THE BALTIC JOURNAL
OF ROAD AND BRIDGE ENGINEERING

2009
4(3): 115–122

ANALYSIS AND EVALUATION OF THE EFFECT OF STUDDED TYRES ON ROAD PAVEMENT AND ENVIRONMENT (I)

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Abstract. In order to determine the effect of studded tyres on road traffic safety, this article, based on Lithuanian and foreign countries researches, gives an overview of the performance of winter tyres, influence of the type of tyres on fuel consumption. Also, it presents the dependency of accident risk on road pavement condition, studies the effect of studded tyres on road pavement and pavement marking, gives an analysis of traffic accidents on Lithuanian roads and streets in different aspects.

Keywords: studded tyres, road traffic safety, traffic accidents, road pavement.

1. Introduction

Currently, there is no single opinion about the use of studded tyres in winter. The traffic specialists and scientists of many countries are still studying the benefit of such tyres for traffic safety as well as their damage for human health, environment and the roads. In Bulgaria, Germany, Croatia, the Netherlands, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Czech Republic, Turkey, Hungary the use of studded tyres is prohibited and other countries have introduced restrictions and charges for their use. The studded tyres are permitted in the following EU member-states: Austria and Sweden – from October 1 to May 1; Latvia – from October 10 to May 1; Belgium, Finland, Luxemburg and Norway – from November 1 to March 1; Lithuania – from November 1 to Apr 10; Denmark and Estonia – from November 1 to April 15; Switzerland – from November 1 to May 1; France – from November 6 to March 26; Italy – from November 15 to March 15; Greece – if the driving speed ≤ 90 km/h on national roads and ≤ 120 km/h on main roads; Great Britain and Ireland – if the driving speed ≤ 96 km/h on national roads and ≤ 112 km/h on main roads); Spain – only on streets covered by snow or ice.

Traffic safety in winter is mostly dependent on the road maintenance level, vehicle condition, especially on tyre quality and by no means – on a rational driving under complicated driving conditions. Depending on the culture and mentality of road users, climatic conditions and other factors, each country implements individual measures to ensure traffic safety. Due to the prevailing Lithuanian climate the traffic safety specialists must pay an especially large attention to road user safety in winter.

2. The effect of studded tyres on traffic safety

In order to determine the effect of tyres on a braking distance, it is necessary to describe the technical parameters and driving conditions of the vehicle for which a braking distance has been estimated. Based on 2009 data provided by the Dept of Statistics under the Government of the Republic of Lithuania, the cars Volkswagen make one of the most popular group in Lithuania (making about 19% of the total number of registered vehicles). Therefore, the Volkswagen Golf and its technical parameters were selected for modelling. In Europe the driving conditions of passenger cars, based on which the fuel consumption and dynamics are measured, are regulated by the driving cycles set in the *Regulation No. 101 (Revision 2) of the Economic Commission for Europe of the United Nations (UN/ECE) "Uniform provisions concerning the approval of passenger cars powered by an internal combustion engine only, or powered by a hybrid electric power train with regard to the measurement of the emission of carbon dioxide and fuel consumption and/or the measurement of electric energy consumption and electric range, and of categories M1 and N1 vehicles powered by an electric power train only with regard to the measurement of electric energy consumption and electric range"*. The *UN ECE R 101* describes 3 driving cycles, i.e. urban, extra-urban and mixed. A driving cycle consists of 4 elementary urban cycles and 1 extra-urban cycle (Table 1).

ISSN 1822-427X print / ISSN 1822-4288 online DOI: 10.3846/1822-427X.2009.4.115-122
http://www.bjrbe.vgtu.lt

Table 1. Urban and extra-urban driving cycles

Test cycle	Description
Urban	The cycle is applied in the laboratory on a road-simulation stand (the wheels are placed on inert hand-wheels causing resistance) at an ambient temperature between 20 and 30 °C. The test is started by driving in an urban cycle with a cool engine. The urban cycle is composed of a sequence of acceleration, driving at a constant speed, deceleration and idle running operations. In the urban cycle the max vehicle speed – 50 km/h, the average speed – 19 km/h. In the sequence of four urban cycles the distance of 4 km is travelled.
Extra-urban	The extra-urban cycle is applied straight after four urban cycles. More than a half of the extra-urban cycle is made of the driving at a constant speed. In other periods of time the car is accelerating and decelerating. In the extra-urban cycle the max vehicle speed – 120 km/h, the average speed – 63 km/h. During the extra-urban cycle the distance of 7 km is travelled.

