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THE INFLUENCE OF DRYING OF THE ROAD MARKING MATERIALS ON TRAFFIC DURING THE APPLICATION OF MARKINGS

abstract

The markings on the roadway are one of the most important components of traffic signalization because their position is in the driver’s center of attention. They consist of a set of longitudinal and transversal lines, inscriptions and symbols, and are usually made of paint (solvent borne or waterborne), thermoplastic or cold plastic. Previous research focused on the study of the impacts of markings on the driver’s behaviour, traffic safety, visibility and durability of the markings and their environmental impact. The goal of this research is to analyse the effects of the drying of material from which the markings are made of on the traffic flow, and thus the traffic safety during the execution, and as such, as known to the authors, it is the first research of that kind focused on the mentioned problematic. The research was carried out by simulating a real traffic situation while renewing the transverse markings in the PTV Vissim simulation tool. The simulation results show the correlation between vehicle flow and the drying time of each material. Also, the flow during the execution of transverse marking with waterborne paint showed to be the highest relative to other materials used (solvent borne paint, cold plastic and thermoplastic).

KEY WORDS

materials for roadway markings making; drying time; traffic safety; traffic flow

1. introDuction

Road markings represent unique traffic management tools that continuously transmit information about the direction of the traffic movement, the center and edges of the roadway, and general traffic-related information without making the driver turn his attention away from the road [1]. They consist of lines, inscriptions and symbols whose combinations form the surfaces of the traffic infrastructure and provide the driver with visual guidance, especially in conditions of reduced visibility.

The quality of the visual guidance of the driver, in addition to the presence of the markings themselves, is affected by its visibility that determines the life of the markings, which is the function of the material type and a number of other factors related to the geographic-climatic-traffic conditions in which the marking is located. Although there is a number of materials for marking making, which differ between application, lifespan, cost, structural characteristics, etc., the most commonly used is the usage of paints and plastic materials. For this reason, the influence of color and plastic materials on the traffic flow during the application of markings is simulated in this study.

Colors are liquid materials that belong to a group of thin layer materials, and consist of pigments, binders, fillers and solvents. Due to the type of binder, they are divided into solvent-based paints and water-based paints. Solvent based paints use different types of solvents to ensure drying and fixing of the material after application. While packed in the packaging, the solvent-based paint is in liquid state just because of the solvent. After the application of the marking on the roadway, the solvent breaks down (dissolves) the binder and thereby dries the marking that goes into solid state. The speed rate of the binder dissolving affects the drying speed of the marking which usually lasts for 30-40 minutes. Solvents evaporate into the atmosphere as harmful compounds or Volatile Organic Compound (VOC) during the drying process. Typically, the level of VOC paint based on solvent is between 400 and 500 g / L (~ 25%) [2].

On the other hand, water-based paints are very similar to solvent-based paints, although the process itself is somewhat more complicated. For solvent-based paints, by evaporating the solvent, the material is dried and strengthened while in water-based paint the same process is based on water vaporization. The main advantages of water-based paints are related to their low cost and good stability during storage. On the other hand, their main disadvantage is the time it takes for the material to become washout resilient (washout time). Namely, as the mentioned material is water-based, if in a certain time after the material is applied it comes into contact with water, it simply becomes diluted and discolored. Color becomes flush-proof when it is no longer affected by rain, and the time it takes to become so depends largely on the chemical composition, i.e. the binder and additive employed [2]. Depending on the parameters listed above, the paint drying speed varies between 8 and 15 minutes.

Plastic materials are multicomponent and are usually made of synthetic binders, natural and artificial resins, pigments, fillers and pearls [3]. They belong to a group of thick-band markers, and can be placed on a roadway of cold or elevated temperature, and can therefore be divided into two basic groups: cold plastics and thermoplastics.

Cold plastic is a liquid state material to which various thickening additives, depending on the manufacturer, are added. After the initial smoothing, it is applied onto the roadway, where it is solidifying for twenty minutes and can be driven over it afterwards [3].

Thermoplastic is a material that needs to warm up to about 180 ° C before applying. After 15 to 20 minutes of laying on the roadway, the mass hardens and it can normally be ridden over it. Due to the increased material strength and the thickness of the application, the thermoplastic markings have a significantly longer life span than the paint markings. Although the number of factors influences the lifespan of the marking, the typical duration of the thermoplastic marking (thickness of 3 mm) is between two and four years, often longer. In addition to all the above mentioned, a very important feature of thermoplastic materials is that they do not contain solvents, nor do they require their use during application. Also, certain binders used to make thermoplastic materials are from renewable sources making these materials ecologically acceptable.

