WINTER SERVICE ON THE BRIDGES ON A2 MOTORWAY IN CROATIA AS A PART OF SUSTAINABLE DEVELOPMENT

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ABSTRACT

On the Zagreb – Macelj motorway, special attention is paid to maintenance on 9 bridges because there is a danger of increased cooling. 5 bridges are connected to the tunnel tubes, which further complicates the maintenance because the natural flow of air through the tunnel leads to increased cooling of the pavement. In order to prevent icing, we treat all bridges equally, with maximum quantities of spread salt. This work analyzed the data collected from year 2009 to 2012 for the five winter months in which temperatures are measured manually in each of the 9 patrols within 24 hours and on 8 locations. From three measured values of the air temperature one average value is calculated, and for each of the five bridges average temperature of the pavement is calculated. The differences between average temperatures of each bridge give us knowledge about the possible differences in treatment for each bridge. Possible savings on the spreading materials on that subsection is 12,3%. By this method we combine all three components of sustainable development: economic savings through the salt consumption and on the equipment, the social component with care for the customers and their safety and environmental protection through the reduction of environmental pollution.

1. INTRODUCTION

Zagreb – Macelj motorway is a part of the Pyhrn road route. The motorway is marked as A2 in Croatia, while it is classified in European road routes as E-59 connecting northern and central parts of Europe with its southern-eastern part. The motorway stretches from interchange Jankomir (part of the Zagreb ring road) up to interchange Trakošćan (Slovenian border, border crossing Macelj).

Since 2004 Concession Company Autocesta Zagreb-Macelj Ltd, which had been awarded the concession by the Republic of Croatia, manages motorway Zagreb-Macelj. Zagreb-Macelj motorway is a typical example of infrastructure project of public-private partnership (PPP) where Strabag is a private partner and the Republic of Croatia is a public partner. Tunnels on the Zagreb-Macelj motorway are in use as of May 2007. The Concession Company contracted an Operation & Maintenance contract with company EGIS Road Operation Croatia Ltd, a company which is part of EGIS Road Operation S.A. that belongs to GROUPE EGIS.

The length of the motorway is 60 km and it is divided into the following sections (from south to north): section Zagreb (interchange Jankomir) - Zaprešić with length of 7.4 km; Zaprešić – Krapina with length of 34.7 km; Krapina – Macelj with length of 17.9 km. The greatest part of the motorway passes through flat area while at section Krapina – Macelj it passes into a mountainous area. Section Krapina – Macelj represents a new motorway section through a mountainous area that consists of a two new interchanges (interchanges Đurmanec and Trakošćan) with toll stations, six tunnels, nine viaducts which were constructed and opened for traffic in May 2007. On portion of this section 3.7 km one carriageway for two-direction traffic was constructed. This subsection consists of two tunnels and three viaducts.

The tunnels are operated from the O&M Centre Krapina, located at the Krapina interchange, which marks the beginning of the Krapina-Macelj motorway section. Section Krapina-Macelj as a mountainous section with total length of 17, 9 km and with nine viaducts with length of 1,88 km.

Five viaducts on Krapina-Macelj subsection as a subject of interest of this paper are shown below:

