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EQUIVALENT STANDARD AXLE LOADS ANALYSIS ON LITHUANIAN ARTERIAL HIGHWAYS

As the flows of vehicles, especially heavy goods vehicles are growing on the roads of Lithuania, the remaining deformations of the pavements are appearing and progressing also cracks originate because of low pavement strength. The biggest loads are caused by heavy goods vehicles, which total number increases 17% annually. This paper presents analysis of the damage caused by transport vehicles axle loads to the asphalt pavement roads. This influence estimated through calculation equivalent standard axle load index.

Introduction. The main purpose of arterial roads is to guarantee interstate transport communication. Maximum vehicles traffic intensity, comfort and safety must be assured on these roads, for these reasons road pavement must be smooth, rough and strength during economically reasoned exploitation period [1]. The main Lithuanian arterial highways, which are part of European highways network, shown in Fig 1.

In Lithuania, as in most of European and other continents countries, the pavements of streets and roads are usually prepared from the hot mix asphalt (HMA), which is suitable to pave layers and satisfy modern transport uses. The asphalt pavement laid on a hard foundation and made from essential properties mixes, exact thickness of layers, regarding technological requirements stays strong enough and durable only if the limiting loads of transport vehicles affect it [2,3].

The loads which affect roads of national importance, started intensively increase after restitution of Lithuania's independence, then in the whole flow of transport vehicles the total number of transit transport vehicles has increased. They especially increased after Lithuania has joined the European Union. In the printed paper [4] ten years ago, the necessity of roads asphalt pavements consolidation had been scientifically reasoned for the first time, as the numbers of transit heavyweight trailers had begun intensively grow. It was pointed that increasing transport flows grows the financial inflow to the nation budget, which is positive from economical sight, but also intensively ruins the roads pavements, which requires additional finance resources for upkeep, repair and strengthening.

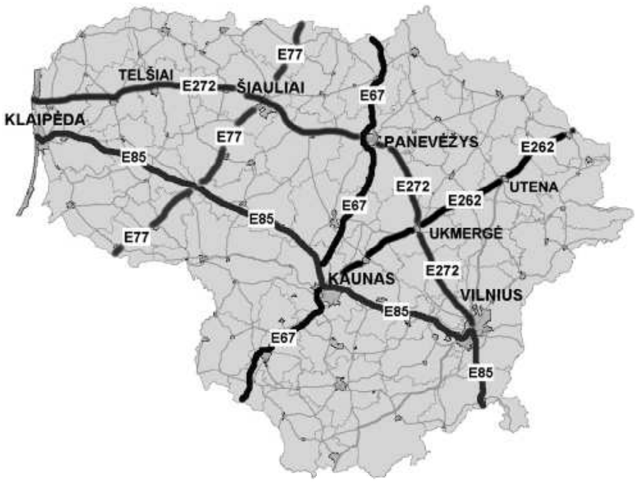

Fig. 1. The main Lithuanian highways

The increase in the roads surface unevenness and in the ruts depth is, fist of all, predetermined by the heavy goods vehicles (HGV). The damage caused by axle loads is proportional to the load value raised to the power four; thus, the negative impact of an average two-axle truck on the road pavement is equal to that of 500 cars, and the negative impact of moderately loaded five-axle truck is equal to that of 50000 cars. Even when the total mass of vehicle is not exceeded but is only distributed on the axles of vehicle is wrong way, the damage caused by truck to the road pavement is 70000 times bigger. In 2004 the intensity of HGV traffic increased 1.5 times if compared with 2003, which means that the negative impact on the road pavement increased 5 times [5].

Plastic deformations mostly forms on the upper layer of asphalt pavement, when the temperature of the pavement keeps from $+30^0$C to $+60^0$C, and the construction of the pavement is affected by heavy loads: brake and acceleration forces of HGV and such a things. The main reasons to formation of plastic deformations in the asphalt road pavements are the following [5,6]. As the flows of heavyweight goods transit vehicles on Lithuania's roads are growing, the remaining deformations of the pavements appear and keep progressing. Because of low pavement strength cracks originates [4]. The plastic deformations, as ruts or waves, on the pavements are forming because of increased traffic intensity and total HGV number on Lithuania's arterial roads and urban streets, also because of increased axle loads for transport vehicles. The forming of ruts on the asphalt pavements may indicate low strength of road pavement construction. Therefore the selection of asphalt pavement building materials which would coincide the traffic and climatic conditions became important, also – design of the mixes components, rational use of technological process for new asphalt pavements, the quality control and formulating of new normative documentation [4].