Most of the current research was focused on the effects of retroreflection (night visibility) of markings on the roadway and their presence on the number of traffic accidents and traffic safety. In the study conducted in Texas, the influence of roadway edge markings on road traffic safety was investigated. On the basis of the comparison of the number of before and after traffic accidents, it has been concluded that in places where there are no boundary markings, there is an increase in the number of traffic accidents [4]. The authors [5] conducted a study on the effect of retroreflection of markings on roadways on the occurrence of traffic accidents during night conditions. According to the collected data, it has been proven that places with a larger retroreflection on the roadway reduce the possibility of traffic accidents during night conditions. In a study published in 2013, the authors analyzed the traffic accidents that occurred during the night: those involving only one vehicle without injured or fatalities, those with fatalities and injuries, and accidents involving a vehicle with fatalities and injuries. The results of the research emphasize the positive influence of the retroreflection of markings on the roadway on general traffic safety [6]. Also, the research done in 2016 shows the persistence of a statistically significant correlation between the retroreflection of markings and the number of traffic accidents. The results of this research, as the authors point out, point to the need of maintenance of the markings on the roadway, because the expected number of traffic accidents is significantly reduced by increasing the retroreflection of the white and yellow fringes [7].

The aim of this research is to analyze the effect on the traffic flow of drying of the material from which the markings are made, and thus on the safety of traffic during the execution. As it is known to the authors, as such, this is the first research focused on the above-mentioned problem. The research was conducted in two parts. The first part is related to the field tests involving the recording of data on the time required for drying of a single material from which transverse markings are made in potentially hazardous locations on the DC 30 state road. The second part of the survey refers to the processing of the data obtained from the field test using the specialized PTV Vissim simulation tool. The PTV Vissim is a microscopic simulation tool for modelling city traffic networks and public transport operations and pedestrian flows [8]. The accuracy and credibility of the simulation model depends mostly on the modelling quality of the vehicle's behaviour in the simulated transport network.

2. METHODOLOGY

The study of the influence on the traffic flow of the drying time of the material for the applying of markings on the roadway was carried out in two parts. In the first part, field tests were conducted to collect data on the drying times of individual materials. As noted above, given the frequency of usage, the study involved four materials: solvent based paint, water-based paints, thermoplastics and cold plastics. The collecting of this data was carried out during the renewal of the transverse markings on two potentially hazardous places on the DC 30 state road. During the application of the markings the weather conditions were satisfactory with relative humidity of 55-75%, air temperature of 11-16 ° C, road temperature 11-18 ° C, wind speeds of 0.5-1.5 m / s, while the application lasted about 6 hours.

The drying time of individual materials was between 2100 and 600 s. The longest drying time was for solvent-based paint (2100 s), then cold plastic and thermoplastics, while the shortest time was recorded for water-based paint (600 s) as shown in Figure 1. The recorded results are consistent with the current knowledge of drying times [9] [10].

Figure 1 - Drying times of individual materials for driveway markings

The second part of the survey refers to the processing of data obtained from the field, using a specially crafted simulation tool: PTV Vissim. Apart from the drying time of individual materials, the input parameter for the simulation was the amount of traffic on the observed part of the road. According to the statistical data from [11], the average annual daily traffic (PGDP) and average daily traffic for the two locations as well as data on the structure of the traffic flow were obtained. Based on the obtained data, it was established that the traffic load for the first location was 2000 rpm, and the load of 600 rpm was for the second location.

Based on the mentioned, a simulation of the actual locations where data was collected was made as shown in Figure 2.



Figure 2. Simulation performance display

3. SIMULATION RESULTS

After the setting of all parameters of the traffic flow, two potentially dangerous places were simulated on the state road DC 30. The overall simulation process was set to the longest time necessary (40 min) for drying of the material, which is in this case solvent-based paint. The simulation process for each material starts by "warming up" the network which moves in the range from 0 to 3600 seconds. After the initial "warming up" of the network, the closing of one traffic lane is simulated for the time required for each material to dry. The entire simulation process during which vehicle flow is measured ranges from 3600 to 6000 seconds. The vehicle flow was measured on each location separately in both directions (North-South and South-North). The given results for both locations are shown in Tables 1 and 2 as the vehicle flow through the observed section in a 40-minute time period (Vehicles / 40 min). The vehicle flow for a given type of material is shown graphically in Figures 3 (first test site) and 4 (second test site).