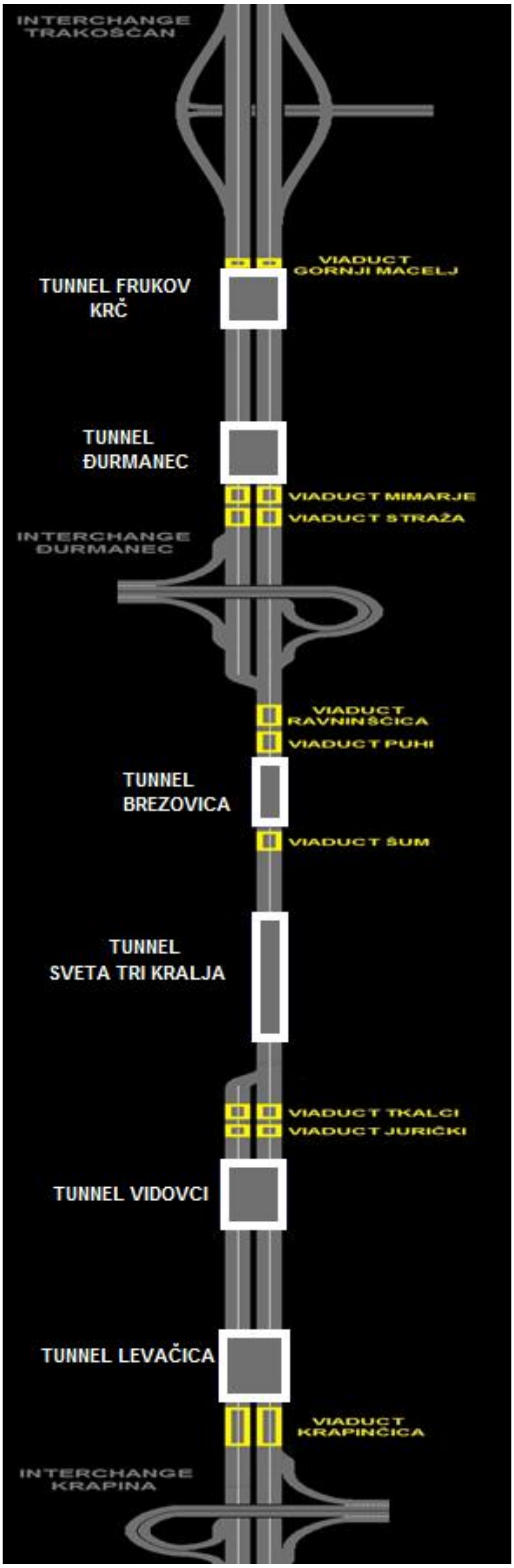

Figure 1 – Krapina – Trakošćan subsection

Photo 1 – Viaduct Krapinčica (579 m)

Photo 2 – Viaduct Šum (160 m)

Photo 3 – Viaduct Puhi (227 m)

Photo 4 – Viaduct Mimarje (197 m)

Photo 5 – Viaduct Gornji Macelj (60 m)

2. ANALYSIS OF METEOROLOGICAL CONDITIONS ON THE SECTION DURING WINTER

2.1. Introduction

2.1.1. Winter service on Zagreb – Macelj motorway

Winter maintenance on the Zagreb Macelj Motorway in the length of 60 KM is organized from two maintenance centers, Mokrice (KM 25) and Krapina (KM 42). From each center maintenance of two subsections is organized; from the maintenance center Mokrice section from KM 0 to KM 10 and from KM 10 to KM 25, and from O&M center Krapina sections from KM 25 to KM 42 and from KM 42 to km 60. In each maintenance center there is a Patrolman, while in the O&MC Krapina a traffic control room is located where two operators are working 24/7 on SCADA system which integrates data from 6 meteorological stations positioned along the motorway. There are three (3) levels of responsibility: level 3 which include two

Patrolmen present on the motorway 24 hours daily; level 2 which is a person on on–call duty from the Highway operation and maintenance department and level 1 – a manager on on-call duty.

Due to elevation we could say that first three sections are passing through flat area and the fourth section is in the mountainous area. Accordingly, the greatest attention within winter maintenance is given to the fourth section; from the interchange Krapina (KM 42) to the interchange Trakošćan (KM 60) and that section is the subject of this presentation. On the section there are 6 tunnels and 9 viaducts which are occupying more than 10% of its total length.

After the section was opened for traffic, meteorological stations (6 on whole motorway and 4 on the subjected subsection) that measure temperature of air and carriageway, together with several thermometers used for measuring air temperature were used for decision making related winter maintenance operations.

In 2008 there was a traffic accident due to slippery carriageway on one of viaducts (Gornji Macelj). Analyses found that temperatures on the whole section were 2°C, so the whole section was in a proper condition beside that viaduct where ice was created. The conclusion is that ice was created because the viaduct is directly connected with the tunnel and the air flow through the tunnel significantly decreased temperature of the viaduct's surface. It was decided that all 9 viaducts should be treated as dangerous points with 40 g/m^2 with each salt spreading. Also, it is decided that carriageway temperature must be measured on each viaduct that is connected with a tunnel tube, using Infra-red device in each patrol (9 patrols within 24 hours, from November till March), except when temperature on meteorological stations is 7°C or more. All measured carriageway temperatures from 5 viaducts (infra-red thermometer) and 3 locations where air temperature is measured are inserted in the table that is prepared for that purpose. Time of measurement, wind and carriageway condition (dry - wet) are else recorded.

Measurements from 2009, 2010, 2011 and 2012 will be analyzed here with a goal to group viaducts considering risk of freezing, and afterwards they are treated per groups with different quantities of salt per m^2, and not equally with maximum quantity as it were done before. In this way significant savings will be achieved.

In 4 years around 3600 measurements were done for each location.