Analysis of the above-mentioned cycles showed that the vehicle driving in an urban regime from the max 50 km/h to 35 km/h shall stop in 10 s, acceleration – 0.42 m/s^2. The largest acceleration is obtained when the vehicle is stopped in 10 s from 30 km/h until the full stop, acceleration – 0.83 m/s^2. The vehicle driving in an extra-urban regime from the max speed of 120 km/h shall stop in 30 s, in this case acceleration reaches 1.11 m/s^2.

2.1. Forces in the tyre-road contact zone

Distribution of pressure (σ_z) in the tyre-road contact zone, if the vehicle is at a standstill, is symmetrical with respect to the centre of the contact zone coinciding with the wheel centre. In this case the road reaction force passes through the centre of the contact zone. With the rolling tyre the pressure distribution becomes asymmetrical to the contact zone centre due to tyre deformation. Due to the re-distribution of pressure the road reaction force moves to the direction of motion and thus the moment of the rolling resistance is created; it is equal to the product of the reaction force F_z and its displacement Δx (Fig. 1) (Genta, Morello 2009).

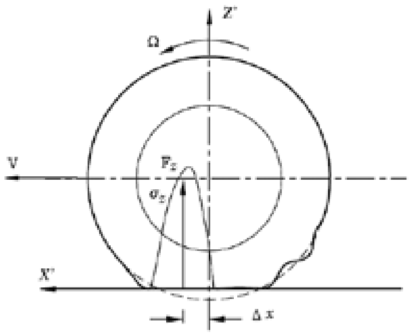

Fig. 1. Distribution of the normal pressure in the tyre-road contact zone

When analyzing forces acting in the tyre-road contact zone, the pressure is divided into the normal (perpendicular to the road surface) (σ_z) and tangential (τ_x, τ_y) components. Tangential pressure also has 2 components in the longitudinal (X) and transverse (Y) wheel planes respectively. On the distribution of pressures in the contact zone (Fig. 2) the normal (F_z), longitudinal (F_x) and transverse (F_y) forces depend and determines the motion of vehicle. The forces acting in the tyre-road contact zone are strongly influenced by tyre structure, load, inflation pressure, driving conditions and other factors (Genta, Morello 2009; Heisler 2002; Reimpell *et al.* 2001).

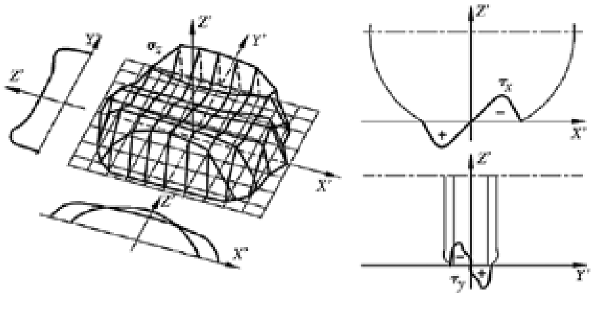

Fig. 2. Distribution of pressure components in the tyre-road contact zone

After the vehicle motion has started in separate areas of the tyre-road contact zone the sliding and rolling processes take place at the same time. To describe the sliding processes the sliding coefficient (σ) is used, it is equal to the ratio between the tyre contact and the wheel centre speeds with respect to road surface. To describe the rolling processes the friction coefficient (μ) is used; it is calculated as the ratio between the longitudinal and normal forces. The inter-dependencies of these coefficients are analogical to the tyre operation in traction and braking regimes (Fig. 3) (Genta, Morello 2009; Reimpell *et al.* 2001).

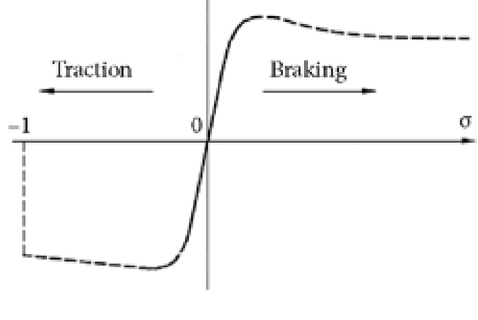

Fig. 3. Dependency of μ on sliding in traction and braking regimes

2.2. Review of tyre operation

The theory of vehicles indicates that the μ of tyres, operating in traction and braking regimes, are equal, and the dependency of these coefficients on sliding is dependent on tyre type, road, traffic conditions, speed and other parameters; therefore, it is very complicated to describe the mathematically non-descriptive values. Determination of μ is very complicated due to the fact that it is very difficult to coordinate conditions for the implementation of experiments.