Figure 3 - Vehicle flow depending on the time necessary for the drying of a certain driveway marking material (first test site)

Figure 4 - Vehicle flow depending on the time necessary for the drying of a certain driveway marking material (second test site)

Based on the obtained data, it is apparent that the flow of vehicles at the second testing location depended on the time required for each material to dry is almost equable. A slight deviation was observed with water-based paint, used as the material used to make the markings on the roadway, where the vehicle flow recorded was slightly higher than with previous materials. By analyzing the data obtained at the first location, it can be seen that the movement of vehicles during the execution of the markings depends not only on the time required for the drying of the individual material but also on the number of vehicles which constitute the traffic load on the observed part in a unit of time. As the number of vehicles rises and the drying time of the material is longer, the vehicle flow in the unit of time is smaller with the appearance of larger waiting periods. The usage of water-based showed as an optimal solution in situations with increased vehicle flow on the observed part, with which the flow of vehicles was considerably higher than with the other materials. The difference in vehicle flow at the first site relative to the time of drying of each material is shown in Figure 5 (the percentage for each material represents the realized vehicle flow in relation to the flow obtained without barriers). According to the data, there is a difference in the vehicle flow compared to the applied material and by applying the water-based paint markings the vehicle flow, compared to the other observed materials, increases by an average of almost 15%. The flow with water-based paint is lower by 16%, with thermoplastic 21%, with cold plastics 26%, and with solvent-based color by as much as 32% versus the barrier-free flow.

Figure 5 - Vehicle flow at the first site (percentage) in relation to the drying time for each individual material

The vehicle flow ratio obtained on the basis of each applied material is shown in Figure 6. Solvent-based paint was found to be the worst with an 8% lower flow rate compared to cold plastics, 16% thermoplastic and even 23% compared to water-based paint. Thermoplastics turned out to be, with water-based paint, the best material with a 7% higher flow compared to cold plastics and 21% lower flow compared to no barriers flow, and 6% less than water-based paint.

Figure 6 - Vehicle flow at the first test site (percentage) in relation to the used material

The difference in vehicle flow at the second location relative to the time of drying of each material is shown in Figure 7. The analysis of the data obtained can be used to determine almost the same flow for solvent-based paint, cold plastics and thermoplastic, which is 80%. Again, the highest flow was obtained by applying water-based paint, 91% in comparison to the flow obtained without the barrier simulation. It is characteristic for this location that due to reduced traffic loads (600 vehicles / h), solvent-based paint, cold plastics and thermoplastics (although the drying time of the material is different) have almost the same vehicle flows, while water-based paint gives better results.

Figure 7 - Vehicle flow at the second site (percentage) in relation to the drying time for each individual material

The flow rate of vehicles at the second location for the testing of each applied material is shown in Figure 8. The solvent-based paint still represents the material with the smallest vehicle flow, with a difference of 14% compared to the water-based paint. Thermoplastic shows an 11% lower vehicle flow compared to water-based paint, but a 2% higher flow compared to cold plastic and 3% compared to solvent-based paint. Cold plastic has a vehicle flow rate of 1% higher than the solvent-based color.

Figure 8 - Vehicle flow at the second test site (percentage) in relation to the used material

4. CONCLUSION

Experience and science confirm that high-quality traffic signalling with high reliability can be achieved with small resources thanks to the modern technology of creating traffic signalization. The effective solving of certain local traffic problems can have a significant qualitative impact on the flow of the entire traffic network, on the increasing of security in the narrower and broader zone, and on motivating the participants in traffic to cooperate [1].

This paper analyzes the influence on the traffic flow of the time required for drying of individual materials for marking on the roadway. By simulating at two potentially hazardous locations on the state road DC 30, transverse markings of different types of materials were applied along with the known drying time for each material and with the traffic load for each tested location. The results obtained by simulation confirm the correlation between the vehicle flow and the drying time of the individual material at a higher traffic intensity.

By comparing materials at both locations, it can be concluded that water-based paint ensures, in comparison to other materials, the best traffic flow during application due to shorter drying times. At the first test site (2000 vehicles/h), vehicle flow is higher by 6% than with thermoplastics, 14% compared to cold plastics and 23% compared to solvent-based paint. At the second test site (600 vehicles / h) water-based paint shows a vehicle flow higher by 11% than with thermoplastics, 13% compared to cold plastics and 14% compared to solvent-based paint. In other words, applying water-based markings causes the least disturbance in the traffic flow, and thus increases the traffic safety when applying the markings. On the other hand, solvent-based paint had the greatest disturbance of traffic flow. Cold and thermoplastics had relatively similar results with the mild advantage of thermoplastics.

From all of the mentioned, it can be concluded that water-based paint affects and obstructs traffic flow the least during application. In addition, with their modernization over the last decade, the durability of water-based paint has been prolonged considerably and recent studies have found that the durability of these markings is over 2 years with high levels of night visibility [12]. Although slightly shorter in durability compared to plastic materials, water-based paint compared to cold and thermoplastic is considerably cheaper. Also, since they are water based, water-based paints represent the most environmentally friendly material for roadway marking with a reduction of harmful VOC emissions to 93% [13].

By comparing all the mentioned facts, water-based paint is shown to be an efficient material for marking the roadway with the material’s satisfactory durability and cost-effectiveness, providing satisfactory negative impact on the traffic flow during application and by minimizing at the same time the adverse environmental impact, which makes them a worthy substitution and competition to plastic materials.

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