Heavy goods vehicles loads and their limits in Europe. Pavement class and construction must be selected considering to traffic intensity, composition, road category, ground-geological conditions, also to local building materials assortment [1]. There are several options to select pavement construction, them can be selected by special calculation methods or standard models – according HGV index VB. HGV index shows traffic influence to pavement construction. VB index determination require to pay attention to: HGV with total mass more then 5,0 tones, designed traffic intensity; enlarged axle loads (115 kN) on arterial roads; traffic lanes number, their width and road longitudinal profile gradient. HGV index applied to select standard pavement constructions.

Designing Lithuanian roads in the past, the biggest axle load was 100 kN. After Lithuania established an independence and dissolved borders, there came ant international demand to increase the biggest axle load to 115 kN, because the same and even bigger permissible axle loads were applied in the most Europe countries (Table 1).

Table 1

Vehicles with trailers and semi trailers mass (tones) limits in European Union

Country	Vehicle mass (t) and number of axles			Permissible axle load, kN
	4	5	6	
Austria	38	38	38	115
Belgium	39	44	44	120
Denmark	38	44	48	115
Finland	36	44	53	115
France	38	40*	40*	130
Germany	36	40	40*	115
Greece	38	40	40	115
Ireland	35	40	44	105
Italy	40	44	44	120
Luxembourg	38	44	44	120
Netherlands	41	50	50	115
Portugal	38	40	40	120
Spain	38	40	40	115
Sweden	38	40	40	115
United kingdom	38	40	44	115
EC Directive Limits for international movements	38	40*	40	115

- *44 tones for combined road/rail transport with axle weight of 100,5 kN.
- Austria permits a 5% tolerance on this limit allowing, in effect, 40 tones. Austria also allows 42 tones for container transport.
- Higher weights allowed for certain long vehicle combinations in Sweden.
- In UK attracts a substantially higher rate of Vehicle Excise Duty so in practice is never used.

Unnecessarily heavier truck has to do bigger damage to asphalt pavement. 44 tones mass truck with 6 axles and even spread load can do less damage than 40 tones mass truck with 4 or 5 axles. Some European Union countries allow that total truck mass would reach 50 or 53 tones, but important, that the axle load wouldn't exceed determined axle load limits.

Loads that influence damage to road pavement depend from total truck and trailer mass and how evenly this weight transmits to road through truck axles. The pavement wearing depends upon each single axle loads but not upon a whole truck mass. If we spread load more evenly and avoid the big load to one axle, we could reduce faster pavement wearing. The distance between axles has an influence to plastic strains appearing.

Beside European Union and countries members determined axle loads and the biggest mass limitation there are more factors, which have an influence to faster pavement wearing. They are trucks constructional decisions, therefore static and dynamic loads increase [7]:

- single wide wheels can make to 10 times biggest static loads than tandem;
- single wheels are more dangerous to ruts appearing than tandem;
- bigger damage caused by vehicles driving wheels are from 1,5 to 2 times than their trailers;
- pneumatic suspension, called „road friendly suspension“ make less damage than steel suspension.

Dynamic loads are from 10% to 30% bigger that static, that depends from vehicle speed and road roughness.

If biggest axle load (115 kN) assume dynamic character it will increase 30%, in that case load can reach even 150 kN. Some road pavement sectors must be especially reinforced because of vehicles dynamic loads. If we design pavement only by static loads, there is a possibility to reduce road lifetime in quarter. Road pavement must be designed the same strength and rigidity in all road or sector. Weak locations under the dynamic loads begin to break, open cracks and wrack. If traffic lane is narrow, the tensile strain is bigger and pavement lifetime could reduce to 40% [8].

The equivalent standard axle loads to the road pavement. Currently the equivalent standard load, of transport flow impact to the pavement, is denominated by equivalent standard axle (ESA) index, which is common all over the world is applied in Lithuania. The ESA counting method for loads impact to the pavements is applied in Lithuania because of compatibility with the software for road's designing HDM-3/HDM-4 (Highway Design and Maintenance). In pavement design systems there is a current method to evaluate the impact of axles of transport vehicles to the deterioration of pavements, according, which the impact of the axel with particular standard load (usually 80 kN or 100 kN) is equated to one. The impact to the pavement deterioration, which is done by axe, which load differs according the standard, is named as equivalent of standard axes. The impact to the road pavement deterioration of all axes of a separate transport vehicle is calculated according the formula:

$$ESA80_V = \sum_{i=1}^{n} \left(\frac{A_i}{80} \right)^4, \tag{1}$$

$$ESA100_V = \sum_{i=1}^{n} \left(\frac{A_i}{100} \right)^4, \tag{2}$$

where $ESA80_V$ – total equivalent of vehicle standard axles (when the standard load is accepted as 80 kN), units.; $ESA100_V$ – total equivalent of vehicle standard axles (when the standard load is accepted as 100 kN), units.; n – total number of axles for a vehicle; A_i – i-axle load for particular vehicle class, kN; *80, 100* – standard axle load, kN.