When the pavement is wet, the water layer lifts the tyre from the road surface, thus reducing the contact area. With increasing speed the area of the contact zone further reduces and, depending on the thickness of the water layer, the σ can reduce to 0.05 at 70 km/h and higher. In order to avoid a negative effect on the friction of tyre and road, 2-ways are possible: laying a permeable road pavement or using a special pattern of tread (Genta, Morello 2009).

The effect of snow and ice on the tyre-road friction is similar to that of water; however, the value of μ depends also on the temperature of icy surface. As the temperature falls, the tyre-road μ increases due to a higher density of ice; besides, with the temperature of ice coming to 0 °C the road surface together with ice or snow is also covered with a water layer due to which the μ becomes < 0.1. Investigation data (Reimpell *et al.* 2001) shows that in winter the roads covered by snow or ice have a significantly lower tyre friction. Efficiency of tyres on winter roads depends on tread type, its pattern and degree of wear. The influence of speed on the value of the σ within the zone of temperature close to 0 °C is insignificant, and the value of μ only slightly exceeds the value of the coefficient of sliding friction μ_S. At the lowering temperature the μ can twice exceed the value of the coefficient of μ_S (Reimpell *et al.* 2001).

2.3. Review of winter tyres

The main function of a tyre – to ensure the transmission of a rolling moment (traction regime), initiated by the engine, or a braking moment (braking regime), initiated by the braking systems, to the contact zone of the tyre and road. To optimize the execution of these functions the tyres of different technical parameters and tread patterns are created and adjusted to be used in certain conditions (Reimpell *et al.* 2001).

The efficiency of friction of studded tyres and icy surface depends on the structure of studs and their protuberance over the height of tread. The effect of stud heights at low speeds has no large influence on the friction; however, it increases with the increasing speed and the wear of road pavement gets more intensive (Reimpell *et al.* 2001). The same investigation indicates that at –5 °C, when the height of studs is 1.9 mm, μ_S reaches the minimum value at a driving speed of 10–20 km/h; when the height of studs is 1.3 mm – at a driving speed of 20–30 km/h.

Traction/braking, durability and comfort parameters are interrelated and depend on tyre structure, material, tread pattern, type of studs and their fastening system. The selection of winter tyres depends on their usage conditions, i.e. their performance is highly different on dry, wet, dirty, snowy or icy road pavement. Therefore, depending on the climatic conditions, the tyre manufacturers supply various winter tyres. For example, the winter tyre manufacturers in Germany must supply winter tyres that are good for driving on dry freeways and icy rural roads, whereas the manufacturers in the Nordic countries have to consider friction on roads covered by snow and ice (Zubeck *et al.* 2004).

2.3.1. Studded tyres

Studded tyres are equipped with studs that protrude over the tread pattern and ensure tyre friction with the road pavement covered by snow and ice. Until the year 1970 the steel studs were used that were later replaced with the studs of new construction using a steel jacket and a tungsten carbide pin. The average length of the upper part of steel studs, penetrating into the road pavement and used until 1970, was 2.2 mm; at present the length of studs with tungsten carbide pin reaches 1.1 mm (Scheibe 2002; Zubeck *et al.* 2004).

Based on the construction of typical studs, they are divided into conventional and lightweight studs. According Zubeck *et al.* (2004), the mass of conventional studs with a steel jacket and a tungsten carbide pin depends on the type of vehicle, i.e. 1.9 g – for passenger cars, 2.4 g – for vans and 2.8–9.3 g – for trucks and the mass of lightweight studs with light metal composite or polymer jacket with tungsten carbide pin are as follows: 1.1 g – for passenger cars, 2.3 g – for vans and 3.0 g – for trucks.

2.3.2. Non-studded winter tyres

Such tyres are produced with a special tread pattern which increases the friction with the road under wet, snowy or icy traffic conditions and selecting a more soft structure of rubber mixture compared to summer tyres. A production technology of these tyres has been continuously improved by optimizing the tread pattern and materials. Tyre manufacturers use different means to improve the tyre-road friction (Zubeck *et al.* 2004):

- micro-bubbles are included into a tyre material,
- silicon carbide and aluminium oxide is admixed to the tyre material, and
- vegetable oils are admixed to the rubber compound.