2.2. Methodology

2.2.1. Calculation of average temperatures, percentage of measurements with wind and wet carriageway

For each of 5 locations average temperatures of carriageway will be calculated per months and total average temperature of carriageway as well. Simultaneously, from 3 locations where air temperature is measured a unique average air temperature will be calculated for each measurement, so for each measured temperature of the carriageway we will have one average air temperature which is considered as average for the whole section. Average air temperature per months and total average temperature will be calculated and then compared with total average carriageway temperatures for each of 5 viaducts. Besides, for each of 5 viaducts percentage of measurements with wind and wet carriageway will be calculated.

2.2.2. Calculation of safety coefficient

Safety coefficient „k" will be calculated. Average air temperature is in rule lower than average carriageway temperature, even from average carriageway temperatures on viaducts. As lower the difference between air and carriageway temperature, carriageway becomes more danger in terms of possibility of freezing.

- for basic calculation of the coefficient „k" the difference between average carriageway temperature on each viaduct and average air temperature „**k0**" are considered.

- Percentages of wet carriageway will be considering that wet carriageway (combines with low temperature) causes creation of ice. Average percentage of wet carriageway will be calculated for 5 structures. For each viaduct difference in relation with an average **„k1"** will be deducted from temperature difference „k0" in relation, (theoretically) 100% = 1°C, or 1% of difference in measurements with wet carriageway = 0,01°C of temperature difference.

- Percentage of measurements with wind recorded will be considered as wind can cause creation of ice. An average percentage of measurements with recorded wind for all 5 structures will be calculated. For each viaduct difference in relation to percentage „**k2**" and deducted from temperature difference „k0" in relation, (theoretically) 100% = 1°C, 1% of difference in measurements with wind = 0,01 °C of temperature difference.

k(safety coefficient) **= k0** (difference to air temperature) **- k1**(difference to average wet road percentage) **- k2(**difference to average wind percentage)

2.2.3. Criteria for grouping

Three groups will be defined in relation with values of coefficient „k", G1 – risky, G2 – very risky and G3 – dangerous

2.2.4. Grouping

Each of viaducts will be classified into one of groups, depending of coefficient „k",

2.2.5. Usage of spreading materials in relation with groups

Table with instructions will be made for decision-makers: after decision about what quantity of salt will be used on the rest of the carriageway (group G), viaducts will be treated differently all according to the group in which each of them is classified: G1=G+10, G2=G+20, G3=G+30 (max=40g/m^2).

2.3. Calculation

2.3.1. Calculation of average carriageway temperatures, percentages of measurements with wind and wet carriageway

Table 1 - Average temperatures, percentages of wet carriageway and wind presence 2009-2012 – per month

	JAN	FEB	MAR	NOV	DEC
V.KRAPINČICA					
TEMPERATURE	0,48	1,25	2,46	2,46	0,69
WET SURFACE	67,62%	51,42%	31,20%	63,53%	78,47%
WIND PRESENCE	25,18%	31,60%	33,76%	11,84%	21,50%
V.ŠUM					
TEMPERATURE	-0,02	1,25	2,83	2,94	1,03
WET SURFACE	69,61%	52,75%	33,25%	64,01%	74,41%
WIND PRESENCE	23,28%	28,83%	32,75%	7,97%	19,22%
V.PUHI					
TEMPERATURE	-0,58	0,53	2,26	2,15	0,24
WET SURFACE	72,22%	55,87%	31,03%	66,91%	74,85%
WIND PRESENCE	28,69%	32,16%	31,72%	9,42%	23,89%
V.MIMARJE					
TEMPERATURE	-0,06	0,64	2,24	2,27	0,45
WET SURFACE	75,76%	56,95%	34,02%	61,84%	75,91%
WIND PRESENCE	25,89%	32,01%	33,51%	12,08%	21,80%
V.GORNJI MACELJ					
TEMPERATURE	-0,33	0,01	1,88	1,83	-0,15
WET SURFACE	79,23%	61,78%	34,24%	75,12%	66,51%
WIND PRESENCE	24,47%	29,77%	30,84%	14,98%	22,25%
AVERAGE AIR TEMPERATURE	**-0,73**	**-1,08**	**0,74**	**1,59**	**-0,5**

Table 2 - Average temperatures, percentages of wet carriageway and wind presence 2009-2012 – total

