roads has changed dramatically. Currently, trucking companies, including domestic ones, transport cargo by mostly foreign-made vehicles with a carrying capacity of 40-60 tons and axle loads much higher than the standard ones.

In Table 1, the characteristics of trucks most widespread on our roads are given [9]. Figs. 1-3 show cars with axle load distribution.

### Table 1

| Item No. | The Truck Make | Maximum Load, kN | Maximum Axle Load at Full Capacity, kN |
|----------|----------------|------------------|---------------------------------------|
|          |                |                  | on the front axle | on the rear axle | on semi-trailer axle |
| 1        | MAZ-5550V38 (2-axle truck) | 205 | 75 | 130 |
| 2        | Scania P380 (3-axle truck) | 396 | 80 | 158/158 |
| 3        | KAMAZ-65115 (3-axle truck) | 252 | 62 | 95/95 |
| 4        | MAZ-6514A8 (3-axle truck) | 419 | 99 | 160/160 |
| 5        | Scania P440 B8x4HZ (4-axle truck) | 500 | 90/90 | 160/160 |
| 6        | Iveco Stralis AT440S 43T (2-axle tractor truck with 2-axle semi-trailer) | 440 | 85 | 135 | 110/110 |
| 7        | Renault Premium Lander 440.26T (3-axle tractor truck with 2-axle semi-trailer) | 600 | 70 | 105/105 | 160/160 |
| 8        | Mercedes-Benz Tourismo RHD C632.410 (bus) | 225 | 71 | 126 |
| 9a       | Scania P360 LA4x2HNA with lowered axle (2-axle tractor truck with 3-axle semi-trailer) | 500 | 74.5 | 145 | 93.5/93.5 |
| 9b       | Scania P360 LA4x2HNA with raised axle (2-axle tractor truck with 3-axle semi-trailer) | 500 | 77.1 | 169 | 126.95/126.95 |
Figure 1. MAZ-6514A8 (three-axle truck).

Figure 2. IvecoStralisAT440S 43T (two-axle tractor truck with two-axle semi-trailer).
Figure 3. Mercedes-Benz Tourismo RHD C632.410 (bus).

As can be seen from the table and the above figures, only domestic manufacturers (KAMAZ, etc.) produce trucks of sufficiently large carrying capacity with axle loads not exceeding standard values. As a rule, at maximum load, foreign-made cars of increased carrying capacity have an axle load significantly exceeding the standard value.

I.e., currently, pavements designed for an axial load of 115 kN are exposed to loads of 130-160 kN. Such an excess of the standard loads negatively affects the pavement work, leading to a loss of strength, defects on its surface, and further premature destruction [10]. As a result, the rated service life of road pavements is not met [11], which leads to additional costs for the repair and maintenance of highways.

However, not only vehicles with increased carrying capacity, the axle loads of which exceed the standard values, negatively affect the motorway pavements. Trucks with a rated axle load not exceeding the standard value but transporting cargoes with overload also pose no fewer problems. As a result, the load on the axle and, accordingly, the road pavement increases [12] quite tangibly.

Thus, in 2017, by order of Avtodor SC, the Rastom LLC measured the weight characteristics of trucks crossing a bridge at 1,034+350 km of the M-4 Don highway [13]. The measurements have shown that 75.4 % of vehicles driving along the highway are overloaded. Thereat, 33 % of trucks are overloaded in not only weight but also axles. The overwhelming majority of overloaded vehicles are transit tractor trucks with semi-trailers weighing from 40 to 70 tons. In some cases, the axle load of such vehicles reached 17 tons (170 kN).

The author obtained approximately the same results in 2017-2018 when performed selective measurements of the axle loads of trucks on the Moscow region roads jointly with the Mosavtodor SBI. Weighing had shown that the axle load of some vehicles reached 15.6-17.8 tons.

Also, as noted above, the study of some highways performed by the author in 2003-2019, in which the traffic intensity, the driving speed, and the traffic flow composition was determined, convincingly showed solid growth of the number of trucks with increased carrying capacity. It can be argued with a high probability degree that a large part of these vehicles has axle loads exceeding the standard values.

The negative impact of loads exceeding the design value on the pavements is explicit [14]. It primarily concerns motorway pavements since the main part of cargo traffic falls on them, and therefore, they perceive the main overloads. According to the Federal Road Agency and the RADOR Association, the damage to highways from heavy vehicles is estimated at RUB 2.6 trillion per year. Thereat, the road funds allocated for motorway repairs allow compensating for only half of the damage caused [15].
4. Conclusions
The analysis of the regulatory documents in force, technical specifications of trucks, and research materials allows drawing several conclusions:

1. The regulatory documents in force, governing the design of motorway pavements do not segregate highways into a separate group. As a result, the motorway pavements are designed for a standard axle load of 115 kN, like other heavy-duty road coatings, given the traffic load on highways, which is several times higher than that on the local motor roads.

2. Currently, along the Russian Federation highways designed for a standard axle load of 115 kN, vehicles are driven with an axle load significantly exceeding the standard value (up to 16-17 tons per axle).

3. Since standard axle load is used as a road pavement design parameter, the road pavements designed are not sufficiently strong and cannot withstand the existing loads. This leads to rapid pavement destruction, various defects in the coating, deteriorated service quality, and permanent repairs.

4. To avoid the negative impact of loads exceeding the standard values, the author proposes using an axial load of 150 kN as a design parameter when designing motorway pavements.

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