The above examples show that at present there is no single technology for producing non-studded winter tyres, unlike the studs, to ensure a sufficiently good friction in winter conditions.

2.4. Comparison of the performance of winter tyres

Investigations by the Technical Research Centre of Finland VTT showed that the friction of studded winter tyres with the vehicle rolling surface (road pavement) is better than that of non-studded (simple) winter tyres on icy or icy and snowy road pavement. When braking on ice-covered road pavement (σ ≈ 0.1), studded winter tyres are by 30% more effective compared to non-studded winter tyres. On a wet pavement the best efficiency is represented by summer tyres.

Laboratory investigations by the Swedish National Road and Transport Research Institute VTI on a special tyre testing stand showed that studded winter tyres are most efficient when braking on an icy road pavement, on a wet pavement – the least effective compared to non-studded winter tyres and summer tyres. It was determined during the test that on a wet asphalt pavement μ is up to 35% higher than σ, on an icy pavement – up to 45%. Analysis of investigation results showed that a braking distance is directly proportionate to the friction coefficient between tyre and road. At the blocked wheels a braking distance is by 35% longer than the effective braking distance, and with the 20 km/h increase in vehicle speed (from 70 km/h to 90 km/h) a braking distance in both cases become longer by 39%.

In Russia the experts of the journal „*За рулем*", based on 1997 investigations, came to a general conclusion that the vehicle with studded tyres drives more reliably than with the non-studded winter tyres (Tilindis *et al.* 1998). However, this cannot be unambiguously stated since the length of braking distance of tyres with the stud height of only 0.3 mm in icy conditions was 61.2 m, and the largest length of braking distance with non-studded winter tyres was 58 m.

Investigations of the Russian Tyre Industry Scientific Research Institute (1997) showed that on pavement covered by loose snow the studs do not reach the road base; therefore, their operation is ineffective. In such conditions the efficiency of studded and non-studded tyres differs by about 0.5%. The efficiency of studs is evidenced on icy pavements. On snowy pavements the braking distance of studded tyres differs insignificantly; however, on pavements with hard ice the difference comes to 70% (Tilindis *et al.* 1998).

2.5. Effect of studded tyres on road traffic safety

The above analysis of the performance of studded tyres shows that their efficiency depends on:

- type of tyres (studded, non-studded, winter, summer) and their technical parameters (dimensions, wear, depth of tread, number and height of studs, etc.), and vehicle technical parameters (wheel load, etc.);
- vehicle driving speed;
- pavement type (asphalt, cement concrete, gravel, soil, etc.) and the surface quality;
- traffic conditions (dry, wet, thickness of water layer, snow, ice, temperature).

Since the operation of tyres and the testing conditions are affected by many factors, the comparison of the above results of experimental investigations is impossible. In order to compare the efficiency of operation of the different type of tyres, the comparative braking distance calculations were carried out. The length of braking distance, depending on the type of tyres and traffic conditions, was modelled when braking the *Volkswagen Golf* vehicle, the mass of which – 1300 kg, from 30, 50 and 70 km/h until its full stop. The modelling was based on the algorithm (Fig. 4), the tyre-road μ was assumed as the average of experimental data in different traffic conditions presented in the literature.

Modelling results showed that the most dangerous traffic conditions are those when the road pavement is covered by ice and the temperature around 0 °C. In such traffic conditions it is impossible to safely brake the car with summer tyres, since at a speed of 30 km/h a braking distance reaches 71 m; the efficiency of studded tyres is 41% higher, the braking distance – 41.9 m, a braking distance of non-studded winter tyres – 59.2 m. When braking the car at 70 km/h, a braking distance of summer tyres in the same traffic conditions exceeds 380 m, of non-studded tyres – 320 m, of studded tyres – 220 m. On dry or wet pavements a braking distance of summer tyres is nearly 2 times shorter than that of winter studded tyres and 15–30% shorter than of non-studded tyres. The most optimum conditions for using studded tyres are only those where the road is covered by snow or ice.