	TOTAL (2009-2012)	
V.KRAPINČICA		
TEMPERATURE	1,18	*av. from 3570 measurements*
WET SURFACE	61,65%	*2170/ 3520*
WIND PRESENCE	25,29%	*891/ 3523*
V.ŠUM		
TEMPERATURE	1,20	*av. from 3500 measurements*
WET SURFACE	61,79%	*2167/ 3507*
WIND PRESENCE	22,95%	805/ 3508
V.PUHI		
TEMPERATURE	0,86	*av. from 3578 measurements*
WET SURFACE	63,17%	*2249/ 3560*
WIND PRESENCE	26,54%	*26,54%*
V.MIMARJE		
TEMPERATURE	0,75	*av. from 3506 measurements*
WET SURFACE	64,84%	*2278/ 3513*
WIND PRESENCE	25,65%	*902/ 3517*
V.GORNJI MACELJ		
TEMPERATURE	0,27	*av. from 3593 measurements*
WET SURFACE	65,89%	*2368/ 3594*
WIND PRESENCE	24,94%	*899/ 3604*
AVERAGE AIR TEMPERATURE	-0,31	*av. from 3505 measurements*

Table 3 – Safety coefficient calculation

	Krapinčica	Šum	Puhi	Mimarje	Gornji Macelj
TEMP	1,18	1,2	0,86	0,75	0,27
AIR TEMP.	-0,31				
Difference to air temp.	1,49	1,51	1,17	1,06	0,58
k0	1,49	1,51	1,17	1,06	0,58
Wet road percentage	61,65%	61,79%	63,17%	64,84%	65,89%
Average	63,47%				
Difference to average	-1,82%	-1,68%	-0,30%	1,37%	2,42%
k1	-0,018	-0,17	-0,003	0,014	0,24
Wind percentage	25,29%	22,95%	26,54%	25,65%	24,94%
Average	25,07%				
Difference to average	0,22%	-2,12%	1,47%	0,58%	-0,13%
k2	0,002	-0,021	0,015	0,006	-0,013
k	**1,506**	**1,548**	**1,158**	**1,04**	**0,569**

k safety coefficient
k0 coefficient - difference to air temperature
k1 coefficient - difference to average wet road percentage
k2 coefficient - difference to average wind percentage

$$k = k0 - k1 - k2$$

Table 4 - Grouping criteria

	k		**Risk level**
	from	till	Classification
G	1,601	…	normal
G1	1,201	1,600	risky
G2	0,601	1,200	very risky
G3	0,000	0,600	dangerous

Table 5 - Classification into groups

Viaduct	k	GROUP 1,2,3
Krapinčica	1,506	**G1**
Šum	1,548	**G1**
Puhi	1,158	**G2**
Mimarje	1,040	**G2**
Gornji Macelj	0,569	**G3**

Table 6 - Usage of spreading materials in relation with groups

G	**G1** (G+10)	**G2** (G+20) (max.40)	**G3** (G+30) (max.40)
10	20	30	40
20	30	40	40
30	40	40	40

Group G considers a carriageway that is not on a viaduct. A person in charge for decision making, will decide which quantity (g) will be spread per m^2 for the Group G. For viaducts it will be defined per table, in relation with group G with maximum $40g/m^2$.

3. COCLUSION

3.1. Main conclusion

Thanks to the method that is presented in this paper, savings in the consumption of salt will be achieved.

According to current practice, all viaducts were treated in the same way – maximum salt spreading with each activity on the motorway. Mostly, the rest of the motorway would be treated with $10g/m^2$ while viaducts were treated with $40g/m^2$. After the coefficient k is calculated and 5 viaducts are classified into groups G1, G2, G3 (G is group where a carriageway is not on the viaduct) savings in salt consumption can be calculated as well. 2 viaducts are in the G1 group, 2 are in G2 and one is classified into G3. If a carriageway which is not on the viaduct is treated with 10g/m2, then 2 viaducts from G1 group will be treat with 20g/m2, 2 viaducts from G2 with 30g/m2 and one from the group G3 with 40g/m2.

Other 4 viaducts which were not the subject to this paper can be classified according to work results: the first two viaducts that are not subject to this study (Jurički and Tkalci) are in the zone between two viaducts from the group G1 (Krapinčica and Šumi), so they can be classified into G1.

The third viaduct that is not studied (Ravninšćica) is connected to the viaduct which was a subject to this study (Puhi) and can be classified into the same group – group G2.

The fourth viaduct that was not studied (Straža) is connected to the viaduct (Mimarje) and can be classified into the same group G2.

In this way all 9 viaducts can be classified into groups G1, G2 and G3.