The equation of fourth grade indicates the structure of road pavement and thickness of layers [9].

The average annual one day impact of transport flow to the deterioration of pavements in a road section which is analyzed is calculated:

$$ESA80_R = \sum_{i=1}^{n} N_j * ESA80_j, \tag{3}$$

$$ESA100_R = \sum_{i=1}^{n} N_j * ESA100_j, \tag{4}$$

where $ESA80_{R,}$ $ESA100_R$ – total annual one day impact of the transport flow to the deterioration of pavements on a road section, units; j – the number of vehicles class according the classification chart which is used; N_j - average annual one day traffic intensity of a j - particular class of transport vehicles, veh./day. $ESA80_{j,}$ $ESA100_j$ – average of standard axel equivalent of transport vehicles, which is identified according statistical analysis.

During tests TRRI appointed average axle loads for separate transport vehicles classes, which are needed for counting the ESA index and calculated average $ESA80_V$ and $ESA100_V$ for each particular vehicle class, those values are indicated in Table 2.

Table 2

Average equivalent standard axle values for particular classes of one vehicle

Vehicles types	Classes	$ESA80_V$, kN	$ESA100_V$, kN
Motorcycles	MOTOC	-	-
Cars	LA	0.0003	0.0001
Minibus	MINIAUT	0.0274	0.0121
Bus	BUS	2.6637	1.1793
Light goods vehicles	LS	0.026	0.0115
Medium class trucks	VS1	0.0274	0.0121
Medium class trucks	VS2	0.6008	0.266
Heavy goods 3 axle vehicles	3AŠ	2.625	1.1621
Heavy goods 4 axle vehicles	4AŠ	2.3437	1.0376
Heavy goods 5axle vehicles	5AŠ	4.6454	2.0566
Tractors	TRA	0.0415	0.0184