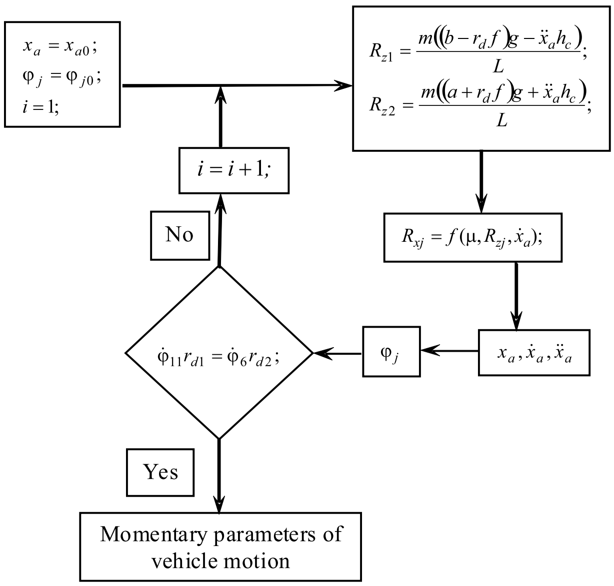

Fig. 4. Algorithm describing the tyre and road interaction (Starevičius 2007)

2.6. Effect of the type of studded tyres on fuel consumption

In icy or snowy pavement conditions the fuel consumption increases by about 15%, if compared to dry pavements. Investigations showed that when the tyre-road μ reduces by 0.1 (from 0.4 to 0.3) the fuel consumption increases by 0.7%. Data of different investigations show that the use of vehicle with studded tyres increases the fuel consumption from 1.2 to 2% compared to the non-studded tyres (Scheibe 2002; Zubeck *et al.* 2004).

3. Impact of studded tyres on road pavement

3.1. Accident risk depending on road pavement condition

Data and conclusions presented in this chapter are based on the results of investigations carried out in Norway, Finland and Sweden. In winter the friction between the road pavement and the tyre obviously worsens if compared to summer. The layers of snow or ice on the road surface reduce friction. This causes a longer braking distance and increases the possibility to loose vehicle control. Humps of ice at the pavement edges narrows the sight of visibility and possibly narrows the carriageway. The studies by the Norwegian researchers show that the road that is partly or fully covered by ice or snow has a lower friction than a clean dry or wet road (Эльвик 2001). μ on the carriageway covered by snow and slush (the value of which varies from 0 to 1) can decrease up to 0.1. The normal values of μ of the snowy or icy road pavement are 0.1–0.4. In case of wet and clean pavement μ, as a rule, is about 0.4–0.7. The μ of dry and clean pavement must be 0.7–0.9. A lower friction lengthens a braking distance. The Norwegian studies show that the drivers do not sufficiently reduce their speed in slippery conditions in order to obtain the same braking distance as in summer. This is one of the reasons for the increased number of accidents when the pavement becomes covered by snow and ice compared to dry and clean pavement. On the basis of investigations (Vaa 1996), the accident risk on Norwegian roads, depending on different road pavement conditions (Table 2).

Table 2. Accident risk depending on road surface condition

Road surface condition	Relative risk
Dry and clean pavement	1.0
Wet and clean pavement	1.3
Slush	1.5
Hard packed snow	2.5
Light snow and snow cover	4.4

Table 2 shows that the accident risk on the road pavement partly or fully covered by snow and ice is 1.5–4.5 times higher than the same risk on the clean and dry pavement.

In bad weather and road surface conditions the road users can postpone their journey or to allot more time for it. The Swedish studies made a conclusion that the traffic volume on iced road becomes 1–5% lower compared to that on clean pavement. Another similar study indicated that there is no decrease in the traffic volume on the snow-covered carriageway if taking into consideration the whole 24 h.

Based on human mobility studies by Gabestad *et al.* (1988), 9% of the drivers had refused one or several journeys by car in winter: 4% – 1 journey, 2% – 2 journeys, 1% – 3 journeys and 2% – 4 or more journeys. Another survey carried out at the road concluded that 6% of the respondents have postponed or refused their journeys in winter under bad weather conditions.

3.2. Pavement damages caused by studded tyres

Tyre studs damage road pavement, thus increasing the losses and the costs of road maintenance and repair. Some researchers state that dust uprising from a wearing road pavement pollute environment, undermine human health; when settling on traffic signs – reduce their visibility. Noise generated by studs also damages human health. Others think that the amount of dust generated by studs is not large, its structure does not allow them to get into human lungs and together with noise they only reduce comfort. Undoubtedly, besides the improved safety on snowy or icy roads, the tyre studs influence the wear of road pavement (especially of cement concrete and asphalt pavements) (Tilindis *et al.* 1998).