Table 7 – Viaducts classified into groups

Viaduct	k	GROUP 1,2or3
Krapinčica	1,506	**G1**
Jurički		**G1**
Tkalci		**G1**
Šum	1,548	**G1**
Puhi	1,158	**G2**
Ravninšćica		**G2**
Straža		**G2**
Mimarje	1,040	**G2**
Gornji Macelj	0,569	**G3**

When consumption is calculated for the section Krapina – Trakošćan with an old way of working and compared with a new way of working; if the rest of the motorway is treated with 10g/m^2 , 4 viaducts are treated with 20 g/m^2 (group G1), 4 viaducts with 30 g/m^2 (group G2), and one viaduct with 40 g/m^2 (group G3), the conclusion is that the new way of working will ensure 12,3% savings of salt , compared with an old way.

By this method we combine all three components of sustainable development: economic savings through the salt consumption and on the equipment, the social component with care for the customers and their safety and environmental protection through the reduction of environmental pollution.

3.2. Other findings

3.2.1. Temperature oscillation within 24 hours

An average temperature is calculated for each of 9 patrols done for each of 5 viaducts and for air temperature and results are shown graphically:

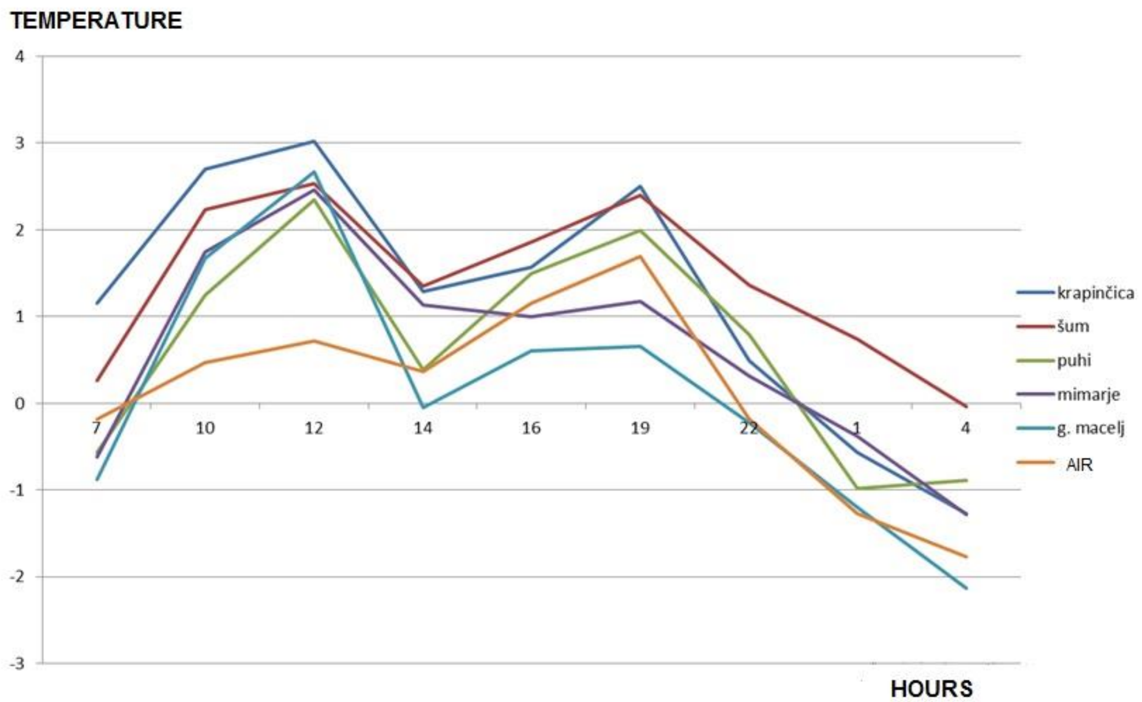

Figure 2 – Temperature oscillation within 24 hours

As expected, the lowest temperatures were recorded in the last night patrol around 4 a.m. It is noticeable that temperatures measured around 2 p.m. are lower than those measured in the previous patrol, as well as in the one afterwards, what must be considered while planning activities.

3.3. Next steps

The results of this method will be used in the work, and possible savings due to different treatment of viaducts will be monitored and compared over previous practice. For the next winter season, two mobile temperature measurement devices (measurement while driving) will be purchased and installed in the Patrol Vans. The Patrolman will be able to have information about temperature of the carriageway he is driving on, at any time. All these data will be used for analyses of carriageway sections that have not been analyzed yet, so the analyses for the plain part of the motorway section (km 0 to km 42) which was not the subject of this paper will be produced.

Analyses presented in this paper will be developed further with inserting data for the year 2013 and further on, because as the time period is longer the analyses results are more precise.

In contact with operators on other motorways analyses of their motorways with this method will be done if possible, to compare results and confirm justification of the method, and to enable corrections in the method for the motorways in different climate regions, accordingly.