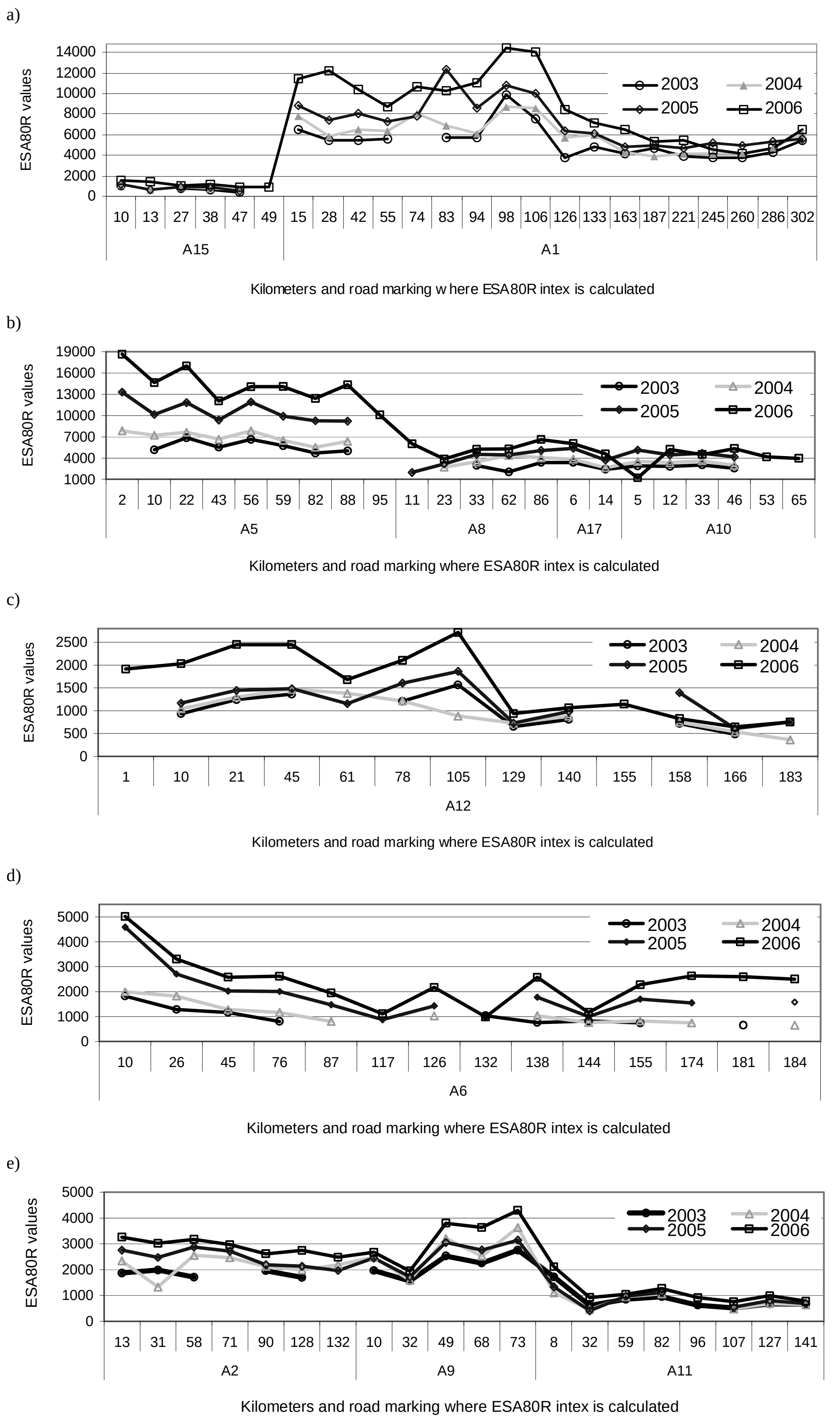

Fig. 2. $ESA80_R$ loads on Lithuanian arterial highways:
a) E85 b) E67- Via Baltica c) E77 d) E262 e) E272

Highway E85 consist from two sectors (roads A15 and A1) and runs from south-east (border of Belarus) to the west (Baltic Sea). It cross biggest Lithuanian cities: Vilnius, Kaunas and port city Klaipeda. $ESA80_R$ index reach the peak values in sector A1 from Vilnius to Kaunas. The maximum value in this sector is ESA80$_R$=14373 shown in Fig.2. The biggest ESA80$_R$ value in Lithuania is in highway E67 named Via Baltica, it runs from south to north. This highway consist of these roads: A5, A8, A17 and A10. ESA80$_R$ peak value is in sector A5 by border of Poland, ESA80$_R$ reach 18643 index. Other highways (E77, E262 and E272) have signally lowest traffic intensity that is why equivalent standard axle loads vary in narrow range. If compare these highways with E85 and E67 we could notice that ESA80$_R$ loads approximately is three times lower and they are not extremely load. There are several general notices for all highways:

- ESA80$_R$ index is growing up every year, as traffic intensity for light vehicles grow stable by 7% and HGV by 17% recent years.
- Equivalent standard axle loads index is high near biggest Lithuanian cities or in the crossroad with highway Via Baltica.
- ESA80$_R$ curve has almost the same sinuosity every year for particular highway.

Although HGV traffic intensity is less from several to ten times than light vehicles, but if evaluate HGV axle loads, we will notice that 99.5% damage to road pavement does HGV and their traffic intensity grows average about 17% annually.

Conclusions.

1. The old pavements is using in nowadays and the most important that new asphalt pavements is plastic (irreversible) deformations, that is why ruts and waves originating. This character of deformations is made not by climatic conditions, but for signally increased vehicles loads on main arterial roads, especially loads accrue to each axle and their intensive (frequent) repeating by summer time. Road pavement construction strength discrepancy to transport vehicles mechanical destructive influence determines quick irreversible deformation increasing.

2. Accomplished vehicles axle loads influence to road pavement analysis on Lithuanian arterial highways, we can propose, that the biggest equivalent standard axle load index is noticed before biggest Lithuanian cities (Vilnius and Kaunas) and Poland border.

3. Standard axle equivalent index *ESA* is calculating referring to average annual traffic intensity data in Lithuania, that is not according to the maximum traffic intensity values, for this reason, during seasonally traffic intensity grow, real axle loads influence to road pavement is more bigger than average.

4. Because of recent HGV traffic intensity and remaining increase tendency, road pavements designed several or more years ago, are not able to resist to HGV destructive loads and that is why we have faster pavement wearing, ruts development and cracks spreads. There is a necessity to reinforce intensively deranging asphalt pavements, adjusting progressive technologies. Pavement strengthening project organization must accord to newest science knowledge and methodic. Strengthening sections and their length rational to choose by ranks estimating implementation priorities and allocating available budget.

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