In winter, at the negative weather and pavement temperatures, bitumen being a constituent part of asphalt concrete becomes breakable and is first of all picked out by the studs. Bitumen particles settle at the roadsides, on traffic signs and vehicles. Together with bitumen the aggregates of the asphalt wearing course also start to wear and in a form of dust particles are lifted into the air and accumulated on the road and at the roadside. According to the date of the Swedish Road Administration, one vehicle with studded tyres having travelled a 1 km of the road picks out approx 5–12 g of asphalt particles on rural road and about 2–5 g of asphalt particles on city streets. In a city wearing of asphalt pavement is slower, since the speeds are lower. Having summed up all the vehicles and their travelled distance, thousand of tones of environmentally hazardous, fine and solid asphalt particles are formed in Sweden that are picked out, lifted into the air and settled at the roadsides.

Vehicles within the width of a traffic lane vary not much as the width of the vehicle track differs not much from the truck to the passenger car, and the traffic lane is narrow enough. Gradually, under the effect of tyre studs and in the result of damage to the asphalt wearing course the damages in the form of ruts occur and become deeper and deeper: when the rut depth reaches several centimetres (even up to 5 cm), the traffic becomes unsafe, since there is a risk to jump the tracks, to loose vehicle stability and create accident situation.

Vehicle wheels load acting on the road pavement may result in permanent deformation in the form of imprints, tracks, corrugations, shovings and ruts. The deformations considerably impair road service properties. Ruts are most dangerous because they might cause vehicles to skid during precipitation (Radziszewski 2007). Only part of the Lithuanian vehicle fleet "wears" studded tyres in winter. Heavyweight vehicles that cause the most significant damage to the road pavement in summer, in winter use winter tyres, the special vehicles – also use winter tyres. Since in the Lithuanian traffic flow only a small part of passenger cars (about 15%) uses studded tyres, a conclusion could be made that damage to asphalt pavements due to studded tyres is not large at present. Damages in the form of ruts caused by winter traffic on the main Lithuanian roads have not been noticed, unlike on Sweden roads.

Since studded tyres are suitable to only snow (packed) and ice, they have no effect for gravel roads that are the last to be cleaned from snow in winter. In Lithuania gravel roads make nearly half of the total Lithuanian road network of national significance. Those drivers who use to drive only by gravel roads should "shoe" their cars with studded tyres to ensure safe journey on packed snow or ice.

3.3. Damage of studded tyres to pavement marking

Studded tyres damage horizontal road signs by covering them with bitumen particles picked out from the asphalt and, as a result, making them dirty and not clearly visible.

Studded tyres directly affect pavement marking lines, that are painted, covered with polymer materials or adhesive tapes. German scientists have studied durability of pavement marking. Durability refers to the length of service life of the marking from they were first used until the time when they have to be renewed. The end of service life due to an excessive wear of the material is when one can hardly understand what the marking means. When less than 50% of horizontal marking remains on the road, the marking lines must be renewed. Investigations showed that with the use of studded tyres the single-component paint wears out in 6 months, with the use of non-studded tyres – in 12 months. When the marking lines, covered by hot plastic, are travelled by studded tyres in winter, they serve for up to 4 years.

In order to mark all the Lithuanian roads of national significance, it is necessary to paint or to cover by polymer materials the area of more than 1 mln m^2. In Lithuania the centre lines of roads are painted every year, whereas the continuous edge lines – every 2 years. The centre lines covered by hot plastic are renewed every 2 years, the edge lines – every 4 years. Since the marking with hot plastic has a longer service life, all the lines should be covered by hot plastic instead of paint. The lines of polymeric materials are usually 3 mm thick, consumption of the material – 6 kg/m^2, consumption of paint – 700 g/m^2. It is worth calculating is it better to spend more money right away (thermoplastic material is 3–3.5 times more expensive than paint) or to renew horizontal marking year by year with lower expenditures. Different type of road (street) pavements must be marked only by the laboratory-certified paint or polymer materials, suitable namely to that pavement surface.

City streets compared to motor roads carry a significantly higher traffic (up to 30 000–40 000 vpd); therefore, horizontal marking wears out significantly faster. The markers of the city streets also follow the *Specifications TS 01-96 „Horizontalusis automobilių kelių ženklinimas" (Horizontal Road Marking)* though they are applicable only to the roads of national significance, where the traffic volume is considerably lower.

Good marking durability is necessary due to the cost-efficiency and this is especially important on highly loaded road sections as the renewal of marking causes traffic interruptions.

In winter the so-called „cat's eyes" installed in the road pavement are also damaged by studded tyres. Their reflecting glass spheres are simply abraded and the markers lose their property to reflect light.

In many countries of the world the specialists discuss the damage of studded tyres to roads. All the participants agree that studded tyres damage road pavement and negatively affect road marking: they scrape off paint or thermoplastic layer and, what is most important, damage the reflecting materials.

4. Analysis of traffic accidents in winter conditions

Road Dept of the Vilnius Gediminas Technical University made the analysis of fatal and injury accidents (further referred as accidents) that took place in Nov–March 2004–2008 on Lithuanian roads. Data on traffic accidents were provided by the Lithuanian Police Traffic Supervision Service, Lithuanian Road Administration under the Ministry of Transport and Communications of the Republic of Lithuania and State Enterprise Transport and Road Research Institute. In Lithuania data about fatal and injury accidents are stored in the Register of Violations of Traffic Rules and Road Accidents managed by the Police Department at the Ministry of Inner Affairs of the Republic of Lithuania. This Register includes the following information about the road accident: code of accident type, date, location, information about the number of road users, people killed and injured, driving conditions, road/street elements, etc. It should be noted that in Lithuania data about the tyres of the accident- involved vehicles (i.e. studded, non-studded, worn out, etc.) is not recorded and not included into this Registre. Therefore, there is no possibility to make an analysis of how many accidents occur with the use of studded tyres, under what traffic conditions and the like.

Lithuanian climatic conditions create large demands for road and street maintenance works in winter season. In our country 3–4 months per year the weather temperature keeps below 0 °C, at longest – in the Eastern Lithuania, at shortest – on the coast. Already in the second half of November the first snow cover is formed and lasts until the middle of March. In winter Lithuania faces frequent thaws, large probability of heavy rain, freezing snow and fog; the daily temperature varies about 0 °C. Lithuanian climate is described as moderately cold, with snowy winter, sufficient amount of precipitation in all seasons and a higher amount of precipitation in a warm period of the year. The mean temperature of the coldest month is below –3 °C, of the warmest month – does not exceed 22 °C. At least 4 months of the year the mean temperature is higher than 10 °C (Laurinavičius *et al.* 2007).

In Lithuania, in November–March 2004–2008 on average 36.18% of traffic accidents take place, where 38.11% of road users were killed and 34.53% – injured. On the average 96.66% of traffic accidents occur on asphalt/cement concrete pavement, 2.69% – on gravel paving, 0.38% – on sett paving, 0.27% – without pavement.

Analysis of the above accidents by pavement condition showed that 48.84% of traffic accidents occurred on wet road pavement, 30.26% – on dry pavement, 11.65% – on snowy pavement, 9.08% – on icy and 0.17% – on dirty road pavement (Fig. 5). It should be noted that under wet pavement conditions when almost half of winter accidents take place the studded tyres give a negative effect on vehicle braking.

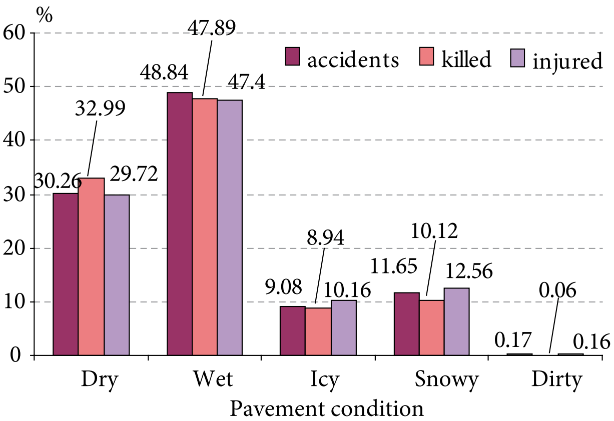

Fig. 5. Distribution of accidents and victims by pavement condition in November– March 2004–2008

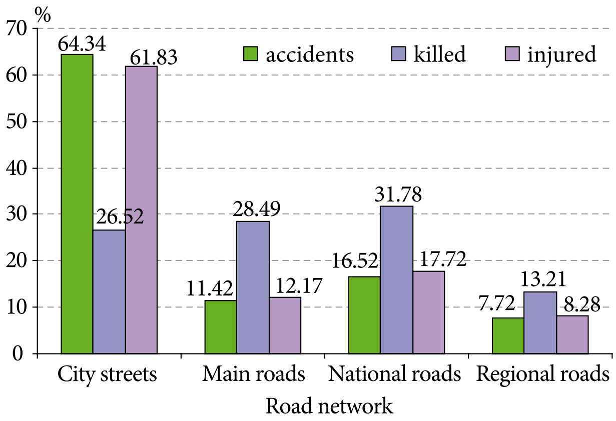

Fig. 6. Distribution of traffic accidents and victims within the road network in Nov–March 2004–2008

Fig. 5 shows that the majority of road users – 47.89% – are killed on wet road pavement, 32.99% – on dry pavement, 10.12% – on snowy pavement, 8.94% – on icy pavement and 0.06 % – on dirty pavement.

The same tendency is observed also when analyzing the distribution of people injured: 47.40% of the road users injured in winter accidents (i.e. in November–March) are injured on wet road pavement, 29.72% – on dry pavement, 12.56% – on snowy pavement, 10.16% – on icy pavement and 0.16% – on dirty pavement.

Fig. 5 shows that on icy and snowy road pavements in November–March 2004–2008 20.73% of accidents took place, where 19.06% of road users were killed and 22.72% – injured.

The dominating types of accidents in a study period were the same as in the annual accident statistics. 2004–2008 accident analysis showed that the accidents which have taken place in November–March are of the following type:

- running on pedestrians – 46.42%;
- collision of vehicles – 28.83%;
- collision with obstacles – 8.74%;
- overturning – 7.14%;
- collision with bicyclists – 4.5%;
- other accidents – 4.37%.

Fig. 6 shows that even 64.34% of winter accidents took place on city streets, 16.52% – on national roads, 11.42% – on main roads and 7.72% – on regional roads. A similar tendency could be observed also when studying the distribution of people injured within the road network (Fig. 6): 61.8% of the road users were injured on city streets, 17.72% – on national roads, 12.17% – on main roads and 8.28% – on regional roads. Since more than half of accidents occur on city streets, the distribution of people killed is nearly the same on national roads, main roads and on city streets (Fig. 6). This indicates that on main and national roads, where speeds are higher, the accidents are more severe.

It should be noted that within the road network different types of accidents prevail. Fig. 7 illustrates the distribution of accidents by accident type depending on the place of their occurrence. For example, based on data of November 2006 – March 2007 the prevailing type of accidents on city streets is running on pedestrians – 57.55%, whereas on main roads this type of accidents makes 32.79%, on national roads – 27.94%, on regional roads – 21.29%. On city streets collisions of vehicles make 25.08% of accidents, on main and national roads 41.39% and 30.94% respectively. Fig. 7 shows that on regional roads quite another type of accidents prevails than on streets, main and national roads. On regional roads such accident types as running on obstacle (27.03%) and overturning (26.43%) are distributed almost equally. Running on pedestrian on regional roads makes 21.29% of accidents.

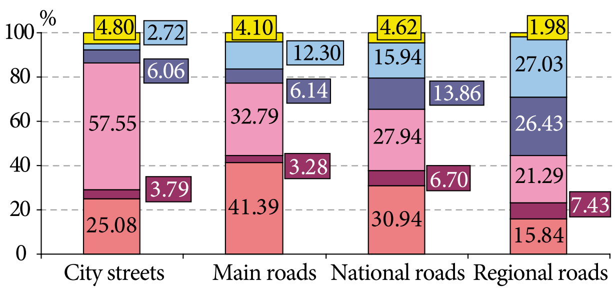

Fig. 7. Distribution of accident types within the road network (based on accident data of Nov 2006 – March 2007):
■ – collision of vehicles; ■ – collision with bicyclist;
■ – running on pedestrian; ■ – collision with obstacle;
■ – overturning; ■ – other accidents

5. Conclusions

Since Lithuania has no official statistics on how many vehicles use studded tyres in winter and data about the tyres of the accident-involved vehicles (i.e. studded, non-studded, worn out, etc.) is not recorded, there is no possibility to make an analysis of the effect of studded tyres on the accident situation.

Analysis of traffic accidents showed that in Lithuania in November–March 79.10% of accidents occur on wet and dry road pavement, when the studded tyres give a negative effect on vehicle braking.

More than half of accidents in November–March take place on city streets.

On the roads of different significance (city streets, main roads, national roads, regional roads) different types of accidents prevail (collision of vehicles, collision with bicyclist, running on pedestrian etc.), therefore, this should be taken into consideration when selecting the traffic safety improvement measures.

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Received 19 March 2009; accepted 27 August 2009